Lab 02: Experiments, Variables, and Graphs DUE: 25 Jan 2024

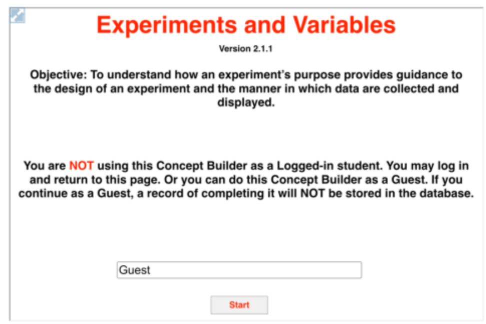
Introduction

Do you know what you are looking at there on the left? It's a soundboard for mixing audio. Do you know how to use it? (I don't.) How do you figure it out?

Do you push every slider up to the maximum at the same time just to see what happens? How do you know which slider had which effect on the sound output? Do you turn every knob clockwise as far as it goes, all at the same time? Of course not, you aren't a toddler. So you test one thing at a time: what happens when you move only *this* slider? Turn only *that* knob? You are controlling your variables. The independent variable is the one you choose to control: the position of the slider. The dependent variable is what happens next (the effect you can measure). So you might test the effect that the position of a slider (independent variable) has on the volume of the sound output (dependent variable).

If you find the slider that controls volume, you probably already intuit that sliding it up will make the sound louder. But what if the relationship is subtle? Not everything is a direct proportionality! That's where a graph comes in handy. Don't groan, graphs are great. Graphs are an entirely visual way to (literally) see what the relationship is between that knob you twisted and the level of the bass—or if there even is a relationship. A graph can also show you that two variables aren't related!

Objectives

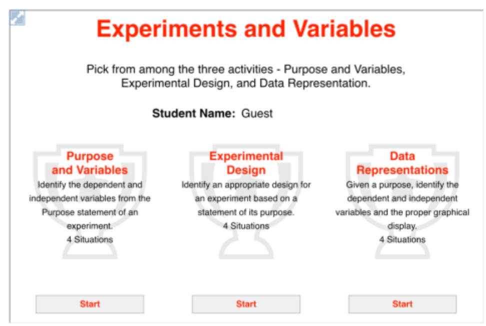


- Practice asking questions to develop a testable hypothesis
- Identify the difference between independent and dependent variables in experimental settings
- Recognize how to experimentally test the relationship between two variables
- Determine the proper way to graphically present data
- Analyze graphical data by calculating the linear slope
- Use graphical methods to predict and extrapolate from data

Equipment

- Internet-connected device capable of running a browser
- Paper and pen or pencil (you're always going to need these)
- Scientific Calculator

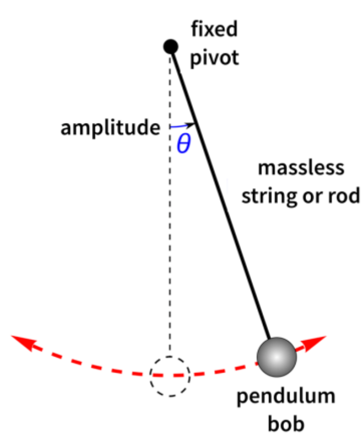
Procedure



1. Read this handout completely before you try to dive in. It will save you time and frustration later. If you are able to print it, you will not have to tab between windows—you can look at this and the simulation at the same time.
2. Do you have paper and pencil handy? Don't forget your calculator.
3. In a browser window, navigate to the Experiments and Variables Concept Builder. Don't try to start doing the lab yet! Just verify that when you click LAUNCH the interactive opens properly.

Experiments and Variables

You should proceed with the Experiments and Variables exercise as GUEST. No need to log in. There are three separate exercises, each with a few situations to resolve. You should begin at PURPOSE AND VARIABLES and work your way through DATA REPRESENTATIONS. Once you have, you should be able to answer the questions below easily. (Hint: Clicking the HELP ME! button is really useful.)

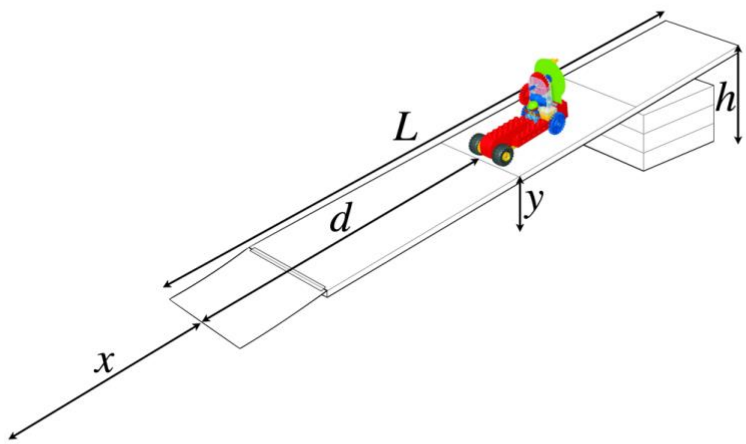


You are watching the pendulum of your grandmother's old-fashioned clock swing back and forth. Because it's a clock, you know that the period (total time for the pendulum to swing back and forth) is one second (otherwise it would not be a very good clock, right?). Now you're wondering *why* the period is exactly one second. In general, a simple pendulum is a mass attached to one end of a string. The other end is fixed in place.

1. Think about the pendulum, and what parameters you could change. Write a short **hypothesis** to explain what you are going to test, and what you predict the result will be. Here's an example hypothesis statement: Increasing the amplitude angle θ of the pendulum will increase the period. (Your hypothesis should not just repeat my hypothesis!)
2. What are the **independent** and **dependent variables** specific to *your* hypothesis?

3. Your lab group is tasked with designing an experiment to test ***my* pendulum hypothesis** from Question 1 (this way, we're all thinking about the same hypothesis!). Choose the most effective experimental procedure.
   A) (i) Measure and record the mass m of the pendulum bob.
      (ii) Choose an amplitude angle θ, release the pendulum, and measure the period T.
      (iii) Repeat steps (i) and (ii) several more times. Each time, use the same angle θ with a pendulum having a different mass m.
   B) (i) Measure and record the length l of the pendulum cord.
      (ii) Choose an amplitude angle θ, release the pendulum, and measure the period T.
      (iii) Repeat (i) and (ii) several more times. Each time, use the same angle θ with a pendulum having a different length l.
   C) (i) Measure and record the mass m and length l of the pendulum.
      (ii) Choose an amplitude angle θ, release the pendulum, and measure the period T.
      (iii) Repeat (i) and (ii) several more times. Each time, change the angle θ but keep m and l the same for each trial.
   D) (i) Measure and record the mass m and length l of the pendulum.
      (ii) Choose an amplitude angle θ, release the pendulum, and measure the period T.
      (iii) Repeat (i) and (ii) several more times. Each time, change the angle θ and mass m while keeping the length l constant.
4. Once you have tested **my hypothesis** from Question 1, how will you present the data you have collected properly?
   A) Independent variable: mass m. Dependent variable: period T. Graph: x–axis = m, y–axis = T.
   B) Independent variable: length l. Dependent variable: amplitude θ. Graph: x–axis = θ, y–axis = l.
   C) Independent variable: period T. Dependent variable: length l. Graph: x–axis = l, y–axis = T.
   D) Independent variable: amplitude θ. Dependent variable: length l. Graph: x–axis = θ, y–axis = l.
   E) Independent variable: amplitude θ. Dependent variable: period T. Graph: x–axis = θ, y–axis = T.

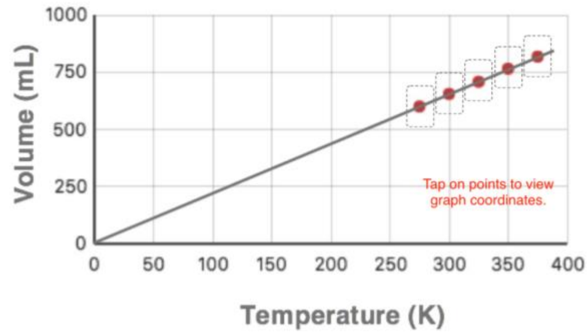
Your little brother has set up a wooden ramp and is playing with his cars. He puts a car on the ramp, lets it go, and it rolls down the ramp and across the driveway, eventually coming to rest. When he releases the same car from a different position on the ramp, it travels a different distance. Is there some kind of relationship here?



5. Write a short hypothesis statement to explain and test your observations. (Refer back to my example in Question 1 for an example of how to phrase a hypothesis sentence!)
6. Identify the independent variable in this situation.
   A) The mass of the car, m.
   B) The total length of the ramp, L.
   C) The distance the car travels on the ramp, d.
   D) The height of the ramp above the ground, h.
   E) The height of the car above the ground, y.
   F) The distance the car travels across the driveway, x.
7. **True or false:** There are two possible independent variables that you could measure. They aren't the same, but they are related.
8. Identify the dependent variable in this situation.
   A) The mass of the car, m.
   B) The total length of the ramp, L.
   C) The distance the car travels on the ramp, d.
   D) The height of the ramp above the ground, h.
   E) The height of the car above the ground, y.
   F) The distance the car travels across the driveway, x.
9. Which procedure would most accurately establish a relationship between your variables?
   A) (i) Weigh one car and record its mass. Release it from the ramp, and measure the distance the car travels across the driveway.
      (ii) Repeat the same process, using three different cars having different masses, recording mass m and distance x for each trial.
   B) (i) Measure and record the height h of the ramp. Release the car from the top of the ramp and measure the travel distance x.
      (ii) Repeat the same process at least three more times, being very careful to use the same release point for the car each time.
   C) (i) Position the car on the ramp and measure its height y. Release the car and measure its travel distance x.
      (ii) Reposition the car at a different height and re-measure y. Release the car and measure x. Repeat at least twice more.
   D) (i) Position the car on the ramp and measure its height y. Release the car and measure the ramp distance d.
      (ii) Reposition the car at a different height and re-measure y. Release the car and re-measure d. Repeat at least twice more.

Using Graphs

Return to your browser window and launch the Using Graphs Concept Builder. Like last time, continue as a GUEST. Also like the previous simulation, there are three sets of exercises to complete. Once you have worked through all three, you should be able to answer the following questions easily. (Hint: Clicking the HELP ME! button is always really useful.)



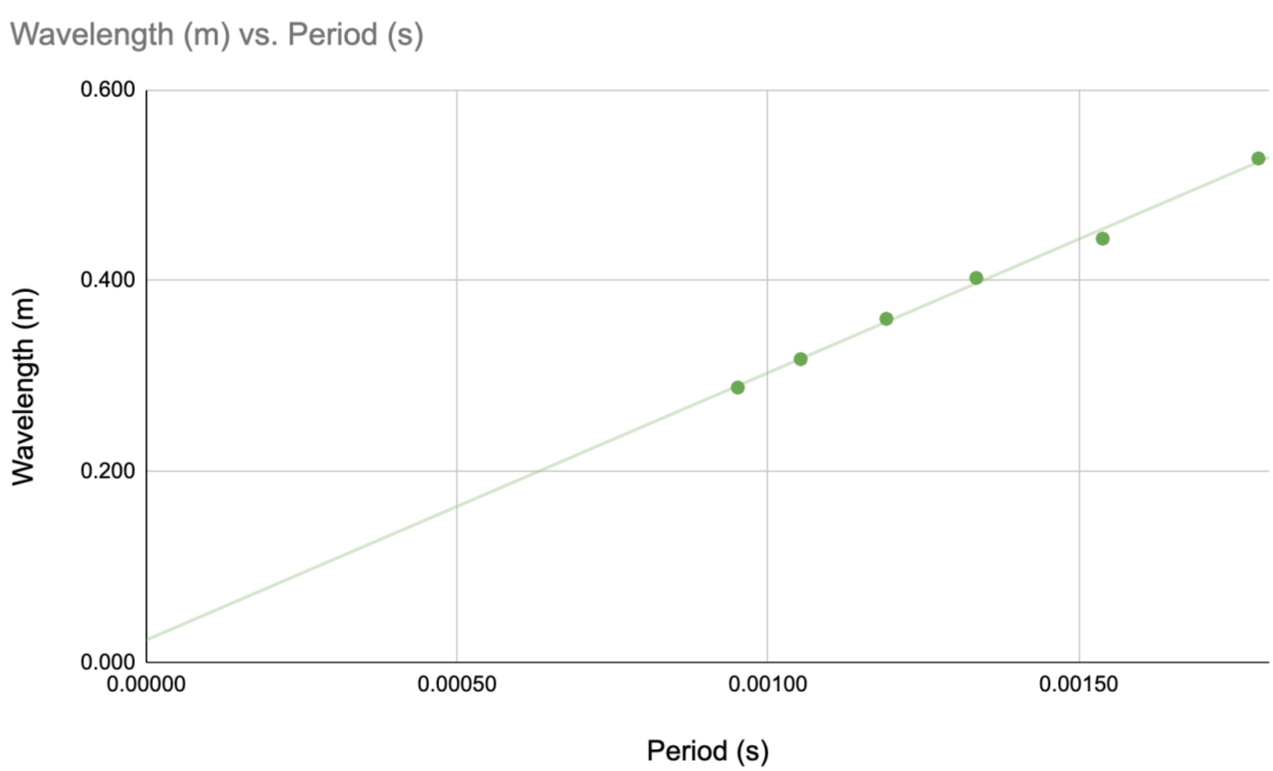
10. Examine the graph on the right. The data are reported with how many significant digits? (You're going to have to tap the points in the sim to see the coordinates! You can't tap this figure!)
    A) Both data are reported with 2 sig figs.
    B) Both data are reported with three sig figs.
    C) Both data are reported with four sig figs.
    D) Volume has one sig fig, but temperature has three sig figs.
    E) Temperature has one sig fig, but volume has three sig figs.
11. What is the slope $m = \frac{\Delta y}{\Delta x} = \frac{V_2 - V_1}{T_2 - T_1}$ of the line shown?
    A) $m = 0.4587$
    C) $m = 2.178$
    B) $m = 0.459$
    D) $m = 2.18$
12. What are the units on the slope?
    A) K
    B) mL
    C) mL/K
    D) K/mL
13. How could you verbally express the meaning of this slope?
    A) For every 50K increase in temperature, there is a corresponding 109mL increase in volume.
    B) For every 50K increase in temperature, there is a corresponding 2.18mL increase in volume.
    C) For every 100K increase in temperature, there is a corresponding 250mL increase in volume.
    D) For every 100K increase in temperature, there is a corresponding 459mL increase in volume.

You have completed an experiment where you have varied the period T and measured the resulting wavelength λ of a sound wave (which, if we were doing in-person labs, you would have done something similar!).

Data	Period T (s)	Wavelength λ (m)
1	0.000951	0.288
2	0.00105	0.318
3	0.00119	0.360
4	0.00134	0.403
5	0.00154	0.444
6	0.00179	0.528

14. Which variable is the independent variable?
    A) Period T.
    B) Wavelength λ.
15. The period T is recorded with how many sig figs?
    A) One.
    C) Three.
    E) Five.
    B) Two.
    D) Four.
    F) Six.

The data from the table are graphed as shown below. Use the graph to answer the following questions.



16. When you determine the slope of the line, are there any points which you should not choose to use in your calculation?
    A) Nope. You can choose any two points from the data table, and you will get exactly the same value for the slope every time.
    B) Yep. You shouldn't calculate using a point which is obviously not on the line, like point 5: $(0.00154\text{s}, 0.444\text{m})$.
    C) It's bad practice to use the first and the last data points, which tend to be the least accurate.
17. Which pair of data points will give you the most accurate slope?
    A) Points 1 and 2 should give you a reliable result.
    B) Points 4 and 5 will give you the best value.
    C) You should use the ratio $\frac{\lambda}{T}$, calculating it for each data point and taking the average value.
18. How many sig figs should you keep when you report the slope?
    A) One.
    B) Two.
    C) Three.
    D) Four.
    E) Five.
    F) Six.
19. Calculate the slope of the graph above, which corresponds to the wave speed $v = \frac{\lambda_2 - \lambda_1}{T_2 - T_1}$.
    A) $v = 0.00335\frac{\text{m}}{\text{s}}$
    B) $v = 0.00340\frac{\text{m}}{\text{s}}$
    C) $v = 0.00494\frac{\text{m}}{\text{s}}$
    D) $v = 202\frac{\text{m}}{\text{s}}$
    E) $v = 254\frac{\text{m}}{\text{s}}$
    F) $v = 303\frac{\text{m}}{\text{s}}$