Exploring and Applying Physics

Facebook group

Posts by Eugenia Etkina from 2022

Eugenia Etkina
1. January 2022.

Hi all, Happy New Year again! I hope it is happy year, we all need it to be! Three (no, four!) things in this post.
1.We have several new members today - WELCOME! Please read my post of yesterday and the notice on top of this group's page to learn how to benefit from our community.
2.If you read this post, please like it or comment.
3.I am reminding you about our repeat meeting dedicated to the essential elements of the ISLE approach on Saturday, Jen 8th 11 am EST. see the events calendar.
4.As promised, I continue with fluids. Chapter 14, Fluids in motion. We start with a qualitative analysis of the phenomena that occur when fluid moves - in the previous chapter the events occurred in stationary fluid. Note that all most of the sections are dedicated to the laminar flow of an ideal fluid. However, we have a section dedicated to viscous flow, which is very important for medical students. Here i am attaching a screen shot fo the qualitative investigation that starts the chapter. It conforms to the ISLE reasoning flow and serves as a conceptual way to invent the relationship between the speed of the fluid's flow and the pressure it exerts. Note, that as always we do not ask students to predict the outcome of the observational experiment. We do not elicit prior knowledge or put students' intuition to the test. However, once they constructed an explanation for the first experiment, they must use this explanation, not their intuition to predict the outcome of the testing experiment. In class, both experiments can be done by the students if you have enough equipment or the Observational experiment can be done by EVERY student and then the testing experiment is performed by the teacher AFTYER the students working in groups make the prediction about its outcome using the explanation that they constructed for the Observational experiment.
5.Have you reached the end of the post? Please like it or comment, thank you!

14.1 Fluids moving across surfaces—qualitative analysis

You learned in Chapters 12 and 13 that a key property of a static fluid is its pressure. What happens to that pressure when a fluid moves? To investigate this, we will analyze the simple experiment described in Observational Experiment **Table 14.1**.

OBSERVATIONAL EXPERIMENT TABLE 14.1 Pressure inside a moving fluid

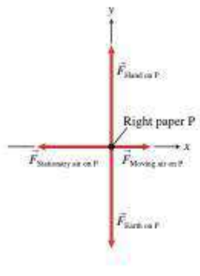
VIDEO OET 14.1

Observational experiment

Hold two pieces of paper separated by plastic blocks and blow down directly between them. You see the pieces of paper coming close together, as if they are pushed toward the moving air.

Analysis

We consider the piece of paper on the right to be our system and examine the moment when the paper starts moving to the left. We draw forces exerted on the paper in the horizontal direction. For the system to start moving, the sum of the horizontal forces must point to the left—from the region of stationary air to the region of moving air.



Pattern

Based on the analysis of the experiment and using the force diagram, we can infer that air moving along the surface of an object exerts a smaller force on the object. Given that force divided by the area over which it is exerted is pressure, we conclude that the air moving along a surface exerts less pressure on the object than stationary air.

Bernoulli's effect

Extrapolating from the pattern in Table 14.1, could it be that for any fluid, the speed with which fluid is moving along the object and the pressure exerted by this fluid on the object are related: the greater the speed, the smaller the pressure? Let's test this hypothesis experimentally.

It is important to note here that in all of the experiments, the movement of the fluid was parallel to the surface of interest. When the fluid is moving perpendicular to the surface of interest, it exerts a force in the direction of motion (you can think of the momentum of fluid particles changing as the particles hit the surface). You can clearly observe this effect if you repeat the experiment in Testing Experiment **Table 14.2** with the hairdryer blowing directly downward into the tube—the water level inside the tube lowers.

TESTING EXPERIMENT TABLE 14.2 How are the speed of a fluid and its pressure related?

VIDEO TET 14.2

Testing experiment

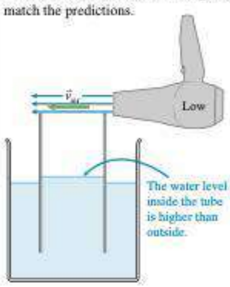
We cut the top and bottom off a plastic bottle to make a plastic tube and put it into a container of water. The level of the water in the tube is the same as in the container. Then using a hair dryer set to cold, we blow cold air parallel to the surface of the water right above the tube, first using a low-speed setting and then a high-speed setting.

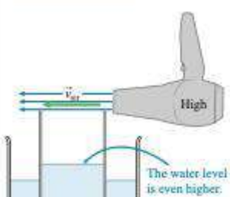
Prediction

If a faster-moving fluid exerts less pressure than a stationary fluid, and we blow air parallel to the opening of the tube, then the pressure at the top of the tube (but also inside the tube) should be lower than atmospheric pressure. When the speed of the moving air increases, the pressure should decrease. The pressure outside the tube, above the surface of the water in the container is atmospheric; therefore, the sum of the forces on an element of water inside the tube should point upward and the water in the tube should rise until the sum of the forces exerted on the raised water inside the tube is zero. The height of the water inside the tube should increase when the hair dryer is switched to high.

Outcome

The outcomes are shown in the figures. They match the predictions.





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Eugenia Etkina
2. January 2022.

Hi all, yesterday, Ashutosh Bhakuni posted some very important points about issues with Bernoulli equation and suggested some excellent papers addressing those issues. Thank you, Ashutosh Bhakuni! We (Gorazd Planinsic and I) are aware of the issues described in these papers and we share the "pain". Those of you, who have the first edition of our book can see how we changed the experiments and how we tried to addressed these issues (obviously, we will need to do more work). On page 427 we added a paragraph called "Using Bernoulli's equation to explain how airplanes fly" in which we show quantitatively using real life data that Bernoulli's effect cannot explain how airplanes fly and that the important idea that need to be taken into account is change in direction of motion of air, which is also the main idea behind the papers suggested by Ashutosh (see the attached screenshot).
The critical issue in our textbook that needs to be revised is the statement (explanation) in the Pattern below the OE 14.1. (page 416): "Based on the analysis of the experiment and using the force diagram, we can infer that air moving along the surface of an object exerts a smaller force on the object." It is not the motion of air per se that causes the observed effects but rather the change of the speed of the air. On the next page, we make it clear that "…as a fluid's speed parallel to a surface increases, the pressure that the moving fluid exerts on the surface decreases." We might also add another testing experiment using the idea from papers suggested by Ashutosh Bhakuni (similar to our TE 14.2 but to insert the tube into a hole in a cardboard and make it flush with its surface) to test the idea that it is not the motion of air alone that causes the change in pressure but the change in the speed of the air.

Using Bernoulli's equation to explain how airplanes fly

You may have heard that airplanes can fly because of the special shape of their wings, which causes the air above the wing to move faster than the air below the wing ($\vec{v}_{\text{above}} > \vec{v}_{\text{below}}$, shown in **Figure 14.10a**). Let us apply Bernoulli's equation to an airplane wing to evaluate this claim. A Boeing 747-8's maximum takeoff mass is 442 metric tons, its takeoff speed is 330 km/h, and its wing surface area is 554 m^2. We assume that the speed of air above the wing is equal to the takeoff speed and the speed of air below the wing is zero (this is a rather unrealistic assumption, but it allows us to estimate the largest possible force due to Bernoulli's effect). In this case we find

$$\Delta p = \tfrac{1}{2}\rho_{\text{air}}v_{\text{takeoff}}^2 = 0.5 \times (1.3\ \text{kg/m}^3) \times (92\ \text{m/s})^2 = 5501\ \text{N/m}^2$$

and

$$F_{\text{air on airplane}} = \Delta p \cdot A = 3.1 \times 10^6\ \text{N}$$

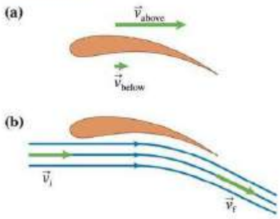
The force exerted by Earth on the airplane is

$$F_{\text{E on airplane}} = m_{\text{airplane}}g = 4.3 \times 10^6\ \text{N}$$

This force is much larger than the largest possible lifting force exerted on the plane due to Bernoulli's effect.

In other words, Bernoulli's effect is at work, but it does not provide a complete explanation of how airplanes fly. The important missing force comes from the change of direction of the air's motion. Due to the shape and the tilt of the wing, the air passing the wing changes its direction of motion from horizontal ($\vec{v}_i$) to slightly downward ($\vec{v}_f$) (Figure 14.10b). For this to happen, the wing must exert a downward force on the air; therefore (remember Newton's third law), the air exerts an equal and opposite force upward on the wing. It is this force that provides the main lift and (together with the force due to Bernoulli's effect) makes the airplane fly. Note that the origin of this force is the change of the direction of motion of air and has nothing to do with Bernoulli's effect.

FIGURE 14.10 Airflow over an airplane wing.



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Eugenia Etkina
3. January 2022.

Today my message is not about physics topics, but about our role as teachers who educate students as whole human beings. If you have not seen "Don't look up" yet please rush (it it is available in your country)! And make sure your students watch it too. Here is a brilliant commentary by Brian Cox - totally worth watching. Conservative movie critics are bashing the movie and it has relatively low ratings on "rotten tomatoes", but this makes it even more urgent to advocate for it and focus on its message.

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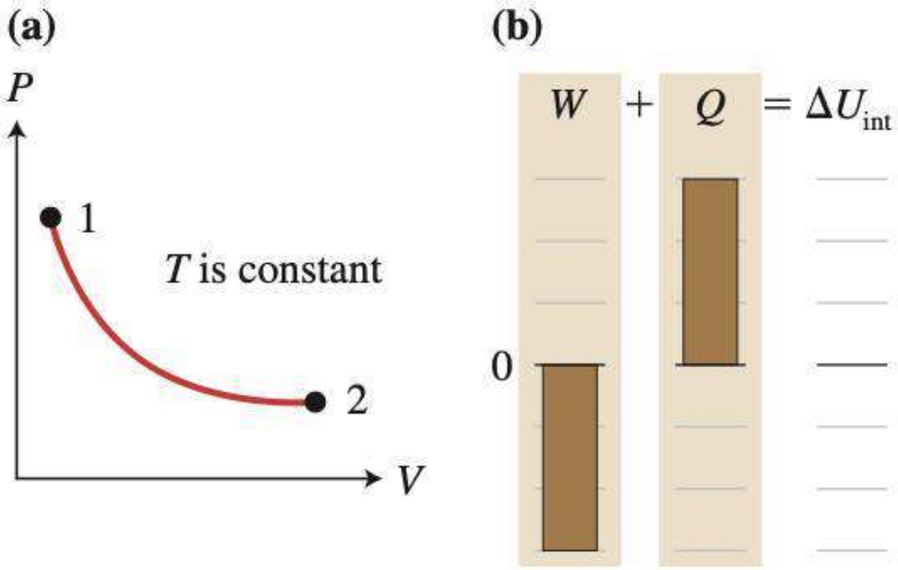
Eugenia Etkina
4. January 2022.

Hi all, two things today. 1) For new members (WELCOME!) I wanted to note that old posts related to different topics of our discussions are compiled in a google folder at https://drive.google.com/.../10qn...
You can read what happened over the years. Textbook related posts are especially important for those who use our textbook College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen.
2) We are moving to Chapter 15, Thermodynamics. This chapter is an excellent example of the coherent picture of physics that we tried to help our students construct. Remember, that in chapter 7, Work and Energy, students learned that work done by the environment on the system is the process through which the energy of a system changes. In these changes we took into account the changes in mechanical energy and internal energy. In thermodynamics, we usually do not have situations when the mechanical energy of a system changes, as we only focus on the changes in internal energy. However, we now have another means of changing energy - a new process (in addition to energy) - heating.
Heating is the process of energy transfer from the environment to the system when they are at different temperatures. Notice that we do not use the word "heat", but the word "heating" to underscore that it is the process of energy transfer, not energy itself. In our approach we only consider work done by the environment on the system and energy transfer through heating from the environment to the system - both can be positive or negative.
With this approach the first law of thermodynamics becomes an extension of the work-energy principle that the students learned in chapter 7 - the total energy change of a system if equal to the work done on the system by the environment plus the energy transferred to the system through the process of heating. Now, the bar chart approach works naturally - see the attached screen shot showing how the first law of thermodynamics applies to an isothermal process. Here there is positive heating but no temperature change of the system as the environment does negative work on it. As always, the bar chart is the step between the phenomenon and the mathematical description of the process.
Tomorrow I will focus on the process through which the students learn all this. 🙂
Please do not forget to respond to the post to make it more visible.

FIGURE 15.6 Analysis of an isothermal process.



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Eugenia Etkina
5. January 2022.

Today, I will continue with Chapter 15 - Thermodynamics. We start the chapter by helping students figure out how to calculate the internal energy of ideal gas and how to determine work that the environment does on it.
Once the students are familiar with both, we present them with a difficulty that we experience when we try to use familiar work energy principle Ei+W=Ef to explain two simple experiments (see the attached Observational Experiment table).
Experiments conducted in this table cannot be explained using the idea that work changes energy of a system. In both experiments, the energy clearly changes but there is no work done. This difficulty motivates the invention of a new physical quantity that accounts for the transfer of energy to the system without doing work- heating or Q. This step - the one described in the attached document is extremely important for the students to help them understand that Q is not energy, but a mechanism of transferring energy, it does not belong to a system.
If you finished reading the post, please do not forget to respond to it - like it or comment! thank you!

15.2 Two ways to change the energy of a system

Throughout this text, we have stressed the importance of defining a system—a carefully identified object or group of objects on which we focus our attention. Everything outside the system is the environment. A system is characterized by physical quantities, such as the system's internal energy, mass, volume, temperature, and number of particles. The interaction of the environment with the system is defined in terms of the work done by the environment on the system. We devised the generalized work-energy equation [Eq. (7.3)] that summarizes these ideas:

$$E_i + W_{\text{Environment on System}} = E_f$$

Using this equation, we find that the total initial energy E_i of the system plus the work done on the system by the environment $W_{\text{Environment on System}}$ equals the total final energy E_f of the system. The energy of the system can be in many different forms, but the only way the total energy of the system can change is if the environment does work on the system.

$$(K_i + U_{gi} + U_{si} + \cdots) + W_{\text{E on S}} = (K_f + U_{gf} + U_{sf} + \cdots + \Delta U_{\text{int}})$$

Are there situations where these ideas are inadequate? Consider Observational Experiment Table 15.1. To analyze these experiments we will use a rewritten version of the generalized work-energy equation:

$$W_{\text{Environment on System}} = E_f - E_i$$

OBSERVATIONAL EXPERIMENT TABLE 15.1 Using the work-energy principle to analyze two processes

Observational experiment	Analysis
Experiment 1. Place a fixed amount of gas in a fixed-volume container. A flame below causes the gas to warm from temperature T_i to T_f. 	• The temperature of the gas increased; hence its internal thermal energy increased: $\Delta U_{\text{int}} > 0$. • The work done on the gas was zero because the gas volume did not change: $W = 0$. • Thus, $0 = \Delta U_{\text{int}}$. *According to the generalized work-energy principle, this process cannot occur—the left side is zero and the right side is a positive number.*

(CONTINUED)

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Observational experiment	Analysis
Experiment 2. Place the same gas (same initial conditions) in a cylindrical enclosure with a heavy piston that can move freely up or down in the cylinder, thus keeping the pressure exerted on the gas constant. A flame below causes the gas to expand and warm from temperature T_i to T_f. It takes longer to reach T_f than it did in Experiment 1. T_i and T_f are the same in Experiment 1 and Experiment 2. 	• The temperature of the gas increased; hence its thermal energy increased: $\Delta U_{\text{int}} > 0$. • The piston pushed down on the gas opposite the direction of its expansion; thus negative work was done on the gas ($W_{\text{Piston on Gas}} < 0$). • Thus, $-\lvert W\rvert = +\lvert U_{\text{int}}\rvert$. *According to the generalized work-energy principle, this process cannot occur—the left side is negative and the right side is positive.*

Pattern

Analyzing both experiments using the work-energy principle, we find that according to this principle the processes cannot possibly occur. However, since we observe these processes in real life, they must be possible. We conclude that either the principle is incorrect or it needs modification.

The generalized work-energy principle is unable to account for the energy changes in the two experiments in Table 15.1. What modification in the principle would help us explain what happened in those two experiments?

Particle motion explains the change in thermal energy of the gas

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Eugenia Etkina
8. January 2022.

Hi all, thank you for coming to the meeting today, we had an amazing group representing almost all continents on Earth. Here is the recording and the link to the slides:
Recording: https://rutgers.zoom.us/.../lZrb9SZE954XOIqy2ELVeMhR... Password: C5E1.su^
Slides link:
https://docs.google.com/.../1o6dcVylrSRdjuRxS1CSj.../edit...
Our next meeting was supposed to be about the strategies for student improvement of work that do not ruin our lives. I suggest the meeting on Saturday, January 29th, 1 pm EST - two hours later than today). If there are people for whom this time does not work, we can always have a repeat meeting. Please comment on the day/time, thank you.

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Eugenia Etkina
9. January 2022.

Hello everyone, happy Sunday! I am continuing with Chapter 15 - Thermodynamics. After the students invented an improved statement of energy conservation - the first law of thermodynamics (adding heating as the means of energy transfer to the system in addition to work Q+W=change in E)), it is great to practice it a little before moving to complex problems (which will come tomorrow). Here is an example from the OALG Chapter 15 (posted here in the FILES) of such an activity for the students. It can be done in a group or individually and then discussed as a whole class. Notice, that there are no numbers here and no calculations but the activity allows the students to apply the first law in three different ways. If you read to the end, please do not forget to respond to the post to make it more visible.

OALG 15.3.3 Explain

Use the generalized work–energy principle with heating, called the first law of thermodynamics $W + Q = \Delta E$, to explain the processes described below in words. Decide whether the gravitational and kinetic energies of the system change.

Verbal representation of the process	**Write an explanation in words using the terms of energy, heating, and work.**	**Indicate the signs of the $W/Q/U_{int}$ terms in the equation.**	**Represent the process with a bar chart.**
A gas, originally at 20.0 °C, resides in a cylinder with a movable piston. You push on the piston, thus compressing and warming the gas. The cylinder is insulated so that there is no thermal energy transfer into or out of the gas. Choose the gas in the cylinder as the system.		*W*: *Q*: ΔU_{int} :	
A gas, originally at 0.0 °C, resides in a cylinder with a movable piston, the cylinder is inside a bath filled with ice water. You push slowly on the piston, thus compressing the gas, but this time the gas does not warm up. The cylinder has thin metal walls and slightly warms the water surrounding it. Choose the gas in the cylinder as the system.		*W*: *Q*: ΔU_{int} :	
A burning match warms a paper cup that holds ice water. After 2 minutes of warming, the water is still at 0°C but now has less ice and more liquid water. Choose the ice water as the system.		*W*: *Q*: ΔU_{int} :	

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Eugenia Etkina
10. January 2022.

Hi all, I continue with Chapter 15 - Thermodynamics.
Using our approach to thermodynamic quantities and the law of energy conservation and bar charts allows us to help student analyze processes in a gas with relative ease. We start with iso processes - please read the attached document and see what happens to the work done on the gas when the gas is expanding. But what is very important is how we explain the gas processes microscopically.
Research by the PER group of late L. McDermott showed that students have tremendous difficulties connecting macroscopic descriptions of processes to microscopic. We do it systematically. In the textbook the section: Mechanism of energy transfer to a gas

microscopically precedes the analysis of the processes. I suggest reading it first, and then the part posted here. Enjoy! And please, do not forget to comment on the post or like it to make it more visible.

Isothermal process (constant temperature)

During an *isothermal* process, the gas pressure and volume change while the temperature remains constant. We will limit our analysis to volume expansion only. To demonstrate this process, we use a cylinder with a movable piston. The cylinder is immersed in an ice water bath to keep all parts at the same temperature. The cylinder walls are made of a thermally conductive material (a material that allows thermal energy transfer—aluminum is a good example, whereas Styrofoam has low thermal conductivity).

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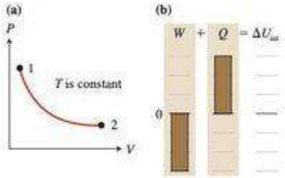
FIGURE 15.6 Analysis of an isothermal process.

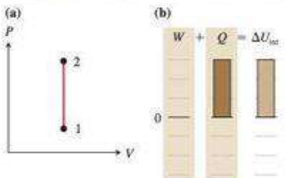


We move the piston very slowly so that the volume of the gas inside the cylinder is increasing (alternatively, we can say that we are letting the gas push the piston by expanding). A graph of this process is shown in Figure 15.6a. The gas pushes on the piston to the right, and the piston pushes on the gas to the left. Let the gas inside the cylinder be our system. In this case, the piston does negative work on the system. Therefore, the thermal energy of the gas should decrease and the temperature should decrease, but because the gas is in a bath of constant temperature, the ice water transfers energy to the gas through the walls of the container, keeping the temperature constant. The energy bar chart for the process is shown in Figure 15.6b. Because the temperature of the gas stays constant, $\Delta U_{int} = 0$. The external work done on the gas is negative ($W < 0$). Transfer of energy through heating ($Q > 0$) is needed to make the thermal energy change zero. The first law of thermodynamics can be written as $-|W| + Q = 0$.

Now let us explain the same process microscopically. We will first look at the interactions of the gas particles with the moving piston. As described before, the gas molecules stick to the inner walls (and the piston) and leave a short time later. Molecules that leave from the *moving piston* (expansion) have on average slightly smaller velocities than before they stuck to the piston. (This is analogous to when somebody throws a ball toward you from a car that is moving away from you. The speed of the ball is smaller than it would be if the person had thrown the ball from a stationary car.) The kinetic energy (and therefore the temperature) of the molecules of the gas that leave the piston is slightly smaller than the kinetic energy of the molecules before we started to move the piston. Such a "cold molecule" eventually hits the inner surface of the wall of the cylinder, which is kept at the constant temperature. When a molecule sticks to the wall, it gains energy from the vibrating atoms and leaves the wall with a velocity that is larger than the velocity it had before it hit the wall. Because the volume of the gas is increasing, the density of the gas is decreasing and so is the frequency with which the molecules are hitting the wall (note that the speed of the molecules remains constant).

Isochoric process (constant volume)

FIGURE 15.7 Analysis of an isochoric process.



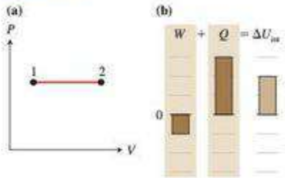
During an *isochoric* process, the volume of the gas remains constant. To demonstrate this process, we now fix the piston so that it cannot move and place the container in a higher temperature bath. The temperature of the gas increases. Because the volume is constant, there is no work done on the gas ($W = 0$). Energy is transferred to the gas through heating ($Q > 0$). The transfer of energy through heating leads to an increase in the internal thermal energy of the gas ($\Delta U_{int} > 0$). The first law of thermodynamics can be written as $0 + Q = +\Delta U_{int}$. Figure 15.7 shows the bar chart for this process.

Microscopically speaking, the container wall transfers thermal energy to the gas through the mechanism explained above. The faster moving molecules of the gas collide with the walls of the container more often and more violently. The gas pressure increases.

Isobaric process (constant pressure)

During an *isobaric* process, the pressure of the gas remains constant (Figure 15.8a). To demonstrate this process, we place the gas in a container that has a heavy piston on top that can move freely up (or down), keeping the gas at constant pressure. The container is placed in a bath at a higher temperature, causing the gas to expand at constant pressure.

FIGURE 15.8 Analysis of an isobaric process.



During this process, the environment does negative work on the gas ($W < 0$). Energy is transferred through heating ($Q > 0$) and is greater than the negative work. The internal thermal energy of the gas increases ($\Delta U_{int} > 0$). The first law of thermodynamics can be written as $-|W| + Q = +\Delta U_{int}$. Figure 15.8b shows the bar chart for the process.

To explain the process microscopically, we again need to consider how the walls of the container exchange energy with the warm bath. The walls transfer energy to the gas molecules through collisions, but the gas warms less because the piston moves outward, slowing the particles in a way similar to the mechanism for the isothermal process. The greater velocity of the molecules is compensated for by less frequent collisions between the molecules and the walls so that the pressure remains constant.

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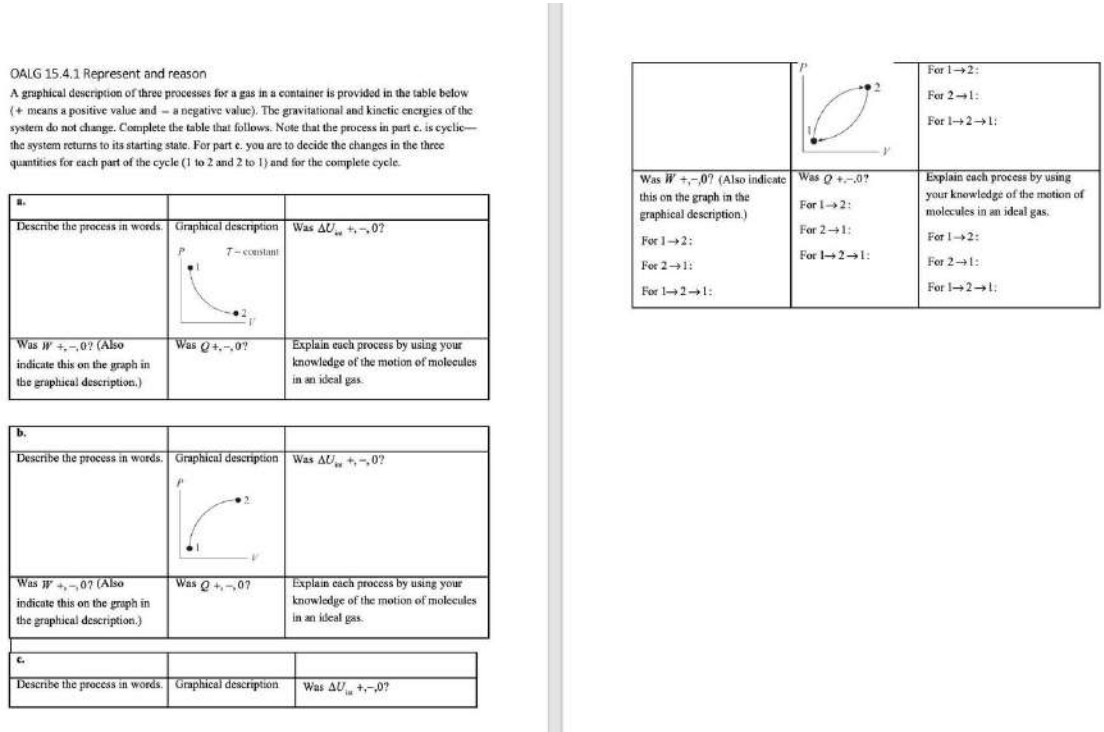
Eugenia Etkina
11. January 2022.

Today my post is about one of my most favorite activities. It was created in response to a quantitative study done by David Meltzer a long time ago and the dissertation by David Brookes that used this problem for an interview study. This activity helps students truly understand the difference between internal energy, work and heating. While students have no problem figuring out that the work done on a gas in a cyclic process can be non-zero, they have a lot of difficulty realizing that it is true for heating too. The steps in this activity help them figure this out and see the difference between internal energy as a state function and work and heating as the physical quantities that are not state functions.



OALG 15.4.1 Represent and reason

A graphical description of three processes for a gas in a container is provided in the table below (+ means a positive value and − a negative value). The gravitational and kinetic energies of the system do not change. Complete the table that follows. Note that the process in part c. is cyclic—the system returns to its starting state. For part c. you are to decide the changes in the three quantities for each part of the cycle (1 to 2 and 2 to 1) and for the complete cycle.

a.		
Describe the process in words.	Graphical description P, T = constant, 1, 2, V	Was ΔU_{int} +, −, 0?
Was W +, −, 0? (Also indicate this on the graph in the graphical description.)	Was Q +, −, 0?	Explain each process by using your knowledge of the motion of molecules in an ideal gas.

b.		
Describe the process in words.	Graphical description P, 1, 2, V	Was ΔU_{int} +, −, 0?
Was W +, −, 0? (Also indicate this on the graph in the graphical description.)	Was Q +, −, 0?	Explain each process by using your knowledge of the motion of molecules in an ideal gas.

c.		
Describe the process in words.	Graphical description	Was ΔU_{int} +, −, 0?
	P, 1, 2, V	For 1→2: For 2→1: For 1→2→1:
Was W +, −, 0? (Also indicate this on the graph in the graphical description.) For 1→2: For 2→1: For 1→2→1:	Was Q +, −, 0? For 1→2: For 2→1: For 1→2→1:	Explain each process by using your knowledge of the motion of molecules in an ideal gas. For 1→2: For 2→1: For 1→2→1:

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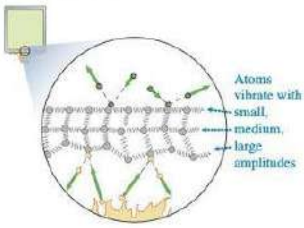
Eugenia Etkina
12. January 2022.

Hello everyone! Today I thought I would share an excellent explanation of the mechanism of energy transfer to the gas through the process of heating. Traditionally we talk about molecules of hotter gas hitting the walls of the container and transferring their kinetic energy to the walls and then the walls - to the gas inside. But is this really accurate? When we were working on the second edition of the textbook College Physics: Explore and Apply, that many of you use, Gorazd Planinsic devised a brilliant explanation of the mechanism. I suggested that you to read it in one of my previous posts, but then I realized that those who do not have the textbook, will not be able to learn from it. I think this is one (of many) gems that we have. And I wanted everyone to have access to it. So - here it goes. Please do not forget to respond to the post after you finished reading it and the attached document.

Mechanism of energy transfer to a gas through heating

We consider a gas inside a container that is being heated by a flame (see Figure 15.5). The initial temperature of the gas is lower than the temperature of the flame. As you read the following description of the heating process, remember that when we talk about the velocities and kinetic energies of molecules, we always have average values in mind.

FIGURE 15.5 Microscopic view of a gas being heated by a flame.



Transfer of thermal energy from the flame's hot gas to the container wall The container wall is made of atoms that cannot move around (solids do not flow) but can vibrate. As we heat the container (in this case with a flame), hot gas molecules hit the outer surface of the container wall. If we assume that these collisions are elastic, as we did when we developed the microscopic model of an ideal gas in Chapter 12, then each molecule rebounds with the same speed without transferring any energy to the wall. To explain how the molecules of the hot gas in the flame transfer energy to the container walls, we need to model the collisions differently. In this new model, when a molecule hits the surface of the wall, instead of rebounding immediately, it sticks to the wall for a very short time and then leaves the surface because it is "knocked" by the vibrating wall atoms (see the magnified part of Figure 15.5). Hot gas molecules have a large velocity (and thus kinetic energy). When they stick to the surface, their kinetic energy is transferred to the wall atoms. As a result, the wall atoms start to vibrate with larger amplitudes. When the gas molecules detach from the surface and fly away, their velocity (and therefore kinetic energy) is smaller than it was before they stuck to the surface.

Transfer of thermal energy through the container wall Atoms at the outer surface of the container wall vibrate with large amplitudes. Since the atoms in the container wall are bound to their nearest neighbors as if they were connected with little springs, the vibrations of outer surface atoms are transferred to the atoms in deeper layers in the wall (Figure 15.5). The amplitude of vibration decreases as we move away from the outer surface (and into the wall), but everywhere in the wall the amplitude of vibration is larger than before we started heating the container with the flame. The atoms on the inner surface of the container and molecules of the gas inside the container undergo a similar process to that at the outer surface of the container. The only difference is that now slow-moving gas molecules stick to the inner surface of the wall, where they receive energy from the vibrating atoms of the wall. As a result, they leave the inner surface with a larger kinetic energy than they had before they stuck to the surface. We can describe this process using the language of energy: the high-temperature flame is transferring energy through heating to the container wall. Thermal energy is transferred through the wall to the gas inside the container. As a result, the temperature of the gas increases.

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Eugenia Etkina

13. January 2022.

Hi all, we finished Chapter 15 (as much as we could) and today I want to invite all our new members to watch a video of my talk about the ISLE approach, posted on you tube by Martín Monteiro. While he posted this link before, I think it will be very useful for those who are not familiar with the ISLE approach to watch it to be able to benefit from the posts here. I am reminding everyone that ISLE website is at islephysics.net - there are lots of materials and instructions on how to get access to more free materials. Here is the video: https://www.youtube.com/watch?v=BKsAGu7RN9k

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Eugenia Etkina
14. January 2022.

Hi all, today I start Chapter 16 - Second Law of Thermodynamics. The first step for the students is to recognize that not every process allowed by the law of energy conservation occurs naturally. We have a couple of excellent activities for it. I am attaching one that has cool videos. The text of the activity is in the screenshot, I am also posting the links to videos below as I am not sure you can get the links form the screenshot.
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16.1.2 Reason

In the table below there are links to videos that show different processes. For each process, describe the energy changes that occur and decide whether the process occurs naturally.

a. Fill in the table that follows.

Process	**Describe the types of energy that change, the work done on the system, and the heating during the processes.**	**Does the processes occur naturally?**
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 [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-16-1-2b]		
 [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-16-1-2c]		
 [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-16-1-2d]		

b. Decide whether any of the processes shown in the videos are prohibited because energy is *not* conserved. Explain.

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Eugenia Etkina
15. January 2022.

Hi all, we continue with the second law of thermodynamics. Once the students learn about reversible and non-reversible processes they proceed to the construction of the idea of the direction of the flow of energy (Direction of thermal energy transfer In an isolated system,

energy always transfers from a warmer region to a cooler region), they are ready to devise the second law of thermodynamics. One of the statements of the law relates to heat engines. But we do not have the term heat in our vernacular. What to do? We thought long and hard about it and came up with a new term - thermodynamic engine. But it is not the name that is important but our approach to a conceptual understanding of why a cyclic process is needed in the engines. I am pasting the text of the subsection on this and the link to the video. Read and watch, it is very helpful for the students.
Here is the link to the video. Watch the ice cube being lifted. and please do not forget to comment on the post ot make it more visible. https://mediaplayer.pearsoncmg.com/.../secs-egv2e-simple...

Direction of thermal energy transfer In an isolated system, energy always transfers from a warmer region to a cooler region.

Thermodynamic (or heat) engines

Why are we interested in organized versus nonorganized forms of energy in the first place? Historically, once people understood that hot compressed gas can push pistons and thus do work (maximizing this work being the main goal), they started dreaming of making machines that use this property. These machines are usually called *heat engines*, but we will use the term *thermodynamic engine* to underscore that the laws of

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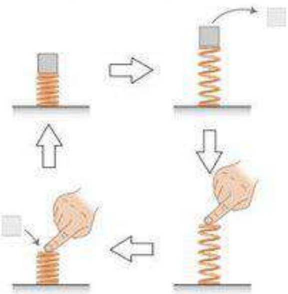
thermodynamics explain their operation. The main difficulty of creating such engines is that the gas cannot expand and push something indefinitely. In order for an engine to work continuously, the piston needs to be brought back to its original state, or some new portion of gas needs to be acquired so it can now expand and push something again.

This is exactly what all thermodynamic engines have in common: they repeat the same process over and over again. We will call such a process a *cyclic* process, and we will call the one "round-trip" during which the device returns to the original state a *cycle*. In any cyclic process, the gas returns to the original state, meaning that the total energy transferred to or from the engine during one complete cycle is zero. If it were not zero, the engine would have had more or less energy at the end of the cycle, meaning that it would not have been in the same state as at the beginning. Therefore, in a cyclic process *all* energy that is transferred to the engine should also leave the engine. But remember—the goal is to maximize the portion of energy that leaves the engine as work. What is the difference between organized and nonorganized forms of energy for this purpose?

It is easier to understand the answer if we use an example. Imagine we want to construct an engine that will lift sugar cubes from a conveyor belt at one level to a higher level. Let's compare two different designs. The first engine uses mostly organized forms of energy, and the second engine uses mostly less organized thermal energy.

The first engine uses a spring to do work. A compressed spring (the system) stores elastic potential energy, which is also an example of organized energy. All parts of a deformed spring exert forces in the same direction on the neighboring parts. The initial state is a compressed spring with a sugar cube on it; the spring decompresses and pushes the cube up. We then push down on the spring and it returns into its initial state. **Figure 16.2** shows one cycle of operation. Each cycle consists of a spring compression and spring expansion during which the spring does work on the cube (considered to be in the environment in this case).

FIGURE 16.2 One cycle of an engine that involves only organized energy.

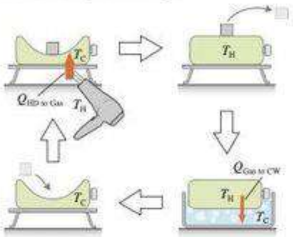


The second engine uses an ideal gas to do work. The gas is inside a closed plastic bottle, and the sugar cube sits on the side of the bottle. The initial state is when the gas is cold (T_C) and the bottle is squished; we then use a hair dryer (HD) to warm up the gas. The positive heating of the gas ($Q_{HD\ to\ Gas}$) causes the gas to warm up to temperature T_H and to expand. During the expansion the gas does work on the sugar cube. To return the bottle to the initial squished state, we need to cool it to temperature T_C, for example, by placing it in cold water (CW), which means that that the energy provided to the gas through the process of heating at this stage is negative ($Q_{CW\ to\ Gas}$), as the gas transfers positive thermal energy to cold water. **Figure 16.3** and the video at right show one cycle of operation.

VIDEO 16.2

Note that this engine (as with the first engine) ends the cycle in the same state as at the beginning of the cycle. Let's analyze energy conversions during one cycle for both engines. In the first engine, the compressed spring that stored elastic potential energy does work on the sugar cube. The amount of work done is almost equal to the stored energy.

FIGURE 16.3 One cycle of an engine that involves nonorganized energy.



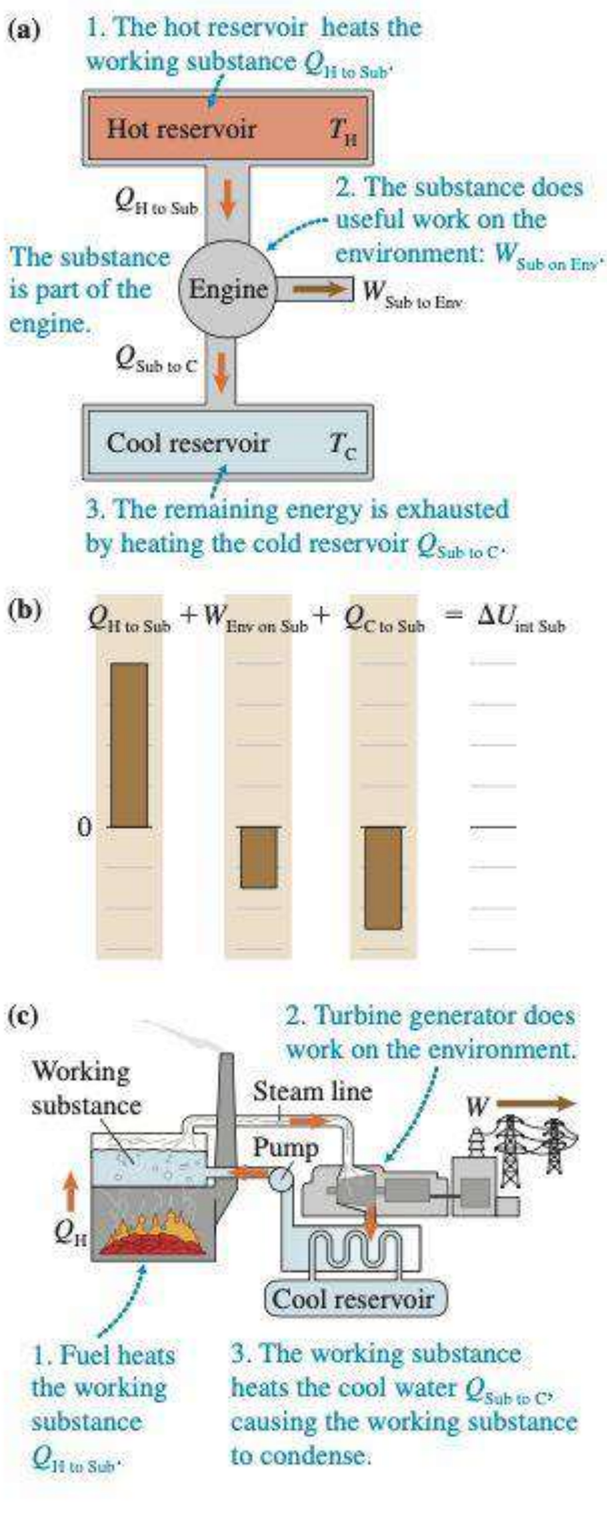
In the second engine, the hot gas that stored internal thermal energy transferred to it by the hair dryer ($Q_{HD\ to\ Gas}$) did work on the cube; however, the amount of work done is less than the amount of energy transferred to the gas through heating. Since the thermal energy of the gas is less organized, we can use only part of the initial thermal energy to do work. Because molecules in the gas are moving randomly, only a small fraction of molecules at a time exert forces that contribute to the work done on the environment. The rest of the energy transferred to the gas ($Q_{HD\ to\ Gas}$) remains in the form of thermal energy, which has to be "dumped" (transferred) from the engine by cooling ($Q_{CW\ to\ Gas} = -Q_{Gas\ to\ CW}$). We cannot avoid this "dumping" of thermal energy from the engine because, in order to complete the cycle, we need to bring the engine back to the initial low-temperature state. Given that, at the end of the cycle, the engine is in the same state as at the beginning, this means that the total work done by the gas on the environment is equal to $W_{Gas\ on\ Cube} = Q_{HD\ to\ Gas} + Q_{CW\ to\ Gas} = Q_{HD\ to\ Gas} - Q_{Gas\ to\ CW}$, where $Q_{CW\ to\ Gas}$ is a negative number.

From the above analysis, we see that we can use all of the organized energy in the system to do work on the environment in a cyclic process, but not all of the nonorganized energy can be used for the same purpose. Unfortunately, the processes in fuel-based https://www.facebook.com/groups/320431092109343/posts/1093332034819241/?__cft__[0]=AZW0bVCpC_9XkmP3a9DXTSCGBPQVepNQpWEzQsSEuTCEKYeCpivA1j38566FBNmtxfA1ZBAEbRbB4CqQK-jqlj60_H5IYJVYcXpiuMEfq35oQrXzGyMxUb22BQKpjljeoVIVE-9JobfBOPZF_d9L_uBQ&__tn__=%2CO%2CP-R

Eugenia Etkina
16. January 2022.

Hi all, I wanted to share multiple representations of the work of thermodynamics engines that might help your students understand their operation. Traditional schematics, work-heating energy bar chart and a sketch of a real thing. Research shows that when there is no time delay between the representations, they help students much better than different representations separated in time and space.
That is why we have it all in one figure in the textbook. I have not taught second law of thermodynamics for a while, I am asking those who have done it recently, to share their experiences and comment on student ideas and difficult issues.

FIGURE 16.7 Thermodynamic engine. (a) A schematic illustration. (b) A bar chart for a cycle. (c) An electric power plant is a thermodynamic engine.



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2bqgp5Bu_HGj3tt5O2zrj8KJXXwL1Q2Yd7mvQaFKB4ZH8pBoIC03nKuMRmRHXG0kOze-YZ98u3DGAPLa37cBf&__tn__=%2CO%2CP-R

Eugenia Etkina
18. January 2022.

Hi all, today I am starting chapter 17 - Electric charge and electric force. Note that there are no electric fields here. The main ideas are two types of electric charge, interactions between charged and uncharged objects and conductors and dielectrics (insulators). As you know, the experiments for electrostatics are very unreliable. They depend on the weather, on the dryness of your hands, on the history of previous experiments. We have all necessary experiments videoed in the textbook, ALG and OALG, but this year, Gorazd Planinsic found a new way to conduct them and made the videos. They are not incorporated in our materials yet, but, in my opinion, they are the best to help students construct ideas of charging by rubbing and electric charge conservation. Watch them and post here the questions that you might ask the students who can perform all these experiments themselves. The videos are for those who teach online and for advice what materials to get. Please do not forget to respond to the post to make it more visible.
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Eugenia Etkina
19. January 2022.

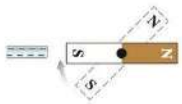
Hi all, I continue with Chapter 17, Electric Charge and Electric Force. Today is a story.
A long time ago, when I was running a workshop for elementary teachers on Electricity and Magnetism. We were doing experiments similar to those that are in the videos in my previous post. The teachers found repulsion of similar objects rubbed with the same material and attraction of the different objects that were rubbed with different materials. They observed repulsion and attraction. I casually asked them how they could explain such interactions.
To my surprise several of them immediately said that the interactions were magnetic. I was not expecting this answer but luckily I had magnets at hand and I asked them to design an experiment to test this idea. They worked in groups and came up with the following: take a magnet and put it on a swivel or hang it so that is hands horizontally. Then take a rubbed object and bring it to one pole and then the other. If these interactions are magnetic, then the rubbed object should attract one pole and repel the other.
What they found after they all did the experiment was that both poles of the magnet were attracted to the rubbed object contrary to the prediction that they made based on the idea

under test(of course, the magnet is made of metal and the metal got electrically polarized in the presence of electrically charged object, which they did not know at the time but we explained this phenomenon later after they learned about conductors and dialectics).
Bottom line, they were very successful in rejecting their idea experimentally and simultaneously finding out some new properties of magnets. This moment is captured in the textbook in the Testing experiment 17.3 (attached here) and in the activities in the ALG and OALG.
You are probably thinking that my students were unusual and nobody else would think that electrostatic interactions are magnetic in nature. This is not true. After my experience, I asked many physics professors and teachers to ask their students the same question and they all received a very similar answer. If you are teaching electrostatics, do not miss this opportunity - not only it addresses student ideas but it also allows the students to practice experimentally testing them and ruling them out. The video of the experiment that students usually design to test this idea is below, there are lots of variations of this experiment. And please do not forget to respond to this post if you read to the end to make it more visible.
https://mediaplayer.pearsoncmg.com/.../secs-experiment...

Is the electric interaction a magnetic interaction?

Do you recall observing any other interaction that involved repulsion? If you've ever played with magnets, you probably know that magnets have poles (north and south). Like poles repel, while unlike poles attract. Both poles attract objects that are not magnets but contain iron—nails, paper clips, etc. Electrically charged objects also attract and repel each other and attract uncharged objects. Perhaps the electric interaction is actually the magnetic interaction, just described using different terminology. We test this hypothesis in Testing Experiment **Table 17.3**.

TESTING EXPERIMENT TABLE 17.3 Testing the electric = magnetic interaction hypothesis (VIDEO TET 17.3)

Testing experiment	Prediction	Outcome
Experiment 1. Bring a negatively charged plastic rod near the north pole of a magnet that is free to rotate about a pivot.	If the electric interaction is the same as the magnetic interaction, then the negatively charged rod should either attract or repel the north pole of the magnet.	The negatively charged rod attracts the north pole. 
Experiment 2. Bring the negatively charged plastic rod near the south pole of a magnet that is free to rotate about a pivot.	If the electric interaction is the same as the magnetic interaction, then the negatively charged rod should repel the south pole of the magnet.	The negatively charged rod also attracts the south pole. 

Conclusion

The outcome of the second experiment is inconsistent with the prediction. Thus we can reject the hypothesis that electric interaction is the same as magnetic. However, both experiments can be explained using our knowledge of electric interactions if we assume that a magnet *also* behaves like a piece of metal and thus attracts any charged object, the way all metals do.

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Eugenia Etkina

20. January 2022.

Hi all, today we focus on an electroscope. While we are all familiar with this device, many of us also know that electroscopes are not very reliable. Sometimes it is hard to charge them (the needle would not stay deflected) and sometimes they would not discharge when we touch them. What is the reason? Watch the following video and see if you can explain the outcome. https://www.youtube.com/watch?v=SE9iPm-I6aU
Spoiler: focus on how the student charges the electroscope. Once you watch the video and explain the outcome, you will see how important it is to always ground the electroscope for proper functioning. We usually do not deliberately ground electroscopes because they are automatically grounded when we put them on. desk (all desks are slightly conductive). But if you have a really well insulated desk or put the electroscope on an insulating material, then weird effects might occur. In my ext post I will attach the paper by Sergej Faletic and Gorazd Planinsic discusses many strange effects that occur to electroscopes (I cannot attach it to this post as I already added a link). Do not miss! And please do not forget to comment on the post after you have read it to make it more visible

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Eugenia Etkina
20. January 2022.

And here is the link to the paper.

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Eugenia Etkina
23. January 2022.

Hi all, we have a large group of Italian teachers who joined our group today. Welcome! To benefit form the group, please read the announcement on the front page explaining what the group is about and visit https://www.islephysics.net/ to learn about the ISLE approach to learning and teaching physics which is the philosophical foundation of the textbook College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen, which was the original reason for the creation of this group. Science then, lots of people who have not heard about ISLE before and do not have the textbook yet joined. We welcome you all and hope that eventually the ISLE philosophy will become familiar and useful for you. We have regular meetings once a month , the next one is on January 29th, see the events calendar. Tomorrow I will continue my posts for textbook chapters, we are on Chapter 18 - Electric Field!

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Eugenia Etkina
24. January 2022.

Hi all! Several things today.
First, please click on Events and check out when our next meeting is. Lots of people are contributing materials to this meeting, it will be a sharing session of those who have their students resubmit their work for improvement. They share how they do it and how their students benefit from it.
Second, Hrvoje Miloloža and I are working on documenting all the posts here, the google folder for all posts is at https://drive.google.com/.../10qn... Please visit it.
Third, I am starting to comment on Chapter 18 Electric Field. The first thing I wanted to talk about is the language that we use. Traditionally in American textbooks the term "electric field" refers to two things - the alteration of space around electrically charged object or a mechanism of interaction of electrically charged objects and the physical quantity E=F/q^test, where F is the force that electric field exerts on a test charge placed in a certain location and q^test is the magnitude of the test charge (presumed to be very small). In order to make a distinction between electric field as a mechanism of interactions and the physical quantity E, we call quantity E "E field" and the mechanism of interactions or the space surrounding charged objects - electric field. To underscore that E field is not the only quantity characterizing electric field, we call the quantity of electric potential - "V field". Now that we established the vernacular, I will continue commenting on E and V fields tomorrow. If you finished reading to the end, please do not forget to like or comment to make the post more visible.

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Eugenia Etkina
26. January 2022.

Hi all, as I mentioned in my previous post, Hrvoje Mililoža and I have been working on saving all the posts in the Facebook group in a google folder, so that you could go there and download any post you want. In our discussions of how to do it best, Hrvoje Mililoža mentioned that in addition to these posts, the Instructor Guide is very helpful in using our materials. I could not agree with him more. I do not post any excerpts from the Instructor Guide as it is posted here in the Files and you can find it on Mastering Physics. However, it is a huge document and it might seem daunting to find the relevant part. So I decided to paste a short discussion of electric potential energy from the Instructor Guide here (going back to Chapter 17 as I skipped the energy aspect of electric interactions there) and ask you whether it might be useful for me to post some excerpts from it in addition to the screenshots of textbook pages and Active Learning Guide activities and follow up explanations. Please respond here whether it will be useful for you to see excepts from the Instructor Guide. Here is the post:

The electric potential energy of a system of two or more point-like charged objects is the subject of Section 17.5. Electric potential energy is glossed over in many textbooks, and yet it forms the fundamental grounding and understanding for the more abstract quantity of electric potential. In our experience, the time devoted to understanding electric potential energy pays off later when students have to wrestle with electric potential. Both the ALG and the textbook follow the same approach.

Student learning of electric potential energy is based on the system approach, which initially involves using bar charts to analyze situations involving electrically charged objects qualitatively. From this analysis, students invent a new type of energy—electric potential energy. Only then do they proceed to the construction of the mathematical description of this energy of two like and two unlike charged objects. We recommend starting off the section on electric potential energy in class with the ALG Activities 17.5.1-17.5.3, making sure that students analyze the situations using the bar charts (textbook Figures 17.15 and 17.16) and follow up with a clicker question, in which you present students with pairs of configurations of two charged objects and ask them which configuration has more electric potential energy. For example, you could ask students to compare the electric potential energy of a system consisting of a positively charged object and a negatively charged object when they are two different distances apart. Then you could ask students to compare the electric potential energy of a system of two negatively charged objects (or two positively charged objects) when they are placed at a different distance apart. In our experience, this is a challenging activity for students because there is more than one variable involved (charge and distance), but it helps them to keep track of how electric potential energy should increase or decrease based on the signs of the charged objects and the distance apart.

It is very important to establish where the electric potential energy of a system is zero. For simplicity, we always assume that the electric potential energy of a system of two electrically charged objects is zero when the distance between the objects is infinite. The signs of the potential energies can cause difficulties. To help students with the signs, use textbook Example 17.6 to analyze energy of the system of two opposite charged objects and then Figure 17.18, in which students examine the graph of the potential energy versus separation distance.

Finally, a general discussion concerning the fact that a system of objects that are attracted to each other has negative electric potential energy (assuming that the same objects being separated by an infinitely large distance do not interact and thus the system does not have any electric potential energy) is extremely important. Discussing an analogy between a gravitational potential energy of system object-Earth and electric potential energy of two

oppositely charged objects might help students understand that if you have to do positive work to separate two objects in the system, the most reasonable choice is to assign a negative sign for the energy of their interaction. Comparing and contrasting positive and negative electric potential energies of different system is also very important. Make sure that you assign the reading exercise (ALG Activity 17.5.5) here. It is different from our common reading exercises and it poses specific questions in addition to the Review Question.
If you read to the end, please like the post or comment on it to make it more visible. And please do not forget about our meeting on Saturday!

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Eugenia Etkina
27. January 2022.

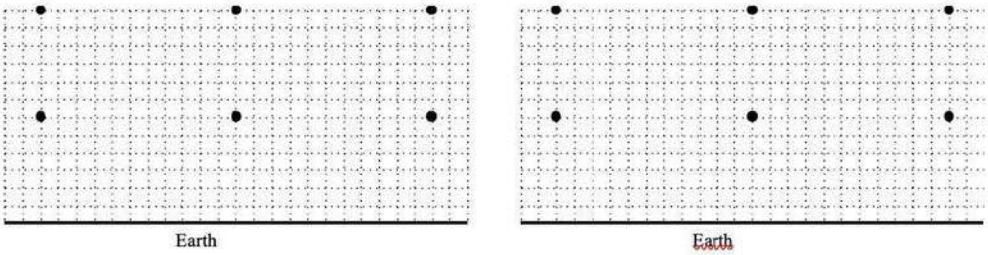
Hi all, today I want to focus on an activity from the ALG and OALG that helps students invent the physical quantity of E field. I am attaching here and I am asking you to first read and do the activity before you continue reading this post.
First, the goal of the activity is clearly defined in the first sentence: "Alicia and Sammy decide to map the gravitational field created by Earth near the Earth's surface (assuming that close to Earth's surface it is flat) by measuring the force exerted by Earth on a test object at the six points shown in the diagram. Alicia uses a 1-kg test object while Sammy uses a 2-kg test object." Second, the students are invited to draw the field vectors in this simplified situation: "a. Draw Alicia's and Sammy's measured gravitational field vectors at the points shown in the diagram. Make sure you draw the vectors to scale."
Now that the students draw these vectors, the activity leads them to questioning the utility of such representation of the E field and simultaneously creating the need to know:
"b. You may notice that in the previous activity, Alicia's and Sammy's fields look different. This is a problem because, conceptually, the field is created by Earth and should be the same no matter what mass the test object used to measure it has. Invent a new physical quantity (the field) that will be independent of the mass of the test object used to measure it (we will call this test object test-mass)." This step invited the students to recognize that they need to divide the force by the mass of the test object.
The next step helps them connect the new quantity to the quantity that would serve the same purpose for electric field:
c. Compare the physical quantity that you invented with the quantity defined in Equation 18.1 on page 537 in the textbook. Then think how you can devise a similar quantity to characterize electric field. Then compare the physical quantity you invented with the one defined by Equation 18.2 on page 538 in the textbook.
This activity follows the "optimal adaptivity corridor" of learning (google it and you will find the work of Schwartz, Bransford and Sears, I wrote about it before): start with a clear goal, engage students in the invention of a new idea, modify this new idea if necessary using teacher help, invent a better idea and then, have the "time for telling". Starting with invention, not telling the students the right answer was found to be much more effective for learning. And I wanted to

use this activity as an example of innovation-efficiency-innovation-efficiency process that allows our students to develop adaptive expertise.

OALG 18.1.4 Represent and reason

Alicia and Sammy decide to map the gravitational field created by Earth near the Earth's surface (assuming that close to Earth's surface it is flat) by measuring the force exerted by Earth on a test object at the six points shown in the diagram. Alicia uses a 1-kg test object while Sammy uses a 2-kg test object.

a. Draw Alicia's and Sammy's measured gravitational field vectors at the points shown in the diagram. Make sure you draw the vectors to scale.



b. You may notice that in the previous activity, Alicia's and Sammy's fields look different. This is a problem because, conceptually, the field is created by Earth and should be the same no matter what mass the test object used to measure it has. Invent a new physical quantity (the $\vec{g}$ **field**) that will be independent of the mass of the test object used to measure it (we will call this test object test-mass).

c. Compare the physical quantity that you invented with the quantity defined in Equation 18.1 on page 537 in the textbook. Then think how you can devise a similar quantity to characterize electric field. Then compare the physical quantity you invented with the one defined by Equation 18.2 on page 538 in the textbook.

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Eugenia Etkina
29. January 2022.

Hi all, it looks like we are going to have a longer meeting today. Nine people contributed to the slide show describing how they do student resubmission of work and their contributions are excellent! I am writing this so that you plan your day accordingly - the meeting might last longer that 1 hour today. See you soon!

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T1tj1WKBwrJenR5kuUqVfduNuHueEzlifnppFpeVpdhlmHSbbtMn-4BFjwXoN7Hb8&__tn__=%2CO%2CP-R

Eugenia Etkina
29. January 2022.

Hi all, thank you for coming to the meeting today! Here is the link to the slides https://docs.google.com/.../1jUEcyjKmWY56Y1ty3sIv.../edit...
and here is the link to the recording:
https://rutgers.zoom.us/.../tlUYoqsbsv3Skb3J-BxckesO... Password: yXnK4+=7
The next meeting will be dedicated to the answers of the questions about different strategies described today - the presenters will answer the questions and to the participants sharing their approaches and how they are going to implement work improvement policies in their courses. I will post the poll for the next meeting day/time tomorrow as well as the link to the google slide deck to put your slides into.
Thank you all of our presenters and all of those who attended!

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Eugenia Etkina
30. January 2022.

Hi all, yesterday during the meeting we agreed to have one more meeting on the same topic - I wrote about it yesterday. We had many presenters and the audience did not have time to think about each method and did not have time to share how they would implement (or are already implementing) student improvement work. I am posting a poll for the choice of the next meeting. I am suggesting moving the time up 2 hours to give an opportunity for people from Australia and New Zealand to join, The meeting will be at 3 pm EST (this will be 9 pm Central European time, I know it is a little late, but this way I think most of the world can join). The possible dates are February 26 and March 5. Please vote!
If you missed the meeting yesterday, please watch the video recording and make sure you access the slides (posted both yesterday). This way you will be able to prepare questions for the next meeting.
I also learned that people had trouble finding the link to the meeting in my posts, next time I will put it right into the even announcement. I did not do it before as people tend to click on it at random times and then an email comes to me that somebody joined the meeting. To avoid it, I did not post the link in the event announcement and then people had trouble finding it in the posts. I am very sorry about it. Please respond to this post to make it more visible and please vote in the poll. If you can make both days, vote for both!

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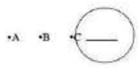
Eugenia Etkina
31. January 2022.

Hi all, I continue with my posts about electric field today. Once the students invented an operational definition of the E field quantity as E=F/q^test, they can learn how to find a cause effect relationship for the E field created by one point like charged object (E=kq^source/r^2) or by many point like source charges (superposition principle). Note that in the cause-effect relationships the source charge and the distance are present while in the operational definition there is no source charge, only the test charge and the force. This is a big distinction and needs a discussion with the students.
The next step is to help them invent the quantity of V field, or electric potential, which is another physical quantity characterizing electric field. I am attaching two ALG activities that show how to do it, please ask questions! There is a subtle problem in this approach, I wonder if you can see it.
Please do not forget to respond to the post once you read it. I see that about 400-500 people look at the posts each day but only 25-35 respond in some way. Try to take a second to respond to make the post more visible. Facebook algorithms work in mysterious ways. If you wish to see all the posts you need to respond to every post you see. Also, I see people responding to the poll about the next meeting, if you wish your voice to be heard, please respond there, I posted it yesterday.

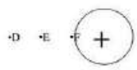
OALG 18.3.1 Represent and reason

A positive test charged object is placed at each of the following points (A through F) near a source charged object. Answer the following questions:

a. Rank the potential energies for the system test-charge-source-charge from greatest to least (for points A-C). (Remember: a large negative number is less than a small negative number.) Show at least one additional point where you can place a test charge so that the electrical potential energy is the same as for the configuration for point C.



b. Rank from greatest to least the potential energies of the system test-charge-source-charge shown below (D-F). Show at least one additional point where you can place a test charge so that the electrical potential energy is the same as for the configuration for point E.



c. How might the magnitude of the potential energy of the system test-charge-source-charge depend on the magnitude of the source charge? How is the magnitude dependent on the distance from the source?

d. Does a system that consists of a single electron have an electric potential energy?

e. Recall and write down the mathematical model for electrical potential energy. How does electric potential energy depend on the source charge? On the test charge?

f. Think of how you can define an energy-type physical quantity that will characterize the electric field from the energy perspective similar to how the quantity of $\vec{E}$ field characterizes the field from the force-type perspective.

g. Compare and contrast the physical quantity you defined with the physical quantity defined by Equation 18.6 in the textbook.

OALG 18.3.2 Reason

a. Why is the test charge present in the definition of the V field even though the value of the V field does not depend on the test object?

b. Compare and contrast operational definitions for $\vec{E}$ and V fields.

c. Think of the analogy of the V field quantity in the gravitational field. Then look around the classroom and find three locations with the largest gravitational potential and three locations with the smallest. Where did you choose the gravitational potential to be zero?

d. Explain how you can relate the surface of a desk and three shelves of bookshelves in the classroom to the concept of gravitational potential.

e. Explain how topographical maps might be related to the physical quantity of gravitational potential.

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Eugenia Etkina
1. February 2022.

Hi all, today I will stop with chapter 18 and go back to 17 to ask a question: Can a single electron have electric potential energy? The answer in our approach is a "no". A single object cannot have electric potential energy even if it is placed near another charged object or gravitational potential energy even if it is elevated above the surface of Earth or some other celestial object (of course we are not talking about the gravitational potential energy of the object itself due to the mutual attraction of its parts to each other).
Only a system of objects can have potential energy - electric or gravitational. Therefore when a brick is lifted 5 m above ground, it does not have any gravitational potential energy, but the system brick-Earth does. Same with an electron. An electron in a hydrogen atom does not have electric potential energy, but the system nucleus-electron does. It is important to remember that the total energy of a bound system is always negative (assuming the energy of interaction is zero when the objects in the system are infinitely far away from each other) as an external force needs to do positive work to separate them. It is true for atoms and it is true for all objects on our planet, if the planet is included in the system. If the planet is not included in the system, it can do work on the objects but they do not have gravitational potential energy. Does this make sense?

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Eugenia Etkina
2. February 2022.

Hi all, February 26 3 pm EST is the winner for our next meeting. I hope that all the presenters from the last meeting can make it. If you cannot, please send me an e-mail.
As we agreed, here is the link to a new google slide deck for all participants of the previous meeting to put their slides or/and questions. Please start posing questions and sharing your ideas - how you are or you will help your students develop growth mindset by setting up a system that allows them to improve their work without punishment for the second or third attempt.
Here is the link to the slides, the title of the meeting is: How to help students develop growth mindset and have a life (answers to the questions from presentations in the last meeting

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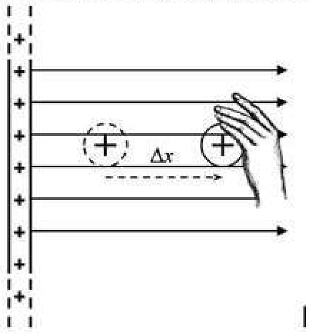
Eugenia Etkina
3. February 2022.

Hi all, today I continue with E and V fields. Please do not forget to respond to the post after you finish reading it. The number of likes for the posts is going down, this means fewer and fewer people will see the posts.
As you know, there is a relationship between them. In the areas where V field is constant, E field is zero. The E field lines point in the direction of the decreasing values of V field. The students can figure out these qualitative relationships by using graphical representations of E field lines and equipotential surfaces for different configurations of electric charges and charged metal objects and finding patterns in those (we have lots of activities for them). But how will they figure out the quantitative relationship between those two fields?
We have an excellent derivation activity that allows your students to do it step by step for a uniform E field. I learned from my previous posts that derivation activities do not cause as much interest as qualitative discussions, but they are needed for our students to learn where "formulas" (we actually never us this word, we use relations or mathematical representations, operational definitions and cause effect relationships) come from. I am attaching the activity and also the link to the slide show where people can add their ideas and questions for the next meeting. I promised to do it in my every post. Please react to this post if you read to the end to make it more visible.
https://docs.google.com/.../1Kf7CqPxTxj5IBKrUWfQy.../edit...

OALG 18.4.2 Derive

Consider a uniform $\vec{E}$ field produced by an electrically charged infinitely large glass plate. We will place a small object with charge $+q$ at some initial point in the field and move it (by hand) at a *constant* speed to some final point, through a displacement Δx, as shown in the diagram below. Calculate the work done by the hand and use that to estimate the difference in potential between the initial and final points in order to find a relationship between the $\vec{E}$ field and the potential difference ΔV. Use the guiding questions below to help structure your derivation.



a. Draw a force diagram showing forces exerted on the charged object by other objects. How are those forces related to each other? Remember, we move the charged object at a constant speed through the field.

b. Calculate how much work is done by the hand in moving the charged object through a displacement Δx.

c. Use the generalized work-energy principle to relate the work done by the hand to the change in potential energy of the charged-object-glass-plate system.

d. Set your work equations equal to find an expression for the $\vec{E}$ field in terms of ΔV and Δx. Does the equation you derived make physical sense? In what way? Come up with specific examples to justify your reasoning.

e. Read and interrogate Section 18.4 in the textbook and find the matching steps in the derivation in the textbook to parts **a-d** that you did. Compare your answer to part **d** to the Equation 18.10 on page 551. Do you need to revise anything?

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Eugenia Etkina
5. February 2022.

Hi all, A few things today. First, we had a few new members joining our group - from Sweden and Italy. Welcome, people! To learn what this group is about, please read the announcement post at the top of the group home page and visit islephysics.net website.
Second, I wanted to talk a little more about hypotheses and predictions. From my experience, the ISLE approach is the only curriculum approach that focuses on the clear definitions and

distinctions of these two terms. I am reminding you that a hypothesis (or an explanation, or a model) is a generalized statement that explains and describes a pattern in certain experiments. It is a general statement, a mental construction. For example: liquids dry because air absorbs little particles that they are made of. It is a hypothesis explaining how a wet spot disappears. A prediction, on the contrary, is not a general statement but a statement that describes an outcome of a specific experiment. For example, if air absorbs the little particles of a liquid, and we put a liquid under a vacuum jar, then it should not dry because there will be no air to absorb it, or it should dry much more slowly than in air assuming that we cannot take all air out of the vacuum jar. The statement after "then" and before "because" is the prediction. You see how it is impossible to make a prediction unless you know exactly what the experiment is about.

The key to the understanding of the ISLE process is that we only ask students to make predictions of the specific experiments AFTER they have observed some other experiments first, created a hypothesis explaining them and now use this hypothesis, not their intuition, to predict the outcome of a new experiment. This approach is different from the PEO (predict-observe-explain approach) and from a lot of materials that plainly confuse hypotheses with predictions.

Today I am sharing an activity where the students need to predict an outcome of a specific experiment in the electric field chapter. The text is in the attachment and the link to the video is here. Notice how the activity asks the students to use their knowledge of electric potential to make the prediction. This sentence should make a student think: what do I know about electric potential that is relevant to this situation. The activity comes right after they have constructed the relationship between E field and change in potential (I posted the derivation activity 2 days ago) and after the students observed and explained the reading of the voltmeter in a similar situation but only with one electrode. The carefully crafted sequence of activities allows the students to be successful in matching the predictions with the outcomes and feeling confident that they can do physics. This focus on making students confident that they can do physics and they belong in a physics world is one of the main intentionalities of the ISLE approach. In this particular activity, examining assumptions for the slight discrepancies between predictions and outcomes will not make students feel that they made "wrong" predictions, but will help them realize that the real objects are more complicated than ideal.

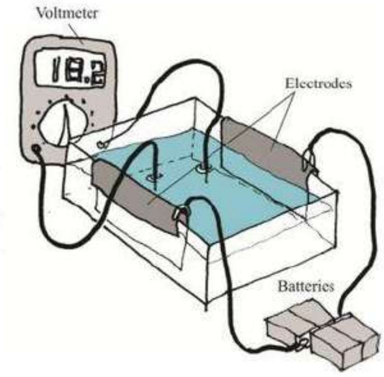
Here is the link to the video, but please read the activity first before you click on the link. And please do not forget to respond to the post after you read it to make it more visible.

https://mediaplayer.pearsoncmg.com/.../sci-OALG-18-4-4b

OALG 18.4.4 Test your ideas

In the following video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-18-4-4a we use a digital *voltmeter* (in Activity 18.4.3 we used an analogue voltmeter) to measure the potential difference between two points. We also use a battery that creates a constant potential difference between two metal strips connected to it.

We filled the container with tap water and placed metal strips (electrodes) as shown in the figure on the right. It is possible to measure potential difference between two points by touching them with the voltmeter leads. These points can be the on the electrodes anywhere in the water.



a. Watch the video and describe in words what happens in the experiment. Then explain how you can predict the results of the experiment using your knowledge of potential difference. Discuss any additional assumptions you need to make.

b. The experiment is then modified so that the distance between the electrodes is fixed. Use your knowledge of electric potential to predict what will happen to the reading of the voltmeter when (1) the two electrodes are oriented along the line perpendicular to the metal strips and are moved along this line; (2) the two electrodes are oriented along the line parallel to the metal strips and are moved along this line, first closer to one of the strips and then closer to the middle of the container. Explain how you made your prediction.

c. Watch the experiment https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-18-4-4b and record the outcome. Did your prediction match the outcome? If not, how do you need to modify the reasoning that led you to the prediction (or some additional assumptions) to account for the outcome?

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Eugenia Etkina
7. February 2022.

Hi all, we have several new members today - WELCOME! If you just joined, please open the group's posts as often as you can so that Facebook notifies you when a new post is posted - which is almost every day. If you reply to the post - like it or comment, you will see more posts. There is an announcement on the top of the page that explains how to use the group's resources. You can also visit islephysics.net website to learn more about the philosophy behind the group.
Today I am starting Chapter 19 - DC circuits. The very first page of the chapter in the textbook is a great example of the ISLE approach and also how we use the findings of physics education research to design curriculum materials. I am posting the screen shot of the first page here and I am asking you to write anything that you notices there that relates to the ISLE approach

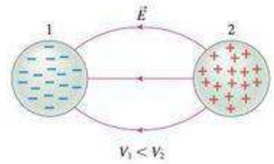
and to the findings of PER or science of learning in general. The link to video that is mentioned in the OET is below. Please read it carefully - just one page and say how the ISLE approach is represented there and how what we know about student learning of DC circuits is reflected. https://mediaplayer.pearsoncmg.com/.../secs-experiment...

Please do not forget to like the post if you are not planning to write a response. This will make the post more visible.

19.1 Electric current

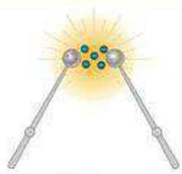
In the previous chapter we studied processes such as grounding that occur when a charged conducting object is connected with a wire to an uncharged conductor. We found that the excess electric charge on the charged object redistributes itself until the electric potential V at both conductors becomes equal. Let us look at similar experiments using a Wimshurst machine (Figure 17.21 shows one example of a Wimshurst machine). Recall that cranking the machine's handle generates opposite charges in the two metal spheres. The charge separation leads to a potential difference between the spheres (Figure 19.1). In the new Wimshurst machine experiments, we'll try to identify common features that might relate to transferring electric charge for useful purposes. Consider the experiments in Observational Experiment Table 19.1.

FIGURE 19.1 The charged Wimshurst spheres produce an $\vec{E}$ field.



OBSERVATIONAL EXPERIMENT TABLE 19.1 Electric potential difference and charge transfer

VIDEO OET 19.1

Observational experiment		Analysis
Experiment 1. Crank the handle of a Wimshurst machine and then bring the oppositely charged spheres of the machine close to each other (about 5 cm apart). You see a big spark. After the spark, when you again bring the spheres close, no further sparking occurs.		There is charge separation and nonzero potential difference ΔV between the two spheres. The spark means that the air between the spheres becomes a conductor, leading to the rapid discharge and the production of light. The original electric potential energy is converted to light and sound energy.
Experiment 2. Crank the handle of the Wimshurst machine and hang a light aluminum foil ball from an insulating thread between the oppositely charged spheres. The ball swings back and forth from one sphere to the other for a few minutes and then stops. When you remove the foil ball and bring the spheres near each other, no spark occurs.		The foil ball must acquire a small amount of negative charge from the negative sphere each time it touches it. The ball carries the negative charge to the positive sphere, deposits it there, and then returns to the negative sphere to repeat the process. This continues until the spheres are discharged and the potential difference between them is zero. The original electric potential energy is converted to mechanical energy and internal energy.
Experiment 3. Crank the handle of the Wimshurst machine and connect the leads of a neon bulb between the charged spheres. There is a flash of light from the bulb. When you remove the bulb and bring the spheres close, no spark occurs.		Before the bulb touches them, the spheres are charged and at different potentials. The bulb and its leads provide a conduction path to discharge the spheres. The discharge causes a flash of light from the bulb. The original electric potential energy is converted to light energy.

Patterns

- In all three experiments, the Wimshurst machine started with negative charge on one sphere and positive charge on the other sphere. There was a potential difference ΔV between the spheres.
- This charge separation and potential difference led to a flow of charge from one sphere to the other.
- The charge flow involved different observable consequences: a spark of light, the swinging ball of foil, and the flash of the bulb.
- After the charge flow, the Wimshurst spheres were discharged and the potential difference between them was zero. No more sparking or movement could occur.

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Eugenia Etkina
9. February 2022.

Hello everyone! First, we have several new members who joined yesterday and today, WELCOME! Please read the announcement post on the top of the group's home page to see how to benefit from the group's activity the most.
Second, I will continue with DC circuits today. My post is about Ohm's law. What is the law about? We write it as I=deltaV/R, where delta V is potential difference across a resistive element of a circuit other than a battery and R is its resistance. The law does not say that R needs to be constant for the law to be true. It also does not say that R is the slope of the line I-vs-deltaV, it only says that to determine the R for the specific I and delta V one needs to divide delta V across the resistive element by the current through it. Notice the language - current through and potential difference (or voltage) across. We never say "voltage drop" as voltage is the term for potential difference already.
Back to Ohm's law. I think the best way to think about it as the operational definition of resistance. the resistance of any element when a particular current is through it is determined by the ratio of potential difference across it and the current through it. This definition does not say WHY the resistance is the way it is, it only tells us HOW to find it. If the resistance does not depend on the current, then the element is called an ohmic element.
While R=deltaV/R is the operational definition, the form of I=deltaV/R is the cause effect relationship because we the current through a particular element (effect) depends on both the potential difference across it (the cause of current) and its resistance. Notice that I am not suggesting to write the Ohm's law as deltaV=IR, as this form does not represent causality. Electric field is the cause of current not the other way around. Right?
All these ideas are in the textbook pages 581-582. And finally there is a tip there which I am pasting here. It addresses a cause of many misunderstandings not only between students but between teachers too.

TIP The equation $R = \Delta V/I$, which allows us to determine the resistance of a circuit element, is an operational definition of resistance. It is not a cause-effect relationship. Resistance is the ratio of the potential difference across the element and the current through it, *not* the slope of the I-versus-ΔV graph.

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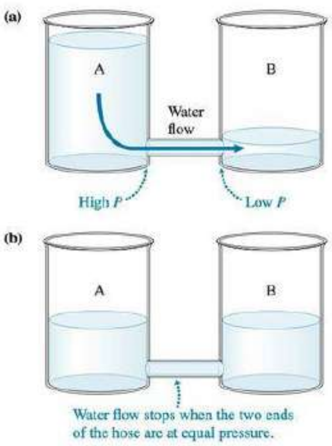
Eugenia Etkina
8. February 2022.

Hi all, yesterday, I posted the very first activity in DC circuits chapter and asked you to comment how it reflects the ISLE approach philosophy. Two people commented and we had a really nice conversation. There are more elements of the activity that are ISLEish but were not mentioned, I would like to keep this discussion going. In the mean time, I use one of the points of the exchange between Bor Gregorčič and myself about the importance of understanding that it is potential difference, not the charge difference that is important in electric circuits.
Students often come up with the water analogy for electric current as our metaphorical language (talking about current as a flow) kind of prompts it. It is good to build on it (for some aspects of DC circuits but not others). Here is how we build on this analogy and emphasize that it is potential difference not the charge difference that matters. Please comment!
I am also reminding you to put your questions and ideas in the google slide deck for our next meeting, here is the link to the slides: https://docs.google.com/.../1Kf7CqPxTxj5IBKrUWfQy.../edit...
And please like the post or comment to make it more visible.

FIGURE 19.2 A water flow analogy for electric charge flow.



Fluid flow and charge flow

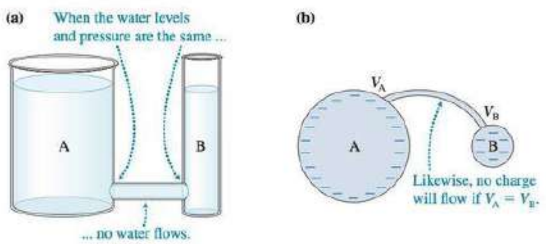
A fluid flow analogy may help us better understand the electric potential difference and conduction pathways of these electrical processes. You have two containers with water—A and B. A is almost full, and B is almost empty. You connect a hose between the two containers (**Figure 19.2a**). Water starts flowing from A to B until the levels are the same (Figure 19.2b), at which point the water flow stops. The volume of water in container A is analogous to the excess positive charge on Wimshurst sphere 2, and the difference in water pressure in the hose is analogous to the potential difference between the spheres. The hose provides a pathway for water to flow until the pressure at both ends of the hose is the same; the electric charge flows until the electric potential at each sphere is the same.

Notice that it is the pressure difference and not the difference in the volume or mass of water in each container that makes the water flow. Imagine a large container A full of water with the water level the same as in small container B—the water will not flow (**Figure 19.3a**). Similarly, it is not the total charge difference between the spheres of the Wimshurst machine but the potential difference that makes the charge flow. Imagine a large sphere A and a small sphere B. Suppose the charge is large on A and small on B; but if the V fields (electric potentials) on the surfaces of these two spheres are the same (recall the discussion of grounding in Chapter 18),

$$V = k_C \frac{q}{R}$$

there will be no charge flow through the wire connecting them (Figure 19.3b).

FIGURE 19.3 There is no (a) water flow if $P_A = P_B$ or (b) charge flow if $V_A = V_B$.



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Eugenia Etkina
10. February 2022.

Hi all, today my post is about student difficulties with DC circuits. Notice, that I did not use the word misconceptions here. And you probably noticed that never use this word. I already posted about it but will do it again. Students do not have robust conceptions. They have tiny ideas based on their life experience and the language that we use that they put together to answer physics questions. We change the context - their answer will change. We change the language - their answer will change. One example is the word "electricity". What does this word mean? Electric charge? Electric current? Voltage? Energy? Power? As long as we have this term in our vernacular, the students will confuse all those quantities. I strongly recommend removing it (together with heat and weight...)
Often student ideas look completely wrong but once we find the right context or revise the language, we will find that they are perfectly correct. There are many names for these ideas in educational research. In physics we call them p-prims (phenomenological primitives, coined by diSessa), facets (coined by Minstrell) or resources (Hammer et al.). Once we are familiar with these three theoretical frameworks, we can easily explain almost every student idea that we encounter. And we can find what everyday experience led them to this idea and in what contexts it is productive. (If you want to learn more about those three frameworks for student ideas, we can have a meeting and discuss them in detail.)
But today I want to attract your attention to the Instructor Guide (it is posted here in the FILES). In each chapter of the guide we discuss student difficulties related to the material in this particular chapter. Here is what we write about DC circuits. I invite you to think how our language and everyday contexts contribute to those difficulties. Below is the text form the Instructor Guide. We have a paragraph like this in EVERY chapter.
Brief summary of student difficulties with DC circuits
The biggest difficulty that students encounter is the concept of a complete circuit. Because we often make an analogy between electric current and water flow, students often think that electric charges making up current can flow in any downward directed wire. Another common difficulty is thinking that when they can make local changes to the circuit (such as removing or adding a resistor) it only affects the branch where the change was made without affecting the rest of the circuit. The next difficulties are thinking that a conventional battery is a source of constant current and the current is being used up as the charge move through a series circuit. Another one is thinking that adding resistors always increases the total resistance of the circuit. Finally, thinking that Ohm’s law I=delta V/R applies to only ohmic resistors.
A difficulty “induced” by instruction is the incorrect idea that the resistance of a circuit element is determined by the slope of the line on the I-vs-delta V graph.
PLEASE do not forget to respond to the post to make it more visible!

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Eugenia Etkina
11. February 2022.

Hello all, first WELCOME to our new group members. We had a few yesterday! Please read the announcement on top of the home page and visit islephysics.net to learn the philosophy behind this group.
Now, today's post is about one more difficulty, also associated with Ohm's law. Before I go on, please do not forget to like the post or comment to make it more visible. Here is the phenomenon: You have a circuit consisting of a 9-V battery, a lightbulb, a switch and some wires. All correctly connected in series. The switch is open. The bulb is not lit. What is potential difference across the switch?
Many students would say it is zero. They will use Ohm's law to reason that if the switch is open, the current I is zero, and I=deltaV/R, so if I = 0, then delta V must be zero as delta V=IR=0R=0. If they measure the potential difference across an open switch with a voltmeter, it would measure 9 V. Would the answer that it is zero a misconception? Of course, you know my attitude towards this word, and would say NO. It is indeed a NO as it is an example of an application of a correct mathematical relation in a tricky context. The resistance of an open switch is infinite. Do our students know how to divide by infinity? Does it mean that Ohm's law does not work for an open switch?
It does, actually (R is equal to infinity, 9 V/infinity=0), but it does not help us find the answer in this case as every number divided by infinity will give us a zero. As there is no current in the circuit, we need to reason using our knowledge of electrostatics, specifically of electric potential which is the same along a conductor in the absence of electric current. Therefore , as one end of the switch is connected to a 0 of the battery and the other one to 9 V, potential difference across an open switch is 9 V. It is a great experiment to make students think deeply about Ohm's law. Here is the page from the textbook with this activity and MORE.

TESTING EXPERIMENT TABLE 19.4 Applying Ohm's law to an open circuit

VIDEO TET 19.4

Testing experiment	Prediction	Outcome			
Use the circuit in Figure 19.16 but with the switch open.	We predict that the current in the circuit is zero, the ammeters will measure zero current $I = 0$, and according to Ohm's law, voltmeters 2–5 will measure zero potential difference $\Delta V = IR = 0R = 0$.	**Ammeter readings**		**Voltmeter readings**	
		Ammeter 1	0 A	Voltmeter 1	8.5 V
		Ammeter 2	0 A	Voltmeter 2	0 V
		Ammeter 3	0 A	Voltmeter 3	0 V
		Ammeter 4	0 A	Voltmeter 4	0 V
				Voltmeter 5	8.5 V

Conclusion

We predicted 0 for voltmeter 5, but it measured 8.5 V. The outcome of the experiment does not match our prediction. We need to either revise Ohm's law or examine how we apply it.

When an outcome does not match a prediction, we need to evaluate the reasoning that led to the prediction. When the switch is open, there is no current in the circuit, so on first glance Eq. (19.3) written as $\Delta V = IR$ predicts a zero potential difference. Let us look at the battery first. Even when there is no current in the circuit, the battery has potential difference across the terminals equal to its emf. Thus, the nonzero reading of voltmeter 1 makes sense. But why would there be potential difference across the switch when there is no current in the circuit? When the switch is open, it stops being a conductor; its resistance becomes infinite. We cannot apply relation $\Delta V = IR$, as we do not know the result of multiplying zero by infinity. Therefore, when we made a prediction that did not match the outcome, it was not Ohm's law that failed us, but how we applied it. How do we explain the existence of the potential difference across the switch? When the switch is open, the whole part of the circuit connected to the positive terminal of the battery is at a potential of 8.5 V. The part of the circuit connected to the negative battery terminal is at a potential of 0.0 V (**Figure 19.17**).

We can find a similarity in the behavior of a switch in a circuit and an LED. Remember that for the "wrong" direction of an LED, the current through the LED is zero. The same holds also for an LED that is connected in the "right" direction but has a potential difference across it that is less than its opening voltage. Thus we can equate an LED connected in the "wrong" direction and an LED connected in the "right" direction for voltages below opening voltage to an open switch. If this is correct and we measure the potential difference across the LED for these conditions, we should measure the same voltage as that of the battery. This is exactly what happens (see **Figure 19.18**)! However, once there is electric current through a switch, the potential difference across it is zero for any current through it, whereas the potential difference across an LED changes very little while the current might change by many factors of 10. This is due to the rapidly decreasing resistance of an LED in the range of glowing potential differences. Therefore, it is useful to remember that when an LED is glowing, the potential difference across it is always approximately the opening voltage.

TIP Any burned out lightbulb causes the current in the line with the bulb to be zero. It is like an open switch. If the light switch on the wall is on, there may be a 120-V potential difference across the contact points in the bulb canister. It is not safe to touch the contact points!

REVIEW QUESTION 19.4 Why does it make sense that all ammeters in Figure 19.16 have the same reading?

FIGURE 19.17 Electric potential in a circuit with an open switch.

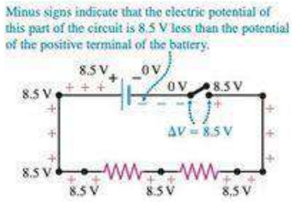
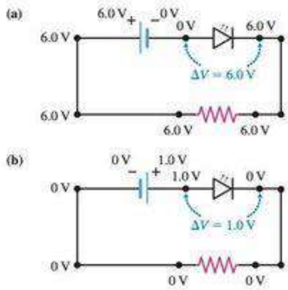


FIGURE 19.18 An LED is similar to an open switch when (a) the LED is connected in the "wrong" direction, and (b) the LED is connected in the "right" direction but the potential difference across it is less than the opening voltage.



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Eugenia Etkina
14. February 2022.

Hi all, thank you for great discussions about new types of problems yesterday! Taking into account that it was Sunday, the level of activity is especially impressive, THANK YOU!

Today is my last post for the Chapter 19, DC current. As you probably noticed, in our textbook we have a lot of material using LEDs. We start with Chapter 2, where blinking LEDs are used to help students construct the idea of a motion diagram. In Chapter 19 we discuss in detail electric properties of LEDs, such as unidirectionality, opening voltage, and I(deltaV) curves. In Section 19.6 Joule's law we finally help students learn WHY LEDs replaced in candescent lightbulbs in our houses. The part of the section is pasted here with the data table and infrared photos.

I want to add that we (Gorazd Planinsic and I) have developed a whole set of materials about LEDs to be used in introductory physics courses (they are published in a 4-paper series in The Physics Teacher and I put them all in the FILES here) and many activities with the videos are now in the OALG Chapter 19 (posted here too). However, from my experience, it is difficult to learn how to run a classroom from a paper, therefore if there is interest, Gorazd Planinsic and I could run a workshop on LEDs. Is there an interest? We could run it in the summer. Please reply here if you are interested. The length will probably be 3 hours.

And please do not forget to respond to this post to make it more visible.

Power of incandescent lightbulbs and LEDs

In the last few years, LED lightbulbs have almost completely replaced incandescent lightbulbs in our homes. Why? A simple observation can give us a hint. When we touch a bright incandescent lightbulb, it is very hot; however, LED-based bulbs are not hot to touch. Therefore, we can hypothesize that traditional bulbs convert a significant fraction of the electric energy to thermal energy rather than to light, while LEDs convert most of the electric energy delivered to them to light energy. Both light energy and thermal energy leave the bulbs and LEDs through the process of radiation.

We can conduct an experiment to investigate this difference quantitatively using a variable power supply, a small incandescent lightbulb, and a white LED. Both light sources are enclosed in white ping-pong balls to ensure that the light they emit is spread evenly, making it easier to compare their brightness (**Figure 19.23a**). In order to compare the light sources more objectively, we will use a special device (a light sensor) that measures the brightness of both sources; its sensitivity to light is similar to that of our eyes. We will change the potential difference across the power supply until the light sensor has the same reading for both sources when placed at the surface of the ping-pong ball. (In Figure 19.23a, the LED appears to have a somewhat different color than the bulb, but despite this, their brightness as measured by the sensor is the same). The data collected in the experiment are shown in Figure 19.23b. A pattern is clearly visible from the data: the white LED needs about 10 times less electric power to emit light of the same brightness as an incandescent lightbulb. Thus the old-time incandescent lightbulb must be converting the rest (90%) of the energy into thermal energy or some other form of light that cannot be detected by our eyes. Figure 19.23c shows thermal images for both light sources: the LED is at room temperature and the bulb is much warmer. We will learn in Chapter 28 the mechanism behind the high efficiency of LEDs.

Paying for electric energy

Electric power companies charge their customers according to the amount of electric potential energy that is converted into other energy forms in the devices that the customer uses. Utility companies do not use the joule. Instead, they use an energy unit called the **kilowatt-hour**. A kilowatt-hour (kW·h) is the electric potential energy that a 1000-W device transforms to other energy forms in a time interval of 1 h ($1\ kW \cdot h = 3.6 \times 10^6\ J$).

FIGURE 19.23 Comparing energy conversions for an LED versus an incandescent lightbulb.

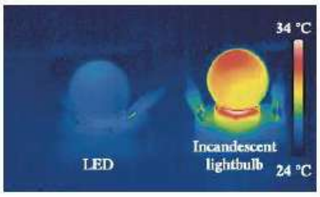
(a) Experimental setup

(b) Table of measurements taken

	LED	Incandescent lightbulb
ΔV (V)	3.1	3.6
I (A)	0.020	0.190
P (W)	0.062	0.680
B (lux)*	450	450

*Brightness of light measured at the surface of the ping-pong ball

(c) Thermal images of the experiment



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Eugenia Etkina
15. February 2022.

Hi everyone, today I will be continuing with cause-effect relationships and operational definitions. We are moving to Chapter 20 - Magnetism. This is where student understanding of the difference between cause-effect relationships and operational definitions becomes really important. There are many difficulties for the students in magnetism, one of which is the three dimensional nature of right hand rules that they are learning. But in those rules hide those two types of the relationships.

Think of right hand rule for the fields - to find the direction of the B field you take your right hand, pint the thumb in the direction fo the current and wrapped around 4 fingers show you the direction of the magnetic field line. This is a cause-effect relationship, as the current causes magnetic field. Here we know the source of magnetic field but we do not know anything about the detector. If the source is a straight wire, you can find the B=I mu zero/2pi r, where r is the distance from the wire. This equation is the cause effect relationship for the field as B depends on all those quantities and I is the cause of the magnetic field.

Now, take right hand rule for the force. You take your right hand, point the thumb in the direction fo the current, the four fingers in the direction of the B field and the line coming out of your palm will show you the direction of the force exerted by the magnetic field on the current carrying wire. For the perpendicular directions of the current and B field, the equation for the force is F=IBL, where the L is the length of the current carrying wire in the magnetic field. Here, the wire is the detector of the field, but the source is not known. However, you can find the field using B=F/IL. This is the operational definition of B as it does not depend on any of these quantities. I is not the source of the magnetic field, it is the detector, now the detector is described by two quantities - I and L. However, is you use F=IBLsin theta, it is a cause-effect relationship because F depends on all of those quantities.

Discussing the difference between these two rules and the difference between the two expressions for the field is very important. If you read to the end, do not forget to respond to the post to make it more visible.

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Eugenia Etkina
16. February 2022.

Hello everyone, I continue with Chapter 20, Magnetism. Here is one of my favorite sequence of activities (20.3.1-20.3.3) for students' invention fo the right hand rule for the force qualitatively and quantitatively. The sequence involves graphical representations, real experiments, developing mathematical models from the data and then testing the models in a new experiment. As the activities did not fit into one screen no matter how hard I tried, I pasted the rest of activity 20.3.3 here. The whole thing is the OALG Chapter 20 posted in the FILES. I am putting the links to the videos below. However, if you are teaching in person, there is no need to use any of those videos, you can use regular materials and run those experiments as lab activities or teacher-shown experiments for which students make explanations or analysis. Here is the continuation of the activity:

b. Compare the rule that you devised to Eq. 20.3 on page 625 in the textbook. How are they the same? How are they different?

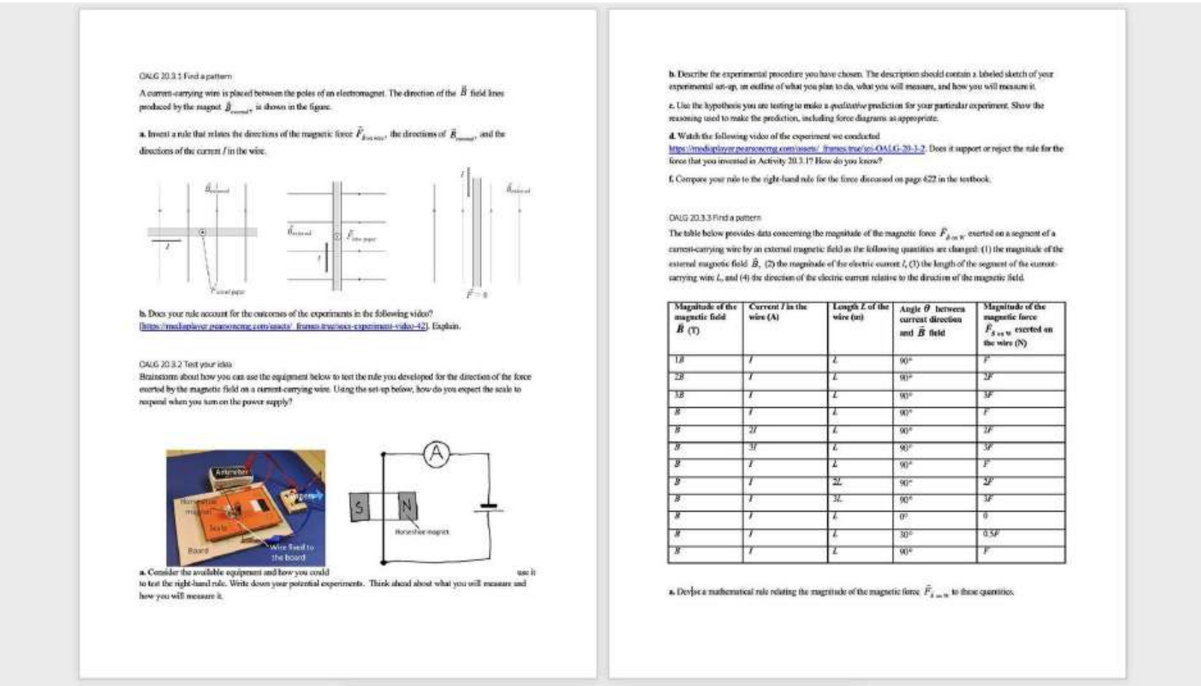
c. Use the set-up in Activity 20.3.2 to test the rule you just invented. Here are some additional measurements: the length of the wire inside the magnet is about 20 mm; the magnitude of the field at the location of the wire is 0.33 T. Using these data (and the value of the electric current from the video you can calculate the magnitude of the magnetic force exerted on the wire. Use the value of the magnetic force and other data from the video to predict the reading of the scale when there is current through the wire. Compare your prediction to the actual reading. Do you need to revise your reasoning?

And here are the links to the videos:

https://mediaplayer.pearsoncmg.com/.../secs-experiment...

https://mediaplayer.pearsoncmg.com/.../sci-OALG-20-3-2

Please reply to the post to make it more visible. Thank you.



OALG 20.3.1 Find a pattern

A current-carrying wire is placed between the poles of an electromagnet. The direction of the $\vec{B}$ field lines produced by the magnet $\vec{B}_{external}$, is shown in the figure.

a. Invent a rule that relates the directions of the magnetic force $\vec{F}_{B \text{ on wire}}$, the directions of $\vec{B}_{external}$, and the directions of the current I in the wire.

b. Does your rule account for the outcomes of the experiments in the following video? [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-42]. Explain.

OALG 20.3.2 Test your idea

Brainstorm about how you can use the equipment below to test the rule you developed for the direction of the force exerted by the magnetic field on a current-carrying wire. Using the set-up below, how do you expect the scale to respond when you turn on the power supply?

a. Consider the available equipment and how you could use it to test the right-hand rule. Write down your potential experiments. Think ahead about what you will measure and how you will measure it.

b. Describe the experimental procedure you have chosen. The description should contain a labeled sketch of your experimental set-up, an outline of what you plan to do, what you will measure, and how you will measure it.

c. Use the hypothesis you are testing to make a *qualitative* prediction for your particular experiment. Show the reasoning used to make the prediction, including force diagrams as appropriate.

d. Watch the following video of the experiment we conducted https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-20-3-2. Does it support or reject the rule for the force that you invented in Activity 20.3.1? How do you know?

f. Compare your rule to the right-hand rule for the force discussed on page 622 in the textbook.

OALG 20.3.3 Find a pattern

The table below provides data concerning the magnitude of the magnetic force $\vec{F}_{B \text{ on } W}$ exerted on a segment of a current-carrying wire by an external magnetic field as the following quantities are changed: (1) the magnitude of the external magnetic field $\vec{B}$, (2) the magnitude of the electric current I, (3) the length of the segment of the current-carrying wire L, and (4) the direction of the electric current relative to the direction of the magnetic field.

Magnitude of the magnetic field B (T)	Current I in the wire (A)	Length L of the wire (m)	Angle θ between current direction and $\vec{B}$ field	Magnitude of the magnetic force $F_{B \text{ on } W}$ exerted on the wire (N)
$1B$	I	L	90°	F
$2B$	I	L	90°	$2F$
$3B$	I	L	90°	$3F$
B	I	L	90°	F
B	$2I$	L	90°	$2F$
B	$3I$	L	90°	$3F$
B	I	L	90°	F
B	I	$2L$	90°	$2F$
B	I	$3L$	90°	$3F$
B	I	L	0°	0
B	I	L	30°	$0.5F$
B	I	L	90°	F

a. Devise a mathematical rule relating the magnitude of the magnetic force $\vec{F}_{B \text{ on } W}$ to these quantities.

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Eugenia Etkina
19. February

Hi all, a few things.

First, I really ask you to take one second to click on like or say that you read the post when you do read a post. It worries me that we have so few responses to the posts, which means very few group members see them. Please take a second to respond if you read a post.
Second, I will continue with the Magnetism. Today, I am attaching screen shot of several end-of-the-chapter problems that show how we can help students reason about physical phenomena without using any equations. Jumping to a "right formula" is the step that separates some of our students from experts. To help them see that they CAN reason without writing any equations, we created lots of problems which require sophisticated reasoning and explanations, including multiple possibility solutions, while have no equations as crutches. Many of those are common on the AP exams. Please examine every one of them and think what kind of reasoning it inspires. Enjoy!

20.1 and 20.2 Magnetic interactions and Magnetic field

1. When a switch is closed, a compass needle deflects from the initial to final direction, as shown in **Figure P20.1**. Say everything you can about this circuit.
2. You have a lightbulb connected to a battery. (a) What happens if a compass is placed under the constant current cable, made of two twisty wires that connect the bulb with the battery? (b) What happens if you separate the wires and place the compass under one of the separated wires? Explain your answers for both parts.
3. The current through a circuit is shown in **Figure P20.3**. The deflection of a compass needle is shown in the figure. Is the picture correct? If not, what is wrong?
4. Draw $\vec{B}$ field lines for the magnetic field produced by the objects shown in **Figure P20.4**.

FIGURE P20.1

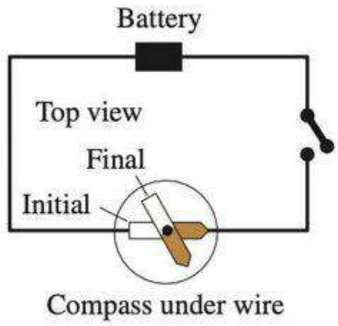


FIGURE P20.3

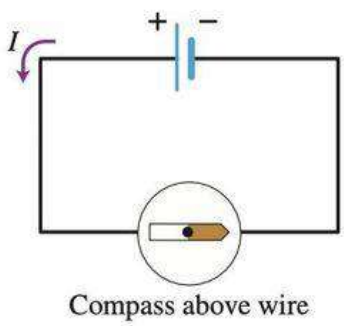
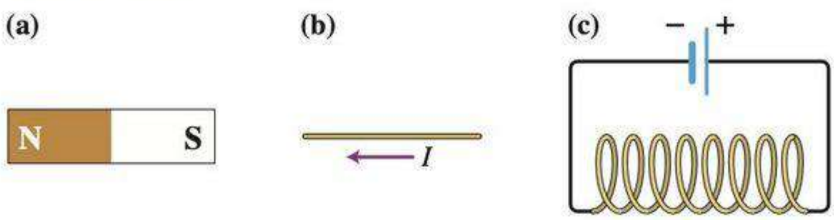


FIGURE P20.4



5. * You need to determine the direction of the $\vec{B}$ field at two points in space and compare the magnitudes of the $\vec{B}$ field at those two points. Describe the experiments that will allow you to accomplish this task.

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Eugenia Etkina
20. February

Hi all,
thank you so much for responding to my plea to respond to posts! We have over 60 people responding, which means that probably 300 more people will se the post compared to the situation when only 20 people reply(this is my very rough estimate). Please, continue responding!!! And Thank you AGAIN!
Today I will continue with the problems for magnetism. Yesterday, I posed examples of problems that do not need any algebra. today - problems with math. But I should a page from the textbook where you can see different examples of problem types and think of what reasoning skills such problems develop. How to they relate to the three dimensions of the NGSS? How do they address AP focus? And most importantly, do they promote interest in physics? Please reply! Tomorrow I will share my thoughts about every problem.

34. * **Equation Jeopardy 2** The equation below describes a process involving magnetism. Solve for the unknown quantity and draw a sketch that represents a possible process described by the equation. Note: T is a symbol that denotes a force (for example, force exerted by a rope, tension), and T is the unit (Tesla).

$$2T - (0.020\ \text{kg})(9.8\ \text{N/kg}) + (10\ \text{A})(0.10\ \text{m})(0.10\ \text{T}) = 0$$

35. * **Equation Jeopardy 3** The equation below describes a process involving magnetism. Solve for the unknown quantity and draw a sketch that represents a possible process described by the equation.

$$100(2.0\ \text{A})(4.0 \times 10^{-2}\ \text{m}^2)(0.20\ \text{T}) - m(9.8\ \text{N/kg})(0.10\ \text{m}) = 0$$

36. ** **EST** The magnitude of the $\vec{B}$ field inside a long solenoid is given by the equation $B = \mu_0 I\,(N/l)$, where N is the number of turns and l is the length of the solenoid. (a) Describe an experiment that can help you test this relation. (b) Explain whether this equation is an operational definition of the magnitude of the $\vec{B}$ field or a cause-effect relationship. (c) Powerful industrial solenoids produce $\vec{B}$ field magnitudes of about 30 T. Estimate the relevant physical quantities for such solenoids.
37. * **Electron current and magnetic field in H atom** In a simplified model of the hydrogen atom, an electron moves with a speed of 1.09×10^6 m/s in a circular orbit with a radius of 2.12×10^{-10} m. (a) Determine the time interval for one trip around the circle. (b) Determine the current corresponding to the electron's motion. (c) Determine the magnetic field at the center of the circular orbit and the magnetic moment of the atom.
38. * Two long, parallel wires are separated by 2.0 m. Each wire has a 30-A current, but the currents are in opposite directions. (a) Determine the magnitude of the net magnetic field midway between the wires. (b) Determine the net magnetic field at a point 1.0 m to the side of one wire and 3.0 m from the other wire.
39. * **Minesweepers** During World War II, explosive mines were dropped by the Nazis in the harbors of England. The mines, which lay at the bottom of the harbors, were activated by the changing magnetic field that occurred when a large metal ship passed above them. Small English boats called minesweepers would tow long, current-carrying coils of wire around the harbors. The field created by the coils activated the mines, causing them to explode under the coils rather than under ships. (a) Determine the current in one long, straight wire to create a 0.0050-T magnetic field at a depth of 20 m under the water. The magnetic permeability of water is about the same as that of air. (b) How might the field be created using a smaller current?

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Eugenia Etkina
21. February

Hello all! Before you go on reading, please do not forget to sign up for our meeting on Saturday! (and to "like" the post to make it more visible).
Yesterday I promised to discuss the problems that I posted for Magnetism. You will need to download my yesterday's attachment before you read on. I first focus on jeopardy problems (#34 and 35 on the list) - the first two problems in the document. It is a type of problems devised about 25 years ago by A. Van Heuvelen, Tom O'Kuma and Curt Heiggelke. These present a solution to a problem in a form of a mathematical relation (or a graphical representation as we started doing later) and ask a student either to draw a sketch of the situation or to pose a problem for which the relation might provide a solution (these two are for the former). There are many benefits to these problems. Based on the two examples that you see in the document those might help students to:
1. Distinguish between physical quantities and their units - when m is italicized, it represents mass (physical quantity), when it is not, it represents meters (a unit).
2. Visualize possible different physical scenarios that can be described with the same mathematical relation.
3. Recall Newton's second law. Draw force diagrams and imagine situations when magnetic force is exerted on an object with other forces.
4. Question why 9.8 has the units of N/kg, not m/s^2. Are they the same?
Problem 36 has a ton of features that are non-traditional although it operates within one relation.
(a) What does it mean to test a relation (key practice in physics)? It means to design an experiment whose outcome you can predict using this relation, conduct the experiment and compare the outcome to the prediction taking uncertainties and assumptions into account. It also means to be able to reason hypothetico-deductively - "if this relation is correct, and I do such and such, then such and such should happen because of such and such". This is a really complicated chain of reasoning, very often confused with the wrong if-then statement (the wrong statement is "if I do such and such, then such and such should happen"). What kind of experiments can students design (this is where their knowledge of physics comes in)? What equipment would they need? What do they need to know about the materials to be able to make the prediction? Lots of great questions there!
(b) Here again we call students' attention to the nature of the "formula" (although we NEVER use this word) (coherence of physics). Does it describe a causal relation or is it a mere operational definition of B? What do you think?
(c) Finally, the students need to think of what kind of solenoids can potentially produce large magnetic fields (real life connection) and what it means to estimate (a skill useful outside of physics).
This problem is an example of how in one problem you can address pure physics goals, science practices, real life connections, development of logical reasoning and practical skills.
I will stop for now and discuss the rest of the problems tomorrow.
Please do not forget to respond to the post and sign up for our Saturday meeting!

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JcVAxBbJKZApNIZwxudzGogSriOaqd5J6n6bAvJJfdC3poFRDO08EUV0s4j82UikbQETjMfEl LJiAU&__tn__=%2CO%2CP-R

Eugenia Etkina
22. February

Hi all, today is the last post about the set of problems from chapter 20 - Magnetism. The last three problems can be called "traditional problems" - they have a set of givens and the students needs to determine a quantity that is specified. There is only one answer to each question and this answer is expressed as a number with units. For these types of problems (most familiar to teachers) we have a 4 step problem solving strategy:
The first step is called "Sketch and translate". First students need to draw a picture of the problem and translate what is written in words to physical quantities. Some things are never written exactly but implied. For example, when we say "an object was dropped" it means that the initial velocity is zero, when we say that an object 'moves across a smooth surface', it means that the friction component of the force exerted by the surface on the object is zero. Therefore it is important that the students learn to "translate" each word into physical quantities and if they do not know what some words mean - ask. I always tell my students that they need to READ the problem statement three times and at least once out loud to make sure that they really understand what the statement says. A huge number of mistakes come from not reading the problem carefully and not visualizing the situation. That is why I ask students: "Tell me what you see", before they start solving. "Seeing" and sketching is the very first step without which it is impossible to solve anything.
The second step is "Simplify and Diagram". Simplify means that they need to think what simplifications they can make based on the sketch and the translated givens. Can the object be modeled as a point-like object? Can they neglect the air? Can they assume the uniform field? Once they decide on this, they they need to think what they choose as a system for analysis and what physics-like representation(s) are useful for representing the problem situation - is it a motion diagram? It s it a force diagram? Is it both? Or a momentum bar chart? Or an energy bar chart? Deciding on the useful representation is basically deciding what fundamental principle to use to approach the problem. However, we do not use the term principle or concept as the representation can be used later for evaluation for consistency and the principle cannot. Once the students decide on the system and representations and draw those, they can think of algebra/calculus. Notice, how much work is already done and there is still no "formulas" involved.
The third step is called "Represent mathematically". This is where the students take the graphical representation(s) from the previous step and USE them to write the mathematical representation. This is where they first check for consistency between the algebra and the force diagram, or energy bar chart.
The last step is called "Solve and Evaluate". Once the mathematical representations are written and evaluated for consistency with the sketch and the physical representation, they can express the needed quantity and solve for it using the givens. After that they need to go back and evaluate the solution and the answer. Is it consistent with their presentations? Does it survive extreme case analysis? Are the units correct? Does the answer make physical sense.
All these steps are based on the analysis of how experts solve problems. Every problem in the book requires some of these steps but only about 50% of the end of the chapter problems

require all. Practicing these steps individually is very important. For those we have ALG and OALG activities in addition to the worked examples and end of the chapter questions and problems.

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Eugenia Etkina
27. February

Hi all, thank you for coming to the meeting yesterday and thank you everyone who shared their work and asked questions. The next meeting will be dedicated to experimental uncertainty - what is the best way to help students learn it? We have our conceptual approach to uncertainty and there is lots of work done around the world on it, so it should be a very interesting meeting. I will post the poll for days/times later today. Here is the link to the recording of yesterday's meeting and the link to the slide show.
https://rutgers.zoom.us/.../sPFhFHtRYnSUESQ6GOFCKm31IEIwJ...
Password: Ek!pk1qs
Link to the slides:
https://docs.google.com/.../1Kf7CqPxTxj5IBKrUWfQy.../edit...

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Eugenia Etkina
1. March

Hi all, three things today. First, I did not post anything yesterday as I was and still am in shock over the war. It did not seem right to post about electromagnetic induction when life as we know it, is at risk. I am not sure how to continue but I know that all of you have to go and teach every day, and in support of this, I will continue to post.
Second, we have quite a few new members who joined the group recently. I want to welcome them. The notice on the top of the group page will tell you what the group is about, the philosophy behind the group is at islephysics.net. This website will show you the logical process behind our materials and our approach to student growth as they learn physics.
Third, I will continue with the discussions of the textbook chapters (for the new members, we use the textbook College Physics: Explore and Apply, the cover of the book is the cover of this group's Facebook page). We are done with 20 chapters, now is Chapter 21, Electromagnetic

induction. Below I am posting the beginning of the OALG Chapter 21 activities for the students (if you are teaching in person, the experiments are done by the students themselves). The sequence follows our ideal ISLE process: observational experiments (moving a magnet with respect to a coil connected to a galvanometer), patterns, invention of a hypothesis (the motion of the magnet induces current), using this hypothesis to predict the outcomes of the new experiments, seeing that some outcomes cannot be predicted (current can be induced without any motion) and revising the hypothesis (the change in magnetic field leads ot the induced current). The sequence has been tried with thousands of students and it works very well. If you teach in person, the first activity is to give students a coil connected to a galvanometer and a magnet and ask them to do whatever they can to get the galvanometer show current. They struggle for a while but then somebody will accidentally move the magnet perpendicular to the coil and observe deflection. When this happens, invite this group to share their discovery with the rest of the groups, and they will all start vigorously experimenting. It is so fun to watch!
OALG 21.1.1 OBSERVE AND FIND A PATTERN
In the experiments that you will analyze in this activity we use a galvanometer to detect current. You learned how a galvanometer works in Chapter 20, Activity 20.3.8
a. Watch the following video https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...and describe what you observed. What patterns do you notice? Note that the circuit with the galvanometer does not have any battery in it.
b. Develop a rule: Devise a preliminary rule that summarizes the condition(s) needed to induce a current in a coil. What are the assumptions that you made?
c.Compare the rule you devised in part b to the patterns identified in Observational experiment table 21.1 in the textbook. The experiments from which the patterns emerged are at https://mediaplayer.pearsoncmg.com/.../secs-experiment....
OALG 21.1.2 TEST AND REVISE YOUR IDEA
The goal of this activity is to test the rule that you invented in Activity 21.1.1. In the following experiments you will have one coil (coil 1)connected to a battery/power supply through the switch. The other coil (coil 2) is connected to the galvanometer.
Experiment 1.Use the rule devised in Activity 21.1.1 part b. to predict what will happen if you move coil 1 relative to coil 2.
Experiment 2. Use your current rule to predict what will happen when you place a coil connected to a galvanometer next to the coil connected to the battery/power supply (so that axis of the coils coincide). Then you
(1) close the switch without moving either coil,
(2) let the current run for a period of time, and finally
(3) open the switch.
a. Describe the experiments in words and sketches and make the predictions of their outcomes using the rule you invented in Activity 21.1.1.
b. Watch both experiments here [https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...] and compare the outcomes to the predictions.
c. Make a judgment concerning the rule that you're testing. If necessary, revise your rule to incorporate your new findings. Note that your revised rule should be consistent with all the experiments you've conducted up to this point.
d. Compare your reasoning to the reasoning in Testing Experiment Table 21.2 in the textbook. Do you need to revise the rule?
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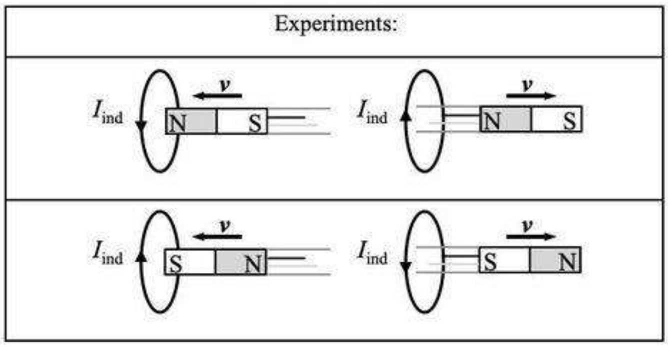
Eugenia Etkina
2. March

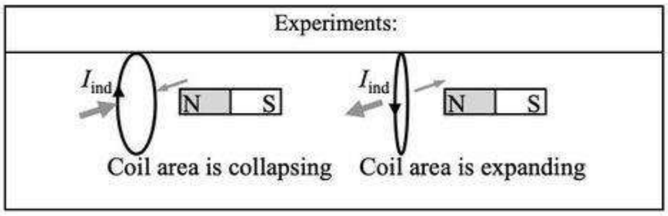
Hi all, I continue with Chapter 21 today, Electromagnetic induction. Please do not forget to like or respond to the post after you finish reading it.
Yesterday I showed how we hep students construct the idea that changing magnetic field induces electric current in a closed coil. Students construct this idea without any help if they follow our activities. The activities use real or video experiments. The next step - inventing the rule for the direction of the induced current - can also be done using experiments and finding patterns, but it is more complicated and takes more time.
To save time and make the process a little easier we present the data to the students in the form of sketches, they still need to find the patterns but they do not need to mess with equipment. I am attaching the screenshot of the activity (the file for OALG Chapter 21 is posted in the FILES) and the link to an amazing experiment that allows the students to apply Lenz rule right away.
https://mediaplayer.pearsoncmg.com/.../sci-OALG-21-3-1

OALG 21.3.1 Observe and find a pattern

The experiments below repeat earlier experiments that used a galvanometer, a bar magnet, and a coil and in which a current was induced. The direction of the induced current is shown in the illustrations.

a. Analyze the 6 experimental scenarios in the table below. For *each* case, on your whiteboard, draw $\vec{B}_{ext}$ field vectors through the coil caused by the moving magnet. Indicate whether the external $\vec{B}_{ext}$ field vectors through the coil are decreasing or increasing in magnitude. Draw induced magnetic field vectors $\vec{B}_{ind}$ created by the induced current in the coil.





b. Devise a rule relating the direction of the induced current in the coil and the change of external magnetic flux through it. *Hints:* (1) Focus on the direction in which $\vec{B}_{ext}$ is changing rather than the direction of $\vec{B}_{ext}$ itself. (2) Compare the direction of the induced magnetic field vectors $\vec{B}_{ind}$ in relation to $\Delta\vec{B}_{ext}$.

c. Formulate a general rule: How does the direction of the induced current in a coil relate to the *change* of external magnetic flux through it?

d. Watch the following video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-21-3-1. Describe what you observed. Use your rule from part **c** to explain the observations.

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Eugenia Etkina
3. March

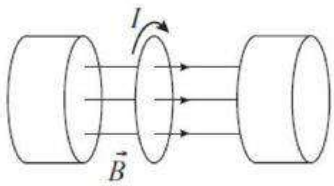
Hi all, I will continue to post about electromagnetic induction. It feels so strange to worry about physics when people are dying for the pleasure of a madman but as I said before, we must go on. so, Faraday's law is today. It is really important to understand why the law uses induced emf instead of induced voltage. As students learn later, there are two kind of electric fields -

electrostatic field whole lines start and end on electric charges and a different field, whose lines do not have the beginning and end, they are continuous loops, and therefore it is impossible to characterize it with the physical quantity of voltage that is applicable for the first kind of electric fields.

When we were first developing ISLE approaches to electromagnetic induction it was a struggle to come up with an experiment which the students could use to "invent" the relationship which we know as Faraday's law. So, I came up with "fake" experiment with the fake data that leads the students to thinking about the emf not the voltage. The screenshot of the activity is pasted below. Please comment what you think about it.

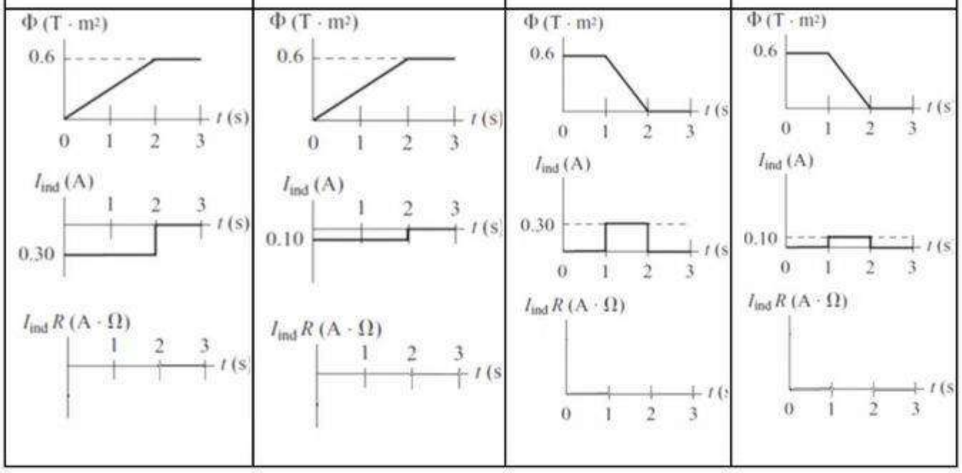
21.4.1 Observe and explain

In the table that follows, the results of four experiments are shown in which a changing magnetic field produced by an electromagnet passes through a loop, as illustrated to the right. This changing $\vec{B}$ field causes a changing flux Φ through the loop and an induced current I_{ind} around the loop of resistance R. The product $I_{ind}R$ is also plotted as a function of time.



a. Draw the third graph that shows the product $I_{ind}R$.

Coil resistance is 1.0 Ω	Coil resistance is 3.0 Ω	Coil resistance is 2.0 Ω	Coil resistance is 6.0 Ω



b. Discuss what the meaning of the product $I_{ind}R$ is and which equivalent quantity this product may represent. Then devise a relationship between $\frac{\Delta\Phi}{\Delta t}$ and that quantity. Do not forget the sign to indicate direction!

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Eugenia Etkina

5. March

Hi all, I did not post yesterday as the war situation touched me personally and I just could not write a post. But I am better today and will continue with the electromagnetic induction.
While we often focus on the phenomenon of inducing electric current in a closed loop of wire placed in the changing magnetic field, the question is WHAT is the cause of this current? Magnetic field does not act along the wire, it does not push electrons inside it, so - what does? It can only be an electric field. But where does it come from?
Changing magnetic field must create it! This is the field that pushes the electrons inside the wire, but if the wire is not there, the field still exists! This is the first step on the path to understanding the nature of electromagnetic waves!
See what we write in the textbook about it and how we prepare our students to TRULY understand Maxwell's equations without ever writing any equations... The equations are not there yet, they come later, but the soil is prepared for them! Please do not forget to respond to the post - last time I did not ask and very few people responded. If you read a post and do not react to it, the post becomes less visible for other people. So, please do your duty and either like it to write comment. Liking it here does not mean that you really like it, it only means that more people will see it. Thank you.

21.8 Mechanisms explaining electromagnetic induction

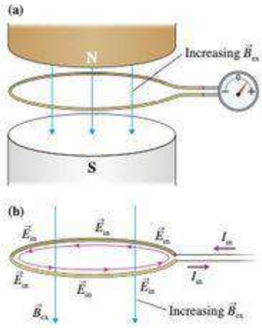
Faraday's law *describes* how a changing magnetic flux through a wire loop is related to an induced emf, but it does not *explain* how the emf comes about. In this section we will explain the origin of the induced emf.

A changing $\vec{B}_{ex}$ field has a corresponding $\vec{E}$ field

We know that a changing magnetic flux induces an electric current in a stationary loop (**Figure 21.26**). Because the loop is not moving, there is no net magnetic force exerted on the free electrons in the wire. Thus, an electric field must be present. The electric field that drives the current exists throughout the wire. This electric field is not produced by charge separation, but by a changing magnetic field.

If we were to represent it with $\vec{E}$ field lines, those lines would have no beginning or end—they would form closed loops. This electric field essentially "pushes" the free electrons along the loop. We can describe it quantitatively with the emf. But this emf is very different from the emf produced by a battery. For the battery, the emf is the result of charge separation across its terminals. For the induced emf, the electric field that drives the current does not originate on the charges but is distributed throughout the entire loop; thus the emf is also actually distributed throughout the entire loop. You might visualize it as an electric field "gear" with its teeth hooked into the electrons in the wire loop, pushing the free electrons along the wire at every point.

FIGURE 21.26 A changing $\vec{B}_{ex}$ creates an electric field $\vec{E}$ that induces an electric current.



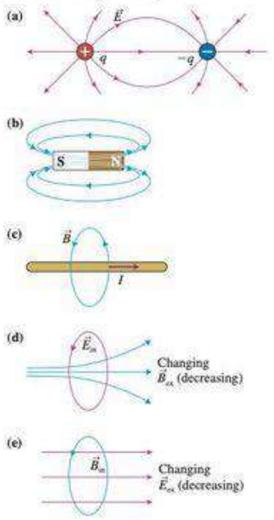
What do we now know about electricity and magnetism?

We have learned a great deal about electric and magnetic phenomena. We learned about electrically charged objects that interact via electrostatic (Coulomb) forces. Stationary electrically charged objects produce electric fields, and electric field lines start on positive charges and end on negative charges (**Figure 21.27a**). In our study of magnetism (Chapter 20), we learned that moving electrically charged objects and permanent magnets interact via magnetic forces and produce magnetic fields. Magnetic field lines do not have beginnings or ends (Figure 21.27b); they are continuous loops. So far, individual magnetic charges, magnetic monopoles, have not been found.

When we studied electric circuits (Chapter 19) we learned that electric fields cause electrically charged particles inside conductors to move in a coordinated way—electric currents. Later we learned that electric currents produce magnetic fields (Figure 21.27c). In this chapter, we learned about the phenomenon of electromagnetic induction and its explanation: a changing magnetic field is always accompanied by a corresponding electric field (Figure 21.27d). However, this new electric field is not produced by electric charges, and its field lines do not have beginnings or ends.

Except for the lack of magnetic charges, there is symmetry between electric and magnetic fields. This symmetry leads us to pose the following question: if in a region where the magnetic field is changing there is a corresponding electric field, is it possible that in a region where the electric field is changing there could be a corresponding magnetic field (Figure 21.27e)? This hypothesis, suggested in 1862 by James Clerk Maxwell, led to a unified theory of electricity and magnetism, a subject we will investigate in our chapter on electromagnetic waves (Chapter 25).

FIGURE 21.27 A summary of some of the main ideas of electricity and magnetism.



REVIEW QUESTION 21.8 Explain how (a) an electric current is produced when only a part of a single wire loop moves through a magnetic field and how (b) an electric current is produced when an external magnetic flux changes through a closed loop of wire.

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Eugenia Etkina
6. March

Hello everyone! I am continuing commenting on the progression fo the material and today we will start Geometrical optics - Chapter 22 - Reflection and refraction. In this chapter students

learn about light and how it interacts with different surfaces and media but not how mirrors or lenses work - those come in Chapter 23. Please do not forget to respond to the post in some form to make it more visible. Thank you.
There are a few crucial things for the students to learn about light in this chapter (the number of crucial things about light is infinite... :)). The main are: to see anything we need a source of light, our eyes are not producing any light themselves. We cannot see light itself unless it hits our eyes directly, we can only see objects from which light bounces and then reaches our eyes. We model propagation of light in one medium with straight lines (rays). Each (EVERY) point of an extended source of light sends light rays in all directions.
To help students construct all those important ideas we start with a very simple and yet very difficult experiment. The students need to go into an absolutely dark room and stay there for a few minutes. It is crucial that the room is absolutely - ABSOLUTELY dark. That is why it is so difficult to achieve. But if you manage to give this experience to your students and ask them if they could see anything (do not ask them BEFORE), they will say that they could not. This is a very important step to which you will come back many times when your students draw ray diagrams starting with the observer eyes. For a long time people thought that we can see objects because our eyes emit special rays that wrap around objects, come back to us and bring us information about those objects. This experiment helps students learn that nothing comes out of our eyes. Here are the activities from the Active Learning Guide:
OALG 22.1.1 OBSERVE AND EXPLAIN
Go into a room that is completely isolated from all external light sources—natural and artificial. Turn off the internal lights and wait in the dark room for several minutes. Record your observations and propose an explanation.
OALG 22.1.2 OBSERVE AND EXPLAIN
Equipment: laser pointer and a spray bottle or chalk dust.
Take a laser pointer and point it at a wall. Can you see the beam of light it sends or only the shiny spot on the wall?
a. What path did the light follow to reach the wall? You can find it by trial and error - by trying to block the light with a small piece of paper at several locations along its path to the wall, or by using the water spray bottle.
b. What can you say about the path of the light from the laser to the wall? Represent that light path by a long line with an arrow, called a ray. A ray is not real; it is just a way to show the direction that light is traveling.
c. Explain why the water droplets (or chalk dust) makes it possible to see the light beam that was previously not visible.
d. Discuss the conditions needed for us to see something.
Video alternate if you can’t find the equipment: https://mediaplayer.pearsoncmg.com/.../secs-experiment...

https://www.facebook.com/groups/320431092109343/posts/1125031984982579/?__cft__[0]=AZVIQD_0JgpzpPyjAk42p6qRdVUz5G-86zh2aqQH3gG6rbe4Mw_HwXILIfeDP9Cr-JEi2PX90GmlKtYfIB34zU2JvJucHZGw1yqkGRXpiCyIy9li5XSOdCE8UyuijgpksXzKlwb3-ia7m0nMmXDelqPCzNubYjbjZQcvpR5spBOZgv2GyNeLGyfPBeYCjBKJ7gY&__tn__=%2CO%2CP-R

Eugenia Etkina

7. March

Hi all, I will continue with Reflection and refraction of light. If you read the post, please respond to it in some way to make it more visible.
As I said yesterday, it is really important for the students to figure out that each point of an object emitting light (or reflecting light) sends an infinite number of light rays in all directions. Without understanding this idea it is impossible to draw images in mirrors and lenses. I am posting the beginning of the discussion of this issue in the textbook. It ends with the proposal of two competing models of how an extended light source emits light. In the ALG and OALG these models are suggested for the students but I never actually use these activities as written. What I do, I turn on a frosted light bulb in a dark classroom and ask the students to tell what they see (see Figure 22.1 in the screenshot I posted). They say- the walls and the ceiling are lit. Then I tell them to use the idea of the rays to show how light from the bulb reaches the walls and the ceiling. Usually all groups draw a one point-one ray model. I ask them to think how they can test it. They come up with the testing experiments that are shown in the Testing Experiment Table 22.2 in the textbook (I am pasting the links to the videos below) and make predictions of the outcomes of these experiments using one ray model. Of course, all predictions do not match the outcomes, so the students go back and revise the model to have more rays coming out of each point. Then we test it again with the pinhole camera experiment. This way take a little longer than the one suggested in the OALG Chapter 22 posted here but it is much more rewarding.
Here is the link to the testing experiments that the students propose, try to make a predictions of the outcomes using one ray model and multiple ray model - which ones match the outcomes?
https://mediaplayer.pearsoncmg.com/.../secs-experiment...
Please do not forget to respond to the post either by liking it or by commenting. Thank you!

22.1 Light sources, light propagation, and shadows 687

How do we represent the light sent by a light source? How do objects illuminated by a light source reflect light into our eyes? We will start by investigating the first question.

Representing light emitted by different sources

A laser pointer is useful for studying light propagation because the emitted light emerges as one narrow beam. However, most light sources, such as lightbulbs and candles, do not emit light as a single beam. These **extended light sources** consist of multiple points, each of which emits light. When we turn on a lightbulb in a dark room, the walls, floor, and ceiling of the room are illuminated (Figure 22.1). Obviously, the bulb sends light in all directions. But does one point of the shining bulb send light in one direction, or does each point send light in multiple directions? Both of these ideas can explain why the walls, floor, and ceiling are illuminated. Let's investigate those two possible models of how extended sources emit light. To do this we will represent the travel of light from one location to another with a **light ray,** drawn as a straight line and an arrow. Diagrams that include light rays are called **ray diagrams**. A ray is not a real thing; it is a model that allows us to show the direction of light.

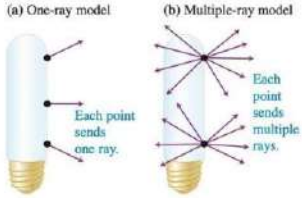
One-ray model: Each point of an extended light source emits light that can be represented by one outward-pointing ray (Figure 22.2a). Different points send rays in different directions.

Multiple-ray model: Each point on an extended light source emits light in multiple directions represented by multiple rays (Figure 22.2b).

To help us determine which model better explains real phenomena, we will use the models to make predictions about the outcome of three experiments (Testing Experiment Table 22.2). All of the experiments are conducted in an otherwise dark room.

FIGURE 22.1 A lightbulb illuminates the ceiling of a room.

FIGURE 22.2 Two models of light emission from a bulb.



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Eugenia Etkina
9. March

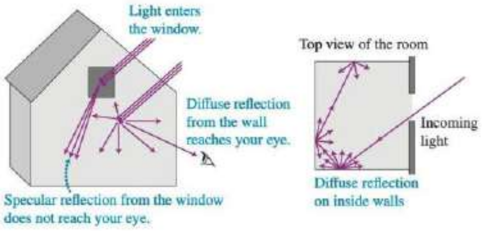
Hi all, I continue with reflection and refraction. Before you read on, please remember to respond to the post!
Helping students construct the law of specular reflection is relatively easy with a simple experiment - mirror, laser pointer and protractor. It is important for them to learn the role of a normal line here, so try to encourage them not to put the mirror horizontally or vertically but at an arbitrary angle with the horizontal to collect data.
After that follows the question - if the laser beam reflects off the mirror at the same angle with the normal as the incident beam, and therefore travels only in one direction, how come we ALL see the spot on the wall when we shine a laser beam on it? This question leads to figuring out that 1) the beam is not a ray, it can be modeled as a set of multiple rays and 2) the wall is not a mirror, but has bumps. Both lead to the fact that different rays reflect at different angles - we have diffuse reflection.
Understanding diffuse reflection not only helps us understand how we all objects, but also why we do not see some. Have you noticed that even on a very sunny day the windows of the houses that have regular glass are always dark? Why is that and how does it connect to the laws of reflection? See the answer in our Conceptual exercise in the textbook that is attached. And please do not forget to respond to the post after you read it.

CONCEPTUAL EXERCISE 22.2 **Dark window on a sunny day**

On a sunny day, a house's uncovered window looks almost black, but its outside walls do not. How can we explain this difference?

Sketch and translate If the window looks black, it must reflect very little sunlight to your eyes. Our goal is to explain why.

Simplify and diagram When light shines on the rough walls of the house, it reflects back diffusely at different angles, and some of the light reaches your eyes—you see the walls easily. When light reaches the transparent surface of the window, most of it passes through the window and into the room and then reflects diffusely many times. During each reflection, some of the light is absorbed; because of this absorption, little comes back out. A small amount reflects off the smooth glass window as specular reflection (see the front view of the house and the top view inside the room in the figures on the right). If you are not standing in the right spot, you see very little light coming from the window—it appears dark. But if you are standing in that one location, you see a bright reflection of the Sun in the window.



Try it yourself Why is the pupil of your eye dark?

Answer The pupil is a hole in the eye—similar to a window in a house. Incident light enters the pupil, and very little is reflected back—the pupil looks dark.

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Eugenia Etkina
10. March

Hi all, Shih-Yin Lin yesterday asked me why I do not like the word "formula". Here is my answer.
There are certain words that have shortcuts in our brains to specific images. Neurons fire together. In my experience the word "formula" in the minds of our students is connected to the words and images of "memorize", "search for" etc. It is not connected to some reasoning process but is connected to remembering. If we wish to disrupt this brain connection, we should not use the term formula.
In addition, this term "covers" different meanings. Is the "formula" a definition of something? Is it communicating a cause and effect relationship? All this questions do not arise when we use this word. That is why I avoid it.
We already discussed why certain terms are not good for learning. My other term to avoid is "worksheet". Worksheets in American schools are often literally sheets of paper with pre-prepared places to fill in answering simple questions (these spaces are often small and assume some very quick answer). I am sure that there are other worksheets but in my experience the students, when they hear the word worksheet, expect some boring work filling out the blanks. That is why I use the word "handout" instead.

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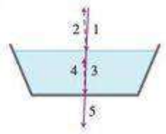
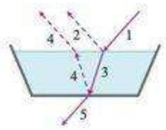
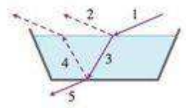
Eugenia Etkina
11. March

Hi all, thank you for responding to the discussion about "formula" issue. A few things today:
Please vote for the date of the next meeting, the poll is on the top of the page.
If you read the post, please do not forget to respond to it.
Among the terms I do not use there is another one - "demo". We already talked about it but I want to repeat. We do not demo, we do experiments - either observational, or testing, or application. Those have epistemological value - observational experiments help students find patterns and generate hypotheses, testing experiments help students test patterns and hypotheses, application experiments help students apply several tested ideas to solve practical problems. Demos - show or illustrate something that the teacher wants to communicate. The name does not help students learn how to think about these. The term demo does not have an epistemological signal in it.
I continue with Refraction. I want to share an observational experiment table that help students come up with the idea that when light encounters a boundary of media, multiple things happen. We sometimes only focus on one of them. The experiments are easy to perform - they can be done by students in groups or by the teacher in the front of the class, but it is the students who need to notice all beams - there are lots of them.

OBSERVATIONAL EXPERIMENT TABLE 22.4 The path of light changes when moving from air to water

VIDEO OET 22.4

Observational experiment	Analysis
Experiment 1. Shine a laser beam straight down into a glass container filled with water with a few drops of milk added to make the beam visible. The container sits on a supporting ring so that light can leave through the bottom. We see red spots on the ceiling and floor of the room and on the bottom of the container. 	Draw light rays to describe the appearance of the red spots. For simplicity we do not draw rays from the spots to our eyes. 
Experiment 2. Shine the laser at an angle, and all four spots change their locations. 	The path of the ray changes as it enters the water—it bends toward the normal. The path changes again when the ray emerges into the air—it bends away from the normal. 
Experiment 3. Increase the angle, and the spots move farther from their original locations. 	Although the incident angles change, the main features of the pattern from Experiment 2 remain. 

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Patterns

When light reaches the air-water boundary at the top surface, the incident light beam represented by ray 1

- partially reflects (ray 2) at the same angle as the angle of incidence and
- partially passes into the second medium (ray 3), bending at the interface *toward* the normal line.

Similar things happen to the light beam represented by ray 3. However, there are some differences. When ray 3 reaches the bottom water-air interface, it

- partially reflects (ray 4) at the same angle as the angle of incidence and
- partially passes from the water into the air below the container (ray 5), bending at the interface *away* from the normal line.

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Eugenia Etkina
13. March

Hi all, as no more votes were added to the poll, the meeting is on April 9th, 3 pm EST (noon US West coast time and 9 pm CET).
I will continue with the Reflection/Refraction posts. While our students learn the laws of reflection/refraction, the question arises - what is light? What is it made of? Historically, as you

probably know, people thought of light as a stream of very small fast moving particles - like tiny bullets.

This model of light explains reflection very well and it explains refraction too (see the attached document, the reasoning there is the reasoning that Newton used to explain refraction using this model). However, the bullet model explaining refraction makes a prediction about the speed of light in a medium other than air.

It predicts, that light will speed up (see the reasoning in the attached document). And as the speed of light is very high, it was impossible in Newton's time to measure the speed of light accurately in water or glass. But but the time people could measure this speed, the bullet model was rejected by other experiments and replaced with a different model, which predicted the speed of light lower in media other than air (or vacuum). If you read to the end, please respond ot the post. The last post got very few responses, it means that a small number of people will see it.

FIGURE 22.20 Newton's particle-bullet model of light.

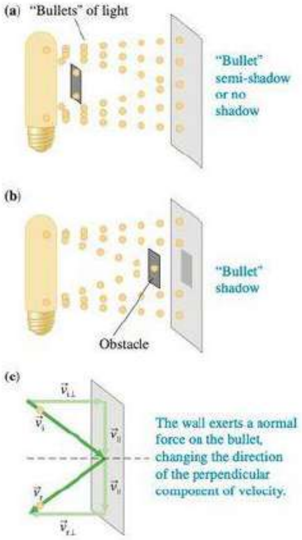
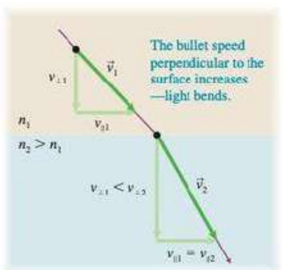


FIGURE 22.21 Explanation of light refraction using the particle-bullet model.



22.7 Explanation of light phenomena: two models of light

We have developed a ray model of light that describes the way light behaves. What other models can we use to explain the way light behaves?

Particle-bullet model

Isaac Newton modeled light as a stream of very small, low-mass particles moving at very high speeds, like bullets. According to this model, light bullets are affected by Earth's gravitational pull and move like projectiles, but since they move very quickly, their deflection from straight lines is not noticeable. Let us use this model to explain light phenomena familiar to us. We will start with shadows.

Imagine an extended light source such as a bulb sending light bullets in all directions from each point. If we place an obstacle close to the light source, bullets of light will still reach each part of the screen—the result will be a semi-shadow or no shadow (**Figure 22.20a**). If the obstacle is farther away, there will be a place on the screen where no bullets reach the screen—a shadow will form (Figure 22.20b). We can explain the reflection of light if we imagine that the bullets bounce elastically off surfaces. For the bullet model of light, the normal force exerted by a surface on the light bullets can only change the component of velocity perpendicular to the wall (because the acceleration of an object is in the same direction as the force exerted on it); the component parallel to the wall stays the same (Figure 22.20c). This is consistent with the law of reflection. Newton's particle-bullet model of light does successfully explain light propagation and reflection.

Can we explain refraction using this model of light? In order for the model to be consistent with Snell's experiments on refraction, the light bullets will have to speed up when they refract into a more optically dense medium (see **Figure 22.21**). The particle-bullet model suggested that the denser medium exerts an attractive force on the light particles, causing their speeds to increase. Accurate measurements of the speed of light turned out to be very challenging, and for many years the speed of light could only be determined in air or in a vacuum (it was found to be 299,792,458 m/s—about 3×10^8 m/s). In addition, the particle-bullet model requires an additional interaction between the surface and the light particles that causes them to speed up when entering the denser medium. Scientists prefer explanations that are as simple as possible. Another model of light that did not require this additional interaction was proposed.

Wave model of light

Simultaneously with Newton's development of the particle-bullet model of light, Christiaan Huygens was constructing a wave model of light. The motivation for the model could have come from the observations that light reflects off objects similar to the way sound reflects. Recall (from Chapter 11) that Huygens' wave propagation ideas involved disturbances of a medium caused by each point on a wave front producing a circular wavelet. Imagine that we have a wave with a wave front moving downward

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Eugenia Etkina
15. March

Hi all, a few things: first, please respond to the event - our uncertainty meeting in April. Second, please respond to the posts if you read them.
Thirds - the end of the story of the models of light that we do in Chapter 22 - reflection and refraction. We return to the models many times in the book - in the wave optics chapter, in the electromagnetic waves chapter and then in the quantum optics chapter. Eventually the students learn that there are no classical models that singularly explain all phenomena that we observe with light. But this is on the future. Now - to the continuation of the story. I had to shrink the view of the pages to make the whole thing visible on one screenshot. The key step is figure 22.23 that explains what happens to wave fronts in different media. Traditionally, the textbooks skip this step and only draw figures such as 22.24, but I think without 22.23 a student cannot understand how the wave model explains refraction.
Notice that we carefully talk about particle-bullet model and wave model, never saying that light is a wave. A wave is just one model explaining the behavior of light, as we will see later, it is deficient.

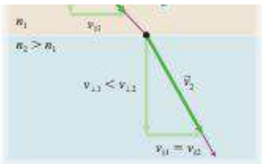
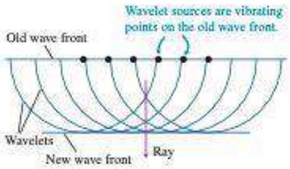


FIGURE 22.22 Wavelets produce a new wave front.



light that did not require this additional interaction was proposed.

Wave model of light

Simultaneously with Newton's development of the particle-bullet model of light, Christiaan Huygens was constructing a wave model of light. The motivation for the model could have come from the observations that light reflects off objects similar to the way sound reflects. Recall (from Chapter 11) that Huygens' wave propagation ideas involved disturbances of a medium caused by each point on a wave front producing a circular wavelet. Imagine that we have a wave with a wave front moving downward parallel to the page (see **Figure 22.22**). We choose six dots on this wave front, and from each dot we draw a wavelet originating from it (as shown in Figure 22.22). Each dot represents the source of a circular wavelet produced by the wave disturbance passing that point. According to Huygens' principle, each small wavelet disturbance produces its own circular disturbance that moves down the page in the direction the wave is traveling. The distance between two consecutive wavelets is equal to the wavelength. Now, note places where the wavelets add together to form bigger waves. These places are where the wave front will be once it has moved a short distance down the page. We also draw an arrow (a ray) indicating the direction the wave is traveling perpendicular to the wave fronts and consistent with the ray model of light propagation. In this model, the ray is the line perpendicular to the wave front.

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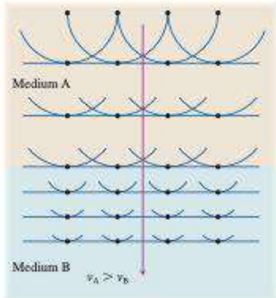
When the waves emitted by the same source travel in different media, their frequency remains the source frequency, but their speed changes depending on the medium. For example, water waves travel more slowly in shallow water than in deeper water. Sound travels more slowly in cold air than in warm air. What does the wave model predict will happen when waves propagate through media with different wave speeds and with zero incidence angles? Imagine that the speed of the wave shown in **Figure 22.23** is greater in medium A than in medium B. When the wavelets from medium A reach the boundary with medium B, their radii reduce because the wave has a smaller speed in medium B. The new wave fronts are therefore closer together.

FIGURE 22.23 Wavelets crossing perpedicularly to the boundary between two regions with different wave speeds.



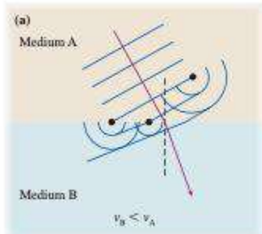
Wave model and refraction

Imagine a light wave moving in a less optically dense medium A and reaching an interface with a denser medium B (where it travels at a slower speed) at a nonzero angle of incidence (**Figure 22.24**). Using the wave model of light, we can now draw wave fronts for this wave as it travels from medium A into medium B. During a certain time interval, the wavelet that departed from the right edge of the wave front is still traveling in medium A. The wavelet that departed from the lower left edge of the wave front at the same time travels a shorter distance in medium B since it is moving slower. Once the point on a wave front reaches the boundary, the radius of the wavelet in medium B becomes smaller than in medium A, while the wavelets for the points on the same wave front that is still in medium A have larger radii. The wave front breaks at the boundary, as shown in Figure 22.24a.

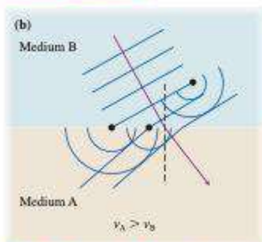
What if a light wave travels from a slower to a faster medium, as shown in Figure 22.24b? Using similar reasoning, we find that the light bends away from the normal. If the wave model is going to describe refraction properly, we must conclude that light travels more slowly in water than in air.

According to the wave model of light, the speed of light should be slower in water than in the air—exactly opposite the prediction of the particle-bullet model. Which model is more accurate? An obvious way to answer this question is to measure the speed of light in water. But this experiment is difficult. Thus, we are left with two models of light that both explain the reflection and refraction of light but lead to different predictions about its speed in water. This dilemma existed in physics for a long time due to the difficulty in measuring the speed of light in different media. Ultimately, the resolution came not from measurements of the speed of light but from overwhelming experimental support for the wave model. We will discuss the wave model in more detail in a later chapter (Chapter 24).

FIGURE 22.24 Huygens' principle explains why the wave changes directions when it reaches the interface between two media.



The wave travels farther on the right side in the less optically dense medium A than on the left side in denser medium B.



Medium B is less optically dense than medium A, causing the wave to bend out rather than in.

Unanswered questions

Although we have learned a great deal about light, there are still questions that we have not answered. We do not know why different media bend light differently. We still do not know whether light propagates faster or slower in water and other media compared with air. We do not know how objects radiate light. Why do some stars look white but others look red? We also have not decided which model of light is better—the particle-bullet model or the wave model. We will investigate these questions in the coming chapters.

REVIEW QUESTION 22.7 What is the difference between the two models of light and the predictions they make for the speed of light in water?

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Eugenia Etkina
16. March

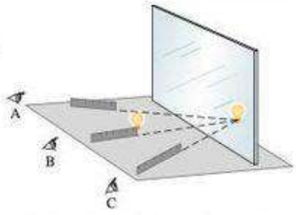
Hi all, we continue with geometrical optics today. But before I write about the physics, i wanted to ask you again, to indicate whether you are going to join the meeting on April 9th. so far we have only 7 people who said that they would join. Does it mean that the topic is not of interest? If yes, we could choose another topic, please propose here. If the topic is on interest and you just did not click that you will attend, then, please, do!
Now, the physics. We are moving to Chapter23 - mirrors and lenses. First we start with plane mirrors. Although they seem rather simple, in fact research shows that they are not. Many students think that the image is on the surface of the mirror and many have trouble with virtual images. Here is our sequence of actions, which addresses both issues. Please read it and comment. How is it different from what you use to do with your students? How is it similar? Thank you.

OBSERVATIONAL EXPERIMENT TABLE **23.1** Seeing a point object in a plane mirror

VIDEO OET 23.1

Observational experiment

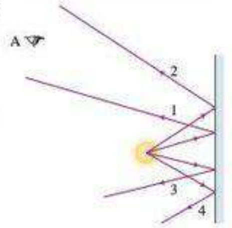
We place a small lightbulb on a table about 20 cm in front of a plane mirror that is held perpendicular to the table, with one side resting on the table. Observers A, B, and C place rulers on the table and point them in the direction of the bulb that they see in the mirror.



Note that the dashed extensions of the rulers all intersect at one point behind the mirror.

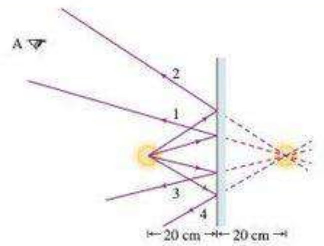
Analysis

For observer A to see an image of the lightbulb when looking at the mirror, one or more rays of light reflected from the mirror must reach his eyes. Rays between 1 and 2 do reach observer A's eyes.



Patterns

- The rulers all point to the same spot behind the mirror. Rays between 1 and 2 reaching observer A seem to originate from that spot. This is the location of the perceived image of the bulb produced by the mirror.
- The ray diagram shows that the perceived image of the bulb is produced at the same distance behind the mirror as the bulb is in front of it.
- To locate the image, at least two rays need to reach the observer's eyes because the perceived image is at the intersection of those rays.



In Table 23.1 we found that the image of the real object seen in the mirror is located where light reflected from the mirror to the eye of the observer *seems* to originate. This perceived image is behind the mirror and not on the surface of the mirror. We also found, using the ray diagram, that the image is exactly the same distance behind the plane mirror as the object is in front of it. Let us test these findings in Testing Experiment Table 23.2, on the next page.

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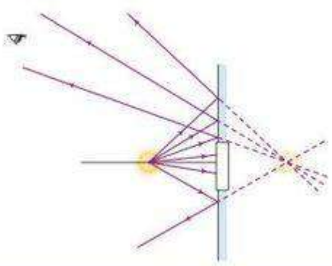
TESTING EXPERIMENT TABLE **23.2** Testing the image location of a plane mirror

VIDEO TET 23.2

Testing experiment	Prediction	Outcome
We repeat the Table 23.1 experiment for observer A but cover the part of the mirror directly in front of the bulb.	If the image is due to the reflected rays, then even if we cover part of the mirror, some of the reflected rays will still reach the observer's eyes. The location of the image should not change. 	The observer sees the image of the bulb exactly where it was before.

Conclusions

The position of the image formation is consistent with our previous experiment. It also disproves the common idea that the image forms on the surface of the mirror.

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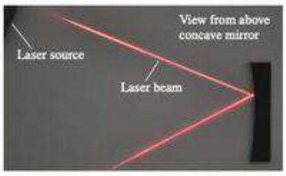
MqLjTvrKJiHYVrpHJHH7GwQ-jIzn4u_XgPNiFQ_Kp-
gc3BdRuIClYCk8wpvqHSVPYKt49By7aKHf-
e06zMuRiQvfHqLR406CIhnLmzNynFBp1S6hoE4kQaD8HFf4U&__tn__=%2CO%2CP-R

Eugenia Etkina
19. March

Hi all, I see 15 people signed up for the meeting, this is great, thank you for doing it! We will do the uncertainties then, and the next one will be about qualitative/quantitative reasoning. To prepare for the meeting, please read the following document: https://drive.google.com/.../1bYPf4GzCTtETFT7C9tz4g791MQp...
Today I continue with mirrors/ lenses. Please study carefully the document that I attached. It shows a sequence of several experiments that the students can do if you have enough equipment, or you can show on a big screen. These experiments reveal two important patterns which allow students to invent the concept of a focal point (a common thing) and a FOCAL PLANE - a concept that is overlooked in most textbooks but is extremely helpful if you wish your students to learn how to find images of objects and in general, to be able to explain a lot of different phenomena.
The idea behind a focal plane is that any set of parallel rays incident on a concave mirror will pass through the same point (different for different parallels but the same for the rays that are parallel to each other) that is located on a plane passing through the focal point and perpendicular to the principal axis. Understanding of this idea will allow students to use parallel rays to find images. I am attaching the screenshot but if you have the textbook, please study carefully Figure 23.5 - it emphasizes the point I am trying to make. Do not skip the concept of the focal plane when you plan your lessons! And please do not skip responding to this post to make it more visible to group members. Thank you!

FIGURE 23.4 A concave mirror reflects a laser beam.



and to provide visibility at blind spots, such as hallway corners and driveway exits (**Figure 23.3**).

In both kinds of curved mirrors, the center of the sphere of radius *R* from which the mirror is cut is called the **center of curvature** C of the mirror. The imaginary line connecting the center of curvature with the center of the mirror's surface is called the **principal axis.**

Concave mirrors

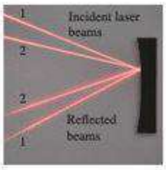
In Observational Experiment **Table 23.3**, we cut a narrow band from a concave mirror and lay it on its edge on a piece of paper (**Figure 23.4**). The paper allows us to observe the paths of laser light incident and reflected from the mirror.

OBSERVATIONAL EXPERIMENT TABLE 23.3 Reflection of light from a concave mirror

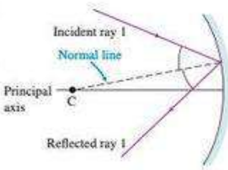
VIDEO OET 23.3

Observational experiment | **Analysis**

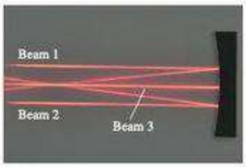
Experiment 1. We shine a laser beam parallel to the plane of the page toward a concave mirror and trace the path of the incident and reflected light on the page.



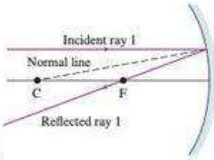
We use the law of reflection to draw a ray diagram. The dashed line from the place where the ray hits the mirror to the center of curvature is a normal line perpendicular to the surface of the mirror. The law of reflection accounts for the path of the reflected ray.



Experiment 2. We send several beams parallel to the principal axis. Reflected beams all pass near the same point on the principal axis.



We draw a ray diagram and use the law of reflection to analyze the paths of the light. The normal lines here are radii of the mirror. We find that all reflected rays pass through the same point on the principal axis (called the *focal point* F of the mirror), matching the outcome of the experiment.



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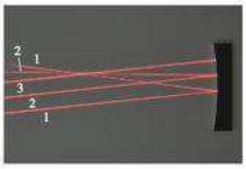
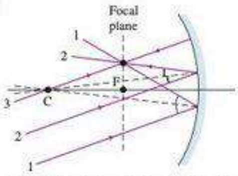
Observational experiment | **Analysis**

Experiment 3. This time we send several beams parallel to each other but not parallel to the principal axis. One ray passes though the center of curvature C. All reflected rays pass through the same point.



We use the law of reflection to draw a ray diagram to analyze the paths of the light. The ray passing through the center of curvature is perpendicular to the mirror and thus reflects back on itself. All other rays after reflection pass through the same point on a line perpendicular to the principal axis and through the focal point. This point is in the *focal plane* of the mirror. The ray diagram matches the outcome of the experiment.



Patterns

- The mirror reflects light according to the law of reflection. The normal line at any point on the mirror goes through the center of curvature. The normal lines are in the radial directions.
- After reflection, all incident rays traveling parallel to the principal axis pass through the same point on the principal axis—the focal point of the mirror.
- After reflection, all incident rays traveling parallel to each other but not parallel to the principal axis intersect at a common point. This point is on the line perpendicular to the principal axis through the focal point.

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Eugenia Etkina
20. March

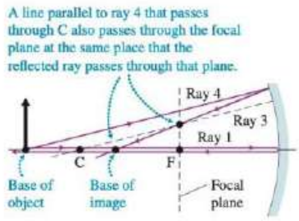
Hi all, today I continue with the discussion of the focal plane and secondary axis in the curved mirrors.
The combination of those two ideas (secondary axis is the one that passes through the center of the mirror but is not drawn horizontally, this means that any ray incident along such axis reflects on itself) allows you to solve problems that are otherwise difficult. The idea is that all incident rays parallel to a secondary axis pass through the same point on the focal plane after the reflection. This knowledge allows you to solve problems that otherwise do not even appear. For example, how to find an image of a source located on a principal axis?
Traditionally, students would erect an arrow up, find an image of the top point and then draw a line perpendicular to the main axis to find its intercept. But how do we know that an object perpendicular to the principal axis will produce an image that is also perpendicular?
Is there a way to find the image of a source on the principal axis without imagining a large object there? The method of secondary axis and the focal plane allows you to do it beautifully. It is described in the screenshot that I attached here.
I see that only 8 people responded to my previous post about focal planes. I have no idea whether only 8 people out of 1200 members of the group saw the post or only 8 responded. Could you PLEASE ALWAYS respond if you read a post? Every time I ask if the posts are needed, I get a very supporting response - lots of people say that they are needed, but then the number of responses goes down and I need to ask again. So, PLEASE!

23.2 Qualitative analysis of curved mirrors 719

Locating the image of the base of an object produced by a concave mirror

So far, our ray diagrams have only included the image of the top of the object. We have assumed that the image of the base of the object is always on the principal axis directly below the image of the top of the object. To validate this assumption we will use a ray from the base of the object traveling along the principal axis as ray 1. It reflects back on itself. Since ray 1 stays on the principal axis, any other ray that we use to locate the image of the base will also have to intersect the principal axis. To find where on the axis the image of the base is located, first draw an arbitrary imaginary ray through the center of curvature. This is ray 3 from Physics Tool Box 23.1. That ray reflects back through C (**Figure 23.8**). Now draw another ray, which we will call ray 4, from the base of the object and oriented parallel to ray 3. Ray 4 will pass through the same point on the focal plane as ray 3. Ray 4 intersects the principal axis at the location of the image of the base of the object. This locates the image of the base. It does in fact lie directly above the image of the top of the arrow (not shown in the figure). The method that we used to locate the base of the object works for locating the image of any point of an object that resides on the principal axis.

FIGURE 23.8 Locating the base of the image produced by a curved mirror.



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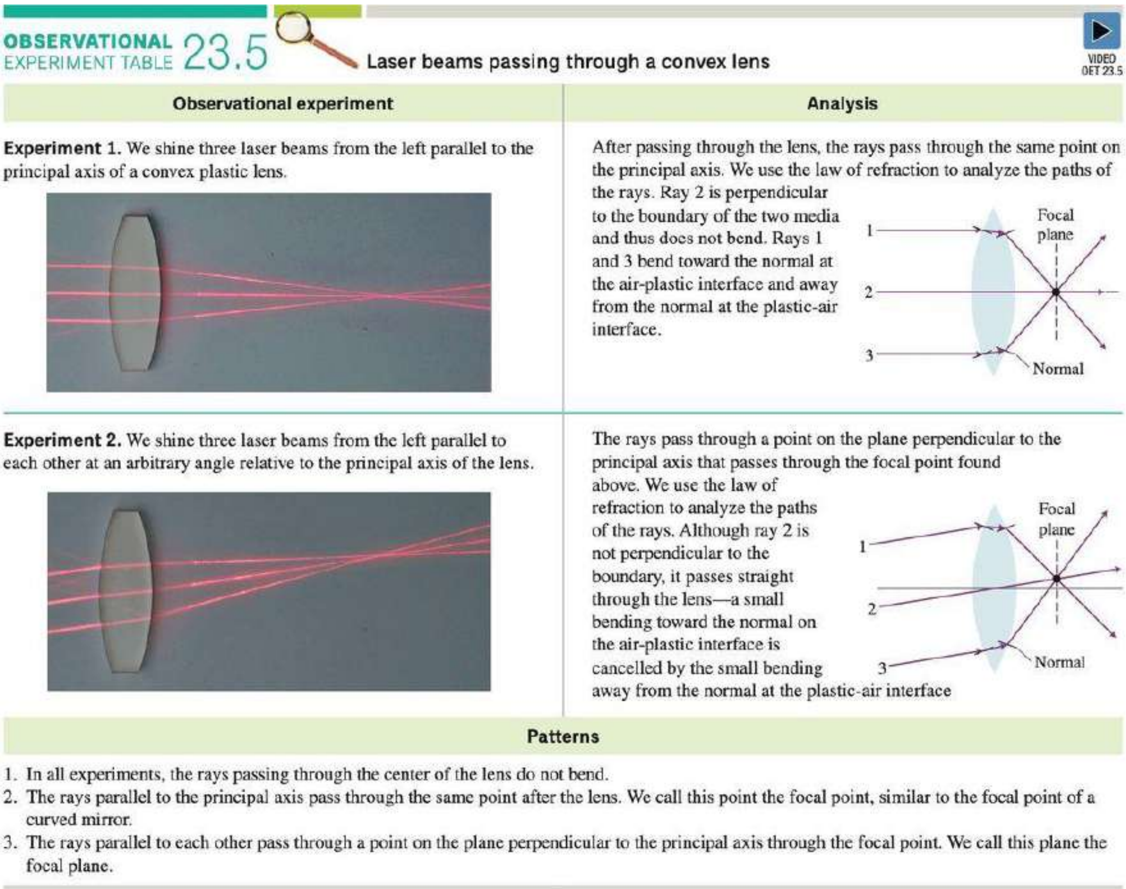
Eugenia Etkina
22. March

Today I continue with the focal plane - this time for lenses. The same way as we found it for the mirrors, you find it for lenses. See the attached screenshot to see how to find the focal plane. We actually all use it when we try to burn something with a convex lens using the light from the Sun. It does not matter how we hold the lens, we can still find where to put the paper for it to start burning. We put it at the specific location in the focal plane!


OBSERVATIONAL EXPERIMENT TABLE 23.5 Laser beams passing through a convex lens

VIDEO OET 23.5

Observational experiment	Analysis
Experiment 1. We shine three laser beams from the left parallel to the principal axis of a convex plastic lens.	After passing through the lens, the rays pass through the same point on the principal axis. We use the law of refraction to analyze the paths of the rays. Ray 2 is perpendicular to the boundary of the two media and thus does not bend. Rays 1 and 3 bend toward the normal at the air-plastic interface and away from the normal at the plastic-air interface.
Experiment 2. We shine three laser beams from the left parallel to each other at an arbitrary angle relative to the principal axis of the lens.	The rays pass through a point on the plane perpendicular to the principal axis that passes through the focal point found above. We use the law of refraction to analyze the paths of the rays. Although ray 2 is not perpendicular to the boundary, it passes straight through the lens—a small bending toward the normal on the air-plastic interface is cancelled by the small bending away from the normal at the plastic-air interface

Patterns

1. In all experiments, the rays passing through the center of the lens do not bend.
2. The rays parallel to the principal axis pass through the same point after the lens. We call this point the focal point, similar to the focal point of a curved mirror.
3. The rays parallel to each other pass through a point on the plane perpendicular to the principal axis through the focal point. We call this plane the focal plane.

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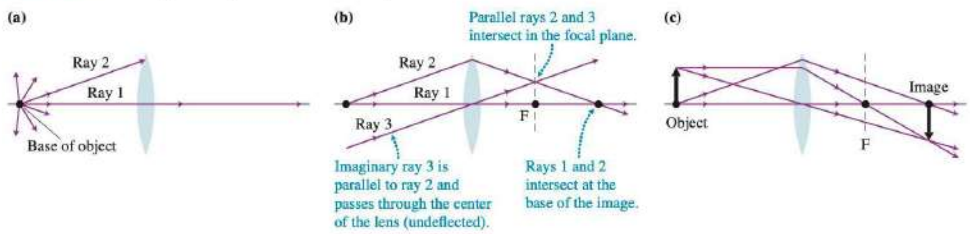
Eugenia Etkina
23. March

Hi all, we continue with lenses. I stopped asking you to respond to the posts and the number of likes went down considerably. I know that it does not mean that people are not reading the posts but it would be GREAT if you took a second to like it - this does not mean that you REALLY LIKE it, it only means that your response gives more people an opportunity to see the post and it gives YOU an opportunity to see more of the posts. Wow, this was long, but it

really pains me when 8 people out of 1200 who are group members respond. PLEASE respond!
OK, lenses. Hrvoje Miloloža tried to make an image of an object using the point on the principal axis and had trouble getting the image to be perpendicular to the principal axis. We figured out why. The focal plane idea only works for paraxial rays. Once you go away from the principal axis or have a very curved mirror or a lens, our simple ray diagrams stop being accurate.
I have a nice ray diagram in the textbook showing how to draw an image of an object using one of the points on the principal axis for lenses. I am attaching it here to show you how helpful the focal plane and secondary axis are. Try to follow all the rays we used to see how the image appears. Tomorrow, I will share our unique jeopardy problems that REALLY make you understand how to draw images.

23.4 Qualitative analysis of lenses 729

FIGURE 23.17 Locating the image of the base of an object.



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Eugenia Etkina
24. March

Hi all, thank you for responding to my yesterday's post. Please continue to respond when you read a post. Today I am posting a problem that makes students really think of how to draw images in lenses (or mirrors). I am posting it without a solution and I challenge you to solve it without making an extended object, but only using the shining point that is given. Take a picture of your solution and post it here. The solution uses the idea of a secondary axis.

The image of a shining point-like object S is produced by a lens (see figure below). The line is the principal axis of the lens. Where is the lens, what kind of lens is it, and where are its focal points?

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Eugenia Etkina
26. March

Hi all, Lane Seeley, Stamatis Vokos and myself just published a paper that explains why we should not use the terms conservative and non conservative forces and other stuff connected to energy. Please read!
Updating our language to help students learn: Mechanical energy is not conserved but all forces conserve energy
American Journal of Physics 90, 251 (2022);

https://www.facebook.com/groups/320431092109343/posts/1137236393762138/?__cft__[0]=AZUTKMYgxL6rsDMrg0E_oBgEHbjSfVldAIvOrWkOfEqM_zm7kCwZcmySMtk_p948W01HboPmAqZeJTdlutJI4ZHO1hRW4y8I0ir4SFQ83-ssc0VTy_6LTg7kI4LOkQfUtIOeOqua98bh6HW4F8IRu_032fhYMCsTNa1Pw4-75V0rBTDu-uF7lrQrWwimzKqgOfWYEeN7xcJqMOU40-mYVvdV&__tn__=%2CO%2CP-R

Eugenia Etkina
26. March

Hi people, in the published paper about energy that I posted yesterday, there is an important typo. Reference 2 should be next to Reference 3, not where it is in the pdf. In our book we do not have conservative and non conservative forces. It is the whole point, I am not sure how I did not notice it yesterday.

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Eugenia Etkina
28. March

Hi all, I continue posting stuff about optics. PLEASE respond to the post after you read it!
As we discussed before, historically there were two models of light first: the bullet particle model (Newton) and the wave model (Huygens). We already learned that while the bullet model explains reflection and refraction, it predicts the higher speed of light in water or glass compared to air. One would think that the experiment measuring the speed of light in water or glass would rule out the bullet model, but historically this experiment arrived too late. By the time people could determine the speed of light in water and glass, they already discarded the particle-bullet model.
And the reason was the experiment in the activity that is attached. The link to the video is below. I love how Gorazd Planinsic made this experiment for two reasons - at the beginning it helps students construct the idea of interference of light from two slits (double slit interference) and later, it allows them to see the role of the width of the slit (single slit diffraction). Do not miss! The activity and the video are a part of the OALG file posted in the FILES. You can have the whole file if you wish.
https://mediaplayer.pearsoncmg.com/.../sci-OALG-24-1-1

https://www.facebook.com/groups/320431092109343/posts/1138988893586888/?__cft__[0]=AZViFeecafkdkdaxoPCTkq9hrgKPQ-K1pdTi3qedfgd3l19XuI8p4Mi_gsR1Z8s-ViP8f02q1zIh5zYUu2FABmOU3De3caNsp2nipyYXUB8EZ_syIbgw_F6ObjhBdD2u54OlPwZ7hQPMgjYVKvwTpxl01ykNSHv18Ay4yYxsBmQJ2JBwlZPsdTa6uFFtafEb258&__tn__=%2CO%2CP-R

Eugenia Etkina
29. March

Hi all, I continue with wave optics today. Please do not forget to respond to the post after you read it.
After the students observed the double slit pattern and explained it arriving to the relation dXsintheta=nXlambda (this is a series of activities in the ALG and OALG), it is time to test their explanations/models. Here is the activity with the video of the result.
The whole sequence (observational experiment, reasoning, testing experiment) is better done in a lab, or, if it is too difficult, I would show them the observational experiment as one for the

whole class, have them work in pairs on derivation for about 3-5 min, then have give them help deriving through whole class discussion, and then let them do the testing experiment (including predictions) in groups. If they can predict what happens to the pattern when the distance between the slits increases, and then see that it REALLY happens, their feeling of success is hard to describe. They are so pleased!
Do not forget that in of double slit experiments we assume the slits to be very-very narrow, each slit sending only one wave front. You will see how important this model is when we get to diffraction on a single slit.
Here is the activity with the link to the video - from the OALG file posted here!
OALG 24.1.6 TEST YOUR IDEAS
a. Use the expressions that you devised in Activity 24.1.5, parts d and e, to predict what will happen to the bright spots on the screen when in the experiment described there the distance between the slits decreases. Will the bright bands be wider or narrower? Will the distance between the brightest parts of the bands increase, decrease or stay the same? Explain how you made your prediction
b. After you make your prediction, compare it to the outcome of the experiment in the following video: https://mediaplayer.pearsoncmg.com/.../secs-experiment...
c. Discuss whether the outcomes of the experiments support the expressions you devised in Activity 24.1.5 parts d. and e.

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Eugenia Etkina
30. March

Hi all, I continue today with cool stuff in wave optics. (Do not forget to respond to the post!) You probably noticed that in the double slit interference pattern there are actually two patterns - one a small scale (dark lines and bright spots) and one of a larger scale (the change in brightness of the whole pattern). The latter one is due to the fact that the slits have a finite width and different parts of each slit send different wavelets that interfere too. This pattern (if any of the students notice this larger scale pattern it could serve as the "need to know" for diffraction. We have an excellent activity that helps the students realize the role that a non-zero width of the slits play. Here is the activity. Make sure you watch the video - it is amazing! Before Gorazd Planinsic made it, I knew what would happen theoretically but never saw it in real life, now we have it!
OALG 24.5.1 OBSERVE AND EXPLAIN
In previous activities involving two or more slits, we used very narrow slits and considered them to be point-like wave sources. In the following video one of the two slits in a double slit experiment is slowly covered https://mediaplayer.pearsoncmg.com/.../sci-OALG-24-5-1. Observe the changes in the patterns on the screen and suggest an explanation. Hint: what

would a pattern look like if each slit were infinitely thin as we assumed in all previous experiments?

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Eugenia Etkina.

1. April

Hi people, one of our group members, Danijela Kuveždić is doing her PhD work studying how teachers interpret student responses to non-traditional problems and how they respond to the students. It would be amazing if you could take about 20 min to respond to her survey. You will see a problem we gave to the students, their responses and you will need to decide what is good about those, what is not so good and what you would say to the student to help them. Your participation would be invaluable for her study. Everything is completely confidential, she does not need to know who you are. The problem is from our textbook, and it is really cool! I thank you in advance. Here is the link to the google form to answer the questions. https://forms.gle/K8sedckbdck5hKhSA

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Eugenia Etkina

2. April

Hi all, happy April 1st, I hope you did not waste this day and tricked your students nicely. I did mine! I invite my former students who are the members of this group to confirm. 🙂
Today, I wish to finish posts about wave optics. In this series (if you noticed) I focused on experiments - observational and testing experiments. Now, it is time for applications experiments and experimental design. I wonder with what kind of designs your students would come up if posed with the following challenge?
The activity below is not just an application experiment, it is an engineering activity that allows the students to focus on different aspects of the goal. Do they with to have clear separation of colors? Do they wish to measure the angles carefully? I have done this activity with my high school students (they used interference gratings, protractors, rulers, double sticky tape and white paper) and they came up with amazing designs!

OALG 24.7.5 DESIGN AN EXPERIMENT
You have probably noticed that stars have different colors—some are white, some are yellowish, and some are reddish. Does this mean that stars of a red color do not emit any blue light? Astronomers use an instrument called a spectrograph to analyze the color composition of starlight. The central mechanism of a spectrograph is a grating. Design a simple version of a spectrograph, an apparatus that will allow you to separate different colors of light emitted by a lamp on your desk (that emits light very similar to the light emitted by many stars) and will also allow you to measure the wavelengths of these different colors. Draw a picture of the apparatus and explain how it works.
Or, and please respond to Danijela Kuveždić survey if you have 20 minutes - I posted the link yesterday. Several people did and the responses are amazing! And do not forget to "like" this post of comment on it. "Liking" makes it more visible. Thank you!

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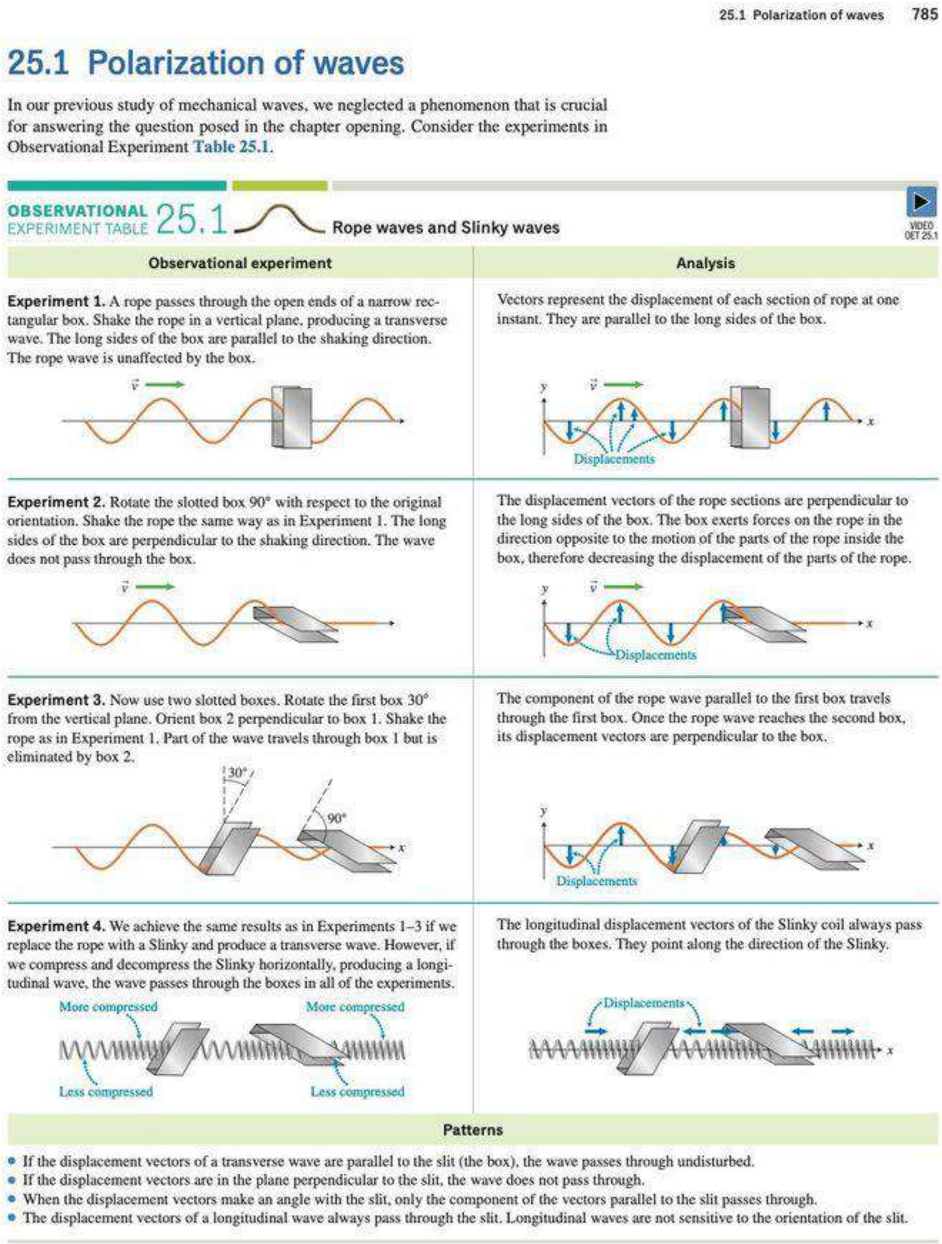
Eugenia Etkina
3. April

Hi all! I continue with the wave model of light. This model explains many phenomena that we observe with light but it does not say what is waving in the "light wave". The answer to this question is in Chapter 25 - Electromagnetic waves. Please do not forget to respond to the post after you finish reading it.
To understand the difficulty with this question - what is waving in the "light wave"? We need to consider another phenomenon common to waves - polarization. We start investigating polarization with simple experiments with mechanical waves, or rather mechanical pulses. Watch this (very long) video and summarize what you have observed.
https://mediaplayer.pearsoncmg.com/.../secs-experiment...
It looks like transverse waves behave differently compared to the longitudinal waves. No matter how we orient the boxes, the longitudinal waves pass through them and transverse do not pass through the boxes that are oriented perpendicular to the direction of vibrations of the rope or the slinky. See the Observational Experiment Table analyzing these explanations. The next step is to connect mechanical waves to light - if a similar phenomenon can be observed for light, it means that we can figure out whether light waves are longitudinal or transverse!


25.1 Polarization of waves 785

25.1 Polarization of waves

In our previous study of mechanical waves, we neglected a phenomenon that is crucial for answering the question posed in the chapter opening. Consider the experiments in Observational Experiment Table 25.1.

OBSERVATIONAL EXPERIMENT TABLE 25.1 Rope waves and Slinky waves

VIDEO OET 25.1

Observational experiment	Analysis
Experiment 1. A rope passes through the open ends of a narrow rectangular box. Shake the rope in a vertical plane, producing a transverse wave. The long sides of the box are parallel to the shaking direction. The rope wave is unaffected by the box.	Vectors represent the displacement of each section of rope at one instant. They are parallel to the long sides of the box.
Experiment 2. Rotate the slotted box 90° with respect to the original orientation. Shake the rope the same way as in Experiment 1. The long sides of the box are perpendicular to the shaking direction. The wave does not pass through the box.	The displacement vectors of the rope sections are perpendicular to the long sides of the box. The box exerts forces on the rope in the direction opposite to the motion of the parts of the rope inside the box, therefore decreasing the displacement of the parts of the rope.
Experiment 3. Now use two slotted boxes. Rotate the first box 30° from the vertical plane. Orient box 2 perpendicular to box 1. Shake the rope as in Experiment 1. Part of the wave travels through box 1 but is eliminated by box 2.	The component of the rope wave parallel to the first box travels through the first box. Once the rope wave reaches the second box, its displacement vectors are perpendicular to the box.
Experiment 4. We achieve the same results as in Experiments 1–3 if we replace the rope with a Slinky and produce a transverse wave. However, if we compress and decompress the Slinky horizontally, producing a longitudinal wave, the wave passes through the boxes in all of the experiments.	The longitudinal displacement vectors of the Slinky coil always pass through the boxes. They point along the direction of the Slinky.

Patterns

- If the displacement vectors of a transverse wave are parallel to the slit (the box), the wave passes through undisturbed.
- If the displacement vectors are in the plane perpendicular to the slit, the wave does not pass through.
- When the displacement vectors make an angle with the slit, only the component of the vectors parallel to the slit passes through.
- The displacement vectors of a longitudinal wave always pass through the slit. Longitudinal waves are not sensitive to the orientation of the slit.

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Eugenia Etkina
4. April

Hi all, today I continue with polarization and how it sheds light (no pun intended) on the nature of light. As we know, only transverse waves can be polarized. Transverse waves require sheer deformation (layers sliding across layers) of the medium. Sheer deformation is only possible in the solid state of matter. Thus, if light can be polarized, then it has to be a transverse wave. The experiments described in the screenshot below show that light can be polarized. Thus it is a transverse wave!

But it can propagate in gases and even in a vacuum. How can this be? The historical answer was that everything, even the vacuum is filed with a special matter- ether - which is invisible but behaves like a solid. Pretty weird, right? But how else was it possible to combine uncombinable ideas? So, the ether entered the stage!

As you probably know, the experiments that rejected the ether were not only important for the study of light, but also for the invention of the special theory of relativity. But similar to the experiments with the speed of light that rejected the particle bullet model that cam too late, these experiments were also too late for the explanation of the nature of the light waves.

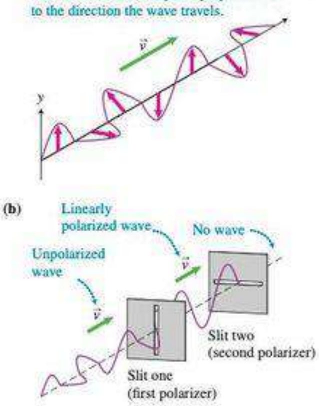
The explanation came from the studies of electricity and magnetism.

We learned in Table 25.1 that slotted boxes with the proper orientation can block transverse mechanical waves but cannot block longitudinal waves. This phenomenon is referred to as **polarization of waves**—polarization is a property of waves that describes the orientation of the oscillations of the wave. As we found in Table 25.1, only transverse waves have this property. Thus, if we observe polarization of light waves, we know that the waves are transverse.

In a **linearly polarized** mechanical wave, the individual particles of the vibrating medium vibrate along only one axis that is perpendicular to the direction the wave travels (there are other types of polarization, but we will confine our discussion to linear polarization). In our experiments, the vibrating medium was the rope. The slotted box is called a **polarizer**. A polarizer is a device that allows only a single component of transverse waves to pass through it. The component that can pass through defines the **axis** of the polarizer.

FIGURE 25.1 The effect of polarizers on a polarized wave.

(a) The particles in an unpolarized wave vibrate in all directions in the plane perpendicular to the direction the wave travels.

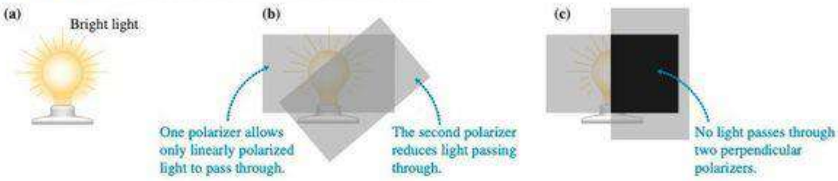


The waves in Experiments 1–3 in Table 25.1 were linearly polarized. An **unpolarized** wave is one in which the particles of the medium vibrate in all possible directions in the plane perpendicular to the direction the wave is traveling (**Figure 25.1a**), often caused by a collection of differently polarized waves. If an unpolarized wave is incident on a polarizer, the wave that emerges from the other side is linearly polarized (Figure 25.1b). A second polarizer whose axis is perpendicular to the axis of the first polarizer blocks the wave completely. Thus, a linearly polarized wave can be reduced to zero by a polarizer whose axis is perpendicular to the polarization direction of the wave. An unpolarized wave is completely blocked by two successive perpendicularly oriented polarizers.

Are light waves transverse or longitudinal? According to our observations in Table 25.1, if we can polarize light waves, they must be transverse.

We can test this hypothesis using a semiprecious crystal called tourmaline, which affects light in the same way that our slotted box affected transverse rope waves. We can compare light from a bulb (**Figure 25.2a**) to the same light after it passes through the tourmaline crystal; the light looks dimmer. Rotating the crystal does not change the intensity of the light. However, when we place a second crystal at a 45° angle to the first, we observe that the intensity of light decreases (Figure 25.2b). When the second crystal is placed perpendicular to the first, the intensity of the light reduces to zero (Figure 25.2c). To explain this experiment, we hypothesize that light is a transverse wave and that a lightbulb emits unpolarized light waves. We also hypothesize that the tourmaline crystal allows only one component of the wave to pass through the first crystal. That component is completely blocked by the second crystal.

FIGURE 25.2 The polarizing effects on light of tourmaline crystal.



Most commonly used polarizers are made of a material that contains elongated molecules that serve as slits for passing light. When these molecules are oriented parallel to each other, their combined effect leads to polarization of passing light. The lenses of polarized sunglasses, for instance, are covered with a film containing such a material. Physics teaching labs often have "polarizers," sheets of plastic that are translucent and thus dark like sunglasses. Light seen through these polarizers behaves similarly to Figure 25.2. Based on these observations we can say that light's behavior is so similar to the behavior of transverse mechanical waves passing through mechanical polarizers that it supports the hypothesis that light waves are transverse waves.

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Eugenia Etkina

6. April

Hi all, two things. First, I am reminding of our meeting on Saturday. Uncertainties - an important but overlooked issue in learning physics. Second, please respond to the posts if you read them. Third - what is waving in a light wave?
In my previous post I showed how to help students figure out that light waves are polarized. Thus, they need to be transverse. But transverse waves that they have encountered so far do not propagate in gases or in a vacuum. So, these have to be some other kind of waves, not the waves that are due to the interactions of the particles of the medium. To construct the idea of these new types of waves, the students need to understand the history - how did people figure it out? It was a long process that started with Maxwell summarizing what was known in electricity and magnetism and extending this knowledge to have symmetry between electric and magnetic fields. Maxwell's equations are usually written in differential or integral form in calculus-based courses but these equations leave students with very little conceptual understanding. We summarize Maxwell's equations conceptually and from those comes the consequence - the spread of the electromagnetic disturbances in a vacuum at a speed of light. See the attached screen shot from the textbook that shows this reasoning process. It is beautiful.

in a vacuum. We know from our study of electromagnetic induction (Chapter 21) that Michael Faraday introduced the concept of a field and the relationship between electric and magnetic fields. According to Faraday, *a changing magnetic field can produce an electric field*. Subsequently, in 1865 Maxwell suggested a new field relationship: *a changing electric field can produce a magnetic field*. This idea was motivated by a thought experiment devised by Maxwell in which he imagined what would happen in the space between the plates of a charging or discharging capacitor. He suggested that the changing electric field between the capacitor plates could be viewed as a special nonphysical current, but one that would still produce a magnetic field (**Figure 25.3**). This magnetic field was first detected in 1929 but not measured precisely until 1985 due to its extremely tiny magnitude. Maxwell summarized this new idea and other electric and magnetic field ideas mathematically in a set of four equations, now known as Maxwell's equations. The equations are written using calculus, but we can summarize them conceptually:

1. Stationary electric charges produce a constant electric field. The $\vec{E}$ field lines representing this electric field start on positive changes and end on negative charges.
2. There are no individual magnetic charges (magnetic monopoles).
3. A magnetic field is produced either by electric currents or by a changing electric field (Figures 25.3 and **25.4a**). The $\vec{B}$ field lines that represent the magnetic field form closed loops and have no beginnings or ends.
4. A changing magnetic field produces an electric field. The $\vec{E}$ field lines representing this electric field are closed loops (Figure 25.4b).

Producing an electromagnetic wave

Maxwell's equations had important consequences. First, the equations led to an understanding that a changing electric field can produce a changing magnetic field, which in turn can produce a changing electric field, and on and on in a sort of feedback loop (**Figure 25.5**). This feedback loop does not require the presence of any electric charges or currents. Maxwell investigated this idea mathematically using the four equations, and to his surprise he found they led to a wave equation similar to Eq. (11.4) in which the electric and magnetic fields themselves were vibrating. The speed of propagation of these waves in a vacuum turned out to be a combination of two familiar constants: $v = (1/\sqrt{\epsilon_0\mu_0})$, where the constants $\epsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$ and $\mu_0 = 4\pi \times 10^{-7}\ N/A^2$ relate to the electric and magnetic interactions of electrically charged particles in a vacuum. The constant ϵ_0 is the **vacuum permittivity** and is related to Coulomb's constant k_C through the relationship

$$\epsilon_0 = \frac{1}{4\pi k_C}$$

(See Chapter 17 for more on vacuum permittivity.) The constant μ_0 is the **vacuum permeability**. We discussed vacuum permeability in the chapter on magnetism (Chapter 20). When Maxwell inserted the values of the constants into the expression for the speed of electromagnetic waves, he obtained

$$v = \frac{1}{\sqrt{\epsilon_0\mu_0}} = \frac{1}{\sqrt{(8.85 \times 10^{-12}\ C^2/N \cdot m^2)(4\pi \times 10^{-7}\ N/A^2)}}$$

$$= \sqrt{9.00 \times 10^{16}\ \frac{N \cdot m^2 \cdot A^2}{C^2 \cdot N}} = \sqrt{9.00 \times 10^{16}\ \frac{m^2 \cdot A^2}{A^2 \cdot s^2}} = 3.00 \times 10^8\ m/s$$

FIGURE 25.3 A changing electric field produces a magnetic field.

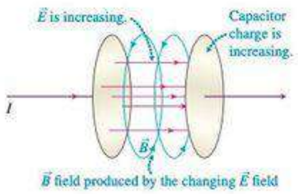


FIGURE 25.4 Changing $\vec{E}$ and $\vec{B}$ fields produce $\vec{B}$ and $\vec{E}$ fields.

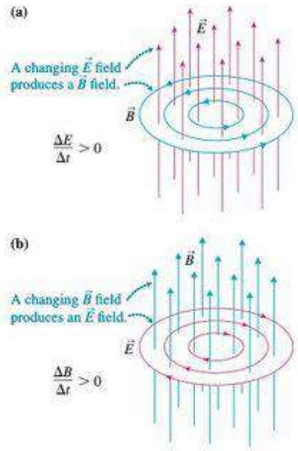
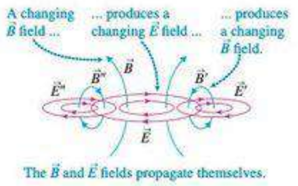


FIGURE 25.5 The changing $\vec{B}$ and $\vec{E}$ fields can spread without any charges or currents.



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Eugenia Etkina
14. April

Hi all, four things today! First, welcome to our new members! We have several people who joined recently. If you are one of them, please read about the philosophy of this group at https://www.islephysics.net/. The textbook which uses this approach is College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen (its cover is the cover page for this group). If you do not have it, ask your Pearson rep to send you an examination copy. There is

also a welcoming message for new members on top of the group page that explains some more stuff about the group. WELCOME!!!
Second - the June workshop google form has 23 people who applied, so we have one more spot left, hurry if you wish to participate. If you try to register and the form says it is not longer available, it means that the workshop is full. Please reply here if you see this message, we need to know how many more people would like to take the workshop.
Third, please do not forget to respond to any post you see in this group to make it more visible for other people. Facebook works in mysterious ways when it decided who should see a post 🙁
Finally, we are starting Chapter 26, Special Relativity. I know that many of you do not teach this topic, but some of it is crucial for understanding the nature of light. So, even if you do not Special Relativity, you might want to use this experiment in your wave optics unit.
As we have been talking about models of light for a while, I will share the beginning of this chapter that describes the experiment that ruled out the existence of ether once and for all and helped solidify the electromagnetic wave nature of light. I am pasting the screen shot describing the experiment and the epistemology behind it. Note that the experiment was done in 1887. Very soon after that, precisely in 1894 this model will be shattered again... Did you finish reading? You know what you need to do...

Testing the existence of ether

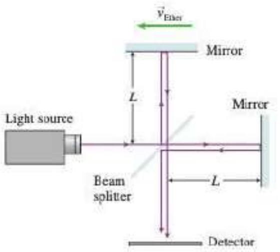
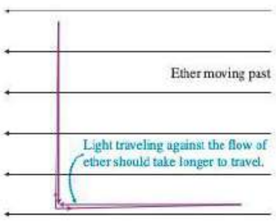
An experiment analogous to the boat experiment can be used to test for the existence of ether. Imagine that ether fills the solar system and is stationary with respect to the Sun. Because Earth moves around the Sun at a speed of about 3.0×10^4 m/s, ether should be moving past Earth at this speed. Shining light waves parallel and perpendicular to the ether's motion relative to Earth is similar to sending boats parallel and perpendicular to a flowing river. Therefore, the travel time for light waves (1) up and back along the direction of the ether's motion and (2) across and back perpendicular to the ether's motion should differ if they travel the same distance. If one could measure this time interval difference experimentally, it would serve as strong support for the existence of ether as a medium for light wave propagation.

In 1887, Albert Michelson and Edward Morley set up such an experiment (although they themselves firmly believed in ether and were trying to measure Earth's speed relative to it). They used a device called an **interferometer** to detect

ether (see Testing Experiment **Table 26.1**). A light beam is sent to a beam splitter (a half-silvered mirror) that causes the light beam to split into two beams. One beam continues forward and the other beam reflects perpendicularly, each beam moving along a separate arm of the device. Mirrors at the end of the arms reflect the two beams back to the half-silvered mirror, where they recombine and are detected.

Because the two beams are formed by splitting a single light beam, the two beams are coherent (have a constant phase difference with respect to each other). When the beams recombine after reflection, an interference pattern results. The details of this interference pattern depend on the difference in the travel time intervals between the two beams along each arm of the interferometer. *If* the ether hypothesis is correct and the interferometer is carefully rotated (causing the direction of each beam of light to change relative to the ether), *then* the time interval it takes each beam to travel along each arm and back should change. As a result, the interference pattern produced by the recombined light should change as the device rotates.

TESTING EXPERIMENT TABLE 26.1 Testing the existence of ether

Testing experiment	Prediction	Outcome
Assume that the ether is moving to the left past the interferometer. We shine a beam of light from the left onto the beam splitter. One beam moves parallel to the ether's velocity and the other beam moves perpendicular to its velocity.	It should take the light longer to travel against and with the ether than to travel sideways across the moving ether. Rotating the interferometer in the plane of the page should lead to a change in the interference pattern formed by the two light beams at the detector.	No matter how we change the interferometer orientation, the interference pattern does not change.
		

Possible conclusions

1. There is no ether through which light travels.
2. There is ether, but it is "stuck" to Earth's surface and does not move relative to the interferometer.

Michelson and Morley repeated the experiment several times, but the phase difference between the two beams never changed. It seemed that light traveled at the same speed independent of its direction. This appeared to clearly indicate that ether as a medium for light to propagate did not exist.

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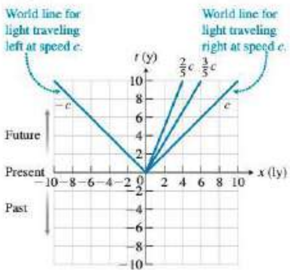
Eugenia Etkina
15. April

Hi all, I continue with Special Relativity. We have a pretty standard treatment, ISLEized, of course, except space-time diagrams. This part was written by Paul Bunson and we are very grateful for his contribution. We also have exercises and ALG activities for them. If you are teaching SR and need the ALG file, please email me. I am attaching a screen shot of the text and figures for space-time diagrams, see for your self how helpful they are - just as motion diagrams in kinematics!
Two more things (three actually). The workshop is full. We closed the registration. If you did not make it but wish to attend a workshop like that, please email me at eugenia.etkina@gse.rutgers edu so that I can put you on a waiting list. Some people might drop out, then you will be in.
PLEASE do not forget to respond to the post after you read it.
And please register for our May meeting, so that I can see how many people plan to attend. Thank you!

26.6 Spacetime diagrams

FIGURE 26.11 World lines for two objects and two light beams drawn on a spacetime diagram.



In relativity, as in other areas, a graph is useful for keeping track of information. This is especially true when there are multiple objects. There is a tool from Chapter 2 that, with only slight modification, comes in handy here. Recall that a position-versus-time graph shows where an object is at any given time. To represent the motion of a stationary object on a position-versus-time graph, we draw a horizontal line. If a position-versus-time graph is a straight line with a positive slope, it means that the object is moving in a positive direction with constant speed. On these graphs, time is represented on the horizontal axis and position on the vertical axis. When physicists are accounting for relativity, the axes are traditionally switched, so that time is represented on the vertical axis and position on the horizontal axis. This new representation is often referred to as a **spacetime diagram** to emphasize that space and time are intertwined. The line showing the time-versus-position graph of an object is called a **world line** for that object (**Figure 26.11**). In Figure 26.11 you see world lines for two objects and two light beams sent in opposite directions. Notice that the two objects move at speeds less than the speed of light and that their world lines are more steeply angled. In general, the slower the object, the steeper its world line. Thus the line for the object moving at $\frac{2}{5}c$ is steeper than that for the object moving at $\frac{3}{5}c$.

Because relativistic effects do not typically appear until close to the speed of light, we will be choosing units that highlight this aspect. And because the ultimate speed limit is the speed of light c, the units are also selected with this in mind. The motion of light is represented by a line with a slope of $\pm 45°$ depending on which direction the light is traveling. There are several systems of units that would give these results. For example, if the unit on the time axis is years (y), then the unit on the horizontal axis will be a **light-year** (ly), defined as the distance light travels in a year. Alternatively, we could have the unit of time as a second and the unit of distance the distance that light travels in 1 s—one *light-second*.

One result of switching the axes is that the slope of the line is no longer velocity; rather, it is the *inverse* of velocity. However, because we chose years (or seconds) for

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our time units and light-years (or light-seconds) for distance units, a line with the slope of ± 1 disregarding the units ($\pm 45°$) corresponds to the motion of an object traveling at the speed of light. Thus, an object that is moving at $\frac{1}{2}c$ would have a world line with slope 2. This leads to an important tip for building spacetime diagrams: **the slope of the world line for an object moving at speed v is c/v.**

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Eugenia Etkina
17. April

Hi all, I am continuing with the models of light - we are on Chapter 27 - Quantum optics. Historically, the sign that there are some issues with the wave model, came from studies of the radiation of hot objects.

This is when a model of a black body was created in attempts to explain the intensity vs frequency dependence of emitted radiation. The weird shape of the curve probably left many

physicists sleepless for many nights. This was until M. Plank came up with his wild idea that light is not emitted as waves - continuously - but as potions of energy, and this energy depends on the frequency of light. This was a truly wild idea and Plank himself thought of it being just a mathematical model not a real thing... How strange it was for him later that his wild idea changed the whole course that physics was taking forever...
While we do not have an activity that allows the students to make this curve, we have an activity that allows them to devise the relationship between the power and temperature using real data. This is a great activity to start quantum optics and it is in the OALG file posted here for Chapter 27. If you have not downloaded all OALG files posted here, now is a good time as we are finishing the textbook! I am attaching the file with this one activity, please take a look! And please respond to this post to make it more visible!

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Eugenia Etkina
19. April

Hi all, today I continue the story of the new model of light. However, before I go on, I first wanted to welcome new members who joined recently - WELCOME! and to remind you to respond to the posts if you read them. Now Facebook shows me the reach of the post - our average is about 500 people, but only about 20-30 of them respond with "likes" or comments. It only takes a second to respond but it makes the post visible to more people, please do not forget!
Now - models of light. Allison Daubert yesterday mentioned a historical table that she likes in the book. The table summarizes the evolution of the models of light up to Plank. I also like this table because it represents perfectly the nature of physics or science in general. Physics (and science in general) are about making more and more sophisticated models (which are are simplifications of some sort) of very complex natural phenomena, light being one of really really complex. None of them is wrong - they all allow us to explain and predict SOME phenomena. But as soon as a new phenomenon that cannot be explained by the existing model is observed, the model needs to be revised. Just as the picture of the logical though in the ISLE process. Enjoy the table and note, it is not the end! 🙂

TABLE 27.1 Evolution of ideas concerning the nature of light

Approximate time period	Model	Experimental evidence that the model explains
1600s	*Particle (bullet) model* Light can be modeled as a stream of bullet-like particles.	Reflection, shadows, and possibly refraction
Early 1800s	*Wave model* Particle model insufficient. Light modeled as wave. Wave mechanism unknown.	Double-slit interference, diffraction, light colors, reflection, and refraction
Middle 1800s	*Electromagnetic wave (ether model)* Light modeled as transverse vibrations of ether medium.	Polarization and electromagnetic wave transmission and all of the above evidence
Late 1800s	*Electromagnetic wave (no-ether model)* Light modeled as transverse vibrations of electric and magnetic fields. No medium required.	Michelson-Morley experiment
Early 1900s	*Quantum model* Electromagnetic wave model insufficient. Light modeled as stream of discrete energy quanta.	Emission of light by black bodies

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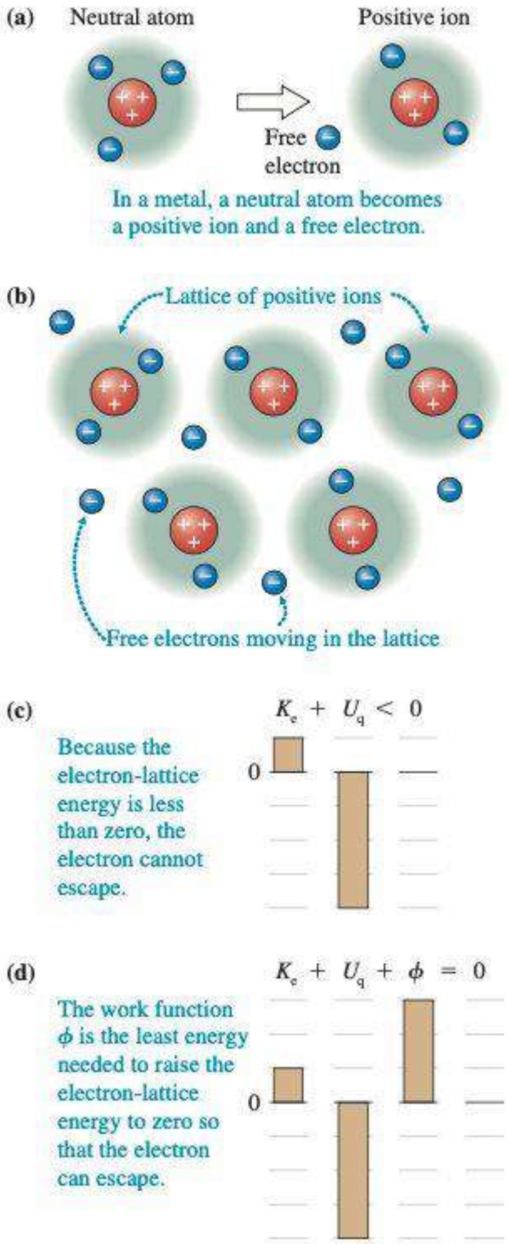
Eugenia Etkina
19. April

As I will be traveling tomorrow, and will not be able to post, I will have two posts today (please see my first post today before you read this one). This one is about a new phenomenon that inspired the extension of Plank's model of emission of light to other light phenomena.
When H. Hertz was testing Maxwell's equations, he noticed some interesting phenomenon that he did not have time to investigate. The discharge of the two charges spheres that he used to emit and detect e/m waves started at lower voltages when the Sun was shining on the electrodes. Enclosing them in a glass box removed the effect. W. Hallwachs decided to investigate the effect. He conducted the following experiment. See the link.
https://www.youtube.com/watch?v=X7EQJU9bxV4
Questions: Why did he conduct this experiment?
Why would he use a UV lamp?
What could be possible explanations of his observations taking into account that the experiment was conducted in 1888 and no quantum model of light existed at that time, but Maxwell's model of light as an electromagnetic wave was accepted?
Note: for the students in order to reason at all about the experiment, they need to understand the internal structure of metals. Although they learned in Chapter 17-19 it is great to review it here, the same way we do it in the textbook and in addition introduce the concept of work function as the minimum energy needed to remove a free electron from a metal . See the attached screen shot. PLEASE respond to the post! and Answer the questions!

FIGURE 27.6 The structure of metals. (a and b) Positive ions and free electrons. (c) Energy bar chart for a lattice-free electron system. (d) Adding the energy equal to the work function makes the total energy of the system zero.



TIP Even though ϕ is called the work "function," it's not a function in the mathematical sense. It is a constant that differs from material to material. It is also not work because it is a property of a particular metal. Finally, although some electrons in metals are called "free" electrons, they are not free to leave the metal; they are free to move around within the metal, however. From this analysis of the vernacular, you can see how important it is to question the terms we use in order not to be confused.

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Eugenia Etkina
20. April

Hello all, today I continue the story of the photoelectric effect. We observed that UV light discharges negatively charged electroscope while the visible light does not. One possible explanation based on the e/m model of light (available at that time) was that electric field in the wave (UV light wave having more energy that the visible light) is able to ionize surrounding air and those positive ions in the air discharge the electroscope (similar to how if you burn a candle next to a charged electroscope, it discharges immediately) If this hypothesis is correct, and we have a positively charged electroscope, then UV light should be able to discharge a positively charged electroscope because in addition to positive ions in the air, there will be free electrons and maybe even negative ions. This is a great testing experiment. See what happens in the video of this experiment: https://youtu.be/EgxVXOnsFx0
Hmmm - UV light does not discharge a positively charged electroscope. We reject the "Ionization of air" model. How else can we explain what happens? Another explanation can be that the electric field in the UV light exerts a force on free electrons and, as they are moving, the work done by the field increase the energy of the system electrons-lattice and it becomes positive - the electron is free. It is repelled by the negatively charged electroscope and flies away. If this explanation is correct and we take a neutral, uncharged electroscope, it should charge positively. Does it? See for yourself: https://www.youtube.com/watch?v=V4NK4IQrXqQ
What??? It does not! Wait a second... Maybe it is not our hypothesis that is not correct, but an assumption, that if light releases an electron from an electroscope, it will leave. Maybe the electroscope did not charge for the same reason as the positively charged electroscope did not discharge in the previous experiment... The leaving electrons make the zinc plate of the electroscope positively charged. It attracts the electrons back and does not let the electroscope to charge. How can we validate this assumption? We need to somehow pull those liberated electrons away from the electroscope. But how to do it? Read on - I will answer tomorrow.
Please do not forget to "like" the post or respond to it in some other way to make it more visible.

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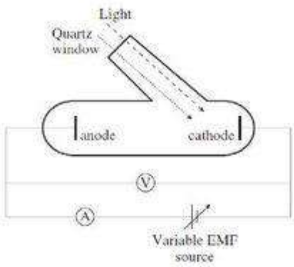
Eugenia Etkina
26. April

Hi all! A few things today. First, we have several new members - WELCOME! To learn about this group, please read the welcoming message on the top of this group's page and visit https://www.islephysics.net/. I recommend checking this group's posts every day if you wish to be notified by Facebook about the posts. We have regular meetings on zoom - see events on the top of the page.
Second, I will continue with the photoelectric effect. We learned that UV light can discharge negatively charged electroscope. It seems totally possible if light behaves like an electromagnetic wave. But so far our observations were purely qualitative. Can we make them quantitative? In fact, we can! Two scientists who are often unknown for the students are Philip Lennard (he was a German and a huge supporter of Hitler) and Alexander Stoletov (he was Russian and for some reason completely unknown outside of Russia) completely independently and at the same time figured out how to study this new effect quantitatively. We use phet simulations for this exploration and I am attaching the screen shot of the activities in the OALG Chapter 27. The whole chapter is posted here in the FILES. As you know it will turn out that some of their observations could be explained by the electromagnetic wave model of light and some could not...
if you read to the end, please respond to the post to make it more visible.

OALG 27.2.5 Observe and explain

Physicists use an evacuated glass container such as the one shown below to study the photoelectric effect. Light of different frequencies can shine through a quartz window onto a metal plate connected to the negative pole of the battery. Such a plate is called the *cathode*. The other plate inside the tube is connected to the positive side of the battery and is called the *anode*. In our experiments the anode and the cathode are always made of the same material. When no UV light shines on the cathode, the ammeter does not register any current. Go to https://phet.colorado.edu/sims/cheerpj/photoelectric/latest/photoelectric.html?simulation=photoelectric, play with the simulations to find as many patterns as you can and record them below:

a. List all the patterns that you found in the simulation (make sure you change the emf of the battery, the material of the cathode, the color of light and the intensity of light).



b. Use the simulation to observe that a UV light shines on the sodium cathode, the ammeter registers a current in the circuit independently of the intensity. How can you explain how UV light can cause the current? *Note*: A voltmeter has very high electrical resistance.

c. Use the simulation to observe that when the emf of the battery is zero, but the UV light still shines on the cathode, the ammeter registers a small current—much smaller than in part **a**. How can you explain it?

c. Use the simulation to observe that when the polarity of the battery is reversed, the plate on which the light shines is at a higher potential than the plate on the left side. When this reversed potential difference reaches a certain value, the ammeter reading drops to zero. Can you explain why? (This potential difference is called a *stopping potential*, V_s.).

OALG 27.2.6 Observe and explain

Referring to the apparatus in Activity 27.2.5, the current is stopped when the metal cathode on which the light shines is at a positive potential relative to the more negative potential of the plate on the left side.

a. Surprisingly, you find that the potential difference that stops the current (see Activity 26.2.5 part **c.**) does *not* depend on the intensity of light. The electric current induced by high-intensity light is stopped as easily as electric current induced by low-intensity light. Can you explain this observation using the electromagnetic wave model of light?

b. While the stopping potential does not depend on the intensity of light, it does depend on the color: the higher the light frequency (UV versus visible, violet versus red), the higher the stopping potential. Can you explain this observation using the electromagnetic wave model of light?

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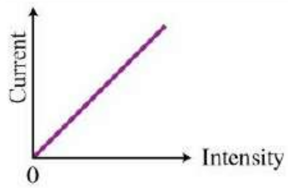
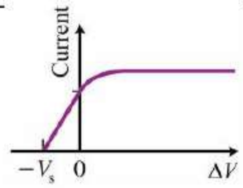
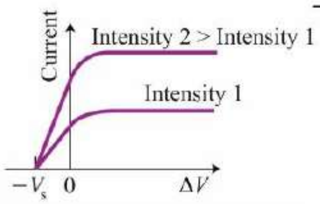
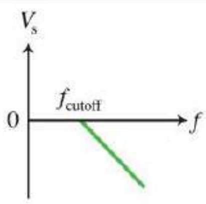
Eugenia Etkina
27. April

Hi all, I will continue with PE effect today. Please respond to the post to make it more visible. The students found patterns in the experiments conducted by Lenard and Stoletov.
Can they be explained by the e/m wave model of light? Remember, that the qualitative experiments could be explained. To make sure that all patterns are addressed, we provide students with a table with all of the patterns (which they first found themselves!) and ask them

to use the electromagnetic wave model of light to explain them. There will be a few patterns that can be explained and a few that cannot be explained. This activities creates "the need to know" for the new model of light - the photon model proposed by Einstein.
What follows in the OALG is exactly the same activity (I will not post it here as you can find it in the document posted in the FILES) when the students need to explain all of the same patterns but using a new model of light (and they can). Does it mean that the e/m wave model of light should be discarded? If you read to the end, please do not forget to "like" the post.

OALG 27.2.7 Observe and explain

In the table below try to use the *electromagnetic wave model* of light to explain each of the experimental results involving the apparatus shown in Activity 27.2.5.

Experiment	**Result**	**Explain using the wave model**
a. As the light intensity increases, the electric current changes as shown in the graph.		
b. The dependence of the electric current on the potential difference across the electrodes is shown. Explain the steady part of the graph. The intensity of light remains constant during the experiment.	 Note: ΔV is positive when the right metal plate (the cathode) connects to the positive battery terminal.	
c. Use the wave model to try to explain why the current decreases to zero when there is a negative stopping potential difference $-V_s$ in experiment **b**.		
d. You repeat the previous experiment for increasing intensity light. The stopping potential difference $-V_s$ does not change.		
e. The potential difference $-V_s$ needed to stop the electric current depends on the light frequency—see the graph.		

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Eugenia Etkina
28. April

Hi all, I continue today with PE effect. The attached screen shot completes the story of a new model of light and how it accounts for all patterns in the experiments by Lenard and Stoletov. What is new in our textbook is the use of work energy bar charts to help students visualize the process and apply the mathematical description of the PE effect devised by Einstein. It is important that we continue to use work energy bar charts that students learned in mechanics throughout the course - in thermodynamics, electricity and now in light. An important point here is that the bar chart describes the processes for the system one electron + crystal lattice of the metal. Electron by itself does not have any electric potential energy of interaction with the lattice, it only has kinetic energy. Therefore if you are going to talk about work function in metals, you need to include the lattice in the system.
Another thing is that the lattice is responsible for the conservations of momentum in the process. A single electron cannot absorb a photon (that is why we have Compton effect), but in the case of PE effect it is the lattice that rebounds and allows the photon to eject an electron in some random direction. The role of the lattice is often overlooked when people talk about PE effect.

27.3 Quantum model explanation of the photoelectric effect

Philipp von Lenard thought that the absorption of UV radiation (and in some cases visible light) by the electron-metal system (the cathode) increased the energy of the system in accordance with the generalized work-energy principle. If the energy is large enough to raise the negative total energy of the system to zero $(-\phi + E_{\text{light}} = 0)$, then an electron could just barely be ejected from the metal (see the bar chart representing the process in **Figure 27.9a**). If the system gained more energy from the EM radiation than it needed to eject the electron, then the electron would have a nonzero kinetic energy after leaving the cathode, and it might reach the anode even if the electric field produced by the electrodes pushed it in the opposite direction (Figure 27.9b). Mathematically:

$$-\phi + E_{\text{light}} = K_{ef} \quad (27.4)$$

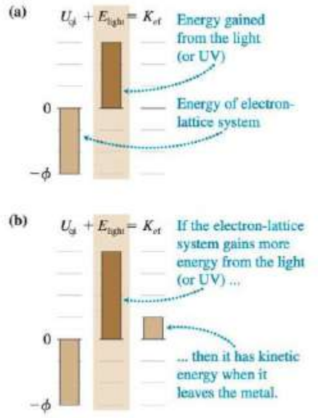
where K_{ef} is the kinetic energy of the electron immediately after leaving the metal. However, von Lenard could not explain why the stopping potential did not depend on the intensity of the incident light. In these experiments, light could mean either visible light or UV—whichever is causing the photoelectric effect. According to his understanding, increased light intensity should lead to greater energy of the light and cause the electron to leave with more kinetic energy, thus requiring a greater stopping potential to prevent it from reaching the anode.

In 1905, Albert Einstein (1879–1955) made a breakthrough similar to Planck's hypothesis. At that time working as a clerk in a Swiss patent office, Einstein suggested that light can be viewed as a stream of quanta of energy not only when it is *emitted* by objects (as proposed by Planck), but also when it is *absorbed* by them. According to Einstein's hypothesis, an electron-lattice system (a metal) can only absorb light energy one whole quantum at a time. If the value of the light energy of a particular quantum is more than the magnitude of the metal's work function, an electron could leave the lattice. If the quantum of light energy is less than that, the electron would stay even if the number of incident quanta is very high (corresponding to high-intensity light.)

According to Planck, the energy of a quantum of EM radiation equals $E_0 = hf$. Using this idea, Einstein rewrote Eq. (27.4) as

$$-\phi + hf = K_{ef} \quad (27.5)$$

FIGURE 27.9 The electron-lattice system gains energy from light and UV. (a) The energy gained from light offsets the negative electron-lattice energy, barely allowing the electron to escape. (b) If the energy gained from the light (or UV) is more than the amount needed to escape, then the electron has kinetic energy when it escapes.



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Eugenia Etkina dijeli poveznicu.
29. April

Hi all, today I finish the discussion of the photon model of light. In the textbook the last section is about photocells and LEDs. The material is too large to post screenshots. Therefore I send you to pages 872 - 874. Our textbook is the only textbook that systematically uses and discusses LEDs in many chapters - kinematics, dynamics, DC circuits (including power), geometrical optics and quantum optics. We have lots of experiments, videos and activities that helps students really learn how an LED works - first from observing their properties without understanding the microscopic structure and finally to the details of the microscopy. Some of the videos are absolutely unique, such as one on page 874 - the internal structure of the LED. I am posting the link here but it probably will not help if have not studied the material in the textbook. It shows the internal structure of an LED under a microscope. The LED is submerged in a liquid with the same index of refraction as the plastic cover, this way you can see the inside without any distortion. Made by Gorazd Planinsic.
We actually have a whole workshop on LEDs. We could run it for those who are already familiar with the ISLE approach as the understanding of the process is needed to fully participate. I wonder if there is interest in a pure LED workshop. Please let me know. Please respond to the post to make it more visible.

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Eugenia Etkina
3. May

Hi people, I see how the number of people who view posts depend on the number of comments - the more you comment, the more people see the post itself. This is wild...
I continue with Atomic Physics. I want to emphasize the role of tools - multiple representations - in learning physics. Research shows that students see physics as a set of disconnected facts and do not appreciate its coherence.
The ISLE approach approaches coherence in many ways, two most important ones are the ISLE process of knowledge construction that repeats again and again when students devise new concepts and thus helps establish epistemological coherence of physics (epistemology

is the study of what knowledge is and how it comes to be) and the use of the same tools throughout learning ALL physics concepts therefore unifying them. One of such tools is the work-energy bar chart. See how it can be used in atomic physics.
I am pasting a screen shot of a worked example that shown not only the use of bar charts but also another unifying element of our approach - the problem solving strategy (PSS). The elements of the strategy repeat for every problem in worked examples with the goal of showing that the SAME reasoning approach works throughout all concepts.
PSS is another tool that students can use when solving ANY problem. Why it is important? - it REPEATS. Repetition reduces fear and anxiety. Remember how small children want you to read them the same book again and again? Why? Because knowing what will happen increases their confidence. This is exactly what the PSS does. It makes problem solving less scary. But it only works if your students really follow it. Do not forget to like the post! Thank you!

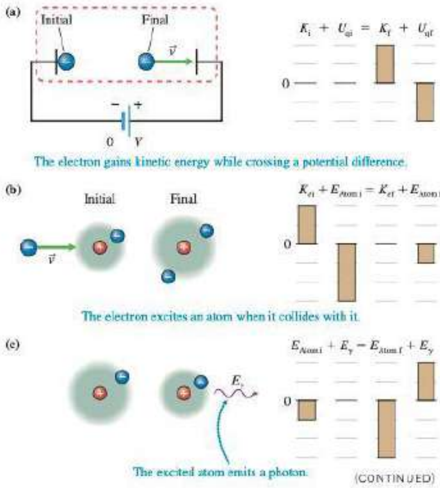
EXAMPLE 28.3 Discharge tube excitation of hydrogen

Use the results of Example 28.2 to estimate the potential difference needed between the cathode and anode in a discharge tube filled with hydrogen to produce hydrogen's visible light spectral lines.

Sketch and translate An illustration of the gas in the discharge tube is shown in Figure 28.14a–c. For the atom to emit a visible photon, it must transition from the $n = 3, 4, 5$, or 6 state to the $n = 2$ state. Therefore, the colliding electrons must have enough kinetic energy to induce the transition of the electrons in the hydrogen atoms from the $n = 1$ ground state to the $n = 3, 4, 5$, or 6 state. Because the transition from $n = 1$ to $n = 6$ requires the most energy, the potential difference between cathode and anode must be high enough to induce that transition. The system is the colliding electron, the electrodes and the electric field they produce, the hydrogen atoms, and the emitted photons.

The overall process has three parts.

I. The electric potential energy of the system is converted into the kinetic energy of the electron, as shown in part (a) of the figure on the top of the right column.
II. The electron collides with and excites the atom [part (b)].
III. The excited atom returns to the ground state, emitting a photon [part (c)].



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Simplify and diagram Assume first that the electron's initial kinetic energy is zero and that it increases only as a result of the decrease in electric potential energy of the system. Assume also that the electric potential at the initial position of the electron is 0 V. Before the colliding electron encounters the hydrogen atom, assume the atom is in the ground state and that the Bohr model is a reasonable way to model the atom. Lastly, assume the electron is not moving relativistically. Energy bar charts shown earlier represent the three stages of this process.

Represent mathematically We can use the bar charts to help us represent these three processes mathematically.

Part I: In the initial state, the electron is at rest at zero electric potential. In the final state, the electron has positive kinetic energy and the system's electric potential energy has decreased.

$$K_i + U_{qi} = K_f + U_{qf}$$

Using the expressions for nonrelativistic kinetic energy and electric potential energy:

$$0 + q_e V_i = \tfrac{1}{2} m_e v^2 + q_e V_f$$

Subtracting $q_e V_i$ from both sides, we have

$$0 = \tfrac{1}{2} m_e v^2 + q_e V_f - q_e V_i$$
$$= \tfrac{1}{2} m_e v^2 + q_e \Delta V = \tfrac{1}{2} m_e v^2 - e\Delta V$$

Part II: The electron collides with and excites an atom from the $n = 1$ to the $n = 6$ state. In the initial state, the colliding electron has considerable kinetic energy, and the atom is in the $n = 1$ ground state. In the final state, the colliding electron stops, and the atom is in the $n = 6$ excited state.

$$K_i + E_{Atom\,i} = K_f + E_{Atom\,f}$$

Inserting the expressions for kinetic energy and the total energy of the hydrogen atom:

$$\tfrac{1}{2} m_e v^2 + \left(\frac{-13.6\text{ eV}}{n_i^2}\right) = 0 + \left(\frac{-13.6\text{ eV}}{n_f^2}\right)$$

Part III: The excited atom emits a photon and transitions to the $n = 2$ state. Initially, the atom is in the $n = 6$ state. In the final state, the atom is in the $n = 2$ state and a photon has been emitted.

$$E_{Atom\,i} = E_{Atom\,f} + E_\gamma$$

Insert the expressions for the total energy of the atom and the energy of the photon:

$$\left(\frac{-13.6\text{ eV}}{n_i^2}\right) = \left(\frac{-13.6\text{ eV}}{n_f^2}\right) + \frac{hc}{\lambda}$$

Solve and evaluate We are interested in finding ΔV. Using our mathematical representation of Part I and solving for ΔV:

$$\Delta V = \frac{1}{e}\left(\tfrac{1}{2} m_e v^2\right)$$

We can determine the kinetic energy from Part II. Solving for $(1/2)m_e v^2$ gives

$$\tfrac{1}{2} m_e v^2 = \left(\frac{-13.6\text{ eV}}{n_f^2}\right) - \left(\frac{-13.6\text{ eV}}{n_i^2}\right)$$
$$= (-13.6\text{ eV})\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Substituting this into the expression for ΔV:

$$\Delta V = \frac{1}{e}(-13.6\text{ eV})\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Inserting the appropriate values and converting to joules:

$$\Delta V = \frac{1}{1.6 \times 10^{-19}\text{ C}}(-13.6\text{ eV})\left(\frac{1}{6^2} - \frac{1}{1^2}\right)\left(1.6 \times 10^{-19}\frac{\text{J}}{\text{eV}}\right)$$
$$= 13.2\text{ V}$$

This value is the smallest potential difference that the electrons need to cross in order to acquire enough kinetic energy to excite hydrogen atoms to the maximum $n = 6$ state so that they can emit photons in the visible spectrum. The potential difference we found is not the potential difference across the discharge tube, but rather the potential difference across the average distance that the colliding electrons travel between two consecutive collisions. The required potential difference across the cathode and anode of the tube is much greater than this.

Try it yourself Estimate the minimum potential difference required to allow the hydrogen in the tube to emit photons from the $n = 4$ to the $n = 2$ transition.

Answer 12.8 V

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Eugenia Etkina
4. May

Hi all, I continue my posts about atomic physics. Please do not forget to respond to the post to make it more visible. The last two posts reached over 500 people, this is GREAT! All this is thanks to your responses!
Today I focus on the negative energy of the atom (hydrogen atom at first). There are several issue common here. First is that people talk about negative electric potential energy of the electron in the atom. But, as we know, a single particle can only have kinetic energy, potential energy is the energy of a system. Thus, it is the atom that has negative electric energy (positive and negative objects attract) and the total energy of the atom is also negative as it is a bound system. Why does a bound system always have negative total energy? Because we need to do positive work or supply positive energy to ionize it.
When the positive kinetic energy of the electron becomes large enough that the sum of electric and kinetic energies is positive or it absorbs positive energy from a photon - the atom ionizes - the electron leaves. A familiar -13.6 eV value sometimes called the electron energy on the energy diagrams is not the energy of the electron, it is the total energy of the hydrogen atom and it is negative as it is the atom. The following set of activities helps students derive this total energy of the atom and to recognize why it is negative.
28.2.6 DERIVE
Class: Equipment per group: whiteboard and markers.
Use Bohr's postulates and your knowledge of electrostatic interactions and circular motion to find the value of the smallest electron orbit in the hydrogen atom.
a. What is the electric potential energy of the electron–nucleus system? Is it positive or negative? Assume that the atom is neutral.
b. What is the kinetic energy of the system?
c. What is the total energy of the system?
d. How is the velocity of the electron orbiting nucleus related to the distance between the electron and the nucleus? Use your knowledge of circular motion and Bohr's third postulate to answer this question.
e. Combine the results of parts a. through d. to determine the smallest-radius electron orbit in a hydrogen atom (the atom is said to be in the ground state).
f. Evaluate your result.
28.2.7 REASON
Class: Equipment per group: whiteboard and markers.
Imagine that a hydrogen atom is in its ground state.
a. What is the total energy of the atomic system?
b. In part a. you obtained a negative value. Does it make sense? Explain.
c. What is the minimum energy of the photon that a ground-state hydrogen atom needs to absorb for the electron to become free? Explain.

d. Express the value that you obtained in part c. in the units of electron volts. One electron volt is the energy that an electron acquires when it passes through a potential difference of 1 V. The magnitude of the charge of the electron is 📷
If you read to the end, please do not forget to like the post.

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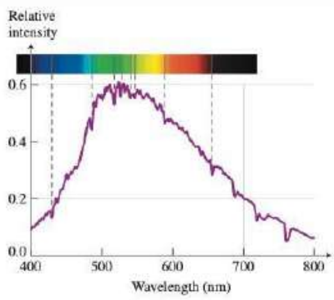
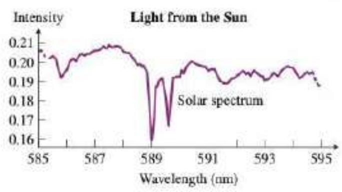
Eugenia Etkina
5. May

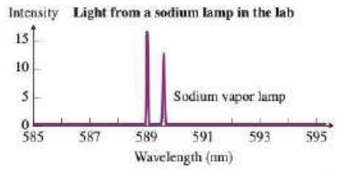
Hi all, I continue with Atomic physics today. One of the big ideas to learn in this chapter is the nature of stellar spectra. Please do not forget ot respond to the post if you read it.
Many think that we know stellar composition because of the light emitted by certain elements. But this is not the case. Stars emit black body continuous spectra that only tell us about surface temperature, not the composition.
So, how do we know what is inside stars? We actually do not know. We only know what atoms in the very outer layers of a star absorb some of the continuous light spectrum coming from the deeper layers. If the atoms are there but are ionized or too cold to absorb the radiation, we do not see them or see very little of them and might devise an incorrect model of stellar composition (thus the famous H-R diagram with the most prominent absorption lines). The process through which one can realize that it is the absorption, not the emission that tells us about the chemical elements in the stars is in the Observational Experiment Table 28.2 in the textbook, I am pasting the screen shot here.
The person who figured out that the visible absorption spectra do not tell us the whole story was a woman - Cecilia Payne Gaposchkin (https://en.wikipedia.org/wiki/Cecilia_Payne-Gaposchkin) - read about her, her life was fascinating. Please do not forget to respond to the post if you read to the end.

OBSERVATIONAL EXPERIMENT TABLE 28.2 Stellar spectra

Observational experiment	Analysis
We observed a spectrum of the Sun using a handheld spectrometer and then recorded the same spectrum using a computer-controlled light detector.	The figure shows a photo of the spectrum from the first experiment and the spectral curve produced by the computer in the second experiment. In the visible region, we see a continuous spectrum but with several dark lines. The lines look dark in the photo, but the matching spectral curve (intensity versus wavelength) shows they are relative reductions in brightness: less light is emitted at particular wavelengths compared to the continuous spectrum.
	If we look at a narrow part of the visible spectrum of the Sun, we see dips in the intensity at particular wavelengths of the intensity-versus-wavelength graph. The wavelengths of the dips in the solar spectrum match the wavelengths of the line spectra emitted by a sodium vapor lamp in a lab. Intensity is shown in relative units. You can see that light from the lamp is much brighter than light from the Sun.

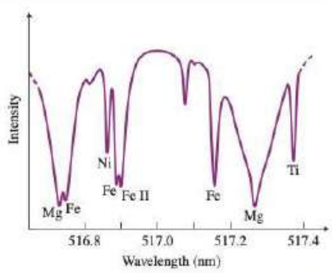






Pattern

If we observe a narrow region (516.6–517.4 nm) of the solar spectrum, we see dips that match the wavelengths of the line spectra of specific elements (iron, magnesium, etc.). The spectra of other stars are similar—continuous emission spectra with specific dark lines.



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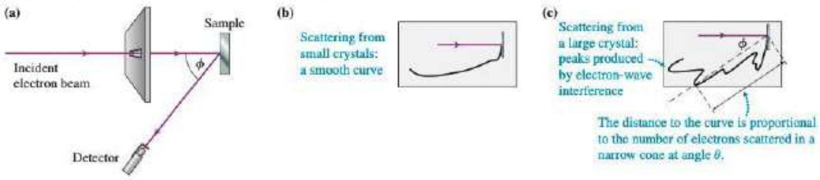
Eugenia Etkina
8. May

Hi all, I continue with atomic physics today. In Chapter 28 students also learn about the wave nature of elementary particles. While we all know about de Broglie waves, not many know that their discovery went through a perfect ISLE process with an amazing testing experiment. Read the attached screen shot to learn about it. Sometimes observational experiments that nobody can explain, later become testing experiments for something else... This happened to particles/waves and later for microwave background radiation discovery, for example. What I am trying to say is that "ISLE lens" or "ISLE telescope" allows you to interpret historical events in a very different way... Do not forget to like the post to make it more visible!

Another test of de Broglie waves

De Broglie's hypothesis was tested again a few years later. Shortly after de Broglie proposed his matter wave hypothesis, two scientists in New York, Clinton Davisson and his young colleague Lester Germer, were probing the structure of the atom by firing low-speed electrons at a nickel target made of small crystals and observing the resulting electron scattering (**Figures 28.28a** and **b**). The experiments did not give them any interesting results until they had a small accident in the laboratory in 1925: their

FIGURE 28.28 Davisson and Germer's experiment and accidental finding. (a) An electron beam excites a sample, and scattering is detected. (b) The scattering from a sample made up of small crystals. (c) The scattering from a sample accidentally turned into a large crystal.



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906 CHAPTER 28 Atomic Physics

equipment malfunctioned, and the nickel target previously consisting of many small crystals suddenly melted and resolidified into one large crystal.

When Davisson and Germer resumed the experiments with the large crystal, they saw a new pattern (compare Figure 28.28c with b). As they changed the position of the detector, they found alternating directions at which electrons were scattered and not scattered. The results made no sense to them until they heard about de Broglie's hypothesis. The large crystal was behaving like a three-dimensional interference grating, and they had observed the wave-like behavior of the electrons. This story is a perfect example of how accidental observations can turn into fundamental testing experiments, or how important serendipity is in science. Later, similar experiments performed with hydrogen nuclei and alpha particles supported the idea that all subatomic particles exhibit wave-like properties.

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Eugenia Etkina
10. May

Hi all, I am starting Nuclear Physics, or Chapter 29. The beginning is a perfect ISLE process - an accidental observational of Henri Becquerel who found that uranium salts behave very strangely. What to do with these observations? Marie Curie was the one to quantify those and through efforts of many people after that the nuclear model was created. There is a big historical difficulty here - both the models of the atom and models of the nucleus were developing at the same time. Placing them in different chapters creates a "historical nightmare". We deal with it the best we can... I pasted below ALG activities for the beginning of the study of radioactivity - they follow the historical progression accurately. Please do not forger to respond to the post if after you finish reading it!

29.1.1 OBSERVE AND EXPLAIN

PIVOTAL Class

Photographic plates are glass plates covered with material that undergoes a chemical reaction when light shines on it – this is called “exposure”. After the photographic plate undergoes another chemical process called “development,” the places on the plate exposed to light change color. In 1896 Henri Becquerel experimented with uranyl crystals and found that when placed on top of a photographic plate the crystals could expose the plate, even when the plate was wrapped in black paper and no light could reach it. Suggest an explanation for this observation.

Hint: Some phosphorescent or fluorescent materials, such as barium sulfide, zinc sulfide, etc., can expose photographic paper after they have been exposed to light when there is a direct path from them to the paper. However, uranyl salts do this without exposure to light. In addition, “rays” emitted by uranyl salts pass through covers.

29.1.2 TEST YOUR IDEA

Class

One of the explanations of Becquerel’s experiments is that uranyl salts emit some kind of charged particles that affect the photosensitive paper in a way similar to light. How can you test this explanation?

29.1.3 EXPLAIN

PIVOTAL Class

Pierre Curie invented an electrometer that could be used to measure how much charge the electrometer loses per unit time (the current). Marie Curie used this electrometer to measure the amount of electric current produced when the electrometer was placed near uranium salts.

• She found that the amount of current was proportional to the amount of uranium present.

• She found that the intensity of the current was independent of the chemical structure of the uranium salt (as long as it contained uranium), its wetness, temperature, physical appearance, or the amount of light shining on it.

a. Explain why the electrometer could lose its charge when a sample of uranium salt was placed nearby.

b. If you were Marie Curie, with a strong background in chemistry, what could you conclude about how the uranium rays are produced? (Hint: Sometimes in science you can determine what a phenomenon is notlong before you have an idea about what it is.)

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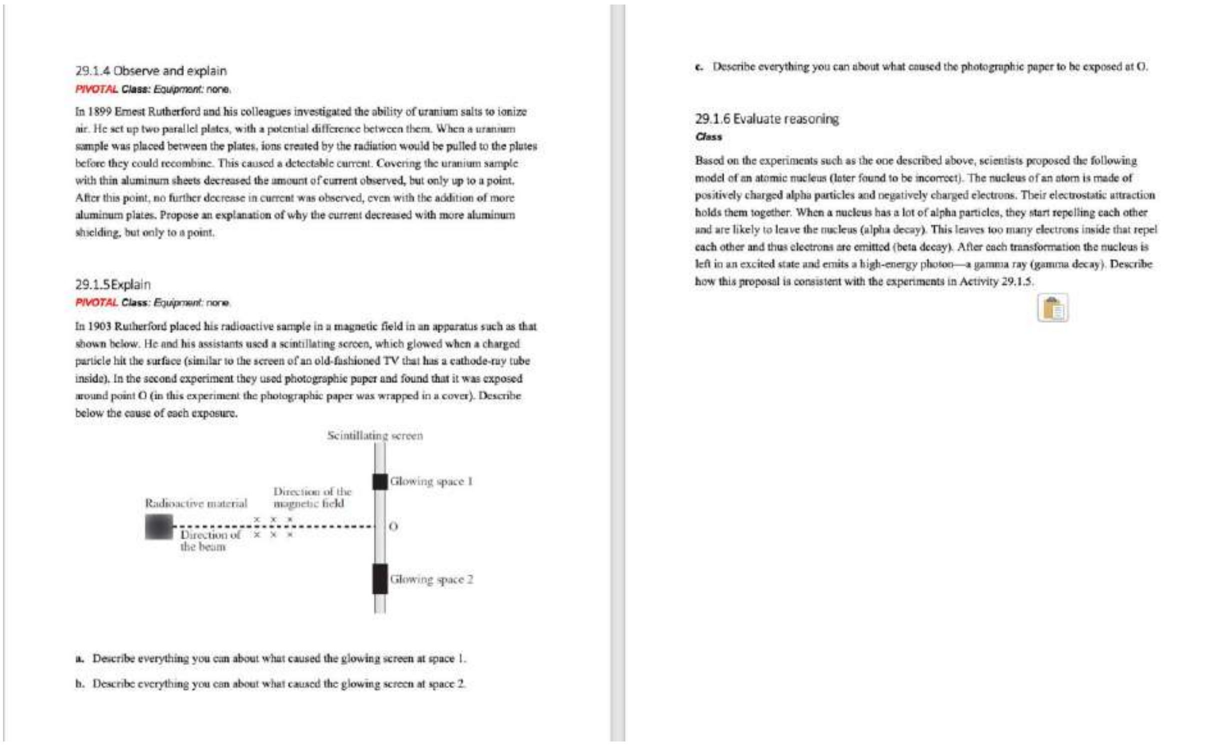
Eugenia Etkina
11. May

Hi all, I continue with nuclear physics chapter (#29). The attached screen shot shows the sequence of activities that led to the first (incorrect) model of a nucleus.
You must be wondering why we let students learn stuff that later was found to be incorrect? Exactly because it allows them to learn how scientific knowledge is constructed (in fancy language it would be learning scientific epistemology). In traditional textbooks the students never see incorrect models and never learn how to reject stuff (for examples, labs are verification of theory labs).
What is missing in these traditional approaches is that 1) students begin thinking that theory is the first step in physics; 2) students never learn how to reject models/hypotheses/ideas. And it is the fact that models/hypotheses/ideas can be rejected experimentally that separates science from religion where it is impossible to find an experiment that would rule out a hypothesis cannot (there is no experiment that can rule out the hypothesis of intelligent design).
I encourage you to do the activities that I posted (ALG Chapter 29) and focus on the questions that ask students to think what observational data this first model of the nucleus explained. Do not forget to respond to the post after you finish reading it!



29.1.4 Observe and explain

PIVOTAL **Class:** *Equipment:* none.

In 1899 Ernest Rutherford and his colleagues investigated the ability of uranium salts to ionize air. He set up two parallel plates, with a potential difference between them. When a uranium sample was placed between the plates, ions created by the radiation would be pulled to the plates before they could recombine. This caused a detectable current. Covering the uranium sample with thin aluminum sheets decreased the amount of current observed, but only up to a point. After this point, no further decrease in current was observed, even with the addition of more aluminum plates. Propose an explanation of why the current decreased with more aluminum shielding, but only to a point.

29.1.5Explain

PIVOTAL **Class:** *Equipment:* none

In 1903 Rutherford placed his radioactive sample in a magnetic field in an apparatus such as that shown below. He and his assistants used a scintillating screen, which glowed when a charged particle hit the surface (similar to the screen of an old-fashioned TV that has a cathode-ray tube inside). In the second experiment they used photographic paper and found that it was exposed around point O (in this experiment the photographic paper was wrapped in a cover). Describe below the cause of each exposure.

a. Describe everything you can about what caused the glowing screen at space 1.

b. Describe everything you can about what caused the glowing screen at space 2.

c. Describe everything you can about what caused the photographic paper to be exposed at O.

29.1.6 Evaluate reasoning

Class

Based on the experiments such as the one described above, scientists proposed the following model of an atomic nucleus (later found to be incorrect). The nucleus of an atom is made of positively charged alpha particles and negatively charged electrons. Their electrostatic attraction holds them together. When a nucleus has a lot of alpha particles, they start repelling each other and are likely to leave the nucleus (alpha decay). This leaves too many electrons inside that repel each other and thus electrons are emitted (beta decay). After each transformation the nucleus is left in an excited state and emits a high-energy photon—a gamma ray (gamma decay). Describe how this proposal is consistent with the experiments in Activity 29.1.5.

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Eugenia Etkina
12. May

Hello everyone! A few things today. First, I wanted to welcome several new members who joined our group in the last few days. WELCOME! If you wish to benefit from the group, you need to check the posts every day. This way you will not miss anything. To learn more about the philosophy of teaching behind the group and resources that are available, visit https://www.islephysics.net/ and ask your Pearson rep to send you a copy of the textbook College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen. The cover of this textbook is the photo on the front page of this group. To see free resources here, go to FILES.
Now I will continue with nuclear physics. As we discussed yesterday, it is very important for the students to learn how physicists ruled out ideas that seemed perfectly fine first. One of those ideas was the structure of the nucleus. Marie Curie showed that Becquerel's radiation could only come from the nucleus, Rutherford showed that the radiation consists of positively charged nuclei of helium (alpha particles), negatively charged electrons (those were just discovered) and neutral electromagnetic waves - gamma rays.
Therefore he proposed the model of the nucleus that consisted of alpha particles and electrons. This model explained all radioactive decay processes but had one problem - the nucleus of hydrogen. Read the screenshot of the textbook page describing how Rutherford solved this problem. However, even though he solved it, another huge problem was on the horizon. What was this problem? And how was it solved?
I will post tomorrow. For today, please do not forget to respond to the post if you read it. Thank you.

The early model of the nucleus

Based on these experiments, scientists developed a provisional explanation for radioactivity: the nucleus of an atom is made of positively charged alpha particles and negatively charged electrons. Their electrostatic attraction holds them together. When a nucleus contains a large number of alpha particles, they start repelling each other more strongly than the electrons can attract them, and the alpha particles leave the nucleus, a process called **alpha decay**. Alpha decay leaves behind a large number of electrons that also repel each other; thus beta particles are emitted (**beta decay**). After each transformation, the nucleus is left in an excited state and emits a high-energy photon, a gamma ray (**gamma decay**). This model provided a start for nuclear physics and was later significantly modified when new findings emerged.

A hydrogen atom, however, is lighter than an alpha particle. What, then, is the composition of its nucleus? In 1918, Rutherford noticed that when alpha particles were shot into nitrogen gas, particles that were knocked out of the nitrogen nuclei moved in curved paths that indicated they were positively charged. Further testing indicated that the particles had the same magnitude charge as an electron (only positive) and a mass that equaled that of a hydrogen nucleus. The particle was called a **proton**. Protons must be the nuclei of hydrogen atoms. The proton became an important part of a new model of the nucleus that began to emerge.

REVIEW QUESTION 29.1 How do we know that radioactive emission consists of three components: positively charged particles, negatively charged particles, and radiation with no electric charge?

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Eugenia Etkina
15. May

Thank you all who participated in the discussion of WHY electrons cannot be inside a nucleus. Calculations and explanations of WHY in the textbook are in the attached screen shot. Once we figure this out, the question becomes (actually two questions!): 1) how to explain the charge of a nucleus (half of the charge of available protons if one considers protons the only particles contributing to the mass of the nucleus) and 2) how without electrons positively charged protons manage to stay together inside a tiny nucleus. They should repel each other as like charged particles!
The answers to these questions came in the form of a new proposed particle (a familiar to us neutron that has zero electric charge and the mass slightly larger than a proton, different numbers of neutrons with the same number of protons give us isotopes) and a new proposed

type of interaction (nuclear interaction which is an attraction much stronger that electric repulsion at the distances smaller than the nuclear size and non-existent at the distances larger than that which affects both protons and neutrons). And with those came the idea of mass defect which we will discuss in the next post. Please do not forget to "like" the post if you finished reading it. I realized that it is the "likes" that make it visible, not so much responses.

Size of the nucleus: too small for an electron

Consider an electron confined to a carbon nucleus whose radius is approximately 2.7×10^{-15} m. The position determinability Δx of such an electron can be no greater

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than the size of the nucleus (**Figure 29.2**). According to the uncertainty principle, this electron must have a momentum determinability of

$$\Delta p \geq \frac{h}{4\pi\Delta x} = \frac{6.63 \times 10^{-34}\ \text{J} \cdot \text{s}}{4\pi(2.7 \times 10^{-15}\ \text{m})} = 1.95 \times 10^{-20}\ \text{kg} \cdot \text{m/s}$$

We can use this value as an estimate for the momentum of the electron confined to the nucleus. Using the equation $p = mv$, we would find that the speed of the electron is hundreds of times the speed of light, so we need to treat the electron relativistically. Using energy ideas, we find that the kinetic energy of the electron is the total energy of the electron minus its rest energy:

$$K = E_{\text{total}} - E_{\text{rest}}$$

Inserting the appropriate expressions:

$$K = \sqrt{(pc)^2 + (mc^2)^2} - mc^2$$

We can evaluate this expression using our estimate for the momentum of the electron, the mass of the electron, and the speed of light:

$$K = \sqrt{[(1.95 \times 10^{-20}\ \text{kg} \cdot \text{m/s})(3.00 \times 10^8\ \text{m/s})]^2 + [(9.11 \times 10^{-31}\ \text{kg})(3.00 \times 10^8\ \text{m/s})^2]^2}$$
$$- (9.11 \times 10^{-31}\ \text{kg})(3.00 \times 10^8\ \text{m/s})^2$$
$$= 5.77 \times 10^{-12}\ \text{J}$$

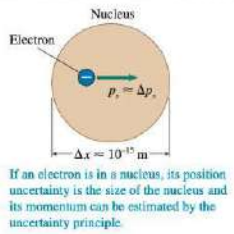
How does this result compare to the electric potential energy between the electron and the nucleus? When studying the Bohr model of the hydrogen atom, we found that the total energy of a system (potential plus kinetic) must be negative for the system to be bound (Chapter 28). Let's think, for example, about a carbon nucleus. Carbon is assigned atomic number 6, so its nucleus has a charge of $+6e$. If there are both protons and electrons in the nucleus, there must be 6 more protons than electrons. We'll make a rough estimate of the electric potential energy between an electron in a carbon nucleus and the rest of the nucleus by assuming that the electron is an average distance from the protons equal to half the diameter of the nucleus, or about 2.7×10^{-15} m. The electric potential energy between the electron and rest of the nucleus (total charge +7) is approximately

$$U_q = k_C \frac{q_{\text{nucleus}} q_e}{r} = \left(9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right) \frac{(7 \cdot 1.6 \times 10^{-19}\ \text{C})(-1.6 \times 10^{-19}\ \text{C})}{2.7 \times 10^{-15}\ \text{m}}$$
$$\approx -6.0 \times 10^{-13}\ \text{J}$$

This value is slightly more than just one-tenth the kinetic energy of the electron. In other words, the total energy of the system (kinetic plus potential) is positive! This result means that an electron in the carbon nucleus would very rapidly escape the nucleus. This form of carbon is stable, however, and does not emit electrons. Similar reasoning applies to other nuclei.

Thus we have determined that, because of the uncertainty principle and their tiny mass, electrons cannot be components of nuclei.

FIGURE 29.2 According to the uncertainty principle, if an electron is confined within a nucleus, its speed would be greater than light speed. Thus, it cannot be within the nucleus.



TIP Notice that if you substitute the mass of a proton into the equation for kinetic energy, the kinetic energy goes to zero, making the proton a possible constituent of a nucleus due to its larger mass.

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Eugenia Etkina
16. May

Hello everyone! Two things today - 1) A reminder about our meeting on May 21st, 3 pm EST - how we build on qualitative reasoning to develop quantitative reasoning in the ISLE approach. 2) The continuation of our discussion of the structure of the nucleus.
For 1) - please sign up to the event - the EVENTS are on the low left of the Facebook group page.
For 2) - It is interesting to notice the contributions of women to nuclear physics. Many of us are familiar with the name of Marie Curie (and her daughter Irene). But how many know the name of Lise Meitner and her contributions? She never got a Nobel prize for her work (Marie received 2 and Irene - 1) and her name rarely appears in physics textbooks. Here are the activities that show her role in the discovery of fission. While for us the idea that shooting neutrons into heavy nuclei will lead to their breaking into smaller parts is absolutely fine, it was not fine or even conceivable in late 30ths of the 20th century. The experiments bombarding uranium with neutrons were expected to produce nuclei heavier than uranium (captured neutron was expected to decay into a proton that would stay in the nucleus and an electron that would leave) and therefore lead to the discovery of new elements. But this is not what happened - read the activities below.
The activities, however, do not explain why Lise Meitner (or Otto Frish) was never recognized for her contributions to the understanding of fission. Otto Hahn received the Nobel prize without her. Life of Lise Meitner was tragic and typical for the life of a woman in physics at that time compounded by the fact that she was Jewish working in a Nazi Germany during world war II. There are several books written about her life - I strongly recommend reading them. She was an extraordinary woman and deserves full recognition.
29.5.4 EXPLAIN
PIVOTAL Class
In the 1940s Lise Meitner, Otto Hahn, and Fritz Strassmann irradiated uranium with neutrons. They found that instead of getting a heavier uranium isotope, the reaction produced lighter nuclei, like isotopes of Ba (barium). How can you explain their findings?
29.5.5 EXPLAIN
PIVOTAL Class: Equipment per group: whiteboard and markers.
Lise Meitner asked her nephew Otto Robert Frisch to help with the explanation. They thought about Bohr’s liquid drop model; heavy nuclei behaved like a drop of water with a kind of “surface tension” holding it together. The only problem was that the nucleus had an electric charge that would counteract the effect of the surface tension, especially if the nucleus was not very spherical. The model suggested that the nucleus could elongate and divide into two smaller pieces. This meant that the uranium nucleus would be very unstable and ready to divide with the slightest provocation. This could happen when a neutron hit it.
a. Explain how Meitner’s and Frisch’s reasoning could explain the findings in Activity 28.3.5.
b. Use the liquid drop model to predict another product or products of uranium disintegration. If a chemist finds such products in the mixture resulted from the irradiation of uranium with neutrons, then the water drop model is a productive model to explain the observations in Activity 28.3.5.

c. Explain how the model of Meitner and Frisch can be used to explain why uranium can be used as a source of thermal energy. Additional information: the products of the irradiation of uranium with neutrons included not only chemical elements in the middle of the periodic table but also extra neutrons.
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Eugenia Etkina
17. May

Hi all, two things today - a reminder about our meeting on Saturday, 3 pm EST, please go to the EVENTS on the left side of the group's page and sigh up for the meeting.
Second, I continue with nuclear processes today and I wanted to show how we use work-energy bar charts in nuclear physics. Specifically, how the bar charts help understand the mass defect. The students start by calculating the mass of the particles that make up a nucleus - in this case, helium nucleus, and compare this sum to the mass of the nucleus to find that the mass of the nucleus is less than the sum of the masses. This empirical finding contradicts the law of mass conservation that they learned in Chapter 5. What to do? Read the attached screen shot of the textbook pages that shows how to use a bar chart to explain this discrepancy. Please do not forget to like the post after you read it and the attached document!

The missing mass is on the order of 1% of the mass of the nucleus. Our prediction matched the outcome of the experiment. The mass of the helium nucleus is less than the sum of the masses of the protons and neutrons that comprise it (Figure 29.6).

In Chapter 6 we learned that mass is constant in an isolated system. Now we have found that this is not true for an atomic nucleus because it is a bound system. This means that the mass of any bound system is less than the mass of its constituents, but at a macroscopic level the difference is tiny. Now we understand that mass is not a conserved quantity. However, energy is. We will use the idea of energy conservation to understand what happens to the energy of a system when a nucleus is formed.

Let us represent a hypothetical process of making helium nuclei from their constituents using a bar chart (Figure 29.7a on the next page). The system is an even and equal number of protons and neutrons. The initial state is when the particles are far apart, and the final state is when they form groups of two protons and two neutrons, helium nuclei. Thus the protons and neutrons initially have zero potential energy and zero kinetic energy. The protons repel each other, so to bring them closer we need to add energy to the system (E_{Add}), for example, by doing work on the protons. Once the particles are so close that the attractive nuclear forces are larger than the repulsive electric forces, the particles start accelerating toward each other, forming helium nuclei. In the final state, each nucleus (two protons and two neutrons) has negative total potential energy (some positive electric potential energy U_{qf} and large negative nuclear potential energy U_{nf}).

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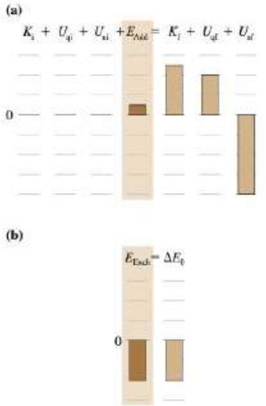

FIGURE 29.7 Energy bar charts representing the process of making a helium nucleus out of several constituents.

Because the final negative nuclear potential energy is much larger in magnitude than the sum of the positive electric potential energy and added energy, some energy converts into the kinetic energy K_f of the chaotic motion of the nuclei, which manifests as thermal energy of the system. We therefore see that to form helium nuclei, some energy initially needs to be added to the system, but at the end of the process, a larger amount of energy is converted into thermal energy, which can leave the system through the process of heating.

If the description above is correct, it should be consistent with the description in terms of masses. Refer back to the calculation on the previous page; instead of masses, we will use corresponding rest energies. The initial state is when the particles are at rest and far apart. In the final state, we have helium nuclei and we will assume that the thermal energy has already left the system. Initially the system has large total rest energy. In the final state, the rest energy of the system is smaller than the initial rest energy. This is consistent with the previous energy analysis: the initial total energy of the system is zero and the final total energy of the helium nuclei (after the thermal energy produced in the process has left the system) is negative. The change in the total rest energy of the system, $\Delta E_0 = E_{0f} - E_{0i}$, is therefore equal to the total energy that the system exchanged with the environment ($E_{Exch} = E_{Add} - K_f$). That is, $\Delta E_0 = E_{Exch}$. We can represent this relation using a new energy bar chart (Figure 29.7b), which is similar to the bar charts we used to represent the first law of thermodynamics in Chapter 15.

We will see in Section 29.5 how this prediction of thermal energy release leads to the production of energy through fusion. As we will also see then, the rest energies in typical processes that involve nuclear particles are much larger in magnitude than the released thermal energies.

Helium is not unique in having a smaller mass than its constituents. For example, the nucleus of lithium $^{7}_{3}Li$ is made of three protons and four neutrons. The atom also has three electrons. Thus we can compare it to three hydrogen atoms $^{1}_{1}H$ and four neutrons. The total mass of the three hydrogen atoms and four neutrons is 7.058135 u, whereas the mass of a lithium atom is 7.016003 u, or 0.042132 u less than the mass of its constituents. On the basis of such findings, we can now define a new physical quantity called **mass defect**.

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Eugenia Etkina
24. May

Hi all, as I promised, now that we finished with the textbook, I will post thoughts about learning and teaching in the ISLE approach. Today my post is about the general language that we use (or mostly do not use). Please do not forget to like the post after you read it.
There are a few terms that are commonly used that I strongly recommend to avoid.
1) Demos. Demos mean that we are demonstrating something for the students. We do not want to demonstrate, we want them to experience and either observe an experiment to come up with explanations (hypotheses or quantitative patterns) - these are observational experiments or hypotheses generating experiments. No predictions are required for those. Or we want our students to test some ideas (hypotheses, patterns, relations) - these are testing experiments for which they need to make predictions based on the idea under test, not their intuition. Or we want them to apply their tested knowledge - these are application experiments. It does not matter who performs them - you or the students, the epistemological framing is important. So, avoid the term demo.
2) Worksheets. Worksheets are associated with filling in the blanks and often busy work. We want the students to think and reason not to fill in the blanks, we want them to be creative. So, avoid the term worksheet. Use "handout" or "activity" or whatever term you find but not the worksheet.
3) Formulas. Formulas often mean something to memorize. We use terms mathematical representation or mathematical relation, or mathematical expression. Avoid terms that might trigger unwanted response in your students' brains.
4) Introduce. When we introduce we share something that we know and a person does not. We do not want to introduce, we want students to construct, to develop, etc.
It might seem that these are just insignificant tweaks. But they are not. They communicate our intentions and send messages to the students. Language is what shapes our thoughts. Language is something that activates our brains. Let activate productive resources in our students' brains, right?

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Eugenia Etkina
25. May

Hi all, thank you for your incredible response to my post yesterday. Today I will continue with language, but this time it will be connected to physics. When you finish reading the post, please do not forget to like it to make it more visible.
My post today is based on the research done by David Brookes and long conversations with Alan Van Heuvelen. It is about forces. According to I. Newton, an external force (this is what we call a force now) is a physical quantity describing the interaction of two objects. It does not exist by itself and does not belong to any of the objects (Newton emphasized it in his Principia). As such, it should be expressed in language as a passive, external to both objects entity. And yet, in our language we treat the force "pre-Newtonially", reflecting the struggle that physicists had defining what we call the force today. I will show a few examples.

The first one is the most common. We say: a force acting on the object is 5 N. As such we imply that the force exists by itself and can do something to an object. In this case the force is expressed by an active external entity.
The second example is also common: an object feels the force of 5N. Here the force is like a feeling, feelings belong to people and as such are internal entities.
But the worst is our language related to weight. The weight of an object is 5 N. This means that weight belongs to an object, to ONE object. Again, it is a passive internal entity.
What to do? In out textbook and in ALL materials that we have developed we use the language and symbols that reflect two important attributes of a force: the passive external nature and the fact that it does not belong to an object or reside in it.
When we talk about forces exerted on a system of interest (notice the passive nature of the verb exerted) we say "the force exerted by rope on the system" (and not "tension in the rope") or the force that exerted by Eugenia on the system (not Eugenia's force, note that in both cases force is passive external) and we ALWAYS use two subscripts to note what the system is and what external objects it is interacting F^R on S - force exerted by the rope on the system.
What about weight then?
We avoid this word. As much as we can. Instead we talk about the force exerted by Earth on the system. Notice, it is NOT the force of Earth. Earth does not have any force. But as it interacts with the system of interest, we can quantify this interaction as the force exerted by Earth on the system. Passive and external.
I know how difficult it is to change our language. But if we want our students to ALWAYS remember that forces do not belong to objects but describe interactions, it will help them if the language we use is consistent with the concepts we want them to master. This will prevent such things as "force of motion" or "force of acceleration" that students often use to describe motion, not the forces the way how physicists now agree to define them.
Thank you for reading, you know what to do now!

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Eugenia Etkina
26. May

Hi all, thank you for your marvelous response to my yesterday's post. The more people like it or comment, the more people view the post. We are over half of the membership of the group for the number of viewers, this is much higher than before, which was on average 25-30%. Thank you! Today I will continue with our language when we teach momentum and energy. Here three key words are crucial: system, conserved, and constant (the latter two ARE NOT the same). This post is based on my work with
Alan Van Heuvelen and the joint work with Lane Seeley and Stamatis Vokos. Both are the members of this group.
Item 1. System. In physics it is an object or a group of objects - any groups WE decide to include in the system. The objects are not included are the ENVIRONMENT. If they are not

included, it does not mean that they not important, in fact, they are VERY important - as they exert forces, impulses, and do work on our system. Objects in the system might also exert forces and impulses on each other, but the sums of those are ALWAYS zeros, otherwise a system would accelerate by itself (which is only possible for observers in non inertial reference frames but we are not concerned with those now).
The idea of a system is crucial for understanding the concept of momentum and potential energy. The former is the vector sum of momenta of system's objects and the latter describes the energy of interactions of objects inside the system. If you have a single object, it cannot have any potential energy (excluding its own gravitational potential energy, which is negligible for macro objects and is almost never used in introductory physics courses, but is crucial in astronomy). Therefore when we say that a 1-kg brick lifted 5 m above Earth has gravitational potential energy, this statement goes against our understanding of GPE, which is the energy of the system brick-Earth. If brick only is the system, then Earth can do work on it, but the brick itself does not have any GPE.
The same is true for electric potential energy. An electron in a hydrogen atom does not have any electric potential energy, but the system electron-nucleus has. An electron does not have any electric potential energy in an electric field, but the system electron-electric field does (here field is another object). An electron does not have any electric potential energy in a metal, but the system electron-crystal lattice does.
Why is this important? You might think: "Who cares? We always used these expressions and students were ok." But were they? According to lots of PER studies of students and our own studies of teachers the lack of understanding of the role of the system choice leads to student difficulties with energy (which is unsurprisingly considered one of the most difficult concepts) such as double counting of work and energy and general confusion when to use work and when to use energy and teachers' inability to help them with those difficulties.
So, before approaching any process or situation for analysis in mechanics or any other field of physics your first question: "What is my system?" will determine the path you take in this analysis and its success. Our textbook and the ALG represent the ONLY resource in introductory physics (in calculus based physics it is the Matter and Interactions curriculum) which teaches students systems approach to the analysis of all phenomena discussed in the physics course. If you have the book, I invite you to study chapters 3, 6, 7, 15 and 17 to see how our language is consistent with the energy approach.
Wow, it is a long post and I am still in #1. I will continue with 2 and 3 tomorrow. Please do not forget to like it or to comment!

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Eugenia Etkina
28. May

Hi all, thank you for your response to my post about the importance of a system. I did not post yesterday as Gorazd Planinsic and I were running an energy workshop for Italian teachers in Trieste for the group organized by Valentina Bologna Longo and Francesco Longo.
I have known some of the participants for a year as I did several online workshops for them in the Fall of 2021. It was so great to see those teachers in person. What an amazing group of teachers! Valentina Bologna Longo and Francesco are doing superb work with the teachers, our workshop was only a tiny part of it.
But what I wanted to write today is that a few undergraduate students (some physics majors and some math majors) came to the workshop. They were in the same group and it is difficult to describe the level of enthusiasm and positive response to our activities. They were such a delight! The were the first to respond to most of the activities as a group, but what is more important was to see their happy faces, their animated discussions! The group had 4 females and 2 males and ALL females were contributing - I was watching them very carefully. I was seeing my "dream students" - those who are in a state of "flow" doing physics ("flow is a psychological state of complete happiness, the term invented by Mihály Csíkszentmihályi).
Why am I writing about it? Many think that as our textbook and all our materials are algebra based, and therefore the students who are not physics majors (bio, pre-meds, etc.) should use it, and the physics majors are good with traditional "rigorous" courses. This is sooo very wrong! Physics majors need our approach the most - it teaches them to think like physicists from the start, not when they come to work for some professor in a lab.
But the change in the physics departments is very slow. Yesterday we had a deputy head of the department join the workshops and be a regular participant. His response was also very positive and enthusiastic. The question is - how can we get more people on board of the ISLE ship? How can we physics majors who later become physics teachers to learn physics through the ISLE approach? These are the questions that keep me up at night. If you have answers, please post them here. I will continue with energy language tomorrow not to make this post too long. Please like it if you read to the end to make it more visible.

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Eugenia Etkina
29.4.

Hi all, today I finish the discussion of the photon model of light. In the textbook the last section is about photocells and LEDs. The material is too large to post screenshots. Therefore I send you to pages 872 - 874. Our textbook is the only textbook that systematically uses and discusses LEDs in many chapters - kinematics, dynamics, DC circuits (including power), geometrical optics and quantum optics. We have lots of experiments, videos and activities that helps students really learn how an LED works - first from observing their properties without understanding the microscopic structure and finally to the details of the microscopy. Some of the videos are absolutely unique, such as one on page 874 - the internal structure of the LED.

I am posting the link here but it probably will not help if have not studied the material in the textbook. It shows the internal structure of an LED under a microscope. The LED is submerged in a liquid with the same index of refraction as the plastic cover, this way you can see the inside without any distortion. Made by Gorazd Planinsic.
We actually have a whole workshop on LEDs. We could run it for those who are already familiar with the ISLE approach as the understanding of the process is needed to fully participate. I wonder if there is interest in a pure LED workshop. Please let me know. Please respond to the post to make it more visible.

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Eugenia Etkina
29. May

Hi all, today my post is about "conserved" and "constant". Please do not forget to respond to it after you finish reading. This is not my first post about this issue, but before I go on, I would like to share some history.
When Alan Van Heuvelen and I were working on the first edition of our textbook (College Physics: Explore and Apply is the second edition, the first one came out in 2013), in about 2008 I suggested that we pay serious attention to the distinction between these two words (conserved and constant), that constant does not mean conserved and conserved does not mean constant when we talk about momentum and energy. The publisher and even Alan responded to it negatively, saying that physicists will not understand us and that when we talk about energy and momentum, the word conserved (or not conserved) is the only word that people use. It was a battle that I won, and even in our first edition those two words are used carefully. Conserved quantities such a momentum and total energy are constant in isolated systems and are ALWAYS conserved in any system even though they might not be constant. The word constant means not changing with time. We talk about constant speed motion, constant acceleration motion, gas processes happening at constant pressure, volume, etc. Although these quantities are not changing in the above processes it does not mean AT ALL that they are conserved quantities. A conserved quantity is such that we can always find a system where this quantity is constant. Think of an object (1) moving at constant acceleration and then stops abruptly because it interacted with some other object (2). Does it mean that its acceleration is now transferred to that other object (2) and in the system of objects 1-2 the acceleration remain the same? Of course not, as acceleration is not a conserved quantity. BUT the total energy of the system 1-2 and total momentum remain the SAME no matter what interaction occurred between them and if there are no other objects with which they are interacting at the moment.
Mechanical energy is not a conserved quantity by default, therefore talking about when mechanical energy is conserved and when it is not conserved is not right fundamentally. We can only talk about systems where mechanical energy is constant or not. Therefore the terms conservative and non-conservative forces are incorrect and confusing. We do not have them

in our textbook for this exact reason. All forces lead to conservation of energy, but for the conservation of TOTAL energy, not mechanical.
I hope the difference between constancy and conservation is clear. In needs to be made clear for the students too. We (Lane Seeley, Stamatis Vokos, and myself discussed these issues in our recent editorial in the American Journal of Physics. Please read! https://aapt.scitation.org/doi/full/10.1119/5.0067448
And please do not forget to respond to the post after you finish reading it!

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Eugenia Etkina
30.5.

Hi all, I am continuing with my posts about language but before that I wanted to clarify a few things that came up in our yesterday conversations.
There are two versions of our textbook - College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen. One is a regular version and the other one is the AP version. The text and problems are identical in both versions but the AP version has materials that show how our text and problems address AP requirements (enduring understandings, science practices, etc.). The types of problems in the section End of Chapter Problems match the types of problems on the AP exams + we have traditional problems and other types that were invented by use before the AP courses were revised. when you ask for examination copy of your Pearson rep, please make sure you tell them which version you are interested in.
The test bank for all Pearson books is the same except our textbook. Our textbook test bank has about 20-25% of problems that match our approach to learning physics and the AP needs. Those were written by Matt Blackman, an amazing physics teacher who makes physics video games.
Each chapter of the book has Reading Passages that prepare pre-med students for MCAT and provide additional connections to biology and medicine for all students.
This way we make learning better for all students by using the ISLE approach, better for AP students by adding to the ISLE approach AP type problems and for college students by preparing them for MCAT.
However, if you teach physics to 9th graders and think that your students cannot read our textbook that has long sentences and complex arguments, or your students do not have enough algebra skills to follow the development of mathematical ideas, we have a more broken down step-by-step activities in our Physics union Mathematics modules (PUM) that have two levels of sophistication - Physics I (for middle school and Physics First) and Physics II - college prep or honors. They are completely free, you just need to request access. The link to the PUM website is on our ISLE website (islephysics.net). I strongly recommend studying the resources on the islephysics.net website to make sure that you take advantage of EVERYTHING that we have developed. And it is a lot!

Wow, it is a long post already. Let me stop here and come back to the language tomorrow. Please like the post if you read to the end to make it more visible.

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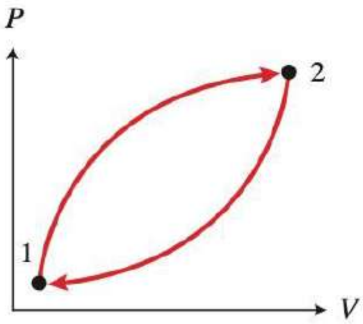
Eugenia Etkina
31.5.

Hi all, today I continue with language. The word is "heat". It is a very difficult word as in everyday life it has a completely different meaning compared to its meaning in physics. In everyday life "heat" is something that an object (or a system) has. We talk about it as a thing, a noun. We say "too much heat in the room", "friction leads to heat" and so forth. There is another issue here. The term heat means unquestionably warmth or warming up. Nobody would associate "heat" with cooling. And yet...
In physics the term heat (when used correctly) has a completely different meaning. It stands for a process - similar to work, a process through which the energy of a system (a thing) can be changed. Heat can increase or decrease the total energy of the system, as heat can be positive or negative. WHAT??? How can this be? It can, if we consider the definition of heat as a process of changing the energy of a system without doing work when the temperature of the system is different from the temperature of the environment. This means that when the temperature of the environment is lower that that of a system, this process leads to the transfer of energy from the system, or heat is negative.
The system can cool down even when the heat is positive! It happens when the work done on the system is negative and its magnitude is larger than that of the energy transferred through heat.
Ad the consequence of how we define them, heat and work are not the state functions, while the total energy is. A system does not possess work or heat but it possesses energy.
Do you see how complicated this is??? To minimize the complication in our textbook and the ALG (OALG) we chose a different word - heating. The goal is to emphasize that it is a process not a thing. "Heating" does not necessarily leads to warming and it can me positive and negative. Research by David Brookes and myself showed a long time ago that those students who use the word "heat" as a process and not as a thing are much more successful solving problems involving the first law of thermodynamics.
In the textbook we have a classic problem (first brought into PER by David Meltzer) that helps students REALLY understand the difference between energy as a state function and work and heating as not being state functions. I pasted it below.
If you finished reading, please do not forget to respond to the post. Thank you.

7. ** Gas in a closed container undergoes a cyclic process from state 1 to state 2 and then back to state 1 (**Figure P15.7**). Describe the processes 1-2 and 2-1 qualitatively using the concepts of work, heating, and internal energy. (a) What happened to the thermal energy of the gas as it went from 1 to 2 and then from 2 to 1? What is the net change in the internal energy after the gas returned to state 1? (b) On the *P*-versus-*V* graph, show the magnitude of the work that was done on the gas by the environment during process 1-2 and during process 2-1. (c) Was the total work done on the gas positive, negative, or zero during the entire process 1-2-1? (d) Discuss the heating of the gas during process 1-2 and then 2-1. Was the total heating of the gas positive, negative, or zero during the whole process 1-2-1?

FIGURE P15.7



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Eugenia Etkina
2. June

Hi all, I continue my series of posts about language. Today it will be about charges and fields. Please do not forget to like the post after you read it to make it more visible.
We differentiate the terms electric field and the quantities of E field (F/q^{test}) and V field (or traditionally called electric potential U^q/q^{test}). The reason is that we use the term electric field for an entity that surrounds charged objects. This entity has several quantities that characterize it - E, V, and D (electric induction - not taught in introductory courses). They are sometimes called their own vector and scalar fields but we treat the electric field as a medium of interaction, like a thing. It can exert a force on objects, for example. The same is true for gravitational field. It can be characterized by several quantities - g field (F/m^{test})or gravitational potential (U^g). See our Chapter 18 for more clarification on this.
Thus we say that there is electric field at a specific location for which we can determine E field and V field.
In addition, we also carefully separate operational definitions of E and V fields and cause effect relationships for those. We already had a conversation about the epistemic difference between those two types of mathematical relations but I think it would be useful to repeat those here. An operational definition tells us how to determine a quantity if we know what is happening to the test object placed in the field ($E=F^{field\ on\ test\ object}/q^{of\ the\ test\ object}$) but it does not tell us what affects this value as F is proportional to q^{test}). When we know the sources of the field and where our test object is, we can have a cause-effect relation for the E field at that

location (for point like sources it is E=sum kQ^source/r^2. In this relation Q and r can be changed independently of each other, they have no relation to each other, both affect the final E. This distinction shows how important it is to ALWAYS say what charge you mean in the relations - the source charge (of the charged object creating the field), or the test charge (the charge of the object placed in the field to study it and whose effect on the field is usually neglected).
If you read to the end, please do not forget to respond! Thank you!

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Eugenia Etkina
4. June

Hi all, today I continue with language. Please do not forget to like the post to make it more visible.
First - the words that in physics have multiple meanings and, when used, obscure the subject. One of them is GRAVITY. What is it? Students use it for free fall acceleration, for gravitational force, for big G, for g-field, and for a physical phenomenon of attraction of two objects. Therefore, I ban this word in my classroom, and ask students to be very specific about what they mean when they refer to something gravitational - force, acceleration, G or something else. The same way I ban the word ELECTRICITY. Students use it for electric charge, current, potential, energy, power and who knows what else. Therefore, it is better to avoid this word all together and require students to be specific when they talk about electric phenomena or electric quantities (there many!)
The next part of the post about a different issue which occurs in magnetism and electromagnetic induction. When physicists use a word that means one thing in everyday language and a COMPLETELY different thing in physics, it is tough for the students. In English this word is FLUX. It means change, instability: My life is in flux - for example. In physics it means a physical quantity that can be constant in time (B x A x cos theta) but can change (but even then we do not say flux of flux). In this case a discussion with the students is in order - the difference in meanings of the same word in physics and in everyday life.
However, come to think about it, MANY terms that we discussed are common in everyday life but have a very specific meaning in physics. Often it is one of the meanings used in everyday language (force for example, one of the common meanings is a pull or a push which is consistent with physics), but it is almost almost never NONE of the meanings, as it is with FLUX.
Can you think of other physics terms that have the meaning opposite to the one in everyday life? Is it in English only? Or in some other language? Please reply! And please do not forget to like the post or comment on it.

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Eugenia Etkina
5. June

Hi all, we have several new members who joined recently and I wanted to welcome them to the group! WELCOME!!! To fully benefit from our group you need to be familiar with the ISLE approach and to have the textbook College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen (regular or AP Edition). The front page of this group is the cover of the textbook. To learn about the ISLE approach - visit https://www.islephysics.net/ and read carefully through all the tabs. To get an examination copy of the textbook, contact your Pearson rep.
Today I will take a break from posting about language as we are running our second day of the 8-hour ISLE workshop. The participants are amazing - motivated, hard working, creative, and enthusiastic. We have the second half starting in half an hour.

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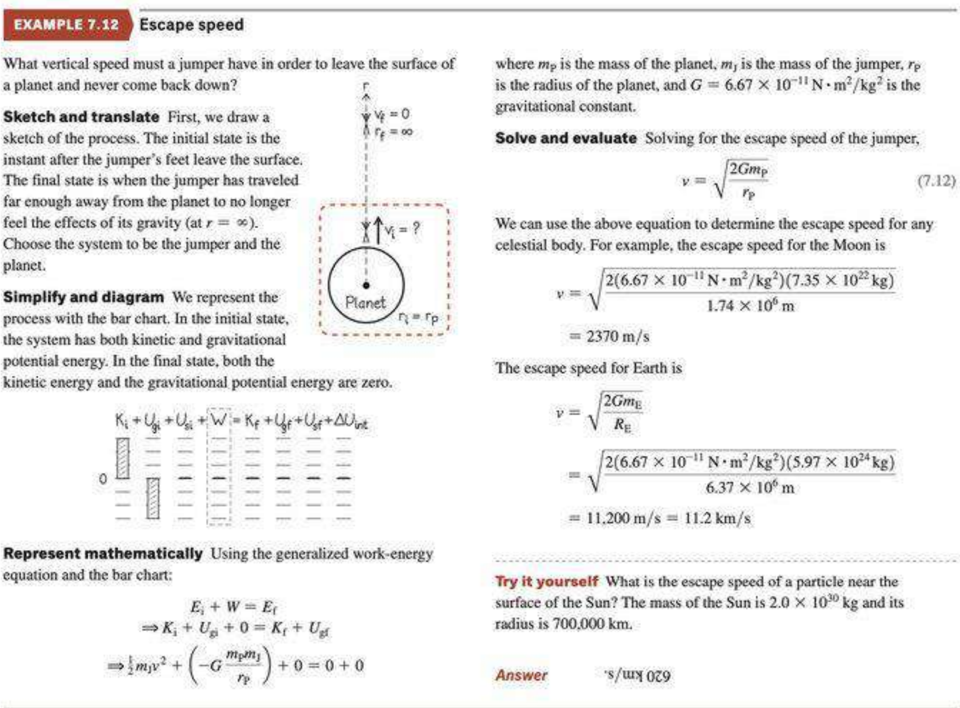
Eugenia Etkina
6. June

Hi all, today first, I wanted to report on our 2-day ISLE workshop. I thank David Brookes, Yuhfen Lin, Josh Rutberg, and Yuehai Yang for co-leading the workshop with me. I am asking the workshop participants to post here what they learned and how the workshop helped them understand the ISLE approach better. Please post!
Second, I will continue with my posts concerning language. This time it is language in atomic physics, specifically "electron energy levels in a hydrogen atom (or any other atom)". Two things are problematic here: 1) electron as a system's choice. A single electron only has kinetic energy, and therefore this energy is only a component of what is going into the value of the "level". 2) the word "level" which invokes an image of a physical location, and sometimes even a horizontal line as we use the word "level" to determine whether something is horizontal. What do say then?
WE use the wording of "energy states (or values) of hydrogen atom" - these energy states are comprised of the electric potential energy of the interaction of the the electron-nucleus system and the kinetic energy of the electron. The former is the energy of interaction of two oppositely charged particles, so it is negative and the latter is always positive. The sum of those two energies needs to be negative for the electron to be bound to the nucleus. When kinetic energy

of the electron is larger than the absolute value of the potential energy of the electron-nucleus system, the total energy of the system is positive and that means that the electron is free - it left the atom. This language is true for any bound systems.
For example a rocket (taken as a system) near Earth has only kinetic energy (always positive), but the system rocket -Earth has also gravitational potential energy (negative as it is the energy of attraction). If the rocket moves fast enough, the sum can become positive and rocket can escape Earth. This is how we calculate escape velocity, right? See attached worked example using the back charts to reason about escape speed. If you read to the end please do not forget to respond to the post!


EXAMPLE 7.12 **Escape speed**

What vertical speed must a jumper have in order to leave the surface of a planet and never come back down?

Sketch and translate First, we draw a sketch of the process. The initial state is the instant after the jumper's feet leave the surface. The final state is when the jumper has traveled far enough away from the planet to no longer feel the effects of its gravity (at $r = \infty$). Choose the system to be the jumper and the planet.

Simplify and diagram We represent the process with the bar chart. In the initial state, the system has both kinetic and gravitational potential energy. In the final state, both the kinetic energy and the gravitational potential energy are zero.

Represent mathematically Using the generalized work-energy equation and the bar chart:

$$E_i + W = E_f$$
$$\Rightarrow K_i + U_{gi} + 0 = K_f + U_{gf}$$
$$\Rightarrow \frac{1}{2}m_J v^2 + \left(-G\frac{m_P m_J}{r_P}\right) + 0 = 0 + 0$$

where m_P is the mass of the planet, m_J is the mass of the jumper, r_P is the radius of the planet, and $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$ is the gravitational constant.

Solve and evaluate Solving for the escape speed of the jumper,

$$v = \sqrt{\frac{2Gm_P}{r_P}} \qquad (7.12)$$

We can use the above equation to determine the escape speed for any celestial body. For example, the escape speed for the Moon is

$$v = \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.35 \times 10^{22}\ \text{kg})}{1.74 \times 10^6\ \text{m}}}$$
$$= 2370\ \text{m/s}$$

The escape speed for Earth is

$$v = \sqrt{\frac{2Gm_E}{R_E}}$$
$$= \sqrt{\frac{2(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.97 \times 10^{24}\ \text{kg})}{6.37 \times 10^6\ \text{m}}}$$
$$= 11{,}200\ \text{m/s} = 11.2\ \text{km/s}$$

Try it yourself What is the escape speed of a particle near the surface of the Sun? The mass of the Sun is 2.0×10^{30} kg and its radius is 700,000 km.

Answer 620 km/s.

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Eugenia Etkina
7. June

Hi all, for the last month I have been posting comments about language in our physics teaching which is independent of the approach that you use in your instruction. Today I am starting to post about ISLE language. During our workshop on Saturday/Sunday I saw once again how this language is different from traditional and how difficult it is for people to switch to it. As I said many times before, the ISLE approach is a philosophy of learning and teaching physics and students learning physics through it use a set of steps to come up with their own understanding of physics ideas. To understand this set of steps it is important to be familiar with the vernacular that we use. Below I pasted the terms and definitions that are crucial for understanding how the ISLE approach works. Please do not forget to respond to the post when you finish reading it.

SHARED LANGUAGE IN THE ISLE APPROACH (PART I)

Eugenia Etkina and David Brookes

Observational experiment is an experiment where you investigate a phenomenon by collecting qualitative or quantitative data without specific expectations of the outcome. No predictions are made of the outcome of an observational experiment. We can call observational experiments "hypotheses generating experiments".

Description is a statement of what was observed in an experiment without explaining it (qualitatively or quantitatively). It answers the question, "What happened?" You can describe with words, pictures, diagrams, etc.

Explanation is a statement of a possible reason for why something happened in the experiment. It answers the questions "why" or "how". An explanation might contain a hypothetical mechanism of how something happened. In this case it is a mechanistic explanation. For example, the mechanistic explanation for drying of alcohol is the random motion of its particles. However, sometimes an explanation does not have a mechanism in it - it only explains the causal aspect of the phenomenon. In this case it is a causal explanation. For example, an object's acceleration is explained by the net force exerted on it and its mass. If you are collecting data, an explanation might be an inference from the data – why the data look the way they do.

Hypothesis is a synonym for an explanation. There are multiple hypotheses that can explain what happened. A hypothesis should be experimentally testable. A hypothesis can be disproved by a series of testing experiments (see below). It can turn out to be wrong.

Prediction is a statement of the outcome of a particular experiment (before you conduct it) based on the hypothesis being tested (see below). It says what should happen in a particular experiment if the hypothesis under test is correct. Prediction is not a guess. Without knowing what the experiment is, one cannot make a prediction. A prediction is not equivalent to a hypothesis but should be based on the hypothesis being tested.

Testing experiment is an experiment whose outcome you should be able to predict using the hypothesis being tested. We can call these experiments "hypotheses testing experiments". A testing experiment tests the hypothesis, not the prediction. A testing experiment cannot prove the hypothesis to be correct (if its outcome matches the prediction) but might disprove it (if the outcome does not match the prediction).

Here an important note is in order: A hypothesis can be disproved by a series of testing experiments (see below). It can turn out to be wrong. A prediction, however, is only wrong when it does not follow from the hypothesis being tested. If the outcome of the testing experiment does not match the prediction, it does not mean that the prediction is wrong. It only means that the hypothesis on which the prediction was based is wrong or some assumptions (see below) were overlooked. In this case the prediction is said not to match the outcome of the testing experiment.

AssumptionAn assumption is some factor in the physical situation you choose to ignore or assume to be true, that simplifies a calculation or a model, or an experiment.

Model: A model is a simplified version of an object, a system, an interaction, or a process under study; a scientist creating the model decides what features to neglect. In many cases the terms models/hypotheses/explanations are synonyms.

Application experiment: an experiment with the goal of solving a practical problem or determining the value of some physical quantity using the relations/models that have not been disproved by multiple testing experiments. We can call application experiments “Multiple hypothesis applying experiments”.

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Eugenia Etkina
8. June

Hi all, today I continue with ISLE language. Thank you for all the likes and comments on my yesterday's post - the more you comment, the more people see the post and contribute.
Yesterday I posted about observational, testing and application experiments and hypotheses and predictions. The confusion between the terms hypothesis and prediction is common and most of science education resources (in print and online) confuse the two. Why is it important to understand the difference? I think that without this understanding one cannot understand the nature of physics and its logical reasoning chain.
While hypotheses are in a way guesses - we guess how to explain something that we observe, right? Predictions ARE NEVER GUESSES. To make a prediction one needs two conditions: first an experiment whose outcome needs to be predicted and second, most important - a hypothesis (or an explanation, or a model) on which to base the prediction. the hypothesis needs to be able to explain some other related phenomenon and be falsifiable. If a prediction is based on a gut feeling, it is not a scientific prediction and we should not engage students in making those.
Here is the chain of reasoning that the students need to learn: IF my hypothesis (state the hypothesis clearly) is true, AND I do such and such experiment (description of set-up of the testing experiment , THEN such and such should happen (this is the prediction), BECAUSE of such and such (this is the explanation of HOW the prediction is based on the hypothesis).
Many people confuse this logical chain with the following IF I do such and such (description of some experiment), THEN such and such should happen (description of the outcome). As you can see, there is no logic in this chain as the prediction is not based on anything.
The above discussion shows that common sequence PREDICT-OBSERVE-EXPLAIN is not a scientific sequence and is not useful for helping students think as scientists. In fact, it harms them, especially females as when their predictions based on their intuition do not match the outcomes of the experiments, they feel stupid and not belonging in physics, especially if this experience repeats day after day after day. Therefore in the ISLE approach the sequence is completely different: OBSERVE AND THINK WHAT YOU OBSERVED, DEVISE SEVERAL EXPLANATIONS (hypotheses) OF WHAT YOU OBSERVED, AND THEN DESIGN EXPERIMENTS WHOSE OUTCOMES THESE EXPLANATIONS (hypotheses) CAN PREDICT. Make predictions, compare them to the outcomes of the testing experiments and then decide what to do about your explanations. This is what we practiced in our last workshop and this is what all of you can practice if you read our textbook.

Each textbook chapter of our textbook College Physics: Explore and Apply is structured according to the above logic and all ALG activities follow this logic. We not only teach the students how physics works, but we let them experience this nature of physics day after day devising their own ideas and testing them as a part of learning what we call "physics content". In our approach traditional "content" becomes the context in which our students learn to think like physicists. Habitually.

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Eugenia Etkina
9. June

Hi all, yesterday Jared Betz commented on my post about hypotheses and predictions by describing an excellent activity from a field different than physics where students come up with several different explanations of a an observed phenomenon and learn to test them experimentally. He asked if we know of any physics activities like this. I responded to him but then I realized that not many people will see my response. So I decided to write about it here. Please do not forget to respond to the post after you finish reading it.
The ISLE approach is based on activities like this. We have several for the first day of classes to get students engaged in hypothetico-deductive reasoning but we also have them in almost ever chapter when students invent new physics concepts (See OALG Chapter 1 posted in the FILES here). I will spend a few posts showing those activities and discussing their purpose. I already showed many of them in my posts before but I guess not everyone reads everything and maybe when I post about content, the pedagogy gets lost a little.
So, here we go. The idea that the students need to invent is that matter is made of particles that move chaotically in all directions. While many students heard about molecules, the molecules are not real to them, it is just a word that use in chemistry. How do we help them come up with the idea of microscopic particles?
This ISLE sequence is the first one that I designed for engaging students in the ISLE process about 27 years ago. The students observe a streak of alcohol smeared on a piece of paper. The streak disappears gradually - this is what they say about their observations. They come up with the explanations of the gradual - alcohol is made of smaller parts and then they are asked to devise at least three mechanism of how these parts disappeared from the paper. The three most common mechanisms are: the parts went into the paper and one cannot see them; air absorbed the parts similar to a vacuum cleaner absorbing dust and the parts can move and they moved out of the paper by themselves. Now the students need to come up with experiments to test those mechanisms. They come up with many and the most common are in the our ALG activities that pasted below. The scale experiment rules out the mechanism of the paper absorbing the parts and the vacuum bell experiment rejects the air absorbing the parts. The moving parts mechanism is left not rejected and the last experiment with dissolving colored alcohol can only be explained by the model of moving parts, and they have to be

moving randomly in all directions. Check out the activities with the eye on the reasoning process.

12.1.1 OBSERVE AND EXPLAIN

PIVOTAL Lab or class: Equipment per group: 90% isopropyl alcohol, strips of paper, whiteboard, markers.

Dip a piece of paper in rubbing alcohol (or rub the paper with alcohol) and place it on a table. Observe what happens. Describe your observations in simple words. [https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...]

One of your friends described the observation in the following way: "The alcohol disappeared gradually". What do you need to assume about the internal composition of alcohol to explain that the alcohol disappeared gradually rather than all at once?

12.1.2 DEVELOP MULTIPLE EXPLANATIONS

PIVOTAL Lab or class: Equipment per group: whiteboard, markers.

Mindy, Marc, Alex, and Nina are working on Activity 12.1.1. They agree that alcohol must be made of small parts to enable the paper to gradually dry. However, they disagree on the mechanism that allows these small parts to disappear. Work with your group to brainstorm possible reasons for how and why the alcohol disappeared from the paper. Come up with at least four different mechanisms and put them on your whiteboard. Share your ideas with another group.

12.1.3 TEST MULTIPLE EXPLANATIONS

PIVOTAL Lab or class: Equipment per group: whiteboard, markers.

Below are four testing experiments that Mindy, Marc, Alex, and Nina decided to perform. Working with your group, predict the outcome of each experiment described below based on each of the four mechanisms you came up with in Activity 12.1.2. (For example, if the small parts soaked into the table through the paper and we hold the paper in our fingers when drying, then the paper should not dry—the table is not there to absorb the alcohol.) Remember that each testing experiment needs four predicted outcomes, one based on each mechanism.

Predict the outcome of each experiment below using all four explanations:

a. Hold the paper that has been dipped in alcohol in your fingers without putting it on the table while it is drying.

b. Weigh the paper before the experiment, when it is wet, and then again when it is dry. [https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...]

c. Take two identical pieces of paper and put the same amount of alcohol on each. Then place one piece of paper under a vacuum jar and the other one just outside the jar. [https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...]

d. Pour some alcohol in a beaker. Place a small drop of colored alcohol in clear alcohol but do not stir it. [https://mediaplayer.pearsoncmg.com/.../sci-phys-egv2e-alg...]

After you have your predicted outcomes on a whiteboard, perform the experiments (or watch the videos of them) and decide which experimental outcomes are consistent with which predictions, and consequently which mechanisms you can or cannot reject.

I also wanted to give you our paper in The Physics Teacher that I write with Gorazd Planinsic where we described several additional activities that help students engage in HD reasoning. I am attaching it here. If you finished reading to the end, please do not forget to respond to the post. Thank you.

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HuPpWKXBo0sSlsCHPDOrRHwGRdA6FUEwz8ESScXd7lupJcYu8jWpZyYS3EI7fc-V3XbgnKowMKlfXXWNJxoyYOHLpaA-TwcdHxpBcf5pyiVoMgh0RDOcEZB8pr06XwSQRleCC1TPsG7E&__tn__=%2CO%2CP-R

Eugenia Etkina
10. June

Hi all, today I am giving one more example - right from our textbook that teaches students to test multiple hypotheses. This is the example that we just used in our ISLE workshop last weekend. The idea that we want our students to construct is that each point of an extended light source emits an infinite number of light rays as opposed to the idea that most people what when they draw the Sun and rays, coming one by one from different points. The process is described carefully in College Physics: Explore and Apply Chapter 22. It is important to see how some experiments fail to reject any hypotheses and what we do after this happens.
I am posting a screen shot here. I had to shrink it to fit on one page, so if you do not have the textbook, just zoom in and you will be able to read everything. I will not go through the process step by step here, I invite workshop participants to describe their experiences when they went through this process. Please comment!

How do we represent the light sent by a light source? How do objects illuminated by a light source reflect light into our eyes? We will start by investigating the first question.

FIGURE 22.1 A lightbulb illuminates the ceiling of a room.

Representing light emitted by different sources

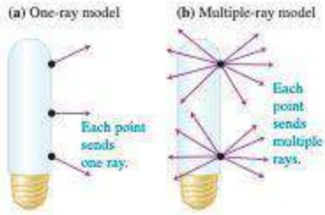
A laser pointer is useful for studying light propagation because the emitted light emerges as one narrow beam. However, most light sources, such as lightbulbs and candles, do not emit light as a single beam. These **extended light sources** consist of multiple points, each of which emits light. When we turn on a lightbulb in a dark room, the walls, floor, and ceiling of the room are illuminated (Figure 22.1). Obviously, the bulb sends light in all directions. But does one point of the shining bulb send light in one direction, or does each point send light in multiple directions? Both of these ideas can explain why the walls, floor, and ceiling are illuminated. Let's investigate those two possible models of how extended sources emit light. To do this we will represent the travel of light from one location to another with a **light ray**, drawn as a straight line and an arrow. Diagrams that include light rays are called **ray diagrams**. A ray is not a real thing; it is a model that allows us to show the direction of light.

One-ray model: Each point of an extended light source emits light that can be represented by one outward-pointing ray (Figure 22.2a). Different points send rays in different directions.

Multiple-ray model: Each point on an extended light source emits light in multiple directions represented by multiple rays (Figure 22.2b).

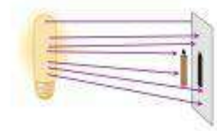
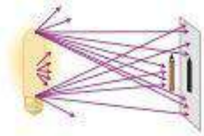
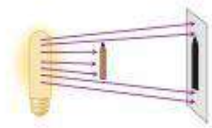
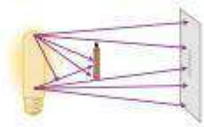
To help us determine which model better explains real phenomena, we will use the models to make predictions about the outcome of three experiments (Testing Experiment Table 22.2). All of the experiments are conducted in an otherwise dark room.

FIGURE 22.2 Two models of light emission from a bulb.



TESTING EXPERIMENT TABLE 22.2 How many rays does each point on a light source emit?

VIDEO TET 22.2

Testing experiment	Predictions: Based on one-ray model	Predictions: Based on multiple-ray model	Outcome
Experiment 1. Turn on a lightbulb and place a pencil close to the wall between the bulb and the wall. 	We predict a dark, sharp shadow behind the pencil where the rays do not reach the wall. 	We predict a dark, sharp shadow behind the pencil where the rays do not reach the wall. 	We see a dark, sharp shadow on the wall.
Experiment 2. Turn on a lightbulb and place a pencil closer to the bulb between the bulb and the wall. 	We predict a dark, sharp shadow on the wall, as in Experiment 1. 	We predict an almost uniformly illuminated wall with a hint of a shadow. 	We see a light, fuzzy shadow (not as dark as in Experiment 1).

(CONTINUED)

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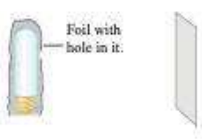
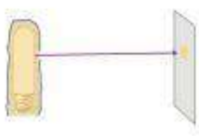
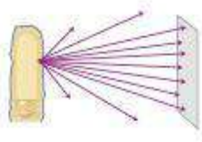
Testing experiment	Predictions: Based on one-ray model	Predictions: Based on multiple-ray model	Outcome
Experiment 3. Cover the bulb with aluminum foil and poke a hole in the foil in the middle of the bulb facing the wall. Turn the bulb on.  Foil with hole in it.	We predict that we will see only a spot on the wall directly in front of the hole. 	We predict that the whole wall will be dimly lit. 	We observe that the wall is dimly lit. If we cover the first hole and poke a hole in a different place, the result remains the same.

Conclusions

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Eugenia Etkina
12. June

Hi all, I continue about language - the language that we share in the ISLE approach. I am pasting a few definitions below, please ask questions and comment! and also I wanted to welcome new members to the group - we had quite a few new people who joined in the last week. WELCOME!
Assumption An assumption is some factor in the physical situation you choose to ignore or assume to be true, that simplifies a calculation or a model, or an experiment. More about assumptions is written by David Brookes and can be found at https://drive.google.com/.../1bYPf4GzCTtETFT7C9tz4g791MQp...
Model: A model is a simplified version of an object, a system, an interaction, or a process under study; a scientist creating the model decides what features to neglect. In many cases the terms models/hypotheses/explanations are synonyms. More about models can be found in our paper in The Physics Teacher (I am putting a citation here as Facebook does not allow me to add anything to this post. Here is the citation, you can find the paper online or ask me to post as a separate post if you cannot find it. Etkina, E., Warren, A., & Gentile, M. (2005). The role of models in physics instruction. The Physics Teacher, 43(1), 15-20).
System: A system is the object (or objects) of interest that we choose to analyze. Make a sketch of the process that you are analyzing. Then, make a light, pretend boundary (a closed, dashed loop) around the system object to emphasize your choice. Everything outside the system is called the environment and consists of objects that might interact with and affect the system's motion. These are external interactions. Interactions of the environment objects with the system cannot be neglected. External objects exert forces on the system, do work on the system, exert impulse and so forth. Internal objects cannot do any of these things. In our textbook the idea of a system is a red thread that goes through all the chapters.
Physical quantity: A physical quantity is a feature or characteristic of a physical phenomenon that can be measured in some unit. A measuring instrument is used to make a quantitative comparison of this characteristic with a unit of measure. Examples of physical quantities are your height, your body temperature, the speed of your car, or the temperature of air or water. Physical quantities that contain information about the direction of some quantity are called vector quantities and are written using symbols with an arrow on top. Force and velocity are vector quantities. Physical quantities that do not contain information about direction are called scalar quantities and are written using italic symbols (m, T). Mass is a scalar quantity, as is temperature.
Operational definition is a rule that tells you what to do (what other quantities to measure and what mathematical operations to use) if you need to determine the value of a particular quantity. For example, for motion at constant velocity, v=delta x/delta t is an operational definition of velocity.

Cause-effect relationship is a rule that tells you what will happen to a quantity when another quantity changes. For example, for motion at constant velocity, delta x= v X delta t is a cause-effect relationship that shows if the time interval of travel is doubled, the distance traveled is doubled. However, the operational definition of velocity is not a cause-effect relationship because if you double the distance that the object travels, the velocity will not change (since the time interval for the doubled distance will be doubled too).
The difference between operational definitions and cause-effect relationships is crucial in helping students not to view all mathematical representations as "formulas" but ask themselves what kind of relationship this particular representation is.
If you finished reading to the end, please do not forget to respond to the post.

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Eugenia Etkina
13. June

Hi all, first I wanted to welcome new members to our group - our community is growing! Welcome!!! Please visit https://www.islephysics.net/ to learn about the philosophical approach behind everything that we do, check out Resources there and here in the FILES.
As I promised yesterday, we will talk about the meaning of the negative sign in physics. Please do not forget to respond to the post after you finish reading it. WARNING: long post!
While in mathematics positive and negative mean the placement on the number line or an operation of taking away, in physics those signs have many different meanings and every time the students meet the negative sign we need to stop and talk about those meanings. Here is the list of the meanings of the negative sign (please add if you find something missing):
Direction. This meaning the students meet at the very beginning - in kinematics, when positive and negative signs are associated with the direction of the chosen positive direction of a coordinate axis when we are dealing with vectors, and then with their scalar components. When the vector is in the same direction as the chosen positive direction, the sign of its scalar component is positive, in the opposite direction - negative. The issue here is that in physics we can point the positive direction of a chosen axis in a direction we want. For example the vertical y axis can be pointed up or down depending on a problem. When you drop something, it is easier to point it down, when you throw something upward - it is easier when the axis points up. This means that the acceleration of a freely falling object is positive in the first case and negative in the second! Thus it is very important to first establish your positive direction and only then discuss the signs of components. This is also true for force components or momentum components.
We often drop the plus sign of the operation and leave negative signs of components when we write Newton's second law in component form or impulse-momentum conservation statement. In Newton's second law the acceleration is proportional to the SUM of the forces, and yet when two forces exerted on an system are in the opposite directions, we drop the addition sign and leave the negative sign indicating direction as in mathematics it does not matter. But these two signs have a completely different meaning in physics in this case! For

example, how do we write the sum of the forces exerted on an object that is being lifted by a rope? We will write mg - F^R on O, although it is in fact mg + (-F^R on O) - Rope on Object when we point the y axis up. Dropping the plus sign makes the understanding of the law difficult - is it a sum or a difference?
The next meaning of the negative sign comes when students meet work. Work is a scalar quantity and does not have any direction. And yet it can have a negative sign. What does this negativity mean? It means that due to this work the energy of a system decreases - negative sign here means taking away. When we do not stop and talk about this issue with the students they begin thinking that work has direction as this is what they are used from the previous topics.
When we write a complete expression for the gravitational potential energy or electric potential energy (- Gm1m2/r) of two oppositely charged objects (kq1q2/r), these energies are negative. This sign does not mean direction at all, but it means that the system of these two objects is bound and one needs to do positive work to separate them. The meaning of this negative sign is the most difficult for the students.
The next is the negative charge. The charge of the electron is written with a minus sign. It does not mean direction or subtraction at all. It is an arbitrary choice of notation. However, one can use this minus sign to reason about charging neutral objects. If we take an object with a charge of zero and add an electron to it - it becomes negatively charged (here I made the charge of the electron 1): 0 + (-1) = -1. If we take a an object with a charge of zero and take away an electron it becomes positively charged 0 - (-1) = +1. Note how in this case we see TWO minus signs in the expression and they mean two COMPLETELY DIFFERENT THINGS: the first one means taking away and the second one means a specific electric charge. How can a novice student navigate all this if we do not stop and discuss these issues?
PLEASE, do not forget to like the post or comment on it if you read to the end. This makes the post more visible for other group members. In general, the more posts you read and comment on, the more of them you see. I try to post every day, unless somebody else posts and then I skip not to distract attention from this other post.

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Eugenia Etkina
14. June

Hi all, today I continue the discussions of the differences between the meanings of math operations in math and in physics. Please do not forget to like the post or comment on it after you finish reading. You do not really need to like it, but clicking on the "like" you make the post more visible. 🙂
Today is about operations.
Addition of real numbers: in math you can add any two real numbers. In physics you cannot. These numbers, representing physical quantities, need to have the same units. It sounds

simple but in fact, it is a learned concept that we take for granted. It is especially important as students often forget to add units to their answers.
Subtraction of real numbers: same as addition - the real subtraction operation can only be performed with the physical quantities that have the same units.
Multiplication. Here we get into complications. In math multiplication means addition of the same number several times. In physics, it only means the same when you multiple a physical quantity by a number without units. For example m=3 kg, 5 m=15 kg. But when two multiplied quantities have different units, the resulting quantity is a new quantity that cannot be found by adding any of the original ones and the units of this new quantity are the product of the units of the original quantities. How wild is that? For example: 1000kg/m^3 X 2 m^3 = 2000 kg (mass from density and volume)
or 2 N X 3 m = 6 Nm=6 J (work from force and distance). I am not even getting into multiplication of vectors and scalars or two vectors. I am only talking about the most simple operations with real numbers. Most of physical quantities are defined as ratio quantities (see division below) but many are product quantities. In both cases the mew quantity is different from both quantities that were used to define it and has different units. Nothing like that happens in math!
Division has the same issues. When we divide distance by time we get a new quantity - speed! The first quantities that the students construct - speed and acceleration - are ratio quantities, later come momentum, work, etc. that are product quantities. Discussing the difference between product and ratio in math and physics is crucial.
Next come issues with the concept of a function and graphing, but this is for a later post...

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Eugenia Etkina
15. June

Hi all, today my post is about functional dependencies and the difference in their representations in math and physics. Please do not forget to respond to the post to make it more visible.
A function in math is a recipe. You have an independent variable (sometimes called argument of a function) x and you do specific things to it to get the function y. The function tells you what to do with x to get a y. In physics an independent variable can be notated as an arbitrary letter, the same as the function. For example when in a math class we write y = mx +b, we know that the recipe tells us that y linearly depends on x, and x is an independent variable and y is dependent. But when we write in a physics class x = 3 m/s t + 5 m, we have t as an independent variable and x as dependent. Or, even worse - v = 3 m/s/s t + 2 m/s where t is independent variable and v is dependent. How can students adapt to those differences?
We suggest discussing this issue upfront the moment the students need to draw their first kinematics graphs and then continue discussing with every new physical representation. It also helps to discuss why t is always an independent variable on kinematics graphs. Time is

truly independent of anything we do... I am attaching a screenshot from Chapter 2 in the textbook where we have an example of such discussion with a Tip for the students. Note, that the Tips in our chapters are for the issues that research has found to be difficult for the students. Do not skip them and encourage the students to discuss those. If you read to the end, please do not forget to respond!

2.5 Representing motion with data tables and graphs 23

Time t is usually considered to be the independent variable, as time progresses even if there is no motion, so the horizontal axis will be the t-axis. Position x is the dependent variable (position changes with time), so the vertical axis will be the x-axis.

Plot the data in each row in Table 2.2 on the axes. Each point on the horizontal axis represents a time (clock reading). Each point on the vertical axis represents the position of a beanbag. When we draw lines through these points and perpendicular to the axes, they intersect at a single location—a dot on the graph that simultaneously represents a time and the corresponding position of the object. This dot *is not* a location in real space but rather a representation of the position of the beanbag at a specific time.

Is there a trend in the locations of the dots on the graph? We see that the position increases as the time increases. This makes sense. We can draw a smooth best-fit curve that passes as close as possible to the data points—a **trendline** (Figure 2.13c). It looks like a straight line in this particular case—the position is linearly dependent on time.

Correspondence between a motion diagram and position-versus-time graph

TABLE 2.2 Time-position data for linear motion

Clock reading (time)	Position
$t_0 = 0.0$ s	$x_0 = 1.00$ m
$t_1 = 1.0$ s	$x_1 = 2.42$ m
$t_2 = 2.0$ s	$x_2 = 4.13$ m
$t_3 = 3.0$ s	$x_3 = 5.52$ m
$t_4 = 4.0$ s	$x_4 = 7.26$ m
$t_5 = 5.0$ s	$x_5 = 8.41$ m
$t_6 = 6.0$ s	$x_6 = 10.00$ m

TIP The quantity that appears on the vertical axis of a graph can represent the position of an object whose actual position is changing along any axis. The position on the vertical axis does not mean the object is moving in the vertical direction.

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Eugenia Etkina
19. June

Today my post is about questions that we ask (I will discuss the questions that students ask or should ask, tomorrow). When you read the post to the end, please do not forget to respond to it (like or comment).
Over the years I came up with the names of "open" questions and "closed" questions for the oral questions that we ask in class (not the questions in the handouts, for those, please see OALG files posted here). Open questions assume multiple correct answers or they even do not care about the correctness, just students' ideas. Multiple students are welcome to answer. Closed questions assume one right answer and one person who knows it. For example, you are interested in how your students understood the concept of acceleration. You might ask:
Who knows what acceleration is?
Or: What is acceleration?
Or: What is the definition of acceleration?
All these questions assume confidence in those who answer and the existence of one right answer. These are closed questions.
How to turn them into open questions? Here are some examples:
Please tell me what you "see" when I say the word "acceleration".
Please give me two examples of real objects that move with acceleration. How will you know?

Think of a few differences between velocity and acceleration.

Eugenia says: "Acceleration is the change in velocity". Why would she say this? Do you agree with her? If you disagree, how you help her agree with your point of view?

David says that an object with acceleration of 5 m/s/s speeds up and an object with acceleration of -5 m/s/s slows down. Eugenia disagrees. What can be possible reasons for her disagreement?

How would you explain the idea of acceleration to somebody who has never studied physics?

Please give me an example of an object that has positive acceleration and is slowing down and negative acceleration and is speeding up.

How do you know if an object is accelerating?

What are your thoughts about acceleration?

How would you represent an object slowing down with a motion diagram?

If you compare the first set of questions to the second, you will find that in the second set each question assumes the existence of multiple answers and no one needs to know all of them. Therefore the "fear of the wrong answer" barrier is reduced and many more students can participate.

In general I avoid starting my questions with: What is XX? What is the answer to XX? Who knows XX?

The next step is how to elicit answers to the questions. Sometimes I think that a question is easy and everyone should be able to answer it. Then I ask the whole class and wait for volunteers. I try not to call on the same person the second time before all others had a chance to participate and try not to miss girls holding their hands (as you know, they are often invisible). But if after 10 -15 seconds no hands rise up, I say: OK, let's have 2 minutes in your groups to come up with ideas and then we will share them. This approach reduces the need for an immediate personal right answer even more.

In general, to invite more students to answer your questions, it is useful to start them with: What are your thoughts about XX? What are your ideas? How would you approach XX? What is your image of XX? How can we convince XX in XX? Tell me more about XX... Who can add to XX? Any ideas about how we can explain XX? Any ideas how we can test XX?

The next step is when somebody answers, I do not validate. I keep a straight face and ask the rest of the class - What do you think? The goal is to communicate the message that I am not the final authority, that they need to figure it out themselves. ("What do you think?" is called a Reflective Toss - the name coined by Jim Minstrell a long time ago.) Then somebody in the class responds and I stay back until the discussion between the students starts. Open questions invite or trigger discussions, closed questions do not.

What is your approach to questions? Please post here. And please do not forget to respond to this post to make it more visible.

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Eugenia Etkina
20. June

Hi all, today I repost my yesterday's post as it was hidden under the welcoming message to the new members and people might not have realized it was there. We have more new members today - WELCOME and please read my post from yesterdays with the directions of what to do.
For the repeat of the yesterday's post: please comment: what are your approaches to questioning students to make them relaxed and comfortable? Here is my yesterday's post:

Today my post is about questions that we ask (I will discuss the questions that students ask or should ask, tomorrow). When you read the post to the end, please do not forget to respond to it (like or comment).
Over the years I came up with the names of "open" questions and "closed" questions for the oral questions that we ask in class (not the questions in the handouts, for those, please see OALG files posted here). Open questions assume multiple correct answers or they even do not care about the correctness, just students' ideas. Multiple students are welcome to answer. Closed questions assume one right answer and one person who knows it. For example, you are interested in how your students understood the concept of acceleration. You might ask:
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Please give me two examples of real objects that move with acceleration. How will you know?
Think of a few differences between velocity and acceleration.
Eugenia says: "Acceleration is the change in velocity". Why would she say this? Do you agree with her? If you disagree, how you help her agree with your point of view?
David says that an object with acceleration of 5 m/s/s speeds up and an object with acceleration of -5 m/s/s slows down. Eugenia disagrees. What can be possible reasons for her disagreement?
How would you explain the idea of acceleration to somebody who has never studied physics?
Please give me an example of an object that has positive acceleration and is slowing down and negative acceleration and is speeding up.
How do you know if an object is accelerating?
What are your thoughts about acceleration?
How would you represent an object slowing down with a motion diagram?
If you compare the first set of questions to the second, you will find that in the second set each question assumes the existence of multiple answers and no one needs to know all of them. Therefore the "fear of the wrong answer" barrier is reduced and many more students can participate.
In general I avoid starting my questions with: What is XX? What is the answer to XX? Who knows XX?
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groups to come up with ideas and then we will share them. This approach reduces the need for an immediate personal right answer even more.
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Eugenia Etkina
21. June

Hi all, today I continue to talk about questions. Two things before I starts: 1) We have many new members again - WELCOME! To benefit from the group, please read the post from 2 days ago and the welcoming message on the top of the group. 2) Do not forget to respond to the post after you read it to make it more visible.
Yesterday I talked about teachers asking questions. This time it is about students asking questions. Although "Asking questions" is the #1 science practice in the Next Generation Science Standards, in a teaching practice we have tools to reward students for good answers but not for good questions. Have you ever given a grade to your student for asking a good question? And what are good questions?
If you look at the history of physics, the scientists who we all know are those who dared to ask a question about something that everyone else accepted as true (dogma in a way). Galileo asked whether it was true that all objects fall at constant speed with that speed proportional to their mass (Aristotelian dogma). Newton asked how the Moon orbits Earth. Einstein asked how we can figure out what would happen if we could travel on a light ray or be placed in a closed elevator in a free fall - would you know that you are not standing on Earth? So, bottom line, asking good questions is as important, even if not MORE important than giving good answers.
When I was teaching high school, on the first day of class, I would tell my students that questions were very important and if anyone asked a great question (I would be the person to judge that), this person would receive the same number of points as they would on a perfectly correct test. And during my teaching about 1 person per term would get these points. And everyone clapped when I would say" "This question is a great question, such and such

scientist asked it too and this is what happened after - I would tell a short story - and the student who asked it would receive the points". Of course, it is a subjective decision but in all my years of teaching no student ever argued that some question that I found worthy of the points was not. Often, a good question would change my lesson plan and we would continue our investigations to answer it. This is true even for questions that were not this remarkable - I tried to show my students that almost every question they asked made me change what I planned to do and follow the "need to know". However, we all know, that sometimes the questions are irrelevant or distracting. For those we need all our tact to show the student that we respect the question but it is out of the field of our studies or that it will be answered later.
Now, how do we teach students to ask good questions? First, the students should feel safe to ask. Neither we, nor other students should ever comment or make make fun of a person asking a question. But this is not enough. The same way as we teach students to reason like physicists, or to read the textbook as experts (interrogation method that is described in the first chapter of our textbook and in the activities in the 1st chapters of the ALG and OALG), we need to teach them to ask good questions. The whole ISLE approach lends to good questions. Below I will give a few examples of good questions based on the ISLE process:
Observational experiments questions: How do we infer a pattern from these data? How do we best represent the data? How can we explain the pattern? How many different explanations can we devise for the pattern? How do I know if it is a good idea to linearize data to find the pattern?
Model/explanation/hypothesis development questions: How do I start thinking about making mathematical model for the pattern? How do go about finding a mechanism? How do I know that my explanation is correct? How do I design and experiment to test the model/explanation/hypothesis? How do I know if this is a good experiment?
Testing experiment questions: How do I make a prediction of the outcome of the testing experiment using the hypothesis under test? How do I know if my experiment would give me the outcome that will allow me to differentiate between two hypotheses that I have? Were there any additional assumptions did I make when I made the prediction? How can I validate them? How do I determine the uncertainty in my result? How do I know if my experiment ruled out the hypothesis/model/explanation?
I can go on the make a list of good questions for application experiments and for different multiple representations, but you probably already see the pattern here. Almost all good question start with How do I know this? (best questions ever) or How do I do such and such? and NOT with the word WHAT. Note also, that I did not list any good questions that start with the word WHY. Why is that? (no pun intended) While the students often ask the questions starting with WHY, those are in fact the questions that have HOW in them. Sometimes though "Why" questions hide the purpose of the phenomenon, not how it happens. And if you answer them, then often the answer is anthropomorphic (Anthropomorphism is the attribution of human traits, emotions, or intentions to non-human entities. It is considered to be an innate tendency of human psychology). For example: why do objects fall down on Earth? Answer: because they want to be in a state with the smallest gravitational potential energy. In fact, the objects do not want anything, and we just gave them human characteristics with our answer. Most famous answer to the question WHY was given by Newton who was asked WHY gravity exists. He said that he did not care why, he only cared HOW to describe it.
To teach students to ask good questions you need to model them and to explain to the student why 🙂)) a specific question is good. And of course, to reward them, as I described above.

We have examples of such questions in our materials, for specific elements of the ISLE process - in the labs at https://sites.google.com/.../scientificab.../isle-based-labs
A long time ago we did a study correlating the quality of the questions that students asked about the material once a week as a homework assignment and their learning gains. Those who asked questions that I described as "good" above has significantly higher gains than those who focused on "what" type of questions. I will post the paper later, Facebook does not allow me to add the file to this post as I already put a link. Please, if you read to the end, do not forget to like or reply to the post. Thank you.

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Eugenia Etkina
22. June

Hi all, three things today (and please do not forget to like or comment on the post when you finish reading it):
First I wanted to welcome new members - our community is growing every day. New members, please read my posts from 2 days ago to learn how to benefit from the group and please ask questions!
Second, I am posting the paper about the relationship between the quality of students' questions and their learning gains.
Third, when I talked to Paul Bunson who led the workshop on relativity last Saturday, he told me that many attendees said that they are not familiar with the ISLE approach. As our group is for those who are using the ISLE approach, or learning to use it and who are using our textbook "College Physics: Explore and Apply" (both regular and AP editions), I am wondering how else I could help people learn about the ISLE approach. We have regular workshops about it (we just finished an 8 hour workshop), we have monthly meetings during the school year, there is a website with the description and resources at islephysics.net and lots of materials posted here in the FILES. What else can we do to help people learn about the ISLE approach? All your suggestions are welcome!

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Eugenia Etkina
23. June

Hi all, today my post is about the new types of problems that we have in our textbook College Physics: Explore and Apply (the cover of the book is the cover of this Facebook group). But before I go on, I wanted to welcome our new members - we got more new members yesterday - WELCOME and remind you to like the post or comment on it to make it more visible.
Now - about the problems. Traditional physics problems are word problems describing a situation and a student needs to find the right answer (there is always one right answer to those problems) and all the simplifications of the situation are given. Such problems in cognitive studies are called "puzzles" as they require to put the pieces together in one right combination.
Real problems do not have one right answer and demand the solver to make simplifying assumptions and evaluate their effect on the answer (they require epistemic cognition). Workplace studies show that those types of reasoning are lacking among college graduates. College Board recognized the limitations of puzzles and revised its AP exams to reflect the importance of the problems that assess conceptual reasoning, ability to work with real data and multiple representations.
In our textbook the types of problems that we have addressed both issues - developing epistemic cognition and preparing students to solve AP types of problems. In addition these new types of problems help students learn to reason like physicists - one of the major goals of the ISLE approach. I attached the table that classifies our non-traditional types of problems and in the next 10 days or so I will post examples of each type and discuss how this specific type develops epistemic cognition and helps students learn to think like a physicist. This table is in the first chapter of the Instructor Guide posted here in the FILES.
I also want to mention that our textbook is the only textbook on the market that has these different types of problems. If you read to the end, please do not forget to respond to the post.

Type of problem	Keywords	Description
Ranking tasks (RAT)	Rank, compare	The students have to rank the values of a certain physical quantity in different situations in descending or ascending order.
Choose answer and explanation (CAE)		The students have to choose the correct answer AND the correct matching explanation (cause-effect or mechanistic) in order to get full credit
Choose measuring procedure (MEP)	procedure	The students have to choose (or propose) the correct (or the best) experimental procedure that will allow to measure/determine a certain quantity.
Evaluate (reasoning, solution…) (EVA)	Evaluate, your friend says, agree, explains, reconcile, comment on	The students have to critically evaluate reasoning of some (imaginary) persons or evaluate the suggested solution to the problem (given either in words, graphs, diagrams or as equation). The students have to recognize productive ideas (even when they are embedded in incorrect answers) and differentiate them from unproductive ideas.
Make judgment (based on data) (MJU)	Hypothesize, decide	The students have to make judgement about one or more hypotheses, based on data or other forms of evidence that are given in the problem, sometimes taking uncertainties into account.
Linearization (LIN)		First, the students have to write the equation that describes the relevant situation. Then they have to rearrange the equation to obtain a linear function (note that independent and dependent variables in this function can be any function of data given in the problem). Students then draw the graph, plot the best-fit line, and determine unknown quantities using the best-fit line. These problems help students combine knowledge of physics, the ability to "read and write" with graphs, he ability to manipulate equations, and the ability to recognize linear dependence in non-standard situations.
Multiple possibility and TELL ALL (NPO)	Everything you can, tell all, make a list, all possible	The students have to list as many quantities as they can that can be determined based on data given in the problem, or tell everything they can about the physical attributes of the objects that appear in the text or relations between them. Normally, students are required to determine the values for only few of the quantities that they identify. These problems allow all students to feel successful.
JEOPARDY (JEO)	Jeopardy, invent a problem, pose a problem	The students have to convert a representation of a solution into a problem statement. If the solution is given in a form of an equation, they need to understand the meaning of the quantities and their units. Such problems emphasize the value of units.
Design an experiment (or pose a problem) (DEX)	Design, invent, write your own problem, pose	The students have to design an experiment, an experimental procedure or a device that will allow the, to measure/determine certain physical quantities or that would meet specific requirements. The students have to pose a problem that involves certain objects with given characteristics. Often there is an additional requirement that the solving the problem should involve the use of a particular physics topic/law/principle. The students may also need to do an additional literature search.
Problem based on real data (RED)		The students have to solve problems that are based on real data, obtained in real-life situations, often using easy available equipment and/or equipment that is typically used in student labs. The types of problems may be traditional or any of the types presented above. The students need to deal with uncertainties, anomalous data and assumptions and to propose meaningful models.

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Eugenia Etkina
24. June

Hi all, I continue my series of posts about problem types. In the table that I posted yesterday (THANK YOU for responding so enthusiastically to it, the number of those who saw the post is almost 700! Please continue to respond to every post you read!) the first type is RAT (cool name) - Which means Ranking Tasks.

Ranking tasks develop metacognition as they invite the solvers to compare and contrast different answers. Research shows that one learn what something IS when they know what it IS NOT. Sounds complicated, right? Here is an example of comparing and contrasting question (also from our textbook): Give an example of. situation when the velocity of an object is zero but acceleration is non-zero. Here you can see how comparing and contrasting allows a student to REALLY understand the difference, especially those who confuse v with delta v.

Now back to ranking tasks that achieve exactly the same goal. While this is not exactly a new type of problems, the way we approach it is different. Traditionally, such problems are similar to multiple choice questions, only instead of choosing one answer you need to rank the given ones in order of increasing or decreasing (this ranking allows the students to compare and to contrast). Below I show one example that illustrates how our approach is different. We ask the students to come up with several answers themselves and then rank them in order of increasing or decreasing. I am attaching a screen shot of the problem, it is from Chapter 7. I invite you to post your answers (it was found to be very difficult for the students and even for physics teachers).

In addition to this example, I am pasting the list of non-traditional problems of all types in Chapter 7. The list is from the Instructor Guide - posted here in the FILES or available freely from Mastering Physics website. If you have our textbook, I strongly recommend downloading the Instructor Guide and studying every chapter before you plan your instruction for the topic. Especially if you are teaching AP 1 or 2. See below how we provide help choosing non-traditional problems.

Nontraditional end-of-chapter questions and problems

Ranking tasks (RAT): P7.72

Choose answer and explanation (CAE): Q7.10, Q7.14, Q7.22

Evaluate (reasoning or solution...) (EVA): Q7.13, Q7.16, Q7.21, P7.29, P7.43, P7.44, P7.75

Make judgment (based on data) (MJU): P7.52, P7.53

Multiple possibility and tell all (MPO): P7.16, P7.28

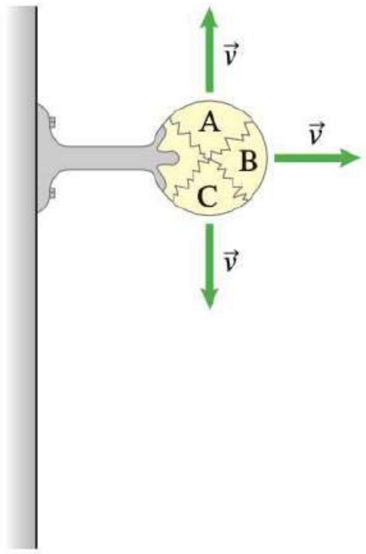
Jeopardy (JEO): P7.39, P7.40, P7.41, P7.42

Design an experiment (or pose a problem) (DEX): Q7.17, P7.74, P7.80, P7.82

If you finished reading, please respond to the post! Thank you!

72. * A spherical street lamp accidentally explodes. Three equal pieces A, B, and C fly off the lamp holder with equal speeds but in different directions, as shown in **Figure P7.72**. (a) Compare the speeds with which each piece hits the ground. (b) Compare qualitatively the times needed for each piece to reach the ground. Indicate any assumptions that you made.

FIGURE P7.72



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Eugenia Etkina
26. June

Hi all, thank you for your responses to my yesterday's post. Today I continue with the problem types and the topic is EVA - Evaluate Reasoning and Solution. Please do not forget to respond to the post after you finish reading it.
In EVA problems and questions students are asked to evaluate somebody else's reasoning or answer. It can be an equation that somebody derived and the students need to evaluate it using limiting cases, or a statement that somebody made and the students need to first reason how that person reasoned, compare their reasoning to the reasoning of that person and sometimes even convince that person in their reasoning.
In these problems and questions the students practice metacognition and epistemic cognition as they need to think about somebody else's thinking, and evaluate reasoning and assumptions. These are the highest levels of cognition and they are not developed at all by solving traditional problems. Research by Aaron Warren showed that ISLE students taught in systematic evaluation outperform other ISLE students on traditional problems. (If you are interested, I will post his paper in PhysREV PER.)
I cannot attach two things to one post unfortunately. I am attaching one example from Chapter 8 (Statics) and challenge you to solve it.

I am also pasting the list of other non-traditional problems in this chapter. I paste them for the chapters from which I take the examples each day so that you can see the richness and abundance of such problems in our textbook. If you do not have the textbook, reach out to your Pearson rep and get an examination copy ASAP! Please do not forget to respond to the post once you finish reading it, thank you!

Nontraditional end-of-chapter questions and problems

Ranking tasks (RAT): P8.67

Evaluate (reasoning or solution...) (EVA): Q8.11, Q8.14, P8.56, P8.57, P8.58, Multiple possibility and tell all (MPO): Q8.16, P8.3, P8.17, P8.18

Design an experiment (or pose a problem) (DEX): Q8.22, P8.58, P8.59

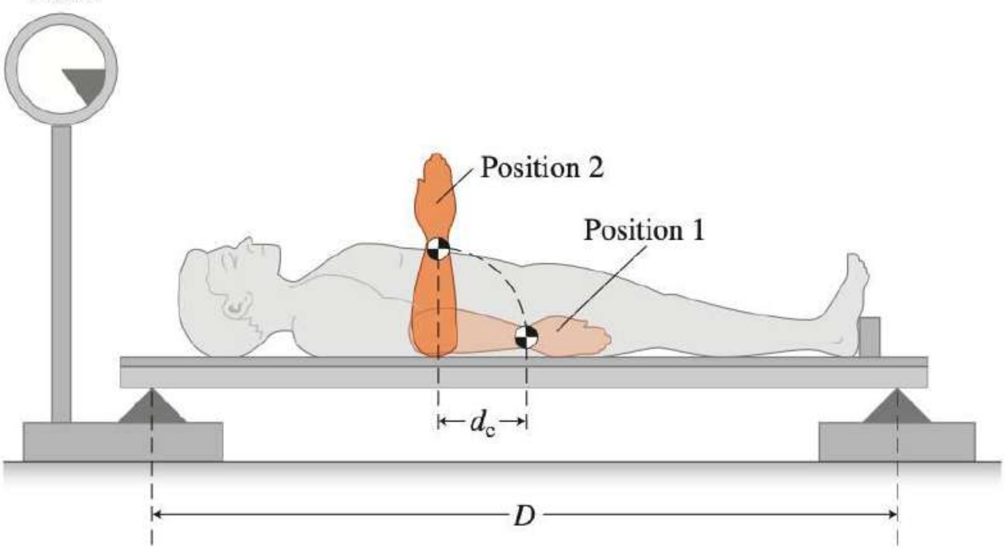
Problem based on real data (that students can collect by themselves) (RED): P8.17, P8.56

57. * BIO While browsing books on neurophysiology, you come across a book published in 1967 by Soviet neurophysiologist Nikolai Aleksandrovich Bernstein, *The Co-ordination and Regulation of Movements*, in which he describes a technique to determine the mass of a part of the human body if the position of the center of mass of that body part is known. His technique for determining the mass of the forearm is described as follows: The person lies on a support board, as shown in **Figure P8.57**. Two readings of the scale are taken: first with the forearm held in position 1 (m_1) and second with it in position 2 (m_2). Knowing the distance from the elbow to the center of mass of the forearm (d_c) and the distance between the knife edges supporting the board (D), the mass of the forearm and hand can be calculated from the following expression:

$$m_{fh} = \frac{D(m_2 - m_1)}{d_c}$$

(a) First, without deriving the expression, evaluate it to see if it is reasonable. Are the units correct? Is the sign of the expression positive? Are qualitative dependences reasonable? (b) Now derive the expression. (c) Why do you think it is important to place the support board on knife edges instead of rigid blocks?

FIGURE P8.57



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27. June

Hi all, today the post is about MEP problems - Choose Measuring Procedure. Those are extremely useful for AP and simultaneously very ISLEish as in the ISLE approach the students continuously engage in experimental design. When you finish reading, do not forget to respond to the post to make it more visible.
As, always I first comment on the levels of cognition involved in solving every type of problems. The MEPs are golden in this respect as they involve all three levels - cognition - as the student needs to understand the content, metacognition as they need to think how to approach the design and epistemic cognition (the highest level) as they need to evaluate all given procedures to decide what is relevant, useful, possible, etc.
I am attaching a problem from Chapter 19 - Electric Circuits and, as always, the list of other non-traditional problems available in this chapter. Please offer your answers! And, please do not forget to respond to the post after you finish reading it and solving the problem!
Nontraditional end-of-chapter questions and problems
Ranking tasks (RAT): P19.16, P19.17, P19.51
Choose measuring procedure (MEP): P19.78
Evaluate (reasoning or solution...) (EVA): Q19.25 Q19.28, P19.24, P19.71
Make judgment (based on data) (MJU): Q19.12
Multiple possibility and tell all (MPO): P19.13, P19.25, P19.53, P19.54
Jeopardy (JEO): P19.39
Design an experiment (or pose a problem) (DEX): Q19.19, P19.9, Q19.26, P19.60, P19.70, P19.74
Problems based on real data (RED): P19.52

78. ** Jesse needs to determine the resistance of a resistor. Which method should he use? If you think that more than one of the described methods is useful, compare your choices and explain which would give the most accurate result. Describe any assumptions that you made. The final step in all methods is to calculate the resistance of the resistor as $R = \frac{\Delta V}{I}$.

(a) Connect a voltmeter to a battery's terminals. Record the voltage reading ΔV. Then (in a different experiment) connect the battery, the resistor, and an ammeter in series. Record the current reading I.

(b) Connect a battery, the resistor, and an ammeter in series and connect a voltmeter in parallel to the resistor. Record the current reading I and the voltage reading ΔV.

(c) Connect a battery, the resistor, an ammeter, and a voltmeter in series. Record the current reading I and the voltage reading ΔV.

(d) Connect a battery, the resistor, and an ammeter in series and connect a voltmeter in parallel to the ammeter. Record the current reading I and the voltage reading ΔV.

(e) Connect a battery, the resistor, and an ammeter in series. Record the current reading I. Then (in a different experiment) connect the resistor to the battery and a voltmeter in parallel to the resistor. Record the voltage reading ΔV.

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Eugenia Etkina
28. June

Hi all, today my post is about the MJU problems - Make Judgment based on Data. As the previous types - it is very common for AP exams and is very ISLEish. Hmmm - I have been writing this a lot lately. Interesting, how AP exams are aligned with the goals of the ISLE approach. Only the ISLE approach was developed much earlier. I do not think that AP developers used the ISLE framework to write the curriculum and make the exams, but I think the match means that the goals that we set for ISLE many years ago are very timely and many educators share them. So, we have MJU problems today, and please do not forget to like or comment on the post after you finish reading it and solving the problem. Yesterday's problem is still not attempted. 🙁

In the MJU problems the students are given quantitative or qualitative data and they need to invent a hypothesis or decide which of the given hypotheses might explain or account for the data. This is an authentic scientific problem as in many fields of physics the scientists do not collect their own data but have to analyze and make sense out of the data collected by somebody else. For example in X-ray astrophysics the data come as tables of photon counts collected by X-ray satellites and astrophysicists have the model these data to decide - Is it a pulsar? A Supernova remnant? A black hole? So the MJU problems are as authentic as they get... Needless to say that they develop the highest level of cognition - epistemic cognition as the solver needs to make a decision about the data and evaluate the reasonableness of the decision.

I am attaching a screen shot of my favorite MJU problem in the whole book. It involves one of my stuffed toys - a Piglet (a friend of Winnie the Puh, who I have too) and therefore is very human. Plus the data are awesome - unexpectedly. I was shocked when we analyzed them. The video was taken, of course, by Gorazd Planinsic. Please take a minute to analyze the data!

The follow-up problem explaining the reasons for the data to be this way is in Chapter 4: (84. *In the situation of Problem 2.71 (Chapter 2) and using the data in the accompanying table, determine the coefficient of kinetic friction between Piglet and the wooden floor.)

I am also pasting all other non-traditional types of problems in this chapter. Notice that it is Chapter 2 in the textbook, just the beginning, and the list is huge. This means that we want the students to consider these problems "normal" physics problems, they will be "traditional" for them if they have to solve them from the beginning. The audience that resists these problems are the teachers, actually, not the students, as such problems take them out of their comfort zone. If you finish reading the post, please respond! Thank you!

Non-traditional end-of-chapter questions and problems

Choose answer and explanation (CAE): Q2.8

Choose measuring procedure (MEP): Q2.11

Evaluate (reasoning or solution...) (EVA): Q2.28

Make judgment (based on data) (MJU): P2.71

Multiple possibility and tell all (MPO): P2.18, P2.24, P2.25, P2.39, P2.59 Jeopardy (JEO): Q2.22, P2.17

Design an experiment (or pose a problem) (DEX): Q2.27

Problem based on real data (that students can collect by themselves) (RED): P2.71, P2.75, P2.76, RP2.

RP is the Reading Passage. If you are teaching pre-med students, these reading passages and supporting MC questions are a must!

71. * While babysitting their younger brother, Chrisso and Devin are playing with toys. They notice that the squishy Piglet slows down in a repeatable way when they push it along the smooth wooden floor. They propose a hypothesis that the toy slows down with a constant acceleration, which does not depend on the toy's initial velocity. For each of five different initial speeds, they measure the distance traveled by the toy from the time they stop pushing it to the time the toy stops moving, and they measure the corresponding time interval. Their data are presented below. Do the data support their hypothesis? Explain. If yes, determine the average acceleration of Piglet and the maximum speed with which Chrisso and Devin push Piglet.

Experiment #	Distance (m)	Time (s)
1	0.96	0.65
2	2.84	1.12
3	1.72	0.87
4	2.53	1.05
5	0.62	0.53

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Eugenia Etkina
29. June

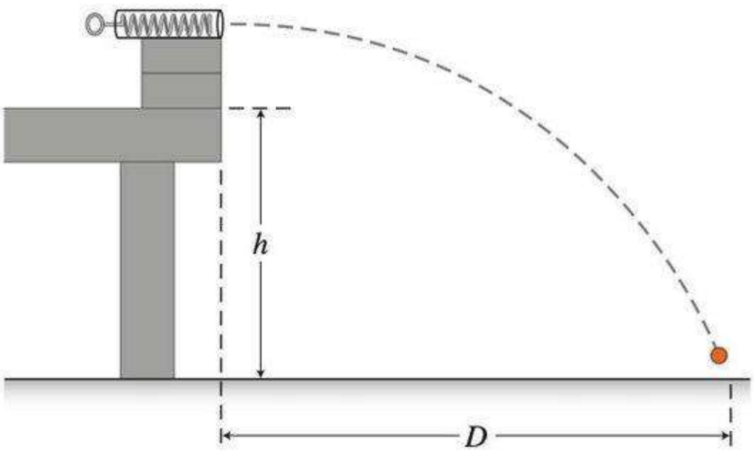
Hi all, I continue today with new types of problems, but before I do it, I wanted to WELCOME our new members (please see Hrvoje Miloloža's post today to find what has been posted here over the years) and try learn about the ISLE approach which is the foundation of everything we do here. To do this, go to islephysics.net and study as much as you can there. And when you read the post, do not skip "liking" it or commenting - your response makes the post more visible for others.

OK - now to problems. Today is the LIN problems - Linearization problems - the favorite of Modeling Instruction approach, AP exams and most of all - physicists, as linearizing the data is the skill that helps find functional dependencies in the data. This is how we describe such problems (copied from the Instructor Guide):
First, students have to write an equation that describes the relevant situation. Then they have to rearrange the equation to obtain a linear function (note that the independent and the dependent variables in this function can be any function of data given in the problem). Students then draw the graph, plot the best-fit line, and determine the unknown quantities using the best- fit line. These problems help students combine knowledge of physics, the ability to “read and write” with graphs, the ability to manipulate equations, and the ability to recognize linear dependence in non-standard situations.
Sounds like a lot of achieved "with one stone"... The example I am pasting here is from Chapter 4 - Applying Newton's laws. This chapter is very special. If you did not study it in detail, I strongly recommend as we have a different approach to friction there compared to the rest of the world. I posted about this approach a few months ago, but if you are new to this group, or just adopted the book or attended the workshop and got access to the e-book, do not skip 4 - it will surprise you!
The chapter is also extremely rich with non-traditional problems - see for yourself:
Nontraditional end-of-chapter questions and problems
Ranking tasks (RAT): P4.55, P4.56
Choose answer and explanation (CAE): Q4.4
Choose measuring procedure (MEP): P4.25
Evaluate (reasoning or solution...) (EVA): P4.39, P4.74
Make judgment (based on data) (MJU): P4.63
Linearization (LIN): P4.86
Multiple possibility and tell all (MPO): P4.18, P4.48, P4.93
Jeopardy (JEO): P4.14, P4.38, P4.59
Design an experiment (or pose a problem) (DEX):, P4.92
Problem based on real data (that students can collect by themselves) (RED): P4.19, P4.75
I challenge you to solve the problem - to determine the speed of the marble and the height. Please share your solution here! And please do not forget to respond to the post when you finish reading it, it will make the post more visible for other group members.

86. ** Debbie wants to determine the initial speed at which a spring toy shoots a marble. She assumes the toy shoots the marble with the same speed every time. She shoots the marble horizontally from different heights, using different numbers of bricks with equal heights of 20 cm on a table as a support (see **Figure P4.86**). In every experiment she records the number of bricks and the distance D from the table the marble lands (see the table at right). When she finishes collecting the data, she realizes that she has forgotten to measure the distance between the surface of the table and the floor, h. Determine the initial speed of the marble and the distance h using Debbie's data. (Hint: This problem requires linearization. First, express distance D as a function of initial speed of the marble and the height from which the marble is shot. Then rearrange the equation to obtain linear dependence on the height, plot the best-fit line, and determine unknown quantities from the data that you obtained from the graph.)

# of bricks	D (m)
0	0.42
1	0.48
2	0.54
3	0.59
4	0.64

FIGURE P4.86



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Eugenia Etkina
30. June

Hi all, today I continue with the types of problems. Please do not forget to respond to the post after you finish reading it. But first I want to WELCOME to our new members (we have new members every day!). Welcome, people! Please visit islephysics.net to learn about the ISLE approach - the foundation of all the activities we discuss here and the textbook that is based on it.

Today my post is about MPO problems - Multiple Possibility and Tell All problems. The goal of these problems is epistemic cognition - the highest level of cognition, when the solver needs to examine possible solutions depending on the assumptions and decide what they can determine using the available data (this addresses the first intentionality of the ISLE approach - helping students learn physics by practicing it). These problems also allow students of different level of preparation to be successful, thus addressing the second intentionality - helping students feel successful and develop their confidence and physics identity. I am pasting below two problems from Chapter 18 Electric field and the list of other non-traditional problems in this chapter, and a screen shot of one more problem from Chapter 20 - Magnetism. Decide which one you would like to solve.

42** Earth's electric field Earth has an electric charge of approximately -5.7 x 10^5 C distributed relatively uniformly on its surface. Determine as many quantities as possible about the electrical properties of the space around Earth. Use any additional information that you need. Indicate any assumptions that you made.

52*The dielectric strength of air is 3 X 10^6 V/m. As you walk across a synthetic rug, your body accumulates electric charge, causing a potential difference of 6000 V between your body and a doorknob. What can you can estimate using this information?

Nontraditional end-of-chapter questions and problems

Ranking tasks (RAT): P18.32, P18.33, P18.57

Evaluate (reasoning or solution...) (EVA): Q18.7, Q18.16, Q18.17, P18.61 Make judgment (based on data) (MJU): P18.58

Linearization (LIN): P18.59

Multiple possibility and tell all (MPO): P18.18, P18.42, P18.52

Jeopardy (JEO): P18.19, P18.20, P18.30, P18.31

Design an experiment (or pose a problem) (DEX): Q18.10, P18.34

If you finish reading (and solving the problems), please respond to this post to make it more visible, thank you!

36. ** EST The magnitude of the $\vec{B}$ field inside a long solenoid is given by the equation $B = \mu_0 I\,(N/l)$, where N is the number of turns and l is the length of the solenoid. (a) Describe an experiment that can help you test this relation. (b) Explain whether this equation is an operational definition of the magnitude of the $\vec{B}$ field or a cause-effect relationship. (c) Powerful industrial solenoids produce $\vec{B}$ field magnitudes of about 30 T. Estimate the relevant physical quantities for such solenoids.

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Eugenia Etkina

1. July

Hi all, today I continue our discussions about non-traditional types of problems. But before I start, we have more new members! WELCOME, people, to our community! To learn the philosophy of the ISLE approach and resources available, go to islephysics.net and also explore the FILES posted here. You will benefit from the group the most if you check the posts every day.

Today the post is about JEO - Jeopardy problems. These are the problems that have an answer in the form of an equation or another physics representation (graph, force diagram, bar chart, etc.) and the student needs to come up with a problem or a situation for this answer and make other representations. These types of problems were invented by

Alan Van Heuvelen and colleagues about 20 years ago and they appeared first in our very first edition of the Active Learning Guide in 2005. Since then the spectrum of the problems expanded and we have a lot of them in the textbook and the ALG/OALG.

The jeopardy problem that only use mathematical expressions of a solution and look very unusual for the students at first and they do not know what to do with them. But these problems are amazing at helping students to appreciate the role of units and learning to visualize problem situations. Do not skip them - once the students get used to these problems, they love them! Jeopardy problems develop metacognition (as the students need to think about their own thinking) and epistemic cognition, as their answer depends on how they visualize the situation, and multiple correct answers exist.

Here are a few examples from Chapter 5 - Circular motion. Notice that 9.8 has the units of N/kg, not m/s^2. These are the units we use for g in the dynamics problems to underscore that it is not the acceleration, but a coefficient helping to determine the force that Earth exerts on a system. If you read the post to the end, do not forget to respond to it and to post answers! Thank you!

32. * **Equation Jeopardy 1** Describe using words, a sketch, a velocity change diagram, and a force diagram two situations whose mathematical description is presented below.

$$700\ \text{N} - (30\ \text{kg})(9.8\ \text{m/s}^2) = \frac{(30\ \text{kg})v^2}{12\ \text{m}}$$

33. * **Equation Jeopardy 2** Describe using words, a sketch, a velocity change diagram, and a force diagram two situations whose mathematical description is presented below.

$$\frac{(2.0\ \text{kg})(4.0\ \text{m}^2/\text{s}^2)}{r} = 0.4 \times (2.0\ \text{kg}) \times (9.8\ \text{N/kg})$$

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Eugenia Etkina
4. July

Hi all, a few things today. First, I wanted to let you know that GIREP conference started today and it gave me an opportunity to meet in person many of our group members who are attending the conference. It feel so wonderful! Second, I want to remind you (again) to respond to a post if you read it. This makes the post more visible for other group members. And finally, third! - back to our problem types.
Today is DEX - Design your own experiment or pose your own problem. Here is how we describe these problems: Students have to design an experiment, an experimental procedure, or a device that will allow them to measure/determine certain physical quantities or that would meet specific requirements.
OR: Students have to pose a problem that involves certain objects with given characteristics. Often there is an additional requirement that solving the problem should involve the use of a particular physics topic, law, or principle. Students may also need to do an additional literature search.
The first type matches AP problems and also develops epistemic cognition as the student needs to evaluate the equipment and decide how different pieces can help them solve the problem. The second type problems have multiple correct solutions, so they also develop epistemic cognition. Here are examples from Chapter 5 (circular motion):
34. ** Banked curve raceway design You need to design a banked curve at the new circular Super 100 Raceway. The radius of the track is 800 m, and cars typically travel at speed 160 mi/h. What feature of the design ensures that all racecars can move around the track safely in any weather? (a) Provide a quantitative answer. (b) List your assumptions and describe whether the number you provided will increase or decrease if the assumption is not valid.
36** Design a quantitative test for Newton’s second law as applied to constant speed circular motion. Describe the experiment and provide the analysis needed to make a prediction using the law.
54.* Loop-the-loop You have to design a loop-the-loop for a new amusement park so that when each car passes the top of the loop inverted (upside-down), each seat exerts a force against a passenger’s bottom that has a magnitude equal to 1.5 times the gravitational force that Earth exerts on the passenger. Choose some reasonable physical quantities so these conditions are met. Show that the loop-the-loop will work equally well for passengers of any mass.
62. Design 1 Design and solve a circular motion problem for a roller coaster.
For those who have the first edition of the book - all those problems are in the first edition too. I am inviting all of you to propose your designs and share how it felt inventing them. Thank you! And please do not forget to like the post or comment on it!

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Eugenia Etkina
5. July

Hi all, today is my last post about problem solving. It is about Problems Based on Real Data (RED). Here is the description of such problems in the Instructor Guide (posted here in the FILES):

Students have to solve problems that are based on real data, obtained in real-life situations, often using easily available equipment and/or equipment that is typically used in student labs. The types of problems may be traditional or any of the types presented above. Students need to deal with uncertainties, anomalous data and assumptions, and to propose meaningful models.

Here are examples of such problems. By the way, nobody solved any problems from yesterday. Please try to solve them - your solutions provoke excellent discussions!

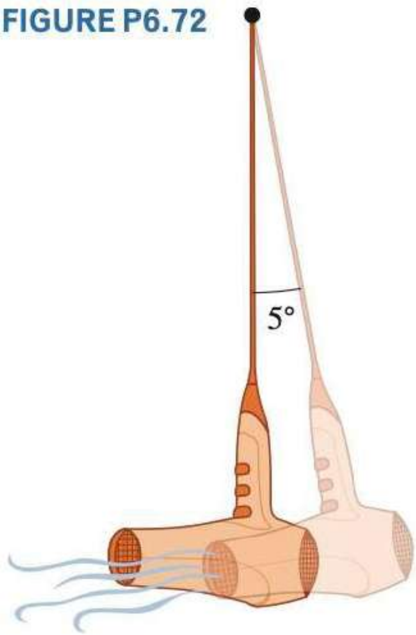
Two problems that I am attaching here involve the experiments that students can perform themselves and collect their own data. They involve hairdryers - equipment very familiar to those who have long hair. The problems are from Chapter 6 - Linear Momentum. There are lots of other problems in the textbook that involve real data provided ti the students, but they all have figures and I can only attach one file to the post. I will post another good example tomorrow. These are fascinating problems

If you finished reading the post, please respond to it to make it more visible for other group members!

a house that measures 10 m × 10 m. Indicate any assumptions you made.

72. * While dangling a hairdryer by its cord, as shown in **Figure P6.72**, you observe that the cord is vertical when the hairdryer is off and that it makes an angle of 5° with the vertical when the hairdryer is turned on. Draw a force diagram for the hairdryer in both cases and explain the outcome of the experiment using momentum arguments.

FIGURE P6.72



73. ** While dangling a hairdryer by its cord, as shown in Figure P6.72, you observe that the cord is vertical when the hairdryer is off and that it makes an angle of 5° with the vertical when the hairdryer is turned on. In a different experiment, you determine that the same hairdryer is pushing 0.03 m^3 of air through itself every second. The mass of the hairdryer is 420 g. Determine the speed of the air that is leaving the hairdryer, assuming that the mass of 1 m^3 of air is 1.2 kg and that the hairdryer is blowing air perpendicular to the wire.

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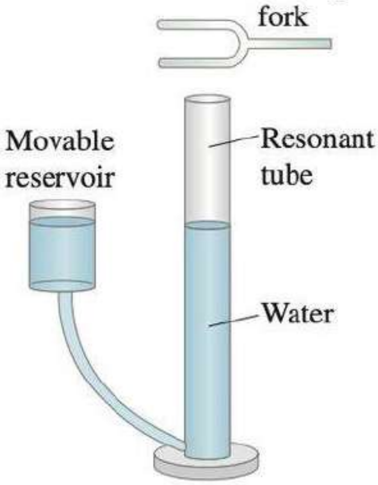
Eugenia Etkina
6. July

Hi all, as I promised, I am pasting two examples of problems - one where students need to analyze given data (RED) and the next one - a Ranking Task (RAT). They are from Chapter 11 - Waves. Below I show all non-traditional problems in this chapter.
Nontraditional end-of-chapter questions and problems
Ranking tasks (RAT): P11.13, P11.59
Evaluate (reasoning or solution...) (EVA): P11.51
Make judgment (based on data) (MJU): P11.43, P11.65
Multiple possibility and tell all (MPO): P11.3, P11.7, P11.9, P11.50, P11.63
Design an experiment (or pose a problem) (DEX): Q11.16, P11.18, P11.25, P11.37, P11.75
Problem based on real data (that students can collect by themselves) (RED): P11.58, P11.79
I also wanted to welcome our new members - WELCOME! and to remind you all to solve the problems that I post and to respond to the posts. Thank you!

58. The speed of sound can be measured using the apparatus shown in **Figure P11.58**. A 440-Hz tuning fork vibrating above a tube partially filled with water initiates sound waves in the tube. The standing sound waves are formed inside the tube when the water in the tube is lowered 0.20 m and 0.60 m from the top of the tube. Use this information to determine the speed of sound in air.

FIGURE P11.58



59. * Four strings of equal lengths are pulled with equal forces. All four strings are made to vibrate with standing wave frequencies. The table shows the vibration frequencies of the strings and the corresponding number of antinodes. Rank the masses of the strings from smallest to largest.

String #	Number of antinodes	f (Hz)
1	1	220
2	2	670
3	1	440
4	3	360

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Eugenia Etkina
7. July

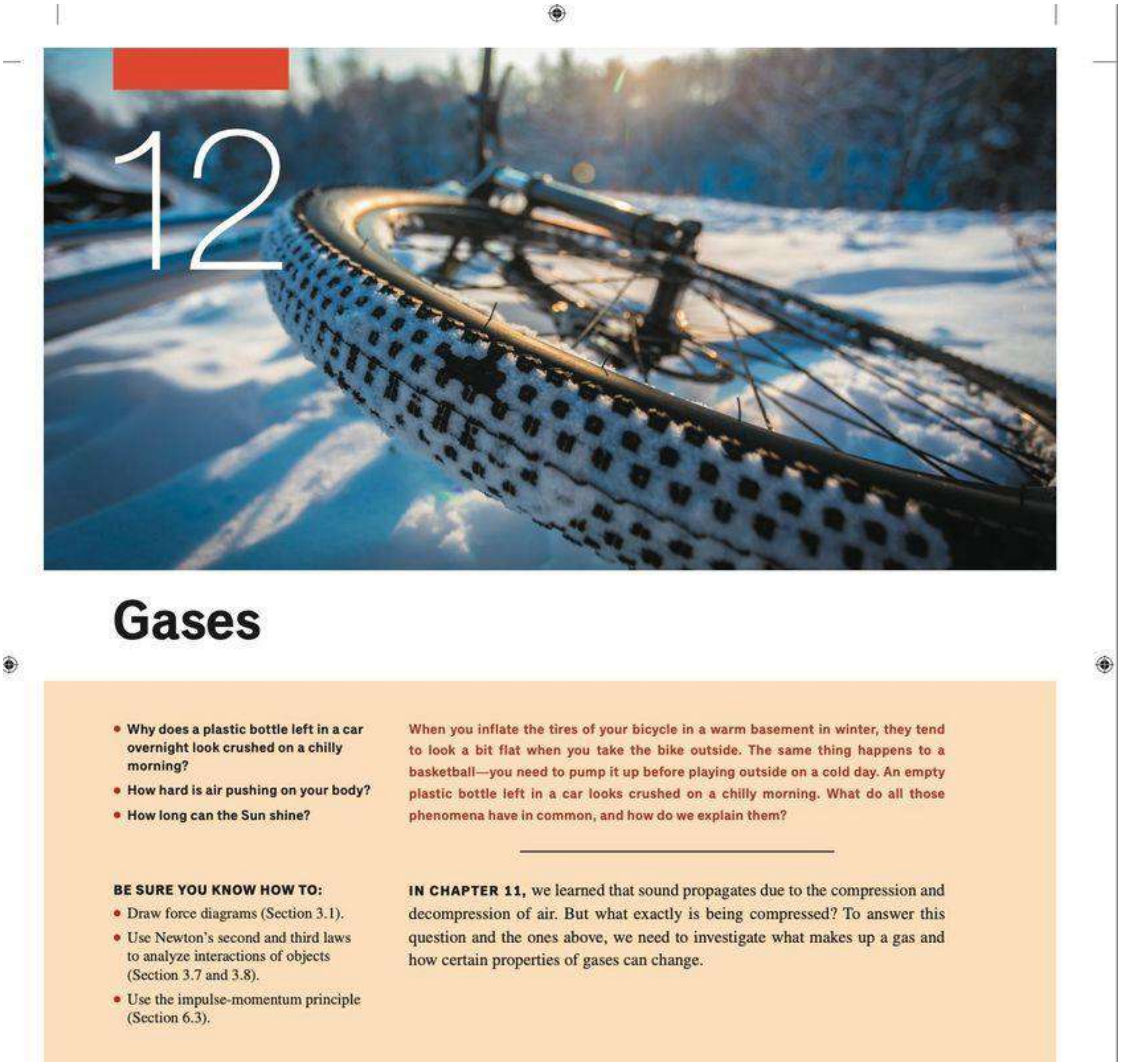
Hi all, I finished the series of posts about problem solving and today I will start posting short pieces about the ISLE approach - the key things that will help you implement it. I will also provide explanations for why we do things differently from most curriculum approaches. But first I wanted to welcome new members - we are having new members every day! WELCOME, people, we are glad to have you in our community. To learn more about the ISLE approach which is the foundation of everything that we do and the resources that are available, please go to islephysics.net and read every tab. also, if you are reading these posts, please do not leave the page before you "like" it or comment on it. This makes the post visible for more people.

So, the ISLE approach. The main two goals are to help students learn physics by actually doing physics (not listening about the outcomes of its process from authority) and to simultaneously feel good (motivated, inspired to work hard, confident) about doing it. Thus, EVERYTHING, literally EVERYTHING that we have in our materials and classroom settings addresses these goals. I repeat - EVERYTHING. This is the sign of an intentional approach to curriculum design.

First step in starting the ISLE approach in your classroom is to position your students. If you have a small class (high school classroom) or a studio set-up, just have the table arrangement that the students can work in groups of 3 or 4. If it is a large lecture hall setting - the students can turn to their neighbors on the right and up and down the rows to make same size groups. In a small class setting you need whiteboards on the tables for the students to put their thoughts or to have boards on the walls of the classrooms so that each group has board space. It is really important as the boards make students accountable for their work and allow them to share the results without taking too much time talking about them. We also give each student in this setting a marker of a different color - to make sure that everyone participates in the creation of the whiteboard in each group. This positioning ensures collaboration of your students in the learning process, which is EXACTLY what physicists do, None of the physicists today works alone. But there is more - when the students work collaboratively, they learn from each other and they also see that everyone struggles, not just them. Finally, talking involves motor function fo the brain that is necessary for people to complete the brain cycle of learning (see the book by J.Zull The art of changing the brain).

Student learning of any topic - velocity, Newton's laws, electric field, etc. starts with what we call "the need to know". We already discussed what "the need to know" is for. It is to motivate the students but NOT to elicit anything or to have any discussion (for example, a person in a car struck by lightning - one of the most cool videos!). "The need to know" is a cool video, an exciting experiment that the students will be able to explain at the end. Show, let them watch, be amazed and then say: "What did you see?" "Isn't is amazing?" We will be able to explain it at the end of our adventure into XX. There are several different ways to create the need to know. 1) Use something really cool! 2) Use something that the students are familiar with but never questioned before. 3) Use a problem that arises from the limits of their current knowledge. In our textbook, College Physics: Explore and Apply the "needs to know" are in the chapter openings of every chapter - the photo and three questions. The three questions are always organized in the same way - the first related to the photo, one related to some aspect of students lives (or their bodies!) phenomenon, and some to pure physics. I attached an example to this post from Chapter 12: Gases. Here you see that the need to know in the photo comes from students' experiences (deflation of bicycle tires in the winter), but two other possibilities relate to student bodies (force exerted by the atmosphere on our bodies) and pure physics - but a cool one (how long will the Sun shine?). All of those are answered in the text of the chapter but not discussed at the beginning. I also want to note that there are NO specific "needs to know" in the ALG or OALG, although some of the activities can be used for this purpose. The reason is that you choose the needs to know based on the interests of your students. On the website universeandmore.com there is a tab Video Vault where you can find some really cool videos for the Need to Know in addition to the ideas in the textbook.

Pedagogical issues with the Need to Know: The key is NOT to ask for any predictions of what should happen and for any explanations of how or why it happens. My question to you - why? Why don's we ask students to predict this new phenomenon that they have not seen before and make a prediction that will not match what they see? And why don't we ask the students to try to explain it right away and see that they can't? I am waiting for your responses. The next step - Observational experiments, is tomorrow.



12

Gases

- Why does a plastic bottle left in a car overnight look crushed on a chilly morning?
- How hard is air pushing on your body?
- How long can the Sun shine?

When you inflate the tires of your bicycle in a warm basement in winter, they tend to look a bit flat when you take the bike outside. The same thing happens to a basketball—you need to pump it up before playing outside on a cold day. An empty plastic bottle left in a car looks crushed on a chilly morning. What do all those phenomena have in common, and how do we explain them?

BE SURE YOU KNOW HOW TO:

- Draw force diagrams (Section 3.1).
- Use Newton's second and third laws to analyze interactions of objects (Section 3.7 and 3.8).
- Use the impulse-momentum principle (Section 6.3).

IN CHAPTER 11, we learned that sound propagates due to the compression and decompression of air. But what exactly is being compressed? To answer this question and the ones above, we need to investigate what makes up a gas and how certain properties of gases can change.

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Eugenia Etkina
8. July
Hi all, today I continue with the series of posts about the ISLE approach. I will try not to repeat what is written on the website islephysics.net but I strongly recommend that you visit the website and click on all the tabs to learn more. When you finish reading the post, please do not forget to respond to it.

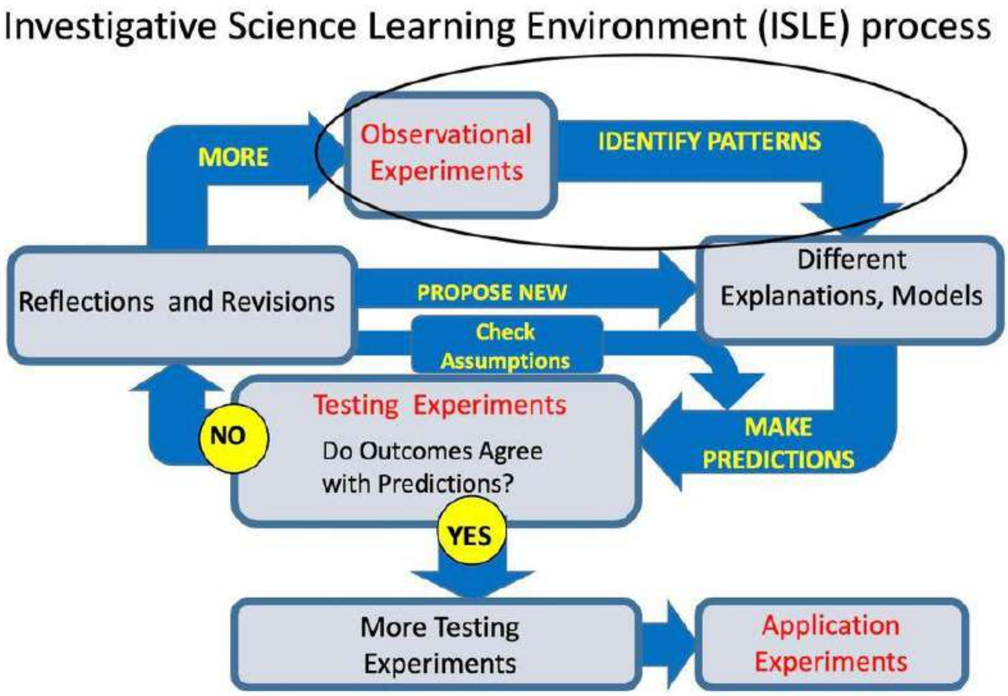
Yesterday I talked about the "Need to know" and how we do not ask the students to make any predictions before it. Today is the first step of the ISLE process - students observing simple experiments and looking for patterns. Note, that these experiments can be either done by the students themselves, or they can observe the teacher doing them or they can watch a video, or they can see a picture of the apparatus and have collected data in a table to analyze. The main idea is that these are the experiments that help students construct concepts that they have to learn as "theory" in traditional physics courses. They can be done in the labs in large enrollment courses or during regular lessons in high school, or even in the "lecture" setting. The point is to give students an experience of "creating theory". This is only the first step but it is crucial for them to see that "theory" does not come from a "theory god" but from their own experiences and reasoning.

To give you an idea where these experiments belong in the process, I attached the diagram of the whole process with the parts that I am discussing today circled with the dark oval.

These are OBSERVATIONAL EXPERIMENTS. Their goal is to help students find patterns and eventually explain them. These experiments are simple so that the students can see the pattern easily. For example to find a pattern that in circular motion at constant speed the sum of the forces exerted on a moving object points toward the center of the circle the students use a bowling ball and a mallet and try to make a moving ball go in a circle, then they take their back packs and turn around to make the backs move in a circle holding the pack with two hands in front of them. The emerging pattern comes from the force diagrams - for both objects the sum of the forces points towards the center (see Chapter 5 for the videos of the experiments). Note that we do not ask the students to make any predictions about the way they need to hit the bowling ball to make it go in a circle. They need to try whatever they can to accomplish this goal. My point here is that we DO NOT ASK FOR ANY PREDICTIONS before observational experiments. We ask students to observe with open eyes and no fear. Then we ask them to say what they saw/did and help to analyze what they saw/did suggesting a useful physics representation. sometimes it is a motion or a force diagram, sometimes it is a graph if collected data are quantitative. In the ALG and OALG these experiments have a title: Observe and find a pattern or Observe and Explain.

The goal of these experiments is not only for the students to move towards constructing some normative concept in physics, but to also make them feel good about it. There are no failures in conducting observational experiments. Each group of students (and students do work in groups) agrees what they saw or did and then shares their finding with the rest of the class. From the discussion of all observations the pattern arises. The students are encouraged to use simple terms so that no one feels excluded from the discussion. It is also important at this state not to confuse descriptions with explanations. for example, when the students observe a spot of a drying rubbing alcohol (Chapter 12), they sometimes say that they observe "evaporation". But evaporation is a scientific term that stands for a specific mechanism of drying. Therefore, before the students construct this mechanism, what they observe is the drying or disappearing of the liquid. Everyone can see or feel it by smelling.

Our approach to Observational experiments is very different from Predict-Observe-Explain approach or from Question-Hypothesis-Experiment-Conclusion approach. In the former the students need to predict something when their prediction is a guess (and scientific predictions ARE NOT guesses) and in the latter the students conduct experiments to support their hypotheses that are also guesses (which is NOT al all how scientists do science). It is very important to differentiate our approach from the above two approaches to really understand the essence of what we are trying to do. If you finish reading the post, please respond to it to make it more visible.



Etkina and Van Heuvelen, 2001, 2007; Etkina, 2015

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Eugenia Etkina
9. July

Hi all, a few things today.
1) 26 people said that they can do the new types of problem workshop on august 27 at 1 pm EDT. Since the voting we accepted lots of new members, so I am repeating that on August 27 at 1 pm EDT (East coast time in US) we will have a 2 hour workshop solving NEW problems that we have been creating. They are all ISLE-based but unpublished and not seen by anyone. I will post the EVENT, please sign up.
2) It looks like I will have some time in August to start our regular monthly meetings. This year I was thinking of having a meeting once a month for the Chapter/s that come up in the next month. So in August we could have a meeting on starting the school year and learning Kinematics through the ISLE approach. What do you think if this idea? Please comment!
3) I continue with the ISLE process. Yesterday I posed about observational experiments and their role in building or inventing normative concepts. The next step is for the students to actually construct/invent those concepts. It is partially done in the step that is circled on the diagram attached to this post. What kinds of concepts do we expect students to construct? Actually all of them (or almost all). But the levels of complexity of these concepts are different.

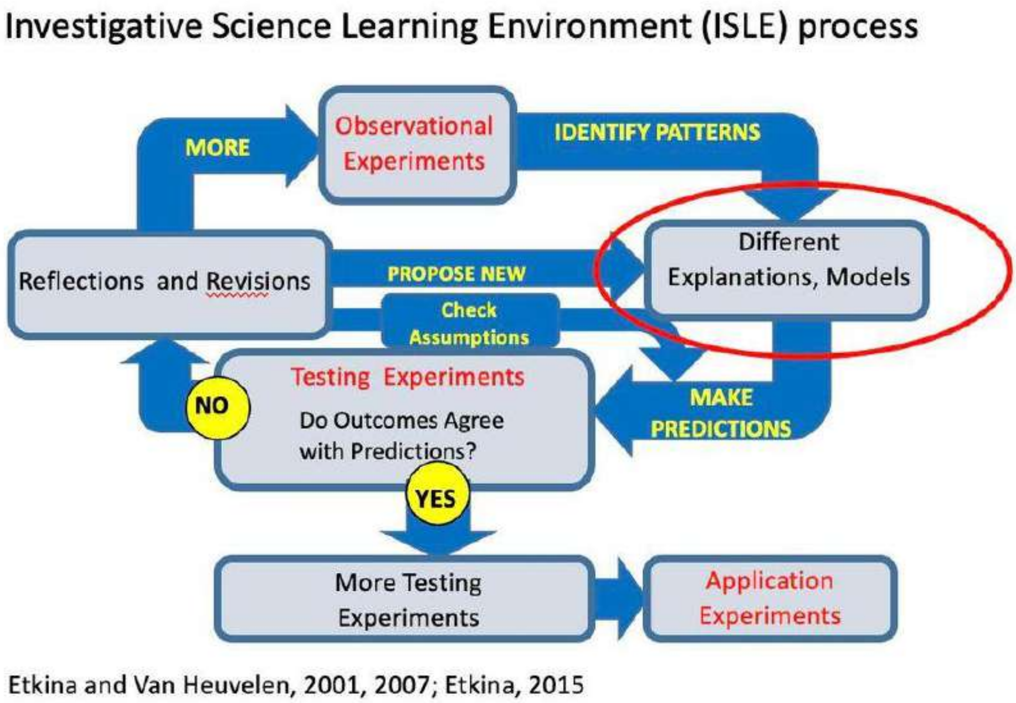
Examples: some of those concepts are new physical quantities that emerge from the analysis of the patterns in the observational experiments (those are for example velocity, acceleration, momentum, electric resistance, etc.) Students collect the data, plot them and figure out the functional dependence or some other regularity, then the teachers helps them focus on a specific pattern and asks them to come up with a name for it. It is only one pattern that can be seen in the data.

Another example when the students generalize the pattern into a causal explanation or a causal model (no mechanism). Sometimes it is a correct model and sometimes it is an incorrect one or an incomplete and it needs to be replaced. An example is the concept of electromagnetic induction - changing magnetic field induces electric current in a closed loop. When the students try to generate electric current using a coil and magnet (observational experiment, Chapter 21 in the textbook), they first observe that some motions of the magnet cause current and come up with a causal explanation/hypothesis that moving magnets can induce electric current in coils. While it is a correct idea, it is not complete, I will show tomorrow how students revise/improve it and eventually arrive to a complete idea of the changing magnetic flux that causes the current. But notice, that there is not mechanism in this explanation. We call is a causal explanation.

Another example of constructing/inventing an explanation is when the observational experiment and the pattern allow the students to come up with multiple possible mechanistic explanations. An example of such is the development of the model fo the internal structure of matter - chaotic motion of microscopic particles that comes out of multiple mechanisms that students invent trying to explain the phenomenon of drying alcohol. Only one of the mechanisms survives the testing experiments that follow. Note, that the circled step of the ISLE process is NOT the end of it, it is somewhere about 40% in.

Bottom line is that it is THE STUDENTS in the ISLE approach who themselves construct the concepts that we want them to "learn". These concepts are constructed in a systematic way as a step to explain simple observational experiments that we choose for them (the construction of these explanations is not by any means the end of the process as I said above). It is an inquiry process but it is a carefully orchestrated and prepared process for the students which mirrors scientific practice.

Those who have our textbook I recommend reading carefully Chapters 2, 6, 12, 17, and 21 to see how students construct different types of ideas analyzing observational experiments. Those who do not have the textbook yet, please use OALG files to follow progressions. If you do not have the textbook ,contact your Pearson rep and ask for an examination copy. If you read the post to the end, please respond to it - 'like it" or comment - this will make the post more visible.



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Eugenia Etkina
10. July

Hi all, first, thank you for signing up for our meeting in august for solving new non-traditional problems. 26 people liked the date and 26 people signed up for the event, this is great! Please, if you are interested, sign up on the event page.
Second, I will continue with the ISLE process today. Students, working in groups discuss the observational experiments, find patterns and come up with hypotheses/models/explanations. Note, the the hypotheses are not wild guesses - they need to explain all available observations and be experimentally testable. They can be qualitative or quantitative, causal or mechanistic. sometimes there is just one model explaining the data, sometimes, there are multiple. but in any case, whatever explanation/ hypothesis/model students come up with, they need to test it experimentally.
What does it mean to test experimentally? It means first, to accept each explanation/model as correct (even if you do not agree with it) and design an experiment whose outcome you can

predict using all explanations/models/hypotheses that you constructed to explain the patterns in observational experiments. Designing an experiment is the first step (it is marked orange on the attached slide), the next step is to use EACH explanation/model/hypothesis to predict the outcome of the experiment (violet circle on the slide). When there are multiple explanations/models, the predicted outcomes need to be different, or the experiment is useless.

This step is VERY IMPORTANT in the ISLE process and it underscores the different between a hypothesis and a prediction. A prediction is NEVER a guess and is should not be made based on one's intuition. It is a statement of an outcome of an experiment (therefore it cannot be made before the experiment is designed) that follows from a hypothesis under test. A Hypothesis/model/explanation EXPLAINS the observational experiment. A Prediction says what should happen in a testing experiment IF the hypothesis is correct.

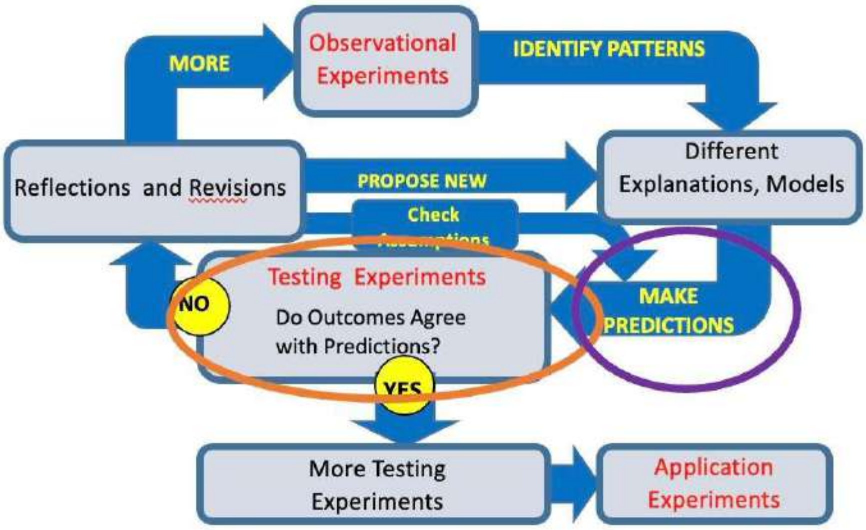
For example you Observe that when a a magnet moves near a coil, there is electric current through the coil (coil A). So your hypothesis/explanation is that it is the relative motion of the magnet and coil that causes the current in A. You design an experiment in which it is not the magnet that moves, but another coil of wire (B) with current in it (connected to a power supply) and predict that there should be current in coil (A) as you already know that a coil of wire acts like a magnet when there is current through it. You run the experiment and the outcome matches the prediction. Does it mean you proved your explanation?

Another experiment is needed (see the arrow YES on the diagram). You come up with another experiment where B is not moving but the switch connecting it to the power supply opens and closes. According to your original explanation, there should be no current through A as there is no motion. Now you run this experiment and see that there IS current through A even there is no relative motion. Now there is a mismatch between the prediction and he outcome. What to do? Follow the arrow NO on the diagram. Revise the hypothesis!

Another explanation can be that it is not just the motion, but something else about the original magnet that led to the induced current in A in the original observational experiments. You revise your explanation and come up with the explanation of changing magnetic field instead of a moving magnet to be the cause of the induced current. Now you need another experiment to test it! What can you do?

Wow, what a long and complicated post! If you finished reading it, please respond! Thank you!

Investigative Science Learning Environment (ISLE) process



Etkina and Van Heuvelen, 2001, 2007; Etkina, 2015

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Eugenia Etkina
13. July

Hi all, I did not post yesterday but I am resuming my posts today. First, we have several new members - WECOME! To benefit from the group, please check the posts every day and go to islephysics.net to lear about the philosophical foundations of this group (the Investigative Science Learning Environment Approach - ISLE) and available materials at islephysics.net and here, in the FILES (marked OALG). Second, please do not forget to respond to post when you read them!
Third, I am continuing with the posts about the logical progression of the ISLE approach. After the students designed (or you suggested) an experiment to test their newly developed explanation (of the Observational Experiments), made a prediction of its outcomes, conducted the experiment, compared predictions to the outcomes and found the mismatch, this means that their explanation needs to be reexamined and maybe rejected. One thing that they need to check first is to examine additional assumptions that went into the prediction of the outcome. For example, the students decided to test Newton's second law using an Atwood machine. They did the analysis of the situation and predicted the acceleration to be (m1-m2)g/(m1+m2) and then the time that it should take the objects to travel a specific distance. When they ran

the experiment the time came out to be larger (and acceleration smaller in magnitude). This does not mean that the second law needs to be rejected, but they need to examine additional assumptions that went into the prediction, such as massless frictionless pulley. What should happen to the acceleration is the pulley has mass r there is friction? Should be smaller or larger than the predicted?
Once the students examine the effects of assumptions, they can either use a smaller lighter pulley to check whether their prediction is closed to the measured acceleration.
Therefore checking additional assumptions is the first step that the students need to take when their prediction does not match the outcome of the testing experiment. Read more about assumptions and their validation on our scientific abilities website sites.google.com/scientificabilities, go to Design Experiments, then to Reference materials and then you will see the document for assumptions at https://docs.google.com/.../0By53x8SYAF1lbVN5Sk9P.../edit...

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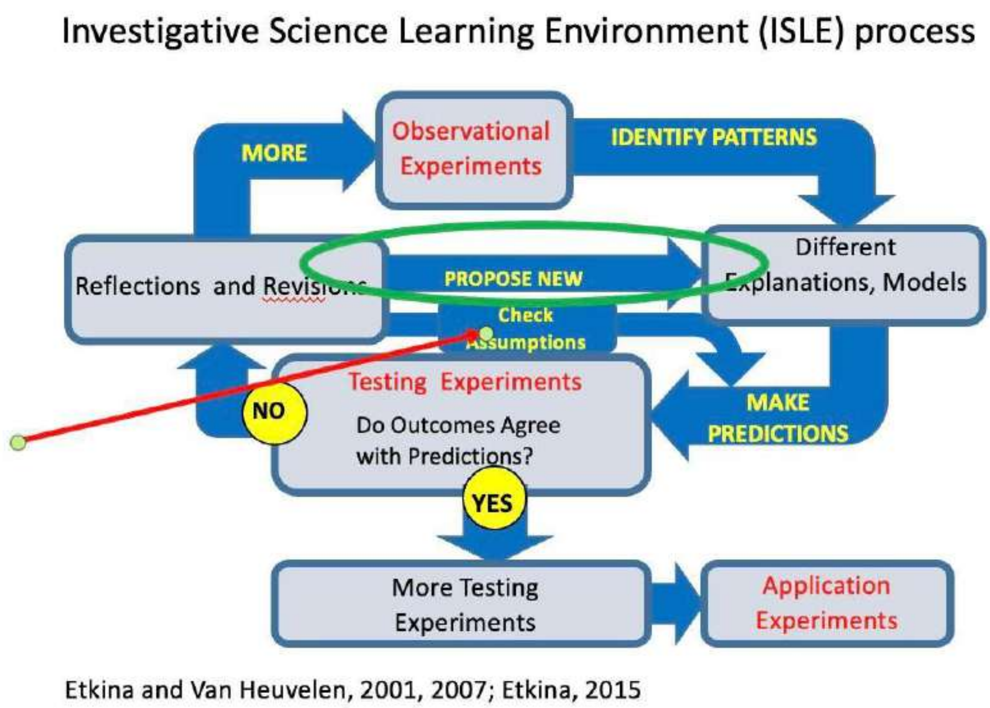
Eugenia Etkina
14. July

Hi all, I continue today with the posts about the ISLE process. But first, as always - welcome new members! Our community grows every day! WELCOME! To benefit from the group, try to check the posts every day and visit islephysics.net to learn about the philosophy behind the approach that is the foundation of this group - the Investigative Science Learning Environment (ISLE) approach. Check our documents in the FILES for the chapters with activities and the tabs on the above websites for lots of resources.
Yesterday I discussed the first step that your students undertake when the outcome of the testing experiment does not match the prediction. However, I omitted one step there before checking assumptions. What does it mean the outcome matches or does not match? If the experiment is quantitative, the students need to take uncertainty in the result into account. The document on how to estimate uncertainty using a simple approach called weakest link rule is posted on the same scientific abilities website. Go to Design Experiments, then to Reference materials and there you will find the document on the uncertainty (we also had a meeting about it in May, check out the google folder for the video recording).
Once the students see that even with the uncertainty interval, the outcome does not match the predictions, they examine the assumptions (see my post yesterday) and revise the design of the experiment if necessary.
But what if the explanation is qualitative and the outcome clearly does not match the prediction? For example, the students observe drying alcohol spot on a piece of paper and one of their explanations is that the liquid was "sucked into the paper". How can they test this explanation? They often come up with the experiment of weighing the wet paper. If the alcohol is absorbed by the paper, then when the paper is dry, it should weight the same as wet. The experiment is easy to perform and the outcome clearly does not match the prediction. What

does this mean? A new explanation is needed. This is another arrow on the ISLE process circled in green on the picture. The assumptions are marked with the red arrow. Notice that in traditional instruction there is no room for revising the explanations or models, as they are provided by the teacher and are only "verified" by the students.
Finally, sometimes we give the students two hypotheses (without them constructing the hypotheses) and they need to design an experiment to rule one of them or both. For example, we give them a fan cart (a low friction cart with an attached fan and a battery) and ask them to test whether the cart moves at constant speed or constant acceleration (sometimes it can be neither if the battery is old). The students need to design and experiment that will allow them to make two different predictions based on two models and then compare the outcomes to the predictions. Here, the most difficult thing is for them to actually base their predictions on the proposed models, not their intuition. If you have fan carts, try this activity and observe how students cope with the results.
If you finished reading the post, please do not forget to respond to it! Thank you!



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Eugenia Etkina
15. July

Hi all, today is the very last step in the ISLE process. Once models/hypotheses/relations devised by the students (under yours and our materials' careful guidance) have been tested and not rejected, the students combine them with other relations that have not been rejected to design application experiments. We have created a new type of experimental investigations for this purpose.
Specifically, the students need to design two independent experiments to determine the same physical quantity using several tested mathematical models. Here are some examples:
Design two independent experiments to determine the coefficient of static friction between your shoe and the floor tile.
Design two independent experiments to determine the sum of the forces exerted on a conical pendulum.
Design two independent experiments to determine te internal resistance of a battery.
The students design these experiments and get two values. To decide whether they are the same or different, they need to use experimental uncertainties and write both numbers as intervals. If the intervals do not overlap, they need to examine additional assumptions.
To help students in this process we have a set of scaffolding questions that repeat for every application experiment and the rubric that students can use for self assessment.
Here are the scaffolding questions - in the example they are in the shoe and tile lab but you will see that the questions are context independent. I am also pasting the link to the self-assessment rubric. If you finished reading, please do not forget to respond to the post!
https://docs.google.com/.../0By53x8SYAF1IbG5CMDJE.../edit...
Brainstorm two independent experiments to determine the maximum coefficient of static friction between your shoe and the sample of floor tile provided. Once you have done this call your TA over and discuss your experiments with them.
Available equipment: Shoe of your choice, spring scale, ruler, protractor, floor tile, tape, string, digital balance, assortment of weights
Include the following in your writeup (a-g are for each experiment. h-i are for after you have performed both experiments):
a) Describe your experimental procedure. Include a sketch of your experimental design. Explain what steps you will take to minimize experimental uncertainty.
b) Decide what assumptions about the objects, interactions, and processes you need to make to solve the problem. How might these assumptions affect the result? Be specific. Considering one of the relevant assumptions, evaluate the effect making the assumption will the results. For example, evaluate how the coefficient of static friction will change if you pull the shoe at an angle of 50 above the horizontal, rather than exactly horizontally.
c) Draw a force diagram for the shoe (recall your assumptions). Include an appropriate set of coordinate axes. Use the force diagram to devise a mathematical procedure to determine the coefficient of static friction.
d) What are the sources of experimental uncertainty? Which measurement is the most uncertain? How did you decide?
e) One of the assumptions you have likely made is that the coefficient of friction does not depend on the normal force the surface exerts on the shoe. (It’s okay if you didn’t come up with that on your own). In order to determine if this assumption is reasonable, perform a quick experiment on the side to evaluate the assumption. Decide if the assumption is or is not reasonable. Explain how you made your decision.
f) Give two different methods for measuring an angle with the available equipment. Which method is likely to provide a result with less uncertainty? Explain your reasoning.

g) Perform the experiment and record your observations in an appropriate format. What is the outcome of the experiment?
h) When finished with both experiments, compare the two values you obtained for the coefficient of static friction. Taking into account experimental uncertainties and the assumptions you made, decide if these two values are consistent or not. If they are not consistent, explain possible reasons for how this could have happened.
i) Describe the shortcomings you noticed in the experiments. Suggest specific improvements.

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Eugenia Etkina
16. July

Hi all, again, WELCOME to our new members! Our community grows every day!
A few things today - for the new members - scroll down to the latest posts to see instructions on how to learn what this group is about. And try to check the group page every day as the new posts appear every day. If you skip a nay or two, it will be difficult to get into the flow.
For those who signed up for our 27th of August meeting - please mark your calendars for correct time for your time zone. The meeting starts at 1 pm EST, 10 am Pacific Time and 7 pm European Central time. We will be solving ABSOLUTELY NEW NONTRADITIONAL ISLE-BASED PROBLEMS.
Two days ago Tom Prewitt asked about introductory activities for the first days of teaching through the ISLE approach. They are all in the ALG file for online instruction posted here. But I am pasting them into this message to make it easier. I recommend doing the first one and one of the following - wet glass or a balloon, bit not both. The point of those is to help students feel that learning physics is a fun game with established rules. But what is even more important is to continue this game through the year, not just doing a few fun activities at the beginning and then switch to traditional physics.
OALG 1.1.1 OBSERVE, EXPLAIN, AND TEST YOUR IDEAS
Watch the video at https://mediaplayer.pearsoncmg.com/.../_fr.../sci-OALG-1-1-1.
a. Come up with at least 3 explanations (crazy ideas) for why the person living in this house has 12 cameras.
b. Make a list of the explanations. How can you decide which one is correct? You can conduct additional experiments but you cannot talk to the person. Describe the experiments you plan to perform.
c. What outcomes of these experiments might convince you that certain explanations (or all of them) are not correct?
d. Read subsection “The process for devising and using new models” on pages 3-4 in the textbook and compare what you planned in parts b and c with what is described on these pages. Do you think there is a way to know with absolute certainty why the person living in the house has 12 cameras?

OALG 1.1.2 OBSERVE, EXPLAIN AND TEST YOUR IDEAS

Equipment: glass or transparent plastic cup, ice cold water, additional materials to test your ideas.

Take a glass (or a transparent plastic cup) and pour ice cold water into it.

a. Carefully observe the glass for a few minutes. Describe what you observe in simple words. Take a photo of the glass to share with the class. If you do not have access to the materials, use the link https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-2a.

b. Think of different explanations (crazy ideas) for the observed patterns. Try to devise as many explanations as possible.

c. How can you find out which explanation is correct? In science we conduct testing experiments. A testing experiment is an experiment whose outcome you predict before conducting it using the explanation under test. You do not need to agree with the explanation, but the prediction of the outcome must be based on it. After you design the experiment and make predictions based on all explanations that you devised, you conduct the experiment and compare the outcome to the prediction. Think about what testing experiments you can run to test the proposed explanations. Try to propose as many as you can by writing each one with a brief description.

d. For each testing experiment, make a prediction for its outcome based on each explanation that you proposed in b. Indicate any of your additional assumptions when making the predictions. (Note: The best testing experiments are those that give different predictions for different explanations).

e. Perform as many testing experiments as you can. Take photos and/or videos of the experiments to share with the class.

f. Compare the outcomes of the testing experiments with the predictions that you made in c. What can you say about the explanations under test now? Can you reject some explanations?

g. One of the testing experiments suggested by other students is as follows: you take a glass, put it on a scale, pour ice cold water into it and record the mass. If the explanation that water on the outside of the glass comes from the outside air is true, then the reading of the scale will increase as the glass becomes wet. If the explanation that water on the outside of the glass comes from the water inside the glass is true, then the reading of the scale should not increase but should stay the same or even decrease a little bit. Watch the experiment https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-2b and compare the outcome to the predictions. What can you say about those two explanations? Which one can you reject? When answering the last two questions you are making a judgment about the explanations. A judgment if the decision to accept or reject an idea/explanation under test, it needs to be back up with evidence.

h. Think of the explanation that you were not able to reject as a new piece of knowledge. Can you think of any application of this knowledge?

OALG 1.1.3 OBSERVE, EXPLAIN AND TEST YOUR IDEAS

Equipment: air balloons, needle, additional materials to test your ideas.

For this experiment you will need an air balloon and a sharp needle. If you have a balloon, inflate it and then pop the balloon using the needle. If you do not have the balloon, watch the video https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-3a

a. Describe what happened when you popped the balloon (or when the person in the video popped the balloon).

b. What makes the sound so loud? Think of several explanations using only simple words.

c. Elana and Rob proposed the following explanations: Elana said that the air escaping the balloon made the loud sound and Rob said that the breaking rubber of the balloon made the

loud sound. Did you come up with similar explanations? How can you test them? Describe the experiments that you would like to conduct.
Elana and Rob came up with the following testing experiments. Predict their outcomes (specifically, whether you will hear the loud sound) using each explanation that they devised separately (what does the air hypothesis predict? What does the rubber hypothesis predict?):
1. Fill the balloon with water and pop it with the needle.
2. Take a plastic bag, inflate it and pop it with the needle.
3. Take a piece of rubber from the first popped balloon, stretch it and pop it with the needle.
d. Watch the experiments (TE1: https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-3b, TE2: https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-3c, TE3: https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-3d) and compare the outcomes with the predictions. What are your judgments of Elana's and Rob's explanations for the causes of the loud sound of the popped balloon?
e. After Elana and Rob examined the original popped balloon they realized that they missed a piece of evidence. Below is the photo of the original popped balloon.
They saw that it exploded into a few separate pieces (not one piece with a small hole). Now, they came up with a new explanation: it is not just the air or just the rubber that makes the loud sound, but the rapid expansion of air through large opening that appears in the balloon due to the elastic rubber. How can they test this new explanation? They propose to take an inflated plastic bag and hit it with a palm so that the plastic bag suddenly tears. If their improved explanation is correct, it should produce a much louder sound than the bag that was just poked with the needle. Watch the video of the experiment https://mediaplayer.pearsoncmg.com/.../sci-OALG-1-1-3e and compare the outcome to the prediction. With this new evidence, what is your new judgement as to which explanation best explains the loud sound of a popped balloon?
Did you read to the end? Then you know what to do now! 🙂

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Eugenia Etkina
17. July

Hi all, we have a big group of new members who joined us after the AAPT meeting. Welcome all! to learn what the group is about, please visit islephysics.net and read the material under all table. The textbook that we use is College Physics: Explore and Apply by Etkina, Planinsic and Van Heuvelen, the book front cover is the cover of this group.
Request an examination copy from your Pearson rep if you do not have it as most of the posts are associated with this textbook and supporting materials - Active Learning Guide (ALG), Active Learning Guide for Teaching Online (OALG) and Instructor Guide (IG). OALG files are posted here in the FILES. The rest is available for free on Mastering Physics Website that your

Pearson rep will give you access to. Try to visit the group every day as new posts appear every day.
Hrvoje Miloloža is the keeper of the group's archive. From time to time he posts the link to the google drive folders with all the posts and records of our meetings and workshops. All our professional development is online and free for anyone in the world. Check events to know when the next meeting is. I will not make any new content today as I want to make sure that the new members know how to use the group. WELCOME! And please respond to posts by liking them or commenting to make sure that the next post comes into your Facebook feed.

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Eugenia Etkina
19. July

Hi all, a few things today. First, we again have new members who joined the group - WELCOME! Please read the FEATURED post about how to benefit from the group and see the even announcement if you wish to participate - sign up!
Second, PLEASE do not forget to respond to the posts after yo read them. Clicking "like" takes a second but this second will make the post visible for more people.
Third, we finished the first round of posts about the content of the textbook and the first round of posts about the progression of material in the ISLE approach. As people have been asking about the activities to do during the first day of the course, I thought it would be a good idea to turn your attention to the instructor guide. When we wrote the latest edition, we had Chapter 1 dedicated to the big picture of the book and the ISLE approach, not the first chapter of the textbook. The ALG also started from Chapter 2 only. Then later, we wrote the second Chapter 1 for the Instructor Guide (it is posted separately on Mastering Physics) which is supposed to help you start the course and understand how the textbook works. If you adopted the textbook, reading of the attached file is a must. If you did not adopt the textbook but are interested in using the ISLE approach in your courses, the very first activity described in the textbook and the ALG/OALG is a very important activity to help your students see how the ISLE approach works. I am pasting the text from the IG chapter 1. I will post the whole file in a separate post.
Here is the text from the IG. I. What is physics is the title of the first section of the first chapter in the textbook College Physics: Explore and Apply.
I. What is physics?
This section is dedicated to the first day of class. Traditionally, people start the first class meeting by going over the syllabus and course requirements, but we suggest that you dedicate the beginning of the first class meeting to activities that will show the students what the course is about. Examples of such activities are in Chapter 1 of the Active Learning Guide.
A brief description of the first activity is in Section 1.1 of the textbook, subsection “The processes for devising and using new models”. The first activity does not involve any physics. It starts with you telling the students that you invite them to your house or your friend’s house where they notice 10 tennis rackets (10 TV sets, 10 computers, 10 bicycles, anything that is atypical to have in such quantity) in the house. Noticing these rackets is what we call an

observational experiment. You can also shoot a short video of your home with these things and show the video. The question is why you would have these 10 rackets? Group your students in groups of 3-4 and ask them to come up with at least three “crazy ideas” (these are actually hypotheses) that explain the data (the 10 tennis rackets) and put their ideas on whiteboards. In 2-3 minutes you will see their ideas. They are usually: you have 10 people living in the house, you repair tennis rackets, you steal them, you collect them and so forth. The students lift their boards and share their ideas.

How would they know which one of their ideas is correct? The students usually say that they would ask you. Then you answer in a language they do not understand (you can make up any language you wish). They will look surprised at you. You say: “You posed the question and you received an answer, but you do not have an instrument to interpret it. Why?” The answer is that they did not expect you to speak in this unknown language. This situation brings up the whole class discussion about testing ideas in physics. Testing means designing an experiment whose outcome you can predict using an idea under test. However, in addition to the crazy idea that is the basis of any prediction, we always make additional assumptions. In this case, the students made two assumptions (1) that they could interpret your answer and (2) that you will answer honestly. As they did not validate their assumptions, the outcome of the testing experiment was inconclusive.

How does one design a testing experiment? There are a few general requirements. First, you should be able to predict the outcome of the experiment using all the ideas under test. But the second one is that these predictions should be different for different ideas. At this moment you ask the groups to go back and think of experiments that they could run to test their ideas (explanations, hypotheses). Then they need to make clear predictions of the outcomes based on each of the “crazy ideas” that they suggested and make sure that they consider any additional assumptions. For example, let’s say they wish to test the ideas that you have 10 people in the house or that you are a tennis racket thief. The table below shows the experiments that they might suggest, the predictions that they might make, and the outcomes that they might find. Note the hypothetico-deductive logical structure of the predictions: if the explanation is correct and we do such and such experiment, then such and such outcome is expected. “If” relates to the hypothesis under test, not to the experiment. See the attached table to follow the reasoning:

Here you again have a whole class discussion about different issues involved. Here are three key points that we suggest you could focus the discussion around:

a. Testing experiments and observational experiments are different from each other; they have different intentions/goals. The first testing experiment in the table was specifically designed to test an idea. It requires a video camera and a person to continuously film the entrance. Thus, this experiment is very different from the first one when you just happen to notice the rackets without any expectations. Understanding the different intentions of observational experiments and testing experiments is key to understanding how physicists create knowledge and is one of the cornerstones of the ISLE approach. Make sure you understand their distinct intentions yourself!

b. Try to make the hypothetico-deductive reasoning process explicit. In our experience, students try to avoid this and don’t see the point of being pedantic about it. They think the reasoning process is “obvious,” and yet as soon as they move from tennis rackets to a physics context, they struggle to perform the process. Try to get as many students as possible (either verbally or on a whiteboard) to articulate the reasoning explicitly: IF idea X1 is correct AND I conduct testing experiment Y THEN Z1should happen. Z1 is the predictedoutcome based on the hypothesis, not the student’s personal beliefs or a hunch. Students mistakenly believe that a prediction is basically a hunch or a guess based on intuition or personal belief. While this may be true in other contexts, this is not how physicists reason. This same statement repeats in the context of testing experiment Y for idea X2, leading to predicted outcome Z2, and so on for all the ideas under consideration.

c. Now let's look at the outcomes of the experiments. The outcome of the first experiment (many people going in and out of the house) matches the prediction based on both ideas and the outcome of the second (you find the receipts) does not match the prediction based on the second idea but matches the first. What judgment can we make about the ideas?Did we prove that the first "crazy idea" is correct? There can be many reasons for people going in and out of the house, thus the match between the prediction and the outcome is not a proof or even a confirmation that the idea is correct. However, the mismatch in the second case is a stronger reason for judgment. It is much more unlikely that you are a thief if we find receipts for the tennis rackets in your house. This simple exercise helps students see that ruling out an explanation is much easier than confirming one. And that a firm proof is not possible.

After this exercise, we suggest that you discuss the general reasoning pattern behind this exercise. It is expressed in Figure 1.3 on page 4 in the textbook. Basically, the figure shows the process they went through: from the initial (often accidental) observational experiments to creating multiple explanations, testing them in new (testing) experiments until some of the possible explanations are ruled out and proceeding forward with those that were not ruled out by many experiments.

The following activities in the ALG (1.1.2 and 1.1.3) engage the students in a similar process only now the context is physics. In Activity 1.1.2, students should arrive to a judgment that water on the outside of the glass comes from the air. In Activity 1.1.3, they should reason that the loud sound is the result of the rapid expansion of air that happened due to elastic properties of the rubber (the rubber moves away very quickly, which allows the air inside the balloon to expand quickly). Note that this activity is an example where the best explanation is a combination of two (competing) explanations while the wet glass activity is a simpler case where one of the proposed explanations is found to be the best explanation.

Finally, Activity 1.1.4 ask students to summarize the steps of the process using guidance from the textbook. It is a very important activity. You can run it as a whole class discussion or let students work in groups to prepare presentations on small whiteboards and make their own decision about how to organize their answers – as a picture with similar elements as in Figure 1.3 or as a table or in some other way. The freedom of organizing their answers will help them take ownership of the process.

While many teachers start their school year by engaging students in some kind of similar activities, we follow with the same process throughout the whole course. You will find observational experiment tables and testing experiment tables and many practical applications for every physics concept that the students have to learn (read the textbook carefully to find them). For the homework after the first day of class, you might assign students to do ALG 1.1.5. We do not have any End of the Chapter Questions/Problems in this chapter in the current edition of the textbook, thus the homework activity comes from the ALG.

If you finished reading the post, please respond! Thank you!

Crazy idea (explanation, hypothesis)	Testing experiment	Prediction based on each idea	Outcome
CD1: You have 10 people living in the house who all play tennis	TE1: Video the entrance to the house for several days	If CD1 is correct & we perform TE1, then we will see different people going in and out. If CD2 is correct & we perform TE1: then we might see people going into the house or we might not.	There are many people going in and out of the house on the video.
CD2: You steal tennis rackets.	TE2: Look for receipts for the tennis rackets.	If CD1 is correct & we perform TE2: then there might be receipts. If CD2 is correct & and we perform TE2: then there should be no receipts.	You find receipts.

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Eugenia Etkina
20. July

Hi all, I continue with the beginning of the school year posts. Today's post is for those who have been and are using our textbook with their students "College Physics: Explore and Apply" either regular or AP edition. BTW, the only difference between regular and AP edition is that in the AP edition there are tables showing how the book is aligned with enduring understandings and science practices. If you are using the book in the US and are not doing AP, the AP edition will help you see how the textbook fully aligns with the NGSS. If you are using it for college, and have pre-med students, then reading passages at the end of each chapter will prepare them for the MCAT exam.
Below I am posting the text from the Instructor Guide Chapter 1 that describes the features of the textbook and how to use them to benefit from everything that we have developed. Attached

is the screen shot of the problem solving rubric that will help your students approach problem solving as experts (in addition to following problem solving strategy) and will help you assess their mastering problem solving skills. Traditional approaches do not develop or reward expert problem solving skills, they only reward correct answer. However, the answer is not as important (I am sure you will agree with me) as the reasoning process. The rubric helps students develop and you evaluate the reasoning process. Another thing that I wanted to add is that in order to help students benefit from our textbook you need read it as if you never studied physics. I already wrote about it but knowing how non-intuitive this message is, I will repeat it again. Every sentence, every experiment, every problem in our book are based on the work of the whole PER field. Lots of innovative approaches that we developed help students succeed. But they will only benefit from these approaches if you are familiar with them. So, invest some time and read the textbook as if you are a student. another point before you go on reading - make sure you have the textbook open on the sections mentioned in the text and have ALG Chapter 1 or OALG Chapter 1 (posted in the FILES here) open so that you can see the activities and textbook material that the text below mentions. And if you do not have the textbook, contact your Pearson rep to get a copy. If this does not work, please send me an email and I will help.

IV. How to use this book to learn physics

Section 1.6 in Chapter 1 is extremely important for the students as it provides them with an overview of how to use the textbook. The section starts with helping students learn how to read the textbook and introduces them to the interrogation strategy (ALG Activity 1.6.1). This is a very important activity and it will save you a lot of time later. Our studies show that those students who learn to work with the textbook in the ways suggested in this activity grow tremendously during the year and receive the highest grades. While it is not about the grades but about learning, if you assess what you want them to learn, grades do reflect learning, and this is what we find. The textbook is an incredibly useful companion in learning but only when the students use it correctly. To assess their ability to apply this strategy, you can use ALG Activity 1.6.2.

The rest of Section 1.6 in the textbook is dedicated to different elements of the book and how they work together to help students learn. We suggest that you go back to this section multiple times when the students are studying examples that are depicted here. For example, when you assign them to read Section 1 in Chapter 2 in the textbook, also assign the part of Section 1.6 (Textbook features, details about Chapter openings). When they learn how to construct force diagrams (Chapter 3), ask them to read the next small part – Physics tool boxes, and so forth. It is absolutely crucial that the students pay attention to Observational Experiment Tables (OETs), Testing Experiment Tables (TETs), and watch all the videos that are available in the textbook and the ALG. Once they meet the first of each, send them to the subsections Observational Experiment Tables and Testing Experiment Tables in the same Section 1.6 in the textbook.

Finally, our approach to problem solving is very different from other textbooks. Once the students work through the first Problem Solving Strategy 2.1 Example 2.12 (p. 40), ask them to go back and read the subsection on Problem solving in Chapter 2. It is important that the students follow the problem-solving strategy as closely as possible because each step represents a reasoning block needed to build their confidence and expert-like approach to problem solving.

The most common difficulty we observe among students when we ask them to solve a physics problem on their own or with a group of peers, without us showing them how to do it first, is that they don't know what to do. They often say things like "I am stuck" or "I don't know how/where to start.” The problem solving strategy provides students with a general framework for how to tackle a problem that they don’t know how to solve. When students say “I’m stuck, what should I do?” you can answer with suggestions like: “draw a force diagram,” or “sketch a diagram of the situation,” depending on what point in the process they’re stuck on. Then you can scaffold that process by reminding them of the key details entailed in that step. For example, if they’re drawing a force diagram, you can ask them: What is your object or system of interest that you’re drawing a force diagram for? We suggest that you do not grade their work on the numerical correctness of the final answer (many problems in our book do not have one right answer) but instead use the following rubric. We devised this rubric to be aligned with the problem solving strategy. It assesses how well students have engaged in the process of solving a problem. The students should be familiar with the rubric before they attempt a problem. Showing students how different parts of the rubric apply to worked examples in the textbook is very helpful. (now check the attached rubric).

The rubric aligns with the problem-solving strategy: Item 2 corresponds to the steps “sketch and translate” and “simplify and diagram.” Item 3 corresponds to “represent mathematically”, but also to the overall choice of how they decide to approach the problem. Note that mathematics is also a method of representation, so representational consistency applies to the “represent mathematically” step in terms of checking for consistency. Rubric item 4 corresponds to “solve and evaluate” in the problem solving strategy. Finally, we introduce rubric item 1: While not corresponding to a single step in the problem-solving strategy, this item serves a higher-level goal of the ISLE approach. Namely, that students should be able to articulate how they know what they know. Ideally to achieve “adequate” on item 1 of the rubric, a student should be able to explain and justify their choices in the key steps of solving a problem. It is not enough to set two forces equal in magnitude to each other. Rather, a student needs to explain why/how they know the forces are equal. For example, they might say “these forces are equal in magnitude because the object is not accelerating in the y direction.” In other words, the student is able to articulate how they know what they know using valid physics reasoning.

Rubric Item	Adequate	Needs improvement	Inadequate
…is able to clearly explain and justify the key steps of their reasoning process	Student verbally explains *what* they are doing and ***why***. Explanation is clear, sufficiently detailed, easy to follow, and shows physical and conceptual understanding.	Student explains *what* they are doing, but missing *why* they are doing it. And/or there is some difficulty in following their explanation.	Explanation is incoherent, confusing, or missing; and/or invokes incorrect/irrelevant physics ideas; and/or is unrelated to that which is being explained.
…is able to create 2 or more *consistent* representations of the problem	Two or more representations are constructed according to accepted standards learned in class, and the representations are consistent with each other.	Two or more different representations are present and they are consistent, but there are mistakes or missing elements in the representations.	There are major (key) mistakes/missing elements in representations or different representations are inconsistent with each other.
…is able to choose and apply productive mathematical procedures for solving the problem	Mathematical procedure is productive for solving the problem. Implementation of procedure is free of major conceptual errors.	Productive mathematical procedures are chosen, but implementation reveals misunderstanding about how to implement them.	Mathematical procedures are unproductive/inappropriate and will not lead to a physically reasonable answer to the problem, even if implemented correctly.
…is able to evaluate the reasonableness of final result.	Evaluates reasonableness of the result, correctly applying all the steps of one of the possible evaluation techniques listed below: a. limiting/special case analysis, b. unit analysis, c. physical reasonableness of answer, d. two independent methods, e. cross substitution consistency, f. consistency of representations. A valid conclusion is drawn from the analysis	An appropriate evaluation technique is used, but there are mistakes in the implementation of the technique (wrong units, misunderstanding of how reasonable the numbers are) and/or student neglects to draw a conclusion from their analysis.	There is no evaluation, or evaluation technique is implemented in an incoherent way, and/or an invalid conclusion is drawn, such as concluding the answer is reasonable when evaluation analysis shows it is not reasonable.

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Eugenia Etkina
21. July

Hi all! A few things today. First - as always - WELCOME new members! We have many who joined yesterday. A month like this and our group will reach 1500 - amazing! New members, please read the featured post on the top of the group's page to know how to benefit from the group. Welcome again, we are a big and a friendly bunch!
Second, ALL - please do not forget to respond to the post after you read it. I see 25-35 responses to every post while about 500 view each. PLEASE, if you read the post - either like it or comment. Anne L. Caraley always responds, thank you Anne L. Caraley 🙂
Third, I will continue a little bit with chapter 1 ALG. We wrote very nice solutions for it that will help you see how to develop hypothetico deductive reasoning. I am pasting the text of the activities below and solutions as an attached file. Hypothetico deductive reasoning is the the most fundamental foundation of science and physics especially, but unfortunately that are no resources (except ours) that teach this type of reasoning to people. Even worse, the modern reasoning approaches (one of them is CER claim - evidence -reasoning) mismatch scientific reasoning and are only used in "school science". Please take this opportunity to examine hypothetico-deductive reasoning and help your students develop it.
Chapter 1
Introducing Physics
1.1 WHAT IS PHYSICS? (DEVISING AND USING NEW MODELS)
1.1.1 TENNIS RACKETS
Class: Equipment per group: whiteboards and markers
Imagine that a new acquaintance (Miha) invited you to his house. You walk in and notice that he has 10 tennis rackets in the hall way. You wonder WHY Miha would have those rackets. Unfortunately, Miha does not speak English and cannot answer your question directly.
Work with your group members to come up with a plan to find out why Miha had 10 tennis rackets.
1.1.2 COOL GLASS
Class:Equipment per group: dry glass, ice-cold water, whiteboards, markers. Note: the higher the humidity in the room, more clearly visible will be the outcomes of the experiments (in our experience humidity of air should be 60% or higher). Alternatively, teacher may show slides with photos.
A teacher puts a dry and empty glass on the table and pours an ice-cold water into the glass.
a. Carefully observe the glass for few minutes. Describe in simple words what you observe.
b. Work with the members of your group to propose different explanations for the observed patterns. Try to devise as many explanations as possible. Put them on the whiteboard.
c. How can you find out which explanation is correct? In science we conduct testing experiments. A testing experiment is an experiment whose outcome you predict before conducting it using the idea under test. You do not need to agree with the idea but the prediction of the outcome must be based on it. After you design the experiment and make predictions based on all explanations that you devised, you will conduct the experiment and

compare the outcome to the prediction. Work with your group members to propose testing experiments that you can run to test the proposed explanations. Try to propose as many as you can.
d. For each testing experiment, make prediction for its outcome based on each explanation that you proposed in b. Indicate any assumptions that you made when making predictions. (Note: The best testing experiments are those that give different predictions for different explanations).
d. Perform testing experiments that you proposed in b. (if necessary, ask teacher for additional equipment).
e. Compare the outcomes of the testing experiments with the predictions that you made in c. What can you say about the explanations under test now? Can you reject some explanations? Do not forget to include the assumptions when making any judgements. Can you verify some assumptions?
f. Think of the explanation that you were not able to reject as a new piece of knowledge. Can you think of any application of this knowledge?
1.1.3 POPPING THE BALLOON
Class:Equipment per class: rubber balloons, needle, plastic bags (thin plastic bags for vegetables and fruits work best), access to water (tap), bucket for catching water. Optional: small embroidery hoop (about 12 cm diameter)
A teacher is holding a fully inflated balloon. The teacher asks the students to observe carefully while she pops the balloon using a needle.
a. Describe what happened when the teacher popped the balloon.
b. What makes the sound so loud? Work in your groups to propose several explanations using only simple words.
c. Propose testing experiments that you can run to test the proposed explanations. Try to propose as many as you can.
d. For each testing experiment, make prediction for its outcome based on each explanation that you proposed in b. Indicate any assumptions that you made when making predictions. (Note: The best testing experiments are those that give different predictions for different explanations).
d. Perform testing experiments that you proposed in b. (if necessary, ask teacher for additional equipment).
e. Compare the outcomes of the testing experiments with the predictions that you made in c. What can you say about the explanations under test now? Can you reject or revise some explanations? Do not forget to include the assumptions when making any judgements. Can you verify some assumptions?

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Eugenia Etkina
22. July

Hi all, a few things today. First we have lots of new members since yesterday - WELCOME! Please read the featured post at the top of the page to learn what this group is about and try to check the posts every day to follow the discussions that go on for several days. See the events to join us for the meeting in August.

Second, I am reminding everyone to respond to the posts if you read them. Like or comment - whatever you do, makes the post more visible for other group members.

Third, I am finishing the series of posts about hypothetico-deductive reasoning, which is the reasoning that scientists employ when doing science. They DO NOT do question-hypothesis-experiment-conclusion and they DO NOT do claim-evidence-reasoning logical chains. Instead the formulate hypotheses to explain collected evidence and then test them experimentally for REJECTION, not confirmation, multiple times in the experiments whose outcomes they predict using the hypotheses under test.

Below you see an activity in the OALG Chapter 1 (posted here in the FILES) that helps your students practice these elements of scientific reasoning using the medical content, not physics. The medical context is important for your female students as research shows that females (on average) are more interested in the contexts that relate to people, plants and animals and the male students (on average) are more interested in the contexts that relate to sports and military activities.

I recommend doing this activity with your students after you did cameras/tennis rackets/tTVs (one of those) and either a balloon or a wet glass (all of those are in the OALG Chapter 1).

OALG 1.1.5 IDENTIFYING THE ELEMENTS OF A PHYSICS PROCESS IN A TEXT

In the text below, identify elements of a process that scientists use when they construct new knowledge (See Figure 1.3 on page 4 in the textbook) and match the sentences with the elements of scientific reasoning by writing a number that you find at the beginning of the sentence into the corresponding row in the table. Note: more than one sentences can match each element and not all elements are necessarily present in the text.

Youth and physical activity*

(1) The skeleton shows greatest flexibility to physical activity-related mechanical loads during youth but is more at risk for failure during aging; yet we know that some old people adapt better to physical load than others. (2) Is it possible that the skeletal benefits of physical activity during youth persist with aging and provide some benefits even decades later? Researchers tried to find the answer to this question by studying professional baseball players (3) because these athletes all undergo the same training routines, have similar levels of activity, and most of them stop physical activity altogether upon retirement. (4) The researchers took CT scans of baseball players of all ages, early career to long retired, and compared the humeri (the bone of the upper arm) of their dominant and non-dominant arms. (5) The researchers expected that if the benefits of physical activity persist with aging, some changes in humeri would maintain later in life. (6) After comparing the CT scans, they found out that the humeri in the throwing arms of the active baseball players were much larger than those in the non-throwing arms. (7) When the researchers compared the bones of former baseball players, they found out that though some benefits of training disappeared over time, the increase in total bone size that resulted from years of throwing was maintained decades later. Even 90-year old former baseball players retained some of the benefits of their training, even though they stopped training more than half a century ago. (😎 The authors stress that their work shows the benefit of physical activity, especially during youth.

Elements of scientific reasoning

Sentence numbers
Observations/identifying patterns
Proposing a hypothesis/explanation
Designing/planning a testing experiment
Making a prediction of the outcome of the testing experiment
Making assumptions
Describing the outcome of the testing experiment
Making a judgment
* Adapted from the short news by Kara Feilich in The Journal of Experimental Biology(2014) 217, 2624-2626. Original article: Warden, S. J., et al (2014), Physical activity when young provides lifelong benefits to cortical bone size and strength in men, Proc. Natl. Acad. Sci.USA 111, 5337-5342.
Some of the items will provoke a good discussion among the groups of your students! Please post here if you tried this activity with your students and how they responded to it. Thank you!
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Eugenia Etkina
23. July

Hi all, yesterday Tom Prewitt commented on my post concerning the bio content of one of the activities as being female-friendly and I wanted to list more things that we do to make female students feel that physics is their subject and that they belong:

1. Look at the cover of our textbook (it is the cover page of this group too). It is the only textbook that has a female student on the cover. The young woman is riding a bicycle and has a back pack. She is heading towards town. This symbolizes a journey from school where she learned physics to the world where she will apply it.

2. Lots of problems in the book have human, bio or medical context and many problems have materials that are more familiar to females than males - such as hairdryers, for example. Over 50 % of the problems that involve humans have female actors in them.

3. Many chapter openings that motivate students for the new chapter involve women. My favorite is the story about Elena Isinbaeva - a former pole vaulter who set many world records in chapter 7, Energy. We have then pole vaulting analyzed in the problems twice in the chapter - qualitatively and quantitatively. I am attaching the chapter opening with her photo, the opening story and the motivating questions.

4. We have female physicists represented in the book more than it is common. For example, we have a story about Lise Meitner with her photo, the person who came up

with a nuclear fission model. We also have Marie Curie, but her name is more common in the textbooks.

5. But most important, we try to have EVERYTHING that students learn be humanely relevant - this relevance helps both females and males. And the whole ISLE logical progression levels the playing field for all genders. They all start from observing simple phenomena without using fancy terms and they all have an opportunity to test their ideas experimentally. As soon as they learn that it is not the right answer that we are looking for but the reasoning process, the females become much more comfortable learning physics.

Recently one of the UK educational officials spoke somewhere and said that physics is not for girls, that girls do not like difficult math. You cannot imagine what storm it caused! We have the magazine Physics World where there are lots of articles with the data about how UK girls are outperforming boys on difficult math tests and how they are enrolling in physics.
The world is changing and we should use our subject to empower all students and make them feel that they belong. If you read the post to the end, please respond to it either by liking or by commenting. Thank you.


7

Work and Energy

- How do pole vaulters reach a height of 5 or 6 m?
- Why does blood pressure increase when the walls of the aorta thicken?
- If our Sun were to become a black hole, how big would it be?

Yelena Isinbayeva from Russia has held the women's pole-vaulting record of 5.06 m since 2009. The men's record is 6.16 m. How can pole vaulters reach such great heights? If you watch the event, you will see three aspects of the vault that are essential: the vaulters run very fast before inserting the pole into the vaulting box; they jump at the moment of takeoff while bending the pole as they start their vertical ascent; and they crunch their muscles at the top of the flight to give a specific body shape as they pass over the bar. All these elements contribute to the height of the vault—in this chapter, we will learn how.

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Eugenia Etkina
24. July

Hi all, today my post is about reading. As you probably know, our students do not use textbooks to learn physics, they mostly use them to check problem solving examples and to solve assigned problems. There are many reasons for it, but I will name two:
1) The textbooks skip important reasoning steps and make student understanding of the text or problem solving examples difficult;
2) The students do know know how to interact with a scientific text. They assume that they just need to read it to understand and learn from it, but this is not how learning actually works.
So, we wrote the textbook that does not skip steps. But because of the second reason it is not enough for the students to learn from it. They need to be able to read it for learning. What does it mean "reading for learning"? - I just coined this term - 🙂
I will remind of you the brain learning cycle (described in Zull's The art of changing the brain). This is how the cycle goes: sensory input - reflective observation - abstract hypothesis - active testing.
What does this mean for reading? When a person reads any text, looking at the text involves sensory input, agree? So the next step would be reflective observation - this means that the person needs to stop and reflect on this sensory input - what does this sentence mean? How does it relate to what I already know?
The next step - hypothesizing is making a connection, a hypothetical connection, to what the person knows and interpreting the text that they just read.
Finally active testing means either talking to somebody about what they read or predicting what should come next and then reading the text that follows. Alternatively, active testing might mean actually doing the proposed experiment!
While this path sounds rather complicated, in fact this is what we all do (but very quickly and subconsciously) when we (experts) read scientific texts. The method is called "Reading interrogation" and it involves "interrogating" every sentence or a paragraph in the texts asking yourself a question "Why is this true?". Answering this question to yourself takes you through all of the stages of the brain learning cycle.
To check whether this is true (no pun intended), I encourage you to open our textbook on page 872 and read the section "Photocells, solar cells, and LEDs". Once you do it and see how this method works, I will proceed with a discussion of how we can help our students read the textbook this way. I am attaching just one page of this text, it is much longer. If you finished reading the post, please either like it or comment on it, or both! Thank you!

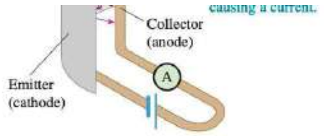


FIGURE 27.14 A photoelectric smoke detector.

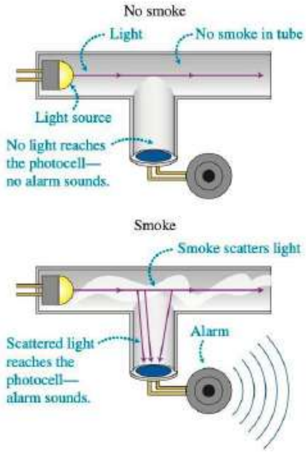
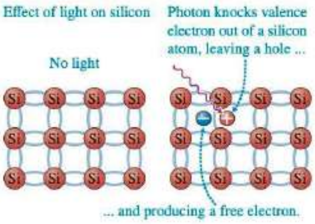


FIGURE 27.15 Light shining light on silicon produces free electrons and "holes."



27.6 Photocells, solar cells, and LEDs

The photoelectric effect has numerous applications. One of them is the **photocell**, which functions similarly to the tube that von Lenard used for his experiments. The cathode of the photocell (also called the *emitter*) is connected to the negative terminal of a battery and therefore is at a lower electric potential than the anode (called the *collector*). The cathode emitter is shaped like a cylindrical concave mirror to focus emitted electrons toward the anode, which has the shape of a thin wire that collects the electrons (**Figure 27.13**). When light of a frequency greater than the cutoff frequency shines on the emitter, electrons are ejected and absorbed by the collector, causing an electric current in the circuit. The magnitude of the current is a measure of the visible light or UV intensity being directed at the photocell. Products that use photocells include light meters (used in photography to adjust the size of a camera lens aperture), motion detectors, and photoelectric smoke detectors (**Figure 27.14**). In such a smoke detector, light from the source shoots across the top of the T-shaped detector. A cathode sits at the bottom of the T. If the air is clear, no light is scattered to the cathode and hence no photocurrent will be produced. However, smoke particles scatter light out of the beam, causing it to reach the cathode of the photocell and producing a photocurrent. When this photocurrent reaches a certain level, the alarm is triggered.

Solar cells

Solar cells, such as the rooftop panels used to generate electric current, are another application of the photoelectric effect. Solar cells are based on the semiconductor technology we discussed in an earlier chapter (Chapter 19). Semiconductors are materials that act as insulators under some conditions and conductors under others.

Silicon is a commonly used semiconductor. A silicon atom has four valence electrons that form covalent chemical bonds with neighboring atoms (each electron is shared between them). As a result, a silicon atom has no free electrons; therefore, silicon is an electric insulator. However, when silicon is heated or when light of sufficient frequency shines on it, some of the electrons gain enough energy to become free to roam around the crystal. The spaces vacated by these electrons lack negative charge and become positively charged "holes." These holes can be filled by other bound electrons that are not energetic enough to become free but can nevertheless move among the still-bound valence electrons. Both free electrons and holes can potentially contribute to a current if the silicon is placed in an external electric field. **Figure 27.15** shows this process—light photons deliver energy to the silicon, increasing its energy and allowing some of its valence electrons to become free. Whether electrons will be freed depends on the frequency of the light.

Adding impurities to silicon—a process called doping—is another way to turn it into a conductor. There are two types of impurities: electron donors and electron acceptors. Phosphorus, an example of an electron donor, contains five valence electrons, one more than silicon's four. The result is one "extra" electron that does not form a strong bond with a neighboring silicon atom and is essentially free to move about the bulk of

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Eugenia Etkina
25. July

Hi all, a few things today. First, WELCOME our new members - we had many people joined yesterday. New members, please see the pinned post about what to do to benefit from the group. Also, checking the posts every day will help you see the flow of the posts and comment. When you like a post or comment on it, more posts come from the group into your Facebook feed.
For all members, I continue the conversation about helping students learn how to read the textbook. Yesterday I explained how reading is connected to brain learning process. Today I will share the strategy that has been found the most helpful by research for student learning

from a scientific text. The method is called "interrogation" and is described in Chapter 1 in the textbook (attached to this post).

Here I am posting the exercise from OALG Chapter 1 that teaches students how to interrogate the text step by step. I encourage you to do this exercise and ask yourself how the comments during reading the text correspond to the steps of the brain learning cycle that I described yesterday. I usually do this exercise with the students in class. I choose a random paragraph from the textbook, we all read it and then I show them this internal conversation with myself (the interrogation) that I do when I read the text. Then I assign the next paragraph to the groups and ask them to come up with interrogation questions for this paragraph and share those. This exercise takes about 30 min and these 30 minutes will pay back during the year. It is good to repeat them one a month or so and in your syllabus assign after sections Review Questions from the textbook for the students to answer (I already commented on those but I repeat now as those are connected to the interrogation techniques.

OALG 1.6.1 INTERROGATION STRATEGY

Below are instructions on how to work with the textbook. The method is called interrogation. Here is an example of your interrogation of the following text (Chapter 1, p.😎. This is how the process works.

1.4 Making rough estimates

Sometimes it is useful to make a rough estimate of a physical quantity to help assess a situation or to make a decision. To do this, we use our personal knowledge or experience to get an approximate numerical value for an unknown quantity. Often the goal of the rough estimate is to determine the order of magnitude of the quantity—is it tens, hundreds, or thousands of the relevant units? Estimating is an extremely valuable skill.

You read the first sentence: “Sometimes it is useful to make a rough estimate of a physical quantity to help assess a situation or to make a decision.” You tell yourself: “What is an estimate? Do I even make estimates to make decisions? Hmmm… When I need to estimate how much money I need to live for one month I think about my rent, groceries, gas and other expenses. The rent is fixed but food expenses change every week, so what I spend on food can only be estimated. This means they are right; I make estimates to make decisions. Now the next question is about physical quantities. What are those? Oh, let me go back to Section 1.3, it is called Physical Quantities. Aha, money can be a physical quantity as it has units – dollars. So, I do make rough estimates of physical quantities. Then you read: “To do this, we use our personal knowledge or experience to get an approximate numerical value for an unknown quantity.” You tell yourself: “This is exactly what I need to use to estimate my monthly food expenses. If I never paid for my groceries, I would have no idea how much it costs a month. It looks like I completely understand what they are saying.” Then you continue reading: “Often the goal of the rough estimate is to determine the order of magnitude of the quantity—is it tens, hundreds, or thousands of the relevant units?” You tell yourself: “Order of magnitude. What is this? Oh, I just read about prefixes on page 6 for the units – these are the mathematical expressions for the powers of ten, for example 1 meter is 100 times bigger than 1 centimeter. So, the order of magnitude is ones, tens, hundreds and so forth. For example, the length of my finger is measured in centimeters, not in meters. For my food expenses example, the estimate would be that I spend a few hundred dollars a month, not a few thousand. This is good to know, especially if I have a better idea, whether it is one hundred or 8 hundred, right?”

This internal dialogue with yourself is exactly the process that scientists do when they read scientific texts. They continuously interrogate every sentence by asking themselves whether it makes sense, whether it is consistent with their prior knowledge, whether what the author is

writing describes an experiment or a hypothesis, and so forth. If the sentence does not make sense, they read the next one to check whether that sentence helps them understand the previous one. They also interrogate figures in the text. Above you see the figure to which the paragraph in the textbook mentions. Your task is to “interrogate it”. What questions would you ask in the process? List possible interrogation questions and answers below.
Please respond to the post after you finish reading it, thank you!

1.6 How to use this book to learn physics

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The goals of this textbook are to help you construct understanding of some of the most important ideas in physics, learn to use physics knowledge to analyze physical phenomena, and develop the general process skills that scientists use in the practice of science. One such skill is learning from a scientific text. Thus, by learning to work with your textbook efficiently and productively, you will not only learn physics but also develop textbook reading skills that will be helpful in any other science subject you study. To take advantage of all the tools that this textbook has to offer, we suggest that you read the text below and then, after you work through the first few chapters, come back to this section and read it again.

The most important strategy that will help you learn better is called **interrogation**. Interrogation means continually asking yourself the same question when reading the text. This question is so important that we put it in the box below:

Why is this true?

Make sure that you ask yourself this question as often as possible so that eventually it becomes a habit. Out of all the strategies that are recommended for reading comprehension, this is the one that is directly connected to better learning outcomes. For example, in Section 1.2 you read the following sentence: “The modeling of objects is the first step that physicists use when they study natural phenomena.” Ask yourself, “Why is this true?” Possibly because real-life phenomena are too complicated to be investigated in detail—it is much easier to describe the motion of a runner if you consider her to be a point-like object than to take into account the details of her arms, legs, hair, etc. Thus, simplifying, (or as physicists call it, modeling) is the first step that we take. By just stopping and interrogating yourself as often as possible about what is written in the book you will be able to understand and remember this information better.

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Eugenia Etkina

26. July

Hi all, today I continue my posts about learning to read scientific texts. I also wanted to WELCOME new members who joined yesterday. Please read the post pinned on the top of the group's page to learn how to benefit from this group the most.

Now, about reading. Research shows that not only students but teachers confuse the terms 'describe' and 'explain'. This means a deeper issue than just vernacular. It means not distinguishing between evidence and inference. This distinction is crucial when reading any social text. What is the author claiming? Evidence? Then what does this evidence look like? Or the text is just some inference? If it is, then was this inference tested experimentally for rejection? Think of how much trouble it would save the US if people and politicians could distinguish between the two and demand rigorous testing experiments for inferences or claims. But, politics aside (although I truly think that we are educating our students to be scientifically minded citizens), how does this speech relate to reading our textbook? It relates directly! To help students understand the differences between evidence, inference and testing the inferences experimentally we have a tool that no other textbook has (no other in the whole world!). We have Experiment Tables: Observational Experiment Tables and Testing Experiment Tables. They are key to helping students learn how physicists reason and how to distinguish evidence from inference.

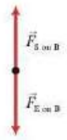
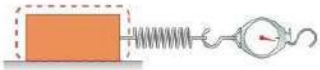
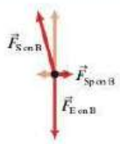
Many readers skip those in favor of plain text, but this is a mistake. All tables are carefully crafted and most have the videos of the experiments to help students learn when evidence come first (observational experiments) and when evidence is needed to reject supposition or fail to reject it.

I am pasting an example of an observational experiment table and I am inviting you to respond about HOW it helps students distinguish evidence from inference. I chose this example because not only that it illustrates my point above but it also reminds you that we see the FRICTION force differently from the traditional approach. So, please focus both on the form of the table and the content.

If you finished reading this post, please like it or respond to it in some other way. "Loving" is good too! 🙂

OBSERVATIONAL EXPERIMENT TABLE 4.1 Pulling a block with a spring scale

VIDEO OET 4.1

Observational experiment	Analysis
A block is at rest on the horizontal surface of a desk. 	The force diagram for the block is shown at right. 
A spring scale pulls lightly on the block; the block does not move. 	The pulling force $\vec{F}_{Sp\text{ on }B}$ is exerted parallel to the surface and $\vec{F}_{E\text{ on }B}$ is perpendicular to the surface. Because the block is not accelerating, the sum of all forces exerted on it must be zero. We therefore conclude that the surface exerts a force $\vec{F}_{S\text{ on }B}$ that, when added to the two forces above, gives zero. The vector component of this force perpendicular to the surface has the same magnitude as $\vec{F}_{E\text{ on }B}$; its component parallel to the surface has the same magnitude as $\vec{F}_{Sp\text{ on }B}$. 

(CONTINUED)

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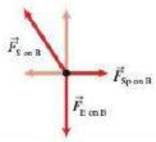
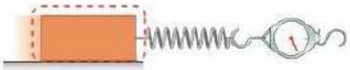
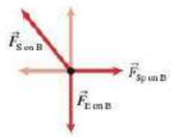
Observational experiment	Analysis
The spring scale pulls harder on the block; the block still does not move. 	The perpendicular component of $\vec{F}_{S\text{ on }B}$ stays the same; the magnitude of the parallel vector component increases. Therefore, the direction of $\vec{F}_{S\text{ on }B}$ changes, too. 
The spring scale pulls even harder on the block; the block finally starts moving. 	The force diagram for the moment just before the block begins moving is shown at right. 

Patterns

- In each of the experiments, the surface exerted a force on the block that can be resolved into two vector components—one perpendicular to the surface and one parallel to it.
- The perpendicular component of $\vec{F}_{S\text{ on }B}$ did not change with the increase of the pulling force, but the parallel component did. The parallel component seems to represent resistance to the motion of the block.
- The magnitude of the parallel component (the resistive force) can only increase up to a certain value. Thus the resistive force must be variable and have a maximum value.

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Eugenia Etkina
27. July

Hi all, two things today. First - more members are joining our group. WELCOME! To benefit from the group, please read the pinned message on the top of the group's page to learn the philosophical foundations of the ISLE approach to learning physics and the library of resources that we offer here and at islephysics.net. Try to check the posts every day to follow the progression. And check the events calendar for the upcoming events.
Second, I continue with the purpose of the experiment tables for learning to read the textbook and understanding the progression of hypothetico-deductive reasoning.
Yesterday I commented how observational experiment tables (the green tables in the textbook) help students learn how to distinguish between evidence and inference systematically. The best thing to do is to work with those experiments in class so that students can observe them, find patterns and come up with the explanations and then go home and read the textbook reflecting on what they learned by themselves and what is written in the textbook. They should not read the Tables before they actually try the experiments (or observe the experiments) and try to interpret them.
The same is true for the Testing experiment tables (purple table in the textbook). These tables teach students how to systematically reason like physicists and how to rule out the hypotheses or inferences. I am pasting examples from Chapter 4 again. After students have constructed the idea that friction force is a component of the force that the surface exerts on the object, they need to find out what this component depends on. The first table in the attached screenshot shows how they figure out what affects the force based on the experiments. From these experiments the students might think that it is the mass of the object that affects the friction force. The testing experiment that follows helps them learn how to rule out this hypothesis. Notice how the prediction before the experiment is based on the hypothesis and how the students view the video AFTER they made the prediction. I repeat again that the prediction is not a guess based on the intuition but a statement of the outcome of the experiment based on the hypothesis under test. There are NO predictions before observational experiments. Note, how in the testing experiments table in the attached screenshot under the column of "prediction" we show if-then reasoning, which is the hypothetico deductive reasoning chain that we want our students to learn.
This reasoning was used by Joseph Wilson to rule out the hypothesis that Iraq was developing weapons of mass destruction. He figured out how to conduct a testing experiment, made a prediction based on this hypothesis and actually ran the experiment which ruled out the hypothesis of the WOMD BEFORE the war with Iraq started. Unfortunately American politicians did not listen to him (even worse) and started the war. The story is portrayed in the movie "Fair Game" made in 2010. I strongly recommend watching it to see how hypothetico-deductive reasoning is important in the world.
If you finished reading the post, please respond to it to make it more visible for other group members. Thank you!

OBSERVATIONAL EXPERIMENT TABLE 4.2 What affects the maximum static friction force?

VIDEO OET 4.2

Observational experiment	Analysis
Experiment 1. ***Changes in the smoothness of the surfaces*** We'll use the spring to pull a smooth plastic block that is resting on three different surfaces: (1) a glass tabletop, (2) a wood tabletop, and (3) a rubber exercise mat. The reading of the spring scale just before the block starts moving is largest for the rubber mat, next largest for the wood tabletop, and smallest for the glass tabletop.	$\vec{f}_{s\,R\text{ on }B} > \vec{f}_{s\,W\text{ on }B} > \vec{f}_{s\,G\text{ on }B}$
Experiment 2. ***Changes in the surface area*** We vary the size of contact area between the block and the rubber mat. The block is shaped like a brick and has faces of three different areas. We use the spring to pull the block while it is resting on each of these three different faces. The reading of the scale just before the block starts to move is the same for all three areas.	$\vec{f}_{s\,R\text{ on }BA1} = \vec{f}_{s\,R\text{ on }BA2} = \vec{f}_{s\,R\text{ on }BA3}$
Experiment 3. ***Changes in the mass of the block*** We take plastic blocks of 1.0 kg, 2.0 kg, and 3.0 kg and place them all on the same wood tabletop. We use a spring scale to pull each of them. The reading of the scale just before the blocks start moving is smallest for the 1.0-kg block, twice as large for the 2.0-kg block, and three times as large for the 3.0-kg block.	$\vec{f}_{s\,W\text{ on }3\,kg\,B} = 3\vec{f}_{s\,W\text{ on }1\,kg\,B}$ $\vec{f}_{s\,W\text{ on }2\,kg\,B} = 2\vec{f}_{s\,W\text{ on }1\,kg\,B}$ The maximum static friction force that the tabletop exerts on the block is directly proportional to the mass of the block.

Patterns

The maximum static friction force that the surface can exert on the block depends on the roughness of the contacting surfaces and the mass of the block, but does not depend on the area of contact between the surfaces.

The patterns in Table 4.2 make testable hypotheses. To test a hypothesis, we need to design an experiment in which we can vary one of the properties and make a prediction of the outcome based on the hypothesis being tested. We will test one hypothesis in Testing Experiment **Table 4.3** (on the next page), that the maximum static friction force is directly proportional to the mass of the object.

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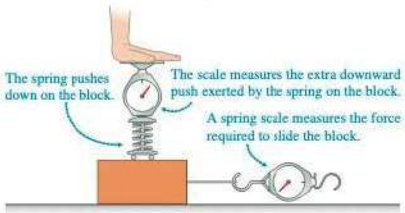
TESTING EXPERIMENT TABLE 4.3 Does the maximum static friction force depend on mass?

VIDEO TET 4.3

Testing experiment	Prediction	Outcome
We use a string attached to a spring scale to pull a 1-kg block. The mass of the block does not change, but we push down on the block with a spring that exerts a series of downward forces on it. For each of these downward forces, we use the pulling string and spring scale to determine the maximum static friction force the surface exerts on the block. The downward pushing spring is on wheels to prevent it from exerting horizontal forces on the block.	If the friction force is proportional to the mass of the block, the friction force should remain constant during the experiment.	The friction force changes—the harder we press on the block, the higher the maximum static friction force.



Conclusion

The outcome of the experiment did not match the prediction; the hypothesis requires a revision.

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P_QFeGojza9ZILEezbAffLqfS9HtV8YhsFMeF-2x-DLxJsQsfPuSKn2sV8xCjbBLGAFBA28h02X9nilucVyjsbD9FseajI8KG8LAqIUN4_3lmJav9ra_ESzHHn-Ejt2tM&__tn__=%2CO%2CP-R

Eugenia Etkina
28. July

Hi all, 3 things today. First, we have more new members joining our group - WELCOME! please read the message pinned on the top of the group's page to learn hot to benefit form the group the most.
Second, to join our group all of you needed to answer the question posted there - Why do you wish to join the group? The question is needed for me to decide who to let in. The group is not for the students or people curious about physics. It is only and exclusively for those who teach physics and wish to teach it differently using the ISLE approach. So, to be admitted, a person needs to indicate that they have interest in ISLE, or they are using our textbook, or that they wish to learn new teaching methods because they are physics teachers. If a person asks to join and does not answer the question, I message them and wait for their answer. Some never reply and I do not admit them. Today I rejected 6 people for not answering the question. Why am I writing this to you if you are already in the group? If you have any friends who are trying to join, please tell them to answer the question. Thank you.
Third thing today. I have been posting about different aspects of the ISLE approach for 2 months now. Those who have been reading the posts probably have lots of questions about it. I am asking you to start posting your questions here so that we can clear them before the school year starts. Please do! When you ask a question responding to my post, it is great, but very few people see the response, when you ask it as a post, then many more people see it. Let's have a week of questions only. when August starts, I will start posting about the content that you will be helping your students learn again.
Also, some time in August we will have another meeting for teaching of kinematics. I will need to find a few days for you to choose and I will announce the meeting. Please respond to this post if you read it. thank you.

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Eugenia Etkina
29. July

Hi all, yesterday Matthew Mac asked a question whether the ISLE approach takes more time that the traditional instruction and what topics teachers address in a school year. He asked this in a comment but I thought it was very important, so I am repeating the answer that Danielle Buggé gave to Matthew Mac responding to his comment. Danielle Buggé teaches in

NJ, in a high school. I am asking group members who use the ISLE approach at a college/university level to share their experiences with how much they omit or what pace they keep when they use the ISLE approach. David Brookes, Yuhfen Lin, Diane Crenshaw Jammula and others, please respond! Below is Danielle Buggé's reply to Matthew Mac:
Matthew Mac, I agree with Eugenia Etkina that once students get the hang of it, the pacing is not much different. As with any new undertaking, it takes time for them to learn the practices, expectations, and language. If some of your students are not 100% proficient after the first exposure to an idea (i.e. creating and interpreting motion diagrams), that is fine - there are many opportunities to practice in future activities. Providing multiple exposures to ideas as we advance the curriculum helps the students engage with ISLE while not becoming 'stuck' on one topic. Creating a sense of urgency (aka setting time limits for tasks) in the classroom also helps the students build the capacity to efficiently engage in the learning process. This past year was a bit different, coming back from virtual learning, but ideally my timeline in a first year high school course that runs September - June is as follows: I aim to finish Kinematics by the first week in October. October - December the goals are Dynamics, 2D Motion and Forces, Circular Motion, and Universal Gravitation. The goal for January and very early February is Momentum and Energy. We typically spend until mid-late April (depending on spring recess and state testing) on Electricity and Magnetism and the last few weeks on Waves and/or Optics. Most years we are able to complete the school curriculum which is modeled off of the Next Generation Science Standards (NGSS) while using the ISLE approach.
Please ask your questions in posts and please respond to the posts after you finish reading them. Thank you!

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Eugenia Etkina
29. July

Hi all, I continue the conversation about what can be done in an ISLE-based course. Here is the link to the Physics for the Sciences - an algebra-based physics course that has been using the ISLE approach since 2003. The person who runs the course is Michael J. Gentile, he can answer all your questions her or if you email him, his email is on the website that I post the link to below.

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Eugenia Etkina
30. July

Hi all, as you are preparing for the new school year, this paper might help you decide on how you set your grading scale. But the best of course, is to do standards-based assessment and have no grades at all. https://journals.aps.org/.../PhysRevPhysEducRes.18.020103…

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Eugenia Etkina
31. July

Jose Garcia asked yesterday to share papers related to the harm grades do to learners. Here is one.
In my personal experience I taught one year in my high school without grades all year. Except the final grades (which were pretty arbitrary). This was my best year of teaching with the most students going on to become physics majors. I did a lot of things to compensate the absence of grades and can share them if you are interested. Overall it was am amazing experience.

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Eugenia Etkina
1. August

Hi all, a few things today. First, we have several new members who joined yesterday - WELCOME! Please read the post pinned to the tope of this group's front page to learn how to benefit from the group the most. And do not forget to check the posts every day to make sure they appear in your feed. If you do not read the posts they stop coming to you and you miss stuff.
Now to continue our conversation about grades. Thank you all for responding yesterday. Martina Bach said that she is forced to give grades and I think we all feel the same. So, how to reduce the harm of grades when we have to give grades?

I see one solution for this problem. To reduce the harm of grades, the grades should not signify the end of learning something. They should only serve as feedback about what to work on. This means that they students should be allowed and encouraged to improve their grades using any system that you, as a teacher, use. We had a meeting in the spring about different approaches to the "resubmission policy" that people in different high schools and different universities use.
When I was teaching high school my students could improve any assignment, including unit tests. All they needed to do is to study and come an hour before school started and retake the quiz or the test. I then asked them a few questions and if we both were satisfied with the outcome, they received a new grade as if the first one never existed. If they were not happy with the outcome, they would come again and we would repeat the procedure. This approach meant that I had to come to school every day an hour early which was a burden, of course, but it also meant that I had happy knowledgeable students who believed that I was there to help them learn not to stamp them with a grade.
I used a similar policy when I ran a course at Rutgers physics department and when I came to Rutgers GSE to prepare future physics teachers, i applied the same rules to their work. Many of them are members of this group, they can share their experiences with their homeworks, projects, etc.
This was one approach to reducing the weight of grades and developing growth mindset in my students (at that time the term growth mindset has not been invented yet). There are many others that were reported at our two meetings. I am posting the links to the slideshows from those meetings and I invite you to pose your questions and the authors of different approaches to answer them.
I also want to add the allowing and encouraging students to improve their work and not punishing them for subsequent attempts is reflective of the second intentionality of the ISLE approach - learning physics should be motivational and inspiring and lead to the improvement of the well-being of our students.
Here are the links to the slides. Please respond to the post if you finish reading it.
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Eugenia Etkina
2. August

Hi all, yesterday I posted the links to google slides from our two meetings on student resubmission of their work. We also had a meeting on the essential elements of the ISLE approach that cannot be omitted if you wish to implement it. I am posting the link to the slides below. Please take a look and ask questions. The slides might help you decide what you need to keep in your curriculum in order to implement the ISLE approach.

Also, as I promised, we will have a meeting in August about how to begin the school year and how to teach kinematics using the ISLE approach. Possible dates are August 19, 20, 21. What is better - Friday or the weekend? Please reply here. And please "like" the post or comment on it when you finish reading it. If you comment, the next post will be on top of your Facebook posts.

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Eugenia Etkina
4. August

Hi all! Today my post is about preparation for our problem solving meeting on August 27th. We will be solving non-traditional problems from different areas of physics and many of them use the language and approaches from our textbook College Physics: Explore and Apply.
To prepare for the meeting you need to carefully review Chapters 2-4 (kinematics and dynamics), 7 (energy), 17 (electric charge and force), 18 (electric field) and 19 (DC circuits). Please make sure that you really study these chapters as we will be using the double notation for forces, systems and energy bar charts, E field and V field representations and so forth.
We have 40 people signed up for the meeting! We have really cool problems, absolutely new! for you to ponder. I am looking forward to seeing all of you!
Please like this post or comment on it to make it visible for more people.

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Eugenia Etkina
5. August

Hi all, we have several new members who joined in the past two days. Welcome! Many of them indicated that they are looking for resources at the freshman level of high school. This is the group that uses the ISLE (Investigative Science Learning Environment) approach to learning physics. This is a philosophy of teaching physics, not a set of activities to pick and choose when you need an activity (please visit islephysics.net to learn more). While we have tons of activities for the students to do every day of their school year published in the Active Learning Guide, On-line Active Learning Guide and PUM materials, the goal is not to plug

some of them into a lesson but to understand HOW the approach works and then use the resources.
The textbook College Physics: Explore and Apply is written for any algebra-based level course - high school AP{, college, whatever as long as your students have developed reading skills and you know what is in the textbook, you can use it with the students at any level.
Activities tailored to Freshman high school physics are in the PUM modules. The link to PUM (Physics Union Mathematics) is on the islephysics.net website in the Free Resources tab. I recommend reading everything on that website before you decide if you wish to use the ISLE approach in your classroom. It is fully consistent with the NGSS, new AP 1 and 2 curriculum and will prepare your students to pass MCAT exams. But it requires a lot of work on your part. This community is one example of how we help those who wish to implement the ISLE approach. Please post your questions and share your concerns. Thank you. If you finished reading the post please like it or comment on it to make it more visible for other members and make other new posts come to your Facebook feed.

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Eugenia Etkina
6. August

Hi all, I just created an event (for the the EVENTS on the top of the group community page) for our meeting dedicated to the first lessons in an ISLE-Based classroom and teaching of the first topic of kinematics using the ISLE approach.
Please sign up for the meeting so that I know how many people are coming. You need to prepare for the meeting though. I will answer all your questions, but to ask them you need to familiarize yourself with the materials.
Please read textbook chapters 1 and 2 and ALG?OALG chapters 1 and 2. Those who do not have access to ALG and the textbook, there is still time to get on Mastering Physics and talk to your Pearson rep to get an examination copy of the textbook. However, the meeting is for those who decided to implement the ISLE approach in their classrooms or have been doing it already. OALG Chapters 1 and 2 are posted here in the FILES. And, of course we have a meeting on the 27th for the new types of problems. Lots of meetings 🙂 Zoom links to both are in the EVENTS .
Please like or comment on the post to make is more visible. Thank you.

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Eugenia Etkina
8. August

Hi all, three things today. First, welcome new members! We had quite a few in the last three days. Please read pinned to the top messages to learn how to benefit form this group.
Second, when you read a post, please do not forget to respond to it - like it or comment. This will make the post visible for more people and it will ensure that you see the next post.
Third, we are going to start preparing for our first meeting of the year which is dedicated to the first lessons and the topic of kinematics. I already posted what to read in the textbook before the meeting, but most importantly is to read the Introductory Chapter to the Instructor Guide. I am attaching it here. The chapter not only introduces you ISLE but also discusses the general goals of the approach and the crucial elements of the textbook. It also discusses fundamental principles on which we base everything that we implemented in the textbook and in the ALG/OALG. These principles are vital for the "easy" implementation of ISLE. So, please read the chapter very carefully and pose your questions here. Thank you!

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Eugenia Etkina
13. August

Hi all, today I continue discussing how our scientific abilities relate to the NGSS (Next Generation Science Standards). In my previous post I showed an example of the relationship between science practices and our scientific abilities rubrics. Today I show how we relate to the cross cutting concepts. Here are examples of cross cutting concepts in the NGSS:
Patterns
Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4)
Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2- 1),(HS-PS2-5)
Systems can be designed to cause a desired effect. (HS-PS2-3)
Systems and System Models
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)
What do we do? Identifying patterns is one of the steps in the ISLE process and it is reflected in the components of the Observational Experiment Rubric (Rubric B). There, the students not

only learn HOW to identify patterns but also how to describe them in words, graphically and mathematically and also how to develop explanations for the patterns.
Cause-and-effect is an important issue when we discuss mathematical relationships (I posted several times about the difference between operational definitions and cause-effect relationships and gave examples from the textbook, I am attaching the screenshot again). In addition to discussing cause-and-effect in the textbook when the students analyze new relationships, we also have elements of the Data Collection and Analysis rubric (G) helping the students identify dependents and independent variables. Here is an interesting issue - sometimes there is a cause-effect relationship between an independent and dependent variable (sum of the forces and acceleration) and sometimes there is none (time and velocity).
Finally systems is a huge thing in our approach. We start systems approach from the very first chapters and carry it through systematically across all chapters. It will be too much to repeat my posts about systems here as you can always read them in the archives on google drive. Hrvoje Miloloža is the keeper of the archive, he will post the link again of you need it. Bottom line - EVERYTHING that we do in the textbook and the ALG/OALG is fully consistent with the NGSS. If you need more examples, please post your requests! If you finished reading the post, please respond to it or like it - it will make the post more visible for other people and you will see the next post for sure.

Newton's second law The acceleration $\vec{a}_S$ of a system is proportional to the vector sum of all forces being exerted on the system and inversely proportional to the mass m of the system:

$$\vec{a}_S = \frac{\Sigma \vec{F}_{\text{on S}}}{m_S} = \frac{\vec{F}_{1\text{ on S}} + \vec{F}_{2\text{ on S}} + \cdots}{m_S} \quad (3.6)$$

Here the subscripts 1 and 2 stand for the objects exerting forces on the system.

The acceleration of the system points in the same direction as the vector sum of the forces.

TIP Notice that the "vector sum of the forces" mentioned in the definition at right does not mean the sum of their magnitudes. Vectors are not added as numbers; their directions affect the magnitude of the vector sum.

Does this new equation make sense? For example, does it work in extreme cases? First, imagine an object with an infinitely large mass. According to the law, it will have zero acceleration for any process in which the sum of the forces exerted on it is finite:

$$\vec{a}_S = \frac{\Sigma \vec{F}_{\text{on S}}}{\infty} = 0$$

This seems reasonable, as an infinitely massive object would not change motion due to finite forces exerted on it. On the other hand, an object with a zero mass will have an infinitely large acceleration when a finite magnitude force is exerted on it:

$$\vec{a}_S = \frac{\Sigma \vec{F}_{\text{on S}}}{0} = \infty$$

Both extreme cases make sense. Newton's second law is a so-called *cause-effect relationship*. The right side of the equation (the sum of the forces being exerted divided by the mass of the system) is the cause of the effect (the acceleration) on the left side.

$$\underset{\text{Effect}}{\vec{a}_S} = \underset{\text{Cause}}{\frac{\Sigma \vec{F}_{\text{on S}}}{m_S}}$$

TIP In the cause-effect relationship, the quantities on the right side of the equation can be varied independently. In our case, these are the sum of the forces and the mass. Each can be changed independently of the other to affect acceleration. In the operational definition, the quantities on the right side of the equation cannot be varied independently. The velocity change depends on the time interval during which it occurs.

On the other hand, $\vec{a} = \Delta\vec{v}/\Delta t$ is called an *operational definition* of acceleration. It tells us how to determine the quantity acceleration but does not tell us *why* it has a particular value. For example, suppose that an elevator's speed changes from 2 m/s to 5 m/s in 3 s as it moves vertically along a straight line in the positive y-direction. The elevator's acceleration (using the definition of acceleration) is

$$a_y = \frac{5\text{ m/s} - 2\text{ m/s}}{3\text{ s}} = +1\text{ m/s}^2$$

This operational definition does not tell you the reason for the acceleration. If you know that the mass of the elevator is 500 kg and that Earth exerts a 5000-N downward

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3.5 Newton's second law 65

force on the accelerating elevator and the cable exerts a 5500-N upward force on it, then using the cause-effect relationship of Newton's second law:

$$\frac{5500\text{ N} + (-5000\text{ N})}{500\text{ kg}} = +1\text{ m/s}^2$$

Thus, you obtain the same number using two different methods—one from kinematics (the part of physics that *describes* motion) and the other from dynamics (the part of physics that *explains* motion).

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Eugenia Etkina
14. August

Hi all, first I wanted to welcome new members - many people joined in the last few days, our group is approaching 1500! WELCOME! Please read the posts pinned to the top to learn how

to use this group for your teaching. To see what events are happening soon, click on the EVENTS and sign up for the meetings/workshops you wish to attend.
Second, I continue posts preparing for the meeting on August 19th - the beginning of the school year in the ISLE classroom. As I said a few times, the ISLE process is an important part of the approach, and it is really crucial that the teacher is fluent in it. We describe it in many papers and we practice it in the workshops, but it is also described and explained in the textbook. I am posting the screen shot of this description. If you are new to ISLE or you do not have a copy of the textbook yet, please read carefully and think how this logical progression can be used for the students to construct their physics knowledge (this is what we do in the rest of the book and the Active Learning Guide Activities).
If you finished the post, please respond to it - comment or "like it". Thank you.

A simple example will help you understand some processes that physicists follow when they study the world. Imagine that you walk into the house of your acquaintance Bob and see 10 tennis rackets of different quality and sizes. This is an **observational experiment**. During an observational experiment a scientist collects data that seem important. Sometimes it is an accidental or unplanned experiment. The scientist has no prior expectation of the outcome. In this case the number of tennis rackets and their quality and sizes represent the data. Having so many tennis rackets seems unusual to you, so you try to explain the data you collected (or, in other words, to explain why Bob has so many rackets) by devising several hypotheses. A **hypothesis** is an explanation that usually is based on some mechanism that is behind what is going on, or it can be a mathematical model describing the phenomenon. One hypothesis is that Bob has lots of children and they all play tennis. A second hypothesis is that Bob makes his living by fixing tennis rackets. A third hypothesis is that he is a thief who steals tennis rackets.

How do you decide which hypothesis is correct? You may reason: if Bob has many children who play tennis, and I walk around the house checking the sizes of clothes that I find, then I will find clothes of different sizes. Checking the clothing sizes is a new experiment, called a **testing experiment**. A testing experiment is different from an observational experiment. In a testing experiment, a specific hypothesis is being "put on trial." This hypothesis is used to construct a clear expectation of the outcome of the experiment. This clear expectation (based on the hypothesis being tested) is called a **prediction**. So you conduct the testing experiment by walking around the house checking the closets. You do find clothes of different sizes. This is the **outcome** of your testing experiment. Does it mean for absolute certain that Bob has the rackets

TIP Notice the difference between a hypothesis and a prediction. A *hypothesis* is an idea that explains why or how something that you observe happens. A *prediction* is a statement of what should happen in a particular experiment if the hypothesis being tested were true. The prediction is based on the hypothesis and cannot be made without a specific experiment in mind.

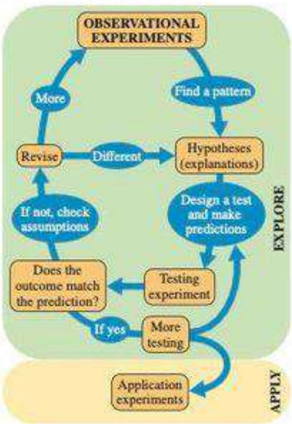
because all of his children play tennis? No; he could still be a racket repairman or a thief. Therefore, if the outcome of the testing experiment matches the prediction based on your hypothesis, you cannot say that you proved the hypothesis. All you can say is that you failed to disprove it. However, if you walk around the house and do not find any children's clothes, you can say with more confidence that the number of rackets in the house is not due to Bob having lots of children who play tennis. Still, this conclusion would only be valid if you made an **assumption**: Bob's children live in the house and wear clothes of different sizes. Generally, in order to reject a hypothesis you need to check the additional assumptions you made and determine if they are reasonable.

Imagine you have rejected the first hypothesis (you didn't find any children's clothes). Next you wish to test the hypothesis that Bob is a thief. This is your reasoning: *If* Bob is a thief (the hypothesis), *and* I walk around the house checking every drawer (the testing experiment), *then* I will not find any receipts for the tennis rackets (the prediction). You perform the experiment and you find no receipts. Does it mean that Bob is a thief? He might just be a disorganized father of many children or a busy repairman. However, if you find all of the receipts, you can say with more confidence that he is not a thief (but he could still be a repairman). Thus it is possible to disprove (rule out) a hypothesis, but it is not possible to prove it once and for all. The process that you went through to create and test your hypotheses is depicted in Figure 1.3. At the end of your investigation you might be left with a hypothesis that you failed to disprove. As a physicist you would now have some confidence in this hypothesis and start using it for practical applications.

Using this textbook you will learn physics by following a process similar to that described above. The section "How to use this book to learn physics" at the end of this chapter will explain how to master this process.

Physicists use words and the language of mathematics to express ideas about the world. But they also represent these ideas and the world itself in other ways—sketches, diagrams, and even cut-out paper models (James Watson made a paper model of DNA when trying to determine its structure). In physics, however, the ultimate goal is to understand the mechanisms behind physical phenomena and to devise mathematical models that allow for quantitative predictions of new phenomena. Thus, a big part of physics is identifying measurable properties of the phenomena (such as mass, speed, and force), collecting quantitative data, finding the patterns in that data, and creating mathematical models representing relations between the quantities.

FIGURE 1.3 Science is a cyclical process for creating and testing knowledge.



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Eugenia Etkina
15. August

Hi all, today I will start a new series of interesting problems in our textbook that help our students not only to learn physics but to expand their general knowledge of the world. The example that I pasted below is from the Active Learning Guide and is for the students who only learned constant velocity motion so this problem (or an activity) can be done by the students in the second/third week of the school year. It is a problem based on real data that we collected during the solar eclipse in 2017. In addition to applying the kinematics that the students just learned, they will learn about solar eclipses, time zones, size of Earth and so forth. The students need to work in groups and need to have access to the internet to google whatever they wish to google. The photo used in the problem is the original photo taken by Gorazd Planinsic during the eclipse that we drove for a long time to watch.
2.6.8 Apply
A total solar eclipse is a rare phenomenon that happens at the same location once in about 200 years. During this phenomenon, the Moon passes directly in front of the Sun as seen from Earth. Given that the visible diameter of the Moon is very close to the visible diameter of the Sun, the Moon covers the Sun completely and the part of Earth in the Moon’s shadow plunges into darkness during the daytime. The average shadow of the Moon on Earth is about 200 km wide and it slowly travels across Earth during the eclipse day. On August 21st 2017, this rare phenomenon occurred in the US. Below are the data about the eclipse. Work with your group members to answer the questions below. (The photo above shows the Sun in Franklin, NC, about 5 minutes before the total solar eclipse in 2017).
a. The 2017 total solar eclipse started on Monday August 21 in Madras, Oregon at about 10:20 am (Pacific daylight time) and ended in Columbia, South Carolina at 2:44 pm (Eastern daylight time). Estimate the average speed of the Moon’s shadow moving across the United States and compare it to the speed of sound in air (340 m/s). Indicate any assumptions that you made.
b. During the same total solar eclipse in Franklin, North Carolina, the Moon cast on Earth a circular shadow with a diameter of about 109 km. The total solar eclipse in Franklin lasted for 2 minutes and 30 seconds. Estimate the speed of the Moon’s shadow moving across Franklin. Compare this answer with the answer in part a. and try to explain any discrepancies.
If you finish reading the post, please like it or comment to make it more visible to the group members.

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Eugenia Etkina
16. August

Hi all, today I continue sharing problems and activities that use real life data and also teach our students something outside of physics. Please do not forget to like or comment on the post after you finish reading it.
The activity is still from Chapter 2 (ALG and OALG) and involves students learning about airplanes. They again need to google and search to decide what airplane we photographed (we do not know it either). They also need to feel ok not knowing the right answer. It is one of my most favorite problems just because of this reason. We all worry about right answers. We reward our students for right answers. And here is an example for a problem for which nobody knows the right answer. Try to figure it out and you will see for yourself.
I am also reminding you about the meeting on Friday. I will post the zoom link again on Thursday and Friday but you can also find it on the EVENTS announcement. The homework is to read Chapters 1 and 2 in the textbook, 1 in the ALG/OALG and the Introductory chapter in the Instructor Guide. If you wish to see the posts on Thursday and Friday, all you need to do is to comment on this one. Then Facebook will deliver next posts to you. I see 400-600 people viewing the posts but only 30-60 like or comment, it would be great to get more likes and comments to make the posts visible to more people, our Facebook group membership approaches 1500!

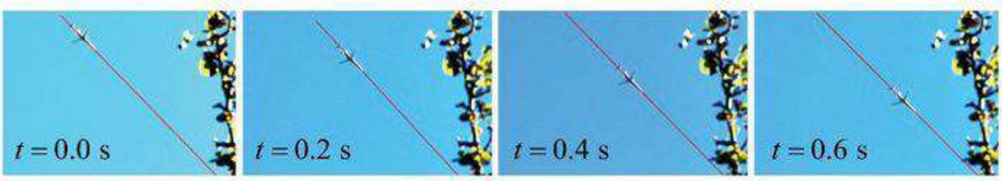
2.9.11 Observe and analyze

Collaborate together with your group to figure this out: Daniel fixed a camera on a tripod and took four successive photos of an airplane that was flying above him. The time interval between the photos was 0.2 s (see the first figure below; a straight line was added later to help you compare the position of the airplane in the different photos).

a. Draw a motion diagram for the airplane.

b. Estimate the length of the airplane using the magnified photo (shown in the second figure below) of the airplane and data that you can find on the Internet. Indicate any assumptions that you made.

c. Draw labeled position-versus-time and velocity-versus-time graphs for the airplane's motion. Indicate your assumptions (they will relate to the airplane you choose and the direction of motion) and the choice of a coordinate system. Make sure the axes of your graphs contain units. Note that you will need a ruler to solve this problem.



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Eugenia Etkina
17. August

Hi all, three things today. First - welcome to our new members! Please read the posts pinned to the top of the home page here to learn how to benefit from participating in this group.
Second, I am posting zoom link to our meeting on Friday, august 19th. The meeting starts at 2 pm Eastern Standard Time (East coast of the US) or at 8 pm European Central Time. If you are in a different time zone, please figure out in advance when the meeting stats for you. We had multiple cases of people missing meetings because of time confusion. If you plan to attend, please say YES in the Event announcement (Events on the home page of the group). Copy and paste this link to your browser.
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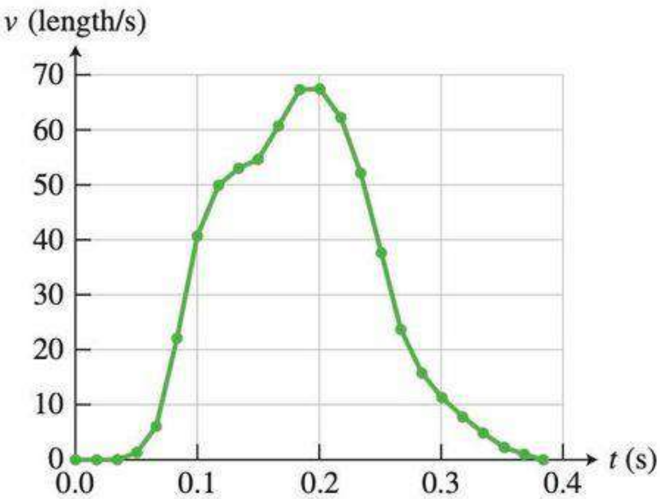
password 164680
Third, I continue with the examples fo problems that allow our students not only to practice their physics knowledge and skills but also learn some new stuff about the world. This problem is gain from kinematics and it is my favorite because I learned from it how amazing water striders are. You need to answer all the questions in the problem to understand what I mean. I am asking you to post your answers here and reflect on them. The video of the strider was taken by Gorazd Planinsic. And finally, please do not forget to respond to the post after you read it. Thank you!

76. * BIO EST **Water striders** Water striders are insects that propel themselves on the surface of ponds by creating vortices in the water shed by their driving legs. The velocity-versus-time graph of a 17-mm-long water strider that moved in a straight line was created from a video (**Figure P2.76**). The insect started from rest, sped up by taking two strides, and then slowed down until it stopped. Estimate (a) the maximum speed (in m/s), (b) the maximum acceleration (in m/s^2), and (c) the total displacement (in m) of the water strider. Note that the velocity on the graph is given in units of length of water strider body per second.

FIGURE P2.76



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20. August

Hi all, we had a great meeting yesterday. Thank you all for coming. It was great to see new people joining our community and the ones who always come. I am posting the recording and the link to the slides. If you missed the meeting and have questions after watching the recording and working through the problems on the slides - please post your questions here. Also, in the folder with all the documents there is a file with solutions for Chapter 2 ALG activities. Our next meeting is on Saturday. It is about new types of problems - how to make them, how to solve them. These will be completely new - not seen by anyone yet. 🙂 Please respond to the post if you finished reading it. Thank you!
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Eugenia Etkina
22. August

Hi all, a few things today. First, WELCOME new members! To benefit from the group, please read the posts pinned to the top of the community page and try to check the posts every day to make sure they come to your Facebook feed. If you comment or like the post, they will definitely show up there.
Second, I wanted to remind you all that we have a meeting (again!) this Saturday that is dedicated to solving new non-traditional problems. See the EVENTS to find the details. To prepare for the meeting, please study Chapters 3, 6, 7, 17, 18, 19, 20 and 21 (I am using the numbers from the second edition, the title is College Physics: Explore and Apply, the cover of the textbook is the photo on the community page of this group). You will need double subscript force notation, force and motion diagrams, momentum and energy bar charts (not just in mechanics but in static electricity too), E field vectors and lines, DC circuits and magnetic fields (including electromagnetic induction). We tried to choose the problems that span many areas of physics and many different types of the problems. If you are teaching AP 1 or 2, those are especially important. I also recommend studying the introductory chapter to the Instructor Guide posted here where the types of problems are described. I am attaching the list again with the AP practices that they address. If you are teaching college, these problems are also extremely important as they will help your students with the MCAT exam as well just in general - how to do physics.
Finally, I wanted to talk about an important issue. Today I was meeting with some faculty members interested in the ISLE approach and they asked me: when do students learn definitions? Don't they need to know what velocity or acceleration are in order to be able to do

observational experiments? This was an excellent question as it uncovered one of the important principles of the ISLE approach: "Image first, name second". This principle goes back to the legendary pioneer of the physics education research Arnold Arons. It turns out that it is also consistent with the brain studies (see J. Zull, the art of changing the brain).
It turns out that our brain can only access something if we store an image of it and this image is connected to other images. Therefore helping students create an image of some important idea and then give it a name helps them retrieve this idea later.
We worked through an example of this approach in our meeting last week on Friday when we went through the steps that the students constructing the concept of velocity go through. They conduct an experiment collecting position and time data of cars moving at constant (but different) velocity (without knowing the name for velocity) and graph the data. Comparing the graphs for the first and slow moving cars (or data for two differently moving bicycles), the students come with the idea that the slopes of the graphs are different for two cars and the car with the larger magnitude of the slope (as the cars can be moving in the negative direction) is the car that they OBSERVED moving faster. They determine the slopes and the steps they used to find them are exactly the steps that we use to determine the physical quantity of velocity! This way the student create an image of velocity as the slope of position vs time graph and then (only then) we give them the name of this slope. All of those activities are in the ALG/OALG and described in the textbook, but only DOING them and DISCUSSING THEM in groups help students develop the image so that they are ready to hear the name.
If you finished reading the post, please like it or comments on it to make it more visible for more people and ensure that the next post comes to your feed.

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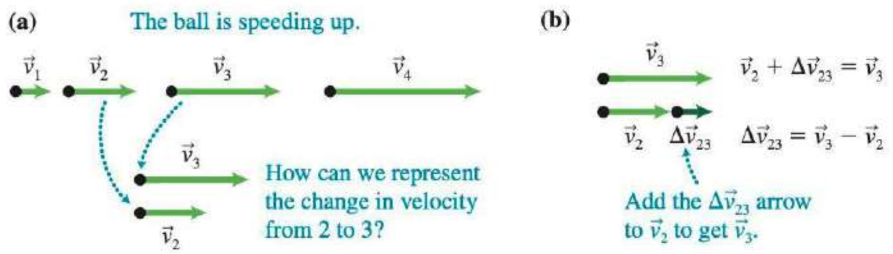
Eugenia Etkina
23. August

Hi all, a few things today. First, I am asking you again to comment on the posts if you read them. Your comments make the posts more visible for other group members. As there are new posts every day, you will benefit the most from being a member of this group if you check the posts every day.
Today my post is about most important things that the students should learn in kinematics. It might seem boring and too mathematical but in fact it is crucial for learning the rest of physics. What are those crucial things?
First, it is a feeling for the units of physical quantities. What does 1 meter mean? How big is it? Try with your students asking them to show you one meter and you will see how different the answers will come out. Then, how fast is the speed of 1 m/s? Ask your students to move at a constant rate of 1 m/s. They will need to walk. What about 2 meters per second? They will switch to a jog. 3 m/s? Who can move at 5 m/s? If you have a large classroom, it will be a great kinestetic exercise for your students. To do it, ask for a volunteer and then ask the rest of the class to give directions to this person what to do. Everyone will be engaged.

The next big issue is the difference between velocity and acceleration. Can the students move with the acceleration of 1m/s/s? What does it mean? This difference is crucial for learning dynamics later. It is also important for them to connect physics to real life and to simply have fun during learning physics. People tend to want to do things with which they associate positive emotions. Remembering it will motivate your students. Agree?
Finally, how to find the direction of delta v arrow on the motion diagram? Knowing how to do it is extremely important for dynamics, for drawing force diagrams and applying Newton's second law. But there is a big caveat here. The difference between the velocity change and acceleration. The velocity change arrow on the motion diagram only shows the direction fo the acceleration, not the magnitude. This distinction becomes important when we study circular motion.
What about kinematics graphs? Aren't they important? They surely are but you can spend months making sure that every student is able to read and write with them and still students will be having problems. My advice, have them try some but do not worry if they cannot do it yet, they will meet the graphs many more times in different topics and learn slowly. But without understanding how to draw velocity change arrow on the motion diagram their ability to understand dynamics will be compromised.
So, when you plan your units, think strategically. What is important for student future learning of physics and what is important for their confidence, motivation, and the feeling that they can do it? This double-arrowed compass will help you make decisions on what to spend time on.

FIGURE 2.4 Determining the magnitude and direction of the velocity change arrow in a motion diagram.



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Eugenia Etkina
24. August

Hi all! A few things today. First - WELCOME to our new members! Please read the posts pinned to the top of the community page to learn what this group is about. To benefit the most from the group, visit islephysics.net to learn the foundational philosophy of learning and teaching physics that this group uses as well as the textbook that is based on this philosophy,

and try to check posts here every day. If you wish the posts to come to your Facebook feed, you need to like them or even better, comment - then Facebook will notify you about every single post.
Today, I continue with images and kinematics. Yesterday my post was about most important ideas that the students should learn in kinematics to be able to move forward and it inspired an excellent discussion of kinematics graphs. Thank you all for contributing.
In this discussion a topic of enacting motion represented by a graph came up. This is a great approach!
To help students remember that to understand what a kinematics graph is telling them, they first need to figure out WHAT kind of graph it is - position vs time, velocity vs time, acceleration vs time or something else. One of my former students, a future physics teacher, came up with a great way to help students do it (during his student teaching internship). He asked his students when they encountered any kinematics graph, to stop and say: "Hello mister graph! My name is Jonathan, and you are.... velocity vs time graph! or position vs time graph!" It sounds silly but it makes the student stop, slow down, before answering our questions about this particular graph. In a way it moves cognitive processes from fast to slow. It is fast processing that is the reason for many mistakes that our students make.
But enough of the graphs! Now to images. As I said two days ago, having an image of an idea before giving it the name is very important. We have images of objects, everyone would agree with that. But should we have images of mathematical representations? (Notice that I am not using the term formula here exactly for the reason of preventing fast processing in my students). Let's say you have the following mathematical representation: $x = 5\ m + (-2\ m/s)t$. What do you "see" or imagine when you see this expression? I literally ask my students to tell me what they "see". And then I ask them to enact this expression.
One person (Anna, for example) comes to the front of the class and the rest of the class give her advice what to do (they do it after discussing in their groups). At first they need to designate the origin - the place where $x = 0$. Then they need to agree on the positive direction fo the x axis. Then they need to put the person at 5 m away from the axis in the positive direction. And then they tell Anna to start jogging (by this time they already know that 2 m/s is a jog) in the negative direction. I ask them if they agree that this is the right image of the mathematical expression. They sit quietly for a while and nobody say anything. And then I ask: "Look at the mathematical expression carefully and ask yourself: What was Anna doing when $t = 0$?" At this point somebody says - Oh, she was already jogging!!! So, how to enact the expression then?
The class goes back to their groups and after oner minute a representative of one of the groups says: Everyone, close your eyes, Anna, please start jogging farther away from 5 m mark moving towards the origin, when you pass the 5 m mark I will say "Open" and you will all open your eyes and see Anna crossing the 5 m mark already jogging. Anna should continue jogging forever 🙂 And then Anna jogs and they all clap. This is what imagining equations can look like in your classroom.
Of course, here you need to be careful to invite a person to the front who is not shy and who is willing to jog. If you have a student in a wheel chair, I would invite them (asking before the lesson if they do not mind). You can change the speed in the equation to walking or to running if you teach athletes.
If you finished reading the post, please like it or comment to make it more visible for other people, thank you!

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Eugenia Etkina
26. August

Hi all, this is my second post today. A few months ago Bradley Moser interviewed me for his Physics Alive podcast series. He asked me about ISLE and I tried to answer his questions as best as I could. Check this out. If you are new to ISLE, this interview can be a short introduction to it. http://physicsalive.com/ISLE/
He has tons of great podcasts on the website - I encourage you to check them out too.

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Eugenia Etkina
28. August

Hi all, first WELCOME to our new members - we had a huge group join yesterday - 24 members, wow! To benefit from the group, please read the messages pinned to the top and visit islephysics.net. It is really important to check posts as often as possible (we post every day) and to like or comment on them - then new posts come to your Facebook feed.
Second, about the meeting yesterday. Thank you all for coming and persisting. I know that solving these new types of problems might look a little intimidating at first, but you did not give up and persevered for over 2 hours! I thought discussions were very insightful and Gorazd Planinsic and I learned a lot. Thank you.
For those who missed the meeting, the documents and google slides are at https://drive.google.com/.../1YpW2TkfLpnl3V3-TSzEzzsPTWcf...
and the zoom recoding is at https://rutgers.zoom.us/.../ymYUA2YNtRm23nae5aLdGxl3M5uyA... Password: gj?7r9+i
The next step is for us to plan the meeting for Dynamics (chapters 3 and 4 in the textbook). I wonder how many people are interested in attending such meetings. Maybe the meetings are too taxing and just reading my posts helps enough? I am asking as for the meeting last night 46 people said that they are coming and only 16 actually came. Please comments here if you need this meeting (linear dynamics) and also about the days/ times when it is convenient. I was doing meetings on Saturdays mostly as people are not teaching then and different time

can be accommodated. So, please comment - both about the need for meetings and days/times. Thank you.

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Eugenia Etkina
29. August

Hi all, many things today! First, we continue accepting more and more new members every day, WELCOME, our new members! To learn about the group please read the posts pinned to the top of the community page and visit islephysics.net website to learn about the ISLE approach and the textbook College Physics: Explore and Apply (both regular and AP editions) that are the foundation of this group's philosophy. We have meetings every month on-line, the next meeting is about teaching Linear Dynamics through the ISLE approach. Finally, if you wish Facebook to let you know when the new post is here, you need to "like" or comment on the post you just read.
This brings me to the second point of today's post. Yesterday I posted a poll about 2 possible dates for the dynamics meeting and twice as many people voted for September 17th compared to September 10th. Therefore the meeting will be on the 17th. How is 1 -m EDT (East coast time US), 10 am West coast time US and 7 pm Central European time - ok?
To prepare for the meeting, please read chapters 3 and 4 in the textbook, go through activities in the ALG/OALG for the respective chapters and please read chapters 3 and 4 in the Instructor Guide.
Finally, Rebecca Kung yesterday posted an example of the "need to know" for kinematics and I responded to her post summarizing the "need to know" ideas for those who did not read my previous posts about it, please read my comment about it in response to Rebecca's post and start thinking of possible "needs to know" for dynamics. Thank you! If you finish reading the post, please respond to it to make the post more visible for other group members.

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Eugenia Etkina
30. August

Hi all, a few things today. First, WELCOME to our new members! We have many more who joined yesterday. To benefit from the group, please visit islephysics.net and posts pinned to the top of this group's community page to learn about the philosophy on which the groups is based (the ISLE approach to teaching and learning physics) and the resources that we use to help students learn physics though this approach (textbook College Physics: Explore and Apply, and supporting materials ALG/OALG and the Instructor Guide. Lots of materials are posted here in the FILES.

Second, I am going to create an EVENT for our next meeting on September 17th for teaching of Dynamics, please sign up there!

Third, I wanted to talk about the role of experiments in the ISLE approach (again) but this time related only to kinematics. As you all know, the ISLE approach groups all experiments that students do or watch into three big categories (observational, testing and application experiments). In kinematics we use qualitative observational experiments to help students invent the concepts of relative motion and of a dot and motion diagrams. When students conduct these experiments, they do not make any predictions, they observe and look for patterns. Finding patterns and then explaining them is the goal of such experiments. But in kinematics we go further. The students conduct quantitative observational experiments collecting data for slow and fast constant motion cars to invent the concept of velocity and of a falling object to invent the concept of acceleration. The invention of both quantities follows the same path - experiment, data collection -data representation as a motion diagram and then as a graph - finding a pattern - giving name for the pattern. In case of velocity, the graph is position vs time graph, in case of acceleration, it is velocity vs time graph. This way the definitions of physics quantities do not come from authority but from the data analysis. I pasted an example of the invention of the concept of velocity from the textbook here.

When do students do testing experiments in kinematics? There are a few ways to engage them in such experiments. As you remember, testing experiments require a prediction which is based on the hypothesis under test before the students perform the experiment. Testing experiments give students a unique opportunity to REJECT hypothesis, a process that they almost never engage in during their education. Here are a few examples: the students need to test a hypothesis that a falling object moves at constant velocity (done before they learn the concept of acceleration). The students are given a fan cart and are asked to test two competing hypotheses: the cart moves at constant speed and the cart moves at constant acceleration. To do this, the students need to first design the experiment, then make TWO predictions based on TWO hypotheses (they do not need to like any of those) and then run the experiment and compare the outcomes to the predictions.

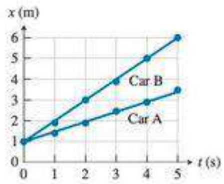
Finally the application experiments require students to solve some practical problem using the knowledge that they have developed. One of such problem is for them to work with given cars to predict where they would meet when traveling along the same straight line. First, the students need to study the cars to figure out how they move and then use kinematics equations or proportional reasoning to make the prediction, run the experiment and compare the outcome to the prediction.

It looks like in both testing experiments and application experiment that I described the students are making predictions, but these prediction are different epistemologically. In the former case, they serve as a tool tool to reject hypotheses and in the latter - to apply hypotheses.

I am pasting an example of an invention of a physical quantity through an observational experiment from the textbook. See ALG and OALG for activities for the students. And if you finished reading the post, please respond to it or "like" it to make it more visible for other members of the group and to make sure that the next post comes into your Facebook Feed. Thank you.

OBSERVATIONAL EXPERIMENT TABLE 2.6 Graphing the motion of cars

Observational experiment				Analysis
Data for car A		**Data for car B**		We graph the data with the goal of finding a pattern. The trendlines for both cars are straight lines. The line for car B has a bigger angle with the time axis than the line for car A.
$t_0 = 0.0$ s	$x_0 = 1.0$ m	$t_0 = 0.0$ s	$x_0 = 1.0$ m	
$t_1 = 1.0$ s	$x_1 = 1.4$ m	$t_1 = 1.0$ s	$x_1 = 1.9$ m	
$t_2 = 2.0$ s	$x_2 = 1.9$ m	$t_2 = 2.0$ s	$x_2 = 3.0$ m	
$t_3 = 3.0$ s	$x_3 = 2.5$ m	$t_3 = 3.0$ s	$x_3 = 3.9$ m	
$t_4 = 4.0$ s	$x_4 = 2.9$ m	$t_4 = 4.0$ s	$x_4 = 5.0$ m	
$t_5 = 5.0$ s	$x_5 = 3.5$ m	$t_5 = 5.0$ s	$x_5 = 6.0$ m	



Pattern

It looks like a straight line is the simplest reasonable choice for the best-fit curve in both cases (the data points do not have to be exactly on the line).

In Table 2.6, the slope of the line representing the motion of car B is greater than the slope of the line representing the motion of car A. What is the physical meaning of this slope? In mathematics the value of a dependent variable is usually written as y and depends on the value of an independent variable, usually written as x. A function $y(x) = f(x)$ is an operation that one needs to do to x as an input to have y as the output. For a straight line, the function $y(x)$ is $y(x) = mx + b$, where m is the slope and b is the y-intercept—the value of the y when $x = 0$.

In the case of the cars, the independent variable is time t and the dependent variable is position x. The equation of a straight line becomes $x(t) = mt + b$, where b is the x-intercept of the line, and m is the slope of the line. The x-intercept is the x-position when $t = 0$, also called the initial position of the car x_0. Both cars started at the same location: $x_{A0} = x_{B0} = 1.0$ m.

To find the **slope** m of a straight line, we can choose *any* two points on the line and divide the change in the vertical quantity (Δx in this case) by the change in the horizontal quantity (Δt in this case):

$$m = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

For example, for car A the slope of the line is

$$m_A = \frac{3.5\text{ m} - 1.0\text{ m}}{5.0\text{ s} - 0.0\text{ s}} = +0.5\text{ m/s}$$

The slope of the line for car B is

$$m_B = \frac{6.0\text{ m} - 1.0\text{ m}}{5.0\text{ s} - 0.0\text{ s}} = +1.0\text{ m/s}$$

Now we have all the information we need to write mathematical equations that describe the motion of each of the two cars:

Car A: $x_A = (+0.5\text{ m/s})t + (1.0\text{ m})$

Car B: $x_B = (+1.0\text{ m/s})t + (1.0\text{ m})$

Notice that the units of the slope are meters per second. The slope indicates how the object's position changes with respect to time. The slope of the line contains more information than just how fast the car is going. It also tells us the direction of motion relative to the coordinate axis.

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Eugenia Etkina
31. August

Hi all, a few things today. First, I created an event for our meeting on September 17th dedicated to helping students learn Newton's laws using the ISLE approach. Please sign up if yo plan to attend so that I see how many people are interested. Last year I posted about teaching specific topics using the ISLE approach every day and this year we have meetings dedicated to all major units once a month. I would like not to repeat my posts about respective content, so I invite you to bookmark the google drive folder for all previous posts (created by our amazing Hrvoje Miloloža) and slowly read the posts dedicated to the topics that you are teaching as you are moving on during the school year. Below is the link to the google drive where you will find all posts and links to the recordings of our previous meetings. I think I mentioned before that if you need a certificate of PD hours for attending the meetings, I will be happy to send you one as Rutgers is an official provider of professional development.
https://drive.google.com/.../10qn...
As I said before, to prepare for the meeting please work through chapters 3 and 4 in the textbook, ALG/OALG and the Instructor Guide to prepare your questions. We will focus on the physical quantity of force, force and motion diagrams, force components, ways for students to construct all laws and so forth.
Second, I would like to welcome our new members. WELCOME, people! Make sure you read the posts pinned to the top of the group's community page to learn what this group is about and what the ISLE approach to learning physics is (see islephysics.net). If you have any questions, please do not hesitate to post. To benefit from the group, try to check the posts every day and when you do so, "like" them or comment - this will make the posts more visible. Thank you!

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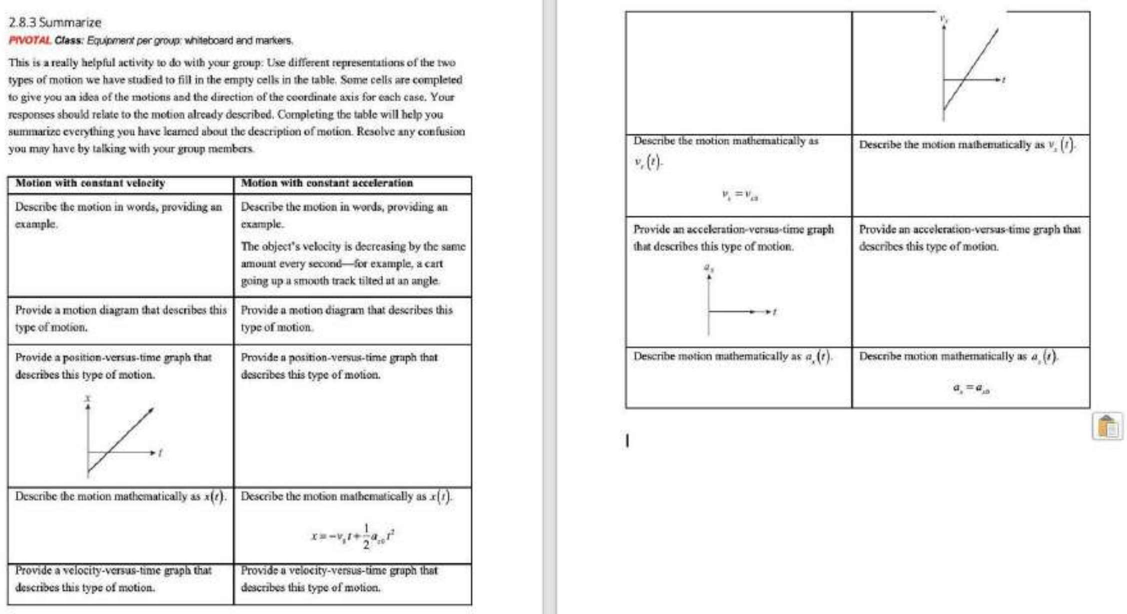
Eugenia Etkina
1. September

Hi all, a few things today. First, if you plant to attend the meeting on teaching of Newton's laws through the ISLE approach, please sign up at the EVENT announcement. Second, please respond to the post after you read it - either like or comment.
Third, I will continue with learning of kinematics, but what I am going to say is relevant to learning of any topic. Often when we wish our students to learn something we focus on what it is. For example, when they are learning acceleration we use motion diagrams, velocity-vs-time graphs, mathematical expressions for acceleration, etc. Everything is focused on helping our students learn what acceleration is. But it turns out that to learn what something IS it is equally important to learn what is IS NOT. This idea is called CONTRASTING CASES. Contrasting cases were not only found to help students learn, but according to the research done by one of PhD students, physicists continually use contrasting cases when they are trying to solve problems.
Therefore, it is crucial to use contrasting cases when trying to help students develop an image or an "understanding" of a specific concept. In kinematics, it is crucial, for example, that the

students understand the difference between acceleration and velocity, that they know that acceleration IS NOT velocity, without this understanding they cannot understand Newton's laws (an object moving at a very high speed might have zero acceleration and vice versa, a stationary object can have huge acceleration).
We have lots of question and problems that help students engage in "contrasting case" reasoning in the textbook and in the ALG/OALG. Some examples from Chapter 2 are below (the numbers show the numbering of the end of the chapter Questions:
25. Can an object have a nonzero velocity and zero acceleration? If so, give an example.
26. Can an object at one instant of time have zero velocity and nonzero acceleration? If so, give an example.
28. You throw a ball upward. Your friend says that at the top of its flight the ball has zero velocity and zero acceleration. Do you agree or disagree?
If you agree, explain why. If you disagree, how would you convince your friend of your opinion?
But in addition to question like those (and many others that we have) it is important at the end of the unit to reflect on those contrasts. An example of an activity for such reflection is in the ALG/OALG and I am putting the screenshot below. Look for Chapter 2 in the FILES here to have the Word version of this activity. It is incredibly useful for the students as it allows them to see SIMULTANEOUSLY those contrasting cases.
If you finished reading the post, please do not forget to respond to it in some way, thank you.


2.8.3 Summarize

PIVOTAL **Class:** *Equipment per group: whiteboard and markers.*

This is a really helpful activity to do with your group: Use different representations of the two types of motion we have studied to fill in the empty cells in the table. Some cells are completed to give you an idea of the motions and the direction of the coordinate axis for each case. Your responses should relate to the motion already described. Completing the table will help you summarize everything you have learned about the description of motion. Resolve any confusion you may have by talking with your group members.

Motion with constant velocity	Motion with constant acceleration
Describe the motion in words, providing an example.	Describe the motion in words, providing an example. The object's velocity is decreasing by the same amount every second—for example, a cart going up a smooth track tilted at an angle.
Provide a motion diagram that describes this type of motion.	Provide a motion diagram that describes this type of motion.
Provide a position-versus-time graph that describes this type of motion.	Provide a position-versus-time graph that describes this type of motion.
Describe the motion mathematically as $x(t)$.	Describe the motion mathematically as $x(t)$. $x = -v_0 t + \frac{1}{2} a_{x0} t^2$
Provide a velocity-versus-time graph that describes this type of motion.	Provide a velocity-versus-time graph that describes this type of motion.
Describe the motion mathematically as $v_x(t)$. $v_x = v_{x0}$	Describe the motion mathematically as $v_x(t)$.
Provide an acceleration-versus-time graph that describes this type of motion.	Provide an acceleration-versus-time graph that describes this type of motion.
Describe motion mathematically as $a_x(t)$.	Describe motion mathematically as $a_x(t)$. $a_x = a_{x0}$

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Eugenia Etkina
3. September·

Hello everyone! If you already started the school year, please share here the ISLE activities you used to start physics: did you use cameras/TV/tennis rackets? What about the wet glass? Did anyone use the balloon activity? If you did use any or more of those, how did the students respond? I wonder if they offered multiple hypotheses and if they could design testing experiments. All of those activities are in the OALG Chapter 1. If you have difficulty finding it in the FILES posted here, please let me know.
Please share! Thank you!

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Eugenia Etkina
4. September

Hi all, thank you all for your responses to my question about the activities of the first day of class. Before I comment on the issues that you described, I wanted to remind you the purpose of those introductory activities. We wish our students to see physics as a game that scientists play when learning about the world. It is a game that has rules and strategies but as every game it requires imagination. However, unlike card games or any other game, the purpose of the physics game is not to win, but to participate in playing. Playing the physics game is doing physics and as your students are in the physics classroom (or a physics lecture hall, or whatever physics place they are), they are expected to play this game. Consequently, the main goal of the first activity is to let students experience this game and then deduce its rules and see where the imagination comes in. So, whatever activity you choose, as long as the students engage in playing and then reflect on what they did thus developing the rules, it is a perfect first day activity. So, what are the rules of the game that we want them to infer?
Physics learning starts from careful observations and noticing patterns in those observations. These observations ARE REAL EXPERIMENTS even though they might not look like experiments at first, as we collect data from those. We need instruments sensitive to the relevant data to actually collect the data. That is why in some classes the cameras' activity was not easy as the students did not have the instruments to recognize that the objects were photo cameras and thus they did not feel the need to explain the data (the next step in the game).
The next step is to invent explanations for those patterns (these can be qualitative and quantitative, causal or mechanistic). All possible explanations are valuable in the game as long as they can be potentially experimentally tested. This is where imagination kicks in the first time!
Designing testing experiments is a careful step as we need to come up with experiments that can rule out as many possible explanations as we can. Imagination again!
Ruling out is only possible if we make a prediction before running the experiment based on the explanation under test (even if we disagree with the explanation!) and then compare the outcome to the prediction. If we see that two different explanations give the same prediction for the testing experiment, this testing experiment is not effective. Making a prediction based

on the explanation under test and NOT your personal feelings or intuition is the RULE of the game.
At the end we might not know which explanation is true 100%. We will only know which ones we can reject with more certainty that others.
These are the rules of the game. You can play it with 10 TVs, 10 tennis rackets (as in the textbook and the ALG), 10 photo cameras (OALG), 10 bicycles (as David Brookes does as he owns a million bicycles) and so forth. The beauty of these games is that they are not related to physics and feel like harmless, almost silly games. We wish our students to relax, see the teacher being a little silly, feel that they can joke and have fun but at the same time they are learning something very valuable. The wet glass and the poked balloon activities serve the same purpose but they have a little bit of physics in them.
But I have to caution you here. Many school years in physics classrooms start with similar games only to proceed to traditional learning of physics. The difference between them and the ISLE classrooms is that the game continues EVERY DAY for EVERY TOPIC of the course. It is helping the students see the parts of the game and keep the fun present that is the most important. Then, when they drop bean bags to make a dot diagram of a moving ball, you ask them - What part of the physics game did we just play? And they answer - Observational Experiments - this is when you win! Does it make sense? If you finished reading the post, please like it or reply to it, thank you!

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Eugenia Etkina
6. September

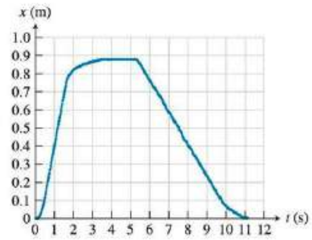
Hi all, a few things today. First, WELCOME to our new members! Please read the posts pinned to the top of the group's community page to learn what this group is about and how to learn what the ISLE approach (the foundation fo this group) works. See islephysics.net for details and resources.
Before I go on, I am asking everyone again to "like" or to comment on the posts if you read them. This increases visibility of the posts for other members and helps you see new posts. Commenting is the best, you do not need to say anything - just say "read".
Today I want to point your attention to the feature of our textbook that will 1) help your students see exciting physics in the world around them; 2) help your students learn to read and interpret text; 3) if you are teaching pre-med students, it will help them on the MCAT exam.
I am talking about reading passages with multiple choice questions at the end of each chapter. To show you an example, I use kinematics, as this is what most of you are working on with your students. One day Gorazd Planinsic and I were walking on College Ave in New Brunswick (this is where the main Rutgers campus is located) and he saw a building with automatic sliding doors. The next day we came back with the camera and I had to go through those doors again and again for Gorazd to make a good video. The result of this video analysis is the problem, that I am attaching below. It is in Chapter 2 of the textbook College Physic:

Explore and Apply. Notice, how this problem combines real life context, with graphical representations and algebraic representations. It is a perfect example of an ISLE-based problem. It also allows the students to get the feel for the values of many physical quantities in the metric system, a difficulty for American students. If you finished reading the post to the end, you know what to do. 🙂

Automatic sliding doors The first automatic sliding doors were described by Hero of Alexandria almost 2000 years ago. The doors were moved by hanging containers that were filled with water. Modern sliding doors open or close automatically. They are equipped with sensors that detect the proximity of a person and an electronic circuit that processes the signals from the sensors and drives the electromotor-based system that moves the doors. The sensors typically emit pulses of infrared light or ultrasound and detect the reflected pulses. By measuring the delay between emitted and received pulses, the system can determine the distance to the object from which the pulse was reflected. The whole system must be carefully designed to ensure safe and accurate functioning. Designers of such doors take into account several variables such as typical walking speeds of people and their dimensions.

Let's try to learn more about automatic sliding doors by analyzing the motion of a single-side automatic sliding door when a person is walking through the door. Figure 2.30 shows the position-versus-time graph of the motion of the edge of the door (marked with a red cross in the photo) from the moment the door starts opening to when the door is closed while a person walks toward and through the door. The doors are adjusted to start opening when a person is 2.0 m away.

FIGURE 2.30



91. How long does it take for the door to fully open?
(a) 1.5 s (b) 3 s (c) 5.5 s (d) 11 s
92. How long does it take for the door to close after it is opened?
(a) 11 s (b) 8 s (c) 5.5 s (d) 3 s
93. A person is walking at constant speed of 1.15 m/s toward and through the sliding door. How far from the door is the person when the door starts closing?
(a) 2.3 m (b) 4.3 m (c) 6.3 m (d) 8.3 m
94. What is the average opening speed of the door?
(a) 0.1 m/s (b) 0.3 m/s (c) 0.6 m/s (d) 3.0 m/s
95. What is the maximum speed of the door?
(a) 0.1 m/s (b) 0.3 m/s (c) 0.6 m/s (d) 3.0 m/s
96. A 50-cm-wide person is walking toward the door. What is the maximum walking speed of the person that will allow her to pass through the door without hitting it (assume the person aims for the opening)?
(a) 0.6 m/s (b) 1.2 m/s (c) 1.7 m/s (d) 2.5 m/s

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Eugenia Etkina
7. September

Hi all, thank you for commenting on my post yesterday, the visibility of that post was much higher than of the ones before, so commenting really helps, thank you!
I am glad that so many of you liked the problem. Remember, that all problems that I post are either in the textbook College Physics: Explore and apply or in the ALG/OALG (OALG files are posted here in the FILES). I cannot post all of them here, it will take forever, so I encourage you to study back of the chapter problems in the textbook - they are full of surprises. For today I want to focus on reaction time.
It is the reaction time that is important to take into account when you are driving behind a car, or encounter a pedestrian crossing a street. What is your reaction time? (Mine varies between 0.2 seconds to 0.6! seconds, really bad...)There are apps that allow you to measure yours and your students' quickly, and when doing so you will also encounter random uncertainty which will help you (and your students) see how to determine the average for each person and the

spread. Once the students have a feeling for their reaction time (they also use the famous experiment in dropping and catching a ruler, after they they learn free fall acceleration). After that, they can see how the ideas of reaction time are used in practice. We have a problem about it that uses real data.
Here it is.
One more thing, did you notice that I used the term "free fall acceleration" and not acceleration due to gravity? It is a conscious choice. In kinematics we do not investigate the causes of acceleration or motion, we just learn how to describe motion. So, when the students use the term "acceleration due to gravity", the word gravity becomes some magic word, that the students use for acceleration, force, universal gravitational constant (big G), gravitational field, and whatever things they mean. Later, when they learn about gravitational forces and the phenomenon of gravitation, they will see that the word gravity is used for different physical quantities and learn to always specify what physical quantity they mean when they use the word "gravity". We also do not use subscript g for the gravitational force, but always specify two interacting objects. So, the force that Earth exerts on an object is written F_sub_ E on O. But we did not get to forces yet, we will during our meeting on September 17th. Do not miss! If you read the post to the end, please do not forget to like it or respond to it. Thank you!

83. * **Data from state driver's manual** The state driver's manual lists the reaction distances, braking distances, and total stopping distances for automobiles traveling at different initial speeds (**Table 2.11**). Use the data to determine the driver's reaction time interval and the acceleration of the automobile while braking. The numbers assume dry surfaces for passenger vehicles.

TABLE 2.11 Data from driver's manual

Speed (mi/h)	Reaction distance (m)	Braking distance (m)	Total stopping distance (m)
20	7	7	14
40	13	32	45
60	20	91	111

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Eugenia Etkina
8. Semptember

Hi all, a few things today. First, WELCOME to our new members! To benefit from this group's work, please visit islephysics.net to learn about the ISLE philosophy and all the resources that we offer. Please, also read the posts pinned to the top of this group's community page to see to learn what we have here and how the group operates. to have the posts come to your Facebook feed you need to comment on the posts you read (simple stuff, just say Read) or like the post to see the next post for sure. To order an examination cope of the textbook check Textbook information tab on the islephysics.net website.
Yesterday my post was about reaction time in kinematics and real world connections and several people commented on the language aspect that I brought up. In fact, the language that we use in many chapters is different from traditional. The reasons are based on the research on the difficulties that students encounter in physics and the field of cognitive linguistics that tells us that people thinking about a concept is often (VERY OFTEN) is affected by how they talk about this concept.
A simple example is how we talk about forces. We say that "weight of an object" which assumes that weight is something that belongs to an object and is always with it. Is this how physicists conceptualize forces? I. Newton in his book Principia was the first to give the term "force" the meaning that physicists use today. Specifically, he said: "An impressed force is an action exerted upon a body, in order to change its state, either of rest, or of moving uniformly forward in a right line. This force consists in the action only; and remains no longer in the body, when the action is over. "
Here, Newton defines carefully the term force as a physical quantity describing an interaction of two objects, and therefore not belonging to or residing in an object. We want our students to understand that objects do not HAVE forces, and yet, in our first encounter with force we confuse them by using the word "weight" for the force that Earth (or any other planet) exerts on an object of interest (the system). No wonder, that our students start thinking of forces as something belonging to objects - forces of motion, forces of acceleration, forces of inertia, etc. In our textbook and all other supporting materials we are very careful of not confusing the students with the language that does not reflect the essence of the concepts we wish them to learn. Therefore I am recommending that when you read the textbook or activities in the ALG/OALG you pay careful attention to the language that we are using. It is very deliberate. I invite you to post here some terms that we use that might confuse the students. I will reply with examples (if we do have examples) of how we avoided those words and with what words we replaced them. If you finish reading the post, please like it or comment. thank you 🙂

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Eugenia Etkina
11. September

Hi all, for a long time we have been talking about student learning through the ISLE approach. But we did not talk about the teacher. What kind of teacher does one need to be to implement this approach successfully? When research talks about teacher preparation or professional

development they focus on three elements: dispositions, knowledge and skills. Today I want to start talking about dispositions. This post is based on our work with Stamatis Vokos and Bor Bor Gregorčič.
Cambridge dictionary defines a disposition as “a natural tendency to do something, or to have or develop something” [https://dictionary.cambridge.org/dict.../english/disposition, retrieved Sept 3 2022]. This general definition does not help us understand teacher dispositions. We can conceive a disposition as a strong (often subconscious) belief or attitude related to some aspect of teaching, that in concert with other factors, shapes a teacher’s thought and behavior (see Korthagen and Lagerwerf, 1996 and Thornton, 2006). Dispositions strongly affect how teachers analyze new information and teaching situations, and how they plan and act in the classroom (Fives and M. Buehl, 2012).
What are examples of dispositions of physics teachers? The most important is probably the disposition towards students learning physics. Can all students learn physics or only very special, selected individual? Teachers of these two different dispositions will run their classrooms (high school or college) very differently. A teacher who believes that all students can learn physics will create opportunities for the students to show their learning in multiple ways, improve their work without being punished for several tries, and develop mistake-rich environment. A teacher who believes that only selected students can learn physics will have one method of assessment (multiple choice exams, for example) that they seem adequate and make judgment of students’ abilities to learn physics based on those assessments.
Another important disposition is towards learning itself – is learning something that a person does on their own or it is a communal activity and without collaboration and communication with other students learning will not happen? Think of how these two different dispositions affect, for example, the set-up of a classroom. When we walk into an amphitheatre with the rows of individual seats all turned towards the stage where the teacher lectures to the audience, we see the implementation of a disposition that students learn by listening and studying their lecture notes. When we walk into a classroom where the tables for 3-4 students are surrounded by chairs and small whiteboards are placed on those tables, we see the implementation of a disposition that students learn by working collaboratively and sharing their ideas.
An example of a disposition related directly to physics is one of the role of “theory” in students’ learning. Does theory come first or experiment? A teacher who believes in the former will start their lessons with the description of theoretical knowledge related to the topic of learning (introducing vocabulary, definitions and mathematical relations) and then showing experiments illustrating the “theory”, while the teacher who believes in the role of experiment as the driving force behind the construction of physics knowledge would begin their lessons with experiments that would help their students see where “theory” comes from.
This is enough for today. Tomorrow, I will post the list of dispositions for the ISLE teachers specifically. Stay tuned, "like" or comment on this post to make sure the next one comes to your feed and other group members see the post.

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Eugenia Etkina
12. September

Hi all, to day I continue the "dispositions story". PLEASE do not forget to like or to respond to the post after you finish reading it to make it more visible.
What kind of dispositions should a teacher who intends to implement the ISLE approach have? All of them need to be consistent with the two intentionalities of the ISLE approach: help students learn physics by practicing it and improve student motivation, persistence, growth mind set (well-being) through learning physics.
I will list some of the teacher dispositions that will help them implement the ISLE approach in the classroom. Some of them are generic for all teachers (marked with one asterisk), some – for all physics teachers (marked with two asterisks), some of them are specific for the teachers who implement active learning techniques in their classrooms (three asterisks), and a few are unique to those who help their students learn physics through the ISLE approach (four asterisk marks). Note, that for a teacher implementing the ISLE approach all of the dispositions on the list below should be important. The order of the bullets does not represent the order of importance of the dispositions. When you are reading through the list, stop after each bullet and ask yourself if you agree with it. It is a good self check on whether your personal dispositions are in agreement with the ISLE-based dispositions.
* dispositions true for any subject
** physics learning related dispositions
*** interactive engagement in physics learning related dispositions (interactive engagement means that the students learn by actively and collaboratively participating in the process, not listening to a lecture, or watching a teacher solve problems on the board, or following cook-book instructions in a lab)
**** learning physics through the ISLE approach related dispositions
LIST
• It is not about me. It is not personal.* (This is the most important disposition for all teachers of all subjects and it means that the teacher believes that what happens in the classroom (student behavior) should always be about the students not the teacher’s feelings about themselves.)
• Learning is changing one’s brain (literally). My role is to help my students rewire their brains, not to demonstrate the prowess of mine. Therefore, my role is to facilitate student learning, not to present the material.* (This disposition again focuses on the students, not the teacher in the classroom but this time it relates to student learning, not their behavior.)
• Learning is a social activity. My role is to create conditions in the classroom when the students continuously collaborate and learn from each other in the atmosphere of mutual respect.* (This disposition again focuses on the students and combines beliefs about their behaviors, classroom setup and their learning).
• I am a physicist, and I am a teacher at the same time. When I think about physics, I think about it as a teacher, when I think about student learning, I bring in my inner physicist.** (This disposition means that encountering any physics problem or learning some new physics, the teacher believes that thinks of how to make this content accessible and exciting for their students pr what experiences their students might already have with this content. When encountering a problem or a situation related to some episode during a lesson, the teacher

thinks of the observed phenomenon (what happened) and tries to develop multiple explanations for it, similar to how physicists construct new knowledge.)

• Physics is all around me; I notice phenomena and apply physics to every (or almost every) one that I observe in my everyday life. And this is exactly what I wish my students to do.** (This disposition relates to life of the teacher outside the classroom they are naturally excited to observe, explain, calculate, or wonder about the causes of the observations – let it be waves passing through two nearby stones that invoke diffraction patterns, a thunder delayed from the lightning that makes them calculate the distance to the storm, or a run to catch a bus that makes them wonder how many joules of their body's chemical energy were just converted into kinetic energy.)

• All of my students would want to learn physics, given the right opportunities, and are capable of learning physics. They might need different time scales and different tools, but they all can learn.**** (This disposition means believing in the growth mindset and therefore that students need different times, different supports, and different representations to learn and it is the duty of the teacher to help students master those different representations, it also means that the teacher believes that the students should be give multiple opportunities to demonstrate their learning.)

• My students come from different backgrounds and cultures and bring different strengths and different life experiences into my classroom. I need to learn as much as I can about my students and make sure that their cultural backgrounds and life experiences are respected and provide the foundation for their learning of physics.* (This means that the teacher believes that individual and cultural diversity affect student learning and it is their responsibility to learn as much as possible about students backgrounds and cultures.)

• If some of my students are not learning, it is not because they cannot, it only means that I have not yet found the way to help them learn and I need to try harder to accomplish that.**** (This disposition means that the teacher believes in their responsibility to find the ways to help struggling students.)

• In order to help my students learn physics, I need to listen to my students and try to understand what they are saying instead of hunting for the right answer.*** (This disposition means that the teacher believes that all students ideas being productive in some context or expressed in a different language, as they are based on their life experiences and therefore it is their existing ideas that will determine own their future learning)

• Listening to my students is more important than talking myself.*** (This disposition means the belief that it is about student constructing their knowledge not transmitting teacher's knowledge.)

• Students' questions are the most important part of the lesson.*** (This disposition means the belief that it is student curiosity and creativity that should be the goal and the driving force of their learning and shows the value that the teacher assigns to students' questions.)

• Students talking to each other about physics is the most valuable part of their experience of the lesson.**** (This disposition means the value given to the instances when students talk to each other about physics, as this when they learn and develop community, exactly the same way as physicists do.)

• It is my role to motivate my students every day, not to expect them to always self-motivate.**** (This disposition means the belief in the importance of the second intentionality of the ISLE approach.)

• For a physicist a mistake is a source of learning, so it should be for my students. They should be able to improve their work and not feel punished for not getting it right on the first try.****

• Experiment (can be an observational experiment) is the start of learning in physics.****

• All student ideas are valuable and need to be carefully used to develop their knowledge further. Student ideas are not to be treated as misconceptions to hammer out but productive ideas to build on.****
• Students should learn by testing their ideas experimentally, not believing in authority.****
• Students are very talented. I believe in them. They are born scientists and my role is to help them feel that they belong in the physics world, that they develop physics identity.****
If you finished reading, please like the post or respond to it. And please add your own dispositions to the list if you found them missing. Thank you!

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Eugenia Etkina
13. September

Hi all, this is a reminder that we have a meeting on Saturday, 10 am PDT, 1 pm EDT and 7 pm CET to discuss the most important points and the logical progression of teaching Newtonian mechanics. To get more info, please go to the EVENT, i am posting the screen shot of the event announcement. To prepare for the meeting - so that you can ask questions, please read Chapter 3 in the textbook, 3 in the Instructor Guide (posted here in the Files) and look through the activities in ALG/OALG files (OALG files are posted here in the files). It looks like the meetings are running longer now that we are discussing the content progression, so, please plan accordingly. If you did not sign up for the meeting, please do it now. I can send you PD certificates for the event if you need them.

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Eugenia Etkina
15. September

Hi all, I forgot to mention that those who plan to come to the meeting on Saturday need to prepare two items: a VERY HEAVY object (could be our textbook 🙂) that they can hold on a palm of their hand and a sheet of paper. Please do not forget! If you have spring scales to measure forces, having a spring scale an a few objects to hang would be good too, but not necessary. Same if you have a medicine ball or a bowling ball at home. Have them handy.

Having a heavy book (A VERY HEAVY BOOK) and a sheet of paper is a must. PLEASE like or comment on this post to make it more visible.

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Eugenia Etkina
15. September

Hi all, today, in preparation for our meeting on Saturday (10 am Pacific time, 1 pm Eastern time and 7 pm European Standard time), I want to invite you to think about Newton's laws. Please like or comment on the post after you finish reading it.
We teach our students those laws often forgetting their biggest limitation - the observer! The second and third laws do not work for most observers on Earth and our students experience this every day when they on a school bus or in a car going to school. They feel being pushed forward and backward without any extra objects interacting with them when the bus starts or stops. They see other objects accelerating without any extra forces exerted on them. How often do we bring these experiences in class?
The reason for them is that when you are an observer in an accelerating reference frame, 2 Newton's laws do not work. And therefore the role of the first law is to limit the observers to only those who do not accelerate themselves. This nuanced meaning of the law is often lost in a traditional statement about EVERY OBJECT CONTINUES BLAH BLAH BLAH. No, every object does not continue.
It only does if the person observing this object does not accelerate themselves. We can see Newton's first law as the statement of the existence of the inertial reference frame observers. Sounds wild, right? But in fact, this is how I learned Newton's first law in 1973 when I first learned physics back in the Soviet Union. The first law stated in my textbook read: Inertial reference frame observers exist. To illustrate my point, I am pasting the video from our Chapter 3 Newton's first law section showing what happens when the observer is accelerating. Try to apply Newton's laws to explain what you observe! 🙂 If you finished reading the post, you know what to do! See you on Saturday!

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Eugenia Etkina

16. September

Hi all, another post in the preparation for our meeting tomorrow. Please make sure you read Chapter 3 in all of the materials - textbook, ALG/OALG, and the IG and prepare questions about what is not clear. I prepared a lot of activities from the ALG/OALG that will take you though every step of helping students construct 3 laws. You will need a heavy textbook, a sheet of paper, if possible a medicine or a bowling ball and a spring scale with some objects to hang (if you do not have those, it's ok). Please read my post from yesterday about Newton's 1st law. And here is the link to the zoom meeting. Please do not be late - 10 am Pacific time, 1 pm EDY, 7 pm CET (central European time). Plan for 2 hours. See you tomorrow. Please like the post or comment on it to make it more visible for other group members. Thank you!
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password 164680

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Eugenia Etkina
17. September

Hi all, we had a great meeting today, thank you all for coming, participating, and persevering! We worked for over 2 hours and almost no one left before the end. Here is the link to the slide show that we used
https://docs.google.com/.../1QBhvQpeRVeqsnclKwgEK.../edit...
And the recording of the zoom meeting:
https://rutgers.zoom.us/.../r65qaooyeGxwQN6c9nHspPf5BMwPt... Password: j$@E2k.m
Please ask questions here! Our next meeting is about force components, 2D situations in dynamics, and what others call normal and friction forces (we don't 🙂).

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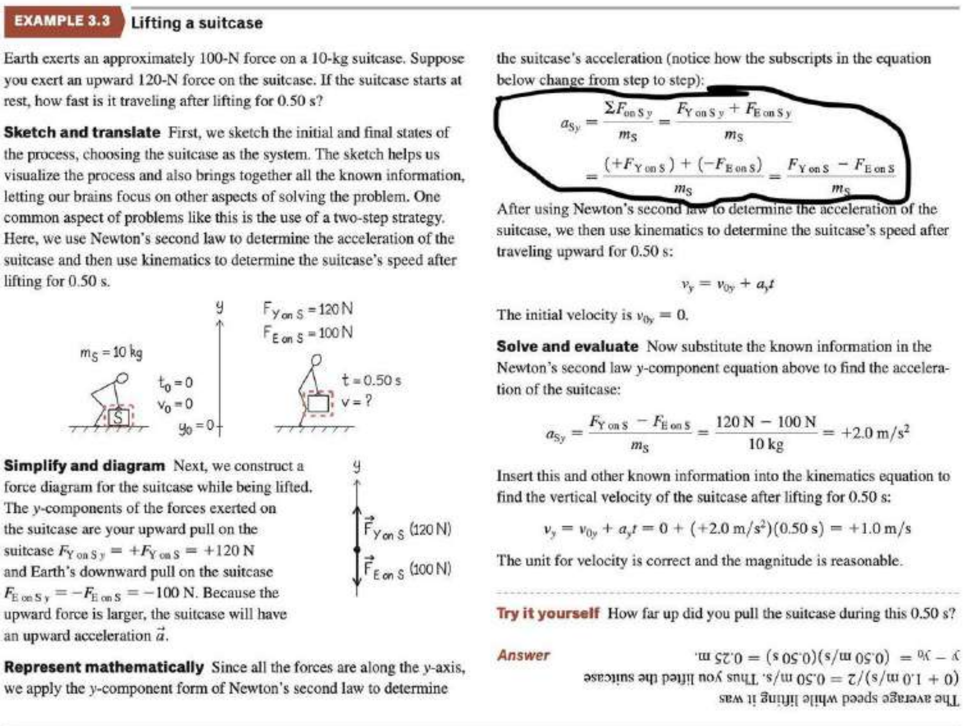
Eugenia Etkina
18. September

Hi all, two things today (three if you count my plea to respond to the posts 🙂).

First, our second dynamics meeting will be on October 8th, same time as yesterday. It is the only Saturday in October when I can do it, so no poll. October 8th 10 am Pacific time, 1 pm Eastern and 7 pm Central European. We will work on Chapter 4. Force components, normal force/friction, and problems. Mark your calendars, hope you can make it.

Second, I wanted to focus your attention on the mathematics of the application of Newton's second law to 1D motion. I am pasting a screen shot of one of the worked examples that emphasizes how we treat components when one of the forces points in the negative direction. I circled on the screen shot the lines to which to pay attention. The main point is that in Newton's second law we ALWAYS have the sum of the forces, even when one of them has a negative components. This step should not be skipped so that the students do not wonder when we add and when subtract. Here the negative sign does not mean the operation (taking away), but direction. The operation is always summation. We talked about the multiple roles of the negative sign in physics before, and I want to remind you to to ALWAYS discuss with your students the meaning of the signs when they work through algebra. There are multiple meanings of the negative sign in physics: direction (force, momentum, velocity components, etc.), taking away (negative work), conventions (negative electric charges), attraction (negative gravitational or electric potential energies), etc. It is really important that the students stop and think what a sign means when they put it into their calculations. Have a good Sunday and do not forget to like the post or comment on it if you finished reading it. Thank you!



EXAMPLE 3.3 **Lifting a suitcase**

Earth exerts an approximately 100-N force on a 10-kg suitcase. Suppose you exert an upward 120-N force on the suitcase. If the suitcase starts at rest, how fast is it traveling after lifting for 0.50 s?

Sketch and translate First, we sketch the initial and final states of the process, choosing the suitcase as the system. The sketch helps us visualize the process and also brings together all the known information, letting our brains focus on other aspects of solving the problem. One common aspect of problems like this is the use of a two-step strategy. Here, we use Newton's second law to determine the acceleration of the suitcase and then use kinematics to determine the suitcase's speed after lifting for 0.50 s.

Simplify and diagram Next, we construct a force diagram for the suitcase while being lifted. The y-components of the forces exerted on the suitcase are your upward pull on the suitcase $F_{Y\,on\,S\,y} = +F_{Y\,on\,S} = +120$ N and Earth's downward pull on the suitcase $F_{E\,on\,S\,y} = -F_{E\,on\,S} = -100$ N. Because the upward force is larger, the suitcase will have an upward acceleration $\vec{a}$.

Represent mathematically Since all the forces are along the y-axis, we apply the y-component form of Newton's second law to determine the suitcase's acceleration (notice how the subscripts in the equation below change from step to step):

$$a_{S\,y} = \frac{\Sigma F_{on\,S\,y}}{m_S} = \frac{F_{Y\,on\,S\,y} + F_{E\,on\,S\,y}}{m_S}$$

$$= \frac{(+F_{Y\,on\,S}) + (-F_{E\,on\,S})}{m_S} = \frac{F_{Y\,on\,S} - F_{E\,on\,S}}{m_S}$$

After using Newton's second law to determine the acceleration of the suitcase, we then use kinematics to determine the suitcase's speed after traveling upward for 0.50 s:

$$v_y = v_{0y} + a_y t$$

The initial velocity is $v_{0y} = 0$.

Solve and evaluate Now substitute the known information in the Newton's second law y-component equation above to find the acceleration of the suitcase:

$$a_{S\,y} = \frac{F_{Y\,on\,S} - F_{E\,on\,S}}{m_S} = \frac{120\text{ N} - 100\text{ N}}{10\text{ kg}} = +2.0\text{ m/s}^2$$

Insert this and other known information into the kinematics equation to find the vertical velocity of the suitcase after lifting for 0.50 s:

$$v_y = v_{0y} + a_y t = 0 + (+2.0\text{ m/s}^2)(0.50\text{ s}) = +1.0\text{ m/s}$$

The unit for velocity is correct and the magnitude is reasonable.

Try it yourself How far up did you pull the suitcase during this 0.50 s?

Answer The average speed while lifting it was $(0 + 1.0\text{ m/s})/2 = 0.50$ m/s. Thus you lifted the suitcase $y - y_0 = (0.50\text{ m/s})(0.50\text{ s}) = 0.25$ m.

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Eugenia Etkina
19. September

Hi all, today my post is about a very interesting contradictory fact. On one hand, Newton's second law says that acceleration of an object is inversely proportional to its mass and on the other hand, our students learned in kinematics that in the absence of air all objects independently of their mass fall with the same acceleration of about 9.8 m//s^2. How can this be?
As you all know, the answer is that the force that Earth exerts on objects pulling them towards its center is directly proportional to their mass- the larger the mass - the larger the force. So, the mass cancels out at the end. We know it. But how will our students learn it?
There are two ways of doing it (I am sure there are more, but I use one of the following). First: have a conversation with your students exactly the same way as I had it above and let them work in groups to come up with possible explanations of this conundrum. Then, after they come up with their ideas (usually they are that the force exerted on all objects is the same and that is why acceleration is the same (I know it does not make any sense, but many students originally think this way) and that the force is proportional to mass). The next step is to test these hypotheses. They need to come up with testing experiments, and they usually do - hang objects of different marked masses on a vertical spring scale marked in newtons and graph the reading of the scale vs the mass of the object. As the reading of the scale is equal to the magnitude of the force that Earth exerts on the object when it is not accelerating, the slope of the graph should either be zero (prediction based on the first hypothesis), or constant and equal to 9.8 N/kg (prediction based on the second hypothesis). Then you have a discussion of how 9.8 N/kg is the same as 9.8 m/s^2. This is the ALG and OALG sequence.
But there is another way to do it. First, ask the students to design an observational experiment to find the relationship between the mass of the object and the force that Earth exerts on them. They will come up with the experiment, similar to the testing experiment that I described above but no predictions, of course, and find that the force is proportional to mass with the coefficient of 9.8 N/kg (or so). Then you focus their attention on how weird this finding is. How can Earth "know" to adjust its pull EXACTLY according to the object's mass This is absolutely amazing, right? And after that you can ask them to design an experiment to test it. They should be able come up with the experiment of dropping objects of different masses but small (to avoid the effects of air) and predict that they will all fall with the acceleration of 9.8 m/s^2 or a little less due to air. And the discussion of the equality of n/kg units to m/s^2 units follows.
This is the reverse sequence. Remember, how Frank Noschese had several questions about the same experiment being potentially useful as as observational or a testing experiment depending on the framing? My examples above show how the same experiment (gravitational force vs mass) can serve both goals but with different framings.
And of course, we all know that the reason for the coincidence is that inertial mass is proportional to the gravitational mass with a coefficient of 1, but this story should be saved for the end of this investigation for more advanced students. I would do it in a calc-based course, but not in the algebra based course as not to have a cognitive overload of my students. In learning, often less is more.
If you finished reading to the end, please like the post or comment on it. I feel very uncomfortable asking people to like something that I wrote, but here the like does not mean

any liking, it just means a way for other people to see the post. So, please like it or comment. 🙂

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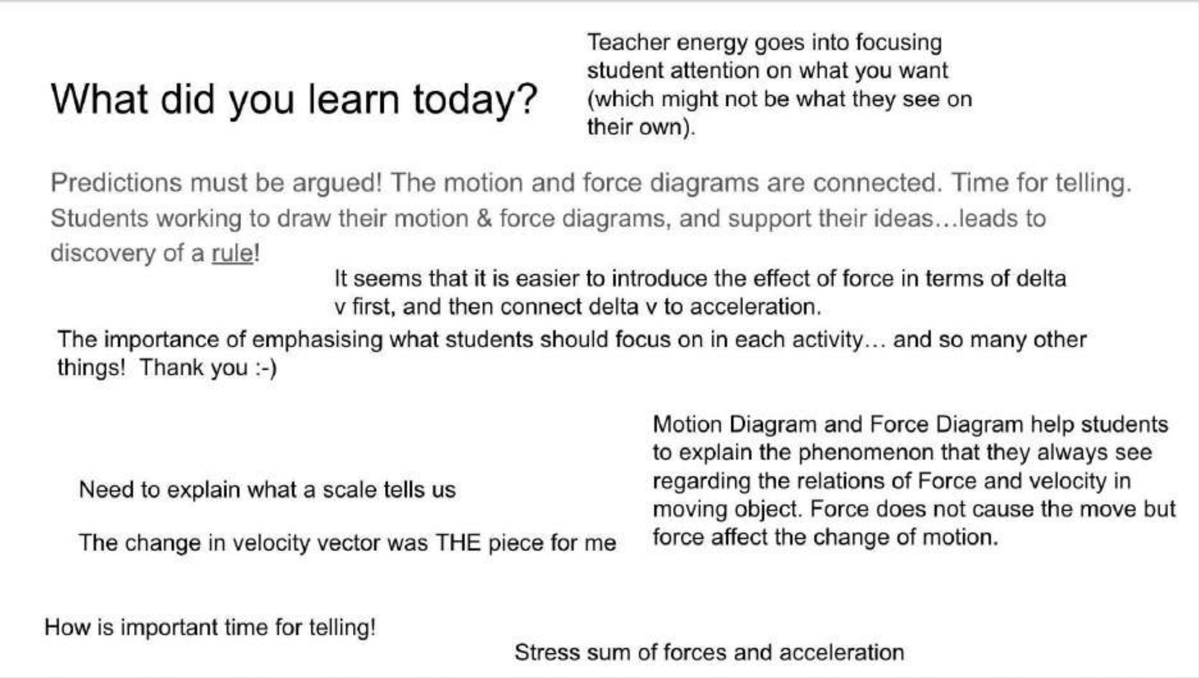
Eugenia Etkina
21. September

Hi all, a few things today. Before I start, please do not forget to respond to the posts you read to make them more visible for other members.
First, thank you, Frank Noschese for posting the story of the arrows! I love the signs for the electric charges. I made "crowns" from paper that the students can wear on their heads. Using crowns or your charge signs they can represents not only static situations but dynamic - ions and free electrons in metals, without electric field and in electric field for example, charges in magnetic field and so forth. The bigger the equipment, the stronger the episodic memory of the event for the students. When it is their own body, the episodic memory is made of not only visual memories but physical too - they will never forget it!
Now, for those who cannot attend meetings, I am reminding you that we always post the video recording and the slide shows links the next day here. Here is the link to all meeting materials that we have ever held. https://drive.google.com/.../1kiYbLqbLP7xMBhmZJBrFQgjdQwL...
We had 11 meetings so far, meeting 12 is coming up, I will set up event announcement later today. The themes of the meetings are not listed in the file names, so you will need to open the slides to see the topic. The goal of this is to encourage you to go through all the meetings and see more! Once you go through the slide show and have questions - please post them here. At the end of each meeting, I ask: "What did you learn today"? Here is the screenshot of the slide form the last meeting about Newton's laws. If you read to the end, you know what to do! Thank you!



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Eugenia Etkina
22. September

Hi all, today I want to talk about a book about the ISLE approach that will help you implement it in your classroom (not the physics textbook, but a book for teachers about ISLE). The book was published in 2019 by the Institute of Physics and includes many of the details that are essential to the understanding of the ISLE philosophy as well as issues that the implementers of the approach face (5 stars on Amazon 🙂. Many of the chapters can be accessed for free on the book website and the whole book is in your university library. Here is the link (it is also provided on islephysics.net website. I recommend investing time in reading it so that you have a big picture of the ISLE approach. https://iopscience.iop.org/book/mono/978-1-64327-780-6
I know that many of our Facebook members read the book, and I am asking those who have done it to comment here. Was it helpful? Was it useful? I am asking these questions as Gorazd Planinsic and I are going to write a sequel - how to use the ISLE approach to prepare physics teachers and conduct professional development programs, and your feedback will be very valuable for us.
Please respond to this post to make it more visible, thank you.
And do not forget to sign up to our next meeting in October (go to the EVENTS).

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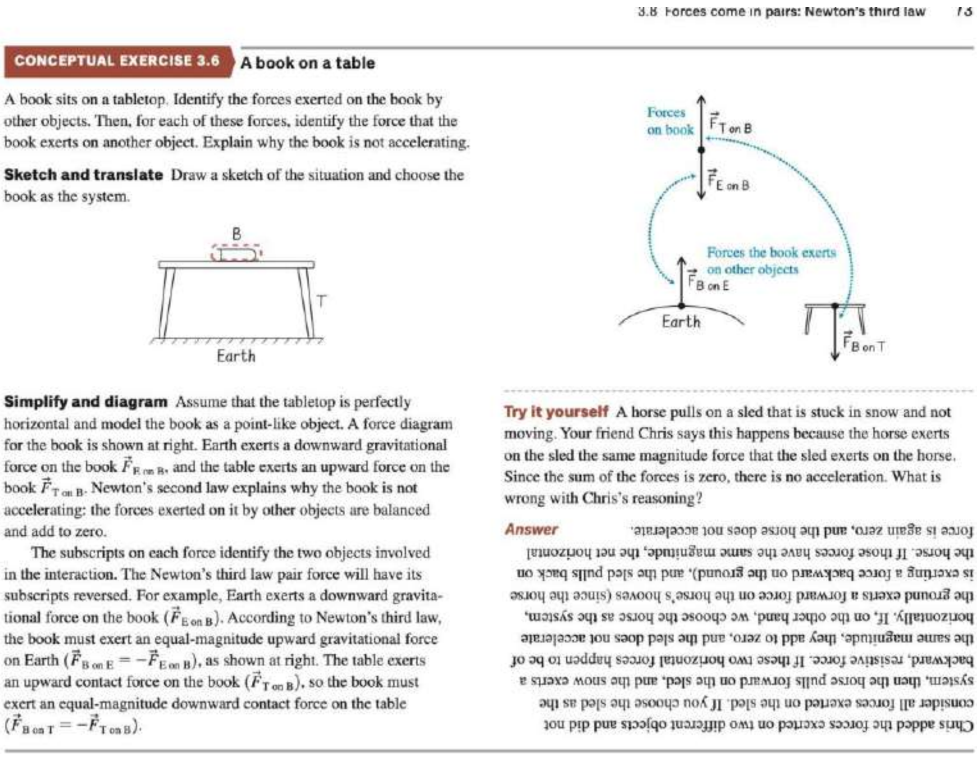
Eugenia Etkina
24. September

Hi all, today is a post about Newton's third law and out force notation. Please do not forget to respond to it after you finish reading, thank you!
As you know, we use double letter force notation. Instead of W for weight (we NEVER even use this word!) we use Force that Earth exerts on the system or Fsub EonS (and NOT force OF Earth on the system as Earth does not have any force by itself). This double notation identifies the interaction of two objects - one is the system of interest that you circle on your sketch and then use a dot on the force diagram, and the other one is the object in the Environment that interacts with the system. The system is always second and the Environmental object is always first when you write down forces.
According to Newton's third law, the object exerts the same force in magnitude and opposite in direction on the Environmental object. So, Fsub EonS = - F subSonE
The important point is, as these two objects participate in the same interaction, the forces that they exert on each other are of the SAME NATURE. If one is a gravitational force, the other one is also a gravitational force. If one is a contact force, the other one is also a contact force, and so forth. Therefore, there are three attributes of Newton's third law forces for your students to learn:
1) these two forces are exerted on two different object and they are not drawn on the same force diagram and they cannot be added to find the sum or the net force;
2) these are forces characterize the SAME interaction and therefore they are of the same nature;
3) they are ALWAYS of the same magnitude and opposite in direction.
As we often focus on the item 3) students start thinking that ANY forces that are the same in magnitude and opposite in direction are Newton's third law forces. Here is a worked example that might help start this conversation with the students. Notice the Try it yourself step - it is very important to do and to help students always ask "What is your system?" when they are trying to work though the questions involving Newton's laws. This should always be the first question.


3.8 Forces come in pairs: Newton's third law 73

CONCEPTUAL EXERCISE 3.6 A book on a table

A book sits on a tabletop. Identify the forces exerted on the book by other objects. Then, for each of these forces, identify the force that the book exerts on another object. Explain why the book is not accelerating.

Sketch and translate Draw a sketch of the situation and choose the book as the system.

Simplify and diagram Assume that the tabletop is perfectly horizontal and model the book as a point-like object. A force diagram for the book is shown at right. Earth exerts a downward gravitational force on the book $\vec{F}_{E\ on\ B}$, and the table exerts an upward force on the book $\vec{F}_{T\ on\ B}$. Newton's second law explains why the book is not accelerating: the forces exerted on it by other objects are balanced and add to zero.

The subscripts on each force identify the two objects involved in the interaction. The Newton's third law pair force will have its subscripts reversed. For example, Earth exerts a downward gravitational force on the book ($\vec{F}_{E\ on\ B}$). According to Newton's third law, the book must exert an equal-magnitude upward gravitational force on Earth ($\vec{F}_{B\ on\ E} = -\vec{F}_{E\ on\ B}$), as shown at right. The table exerts an upward contact force on the book ($\vec{F}_{T\ on\ B}$), so the book must exert an equal-magnitude downward contact force on the table ($\vec{F}_{B\ on\ T} = -\vec{F}_{T\ on\ B}$).

Try it yourself A horse pulls on a sled that is stuck in snow and not moving. Your friend Chris says this happens because the horse exerts on the sled the same magnitude force that the sled exerts on the horse. Since the sum of the forces is zero, there is no acceleration. What is wrong with Chris's reasoning?

Answer Chris added the forces exerted on two different objects and did not consider all forces exerted on the sled. If you choose the sled as the system, then the horse pulls forward on the sled, and the snow exerts a backward, resistive force. If these two horizontal forces happen to be of the same magnitude, they add to zero, and the sled does not accelerate horizontally. If, on the other hand, we choose the horse as the system, the ground exerts a forward force on the horse's hooves (since the horse is exerting a force backward on the ground), and the sled pulls back on the horse. If those forces have the same magnitude, the net horizontal force is again zero, and the horse does not accelerate.

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Eugenia Etkina
24. September

Hi all, there is a very nice discussion of the force subscripts in response to my yesterday's post. Please read. People started discussing the subscripts for normal and friction force (same subscripts as these are two components of the same force due to the interaction of an object with the surface). We will learn how to help students construct these ideas in our next meeting on October 8. Please sign up to attend it. If you cannot attend, I will share the slide show and post the link to zoom recording after. We already had a discussion of this topic last year, so if you are interested, please visit the Facebook archive where all posts are recorded. Here is the link https://drive.google.com/.../10qn...
and go to "Textbook posts, work in progress". The google folders are kept updated by Hrvoje Miloloža. Thank you, Hrvoje for your work! The posts are organized by textbook chapters, so scroll down and you will find everything that was posted before on the topic of your interest. And please do not forget to respond to this post to make it more visible. We have lots of new members who do not know yet where the old posts are kept. Help spread the word! Thank you.

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Eugenia Etkina
25. September

Hi all, we have talked a lot about different conceptual skills that we wish ISLE students to develop, one of the most important is hypothetico-deductive reasoning. But there are also some quantitative skills that we would like our students to learn. Such as finding patterns in the data and using the data to describe relationships quantitatively. One of such methods involves linearizing data, which is a skill often tested on AP exams. We have end of the chapter problems asking students to do it, but before they try, they need to learn from a worked example. I am posting a worked example from Chapter 3 here. Do not skip it if you wish your students to start building this skill and to be able to do linearization on their own. Note that the problem is based on real data, which is valued in AP exams a lot. The skill of linearization is emphasized in Modeling Instruction.
If you read the post to the end, please respond to it! Thank you!

EXAMPLE 3.8 **Learning to linearize data**

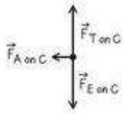
Alex is investigating the motion of a battery-powered fan attached to a low-friction cart (a fan cart) that is moving on a horizontal track. As the fan blades rotate, they exert a force on the air, and the air exerts an equal and opposite force on the blades, making the cart move (an analogy for the fan cart is a hairdryer on wheels). Using a motion detector, Alex finds that the cart moves with constant acceleration. He also measures how the acceleration of the cart a_x depends on the mass of the objects that he adds to the cart (m_{added}). His measurements are shown in the table below.

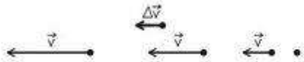
m_{added} (kg)	a_x (m/s^2)
0.10	0.25
0.20	0.21
0.30	0.19
0.40	0.17
0.50	0.15

(a) Draw a force diagram for the cart and use it to explain why the cart moves at constant acceleration for fixed added mass. (b) Two physical quantities that are not listed in the table affect the motion of the cart. Determine these two quantities using the data above. (Hint: Rearrange the mathematical expression for the acceleration of the cart to obtain linear dependence on added mass and then plot the graph using the data in the table.)

Sketch and translate The cart is moving to the left on a horizontal surface. The acceleration of the cart is also to the left due to the fan pushing air to the right (the fan works in a similar way to the hairdryer that we investigated in the previous example). We know the masses of the additional objects on the cart and the respective accelerations. We also know that the acceleration of any system is affected by the sum of the forces exerted on it and the system's mass. Because the mass of the cart (together with the fan) contributes to the system's mass, we hypothesize that the quantities that we need to determine are the sum of the forces and the mass of the cart.

Simplify and diagram We assume that the fan cart can be modeled as a point-like object and that the track is smooth, so we do not need to worry about friction. The only objects interacting with the cart (C) are Earth (E), the track (T), and the air (A). The motion diagram and the force diagram for the cart are shown in the figures below and at right. From the force diagram, we see that the forces exerted on the cart by Earth and the track add to zero, and the only force that is causing the acceleration of the cart to the left is the force exerted by the air.





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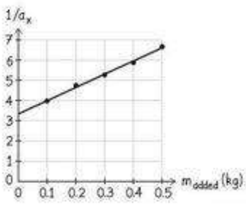
Represent mathematically We write Newton's second law in component form along the axis of motion:

$$a_x = \frac{F_{A\ on\ C}}{m_{added} + m_C}$$

Since m_{added} is changed in each experiment (it's an independent variable), it is useful to rearrange the equation so that it is a linear function with linear dependence on m_{added}:

$$\frac{1}{a_x} = \frac{m_{added} + m_C}{F_{A\ on\ C}} = \frac{m_{added}}{F_{A\ on\ C}} + \frac{m_C}{F_{A\ on\ C}}$$

and to plot $1/a_x$ against m_{added} (see graph at right). The function for $1/a_x$ is a linear function of the form $mx + b$; thus $m = 1/F_{A\ on\ C}$ is the slope of the graph and the intercept is $b = m_C/F_{A\ on\ C}$. (Do not confuse m for the slope with the symbol m for mass.)



Solve and evaluate The intercept of the graph with the vertical axis is 1 divided by the acceleration the cart would have had if the added mass was zero. Thus $m_C/F_{A\ on\ C} = 3.35$ kg/N.

We can find the slope of the graph as Δy divided by Δx. For example, when $\Delta y = 6 - 3.35$ and $\Delta x = 0.4 - 0$, this ratio is $2.65/0.4 = 6.63$. The slope of the graph is thus

$$\frac{1}{F_{A\ on\ C}} = \frac{\Delta y}{\Delta x} = 6.63\,\frac{1}{N}$$

Therefore, $F_{A\ on\ C} = 0.15$ N and $m_C = 0.51$ kg.

Try it yourself How would the graph change (consider intercept and slope) if you placed a second fan on the same cart and repeat the experiment?

Answer The slope of the graph is inversely proportional to the force exerted by the air on the cart; therefore the slope will be cut in half. The intercept is inversely proportional to the force that the air exerts on the cart and directly proportional to the mass of the cart and fans; therefore there is not enough data to determine it. But if we assume that the mass of the fan is much smaller than the mass of the cart, then the intercept will be between the original one and half of its value.

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Eugenia Etkina
27. September

Hi all, first I wanted to welcome new members - we have a few recently and I have not welcomed them yet. So, WELCOME! Please visit islephysics.net to learn what this group is about. It is about the ISLE approach. Once you study the materials on that website, please read the messages pinned to the top of the community page here. Try to visit the group every day as we have posts every day and make sure that you respond to the posts - this will make the posts more visible for you and other group members.
Today I want to go back a little bit (still staying within Newton's laws chapter) and share an activity that we devised almost 20 years ago to achieve three goals: 1) let students test some of the ideas that they might have without harming their self-confidence; 2) let students practice hypothetico-deductive reasoning; 3) let students solidify they understanding of the most fundamental idea of Newtonian mechanics. Here is the activity (in the in the ALG Chapter3 and in the textbook too), if you did it with your students, please share your experiences, and if you did not, please pose questions! The key to the activity is to help students recognize that the mallet exerts the force on the bowling ball ONLY when it is in contact with it.
3.3.3 TEST AN IDEA
PIVOTAL Lab: Equipment per group: 1 bowling ball, multiple sugar packets, stopwatch (alternative: cellphone app.), 1 meter stick, 1 mallet
Shawn says that an object always moves in the direction of the sum of the forces exerted on it by other objects. Jade says that an object’s delta v arrow on the motion diagram is always in the direction of the sum of the forces exerted on it by other objects. How can you decide who is right? You need to test both ideas. To test them:
a. Work with your group members to design an experiment whose outcome you can predict using both ideas. The predictions about the outcome of the same experiment based on two ideas need to be different in order to help you make the decision. Think of what additional assumptions you used in the predictions (an assumption is something that you accept as true.)
b. Draw sketches of the experiments and show clearly how the predictions are based on the ideas under test.
c. Perform the experiment and record the outcome. What can you say about the ideas? What can you say about your assumptions?
If you finished reading the post, please like it or comment, thank you!

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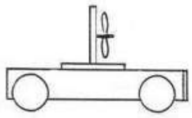
Eugenia Etkina
27. September

Following Rob Mason's post, I am sharing another linearization activity from Chapter3. It is from the OALG, so the full file is posted here in the FILES. It is easier than what Rob Mason was trying to do as the data are provided. That is why it is good for practice. Thank you all who responded to Rob. That is exactly what this group is for! And of course, WELCOME to our new members - we had quite a few in the last two days. Ou group is growing every day. If you are invite somebody, please ask them to answer the question when they apply, I do not let anyone it who did not answer the question (unless I know them personally). And please do not forget to respond to the post if you read it!

OALG 3.9.2 Linearize

Alex was investigating the motion of a low-friction fan cart on a horizontal track. As the fan blades rotate, they exert a force on the air and therefore the air exerts an equal and opposite force on the blades (see the sketch on the right). Using a motion detector, he found out that the cart was moving with constant acceleration. He also measured how the acceleration of the cart depends on the mass of the weights that he added to the cart. His measurements are shown in the following table:



Added mass (kg)	Acceleration of the cart (m/s^2)
0	0.30
0.10	0.25
0.20	0.21
0.30	0.19
0.40	0.17
0.50	0.15

What are the two unknown quantities in Alex's experiment that also determine the motion of the fan cart? Try to determine these two quantities using the data above. (Hint: rearrange the mathematical expression for the acceleration of the cart to obtain a linear dependence on added mass, and then plot the graph using the data in the table.)

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Eugenia Etkina
29. September

Hi all, today my post about the role of the observer when we use Newton's laws. I commented on this before but the idea is so important, that I am going to do it again.
Imagine, that you are standing on a bathroom scale in an elevator. You look at the reading of the scale and see that it changes (increases and decreases) without anyone pushing down on you or pulling you up. If you draw a force diagram, you will find only two forces exerted on you - by Earth and by the scale. How can then, the scale's reading (the scale reads the magnitude of the force that it exerts on you) change? Being in that elevator you cannot explain it. BUT!

the person on the ground who knows that the elevators just went up a few floors and stopped, can explain it using Newton's laws! This example shows you that observers are not EQUAL when it comes to Newton's laws. For some the laws work and for some they don't. Omitting this issue with the students makes them feel that physics does not apply to real life.
What I was talking about here are inertial reference frames. Our book is the only algebra-based book that brings up inertial and non-inertial reference frames before students learn second and third laws. BECAUSE those laws are only true for the observers in inertial reference frames (the frames that do not accelerate themselves). Newton's first law is essentially the statement about the observers - for whom the second and third laws would work. Below I paste the text in the Instructor Guide helping you navigate the textbook and the ALG for this concept.
Instructor Guide: In Section 3.3 students learned that objects change their motion when the sum of the forces exerted on them is not zero. However, in the real world, they observe objects that change their motion without any visible external influences. To explain this seeming contradiction, students need to understand the role of the observer in these cases. That is why we tie Newton’s first law to the existence of inertial reference frame observers.
Students can do ALG Activity 3.4.1 and read Section 3.4 in the textbook (make sure they watch the videos!), or you can use the material of this section to have a discussion in class. The goal is to apply the rule relating the motion and force diagrams to explain the motion of an object from the point of view of two different observers. For one observer the rule works; for the other it does not. Note that we formulate Newton’s first law slightly differently than other textbooks do, emphasizing the importance of identifying the observer. Consider a system that does not interact with the environment or whose interactions with the environment are balanced (the sum of the forces exerted on the system is zero). Only an observer in an inertial reference frame sees this system moving at constant velocity. In this approach, Newton’s first law serves as a definition of reference frames for observers for whom the subsequent second and third law would be true. In summary, Newton’s second law (an object’s acceleration is proportional to the sum of the forces and inversely proportional to its mass) holds true in inertial reference frames. EOC Questions 2, 4 and Problems 14 and 15 are appropriate here.
If you finished reading the post - please like it or comment on it.
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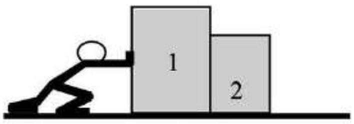
Eugenia Etkina
2. October

Hi all, a few things today. First, WELCOME to our new members! Please read the posts pinned to the top of the group's community page to learn what this groups is about, do not forget to visit islephysics.net website to gather information about the ISLE approach and all the resources that we offer.

Second, I wanted to share an activity that is very helpful for your students to REALLY understand Newton's third law (they need to do it AFTER they go through the ISLE process constructing it, the process is outlined in the textbook and the steps are easy to follow if you download OALG Chapter 3 from the FILES here).
The activity that I am sharing today is in the ALG and OALG and I am pasting a screenshot here to make sure that you do not skip it. When students work in groups on this activity, it promotes excellent discussions and eventually they arrive to the correct answers. While they are arguing and struggling, try not to interfere or guide them (guiding is not a good strategy in general) but wait patiently for them to go through all questions. The questions are written in a way that it will be impossible to them not to arrive to the "right answer". Try - and you will see. It is one of my most favorite activities for Newton's third law.
Third, I am reminding you of the meeting next Saturday - we will continue Newton's laws with force components and normal and friction components of the force that the surface exerts on an object. Do not forget to respond to this post if you read it to the end.

3.8.3 Represent and reason

***Class:** Equipment per group:* whiteboard and markers.



You push horizontally on two crates of different mass. The surface on which the crates move is smooth. Draw separate force diagrams for crates 1 and 2 for the two scenarios **a.** and **b.** below. When drawing force diagrams, use the rule relating the forces that two interacting objects exert on each other (devised in Activity 3.8.1, part d.).

a. You first push crate 1, which pushes against the smaller crate 2.

b. You now reverse the positions of the crates and push crate 2, which pushes against the larger crate 1.

c. Based on your diagrams in parts a. and b., should it be easier to push the crates in one situation or the other? Explain.

d. Is your answer to part c. consistent with the idea that you are pushing the same amount of matter, independent of the order of the crates?

e. If it is equally difficult to push the crates independent of their order, then how should the *sum* of the forces exerted by crate 1 on crate 2 and by crate 2 on crate 1 for part a. compare to the *sum* of these forces for part b.? What does this imply about the magnitude of the force that one crate exerts on the other and vice versa? (Note: the sum of the forces used here is the sum of the forces exerted on different objects, thus it does not determine the acceleration of any object.)

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Eugenia Etkina

2. October

Hi all, today my post is about motivation. Some people say: "ISLE is more difficult that traditional teaching (telling students explanations) and traditional learning (listening to somebody's explanations and repeating them back), how do you motivate teachers to use it or students to learn through it?"
In order to answer both questions, we need to think what motivates us to do anything. I group motivational things into 4 groups:

1. we do something because it is cool;
2. we do something because it is of personal interest to us;
3. we do something because we are good at it or we feel that we are getting better at it;
4. we do something because our friends do it and we want to be with them.

Did I miss anything? There is another reason why we do something - because we are addicted to it. Addiction releases a neurotransmitter dopamine - which makes us feel good. We seek the release of dopamine.
Now, how does ISLE help with all 4 (or I would say 5 aspects of motivation).

1. We look for cool "needs to know", and we specifically comment on the "coolness" of a student's idea or suggestions.
2. We connect the "need to know" to personal interests of our students. That is why we do not have "needs to know" in the ALG - each teacher, knowing their students needs to choose based on their interests. We only make some suggestions in the Chapter opening pages.
3. We encourage students to improve their work - "revise and resubmit" policy (we had 2 meetings about those last year), but most important, we carefully notice each student's progress and comment on it personally and to the whole class. Our students have a difficulty judging how much they are learning when they are constructing ideas themselves. Thus we need to continuously help them see their progress. I would say: Wow, you, my people, today made predictions based on the hypotheses under test - this is the first time when all predictions were based on the hypotheses! Or I would say: See, Matt, you have a perfect force diagram here and is is totally consistent with the motion diagram, this is amazing progress that you made! We need to show that we are genuinely impressed with their progress. Not with how smart they are but how their hard work translates into being able to do something that they could not do before. This is a huge motivation for learning.
4. We put them in groups and we make those groups who work hard look cool. We also need to make personal connections to the "leaders" of each class and make sure that they think that it is cool to do physics. If they think that it is cool, everyone else will follow. One way to do it is to invite them to help you - setting up the equipment, repairing it, searching for the right information, explaining how physics works in a specific game, etc. Make them help you and they will think that you are awesome.
5. Finally - dopamine. Do you know that when we solve a problem the same dopamine is released in our brains? Problem solving is addictive! So, engaging our students in problem solving, in solving interesting problems, relevant to them, challenging, will cause them to get addicted to the process.

I am asking you all to share your approaches to motivating students. Now, what about teachers? Please share what motivates you to do ISLE. And if you read this post to the end, please like it or comment on it to make it more visible to other members of our group. Thank you!

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Eugenia Etkina
4. October

Hi all, we have a lot of new members who joined this week, I would like to welcome them! To benefit from the group, please visit islephysics.net to learn what this group is about. The ISLE approach is the philosophy behind the teaching approach that we use and the website helps you learn about and navigate a ton of resources that we have. To benefit from the group you need to open the posts every day and after you read them like or comment, this way you will get a notification about the next post and more people in the group will see the current post. We have meetings once a month, the next meeting is coming up this Saturday. See EVENTS calendar for the details. In the FILES on the community page of this group there are lots fo documents for you to read and free materials to downloads. Two messages pinned to the top of the community page also explain what the group is about. The old posts are archived on the google drive. I will post the link in the new message, somehow Facebook does not allow me to add it to this one. Please respond to this message to show that you are participating in the group. Thank you and WELCOME again!

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Eugenia Etkina
4. October

Hi all, if you are trying to learn about the ISLE approach, reading about it on our website at islephysics.net should help. But, as we all know, watching or listening might be even more effective. Since the start of the pandemic I gave numerous talks about ISLE, scientific abilities, etc. Some of them were recorded and put on youtube. If you wish to watch them, they are in our google drive folder where Hrvoje Miloloža systematically transfers everything that happens on the group. I put the videos there at the suggestion of Jane Jackson, thank you, Jane!

The link to the google folder is https://drive.google.com/.../10qn... and the folder with videos is there - it says Videos. Check them out, they might help you see how the ISLE approach works a little better.
if you read the post to the end, please like it or comment on it.

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Eugenia Etkina
5. October

Hi all, two things today - first, please do not forget that we have our monthly meeting on Saturday. 10 am West Coast time, 1 pm East Coast time and 7 pm Central European time. Check your time zone and calculate carefully the start time.
Second, I wanted to talk today about routines. Routines are what makes our life predictable, and predictability means safety. This is why little children like to hear the same story again and again - they can predict what will happen next and thus, feel safe. Feeling safe also means that we have control over our life.
One of the main goals of the ISLE approach is to create this predictability or the feeling of safety or control. You might be thinking - what is safe about creating your own ideas? Struggling? Not knowing the right answer? The predictability and safety are in the ROUTINE. The routine of the ISLE process helps students see the predictability of their learning. They know that when they are observing something without making predictions, it means that they are going to devise a new idea. They know that after these observations the next step comes - identifying patterns. After patterns come explanations. Then designing testing experiments and so on.
With my own students I would constantly ask them - what are we doing today? And they would scream - observing! And then I will ask: So, what should we do next? And they yell - Look for patterns. And so on. They knew exactly what was coming, it was not my blind choice, it was the path of science. Creating this predictability is very important if you wish your students to feel safe. Of course, many other things are needed for the feeling of safety, this is only one of them.
But I had another routine that my students knew very well. Every class meeting started with a short quiz. Every single one, no exceptions. They knew that once they enter my classroom, they would get a piece of paper with a question. It would take them only 3-5 minutes to answer it, but the question would be there. This routine not only helped me do formative assessment at the beginning of each lesson and them to know that if they did the homework, the question would be a piece of cake, but also helped them to know exactly what is going to happen in the physics classroom. Routine. Predictability. Safety.
This means that the word quiz was not a scary word, something that fell out of the sky for them - today! But something that happens EVERY day and is a part of their learning. I would explain to them the role of these quizzes and I would call them "physics teeth brushing". We brush our

teeth every morning and every night and it is not scary, but it helps us be healthy, so does the quiz. It is physics "tooth brushing".
I had many other routines, which I will share tomorrow, but before I do that, I would love to hear from you.
What routines have you established in your classrooms? What are the reasons for those routines? If you finished reading the post, please like it or comment on it. This will make new posts visible for you and this post more visible for other group members. It only takes a second to like it. Make it your new ROUTINE, please. The same as making a post for you every day is my routine.

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Eugenia Etkina
6. October

Hi all, two things today.
Please share your routines - I posted about routines yesterday.
Please prepare for the meeting on Saturday. Please read Chapter 4 in the textbook, Instructor Guide and Active Learning Guide/Online Active Learning Guide (the files for the latter are posted here), and prepare your questions.
The zoom link to the meeting is https://rutgers.zoom.us/my/etkina...
password is 164680
Please save the link and do not click on the link before the meeting. The meeting is on Saturday, 10 am Pacific time, 1 pm Eastern Standard Time and 7 pm Central European time. Joining 10 min before helps to be on time if zoom asks you to update. The meeting is about teaching force components, normal and friction forces and projectile motion using the ISLE approach. And please share your routines! and do not forget to like the post or comment - you do not really need to "like " it, but clicking the like button makes the post more visible to other group members. Thank you.

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Eugenia Etkina
7. October

Hi all, as always, two days before our monthly meetings I stop posting new content and only bug you about the meeting. Here it is again: the meeting is a continuation of our work on Newtonian dynamics. We will work on components from all angles. All in the ISLE style. It is Chapter 4 in the textbook and all learning guides and the instructor guide. Please spend some time studying those to have questions that we can discuss. The meeting is at 10 am Pacific Time (US), 1 pm Eastern Standard Time (US) and 7 pm Central European time. If you are in a different time zone, please check what time it is in your time zone. The zoom link is https://rutgers.zoom.us/my/etkina...
Try to log in about 5-7 min before the start of the meeting in case zoom will ask you to update. I will see you tomorrow! Oh, please do not forget to respond to this post to make it more visible. Thank you.

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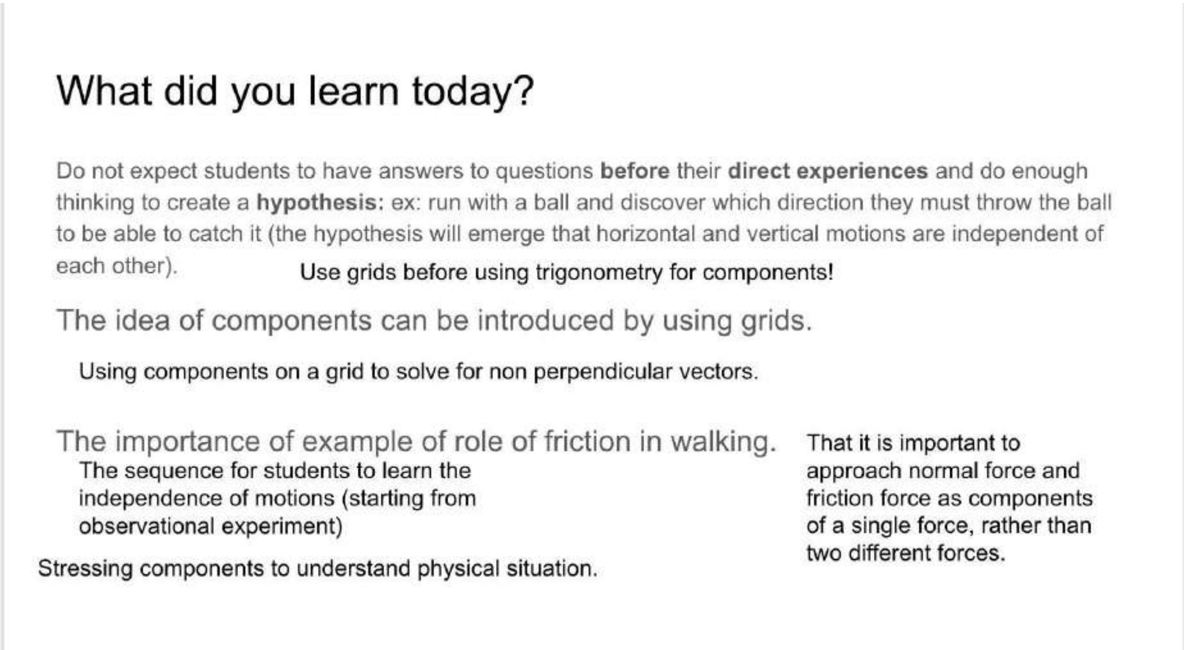
Eugenia Etkina
9. October

Hi all, yesterday I posted the links to the zoom video recording of our meeting the meeting materials but I did not attach the screen shot of the reflection slide. Here it is! Those who attended the meeting, please share additional things that you learned. Thank you all again, for coming! And if you read the post, please like it or comment on it to make it more visible.



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Eugenia Etkina
9. October

Hi all, we had a great meeting today. Thank you all those who joined the meeting and worked hard for 2 hours on a Saturday! Send me an email if you need PD hours. The link to the video recording is below.
https://rutgers.zoom.us/.../3gPSuAo3uqZ7fTSZsJ7zkeKvKuw...
password is Xix$*zQ9
The link to the google folder with all material is at https://drive.google.com/.../1jNA1isK4ylWRT7W7N3kLNeRpt1x...

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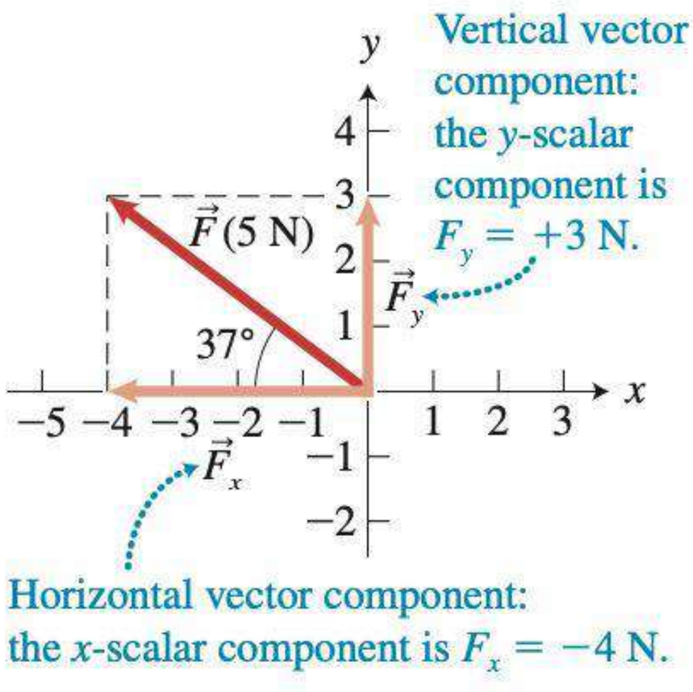
Eugenia Etkina
10. October

Hi all, today my post is about vector and scalar components of a vector. This is an important issue as without understanding scalar components, one cannot use Newton's second law which is written for vectors. To receive a number with units, we must turn the vector relation into a scalar.
So, what are vector and scalar components of a vector? The attached screen shot of a figure in Chapter 4 helps visualize them. An arbitrary vector F (in red color) that has a magnitude of 5 N and is pointed at 37 degrees above horizontal with respect to the negative direction of the x axis can be seen as the sum of two perpendicular vectors (orange vectors F^x and F^y).
These vectors also have their magnitudes and directions - F^x vector points along the x axis in the negative direction and F^y vector points in the positive y direction. These are VECTOR components of the original vector F. We still cannot use them to operate with numbers. To "convert" vectors into "numbers" we need one more step. We consider scalar components of vectors F^x and F^y to be the numbers that can be found if we subtract the tails coordinate of each vector from the head coordinate or in other words, take their magnitude and add a + sign to it if the vector is pointing in the positive direction of the axis and the - sign if the vector is pointing in the negative direction of the corresponding axis. In this particular case, the scalar component of vector F^x is equal to the negative 4 N, or -4N, and the scalar component of vector F^y is positive 3 N or +3N.

Those two numbers are ALSO two scalar components of the original vector F (the red vector that we started with). So, every time we need to find scalar components of a vector that is not aligned with one of the axis, we first BREAK IT INTO VECTOR COMPONENTS ALONG EACH OF THE AXES , then find the scalar components of those two and those are the scalar components of the original vector. If our original vector is aligned with one of the axes, then we can find its scalar components right away. Then you can use Newton's second law in components form to analyze physical situation: a subx = sum of F sub x/m and a sub y = sum of F sub y/m. HERE F sub x and F sub y are the scalar components of the forces.
I cannot use vector signs about the vector components here as I do not know how to add vector symbols while typing on Facebook. But I hope that you get the point of the DIFFERENCE between the vector components of a vector and scalar components. You can see the absence of arrows above scalar components in the figure that I attached. Please post your questions here if the distinction is not clear. And PLEASE like or comment on the post if you read it. I see about 20-25 likes and comments on the posts that have been viewed by 500 people. Please take a second to click, it will make the post more visible to the rest of the group. And one more thing: our next meeting can be on Saturday, November19 or November 26 and it will be on Circular motion and Law of universal Gravitation. Please post which date is better for you. I will do a poll tomorrow. Thank you.

FIGURE 4.3 The vector and scalar components of a vector.



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Eugenia Etkina
12. October

Let's welcome our new members:
Rachel Atay,
Paul Wolf,
Claudia Mihesan,
Reece Geursen,
Scott Berger
To benefit from the group, please see two posts pinned to the top of the community page and visit islephysics.net. Try to see posts every day and respond to them in some way so that the next post comes to your feed and more members of the group see the posts. The group only functions if we all participate. I looked up the stats today and we are a very international groups. I am attaching the screen shot of the geography - it is very impressive. Tomorrow I will start posting systematically about chapter 4 - the one we had the meeting for last Saturday.

Top countries

United States	1,213
Canada	59
Sweden	44
Italy	33
Australia	26
United Kingdom	18
Philippines	13
Indonesia	13
India	13
Slovenia	11

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Eugenia Etkina
13. October

Hi all, you need to read this! The paper has not been published yet, but it is available for reading.
https://arxiv.org/pdf/2210.03522.pdf
How well-intentioned white male physicists maintain ignorance of inequity and justify inaction
Melissa Dancy, Apriel Hodari

https://www.facebook.com/groups/320431092109343/posts/1273582583460851/?__cft__[0]=AZXM1lU7SVPPEIzjInr4WdfRDrGHDrmzkJ0CYkfSZFisDFumxMCnCcZSysH5K3D2oyMYD0Ucde_EFIPlckkVibK_BJ0UzSCs2LhJ9A_maJU-xzavj3o9pQo__BiHee6Oh_iQ4hzYELZwvMJmLiTjF9oEB9WcFmYZ0FUU-vvcZvK6i4gZXdhHj_TRzTjNg65q8jQ&__tn__=%2CO%2CP-R

Eugenia Etkina
13. Ocotober

Hi all, this is my second post today. As you all know, the ISLE approach is based on how physicists "do physics". This is where the observational experiments, hypotheses, multiple testing experiments and predictions of their outcomes based on hypotheses, and application experiments come from. They originally came into ISLE from the history of physics. Then we conducted educational experiments documenting how physicists solve experimental problems in real time. We found the same elements in their work and very similar logical progression. I am attaching a story of the Nobel Prize in Physics in 2022 that follows the exact same path. When you read it, try to find observational experiments, two competing hypotheses, lots of testing experiments and application experiments. It is an amazing story not only in how long it was, but also how it goes through the same steps in which we are engaging our students when they learn physics through the ISLE approach. They literally participate in REAL SCIENCE PRACTICES. Read and enjoy.

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Eugenia Etkina
14. October

Hi all, first I wanted to thank Frank Noschese for his post yesterday - over 700 people viewed his post. My posts never reach this number. Thank you, Frank Noschese, you are a master of engaging the audience!
Today I wanted to continue our conversation about force components. I posted about vector and scalar components two days ago, today I want to show you how we move to Newton's second law with the knowledge of components. See attached screen shot of the beginning of

the textbook section. What is important there is that in Newton's second law the components of forces are ALWAYS SUMMED UP to find the components of acceleration. Even if the component is negative, it is still ADDED as a negative number to the positive components. It is crucial to distinguish between the + plus of summation and the + for the direction of the force, or minus - for the direction of the force. Those signs have different meanings. We never subtract forces, we always add them, but some of them have positive scalar components and some have negative scalar components.

Finally, it looks like November 26 is the winner for our next meeting. If you did not vote yet, and you want the 19th, please vote!

If you finished reading the post, please respond to it! Thank you!

4.2 Newton's second law in component form

In this section we will apply Newton's second law to more complex situations in which one or more of the forces exerted on the system do not point along one of the coordinate axes. The figure in Quantitative Exercise 4.1 is an example of such a situation. If the knot in that figure is not accelerating, the sum of the forces exerted on the knot is zero:

$$\Sigma \vec{F}_{\text{on K}} = \vec{T}_{1 \text{ on K}} + \vec{T}_{2 \text{ on K}} + \vec{T}_{3 \text{ on K}} = 0$$

It is difficult to use this vector equation to analyze the situation further—for example, to determine one unknown force if you know the other two forces. However, we can do such tasks if this situation is represented in scalar component form.

Notice in the force diagram in Quantitative Exercise 4.1 that the y-scalar components of the forces that the three ropes exert on the knot add to zero. Ropes 2 and 3 exert forces that have positive y-scalar components $+300\text{ N} + 100\text{ N} = +400\text{ N}$, and rope 1 exerts a force with negative y-scalar component -400 N. Consequently:

$$a_{\text{K}y} = \frac{T_{1 \text{ on K} y} + T_{2 \text{ on K} y} + T_{3 \text{ on K} y}}{m_\text{K}} = \frac{-400\text{ N} + 300\text{ N} + 100\text{ N}}{m_\text{K}} = 0$$

Similarly, the x-scalar components of the forces exerted on the knot also add to zero:

$$a_{\text{K}x} = \frac{T_{1 \text{ on K} x} + T_{2 \text{ on K} x} + T_{3 \text{ on K} x}}{m_\text{K}} = \frac{0 + 400\text{ N} + (-400\text{ N})}{m_\text{K}} = 0$$

Thus, we infer that when the x- and y-scalar components of the sum of the forces exerted on the system are zero, it does not accelerate:

$$a_x = 0 \quad \text{if} \quad \Sigma F_{\text{on K} x} = 0$$
$$a_y = 0 \quad \text{if} \quad \Sigma F_{\text{on K} y} = 0$$

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88 CHAPTER 4 Applying Newton's Laws

Suppose that in general objects 1, 2, 3, and so forth exert forces $\vec{F}_{1 \text{ on S}}, \vec{F}_{2 \text{ on S}}, \vec{F}_{3 \text{ on S}}, \ldots$ on a system and that the forces point in arbitrary directions and do not add to zero. If the system has mass m_S, it has an acceleration $\vec{a}_\text{S}$ as a consequence of these forces (Newton's second law):

$$\vec{a}_\text{S} = \frac{\vec{F}_{1 \text{ on S}} + \vec{F}_{2 \text{ on S}} + \vec{F}_{3 \text{ on S}} + \cdots}{m_\text{S}}$$

Because this equation involves vectors, we can't work with it directly. However, we can split it into its x- and y-scalar component forms to use Newton's second law to determine the system's acceleration.

TIP In practice, we usually choose the axes so that the object accelerates along only one of these axes and has zero acceleration along the other axis.

Newton's second law rewritten in scalar component form becomes:

$$a_{\text{S}x} = \frac{F_{1 \text{ on S} x} + F_{2 \text{ on S} x} + F_{3 \text{ on S} x} + \cdots}{m_\text{S}} \quad (4.2x)$$

$$a_{\text{S}y} = \frac{F_{1 \text{ on S} y} + F_{2 \text{ on S} y} + F_{3 \text{ on S} y} + \cdots}{m_\text{S}} \quad (4.2y)$$

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Eugenia Etkina
15. October

Hi all, first I wanted to thank Allison Daubert for her post yesterday - if you did not see it, please do! It is about the importance of a routine. The routine she described is to ask your students to reflect at the end of each lesson what they learned.
If you come to our meetings, you know that this is what we do at the end of each meeting. Now I even started posting the slides with those reflections after the meeting here.
The idea of such reflections came to me a long time ago (in 1997) when I was teaching a summer course at Rutgers. I asked my student to reflect once a week about answering 3 questions:
1. What did you learn this week?
2. What remained unclear?
3. If you were the professor, what questions would you ask to find if your students understood the material?
The responses of my students were eye opening. It turned out that what they thought they learned were not the most important things but small details, but they had questions about the important things. I used their responses as formative assessment to structure my Monday classes. And I wrote a paper about it that was published in Science Education. Here is the reference: Etkina, E. (2000). Weekly Reports: A two-way feedback tool. Science Education, 84, 594-605.
When I started the physics teacher preparation at Rutgers, and we only had courses that met once a week for 3 hours (Allison Daubert was my student a long time ago), I realized that it was important for me to know what my students learned in every class. So, we had these reflections at the end of each class: What did you learn today in physics? What did you learn today as a teacher? The rule was that you cannot repeat what the previous person said, so those who waited to raise their hands were in a difficult position. Everyone was trying to keep a list of what they learned during these long classes.
In the summers, I co-ran a program for high students in astrophysics. There were about 25-30 students in the program, and they spend 5 hours every day learning about stars and X-ray astronomy. We had them reflect at the end of each day - what did you learn today and how did you learn it? When time was tight, we asked them to have a list from each group and then we went around listening to one from each group, and again, they could not repeat what another group said. This way we knew if the goals of each day were accomplished. My students, future physics teachers started using this method in their classes once they had graduated.
If you ever attended any of the ISLE workshops, you also reflected at the end on what was that most important thing that you would take away from it. Why is reflection so important?

According to J. Zull (The art of changing the brain), reflecting on what you learned and SPEAKING about it is a crucial element of the brain learning cycle. You have to search in your brain for what is it that you learned, and you have to speak about it, which engages the motor function of the brain, which is the last step of the brain processing information.
In my later research with D. May we found that those students who can reflect productively actually learn more. Or those who learn more, demonstrate higher quality reflections. We also found that those who have deeper questions, learn more. These are old papers, I am putting the references here, if you can't find the files, please email me and I will send you the papers.
May, D. & Etkina, E. (2002). College physics students' epistemological self-reflection and its relationship to conceptual learning. American Journal of Physics, 70(12), 1249-1258.
Harper, K., Etkina, E., & Lin, Y. (2003). Encouraging and analyzing student questions in a large physics course: Meaningful patterns for instructors. Journal of Research in Science Teaching, 40(😎, 776-791.
Please do not forget to respond to the post after you finish reading it. Thank you.

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Eugenia Etkina
16. October

Hi all, a few days ago I posted a story of the latest Nobel prize work that illuminated again the features of the ISLE approach. But in the story we did not see the original puzzling observational experiment that started the process. The story, the link to which I am posting today has all the ISLE steps in a mind-blowing process. You will see an initial observational experiment, multiple explanations, a quantitative model with multiple representations, a predictions, and a testing experiment. It is a story in astronomy, so nobody could run a specially designed experiment therefore it is important to learn how testing experiments are done in the fields where the immediate manipulation of the equipment is not possible. My point is (and has been for 30 years) that that ISLE process mirrors actual scientific practice and our students can do REAL PHYSICS from the first day of class. It is the process that is at the core of physics (and all of the sciences) and not a set of facts that for many years were the heart of our science education. While the NGSS (Next Generation Science Standards) recognize the importance of science practices, they do not offer a clear path for the students to engage in them in a logical manner. The ISLE approach does.
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Eugenia Etkina
17. October

Hi all, during our meeting dedicated to Chapter 4 2 a week ago we used walking as the "need to know" for this chapter. We focused our attention on both feet during one step and found that the friction component of the force exerted on each foot is responsible for each step. The force is exerted forward on the back foot and backward on the front. Walking on sand helps us see how the surface exerts a force that can be resolved into two components. Watch the video and draw a force diagram for each foot, remembering the ONE object can only exert ONE force on the other object for the same interaction. The activity is from the OALG file for Chapter 4. It is posted here in the files. Do not forget to respond to the post once you finish reading it.
OALG 4.3.6 OBSERVE AND EXPLAIN
a. Watch the video of Eugenia walking on sand (from Activity 2.9.2) https://mediaplayer.pearsoncmg.com/.../_fr.../sci-OALG-2-9-2.
b. Draw force diagrams for Eugenia (consider the person to be a point like object) when she starts a step and when she finishes the step. What object is exerting a force that makes her accelerate?
c. How does the shape of the sand help us determine the direction of the force that the sand exerts on the person?

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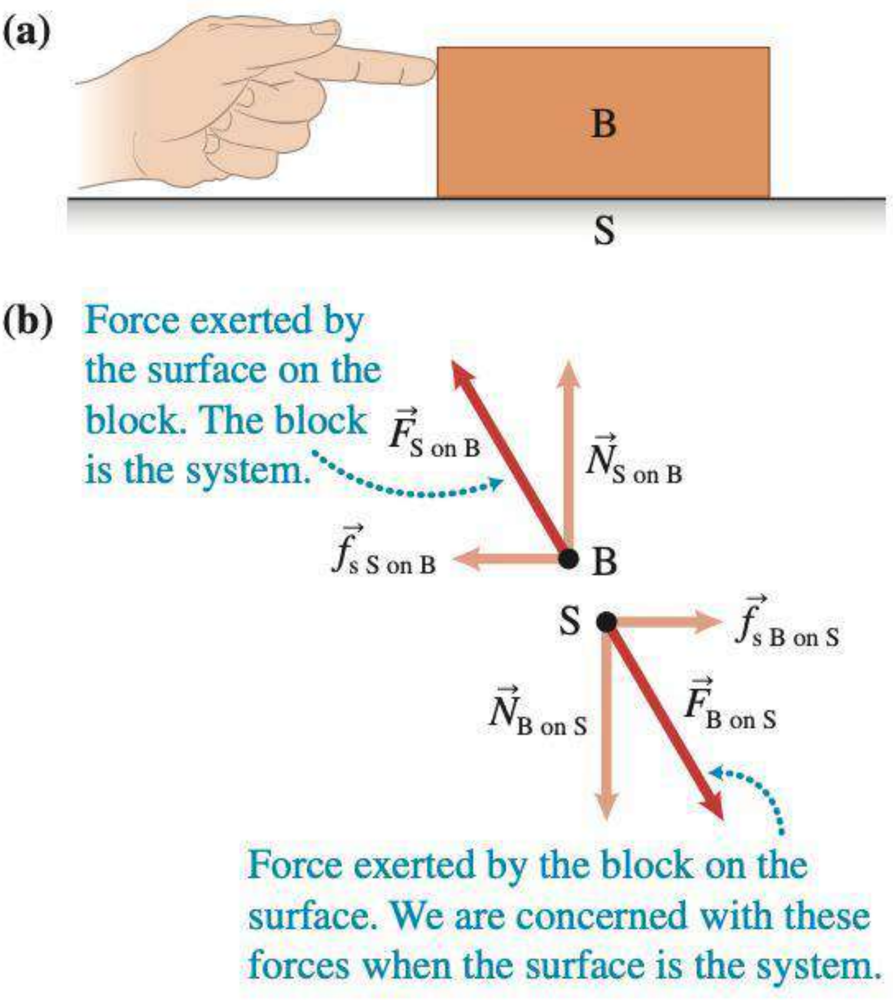
Eugenia Etkina
18. October

Hi all, to follow up on our conversation of walking and the role of friction there, I want to share an example that is crucial for understanding how it works and also the shape of the sand in the video that I posted yesterday. Hrvoje Miloloža commented on it, his comment is very important - that is why we chose sand as a surface to walk on. Look at the figure that I pasted below to see how Newton's third law is necessary to understand how friction works.

FIGURE 4.6 Force analyses when we choose different objects as the system.



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Eugenia Etkina
20. October

Hi all, today my post is about Jeopardy problems. These are the problems where the students need to work backwards - from the solution that is given to a possible problem for which this solution might work. These problems are extremely useful for the students to work through consistency of representation, to engage their creativity and to see the value of units. While we have jeopardy problems in every chapter, I wanted to share a worked example with a jeopardy problem in Chapter 4 (which we are working through now). The steps follow our problem solving strategy steps: sketch and translate, simplify and diagram, represent mathematically and solve and evaluate but the order of the steps is reversed! As the first representation is the mathematical representation, the students need to solve first, then simplify and diagram and then sketch and translate. After they work though this worked example, it is good to give them problems 14 and 38 from the back of the chapter problems. If you have never done those problems with your students, start slowly. Let them read the problem and work on it in groups for about 5 minutes, then see where they are, and, building on the most successful group's solution, continue on the board with the explanation of each step. Giving them the first 5 min to struggle themselves is very important, so that their brains are "warmed up" and they have the "need to know ". When you finished reading the post, please respond to it.

EXAMPLE 4.4 **Equation Jeopardy**

The equations below are the horizontal *x*- and vertical *y*-component forms of Newton's second law applied to a physical process. Solve for the unknown quantities. Then work backward and construct a force diagram for the system of interest and invent a process and question for which the equations might provide an answer (there are many possibilities). Remember that the italicized *N* is the symbol for normal force, and the roman N is a symbol for the newton.

x-component equation:

$$(200\ \text{N})\cos 30° + 0 - 0.40N_{\text{S on O}} + 0 = (50\ \text{kg})a_x$$

y-component equation:

$$(200\ \text{N})\sin 30° + N_{\text{S on O}} + 0 - (50\ \text{kg})(9.8\ \text{N/kg}) = (50\ \text{kg})0$$

Solve Inserting the cosine and sine values, we get:

x-component equation:

$$(200\ \text{N})0.87 + 0 - 0.40N_{\text{S on O}} + 0 = (50\ \text{kg})a_x$$

y-component equation:

$$(200\ \text{N})0.50 + N_{\text{S on O}} + 0 - (50\ \text{kg})(9.8\ \text{N/kg}) = 0$$

We can solve the *y*-equation for the magnitude of the normal force: $N_{\text{S on O}} = 390\ \text{N}$. Inserting this value into the *x*-equation produces the following:

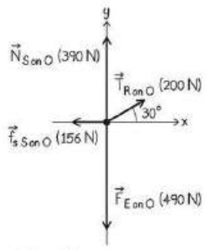
$$(200\ \text{N})0.87 + 0 - 0.40(390\ \text{N}) + 0 = (50\ \text{kg})a_x$$

This can now be solved for a_x:

$$a_x = (174\ \text{N} - 156\ \text{N})/(50\ \text{kg}) = +0.36\ \text{N/kg} = +0.36\ \text{m/s}^2$$

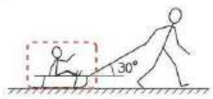
Simplify and diagram The equations provide the components for each of the four forces exerted on the system (since there are four terms on the left side of each equation). Consider the *x*- and *y*-scalar components of each force:

1. A 200-N force oriented 30° above the positive *x*-axis—maybe a rope is exerting a force on an object.
2. A 390-N normal force points along the *y*-axis, perpendicular to a surface.
3. It looks like a friction force of $0.40(390\ \text{N}) = 156\ \text{N}$ points in the negative *x*-direction with a coefficient of friction equal to 0.40.
4. A 490-N gravitational force points in the negative *y*-direction perpendicular to the surface.



We can now use these forces to construct a force diagram.

Sketch and translate The situation could involve a sled or wagon or crate that is being pulled along a horizontal surface, as shown below. Note that the rope is at an angle with respect to the horizontal, so the force that it exerts has a +100-N *y*-component. It combines with the normal force's +390-N *y*-component to balance the gravitational force's −490-N *y*-component.



One possible problem statement Determine the acceleration of a 50-kg sled being pulled across a horizontal surface by a rope oriented 30° above the horizontal and pulling with a force of 200 N. The coefficient of kinetic friction between the sled and the surface is 0.40.

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Eugenia Etkina
22. October

My good friend and a member of this group Stamatis Vokos shared with me a very interesting article related to the place and role of hypotheses in physics research. Needless to say that the article is in complete agreement with the ISLE approach - OBSERVATIONAL experiments are not based on any hypotheses and they are crucial for the new hypotheses to be formed. Just the way we do it when we teach physics through ISLE. This article is very important as many science educators argue that experiment in science is "theory laden" (see work on NOS - the Nature of Science in science education). As you can see from the article, it is not true. The same goes for predict-observe-explain sequence. While in the ISLE approach we make predictions but ONLY after we observe something, create an explanation for it (a hypothesis) and then test it experimentally by designing a new experiment whose OUTCOME we PREDICT using the hypothesis under test and remembering that we can never prove a hypothesis, we can only fail to reject it. Please read and enjoy!

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Eugenia Etkina
23. October

Hi all, I want to continue with non-traditional problems today and stay with Chapter 4 as this is what we have been working with for a while. Traditional problems have several features that distinguish them from real life problems and make them not problems but PUZZLES. You can think of a puzzle as a set of steps that need to completed to have one right answer and this answer is known to the creator of the puzzle. In physics, these are usually worded scenarios of unrealistic physical situations (surfaces with no friction, absence of air, constant acceleration of falling objects, etc.) that, when solved, give one right answer. Students figure out very quickly how to be successful on those and that is why they use the famous plug-and-chug strategy. How can we engage them in different activities? How do we make them stop and think what is going on and how to approach the problem other than looking for the right "formula"? In our textbook we have a huge number of such problems. Many of them will help your students do well on AP exams as the new AP curriculum uses these non-traditional problems a lot. As I said before, they are all marked in the Instructor Guide - every chapter. I will paste the list from Chapter 4 here but also show an example of one of the back-of-the-chapter problems that has a different structure and goals compared to traditional.
Nontraditional end-of-chapter questions and problems
Ranking tasks (RAT): P4.55, P4.56
Choose answer and explanation (CAE): Q4.4
Choose measuring procedure (MEP): P4.25
Evaluate (reasoning or solution…) (EVA): P4.39, P4.74
Make judgment (based on data) (MJU): P4.63
Linearization (LIN): P4.86
Multiple possibility and tell all (MPO): P4.18, P4.48, P4.93
Jeopardy (JEO): P4.14, P4.38, P4.59

Design an experiment (or pose a problem) (DEX):, P4.92
Problem based on real data (that students can collect by themselves) (RED): P4.19, P4.75

25. * You want to determine the coefficient of kinetic friction between a 1 m × 1 m rug and a wooden floor. You obtain a piece of the same rug of size 10 cm × 10 cm (which has a surface area 100 times smaller than the entire rug), a scale for measuring mass, a force meter, and an object of mass m_O. Which of the following procedures would you choose to obtain the correct value of kinetic friction between the rug and the floor?

(a) Put the object on the piece of rug. Measure the force $F_{\text{H on RP}}$ exerted by the hand on the rug piece in the horizontal direction while moving it with constant speed along the wooden floor. Calculate the coefficient of kinetic friction as $\mu_k = \dfrac{F_{\text{H on RP}}}{m_O g}$.

(b) Use the same method described in (a) but calculate the coefficient of friction as $\mu_k = \dfrac{100 \cdot F_{\text{H on RP}}}{m_O g}$.

(c) Use the same method described in (a) but also measure the mass of the rug piece m_{RP} and calculate the coefficient of friction as $\mu_k = \dfrac{F_{\text{H on RP}}}{(m_O + m_{RP})g}$.

(d) Use the same method described in (c) but calculate the coefficient of friction as $\mu_k = \dfrac{100 \cdot F_{\text{H on RP}}}{(m_O + m_{RP})g}$.

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Eugenia Etkina
24. October

Hi all, today I want to talk about contrasting cases. A contrasting case is when we compare two things to learn what one is and what one is not. We often ask students to solve examples when they continuously operate with the same idea. But it turns out that knowing when this idea does not work is important as well, Contrasting cases were found to be very useful for learning new material by the students and, according to research by Darrick Jones (my former PhD student), physicists use contrasting cases all the time when trying to solve new problems. For example, contrasting velocity and acceleration helps students learn that a rocket can have very high velocity and zero acceleration. Or vice versa, when we start moving, we have zero velocity, but non-zero acceleration. How can we make problems contrasting multiple ideas? I am attaching a screenshot of a problem form Chapter 4 that does just that. It also achieves another important cognitive processing goal - it lets the students see the contrasts simultaneously - an important condition for understanding what is going on. Think of what you can ask your students to contrast today. And if you finished reading the post, do not forget to respond to it! Thank you!

that the resistive force exerted by the air is negligible.

56. * A frog jumps at an angle 30° above the horizontal. The origin of the coordinate system is at the point where the frog leaves the ground. Complete Table P4.55 by drawing check marks in the cells that correctly connect the quantities in the first column that describe the motion of the frog and the descriptions of what is happening to these quantities while the frog is moving. Consider the frog as a point-like object and assume that the resistive force exerted by the air is negligible.

TABLE P4.55

Physical quantity	Remains constant	Is changing	Increases only	Decreases only	Increases, then decreases	Decreases, then increases
x-coordinate magnitude						
y-coordinate magnitude						
Direction of velocity						
Magnitude of velocity						
Direction of acceleration						
Magnitude of acceleration						

Eugenia Etkina
25. October

Hi all, I have a question: when you joined the group, could you see the question posted there? I do not let anyone in unless they answer the question or it is clear from some other signs that they are physics teachers/professors. Recently we have a lot of people who wish to join but they do not answer the question. I message them individually and wait for their responses but they usually do not come as they might not see my texts. If you tell people about the group, please tell them that they MUST answer the question or they will not be let in. Thank you.
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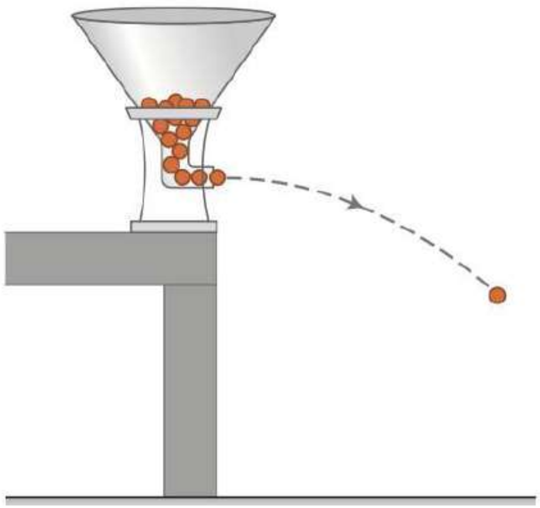
eozysblYJUl0txo15fiwkBJLp4sbHYrZthcNUAVPHWwsjYO8U3eMZxg&__tn__=%2CO%2CP-R

Eugenia Etkina
26. October

Hi all, thank you for responding to my post about the question to enter the group. I rejected all of those who did not answer the question. If it is clearly visible, then there is no need for me to text people begging them to answer the question. Thank you.
Today, I would like to continue with chapter 4 non-traditional problem. See the one that I attached to this post. What is unique about it? How is it different from typical end-of-the-chapter problems? I think there are 3 fundamental differences, although to solve it one needs to know only traditional projectile motion mathematical representations. Can you find those three fundamental differences? And maybe more?

63. * Marbles are exiting a container through a horizontal nozzle positioned 1.3 m above sandy ground (see **Figure P4.63**). You notice that all the marbles land between 0.25 m and 0.45 m from the point directly below the end of the nozzle. How do you explain this observation? What can you determine based on the data given in the problem? Indicate any assumptions that you made.

FIGURE P4.63



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Eugenia Etkina
27. October

Hi all, today I wanted to talk about responding to the students. We often ask a question in a whole class discussion or when they are reporting on their group work, and a student answers with one word. If this word is correct, we often validate and move on. But does it always mean that the student really understands what they said? A good way to make sure is the ask the questions: "What do you mean?". This is a simple way to elicit their real understanding. Try today and you will see how much more you will learn from their response to "What do you mean?". The next step, even if they provide a good answer is to NOT validate it, but to toss it back to the class- do you, people, agree? What do you think? Sometimes, when one student answers a question the others do not listen or do not understand. "Do you agree?" question and the expectation that somebody else would answer makes everyone focused on what the first student was saying. Habitually asking the rest of the class to evaluate each other's answers will become routine for them. Try "What do you mean?" today and report on what happens! And please do not forget to respond to this post to make it more visible for other group members. Thank you.

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$$\frac{64}{16} = \frac{\cancel{6}4}{1\cancel{6}} = \frac{4}{1} = 4$$

Eugenia Etkina
28. October

Hi all, today I wanted to follow up on David Harrison's response yesterday about assuming what the students think without asking them to elaborate. A long time ago Charles Henderson and collaborators did a study comparing how different university physics professors (traditional and reformed) grade student problem solving work. They found that "traditional" professors (who teach in a transmission mode) when see the right answer, assume that the student had the right reasoning and that "reformed" professors (those who subscribe to student-centered active learning) do not assume but push the students to explain how they did the work. They found that it is the explanations that are most difficult for the students and the latter approach is much more effective for learning. Therefore, use all the strategies that were mentioned in the post and comments on the post yesterday to help your students EXPLAIN why they think so and HOW they arrived at the answer. Also, our textbook reading interrogation strategy helps them learn how to interrogate the text, which, in turn, helps them learn to elaborate on their reasoning process. Lots of research found that it is the explanations and not the answers that are most important.
Another important strategy is to ask some other student in your class to repeat what the student who provided the answer said. If you always do it, the students will listen to the those who speak and try to understand. And, of course, your own careful listening to what a student says is the first step (see again, David Harrison's comment yesterday).
Please do not forget to comment on this post after you finished reading it.

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Eugenia Etkina
29. October

Hi all, as we continue with the questions aimed at eliciting student reasoning, I would like to focus on specific ISLE-based questions. There are TWO most important ISLE questions: 1) related to an Observational Experiment and 2) related to Testing Experiments. For 1) the most important question is: "What did you observe? Please DESCRIBE in simple words that a 5 year old can understand". This is one of the first rules of the ISLE game,
The key here is not to accept the answers that contain scientific terms or the answers that are explaining not describing. For example, the students observe a drying wet spot. You ask them: What did you see? And they say: The spot evaporated. This is not an acceptable answer. It contains a scientific term which is an explanation not something that a student saw, but they are using it just to mean that the spot dried. What you want them to say is that they observed the wet spot disappearing slowly/gradually. To elicit this answer you need to ask them what they meant in simple words that a 5 year old can understand.
Habitually asking your students to DESCRIBE what they observed without first trying to explain it is very important for them to understand the difference between a description and an explanation. Research shows that many teachers use these term interchangeably while scientists never confuse them.
There are several other questions that we recommend always asking when students conduct observational experiments. They are best seen in our labs that are posted on https://sites.google.com/site/scientificabilities/ - you need to go to ISLE-based labs and click on Algebra-based labs or Online labs. The scientific abilities rubrics describe good answers to those questions. I am attaching a screenshot of a rubric for observational experiments that shows what we expect students to think about when they conduct those. I will return to 2) (Testing experiments) tomorrow. Please do not forget to respond to the post when you finish reading it.

RUBRIC B: Ability to design & conduct an observational experiment					
	Scientific Ability	Missing	Inadequate	Needs improvement	Adequate
B1	**Is able to identify the phenomenon to be investigated**	No phenomenon is mentioned.	The description of the phenomenon to be investigated is confusing, or it is not the phenomena of interest.	The description of the phenomenon is vague or incomplete.	The phenomenon to be investigated is clearly stated.
B2	**Is able to design a reliable experiment that investigates the phenomenon**	The experiment does not investigate the phenomenon.	The experiment may not yield any interesting patterns.	Some important aspects of the phenomenon will not be observable.	The experiment might yield interesting patterns relevant to the investigation of the phenomenon.
B3	**Is able to decide what physical quantities are to be measured and identify independent and dependent variables**	The physical quantities are irrelevant.	Only some of physical quantities are relevant.	The physical quantities are relevant. However, independent and dependent variables are not identified.	The physical quantities are relevant and independent and dependent variables are identified.
B4	**Is able to describe how to use available equipment to make measurements**	At least one of the chosen measurements cannot be made with the available equipment.	All chosen measurements can be made, but no details are given about how it is done.	All chosen measurements can be made, but the details of how it is done are vague or incomplete.	All chosen measurements can be made and all details of how it is done are clearly provided.
B5	**Is able to describe what is observed without trying to explain, both in words and by means of a picture of the experimental setup.**	No description is mentioned.	A description is incomplete. No labeled sketch is present. Or, observations are adjusted to fit expectations.	A description is complete, but mixed up with explanations or pattern. The sketch is present but is difficult to understand.	Clearly describes what happens in the experiments both verbally and with a sketch. Provides other representations when necessary (tables and graphs).
B6	**Is able to identify the shortcomings in an experimental and suggest improvements**	No attempt is made to identify any shortcomings of the experimental.	The shortcomings are described vaguely and no suggestions for improvements are made.	Not all aspects of the design are considered in terms of shortcomings or improvements.	All major shortcomings of the experiment are identified and reasonable suggestions for improvement are made.
B7	**Is able to identify a pattern in the data**	No attempt is made to search for a pattern	The pattern described is irrelevant or inconsistent with the data	The pattern has minor errors or omissions. Terms proportional are used without clarity- is the proportionality linear, quadratic, etc.	The pattern represents the relevant trend in the data. When possible, the trend is described in words.
B8	**Is able to represent a pattern mathematically (if applicable)**	No attempt is made to represent a pattern mathematically	The mathematical expression does not represent the trend.	No analysis of how well the expression agrees with the data is included, or some features of the pattern are missing.	The expression represents the trend completely and an analysis of how well it agrees with the data is included.
B9	**Is able to devise an explanation for an observed pattern**	No attempt is made to explain the observed pattern.	An explanation is vague, not testable, or contradicts the pattern.	An explanation contradicts previous knowledge or the reasoning is flawed.	A reasonable explanation is made. It is testable and it explains the observed pattern.

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Eugenia Etkina
1. November

Hi all, Yuehai Yang asked an excellent question today, and I wrote my answer. I want to remind you all that we have a whole set of scientific abilities rubrics that will help students not only develop scientific abilities while learning in your course but also do independent research. The question that we have in our labs (also posted on the same website, see Algebra-based labs) will help the students while they are working on experiments. But the same questions can be asked during class discussions! David Brookes and Yuhfen Lin use the rubrics to score exam questions. Please do not forget about this rich resource that we have! https://sites.google.com/site/scientificabilities/ Make sure you read the introduction first and then proceed to the rubrics. And please do not forget to respond to this post after you finish reading it!

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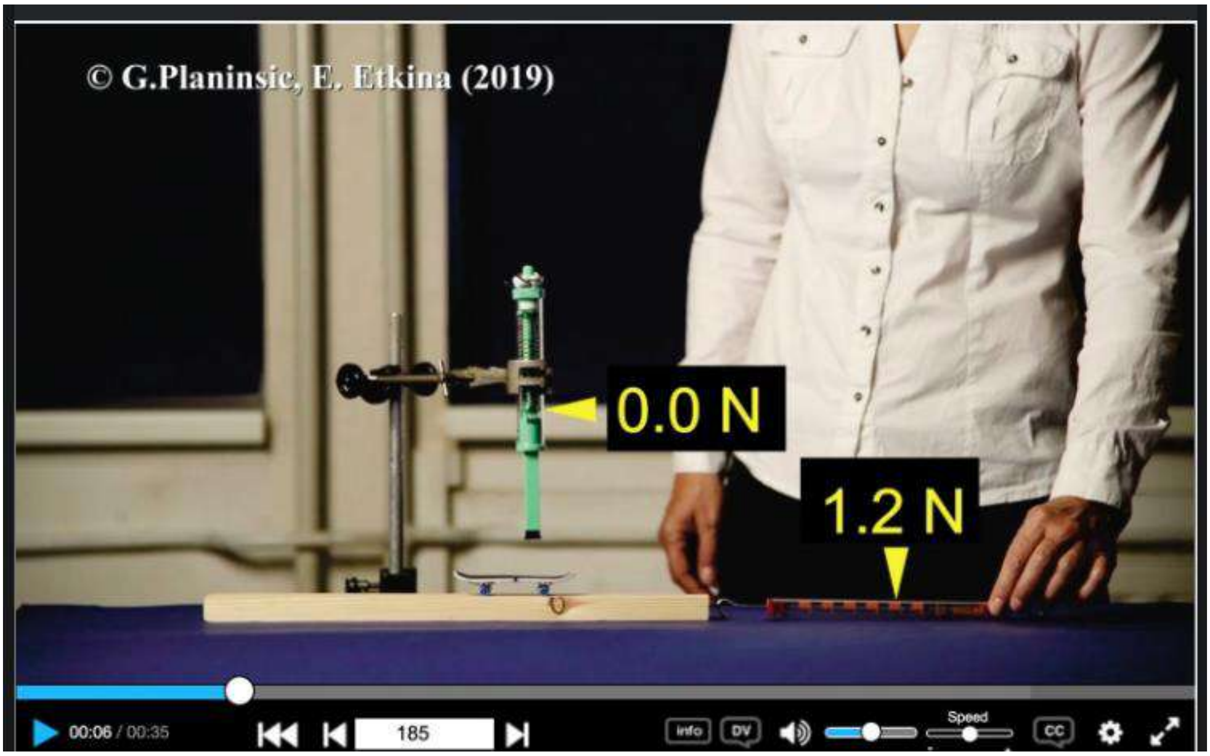
Eugenia Etkina
2. November

Hi all, I want to remind you that all videos that we made for the textbook and the ALG are freely available on Pearson website. You do not need Mastering Physics to access them. See https://media.pearsoncmg.com/aw/aw_etkina_cp_2/videos/.
The videos have several goals: 1) to save your time putting the equipment together in class; 2) to give you ideas of what experiments you can assemble or what equipment to buy or to build in advance for the students to be able to do experiments themselves; 3) to assign those for homework - so that the students can watch videos for observational experiments, for example, and ponder the explanations on their own first before they come to class and discuss them with peers.
There are many more videos of experiments in the OALG files that are posted here. I recommend checking the videos for the chapter that you plan to teach next month in advance to decide what you will let the students watch in class, what - at home, and what experiments they will do themselves. Note that some experiments are ingenious in their design (due to the creativity of Gorazd Planinsic) and require a lot of discussions with the students. An example is Testing experiment 4.3 (does the maximum friction force depend on mass). The link is at https://mediaplayer.pearsoncmg.com/.../secs-egv2e-does... - check it out and keep checking the videos before you plan your lessons!



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Eugenia Etkina
3. November

Hi all, I want to share an email that came to me today from Sweden from a professor who was interested in the differences between IBSE and ISLE. IBSE is a popular curriculum approach in Europe, stands for inquiry based science education. There is lots online about it. As we have many European members in this group, I thought I would share what I wrote back.
"Concerning the IBSE and ISLE there is a big difference. IBSE follows the flow of predict-observe -explain which contradicts the ISLE philosophy. We do not ask students to make predictions using their intuition before they observe something. We ask them to observe, find patterns and then come up with the explanations. To test the explanations, they need to design new experiments and only then they make predictions of their outcomes using the explanations under test, NOT their intuition as the IBSE does. We do not make students feel bad about their intuitions, we help them learn to make predictions based on the ideas that they are testing, not their personal intuition. There are many other differences too, but they are less important than this major one (we have clearly articulated intentionalities and the difference I described before addresses both - we mirror scientific practice and help students feel good about learning physics)."
I posted before about the differences between the POE approach (or elicit-confront-resolve as known in PER) approach and the ISLE approach. But we have lots of new members and I thought I would explain once again why we do not ask for predictions before observational experiments.
WAIT A MINUTE! Why don't I ask you why we don't do it. Please, can you explain for the rest of the group why in the ISLE approach we NEVER ask students to make predictions before observational experiments and ALWAYS ask to make predictions before testing experiments. Please do! Thank you!

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Eugenia Etkina
4. November

Hi all, thank you for responding to my post yesterday! It was so wonderful to see your deep understanding of the reasons why we do not ask for predictions before observational experiments. Building on our yesterday's conversation I would like to say a few words about observational experiments in general. How do we choose them?
Observational experiments can be qualitative or quantitative but most importantly, they need to be plain simple. Truly simple, so that the pattern can be easily seen and every student can be successful identifying the pattern. Second, they need to be familiar (if possible) to the students, to remind them of something that they did or observed. No tricks, no surprises. Our role as teachers is to focus the attention of the students on the patterns that are relevant and the ones we want them to notice.
Most of observational experiments in our textbook and the ALG are based on historical experiments (with lots of modifications, of course). Thus, if you wish to design your own, the first step is to study the history of the phenomenon or a concept and see how scientists went about figuring it out. How did they start? The very first observations experiment that leads to the construction of dot and them motion diagrams is based on Galileo's writings. The observational experiment for magnetic fields is based on Oersted's accidental observation,

observational experiments for photoelectric effect are the repeat of the experiments done by Wilhelm Hallwachs, and so forth. Not any experiment can be an observational experiment. We want the students to be successful identifying patterns and feeling that physics is something that they can do!
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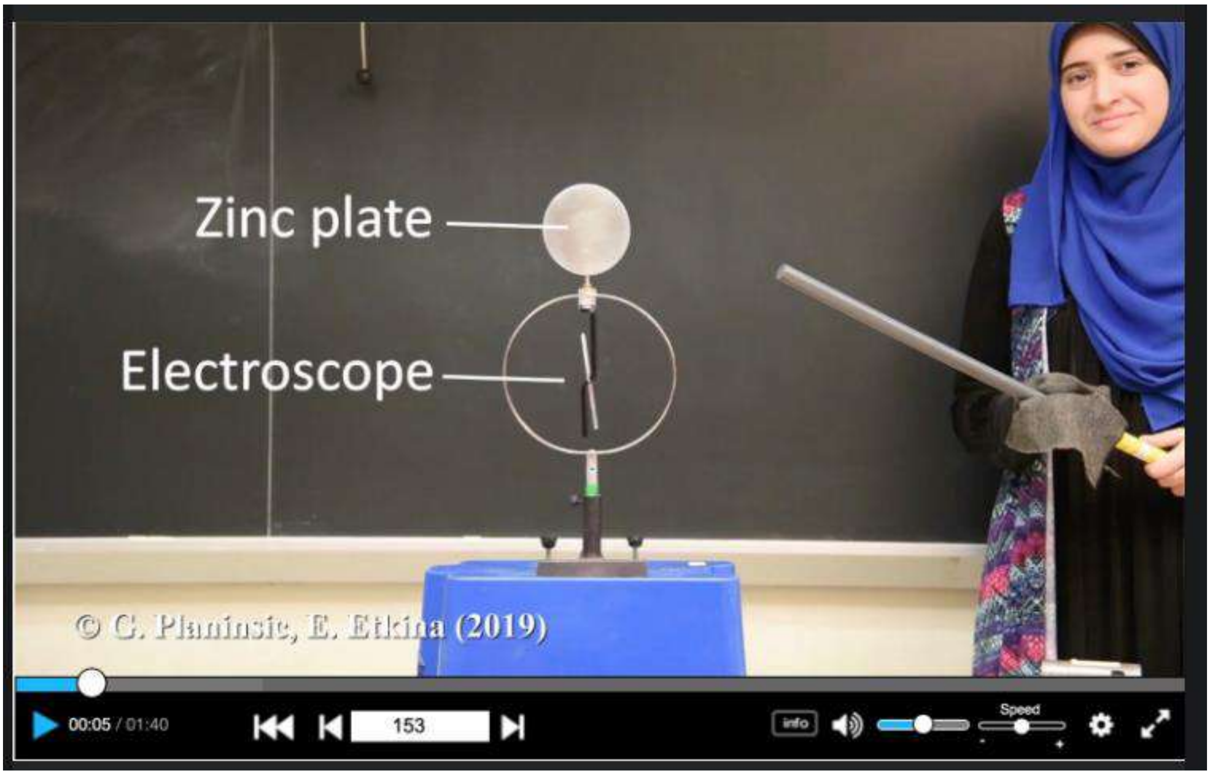

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Eugenia Etkina
5. November

The post has two parts - read to the end please!
Let's welcome our new members:
Fred Wafula,
Andria Schwortz,
Steven Henning,
Susan Rolke,
Fig Newton,
Sean Linden,
Blake Laing,
Paul Holder,

Louise Taylor,
Tiffany Estes Dickson,
Jonathan Bowen,
Rj Predny
Please read two posts pinned to the top of the community page, visit islephysics.net to learn more about the ISLE approach - the foundation fo this group and check out archived posts at https://drive.google.com/.../10qn...
You will benefit form the group if you check the posts every day - as they come every day. Do not forget to respond - like or comment. This will bring new posts to your feed and make them more visible for other group members. Welcome again!
Some of those new members attended today my talk about the ISLE approach at the AAPT New England Section meeting. After the talk one of the participants asked a question: "Eugenia, in your podcast on physics alive (here is the link http://physicsalive.com/ISLE/) you said that 9th graders are better responding to the ISLE approach than seniors in high school Why do you think that?" I am not going to write here what I said when I was answering the question and I wonder if you would have the same question or you can answer the question posed by that person. Any volunteers?

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Eugenia Etkina
6. November

Hi all, I promised to Juan Regalon yesterday to explain how my answer to the questions: "Why did you say that 9th graders are better with ISLE than seniors" is similar but slightly different from his. To follow this post, please read my yesterday's post and our exchange with Juan. Other people responded too (Dedra Demaree, Tom Prewitt) and, while I agree with every word they said, there was a common theme in all responses. The responses focused on the students. What is "not right" (sorry for the language, I want to make a point here) with the students that they are not excited about exploring the physics and figuring it out by themselves when they are older. And while this is true, as students are the learners, I would like you to think why the students in 9th grade are more receptive to our methods than seniors.

The problem is not in the students. It is in the system. It is the educational system that transforms eager, shining eyes children who are looking forward to learning and who learn every day lots of stuff by themselves with those shining eyes and incredible persistence into the students are only interested in the right answer and the grade (again, exaggeration to make a point) with glassy eyes. Year after year we collectively, as an educational system (the country does not matter, it is all the same over the world) beat out of our students the excitement, curiosity, creativity, and perseverance with which they come to the first grade and which they all have outside of school. So, it is not the students, it is us. The longer they spend with us, the harder it is for them to keep alive the inner excited learner that they all have. We do not need to change the students, we need to change the environment.

We need to replace the schooling environment with a learning environment. This is what the ISLE approach is about. And it is our responsibility to change it. Think about the ramps for wheelchairs that every building in the US is supposed to have. It is the change in the environment so that anyone can enter the building (same for sidewalk ramps, bumps to make them visible for blind people, etc.). These are all the result of the Universal Design approach which says that we need to change the environment to make all people able to do X, Y, and Z and not the people to fit the environment. We need to think about learning using this framework - changing the environment, not the students if we wish to see learners in our classes. And then, 12th graders will be as excited about figuring things out on their own as 9th graders. Again, I want to add, that I agree with all people who responded to my post yesterday, but I wanted to shift the attention from the students to us - the educators, the professionals. We are responsible.

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Eugenia Etkina
7. November

Hi all, first, thank you so much those who responded to my questions the day before yesterday and commented yesterday. And thank you all those who post their ideas and questions!

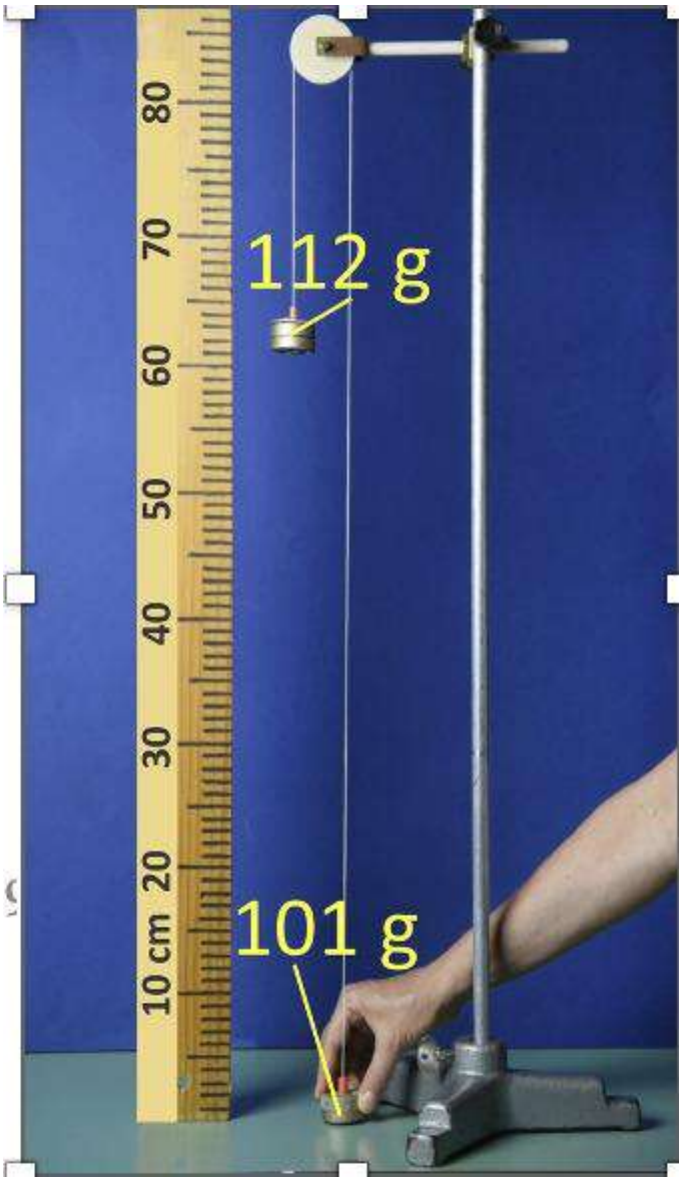
Today I want to attract your attention to an activity in the OALG Chapter 4:

OALG 4.4.5 TEST YOUR IDEAS

The video https://mediaplayer.pearsoncmg.com/.../_fr.../sci-OALG-4-4-5 shows the following experiment:

The object on the left has a mass of 112 g and the object on the right, 101 g. The experimenter holds the right object on a table; the left one is about 1 meter above the table. Use your knowledge of Newton’s laws and kinematics to predict how far the object on the left will move in the first second after letting go of the object on the table. After you have made that prediction, watch the video and use the frame count to determine the time. The video is recorded at 30 frames per second. Did the outcome match that prediction? Consider the assumptions that you made about the motion of the objects, the pulley, and the uncertainties in the data.

Here you have a traditional problem turned into a testing experiment. The students make a prediction and compare it to the outcome of the experiment. We can call it also an application experiment if the students already tested Newton's second law. This activity allows a full exploration of experimental uncertainties and assumptions. See the rubrics for those on the scientific abilities website. It can also be done by the students with real equipment.



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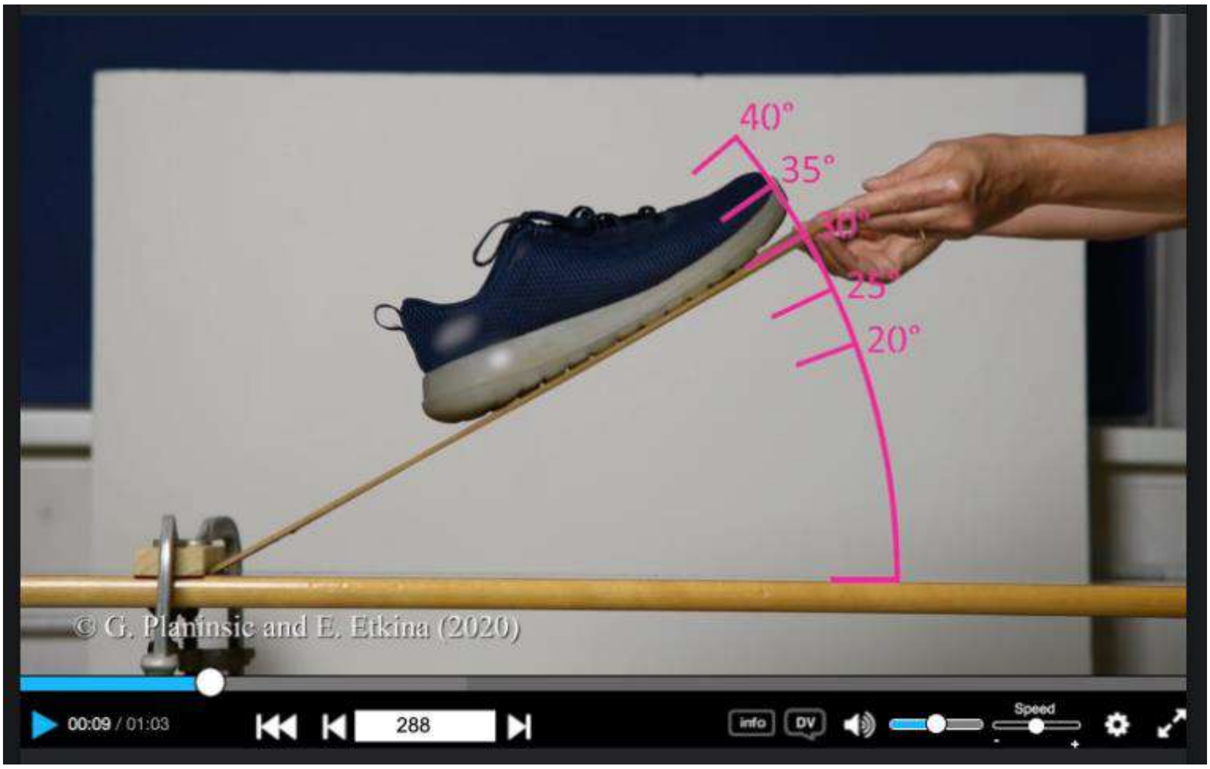
Eugenia Etkina
9. November

Hi all, we have been talking about observational experiments and testing experiments a lot. However, there is the third type of experiments in the ISLE approach - application experiments. Many of them involve students determining a value of some quantity using two independent methods and comparing the results. The rubrics for those experiments are on the scientific abilities website. My favorite application experiment is determining coefficient of static friction between your shoe and the floor tile. Why is it my favorite? Because it is related to students' lives directly, and because nobody knows the "right answer". Here is the same activity in the OALG and in the ALG (without the video, of course). I am pasting the texts of both. The beauty of this activity is that it helps students see the importance of uncertainties (Rubric G) and assumptions. If you have not tried yet, please do! If you did - share the results! Thank you!
OALG 4.4.9 DESIGN AN EXPERIMENT
Watch the videos to determine the coefficient of static friction between the shoe and the board https://mediaplayer.pearsoncmg.com/.../_fr.../sci-OALG-4-4-9.
a. Take your measurements, devise a mathematical procedure to determine the coefficient of static friction, record your results, and estimate the uncertainty in your determined value of ms for each method.
b. Compare the outcome of the two methods. Do your two measurements agree within expected uncertainties? Explain. Discuss what assumptions you made to implement each mathematical method and how these assumptions might impact the results you found.
ALG Activity:
4.4.15 DESIGN AN EXPERIMENT
PIVOTAL Lab: Equipment per group: whiteboard and markers, spring scale [alternative: force probe and computer], rigid floor tile [alternative: any rigid wooden board or plank], meter stick. Your group is tasked by a floor tile company to determine the coefficient of static friction between your shoe and their floor tile in two different ways. You have the following equipment: a shoe, a spring scale or force probe, a floor tile, and a meter stick.
a. Devise the first method using the spring scale or force probe as your only measuring instrument. Include a sketch of your proposed method, a force diagram, and a detailed mathematical description that can be used to get a quantitative answer to the problem. Take your measurements, record your results and estimate the uncertainty in your measured value of ms.
b. Devise a second method using the meter stick as your only measuring instrument. Include a sketch of your proposed method, a force diagram, and a detailed mathematical description that can be used to get a quantitative answer to the problem. Take your measurements, record your results and estimate the uncertainty in your measured value of ms.
c. Compare the outcome of the two methods. Do your two measurements agree within expected uncertainties? Explain. Discuss what assumptions you made to implement each mathematical method and how these assumptions might impact the results you found.



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Eugenia Etkina
10. NOvember

Hi all, two things today: the welcome message for our new members and our continuing work on Chapter 4 - Applications of Newton's laws.
Welcome to our new members:
Odedeji Idowu Titus,
Michelle Owen Girage,
Lana Ivanjek,
Aungadh Tiwari,
Lisa Marie,
John Robbins,
Anita Borsody Lotti,
Kaitlyn Diver,
Patrick Makowski,
Omer Peretz,
Adam Ulen,
Martin Sandino,

Louise Sutton

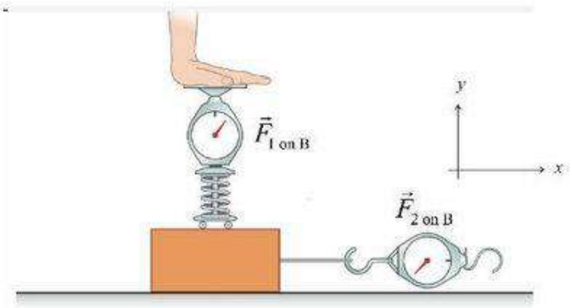
To benefit from the group and participate in its work, please see two messages pinned to the top of the community page and visit islephysics.net to learn about the ISLE approach, which is the foundational philosophy of this group and all the resources that we provide (this group is not about individual activities but about learning physics through a specific philosophical lens). Check out the FILES here - lots of materials have been posted. Make sure you check the posts every day and either like them or respond. This makes new posts visible for you and the current post more visible to other group members.

I continue with applications of Newton's laws. We talked about the importance of teaching students to linearize data. It is one of the methods used by physicists and it is also used on AP exams. Here is an example from Chapter 4 Active Learning Guide that will help your students practice this skill. Those who used the activity, please comment!

4.6.4 Linearize

Class: *Equipment per group:* none.

We use a string attached to a spring scale to pull a wooden block. The mass of the block is unknown and it does not change during the experiment. We push down on the block with a spring that exerts a series of downward forces $\vec{F}_{1 \text{ on B}}$ on it. For each of these downward forces, we use the pulling string and spring scale to determine the magnitude of the maximum force $\vec{F}_{2 \text{ on B}}$ that we can exert on the block in the horizontal direction before the block starts sliding. The downward pushing spring is on wheels to prevent it from exerting horizontal forces on the block.



Using the measurements in the table, determine the coefficient of static friction between the block and the table, and the mass of the block.

$F_{1 \text{ on B}}$ (N)	$F_{2 \text{ on B}}$ (N)
0.0	1.2
1.0	1.8
2.0	2.2
3.0	2.6

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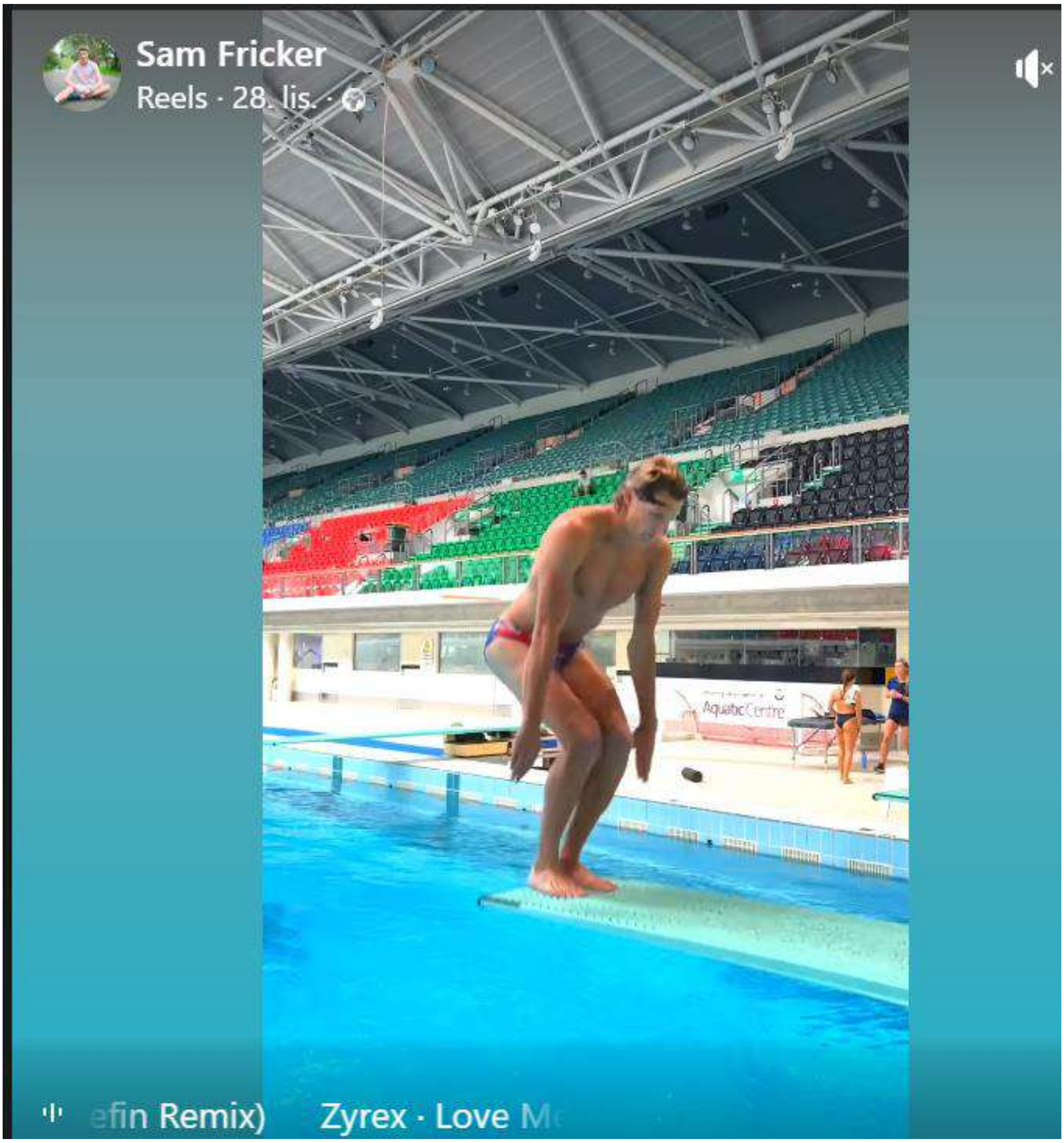
Eugenia Etkina
11. November

Hi all, somehow I saw this video on Facebook and realized that you can use it in multiple units - kinematics, forces, linear momentum, torques, rotational momentum, and maybe something else that I did not figure out yet. It is an example of a phenomenon that is very complex but if you break it up and analyze using different systems, at the end the students will be able to explain every step. For dynamics you can start by analyzing take off and going into the water. Do not worry about rotation, just the interaction of the diver with the board and the water. You can also choose the front part of the board as a system and analyze forces exerted on it too. Fascinating video!!!!
https://www.facebook.com/reel/634187481530304/?s=single_unit



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HKt3jbwJzI2zAiMBNTeDBTWF-
GTRd7zYu2CJakZetaJY9wluC4GRexOAoDyacEnYqt2gBbqL1BcdnWWw-
WimGcHycOT0c1MDqeF01s&__tn__=%2CO%2CP-R

Eugenia Etkina
12. November

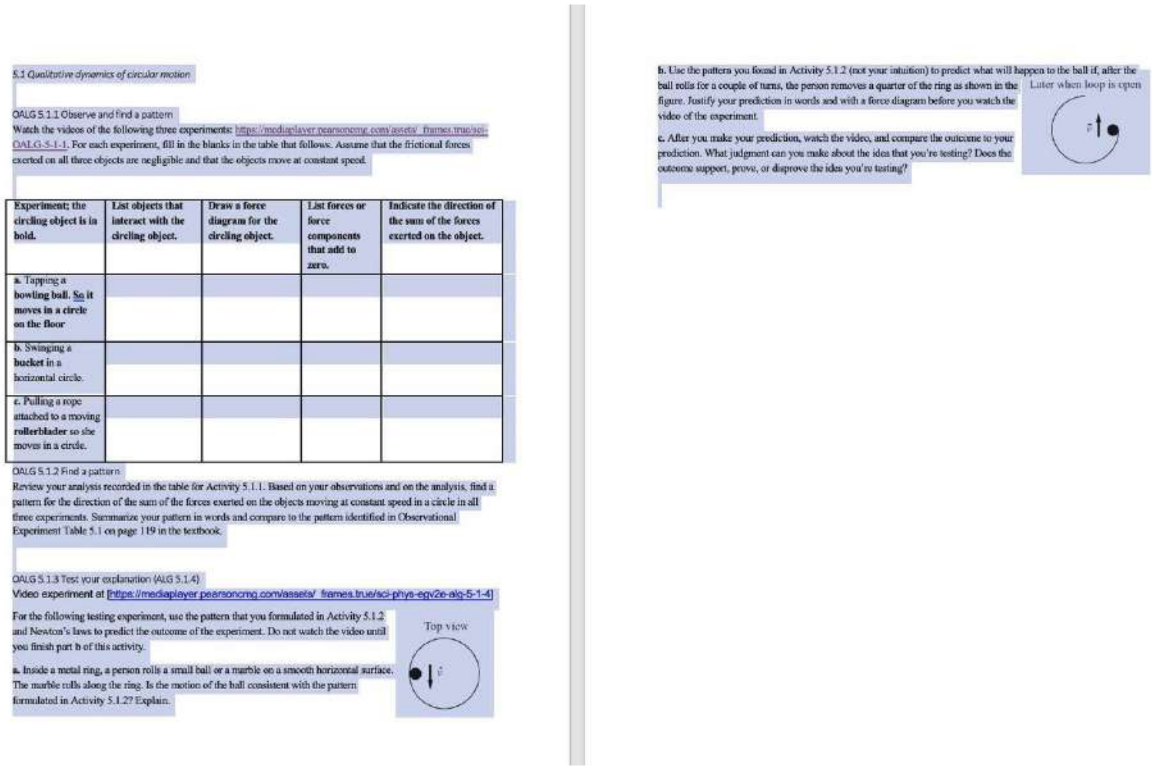
Question: Can you please share where you are in the sequence of topics with your students? We have our next meeting on circular motion in 2 weeks, so I was wondering if anyone started circular motion already. I will begin commenting on it. If you are still doing Newton's laws in 2 dimensions, I will not rush. Please hare here and I will adjust the content of the posts accordingly. I assume that people who are teaching in colleges/universities are moving faster. Please comment! As this post does not have an attached photo, it will be automatically seen by fewer people, thus it is REALLY important that those who view the post - respond. Please do, and thank you.

https://www.facebook.com/groups/320431092109343/posts/1295104437975332/?__cft__[0]=AZW_dkH0jS3oGthf6NnSvkUf0cqYzg2HyQKHF_a86E_8blFR82wz18SVtk0UDOVFRguMytWS27TUKaY3kJHZJWtXtcU82BwWWdNQPFt3JYyiuKz9BHt9_F3H0rwt4DrnrMOgTAgxKKsfV8jx2HGL6sKrYakeRBp6guuVG_kEFN0jo5JY6VenorQM1DPyXRRa1Z4&__tn__=%2CO%2CP-R

Eugenia Etkina
13. November

Hi all, thank you for answering my question about where you are in curriculum now. I see that although many people are moving in sync with our meetings, some will be starting circular motion on Monday. Therefore I am want to slowly ease into circular motion (Chapter 5 in the textbook) before we actually do the meeting. So, if you signed up for the meeting, try to read my posts starting today.
As always, when we start a new topic, we need to create the "need to know" - the motivation that will sustain student interest as they are learning new ideas. I am reminding you that the need to know activity does not involve students' predictions or explanations. It is a question, an experiment, a video that is "cool" and puzzling. The students watch the experiment or a video and you say: "Is't it interesting? Or cool? Or surprising? We are not going to explain our observations today but I promise you that at the end of the unit you will be able to do it yourselves". there are a few "cool" videos for the need to know in circular motion. One of them was posted. H a few days ago by Sheehan H Ahmed. Here is the link: https://arstechnica.com/.../nascar-driver-stuns.../... Another one is the video that I have been using in the past 5 years:
https://www.youtube.com/watch?v=dSDb9oKMCRc&t=19s
You can use any of those.
To start explaining the experiments in those videos, students first need to construct an idea of radial component of the net force exerted on an object moving in a circle. As we start with a

simple case of constant speed circular motion, the sum of the forces exerted on an object should be in the radial direction. The students construct this idea through the ISLE process by first doing observational experiments, analyzing them finding patterns and then testing them in new experiments. The sequence is presented in the textbook, ALG and OALG (posted here in the FILES). The key here is to identify the system for analysis and then draw a force diagram for it. If you have bowling balls and mallets, it is best to let students do the first two experiments themselves. For the first one, ask them to figure out how to use the mallet and the moving bowling ball to make the ball move in a circle. Try it yourself and you will see that it is not easy. The video will help! The students should find that in all experiments the sum of the forces exerted on the system is pointed towards the center. They test this idea with the ring experiment. Then next step is find out WHY the sum of the forces needs to be towards the center. Stay tuned and check my post tomorrow.


5.1 Qualitative dynamics of circular motion

OALG 5.1.1 Observe and find a pattern

Watch the videos of the following three experiments: https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-5-1-1. For each experiment, fill in the blanks in the table that follows. Assume that the frictional forces exerted on all three objects are negligible and that the objects move at constant speed.

Experiment; the circling object is in bold.	**List objects that interact with the circling object.**	**Draw a force diagram for the circling object.**	**List forces or force components that add to zero.**	**Indicate the direction of the sum of the forces exerted on the object.**
a. Tapping a **bowling ball. So it moves in a circle on the floor**				
b. Swinging a **bucket** in a horizontal circle.				
c. Pulling a rope attached to a moving **rollerblader** so she moves in a circle.				

OALG 5.1.2 Find a pattern

Review your analysis recorded in the table for Activity 5.1.1. Based on your observations and on the analysis, find a pattern for the direction of the sum of the forces exerted on the objects moving at constant speed in a circle in all three experiments. Summarize your pattern in words and compare to the pattern identified in Observational Experiment Table 5.1 on page 119 in the textbook.

OALG 5.1.3 Test your explanation (ALG 5.1.4)

Video experiment at [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-5-1-4]

For the following testing experiment, use the pattern that you formulated in Activity 5.1.2 and Newton's laws to predict the outcome of the experiment. Do not watch the video until you finish part b of this activity.

a. Inside a metal ring, a person rolls a small ball or a marble on a smooth horizontal surface. The marble rolls along the ring. Is the motion of the ball consistent with the pattern formulated in Activity 5.1.2? Explain.

b. Use the pattern you found in Activity 5.1.2 (not your intuition) to predict what will happen to the ball if, after the ball rolls for a couple of turns, the person removes a quarter of the ring as shown in the figure. Justify your prediction in words and with a force diagram before you watch the video of the experiment.

c. After you make your prediction, watch the video, and compare the outcome to your prediction. What judgment can you make about the idea that you're testing? Does the outcome support, prove, or disprove the idea you're testing?

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Eugenia Etkina
14. November

Hi all, yesterday I started posting the sequence of activities and reasoning for circular motion. I am doing it for all of you, of course, and for those who are starting circular motion before we have our meeting in 2 weeks. However, if I am posting these things, I do not plan to repeat them during the meeting. How do I make sure that all 24 people who signed up for the meeting are reading these posts? 10 people liked my post yesterday and over 300 saw it. I wonder if those who are planning to go to the meeting saw the post yesterday. Please respond here. I will run the meeting on the 26 with the assumption that you followed the posts during these two weeks. Please respond. In the mean time I will continue.

Once the students figured out that for an object to move in a circle at constant speed the sum fo the forces exerted on it should point towards the center. Why is that? To answer this question the students need to examine the motion of an object, especially its velocity. How can the students "see" the velocity? Take a meter stick and hold it in your hand so it points in the direction of your motion. Walk around the circle at constant speed (I usually use rollerblades in this experiment) and ask the students to observe what is happening to the meter stick. They will see that at every location it points tangent to the circle. Let them draw the direction fo the meter stick. After that ask whether the object moving at constant speed in a circle is accelerating. They should say YES as the direction of the velocity is constantly changing.

How do we determine the direction of the acceleration? Here we use the motion diagram approach but slightly differently. When we are interested in the direction of a delta v arrow at a point, we need to examine the velocity vectors right before and right after that point (see the attached screenshot). The next step is to use the technique in the figure below to determine the direction of the acceleration at each point of the circle trajectory. Stay tuned. And please do not forget to respond to the post once you finish reading it, and those who signed up for the meeting, please respond too! Thank you!

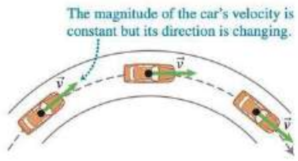
Consider the motion of the car shown in **Figure 5.1** as it travels at constant speed around a circular track. The instantaneous velocity of the car is tangent to the circle at every point. Recall from Chapter 2 that an object has acceleration if its velocity changes—in magnitude, in direction, or in both. Even though the car is moving at constant speed, it is accelerating because the *direction* of its velocity changes from moment to moment.

To estimate the direction of acceleration of any object (including that of the car) while passing a particular point on its path (see Physics Tool Box 5.1), we use the **velocity change method**. Consider a short time interval $\Delta t = t_f - t_i$ during which the car passes that point. The velocity arrows $\vec{v}_i$ and $\vec{v}_f$ represent the initial and final velocities of the car, a little before and a little after the point (note that the velocity arrows are tangent to the curve in the direction of motion; this is Step 1 in the Tool Box). The velocity change vector is $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$. You can think of $\Delta\vec{v}$ as the vector that you need to add to the initial velocity $\vec{v}_i$ in order to get the final velocity $\vec{v}_f$, that is, $\vec{v}_i + \Delta\vec{v} = \vec{v}_f$. Rearranging this, we get $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$ (the change in velocity).

To estimate $\Delta\vec{v}$, place the $\vec{v}_i$ and $\vec{v}_f$ arrows tail to tail (Step 2 in the Tool Box) without changing their magnitudes or directions. $\Delta\vec{v}$ starts at the head of $\vec{v}_i$ and ends at the head of $\vec{v}_f$. The car's acceleration $\vec{a}$ is in the direction of the $\Delta\vec{v}$ arrow (Step 3 in the Tool Box) and is the ratio of the velocity change and the time interval needed for that change:

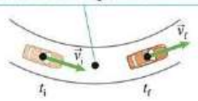
$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

FIGURE 5.1 Since the direction of the velocity is changing, the car is accelerating.

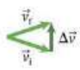


PHYSICS TOOL BOX 5.1 Estimating the direction of acceleration during two-dimensional motion

1. Choose the point at which you want to determine the direction of acceleration and draw velocity vectors at equal distances before and after the point.



2. Place the $\vec{v}_i$ and $\vec{v}_f$ arrows tail to tail. Draw a $\Delta\vec{v}$ arrow from the head of $\vec{v}_i$ to the head of $\vec{v}_f$.



$\vec{v}_i + \Delta\vec{v} = \vec{v}_f$ or $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$

3. The acceleration arrow $\vec{a}$ is in the direction of $\Delta\vec{v}$.

$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$

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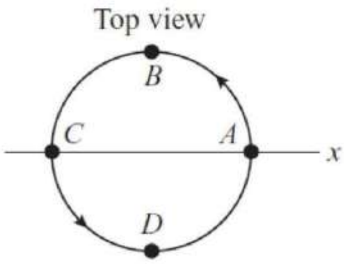
Eugenia Etkina
15. November

Hi all, I continue with circular motion today. Once the students learn the technique to determine the direction of the delta v arrow at a specific point (see my post yesterday), they need to figure out where the delta v arrow points when an object moves in a circle. Here is one of my most favorite activities for this. Each group determines only one point, but the whole class together, after reporting what they found on their whiteboards, will see that at every point the delta v arrow points towards the center. (They can also divide the points within one group as shown in the activity posted below.) The direction of the delta v arrow is the same as the acceleration, thus the acceleration always points in the radial direction. This is not consistent with Newton's second law qualitatively but not quantitatively. We also have not tested this qualitative relationship yet. This will be our next step. Please do not forget to respond to the post or like it to make it more visible to other group members. Thank you.

5.2.2 Represent and reason

PIVOTAL Class: *Equipment per group:* Whiteboard and whiteboard markers



An object moves at constant speed in a circle.

a. The task of your group is to determine the direction of its acceleration at each of the four positions shown in the illustration. Split the work among group members so that each member is responsible for one point. Work on a shared whiteboard. Use what you learned in Physics Toolbox 5.1. Make sure you take a point right before the point of interest and right after, and use a ruler to make sure the lengths of the velocity vectors remain the same and their directions are tangent to the circle.

b. Examine the findings of other members of the group. Can you agree on a pattern in the directions of the acceleration vectors? If so, what is it? Summarize your pattern on your whiteboard and compare what you found with the findings of another group

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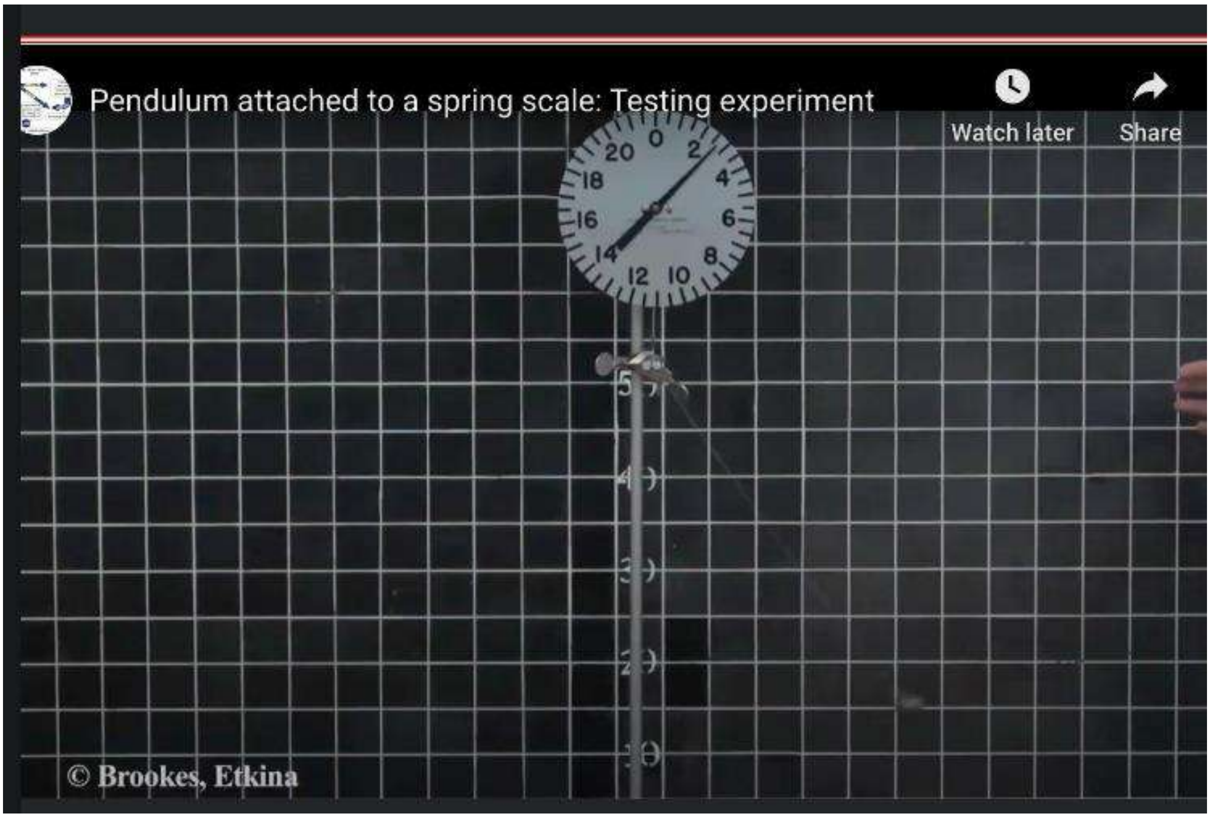
Eugenia Etkina
16. November

Hi all, today I will talk about testing experiment for the conceptual part of Newton's second law for circular motion that the students have invented (see my post yesterday). It is an example when we offer the experimental setup to the students and they need to make predictions of the outcome using the motion and force diagrams. The setup is a pendulum connected to a spring scale. When the bob of the pendulum is hanging at rest the scale reads a certain number of Newtons. Will the scale read the same, more , or less when the pendulum is passing though the bottom point during a swing? Here is the text of the ALG activity:
5.2.6 TEST YOUR IDEAS
PIVOTAL Lab or class: Equipment per group: Pendulum with a 1 kg bob on a string attached to a 20 N spring scale calibrated in newtons. [Note: equipment is flexible: if using a 500 g bob, use a 10 N spring scale.]
Now that you have figured out how to determine the direction of the acceleration of the pendulum bob at the bottom of its swing, use everything you have learned about circular motion so far to make a prediction of the outcome of the following experiment:
a. A 1.0-kg ball hangs from a 1.0-m long string. The other end of the string is attached to a Newton force measuring scale. The string pulls up on the ball exerting a 9.8-N force and the string and ball in turn pull down on the scale exerting a 9.8-N force—the scale reads 9.8 N. Imagine that you pull the ball to the side and release it so that the ball swings like a pendulum at the end of the string. Predict the scale reading as the ball passes directly under the scale (i.e., is it more than, less than, or equal to 9.8 N?).
b. Perform the experiment; record the outcome and compare it to the prediction. Did the outcome support the pattern?
Here is the video: http://islephysics.net/pt3/experiment.php?topicid=5...



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Eugenia Etkina
17. November

Reconciling our knowledge of circular motion with everyday experience
Hi all, Facebook added an option to add a title to a post, so now I will be adding titles. if you post, please add titles too for easier searching. Today, I will continue with circular motion. A long time ago one of my students asked: We learned that when an objects moves in a circle with constant speed the sum of the forces exerted on it points towards the center of the circle. Why do I feel being thrown out when a car makes a turn? What would you do if you heard this question? Please post! Thank you!

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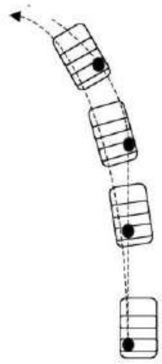
Eugenia Etkina
18. November

Explaining why we feel thrown out in a car making a turn.
Hi all, yesterday I posed a question asked by a student about the feeling of being thrown out when sitting in car making a turn instead of feeling a force being exerted towards the center. Many provided good responses but all of them were to explain what is going on from the point of view of a person standing on the ground. This does not help explain why the PERSON SITTING IN THE CAR feel this way. The person sitting inside a turning car is an accelerating observer in a non-inertial reference frame. Therefore this person cannot use Newton's laws to explain what is happening to them. We can only use Newton's laws if we are observing phenomena being in inertial reference frame (see chapter 3). Here is the explanation given in the solutions for such activity in the ALG. I posted this question to remind you how important an observer is when using Newton's second law. Imagine standing on a bathroom scale in an elevator. all of a sudden the reading of the scale increases. This means that the scale starts exerting an extra force on you, while you remain at rest. How can you explain it? You cannot. Only the person on the ground can. Do not forget the importance of the observer when applying Newton's laws!

circle.

5.2.9 Discuss



Pivotal, class: Equipment per group: Whiteboard and whiteboard markers.
Talk with your group about the following question, and draw diagrams on your whiteboard as needed: How can you reconcile the dynamics of circular motion with a feeling of being "thrown outward" when a car moves around a curved road?

As you are in an accelerating car, you are an observer in a non-inertial reference frame and therefore Newton's laws do not apply to you. You cannot explain why you tend to slide across the seat away from the center of the circle. However, an observer on the ground can explain this. Assuming that there is no seatbelt and the seat is smooth, the sum of the forces exerted on you is zero, thus you are moving in a straight line (Newton's second law. But the car is turning left underneath you, the car is sliding under you to the left causing you to bump into its right door and start moving in a circle.

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Eugenia Etkina
21. November

Are our students wrong?
Hi all, today my post is about student ideas. Notice, that I did not use the word misconceptions. And you probably noticed that I never use this word. I already posted about it but will do it again. Students do not have robust conceptions. They have tiny ideas based on their life experience and the language that we use that they put together to answer physics questions that we pose and they have never thought about before. We change the context - their answer will change. We change the language - their answer will change. One example is the word "electricity". What does this word mean? Electric charge? Electric current? Voltage? Energy? Power? As long as we have this term in our vernacular, the students will use all those terms interchangeably.
Often student ideas look completely wrong but once we find the right context or revise the language, we will find that they are perfectly correct. There are many names for these ideas in educational research. In physics we call them p-prims (phenomenological primitives, coined by diSessa), facets (coined by Minstrell), or resources (Hammer et al.). Once we are familiar with these three theoretical frameworks, we can easily explain almost every student idea that we encounter. And we can find what everyday experience led them to this idea and in what contexts it is productive. What I am trying to say is that approaching student ideas as something that is wrong is a dead end. When we have an idea in our brain, there is nothing that can be done to remove it from there (unless you do brain surgery). What we can do it to help our students use this idea in an appropriate context or slightly tweak it using language. But if we see student ideas as resources on which to build on, possibilities are endless! Not only we challenge ourselves to understand what our students are saying and thus growing

ourselves, but we help our students develop confidence and self efficacy. Instead of thinking of themselves as incapable and not belonging in physics, they start seeing themselves as intuitive physicists who need a little bit of help to align their ideas with the formal physics stuff. Our students are infinite wells of observations, intuition, and curiosity. Let's draw from those wells instead of closing their lids!

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Eugenia Etkina
November 23

What do we need to learn?
Hi all, I am reading a very interesting book called How we learn? by S. Dehaene. This is how he writes about the conditions that people need to learn (see the quote below). While you are reading it, I would like you to think how these conditions related to the ISLE approach. We will discuss them more during our meeting on Saturday.
There are 4 pillars of learning. "These pillars are:
• Attention, which amplifies the information we focus on.
• Active engagement, an algorithm also called “curiosity,” which encourages our brain to ceaselessly test new hypotheses.
• Error feedback, which compares our predictions with reality and corrects our models of the world.
• Consolidation, which renders what we have learned fully automated and involves sleep as a key component.
Far from being unique to humans, these functions are shared with many other species. However, due to our social brain and language skills, we exploit them more effectively than any other animal—especially in our families, schools, and universities.
Attention, active engagement, error feedback, and consolidation are the secret ingredients of successful learning. And these fundamental components of our brain architecture are deployed both at home and at school. Teachers who manage to mobilize all four functions in their students will undoubtedly maximize the speed and efficiency with which their classes can learn. Each of us should therefore learn to master them." p.176-177.
Please do not forget to respond to this message or like it to make it more visible to other group members, thank you!

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Eugenia Etkina
November 25

Zoom for our meeting tomorrow and more from "How we learn" book
Hi all, I am posting the zoom link again (actually, it is the same zoom link for all our meetings, so if you attended once and saved the link you can use it for any meeting). The meeting is at 10 am PST (West coast US), 1 pm EDT (East coast US) and 7 pm CET (Central European Time). Check your time zone to avoid missing it. Here is the link: https://rutgers.zoom.us/my/etkina...
Now, I will continue with the wisdom from the book. I hope that you followed the conversation of John Davisson and Hrvoje Miloloža who were discussing issues with student motivation. They brought up several very important points!
Dehaene, the author of the book that started the discussion emphasizes the role of attention in student learning. He writes how if the students do not know what is important to pay attention to, their brain does not engage in learning (they use the brain scans). Another person who wrote a great book about how people learn (I mentioned him many times, James Zull, the Art of Changing the Brain) also emphasizes the need to focus student attention on what is important. he writes how novices do not know what to focus their attention on when the new material and because of that they do not learn. So, helping students to know what is important in the new stuff is really IMPORTANT. But
Dehaene wrote more about focusing attention. He talks about of the importance of EYE CONTACT to help learners see what is important. I always teach my future teachers to establish eye contact with every student multiple times during a lesson to let the students know that you see them. But I never thought that the eye contact is crucial for a person to recognize what is important in what they are supposed to learn (they have really cool testing experiments for this idea in the book). The need for eye contact explains again (and again) why people do not learn by listening to lectures.... It also explains why group work is better for learning that whole class discussions. In the group work every group member who is talking/explaining can establish eye contact with every other group member. It also explains the success of individual tutoring sessions...
Bottom line - when you are in the classroom next time, check how many times and when you establish eye contact with every one of your students. If you finished reading this post, you know what to do! Please do it! Thank you!

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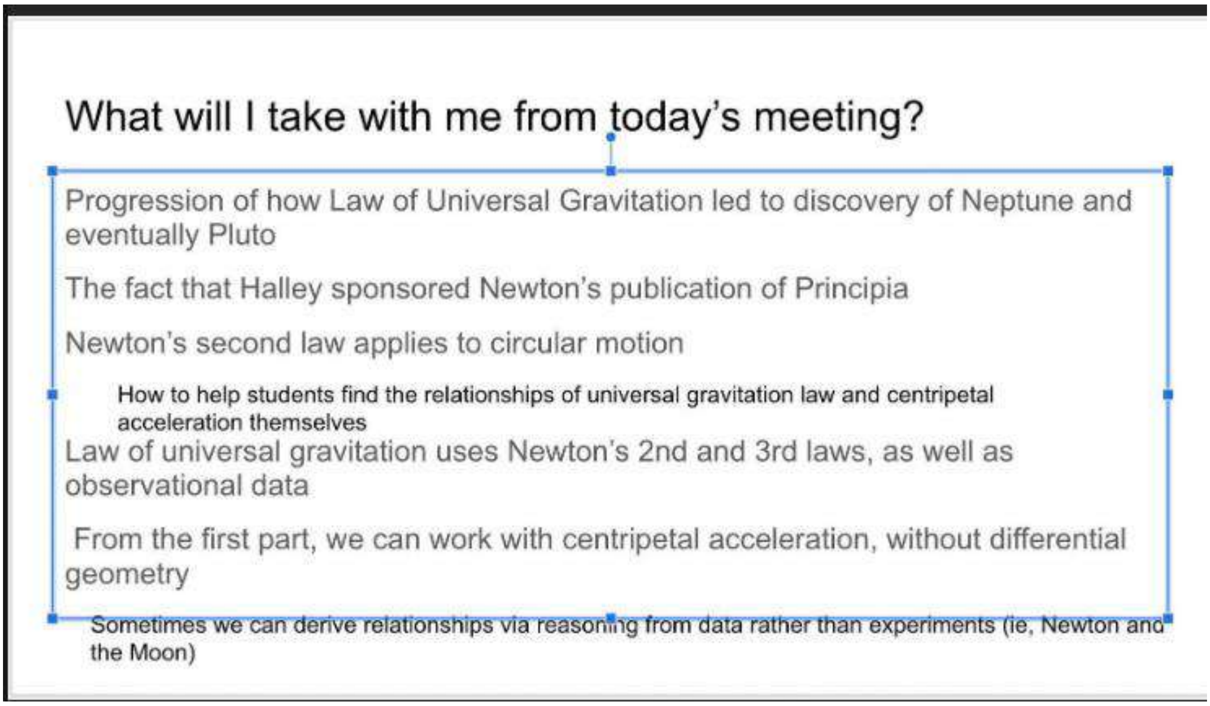
Eugenia Etkina
November 27

Yesterday's meeting recording and slides

Thank you all those who came to our meeting yesterday, we did a lot of work there! Here is the link to the slides from the meeting https://docs.google.com/.../1WKXHDnIEqpRwkmlOgDKs.../edit...
and the recording of the meeting: https://rutgers.zoom.us/.../LAUAzD7grefr9HFm...
password is T99&KsJi
I am pasting the What did you learn in the meeting slide here. Thank you all again for a wonderful meeting!



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Eugenia Etkina
November 29

Circular motion and rolling
Hi all, as we had our meeting on circular motion, I will make a few posts about the "jewels" that we have in the textbook and the ALG/OALG so that you do not miss them. One of them is rolling motion. It often gets neglected in physics courses as it is not clear where it belongs - circular motion (which is a revolutionary motion) or rotational motion? In any case, we have two really cool problems that will help students understand how rolling motion works. I always think of it as a combination of circular motion and translational motion. Analyzing rolling motion helps also understand the role of the observer - which brings us back to the relative nature of motion.

I attached the screen shots to this post and I would like to see your reasoning for problem 12. Gorazd Planinsic made those photos when I was driving a car on a highway and I bet many truck drivers were wondering what the guy is doing taking pictures of their trucks! 🙂 I can post a bigger photo from problem 12 if you do not have the textbook. Please share your thoughts! And please do not forget to respond to this post once you finished reading it.

11. * Rolling is a combination of linear and circular motion. In order to study rolling motion, we perform the following experiment. We mark three points A, B, and C on a bicycle wheel and observe how these points move while the bicycle is pushed forward 2 cm, a distance much smaller than the radius of the wheel. **Figure P5.11** shows a long-exposure photo of the experiment. The camera (i.e., the observer) is standing still on the ground. A is the point where the wheel is initially touching the ground, B is the point at the wheel's axis, and C is the point on the top of the wheel, directly above point A. (a) Determine the displacements of points A, B, and C as observed by the stationary observer. (Hint: Use similar triangles.) (b) Using your answers from part (a), determine the speed of the points A, B, and C with respect to the ground for the bicycle that is moving at constant speed v. How would the answers to part (b) change if the observer were moving in the same direction as the bicycle but (c) with the same speed as the bicycle or (d) twice as fast as the bicycle?

FIGURE P5.11

12. ** **Figure P5.12** shows photos of car wheels that were obtained in four different ways:
    i. A person standing on the sidewalk took a photo of a car that was passing by.
    ii. A person in a moving car took a photo of another car. Both cars were moving with the same speed.
    iii. A person in a moving car took a photo of another car that was moving faster than the photographer's car.
    iv. A person in a moving car took a photo of another car that was moving slower than the photographer's car.

    Match each photo (a) to (d) with the corresponding photographing procedure. [Hint: If you have difficulties with this problem, solve the previous problem.]

FIGURE P5.12

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Eugenia Etkina
November 30

Next meeting and other stuff
Hi all, three things today. First, I created an event for our meeting on December 10th. Please sign up there so that I know how many people plan to attend.
Second, I will be traveling for the next 5 days and will not be posting much.
Third, I wanted to explain why we do not use the term "centripetal force" in our textbook and in our vernacular in general. The reason is that every time we give a special name for something, our students might think that it is a separate thing. They think that there are forces exerted on an object, and then there is this special centripetal force. The truth is, there is no such thing. The term "centripetal force" is reserved for the component of the sum of the forces exerted on an object that is moving in a circle. Therefore, it is better to just name all the forces and then find the sum. When the object is moving in a circle at constant speed, this sum will be pointed towards the center. If there is only one force exerted on an object moving in a circle, it will point towards the center.
Notice also that we do not use the term net force (or use it very rarely). The same reason. You give it a name and the students think that there is a special force, called the net force. so, it is better to always talk about the sum of the forces to establish brain pathways that would never lead the students to think that F=ma. Because it does not. It is the sum of the forces that is equal to the product of the mass and acceleration. If you finished reading the post, you know what to do!

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Eugenia Etkina
December 6, 2022

Physics on rollerblades
Hi all, some time ago I posted about teaching mechanics on rollerblades - a method that I invented in 1997. I wrote a paper about it in the Physics Teacher and my first talk at the AAPT was on rollerblades! Since then, all my students - future physics teachers learned how to use rollerblades to help their students learn relative motion, dot diagrams, Newton's laws, etc. And

once a year we would rent a rollerskating rink and practice the techniques (they look very simple but in fact they require a lot of practice). In the last 3 years because of Covid, we did not do it, and then I retired. So, in November, when I came to NJ we rented a huge rollerskating rink (thanks to Danielle Buggé) and lots of people from the community of my graduates came to the lesson. We skated for 2 hours and it was such fun! I am sharing a few pictures taken by Henry Chen. You can see dot diagrams, passing a medicine ball for Newton's third law, difference between linear velocity and rotational velocity and many others. I am also reminding you of the meeting on Saturday, more about it tomorrow.

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Eugenia Etkina ·
December 8, 2022
·
Info for the upcoming meeting on Saturday
Hi all, as always, I start posting information for the meeting a couple of days in advance, so that you can find the zoom link easily. The meeting is on Saturday at 10 am PST (US West Coast), 1 pm EDT (US East coast) and 7 pm CET (Central Europe - Italy, Slovenia, Croatia, etc.) The topic is conservation vs constancy and linear momentum. To prepare, please read section 1 in Chapter 6. The concept of the difference between these two terms is very difficult for the teachers who are used to the term conservation to mean both. We distinguish between those terms to make clear that conserved quantities are ALWAYS CONSERVED WITH NO EXCEPTIONS but they might not be necessarily constant in a particular system. I repeat again, that this is a difficult concept and that is why I invite you to start working on it before the meeting, but reading section 1 in Chapter 6 in the textbook. Here is the link to the zoom meeting and the password:
https://rutgers.zoom.us/my/etkina...
password 164680 Please do not click on the link before the meeting day/time (15 min in advance is great!) as this is my universal link for all of my meetings. Please also sign up on the EVENTS page so that I know how many people are coming. Thank you, I am looking forward to our meeting on Saturday!
PS It looks like we are going to have a rollerblading session in the Bay area some time in late January - early February, stay tuned if you live near by.
Please do not forget to like this post or comment on it to make it more visible.

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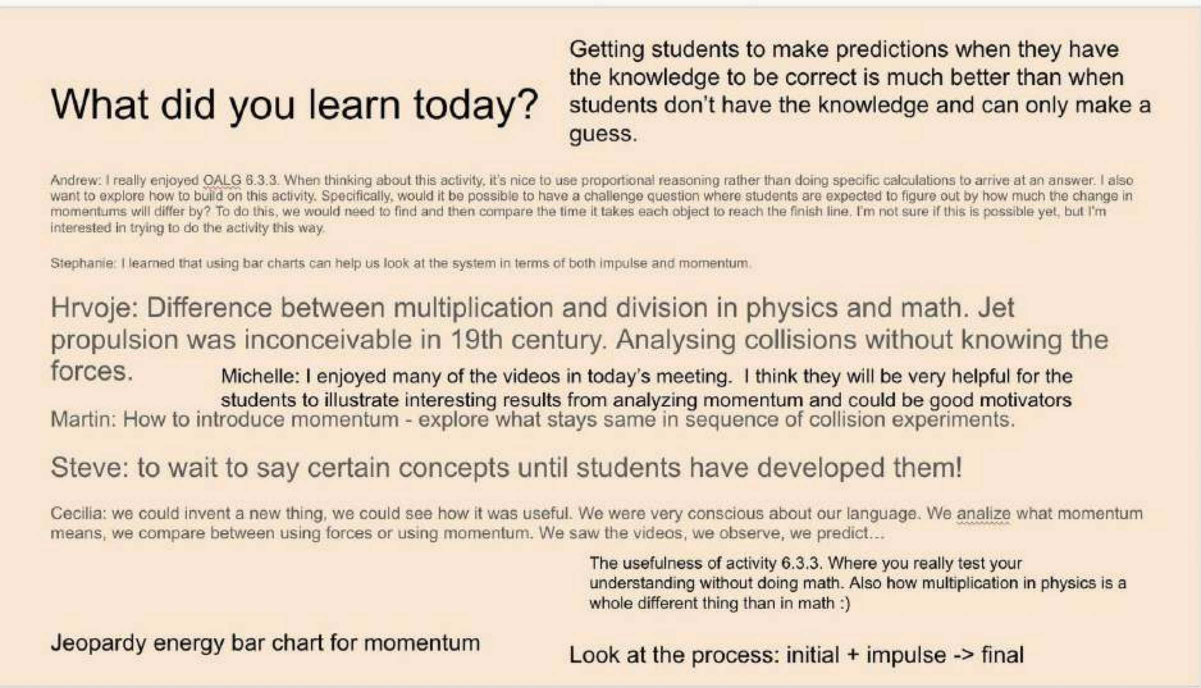
Eugenia Etkina
December 11, 2022
·
Hi all, this the information about our meeting yesterday. First, thank you all those who attended! I think we had one of the biggest attendances yesterday! We have a very stable group of those who participate in every meeting and then new people who come for the first time and then continue coming. It is great to see people from 10 different countries working together!
Second, here is the link to the zoom recording https://rutgers.zoom.us/.../ZwFfo0jyW8E8cVw2cmdduQohG5... and here is the password: U.92sF%!
The google slides are at https://docs.google.com/.../1kyryevA0wGWW0Hz68fp3.../edit...
Please do not delete the slides when you view the deck. I made them editable so that you can copy what interests you but this editable feature is dangerous as you can accidentally delete

a slide. Please make sure you do not do it. On the first slide there is the link to all materials for the meeting.
And finally I am posting the reflection slide - what people thought they learned during the meeting. Please ask questions if something is not clear. The biggest issue was the difference between the words conserved and constant.
Third - please do not forget to like the post or comment on it to make it more visible for other people and to make sure that the next post comes to your feed! Thank you!



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Eugenia Etkina
Admin
·
December 12, 2022 at 8:14 AM
·
Hi all, today I wanted to show how you can use both the ALG/OALG and the textbook to help students develop a specific idea. In class, the students do activities in the ALG/OALG in groups, share their whiteboards and have a discussion. THEN they go home and read the textbook where THE SAME activities are described (usually the same experiment with the analysis that they just did themselves). This way two goals are achieved: students Innovate first and then the have Time for telling (the book does the telling) and they construct the concept first and then learn the name for it. Here is the beginning of the progression for the concept of linear momentum. Look at the parallels in student learning:

OALG 6.2.1. OBSERVE AND FIND A PATTERN

Observe the following four videos of the experiments with a two-object system. Two carts (the system consists of both carts) move on a dynamics track:

a. Cart A (500 g), moving right at constant 0.37-m/s speed, hits identical cart B (500 g) that is stationary. Cart A stops and cart B starts moving at the speed of 0.37 m/s to the right. https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-2-1a

b. Cart A loaded with a block (total mass of the cart with the block is 1470 g), and moving right at 0.31 m/s hits stationary cart B (mass 500 g). After the collision, both carts move right: cart B at the speed of 0.47 m/s and cart A at the speed of 0.15 m/s. https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-2-1b

c. Cart A (500 g), with Velcro attached to its front, moves right at 0.31 m/s. Identical cart B (500 g) moves left at constant speed 0.31 m/s. The carts collide, stick together, and stop https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-2-1c

d. Repeat experiment c. but this time cart A is loaded (with a block, total mass is 1470 g) moves right at constant speed of 0.35 m/s. Cart B (500 g) moves left at constant speed of 0.35 m/s. After the collision, both carts stick together and travel right at the speed of 0.17 m/s. https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-2-1d

For each experiment, sketch the process before the collision and after the collision. Create a table like the one that follows to help you determine if anything is the same before and after the collision for the two-cart system. (Use the table below to look for quantities.) [The table did not come through here, you can see it in the OALG document or in the meeting folder - our last meeting]

Possible physical quantity

Mass

m

Speed

v

Velocity

Mass times speed

mv

Mass times x- velocity component

mvx

Cart A

(before collision)

Cart B

(before collision)

Combined physical quantity for Cart A & Cart B (add line

1 and line 2 for each quantity)

Cart A

(after collision)

Cart B

(after collision)

Combined physical quantity for Cart A & Cart B (add line

1 and line 2 for each quantity)

After you come up with a physical quantity that is the same before and after each collision, decide whether this quantity remains constant in all four experiments. Then, read and interrogate Observational Experiment Table 6.1 on page 149 in the textbook. Did you come up with the same quantity?

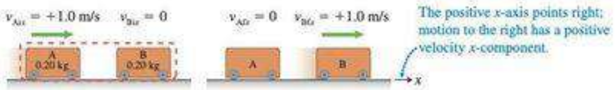
Below is the screenshot of the textbook analyzing similar experiments. They help students solidify the idea that it is the sum of mass times velocity for all objects in the system that remains constant before and after the collision. Note, that there is still NO NAME for this new quantity as it has not been tested yet.

We do not only parallel the invention of the new ideas, we also parallel problem solving allowing the students first to struggle themselves and then read the model solution in the textbook. But this is for tomorrow. 🙂

If you finished reading the post, you know what do do now! Thank you.

OBSERVATIONAL EXPERIMENT TABLE 6.1 Collisions in a system of two carts

VIDEO OET 6.1

Observational experiment	Analysis
Experiment 1. Cart A (0.20 kg) moving right at 1.0 m/s collides with cart B (0.20 kg), which is stationary. Cart A stops, and cart B moves right at 1.0 m/s.	 • *Speed:* The sum of the speeds of the objects is the same before and after the collision: 1.0 m/s + 0 m/s = 0 m/s + 1.0 m/s. • *Mass · speed:* The sum of the products of mass and speed is the same before and after the collision: 0.20 kg(1.0 m/s) + 0.20 kg(0 m/s) = 0.20 kg(0 m/s) + 0.20 kg(1.0 m/s). • *Mass · velocity:* The sum of the products of mass and the x-component of velocity is the same before and after the collision: 0.20 kg(+1.0 m/s) + 0.20 kg(0) = 0.20 kg(0) + 0.20 kg(+1.0 m/s).

(CONTINUED)

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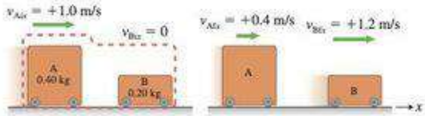
Observational experiment	Analysis
Experiment 2. Cart A (0.40 kg) moving right at 1.0 m/s collides with cart B (0.20 kg), which is stationary. After the collision, both carts move right, cart B at 1.2 m/s and cart A at 0.4 m/s.	• *Speed:* The sum of the speeds of the objects is not the same before and after the collision: 1.0 m/s + 0 m/s ≠ 0.4 m/s + 1.2 m/s.  • *Mass · speed:* The sum of the products of mass and speed is the same before and after the collision: 0.40 kg(1.0 m/s) + 0.20 kg(0 m/s) = 0.40 kg(0.4 m/s) + 0.20 kg(1.2 m/s). • *Mass · velocity:* The sum of the products of mass and the x-component of velocity is the same before and after the collision: 0.40 kg(+1.0 m/s) + 0.20 kg(0) = 0.40 kg(+0.4 m/s) + 0.20 kg(+1.2 m/s).
Experiment 3. Cart A (0.20 kg) with a piece of clay attached to the front moves right at 1.0 m/s. Cart B (0.20 kg) moves left at 1.0 m/s. The carts collide, stick together, and stop.	• *Speed:* The sum of the speeds of the objects is not the same before and after the collision: 1.0 m/s + 1.0 m/s ≠ 0 m/s + 0 m/s.  • *Mass · speed:* The sum of the products of mass and speed is not the same before and after the collision: 0.20 kg(1.0 m/s) + 0.20 kg(1.0 m/s) ≠ 0.20 kg(0 m/s) + 0.20 kg(0 m/s). • *Mass · velocity:* The sum of the products of mass and the x-component of velocity is the same before and after the collision: 0.20 kg(+1.0 m/s) + 0.20 kg(−1.0 m/s) = 0.20 kg(0 m/s) + 0.20 kg(0 m/s).

Pattern

One quantity remains the same before and after the collision in each experiment—the sum of the products of the mass and the x-velocity component of the objects.

In the three experiments in Table 6.1, only one quantity—the sum of the products of the mass and the x-component of velocity, $\Sigma m v_x$—remained the same before and after the carts collided. Note also that the sum of the products of the mass and the y-component of velocity, $\Sigma m v_y$, did not change—it remained zero. Perhaps $\Sigma m\vec{v}$ is the quantity characterizing some quantity of motion that is constant in an isolated system. But will this pattern persist in other situations? Let's test this idea by using it to predict the outcome of the experiment in Testing Experiment Table 6.2.

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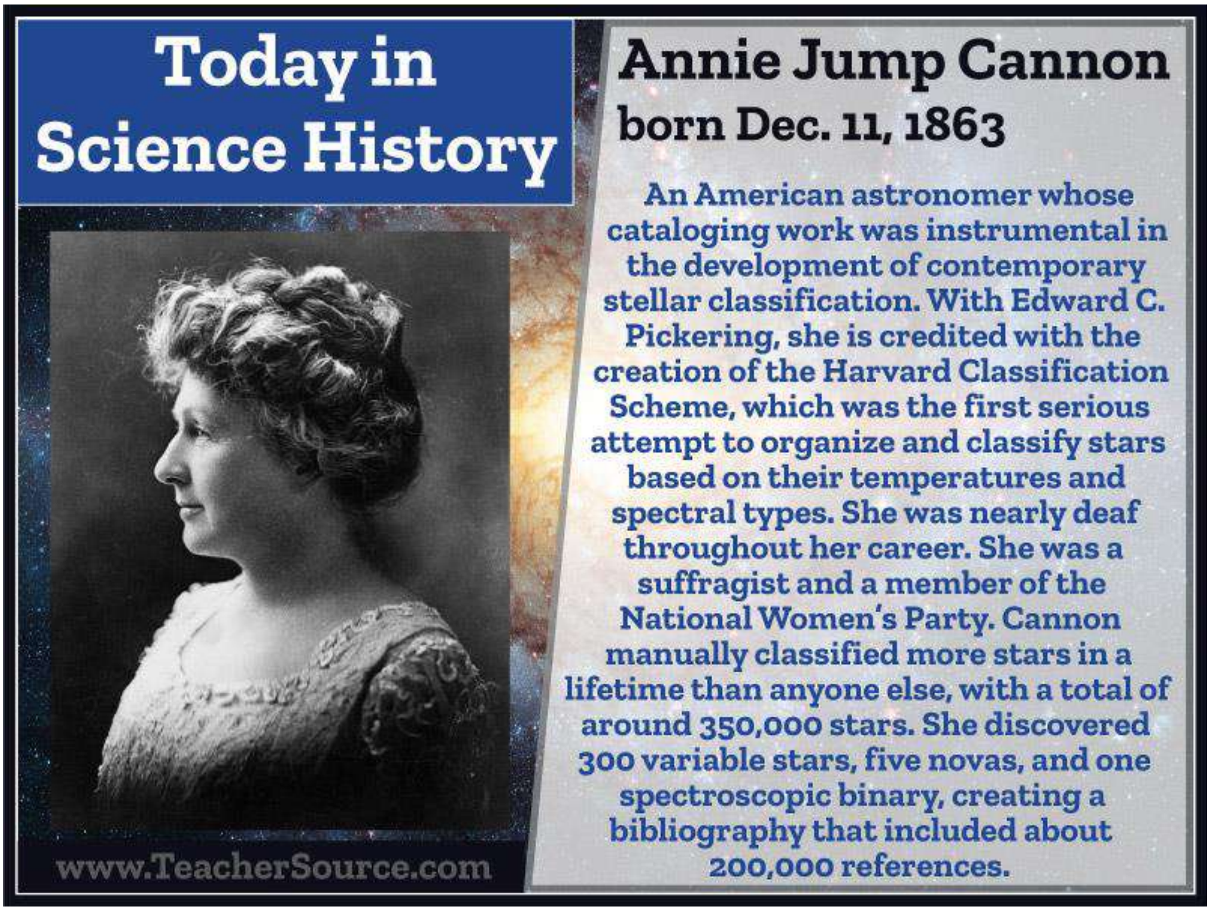
Eugenia Etkina
December 12, 2022 at 1:45 PM
·
For those who are looking into information on women in physics/astronomy, this is a great reference! https://www.facebook.com/.../a.21356957.../1159029781386121/



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Eugenia Etkina
December 14, 2022 ·

Hi all, we had a meeting on Momentum, the next is Energy. Our approach to energy is very different from traditional as we include internal energy in the investigations from the beginning, not just mechanical energy and talk about the total energy. As always, the idea of a system is central to our approach and we use work-energy bar charts. It looks like one meeting will probably be not enough to discuss everything, so we should be prepared to have two. The first one I propose to have on January 7th (the first Saturday that is not a holiday, if you consider Dec 31 to be a holiday already). Please respond here if January 7th is a good day to have the first meeting for energy.
Thank you!

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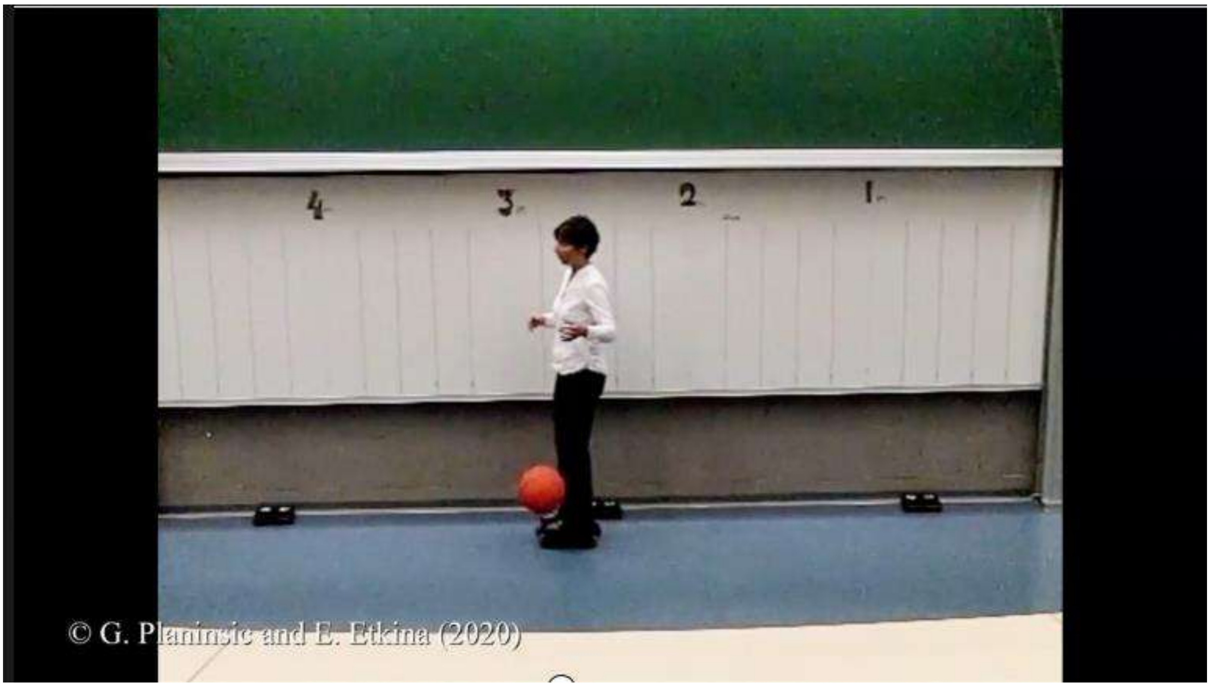
Eugenia Etkina
Admin
·
December 15, 2022 at 11:08 AM
·
Hi all, today I want to talk about momentum and the activity that caused a lot of discussion during our meeting. It involved a person (in this case myself) dropping and throwing a medicine ball while rollerblading. I am pasting the text of the activity for you to ponder and then we can talk about what important ideas it can help students develop. What are your thoughts? Why is this activity so important?
OALG 6.4.6 REPRESENT AND REASON
a. Watch Eugenia wearing rollerblades and holding a ball https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-4-6a. She pushes off the floor once and continues rolling at constant speed across the floor. Then she drops the ball. Describe everything you can about momentum in this process using words, bar charts, and mathematics. Choose Eugenia and the ball as the system and initial state is when Eugenia is rolling while holding the ball and the final state is right after she lets go of the ball. Does dropping the ball change Eugenia's speed? What if, instead of the basketball, she dropped object that is 1/10 of her mass in the same manner as before? Would her speed change? To answer these questions, remember that momentum is a vector quantity.
b. Watch Eugenia wearing rollerblades and holding a heavy medicine ball https://mediaplayer.pearsoncmg.com/.../sci-OALG-6-4-6b. She pushes the ball away from her. Describe everything you can about momentum in this process using words, bar charts, and mathematics. Decide what your system is and what the initial and final states are.

I also want to thank Gorazd Planinsic who made all those amazing videos that we used in our meeting on momentum. In the second video in the above activity you see Bor Gregorčič.



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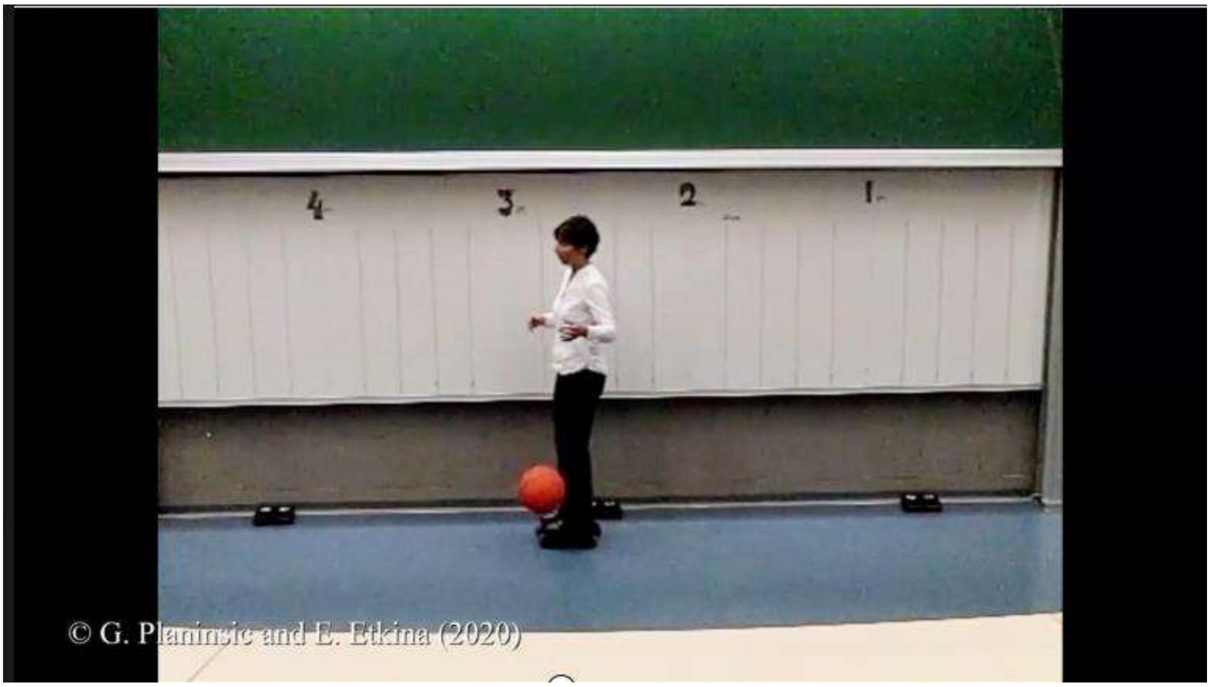
Eugenia Etkina
Admin
·
December 16, 2022 at 11:11 AM
·
Hi all, yesterday I posted an activity related to momentum (Please read my yesterday's post before you continue reading this one).
There, in the first video, I move forward on rollerblades and drop the ball I am carrying which falls down but continues to be next to my body during the fall and lands by my feet. The question is - what happens to the momentum in this process?
If we take Eugenia as the system, then the answer is Nothing. There are no extra external forces exerted on me, thus my momentum does not change - which is clear from the video - I do not slow down or speed up.
But what if we take me and the ball as the system? In this case, we need to remember that momentum is a vector quantity and we analyze x component separately from the y component. In the x direction there are no external forces exerted on the system, therefore the momentum of the system is CONSTANT. This means that if before I dropped the ball, I was moving at velocity v in the x direction and the ball was moving at the velocity v in the same direction, we

continue moving the same way (until the ball touches the floor). The x momentum of the system did not change when I dropped the ball!
But in the y direction, there is an external force exerted on the ball that previously was cancelled by the force exerted by my hand. After I drop it, the ball's momentum CHANGES because of the impulse exerted by Earth - it accelerates towards the floor. But even though the system's momentum is not constant in the y direction, the momentum of the system is still CONSERVED.
WHAT??? How is this possible - CONSERVED BUT NOT CONSTANT? Exactly!
The momentum is conserved because if we redefine the system to include Earth we will find that as the ball acquires the downward momentum due the the pull of Earth, Earth itself acquires the upward momentum due to the pull of the ball. EXACTLY the same momentum in magnitude but in the opposite direction. So, if we include Earth in the system, the total momentum in both directions remains CONSTANT. And this is the main difference between conserved quantities and the quantities that are not conserved. If a quantity is a conserved quantity, then we can ALWAYS find a system in which this quantity is constant. It does not disappear without a trace and does not appear from nowhere (for example, velocity and acceleration are not conserved quantities, although they can be constant in some processes but momentum and total energy are, as well as electric charge for example are conserved quantities but they are not necessarily constant in some systems - see Emmy Noether theorem for the explanation).
I hope that this brief example helps you see the very important difference between the words CONSTANT AND CONSERVED. When a quantity is constant, is is not necessarily conserved. When the quantity is conserved it is not necessarily constant. If you finished reading to the end, you know what to do next, thank you!



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Eugenia Etkina
December 19, 2022 ·

Hi all, in the last couple of days we had very interesting discussions related to the AI bots responding to our questions. Frank Noschese, Bor Gregorčič, Peter Bohacek, Gorazd Planinsic all contributed to those, thank you all!
Today I wanted to talk about why the bots give wrong answers to many of our questions. If you think of a traditional answer to this questions - "students have robust misconceptions", you will realize how wrong this answer is using the bots' difficulties answering our questions. Nobody programmed any wrong physics ideas into them, they have difficulties when putting these ideas together being triggered by the context or some word in the question (Gorazd Planinsic tried changing just ONE word in the problem and the bot went from a completely right answer to a totally wrong one). This means that the bots (just as our students) have trouble putting ideas together when being put on the spot with our questions. EVEN having all CORRECT equations and ideas programmed into them, they still make mistakes. Those bits of information programmed into the bots need to be viewed as RESOURCES which the bots use, sometimes productively and sometimes not. But if we remove this resources (and this is what the misconception approach tells us to do - do away with misconceptions, remove them from students brains!), there will be nothing for the students (or bots) to build on and no learning will occur. That is why the misconception approach is inherently flawed and we should be using the resources (including p-prims) approaches to interpret student responses. If you are not familiar with the p-prims approach, I can explain tomorrow.

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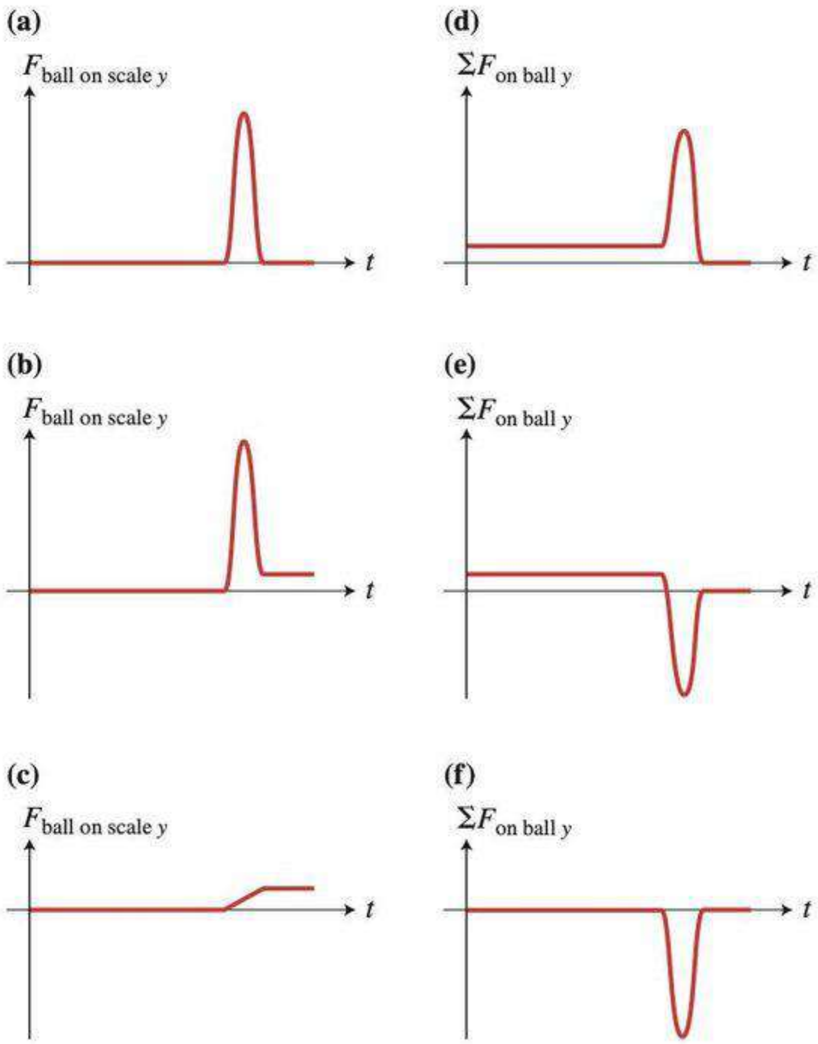
Eugenia Etkina
December 20, 2022
·

Hi all, representing ideas in multiple ways helps all students learn. There is no question anymore about different learning styles - those do not exist, instead, there is a firm consensus about specific instructional methods that help ALL students learn. One of those methods is multiple representations.
The pioneer and the advocate of this method in the PER community was Alan Van Heuvelen. Since his first papers many curriculum developer came up with various graphical representations but it is his idea of using the graphical representation as a concrete bridge between abstract words and abstract equations that is the most powerful. Building on these ideas, we extended graphical representations in many directions, one of those being graphs

of the quantities that are normally not used in specific topics. Here is an example of such use in momentum (as we have been working on momentum since our last meeting). This is the problem from the back of the chapter problems in our textbook (Chapter 6), there are many more different representations in that chapter, check it out!
Two more things. Yesterday I mentioned p-rims as a type of student ideas and I said that I would elaborate on those if you are not familiar with them. Nobody asked any questions about p-prims, does it mean that they are clear? Finally, please do not forget to like the post or respond to it to make it more visible for other members. Thank you.

12. You hold a clay ball above a scale and then drop it. After hitting the scale, the ball sticks to it. In **Figure Q6.12**, which of the graphs (a) to (c) correctly shows the qualitative time dependence of the force exerted by the ball on the scale, and which of the graphs (d) to (f) correctly shows the qualitative time dependence of sum of the forces exerted on the ball? Assume the y-axis points vertically down.

FIGURE Q6.12



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Eugenia Etkina
Admin
 ·
December 21, 2022 at 3:45 PM
 ·
Hi all, I promised to explain what p-prims and resources are but I think I need to start by defining the context in which ideas appeared. so, I plan to do at least 4 posts on this topics - next 4 days. If you are interested, please make sure that you check the posts every day. The text that I will be sharing here is a draft of one of the chapters in the new book that Gorazd Planinsic and I are working on - this is the sequel to our first ISLE book and is focused on helping to prepare physics teachers who will implement the ISLE approach with their students.
So, here is the first part:
The disagreement of how to treat student ideas is as old as the idea that the students are not blank slates when they come to us. The recognition that students come to us with existing knowledge is the first step in helping them learn (Dehaene, 2022 and Zull, 2002). Investigating those ideas is the next important step (see the work of the University of Washington group led by late Lillian McDermott). Often, these ideas look “wrong” at a first glance as they do not match the normative physics understanding that we wish our students to develop. However, after that the paths of the educators diverge.
Some travel in the direction of labelling student ideas that they bring into the classroom as “misconceptions”(sometimes labelled as preconceptions, alternative conceptions, etc.) (Clement 1982; Halloun and Hestenes 1985b; Kaltakci-Gurel et al. 2016; McCloskey 1983), some label them as “resources” (Smith et al., 1993/1994 and more below).
When researchers or teachers talk about misconceptions (or whatever label they give to those) they usually mean that students hold firm cognitive structures (conceptions) that are strongly held, different from experts, affect how students understand and explain natural phenomena and must be overcome. In other words, if a student has a misconception about something, first, it means that they have some robust conception and second, it means that this conception is wrong and needs to be cleared out from their mind and hopefully replaced by the correct conception. As D. Hammer put it a long time ago (1996), “This view frames research designed to identify misconceptions and instruction designed to reveal, confront, and replace them.”
While, as we said above, this view looks to be consistent with constructivist ideas that students are not blank slates, it also imposes certain tasks on the teacher – identify those ideas in student minds and help them get rid of those.
That last step breaks the connection with constructivism, as if we “remove” those wrong ideas from students’ minds, then how do we help our students build new ideas which (as brain research tells us, see Dehaene, 2022) can only be developed when they connect to previously existing ones.

But students do come up with incorrect ideas, don't they? We all have those experiences when students express the views completely inconsistent with the laws of physics. For example, many researchers documented student "misconception" that "motion implies a force, and when there is no force, motion ceases" (impetus theory as described by Hestenes, Wells, & Swackhamer,1992). It looked like in many instances (including standardized assessments, such Force Concept Inventory) the students have this robust wrong idea. However, when Brookes and Etkina (2009) conducted a linguistic analysis of student responses, they found that the students do not see the force as a cause of motion but treat it as a property of motion (similar to momentum or kinetic energy) and thus their responses are completely correct and require some language correction not the correction of the conception. Based on similar analysis, "Smith et al. (1993/1994) and diSessa (1988, 1993) challenged the idea of a discontinuity between student and expert knowledge, arguing that it conflicts with the constructivist account of how we develop new understanding. To be continued! Please like or comment to ensure that the next post comes to your feed.

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Eugenia Etkina
Admin
·
December 22, 2022 at 11:15 AM
·
Hi all, I continue the series of posts about student ideas. Please read my yesterday's post to follow. I start from the end of yesterday's post.
...In focusing only on how student ideas conflict with the expert concepts, misconceptions approach offers no account of productive ideas that might serve as resources for learning. Because they are fundamentally flawed, misconceptions themselves must be replaced. ... An account of useful resources that are marshalled by learners is an essential component of a constructivist theory but the misconception perspective fails to provide one. (Smith et al., 1993/1994, p. 124 as cited by Hammer, 1996).
At the same time, several researchers started investigating student ideas in detail and found that they are not robust ideas, but depend on the context and the wording of a question (Schuster, 1993, and many others). For example, the students have small experience-based ideas that they put together when asked a scientific question.
Is it possible, that students (and all people) construct cognitive structures based on their every-day experience and then apply these structures to answer physics questions? A. diSessa answered this question positively when he developed the concept of "phenomenological primitives" (means simple ideas that grew out of generalizations of everyday phenomena) or 'p-prims' (1993). These p-prims are small ideas that students have and they put them together to answer our questions. Using the pr-prims idea, we can think that student answers are not based on stable cognitive structures, but are the results of them trying to apply and combine

their previous ideas to respond to us. The emergent answer is often made on the spot in response to our request.

diSessa (born in 1947, I put his photo here) identified several p-prims in student reasoning. Here are some examples: maintaining agency (for example food is needed on a hike), actuating agency - the consequence of something lasts longer than this something (for example, if you burn your tongue eating hot food, the pain lasts longer than the contact with the hot beverage), closer means stronger (the closer you are to the stove, the hotter it is), Ohm’s p-prim – the stronger the cause, the stronger its effect, the stronger the resistance or impediment, the stronger its effect, and several others.

Now, you can see that p-prims can be used to explain many physical and social phenomena but they are not directly connected to normative physics knowledge. When we ask a student a physics question, they activate one (or more) of the available p-prims and sometimes the answer is correct (current through a resistor is directly proportional to the potential difference across it and inversely proportional to its resistance) and sometimes it is not (velocity is not directly proportional to the force and inversely proportional to the mass).

Being able to habitually identify the p-prim on which the student based their reasoning is extremely important. If we can do this, we can use the existing p-prim and build on it by tweaking the language or the context. We need to view p-prims as productive resources on which to build students’ new knowledge (Smith et al., 1993/4). ... End of today's post.

To be continued. If you read to the end, please like the post or respond to it, so that my tomorrow's post comes to your feed.

PS Notice, that I am citing very old papers that refute the idea of misconceptions and provide a different approach to student ideas. The question remains: Why do so many educators hold the "misconceptions approach" even now? As a member of the editorial boards of several physics education journals, I regularly receive papers to review that describe students' misconceptions in different areas of physics, including quantum mechanics. I wonder, how many students thought and formed conceptions (wrong conceptions) about quantum mechanics models before they came to class? The answer would be none. And yet, those papers come. Stay tuned!

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Eugenia Etkina
Admin
·
December 23, 2022 at 11:07 AM
·
Hi all, I continue with student ideas today. Please read three last posts before reading this one (if you missed them) as they build on each other.
Yesterday I finished with the idea that we need to view p-prims as productive resources on which to build students' new knowledge. Here is the continuation of the story:
David Hammer (see his photo attached) and his collaborators developed the idea of resources further (see for example Hammer 2000; Hammer and Elby 2003; Hammer et al. 2005). They proposed that resources are bits of prior knowledge that can be activated alone or with other resources as a student reasons about a physics topic. Resources are often context-dependent and may not be robust in their activation, i.e., a student may abandon a resource or change which resources are being activated rather quickly. AJ Richards, D. Jones, and I in the paper "How Students Combine Resources to Make Conceptual Breakthroughs" (Richards, Jones, & Etkina, 2018) describe resources using the definitions of different researchers as "cognitive

elements at various grain sizes that may be in different states of activation at any given moment" (Conlin et al. 2010, pp. 19–24); they can range from small, basic elements like Disessa's, to more complex conceptual structures such as "coherent theories about physical phenomena"(Harrer et al. 2013, p. 23101).
Hammer and colleagues discuss conceptual and epistemological resources. Conceptual resources are similar to p-prims but differ from them in size and scope and many of them are physics related. For example, a conceptual resource of energy as a substance can help a student successfully explain how a battery powers a lightbulb but when used to analyze what happens to electric current in a circuit might lead to an incorrect answer that current is used up in a circuit.
Epistemological resources relate to the nature of knowledge and learning (Hammer and Elby, 2003). An epistemological resource of "knowledge as fabricated stuff" can help students think of developing their own explanations but if they have a resource that "knowledge comes from authority", they would want you to "give them an answer". As the p-prims, both types of resources are activated when we ask students questions or when they are interpreting reading materials. While these p-prims and resources sometimes make the students give answers that are "wrong" or seem wrong, we should try to "diagnose" the source of their ideas and channel this source in a productive direction.
Here is an anecdote that might help. In the Rutgers Physics Teacher preparation program in the course "Development of Ideas in Physical Science" there is an assignment when the students (future physics teachers) need to interview a novice about a specific physics concept, transcribe the interview and then interpret what the subject said. One of the pre-service teachers had to interview a novice about electric charge. This was his comment at the end of the discussion of the interview: "It looks like my interviewee did not know anything about electric charge, but if you replace the word "energy" with the words "electric charge" in his answers, most of them are absolutely correct". This comment shows how important it is to listen to the students carefully and think of what resources they activate when responding to our questions. Without a doubt, I consider the frameworks of p-prims and resources to be much more productive in helping students learn than the frameworks of misconceptions (or alternative or naïve conceptions) and I try to avoid the term "misconceptions" as much as possible when talking about student ideas. End of post.
There is one more post left in this series, stay tuned and please do not forget to like the post or respond to it in some other way so that the next post comes to your feed and is more visible for other group members. Thank you.

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Eugenia Etkina
Admin
·

December 24, 2022 at 11:53 AM

·

Hi all, today is the last post in the series concerning student ideas and why the misconception approach to those ideas is not productive.

While in the previous posts I tried to convince you that listening to the students and building on their ideas is more productive that trying to help them get rid of their initial ideas. However, this approach does not mean that we think that students do not have difficulties constructing physics ideas. There are several well documented student difficulties (most are created by instruction, or by the confusing language, or by the context of our questions that is unfamiliar to the students) that we acknowledge and list them in every Chapter of the Instructor Guide (posted here in the FILES).

Here is an example from Chapter 3 Newtonian mechanics:

"The most difficult is the meaning of the word "force" as a quantity that characterizes an interaction between two objects as opposed to the motion of an object. The reason for this difficulty is the language we use in everyday life. The difficulty that stems from our teaching is thinking that ma is a force and using ma to calculate any force. Other common difficulties include thinking that objects move in the direction of forces, and that any two forces that are the same in magnitude and opposite in direction are Newton's third law forces. When drawing force diagrams for an object of interest, students mistakenly put forces exerted by the object of interest on some other object."

This example shows the causes of the first two difficulties but does not address the causes of the rest. We can think of moving in the direction of the force difficulty arising from focusing on the experience when any motion starts – the object always starts moving in the direction of the sum of the forces. Therefore, this difficulty stems from generalizing some of real-life experiences and forgetting about others. If we start from this experience and then ask students to analyze the experience when the forces are exerted on an already moving object (for example, an object thrown upward, remembering to ask the students first what the word "force" means), they will see that their rule only applies for the start of the motion, not when the object is already in flight on the way up.

The difficulty with Newton's third law stems from teachers' focus on "equal in magnitude and opposite in direction" and not so much on the fact that these two forces characterize the same interaction. Here, student thinking is very productive for applications of Newton's second law and all we need to do is ask on what systems those equal and opposite forces are exerted and what interactions they describe. Again, there is nothing wrong with student thinking, it is simply misapplied. And the last difficulty can again be caused by teaching – not identifying the system and the environment before drawing the forces. What is interesting here, is that combining student reasoning related to Newton's third law above and this difficulty, helps the student with the the application of the third law when they are trying to put the forces that the system exerts on the object in the environment on the force diagram. Therefore, none of those difficulties is a firm wrong concept that needs to be removed from students' minds but a productive resource that can be used to develop conceptual understanding.

Recently, the AI developers created physics bots that answer physics questions and solve physics problems. Any student can put any question or a problem and the bot will answer. The bots are programmed with correct physics knowledge and physics laws. But surprisingly, they have difficulties answering very simple questions.

Here it is clear that the explanation that "students have robust misconceptions", won't work for bots. Nobody programmed any wrong physics ideas into them, but they have difficulties when putting these ideas together being triggered by the context or some word in the question

(changing just ONE word in the problem and the bot went from a completely right answer to a totally wrong one). This means that the bots (just as our students) have trouble putting ideas together when being put on the spot with our questions. Even having all correct equations and ideas programmed into them, they still make mistakes. Those bits of information programmed into the bots need to be viewed as resources which the bots use, sometimes productively and sometimes not. But if we remove these resources (and this is what the misconception approach tells us to do - do away with misconceptions, remove them from students' brains!), there will be nothing for the students (or bots) to build on and no learning will occur. That is why the misconception approach is inherently flawed and we should be using the resources (including p-prims) approaches to interpret student responses.
End of post. If you reached the end, please do not forget to like it or comment on it, these actions will make the next post visible for you and this post visible for more members. Thank you!

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Eugenia Etkina ·
December 28, 2022 at 3:42 PM
·
Hi all, this post is to fill your coffers with the information about women scientists.
I asked ISLE users to explain how the ISLE approach deal with students ideas and they did a marvelous job - see their yesterday's comments. I will add my thoughts tomorrow. Today please read is this! Have a great day!

https://www.facebook.com/groups/320431092109343/posts/1329697424516033/?__cft__[0]=AZW9n9e15cp6riq3kXVpy9G0QRGIpb0K7OZ6z0P7dw6jVx5agmf07piT1AqDW4XRCgh65__ia0ToA29D_agJ4kU0b_bmBHLH8mWzOTnzI-sq3YA7ee38a86KjUEEZb0xcExT-5oRMveNHDxToC7DhhnnBlMkkJSCZAVdSsNuvwPXC4K9LzJDGhwVoGtKGVOodzzmD8d6haPTC4ptgxcFwIMf&__tn__=%2CO%2CP-R

Eugenia Etkina
Admin
·
December 29, 2022 at 3:53 PM
·

Hi all, today, as promised, I will summarize (or start summarizing) how the ISLE approach relates to resources, p-prims and such. I will repost some of the posts of the group members too, specifically, Allison Daubert and Christopher Robin Samuelsson. It is a long post, so, please be prepared 🙂
As we do not ask the students to make predictions before initial observational experiments, they are free to observe the phenomenon/a without any expectations. When they describe what they observed using simple language, again, we are trying not to tap into their resources (yet). But when they have to come up with "wild ideas" explaining the observational experiments, this is when their resources and p-prims come into play. For example, they conduct an observational experiment described in Chapter 22 in the textbook with a light bulb illuminating the walls and the ceiling of the room (see attached screen shot, Figure labeled

22.1). The students need to represent how the bulb's light rays reach all the points of the room (they have a model of a light ray by then).
The first model that they draw looks like Figure 22.2.(a) - each point of the bulb emits one ray. Why would they come up with this model? The resource here that they tap, is a commonly used drawing of the Sun, where one point of the surface sends one ray. While this will turn out to be a wrong model, the beauty of this model is that it is easily testable. When the students themselves devise the testing experiments, make predictions of their outcomes using their model, run the experiments and find that the outcome do not match the predictions (see experiments and predictions based on this model in Testing Experiment Table 22.2), they do not get upset at all. In fact, they get intrigued and think how they can tweak the model to account for the outcomes. This is when they come up with the model in Figure 22.2b. Therefore, you can see that in ISLE the students bring their ideas at the stage of the testing experiments and reflect why those ideas have been rejected sometimes. These actions become epistemological resources – every idea needs to be experimentally testable, which help them navigate new physics knowledge.
Another example of the ISLEish approach to student ideas is to use the observational experiments to help the students create a "correct" model on the first try, but the model is so counterintuitive, that they do not believe it. This is how one of the ISLE users, Allison Daubert describes this experience:
"The biggest place where I think we bring in student ideas is during testing experiments. (Key here - not observational experiments at the beginning). So, as an example, for Newton's 3rd Law, students observe that the readings of F 1 on 2 is always the same as F 2 on 1, but really, they don't believe it yet. We let them test all of their own ideas about how motion or mass might affect the sizes of these forces in the testing experiments where they themselves design the experiments and they themselves get to disprove these ideas. I often discuss with students at the end of the testing experiments about how their initial ideas just contained slightly wrong language - that's all. While yes, the objects exert the same magnitude forces on each other their accelerations are drastically different, and *that's* the experience that they have in life, and that's the value in their idea." (Allison Daubert, December 27th, 2022)
Finally, the students bring in their experiences to make analogies when explaining observational experiments and use their ISLE-based epistemological resources to self-regulate their learning. From a post of another ISLE user, Christopher Robin Samuelsson
"Some of the conceptual resources that I always find interesting are exemplars (see Smith, 2014 or Nosofsky & Zaki, 2002 for more on the concept), i.e. resources that are specific instances or events (in contrast to p-prims that are more similar to prototypes). Students will at many times (in our ISLE-based activity) find useful events that they employ in order to compare with an observation or to formulate a hypothesis.
For example, it is very common that students (in our study three pairs of engineering students and three pairs of physics teacher students) almost immediately compare the observation of ice melting when salt is added to it with "adding salt on roads during winter" and that they are explicit with the resource as in "but we know that.../I remember that.../I am thinking of this.../I have seen that...". This can then lead them to construct the meaning of freezing point depression (even though they may not remember what it is called) by mediating their conceptual resources through semiotic resources such as specific hand gestures (gesturing a scale of temperature). Additionally, when having observed the temperature decrease of the solution on the ice with an IR camera, they formulate some of the hypotheses by employing exemplars such as "caloric theory as presented in that thermodynamic lecture" (historical theories and models can be great exemplars for ISLE or ISLE-based activities)."

Exemplars can be deceiving though as they are based on our memory and memories can be affect by reconstruction during recall. An exemplar can thus be altered compared to what the student actually experienced, for example one student employed the exemplar of "that time when I was cooling beer" and made the assumption that they could use liquid water in their testing experiments of their hypotheses (of the observation that the temperature of the solution decreases when salt is added to the ice) instead of ice as the exemplar involved putting bottles of beer in water which had salt added to it. However, as the students were experienced with ISLE, they self-regulated toward ISLE (one of the epistemological resources that the students brought to the activity) throughout their activity which also acted as a self-assessment of the conceptual resources that they employed and the pair with the "cooling beer" exemplar realized that they had to use ice in their experiments after additional testing experiments.

Although conceptual resources such as exemplars may be a great support for students in formulating observations and hypotheses, it seems that the epistemological resources, e.g. the self-regulation toward ISLE, are important in directing the employment of resources and that they can act as a sort of tool for self-assessment of employed conceptual resources." (Christopher Robin Samuelsson, December 27, 2022)

From the above three examples emerges a very big idea. One of the mains goals of the ISLE approach is to help students create new epistemological resources which resemble epistemological resources of scientists! Or in a more fancy way is to say that one of the main goals is to help our students develop scientific epistemology (I remind you that the word epistemology means the study of the structure and development of knowledge). Having scientific epistemology, i.e. the approach to the nature and development of knowledge that scientists have, will allow our students to learn how to question claims that people make, how to view scientific knowledge as continuously improving (this is something that lay people have a hard time accepting), how to separate experimental facts from hypotheses or opinions, and so forth. If you are truly implementing the ISLE approach, your students will develop all these resources and they will be using them for the rest of their lives.

If you finished reading the post, you know what to do!

question.

Representing light emitted by different sources

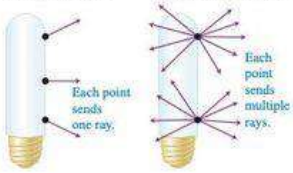
A laser pointer is useful for studying light propagation because the emitted light emerges as one narrow beam. However, most light sources, such as lightbulbs and candles, do not emit light as a single beam. These **extended light sources** consist of multiple points, each of which emits light. When we turn on a lightbulb in a dark room, the walls, floor, and ceiling of the room are illuminated (Figure 22.1). Obviously, the bulb sends light in all directions. But does one point of the shining bulb send light in one direction, or does each point send light in multiple directions? Both of these ideas can explain why the walls, floor, and ceiling are illuminated. Let's investigate those two possible models of how extended sources emit light. To do this we will represent the travel of light from one location to another with a **light ray**, drawn as a straight line and an arrow. Diagrams that include light rays are called **ray diagrams**. A ray is not a real thing; it is a model that allows us to show the direction of light.

One-ray model: Each point of an extended light source emits light that can be represented by one outward-pointing ray (Figure 22.2a). Different points send rays in different directions.

Multiple-ray model: Each point on an extended light source emits light in multiple directions represented by multiple rays (Figure 22.2b).

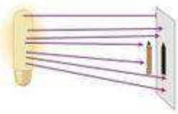
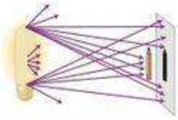
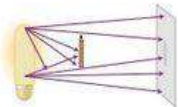
To help us determine which model better explains real phenomena, we will use the models to make predictions about the outcome of three experiments (Testing Experiment Table 22.2). All of the experiments are conducted in an otherwise dark room.

FIGURE 22.2 Two models of light emission from a bulb.

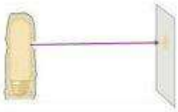
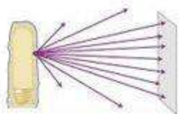


TESTING EXPERIMENT TABLE 22.2 How many rays does each point on a light source emit?

VIDEO TET 22.2

Testing experiment	Predictions: Based on one-ray model	Predictions: Based on multiple-ray model	Outcome
Experiment 1. Turn on a lightbulb and place a pencil close to the wall between the bulb and the wall. 	We predict a dark, sharp shadow behind the pencil where the rays do not reach the wall. 	We predict a dark, sharp shadow behind the pencil where the rays do not reach the wall. 	We see a dark, sharp shadow on the wall.
Experiment 2. Turn on a lightbulb and place a pencil closer to the bulb between the bulb and the wall. 	We predict a dark, sharp shadow on the wall, as in Experiment 1. 	We predict an almost uniformly illuminated wall with a hint of a shadow. 	We see a light, fuzzy shadow (not as dark as in Experiment 1).

(CONTINUED)

Testing experiment	Predictions: Based on one-ray model	Predictions: Based on multiple-ray model	Outcome
Experiment 3. Cover the bulb with aluminum foil and poke a hole in the foil in the middle of the bulb facing the wall. Turn the bulb on. 	We predict that we will see only a spot on the wall directly in front of the hole. 	We predict that the whole wall will be dimly lit. 	We observe that the wall is dimly lit. If we cover the first hole and poke a hole in a different place, the result remains the same.

Conclusions

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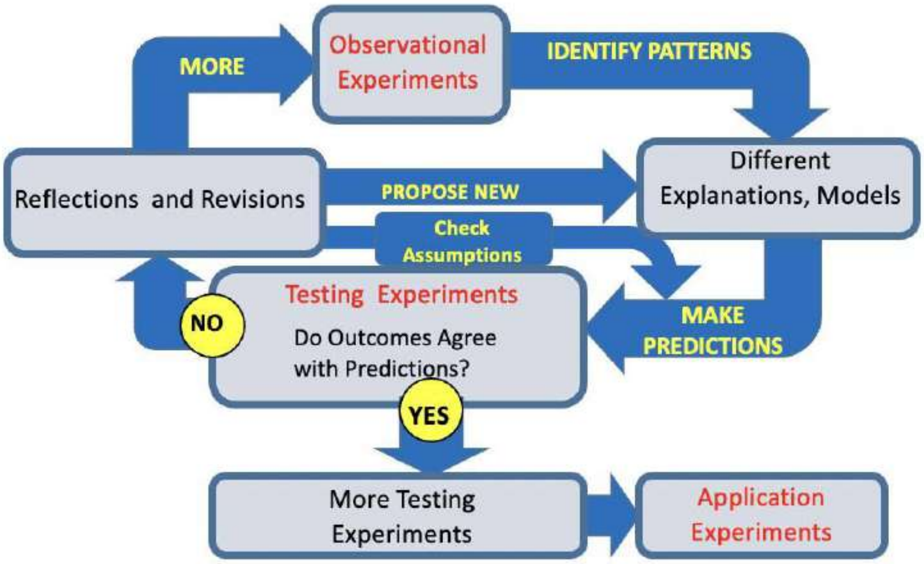
Eugenia Etkina
Admin
·
December 30, 2022 at 4:34 PM
·
Hi all, a few things today. First, guess how many members our group has now? An amazing number!
1741!!!
Seventeen hundred forty one! Wow!
The average number of people seeing every post is about 500, some posts have more than a 1000 people viewing them. This is an mazing engagement!
The contributions! I would say that now the members' contributions (other than myself) account for the majority of posts! It looks like we managed to form a real community of those who are interested, learning, practicing, and sharing their expertise about the ISLE (Investigative Science Learning Environment) approach to learning and teaching physics.
In 2022 we had 10 zoom meetings, with 7 of them lasting over 2 hours (3 meetings were 1 hour long) and one 8-hour zoom-based workshop. This means that the group delivered 25 hours of activities-based professional development in addition to every-day posts (often multiple!!!) dedicated to learning and teaching physics. The average number of participants in every meeting or a workshop was about 20, therefore we had 500-person hours of professional development.
People attending the meetings came from every continent except Antarctica - Africa, Australia/New Zealand, Asia, Europe, North and South America!
Group participants established personal connections and as the result were invited to give in-person talks, to do in-person workshops and started collaborating on research.
All this makes me think that we have been very productive and successful this year and I am looking forward to 2023!
Our next meeting is January 7 - it will be dedicated to teaching energy through the ISLE approach. We do not stop 🙂
Happy New Year all, I am taking tomorrow off posting, I will be back NEXT YEAR!

Investigative Science Learning Environment (ISLE) process



Etkina and Van Heuvelen, 2001, 2007; Etkina, 2015

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