



Using a Pendulum to Measure Gravity's Acceleration

Elizabeth B. Chesick

Topic

Motion of a pendulum; gravity



Time

1/2 hour



Safety

Please click on the safety icon to view the safety precautions.
Be careful not to hit anyone or knock anything over with the pendulum.

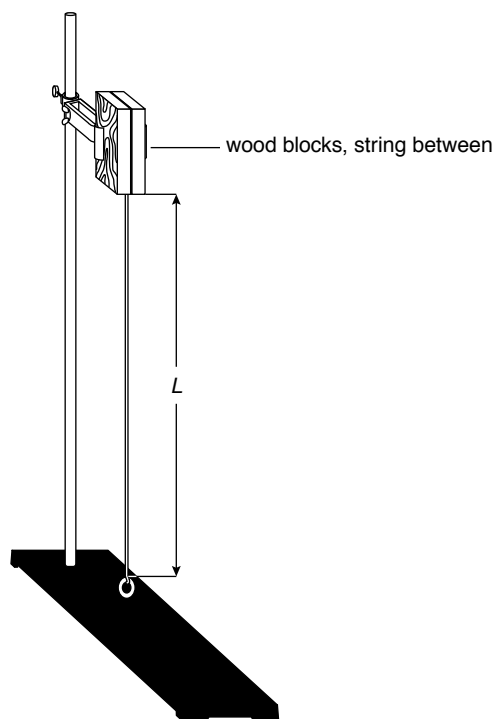
Materials

stopwatch	1.5 m of good string
meterstick	spring clamp
three metal washers, about 2 cm in diameter	two small pieces of wood or two coins that may be closed in the jaws of the clamp
ring stand or other support for clamp for pendulum	protractor

Procedure

1. Attach the clamp to the ring stand or other support so that it is free to hold the string for the pendulum. It is important that the pendulum suspension be friction-free so that the wood blocks or coins are used to provide a point suspension for the string. Put the blocks or coins together with the string in between, and sandwich the combination between the jaws of the clamp. (figure 1).
2. Tie the washers to the other end of the string to make a pendulum. The pendulum should swing freely without hitting anything.
3. Measure the length of the pendulum in centimeters from the place where the string leaves the blocks to the middle of the suspended washers. This value should be recorded on the data table as length (L) for trial 1.
4. Pull the pendulum away from the vertical at an angle of 15 degrees (use your protractor to check the angle), and let it swing. With the stopwatch, time how long it takes to make 10 complete back-and-forth swings. Record this result on the data table.

Figure 1



5. Release the clamp and change the length of the pendulum. Measure and record this new value for L on the data table. Again bring the pendulum out to 15 degrees, and measure and record the time for 10 complete swings.
6. Repeat step 5 three more times for a total of five trials. Each trial should use a pendulum with a different length.
7. Complete the data table. To find the period (T) of one swing, divide your time values for 10 swings by 10. Then calculate and record T^2 .

DATA TABLE				
Trial	Length (L) (cm)	Time for 10 swings (sec)	Period (T) (sec)	T^2 (sec ²)
1				
2				
3				
4				
5				

8. Make a graph of T^2 as a function of L . Put the independent variable L on the horizontal (x) axis and the dependent variable, T^2 on the vertical (y) axis. Start the graph at the origin (0,0) and graph the five points determined by the values of T^2 and L for the five trials.

9. Draw the best possible *straight* line through 0,0 and the five graphed points, not necessarily touching any of the points (figure 2a).

Figure 2a

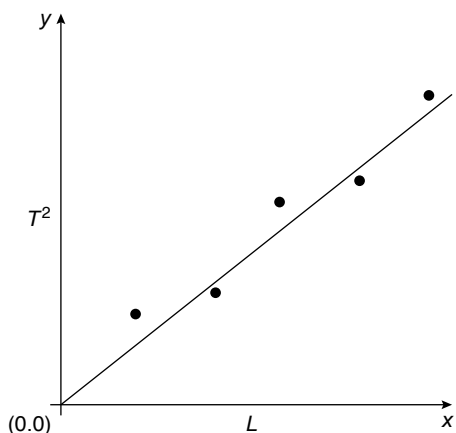
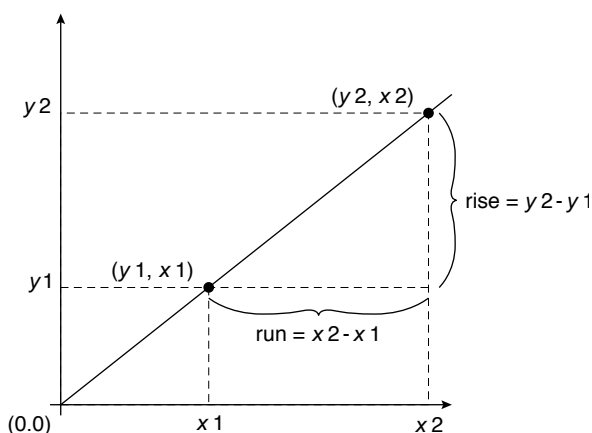


Figure 2b



10. Find the slope of your line. Slope is the change in y (T^2) divided by the change in x (L), or the rise divided by the run (figure 2b). To find the slope, choose any two points, y_1, x_1 and y_2, x_2 , on your graph. Divide the difference in y ($y_2 - y_1$) by the difference in x ($x_2 - x_1$).

Record your answer here: $y_2 - y_1 / x_2 - x_1 = \underline{\hspace{2cm}}$ slope.

11. Scientists have determined that the equation for the period of a pendulum (T) with length L is the following:

$$T = 2\pi \sqrt{L/g}, \text{ where } \pi \text{ is the constant } 3.14.$$

Squaring both sides we get

$$T^2 = 4\pi^2(L/g) \quad \text{or} \quad T^2 = L \frac{4\pi^2}{g}$$

12. Look at this last equation and recall the general equation for a straight line: $y = mx + b$, where m stands for the slope of the line. For a line through the origin $(0,0)$, $b = 0$.
13. Substituting the terms from the pendulum equation, which you have graphed as a straight line through the origin, into the $y = mx + 0$ format, we get

$$T^2 = L \frac{4\pi^2}{g}$$

$y = T^2$, $x = L$, and m , the slope of the line given by the pendulum equation, is $4\pi^2/g$. So, slope = $4\pi^2/g$ and $g = 4\pi^2/\text{slope}$.

14. Using the value for the slope of your graph that you recorded above, solve this equation for g :

$$g = 4\pi^2/\text{slope} = \underline{\hspace{2cm}}$$

15. This procedure generally yields very accurate results. In any experiment, though, there is some degree of error. What part of the procedure do you think would be most likely to introduce some error into your results?

What's Going On

The calculation $g = 4\pi^2/\text{slope}$ should give a value of g close to 9.8 m/sec^2 , the generally accepted value of g . The range of error should be from about 9.2 m/sec^2 to 10.1 m/sec^2 if the procedure is done very carefully. The largest error is in timing the pendulum's 10 swings. There is also some error in measuring the length of the pendulum.

Connections

It is difficult to directly measure the acceleration due to gravity (g). However, it is possible to indirectly measure gravity very accurately using a pendulum. The time it takes a pendulum to complete one back-and-forth swing, called the pendulum's *period*, depends only on the pendulum's length and the value of gravity. In this project, you obtained experimental values of periods for pendulums of different lengths and graphed these data to calculate the value of gravity.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say “be careful with hot liquids” or “don’t cut yourself with the knife” does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don’t use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES