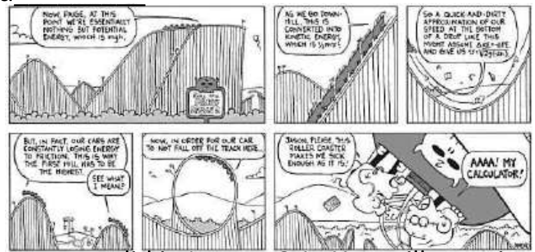
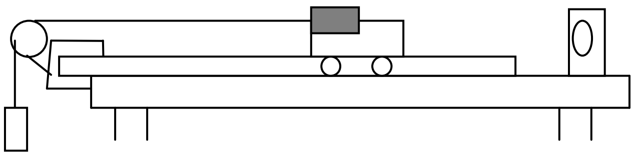
Name_______________________________________
Period_________

Lesson 8: Work and Energy



8.1 Experiment: What is Kinetic Energy?

(a) Set up the cart, meter stick, pulley, hanging mass, and sensors as you did in Lesson 6.1. You will examine the distance and applied force. Let the string pull the cart and measure the tension force. Fill in the table.



(b) Release the cart from rest so that it is pulled by the string through a distance you know along the meter stick and observe the run. Measure the mass of the cart and calculate the final velocity of the cart when it reaches the end of the distance you measured.

Mass of Cart (kg):			Distance used (m):		
Mass on Cart (kg)	HangingMass (kg)	Mass of System (kg) $m_{cart}+m_{on\ cart}+m_h$	Average Tension Force Applied (N) [from graph]	Acceleration $=Force/m_{system}$ (m/s^2)	Final velocity (m/s)

(c) Solve the same problem you did in (a), but for the general case where the initial velocity is v_i, the final velocity is v_f, the distance is d, the force is F, and the mass is m. Solve the problem for F times d.

*The term ½ mv^2 should have come up in the solution. This is the equation for *Kinetic Energy*, the energy of motion.

(d) Now hold a cushion at the end of the track. Disconnect the string and give the cart a push into it. What happens to the cushion when the cart gets there?

(e) What makes it possible to compress the cushion? Would it be able to compress the cushion if the cart were not moving?

*The ability to do things because of motion (like compressing a cushion) is called *Kinetic Energy*.

8.2 <u>Experiment: What is Potential Energy?</u>

(a) We want to make small craters in a dish of sand. What can we do to make these craters? Generate ideas – how do you think you could use the mass to make these craters?

(b) Now lift the lighter mass (marble) up 5 cm above the surface of the sand and drop it from rest into the sand pit. Describe the resulting “crater”.

(c) This time lift it 10 cm above the surface of the sand and drop it again. Describe the resulting crater this time. Did this do more or less sand-moving than before?

(d) What makes the difference between small and larger craters? What did you change that made all the difference?

(e) Now drop the heavier mass from 5 cm into the sand. Was this crater more like the lighter one at 5cm or at 10cm?

(f) Summarize your conclusions: What factors affect how large a crater is formed?

*The mass was able to do more when it was raised higher. Also, a larger mass could do more when raised to the same height as the smaller mass. This shows that the mass gains energy as its height increases. The energy stored in the height is called *gravitational potential energy*. *Gravitational potential energy* (PE_g) can be found by multiplying an object's mass times the gravitational acceleration times its height. ($PE_g=mgh$)

8.3 Experiment: How is Energy Changed?

(a) What do you have to do to give a mass more gravitational potential energy?

(b) Refer to 8.1 (a). Using the same distance again, what could you do to give the lab cart more kinetic energy using the string and mass?

(c) What if you can't change the hanging mass, but you could adjust the distance (in 8.1a). What could you do to give the lab cart more kinetic energy by adjusting the distance?

*Notice that the above three answers have something in common? They all involve pushing things through a distance. We will explore that more here.

(d) Use a spring scale to apply a constant force of about 1N to a cart with a kilogram on it moving it a distance of 10cm. Observe the motion of the cart. How fast is it moving at the end of the pull? (Qualitatively)

(e) Now apply 1N for 20cm (twice the distance). Describe your observations. How fast is it moving at the end now?

(f) Does the cart move faster or slower at the end of the 20cm pull? Does that give it more or less kinetic energy?

(g) Now apply a force of about 2N over 10 cm (twice the force instead). Describe your observations. How fast does it move at the end of the pull this time?

(h) Was the final <u>speed</u> more like the first pull (1N for 10cm) or the second pull (1N for 20cm)?

(i) Was the final <u>kinetic energy</u> more like the first or second pull?

(j) Describe two ways to increase the amount of energy an object gains.

*This ability to change energy is called "*Work*" and can be found by multiplying force times distance. (W=Fd)

8.4 <u>Experiment: Work with Force at an Angle</u>

(a) Use a spring scale to pull a cart with 1N of force for 5cm (0.05m). Calculate the work done.

W = ________Nm

(b) Now give the cart a push and use the spring scale to pull *upward* on the cart with a force of 1N as it moves forward. Be sure to follow along with the cart so your force doesn't make a diagonal angle at any time. Does the cart speed up or slow down because of your pull?

(c) How much does the kinetic energy change?

How much work is done?

(d) Now pull the cart at an angle of about 30^o. Does the part of your pull that is upward (perpendicular to the motion of the cart) do any work? Hint: refer to your upward pull observations from part (b) and (c)

Does the horizontal part (parallel to the motion) of your pull do any work?

*When calculating work, only the part of the force that is parallel to the direction of motion of the object does any work. This is why the equation for work is often written as: $W = F_{parallel} * d = (F\cos\theta) * (d) = Fd\cos\theta$
Any force component perpendicular to the direction of motion does no work at all.

(e) Now give the cart a push and pull back against it to slow it down a bit. What happens to the speed of the cart?

(f) Does this result in an increase or decrease of kinetic energy?

Should we call this positive or negative work?

(g) Work is all about changes of energy, gains or losses. (fill in the blanks with "positive" or "negative")

If the work results in a gain of energy, we can say that ________________ work was done.

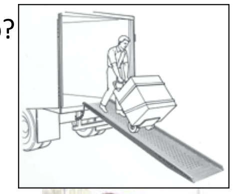
If it results in a loss of energy, we can say that _________________ work was done.

*Negative work doesn't mean work done to the left, it means that the work took energy away. In fact, because there is no direction (no *angle* for instance) to the amount of work that is done, work (and energy) is not a vector, but a *scalar* quantity. It has to do with <u>amounts</u> only, not directions.

8.5 Experiment: The Moving Van Paradox

Is it more *work* to lift a refrigerator straight up to load it onto a moving van or to roll it up an incline?

(a) PREDICT: Which way do you think would take more *work*: lifting straight up or using a ramp?



Explain.

(b) Place a lab cart on top of a tilted wooden surface and use a spring scale to pull the cart up diagonally (along the surface) from the bottom to the top of the incline at a constant speed.

What force was required (from the spring scale)? $F_{\text{diagonal pull}}$ = ___________________________ N

(c) This time use the spring scale to lift the cart straight up from the tabletop to the top of the incline directly (at a constant speed).

What force was required this time (again from the spring scale)? $F_{\text{vertical lift}}$ = ________________________ N

(d) Does it require *more force* to lift directly or to slide up the incline? (Think: What about work?)

(e) Now determine the *distance* the cart has to roll by measuring the length of the incline diagonally.

$d_{\text{diagonal roll}}$ = ________________________ m

(f) Determine the distance the cart has to move to go straight up to the top of the incline by measuring the height of the elevated end above the tabletop.

$d_{\text{lift straight up}}$ = ________________________ m

(g) Calculate the work done in each case by multiplying: Record both values here.

$W_{\text{incline}}=(F_{\text{incline}})(d_{\text{diagonal}})$ = (______________ N)(_______________m) = ________________________ J

$W_{\text{lift}}=(F_{\text{lift}})(d_{\text{straight up}})$ = (______________ N)(_______________m) = ________________________ J

(h) In which case is significantly more work required?

Why?

(i) Was friction on the incline negligible (small enough to ignore) in your experiment?

(j) In which case is the height of the mass at the top of the incline greater?

(k) In which case is the potential energy of the mass at the top of the incline greater?

(l) Does it take more work to lift a refrigerator straight up to load it onto a moving van or to roll it up an incline?

8.6 Pendulum Energy and Total Energy Conservation

(a) Attach the pendulum on the stand so that the pendulum bob will approach the motion detector at the bottom of its swing (as shown in class). Be sure the pendulum is at least 50 cm from the motion detector. Raise the pendulum vertically 5 cm, 10 cm, 15 cm, then 20 cm above its lowest position and release the pendulum to swing in each case. Use a vertical meter stick to measure heights. Record the maximum speeds from the part of the graphs that show maximum speed while the pendulum was in front of the detector in each case to fill in the table below. Be careful to note the maximum velocity while the pendulum is still in front of the motion detector (it's fastest at the bottom).

pendulum mass: ______ kg									
initial vert. height (h top)	lowest vert. height (h bottom)	Vmax = Vel. at bottom of swing	Vtop = Vel. at top of swing	KE bottom (1/2mVb^2)	PE bottom (mgh)	KE top (1/2mVt^2)	PE top (mgh)	E total bottom (KE + PE)	E total top (KE + PE)
5cm = 0.05m									
10cm= 0.10m									
15cm- 0.15m									
20cm= 0.20m									

(b) Perform the necessary calculations to find the gravitational potential energy (PE_g) at the top and bottom of the swing and the kinetic energy (KE) at the top and bottom of the swing then add them together to find the total energy at the top and bottom in each case. Fill them into the table.

(c) Compare the PE to the KE for each height. When the PE decreases, does the KE increase or decrease?

(d) What was the total amount of energy at the top when it was initially released in the first trial?

(e) What was the total amount of energy at the bottom where it was moving the fastest in the first trial?

(f) Compare your answers to the previous two questions. What does this say about the total energy of a system of objects as it moves? Does the total tend to increase, decrease, or stay the same?

(g) What experimental issues might interfere with finding perfect data in this experiment?

What might be happening to the pendulum as it swings through the motions that could change the times or heights?

*The *total energy* of a system is the sum of its kinetic and potential energies. If energy is conserved, the sum of the kinetic energy and potential energy at one moment will equal their sum at any other moment. For a pendulum, the kinetic energy is zero at the top and the potential energy is minimum at the bottom. Thus, if the energy of a pendulum is conserved, the extra potential energy at the top must equal the kinetic energy at the bottom. For convenience, potential energy at the bottom can be defined to be zero. For this experiment, the sum of kinetic and potential energies was conserved.

8.7 <u>Experiment: “Cut Short”</u>

(a) Use the same pendulum setup from the last experiment.
PREDICT: If you lift the pendulum bob then release it from rest and let it swing all the way to the other side, how high will it rise on the other side?

(b) Now test it out: measure the release height and have a lab partner ready on the other end to check the height as it rises up on the other side. Record your measurements:

Release height: ___________________m Rise height (other side): ___________________m

(c) PREDICT: What if you were to partially *block* the string this time by placing a pencil in the way of the pendulum midway up, suddenly changing the length of the pendulum so that it comes up short on the other end: Will this launch it lower or higher on the other end, or might it make no difference at all?
What do you think? (***predict** here*)

Explain your reasoning.

(d) Now try it out and record your measurements:

Release height: ___________________m Rise height (other side): ___________________m

(e) Just to be sure, try it again at another height and record your measurements here:

Release height: ___________________m Rise height (other side): ___________________m

(f) Does the pendulum have more potential energy at the release point or at the other end?

(g) **If** the pendulum goes <u>higher</u> on the other end, does it end up with more or less potential energy after swinging?

Under what circumstances could this happen?

(h) **If** the pendulum goes <u>lower</u> on the other end, does it end up with more or less potential energy after swinging?

Under what circumstances could this happen?

8.8 Demonstration: Bowling Ball Pendulum

(a) Consider a bowling ball tied to the ceiling via a long cord and pulled back until it touches someone's nose. PREDICT: If that person releases the bowling ball at that point and does NOT move, what will happen when the bowling ball returns?

(b) Now you will be shown this scenario. What actually happens?

(c) Did the bowling ball go higher, lower, or the same height when it came back to the same side again?

Explain why this happens:

8.9 Graphs

(a) Recall velocity versus time graphs. The area under a graph of constant velocity is shaped like a rectangle. The area is the base times height of the rectangle, which is *time* times *velocity*.
What does the *area* between the data line on the velocity graph and the time axis represent?

(b) Now consider a graph of *force* on the y-axis and *distance* on the x-axis. Draw a force-versus-distance graph of a constant force of 5 Newtons acting from 1m to 5m.

(c) Calculate the area under the graph. Remember to include units.

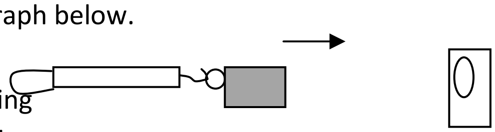
Area under this Force vs distance graph = ________________________

(d) What do these units represent? (Are they force units? energy units? what are they?)

*The <u>area</u> under a <u>force versus distance graph</u> <u>is</u> the <u>work done</u> by the force. Like velocity graphs, it works out in general, even if the force is not constant.

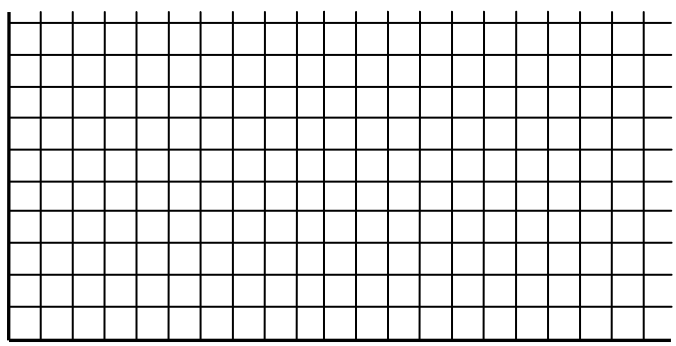
8.10 <u>Spring Energy</u>

(a) Create a graph of force versus distance using a spring scale by stretching it using a force probe pointing at a motion sensor. This will measure how far the spring is stretched for each Newton over the first few Newtons. Draw the graph below.

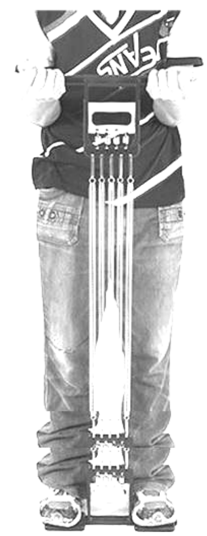


Hold spring scale still

Force (N)



Distance (m)



(b) The slope of your line is called the “spring constant” k. This represents how stiff a spring is (in units of Newtons/meters).
<u>Find the slope</u> by performing a “linear fit” using the analysis software and record the value of the slope as “k” here:

k = ______________________N/m

*The equation of your line is **F = kx** where x is the stretch amount, F is the force you pull on the spring with, and k is the spring constant. Since you graphed the force *on* the spring, it’s positive, but springs pull back on you with the same force, so the actual spring’s force is $\mathbf{F_s = -kx}$ (called **“Hooke’s Law”**).

(c) Measure the work done by the spring by finding the area under the graph using the "integral" command in the analysis software:

Work from area = _________________ J

(d) Now use your line equation **F = kx** to find the maximum force $F_{max} = kx_{max}$. It should be similar to the force you measured directly.

F_{max} = (_________N/m)(__________m) = ______________N

(e) Calculate the Work done using this new F_{max} as the height of the triangular area from the graph. (show your calculations)

Work using new F_{max} = _______________ J

*You just used the method of substitution to substitute (kx) in for (F) in your triangle area equation used to find the work done by the spring.
To do it all at once, it would look like this:

$Work_{spring}$ = Area
Area = ½ (base)x(height)
= ½(x)(F_{max})
= ½(x)(kx)
= ½ (k)(x^2)
so
$Work_{spring} = ½ kx^2$

and since a spring stores the work you do on it as potential energy:

$PE_{spring} = ½ kx^2$

Energy stored in this way (in the stretch of an object) is called *Elastic Potential Energy* (PE_e).