LAB 21

Lab Handout

Lab 21. Conservation of Energy and Pendulums: How Does Placing a Nail in the Path of a Pendulum Affect the Height of a Pendulum Swing?

Introduction

Two of the most influential thinkers in history were Aristotle in the 4th century BC and Galileo in the 16th–17th centuries. Aristotle took a philosophical approach to understanding the natural world, whereas Galileo preferred a more empirical one. Thus, they developed some very different explanations about the motion of objects. For example, Aristotle claimed that heavier bodies fall faster than lighter ones in the same medium, whereas Galileo claimed that in a vacuum all bodies fall with the same speed.

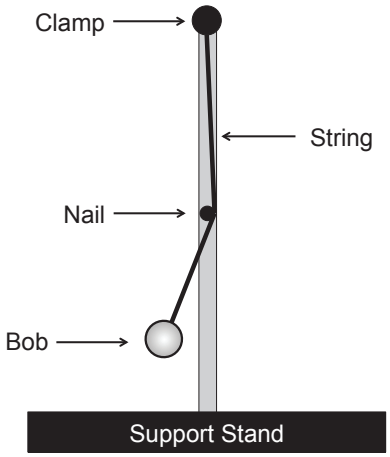
Aristotle and Galileo also did not agree about the nature of energy. Historians of science attribute the first use of the word *energy* to Aristotle (in classical Greek, *energeia*). Historians debate what exactly Aristotle meant by the word *energeia,* with the most common translation being "activity or operation." Historians do agree, however, that Aristotle used the concept of energeia not only to analyze the motion of objects but also to understand ethics and psychology. According to Aristotle, a person's desire to be happy was a type of energeia. Galileo, on the other hand, provided a more modern view of energy and suggested that energy was a property of objects. Thus, he decoupled the term *energy* from the study of ethics or psychology.

Since Galileo's time, other physicists have contributed to our understanding of forces, motion, and energy. Isaac Newton, in the 17th and early 18th centuries, provided the mathematical foundation for the study of force and motion. In the 19th century, Thomas Young was the first to define *energy* in the formal sense, and Gaspard-Gustave de Coriolis expanded on Young's definition of energy by introducing the concept of kinetic energy. Also in the 19th century, William Rankine was the first to propose the idea of potential energy, and James Prescott Joule and William Thomson (better known as Lord Kelvin) developed the law of conservation of energy, which states that the total energy in a closed system remains constant. We now use these ideas about energy to help understand and explain a wide range of natural phenomena.

In this investigation, you will have an opportunity to use these important ideas about energy to explore the motion of a pendulum. The motion of a pendulum has been studied for hundreds of years. Galileo, for example, used the motion of a pendulum to help quantify his ideas about falling objects. Other scientists have also used the pendulum to investigate forces and energy. One of Galileo's most informative and important investigations about the behavior of a pendulum, however, was when he placed a nail in the path of a swinging pendulum as shown in Figure L21.1. This simple modification to a basic

pendulum allowed Galileo to explore the energy of the pendulum bob as it swings back and forth.

FIGURE L21.1
Pendulum and nail setup



Your Task

Use what you know about energy, cause-and-effect relationships in science, and the importance of identifying and explaining patterns in nature to design and carry out an investigation to determine how the height of a pendulum swing changes after coming into contact with a nail in its path.

The guiding question of this investigation is, ***How does placing a nail in the path of a pendulum affect the height of a pendulum swing?***

Materials

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

- Safety glasses or goggles (required)
- Video camera
- Computer or tablet with video analysis software
- Support stand Clamps Nail
- Hanging mass set
- String
- Meterstick

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. Handle nails with care. Nail ends can be sharp and can puncture or scrape skin.
3. Keep fingers and toes out of the way of moving objects.
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 an investigation to determine how the height of a pendulum swing changes after the string comes into contact with a nail as the bob swings back and forth. Be sure to focus only on the height of a pendulum swing during the first few oscillations, because air resistance will cause the pendulum

to eventually slow down and come to rest. It is also important to examine pendulums with different lengths of string and different bob masses during your investigation. With these issues in mind, you can now decide what type of data you need to collect, how you will collect it, and how you will analyze it.

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?
- What could cause a change in the height of the pendulum swing?
- How will you determine the height of pendulum swing?
- Is it useful to track how energy flows into, out of, or within this system?
- What else will you need to measure during the investigation?

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

- What type of research design needs to be used to establish a cause-and-effect relationship?
- How could you track the flow of energy within this system?
- How long will you need to observe the pendulum swinging back and forth?
- What types of comparisons will be useful?
- How will you vary the length of the string and the mass of the bob?
- What will be the reference point for your measurements?
- What equipment will you need to use in order to make the measurements you need?
- 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 types of patterns might you look for as you analyze your data?
- How could you use mathematics to determine if there is a difference between conditions?
- How precise is your video (frames per second)?
- 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

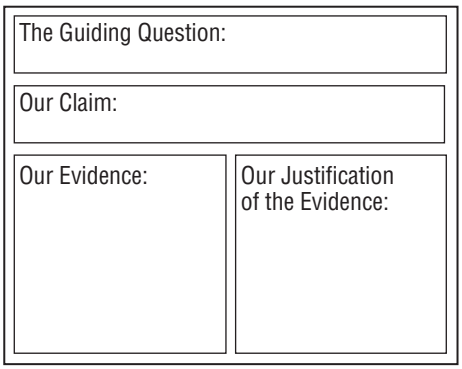
As you work through your investigation, you may want to consider

- the difference between observations and inferences in science, and
- how scientific knowledge changes over time.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument must include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to 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 L21.2.

FIGURE L21.2
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:

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!