Pendulum

Learning Goals

By the end of this lab, you should be able to...

- Describe how varying different parameters of the pendulum affects its motion.

Your Pendulum and Your Pulse Experiment

A Bit of History

Though you may not appreciate it, a ball on a string is a wonderful thing. Until the 1930s, the pendulum clock was the most accurate timepiece ever created. Léon Foucault used a very long pendulum to demonstrate the rotation of the earth. Newton used a pendulum to test the Equivalence Principle, which would become one of the postulates of Einstein's theory of General Relativity a couple centuries later. These are just three historical examples of the greatness of this seemingly simple apparatus.

But before all of these came Galileo, the first person to do rigorous scientific studies on the pendulum. Most of the properties of pendulums that introductory students discuss in the 21st century were fleshed out by Galileo at the beginning of the 17th century. His student and biographer Vincenzio Viviani wrote of how Galileo first became interested in the pendulum. Roger G. Newton recounts the tale in his book *Galileo's Pendulum*:

> He was seventeen and bored listening to the Mass being celebrated in the cathedral of Pisa. Looking for some object to arrest his attention, the young medical student began to focus on a chandelier high above his head, hanging from a long, thin chain, swinging gently to and fro in the spring breeze. How long does it take for the oscillations to repeat themselves, he wondered, timing them with his pulse. To his astonishment, he found that the lamp took as many pulse beats to complete a swing when hardly moving at all as when the wind made it sway more widely.

While this basic story is easy to find in the literature, it is almost always accompanied by the disclaimer that it is fictional.

The Story

Apocryphal stories like Galileo's chandeliers are not uncommon in the history of science (think Newton's apple). Even though we know this particular story isn't true, it's interesting to ask ourselves if it *could* be true. *Can a pulse actually be used as a timer to discover the properties of the pendulum?*

Equipment

- 6 pendulum bobs (wood, white plastic, black plastic, aluminum, steel, brass)
- Pendulum
- Protractor
- Meter stick
- Digital scale

Question 1: Select two pairs of properties of the pendulum provided and study the effect of one property to the other.

What to actually do today:

1. Observe! Let the pendulum swing and discover various parameters you can change and/or measure. Discuss with your lab partners and make a list.

   Did you list Period, *T*, the time it takes for one complete oscillation? How about frequency, *f,* the number of oscillations in one unit of time? Did you think about the length of the pendulum and the mass of the bob? What about the releasing angle of the pendulum? Did you consider the height from the floor? What about if you observed the pendulum on another planet?

2. Explore! What changes can you make in the experimental setup? This is a great starting question to discuss with your lab partners. Once you figure out *what* to change, you can explore over what *range* to make the changes. For example, you can change the mass of the bob of the pendulum. Would that affect other properties, like frequency of the pendulum or period?
3. Design *two* experiments! Answer the question "How does _____(your selection) affect _____(your selection) of a pendulum?" Think carefully about the quantities you must keep constant.

But there's a twist: you may only use your pulse to keep time. That is, **your heart is your only clock**. **You may in no way refer to any other clocks as you do your experiment.**

Useful Notes:

- If you decide to change the length of the pendulum, you should have no less than 10 different lengths in a range from about 10 cm to about 100 cm. Measure the length from the center of the bob.
- If you decide to change the mass of the bob, you should use all 6 bobs provided.

- If you decide to change the angle - you must have measurements for the following values 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90 degrees. Careful when using the protractor - ask if you are not sure how to use it.
- Perform at least 3 trials for a single measurement of the dependent variable and list the variables you kept constant along with their values.
- Remember: in cases when the trend of the data looks like a curve, you must use linearization to confirm the relationship.

What to include in the lab worksheet:

- What relevant parameters for the pendulum are varied (IV), what is investigated (DV) and what are kept constant (CV).
- Data tables (clear heading, units, trials, uncertainties, and necessary calculations)
- A plot for each experiment with error bars, analysis, linearization if needed, relationship found, plausibility of the plot.

Time to Clean Up!

Please clean up your station according to the Station Cleanup! Slideshow found in the lab module.