LAB 13

Lab Handout

Lab 13. Simple Harmonic Motion and Pendulums: What Variables Affect the Period of a Pendulum?

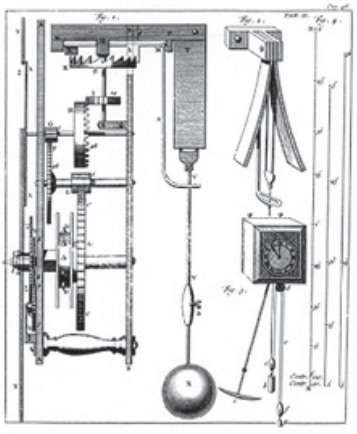
Introduction

A pendulum, which is a mass swinging at the end of a rope, has a wide range of uses in our daily lives. One of the most frequent uses of a pendulum is in a clock. Christiaan Huygens built the first pendulum clock in 1656 (see Figure L13.1 and version available at *www.nsta.org/adi-physics1*), and his use of a pendulum to keep accurate time was considered a breakthrough in clock design. Pendulums can also be found as parts of amusement park rides, in religious ceremonies, and in tools that help musicians keep a beat. Most school-age children are also familiar with pendulums, because playground swings are just a pendulum with a person at one end.

Pendulums are part of a class of objects that undergo simple harmonic motion; such objects are called oscillators. Harmonic oscillators are objects that move about a point called the equilibrium position (see Figure L13.2). When a pendulum is not moving, the bob will rest (or hang motionless) at the equilibrium position. When an outside force moves the bob from its equilibrium position, a restoring force causes the object to move back toward its equilibrium position. This process is then repeated multiple times as the bob swings back and forth. This motion is referred to as *simple,* because after the initial force to move the bob from equilibrium, the only forces acting on the bob are the restoring force and the tension in the string. Other types of harmonic motion are called *damped,* when friction slows down the motion, or *driven,* when an outside force is repeatedly exerted on the oscillator. There

FIGURE L13.1

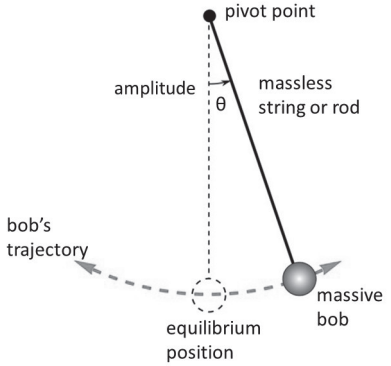
The original pendulum clock built by Christiaan Huygens in 1656



Note: This image is best viewed on the book's Extras page at *www.nsta.org/adi-physics1.*

FIGURE L13.2

The components of a pendulum



are many ways to describe the motion of a bob. The most frequent is the period (T), which is how long it takes a bob to make one full swing back and forth.

For most pendulums, the period does not change from one swing to the next. This makes the pendulum a particularly useful tool for timekeeping, such as in the pendulum clock shown in Figure L13.1. Early physicists recognized this and investigated the pendulum to understand what variables influence its period. This would allow them to more effectively use pendulums in clocks, as well as in other devices.

Your Task

Use what you know about simple harmonic motion, causal relationships, the relationship between structure and function in nature, and the importance of patterns to design and carry out a series of experiments to determine which variables do and which variables do not change the period of the pendulum.

The guiding question of this investigation is, ***What variables affect the period of a pendulum?***

Materials

You may use any of the following materials during your investigation:

Consumables
- Tape
- String

Equipment
- Safety glasses or goggles (required)
- Electronic or triple beam balance
- Washers
- Paper clips
- Protractor
- Ruler
- Meterstick
- Stopwatch
- Scissors

To use a photogate system, you will need to have a sensor interface and a computer, tablet, or graphing calculator with data collection and analysis software. To use video analysis, you will need to have a video camera and a computer or tablet with video analysis software.

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Keep fingers and toes out of the way of moving objects.
3. Use caution when working with scissors. They are sharp and can cut or puncture skin.

4. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out several different experiments. Each experiment should look at one potential variable that may or may not affect the period of a pendulum. Some potential variables include the mass of the bob, the length of the pendulum, and the release angle. For each of your experiments, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it before you begin.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How can you describe the components of the system quantitatively?
- How could you keep track of changes in this system quantitatively?
- How might changes to the structure of pendulum change how it functions?
- What might be the underlying cause of a change in the period of a pendulum?
- What will be the independent variable and the dependent variable for each experiment?

To determine *how you will collect the data,* think about the following questions:

- How will you set up your pendulum?
- How will you measure the period of the pendulum?
- What will you need to hold constant during each experiment?
- What conditions need to be satisfied to establish a cause-and-effect relationship?
- What measurement scale or scales should you use to collect data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What type of calculations will you need to make?
- What types of patterns might you look for as you analyze your data?
- How could you use mathematics to show a cause-and-effect relationship?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

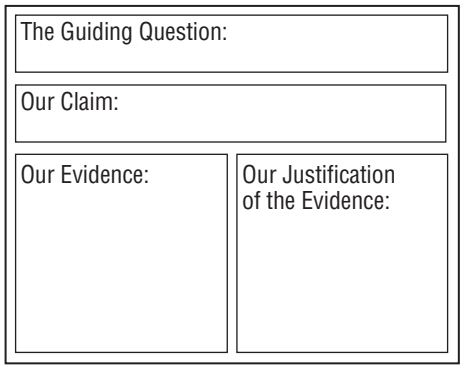
- the difference between data and evidence in science, and
- the nature and role of experiments in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L13.3.

FIGURE L13.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

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If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

Reference

Jeremy Norman's HistoryofInformation.com. 2016. Huygens invents the pendulum clock, increasing accuracy sixty fold (1656). *www.historyofinformation.com/expanded.php?id=3506.*