# Chapter 1

# Introducing Physics

## *1.1 What is physics? (Devising and using new models)*

### OALG 1.1.1 Observe, explain, and test your ideas

Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames.true/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/assets/_frames.true/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/assets/_frames.true/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/assets/_frames.true/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/assets/_frames.true/sci-OALG-1-1-3b, TE2: https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-1-1-3c, TE3: https://mediaplayer.pearsoncmg.com/assets/_frames.true/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/assets/_frames.true/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?

## OALG 1.1.4 Represent and reason

**a.** Examine Figure 1.3 in the textbook and match the elements of reasoning to the steps you took to figure out answers to each of the activities above. Specifically:

What were the observational experiments?

Patterns? Hypotheses (explanations)?

Testing experiments? Predictions?

Outcomes?

How did you arrive at a judgment?

Were there any application experiments?

**b.** After you identify the elements, read Section 1.1 in Chapter 1 in the textbook and compare your answers to the answers to the tennis racket activity in the text.

## 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. (8) 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.

# *1.6 How to use this book to learn physics*

## 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.8). This is how the process works.

### 1.4 Making roughestimates

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.

## OALG 1.6.2 Practice interrogation strategy

To practice the interrogation strategy, read the rest of the subsection 1.4 in the textbook and interrogate it. Reflect on how this strategy helped you understand the content of the section.