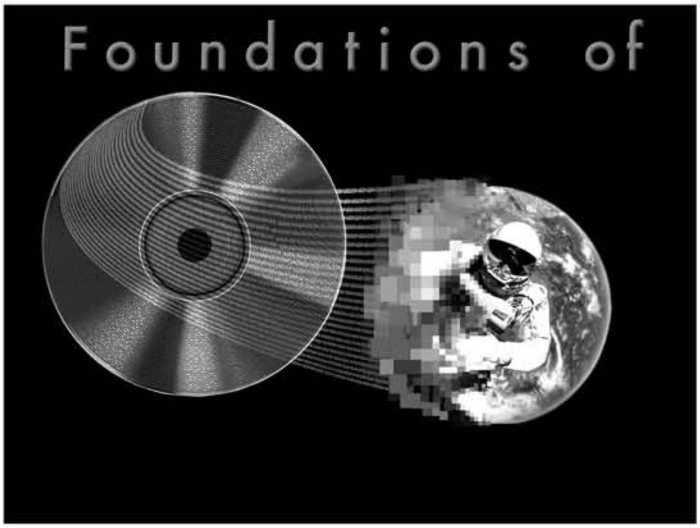

Physics

Tom Hsu, Ph.D.

Investigations

cpo science

FIRST EDITION

CPO Science

Peabody, Massachusetts 01960

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USING ICONS TO LOCATE INFORMATION

Icons are symbols that convey meaning without words. In the CPO program we use icons to point out things such as safety considerations, real-world connections, and when to find information in the reference pages, complete a writing assignment, or work in a team. The chart below lists the icons that refer to instruction and safety and the meaning for each one.

	Reading: you need to read for understanding.		**Real-world connections:** you are learning how the information is used in the world today.
	Hands-on activity: you will complete a lab or other activity.		**Teamwork:** you will be working in a team to complete the activity.
	Time: Tells how much time the activity may take.		**Economics:** you are learning about how science impacts the economy.
	Research: you will need to look up facts and information.		**Formula:** you are reading information about a formula or will need to use an equation to solve a problem.
	Setup: directions for equipment setup are found here.		**Use extreme caution:** follow all instructions carefully to avoid injury to yourself or others.
	History: you are reading historical information.		**Electrical hazard:** follow all instructions carefully while using electrical components to avoid injury to yourself or others.
	Environment: you are reading information about the environment or how to protect our environment.		**Wear safety goggles:** requires you to protect your eyes from injury.
	Writing: you need to reflect and write about what you have learned.		**Wear a lab apron:** requires you to protect your clothing and skin.
JAN FEB MAR	**Project:** you need to complete an assignment that will take longer than one day.		**Wear gloves:** requires you to protect your hands from injury due to heat or chemicals.
	Apply your knowledge: refers to activities or problems that ask you to use your skills in different ways.		**Cleanup:** includes cleaning and putting away reusable equipment and supplies, and disposing of leftover materials.

Investigation Text

Investigations are hands-on activities that accompany the student text. For each section of the text, you will complete a hands-on activity, answer key questions, and find results. The Investigation Manual is a soft cover book containing investigation activities that accompany each section you are reading. Sometimes you will read the student text before doing an Investigation activity, but usually you will complete the Investigation before you read the section.

The Investigations are the heart of the CPO program. We believe that you will learn and remember more if you have many opportunities to explore science through hands-on activities that use equipment to collect data and solve problems. Most of the Investigations rely on the use of CPO equipment to collect accurate data, explore possibilities and answer the key question. The equipment is easy to set up, and your teacher will help you learn how to use the equipment properly.

Features of the Investigations

Key Question: Each Investigation starts with a key question that conveys the main focus of the learning. This question tells you what information you need to collect to answer the questions at the end of the Investigation.

Data Tables: Data tables help you organize and collect your data in a systematic manner.

Learning Objectives (Goals): At the top of each Investigation are the learning goals. These statements will explain what you will have learned and can do after completing the investigation.

Brief introduction: This information helps you understand why the exercise is important and, in most cases, how it connects to other sections you have read or will be reading.

Icons and Section title: The icon reminds you of the unit that you are studying and the section title. This section title corresponds to the reading in your Student Edition.

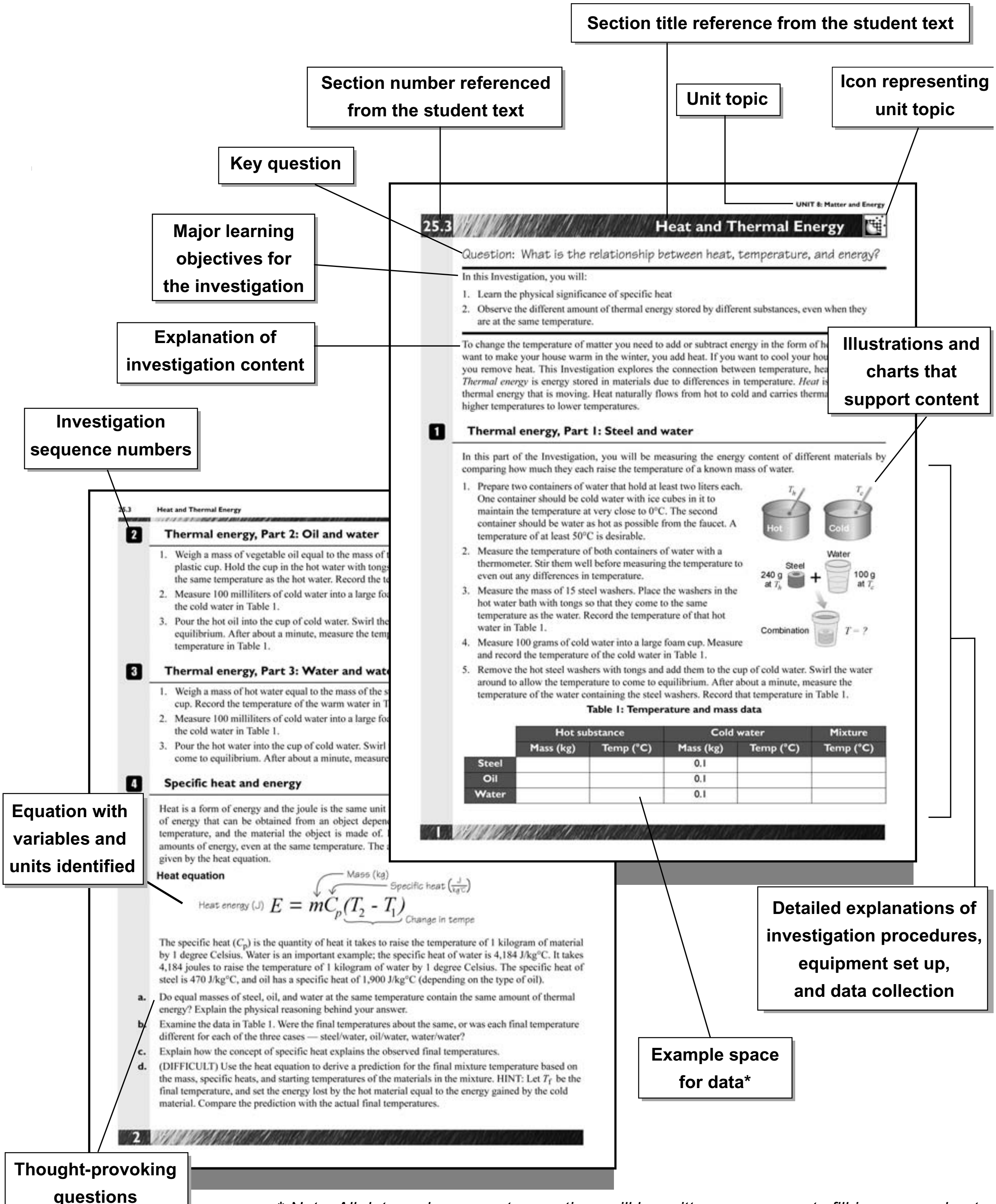
Numbered Steps: The Investigation sequence numbers point out the sequence of steps you will need to follow to successfully complete the Investigation. These steps highlight specific stages of the scientific method such as: following directions, completing hands-on experiments, collecting and analyzing data and presenting the results. The Applying Your Knowledge step asks you to reflect on what you have learned.

Illustrations: The illustrations support your understanding of the Investigation procedures.

Fill-in answer sheets: Your teacher will provide you with answer sheets to fill in the data tables and the written responses and may collect your information. You can also use the sheets to reinforce your reading in your student text.

Formula: Each time a formula is used in an Investigation, the equation variables and units of measurement are identified. The same format is used throughout the text.

INVESTIGATION PAGES



** Note: All data and answers to questions will be written on a separate fill-in answer sheet*

SAFETY

In scientific investigations, you often work with equipment and supplies. These are fun to use, especially because they help you make discoveries. However, using equipment and carrying out certain procedures in an investigation always require safety. Safety is a very important part of doing science. The purpose of learning and discussing safety in the lab is to help you learn how to be safe at all times.

The Investigations that you will be doing as part of the CPO Foundations of Physics curriculum are designed to reduce safety concerns in the laboratory. Most of the Investigations use equipment that is stable and easy to use. A few of the Investigations use chemicals. Although these chemicals might be familiar to you, they still must be used safely.

You will be introduced to safety by completing a skill sheet to help you observe the safety aids and important information in your science laboratory. In addition to this skill sheet, you may be asked to check your safety understanding and complete a safety contract. Your teacher will decide what is appropriate for your class.

Throughout the Investigation Guide, safety icons and words and phrases like “caution” and “Safety Note” are used to highlight important safety information. Read the description of each safety icon carefully and look out for them when reading your Student Edition and Investigation Guide.

	**Use extreme caution:** follow all instructions carefully to avoid injury to yourself or others.
	**Electrical hazard:** follow all instructions carefully while using electrical components to avoid injury to yourself or others.
	**Wear safety goggles:** requires you to protect your eyes from injury.
	**Wear a lab apron:** requires you to protect your clothing and skin.
	**Wear gloves:** requires you to protect your hands from injury due to heat or chemicals.
	**Cleanup:** includes cleaning and putting away reusable equipment and supplies, and disposing of leftover materials.

Safety in the science lab is the responsibility of everyone! Help create a safe environment in your lab by following the safety guidelines from your teacher as well as the guidelines discussed in this document.

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13.1 Harmonic Motion

Question: How do we describe the back-and-forth motion of a pendulum?

In this Investigation, you will:

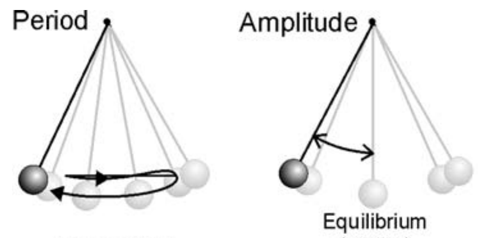
1. Measure the amplitude and period of a pendulum.
2. Determine how to change the properties of a pendulum.
3. Learn to read and represent frequency, period, amplitude, and phase on a graph.

Objects generally have two kinds of motion. One kind of motion goes from one place to another like a person walking from home to school. This is *linear motion*. We use words such as distance, time, speed, and acceleration to describe linear motion. The second kind of motion repeats itself over and over like a child going back and forth on a swing. This kind of motion is called *harmonic motion*. The word *harmonic* comes from the word *harmony* meaning "multiples of." Any system that exhibits harmonic motion is called an *oscillator*.

1 The pendulum

A pendulum is an oscillator made from a mass on a string. The mass is free to swing back and forth.

- A *cycle* is one complete back-and-forth motion.
- The *period* is the time it takes to complete one full cycle. The period of a pendulum is the time it takes for the pendulum to swing from left to right and back again.
- The *amplitude* describes the size of the cycle. The amplitude of a pendulum is the amount the pendulum swings away from equilibrium.

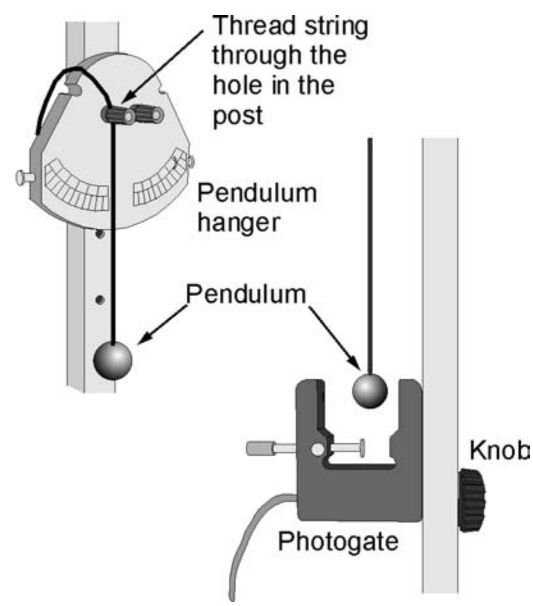


The ***period*** is the time to complete one cycle.

The ***amplitude*** is the maximum amount the system moves away from equilibrium

2 Setting up the pendulum

1. Attach the pendulum hanger to the top hole in the physics stand.
2. You will use the medium-sized ball on the string as your pendulum. Loosen the post and slip the string through the hole in the center of the post. Note: The post does NOT unscrew all the way off. Loosen it just enough to expose the hole for the string to go through. Gently tighten the post to hold the string. DO NOT tighten the post too tight or you will damage the string. It takes very little pressure to hold it.
3. Use one of the threaded knobs to attach a photogate to the stand so that the pendulum ball breaks the light beam as it swings through. You may need to adjust the leveling feet on the stand to make the ball swing through the center of the photogate. It does not matter if the pole is not exactly vertical.



3 The three pendulum variables

In this experiment, the period of the pendulum is the dependent variable. There are three independent variables: the mass, the amplitude of the swing, and the length of the string.

1. Put the Timer in period mode and attach the photogate to input A. When the A light is on, the display shows the period defined by successive breaks in the light beam as the pendulum swings through. The red (O) button resets the Timer to zero. It takes a few swings for the Timer to make the measurement.
2. The Timer in period mode measures the time interval between one break of the light beam and the next. This time interval is only half the period of a pendulum because a pendulum swings through the photogate *twice* on each cycle. To determine the period of the pendulum, multiply the Timer reading by two. Record your information in Table 1.
3. The length of the string can be changed by sliding it through the hole in the post. Measure the length from the underside of the post to the center of the steel ball. Put your data in column 3.
4. Change the mass by using one of the other sizes of steel balls.
5. The amplitude can be changed by varying the angle that the pendulum swings.

Design an experiment to determine which of the three variables has the greatest effect on the period of the pendulum. Your experiment should provide enough data to show that one of the three variables has much greater an effect than the other two. Be sure to use a technique that gives you consistent results.

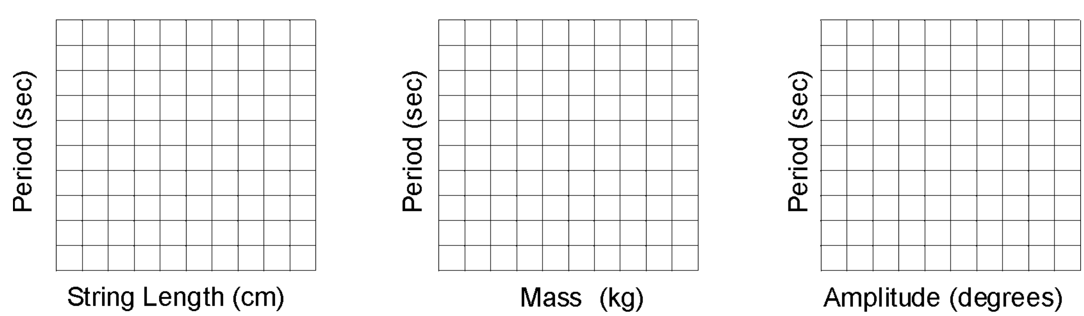
Table 1: Period, amplitude, mass, and length data

Mass (g)	Amplitude (degrees)	String length (cm)	Time from Timer (seconds)	Period of pendulum (seconds)

4 Analyzing the data

a. Of the three things you can change (length, mass, and angle), which one has the biggest effect on the pendulum, and why? In your answer, you should consider how gravity accelerates objects of different mass.

b. Split up your data so that you can look at the effect of each variable by making a separate graph showing how each one affects the period. To make comparison easier, make sure all the graphs have the same scale on the *y*-axis (period). The graphs should be labeled as shown in the example below:



5 Applying what you know

Pendulum clocks were once among the most common ways to keep time. You can still buy beautifully made contemporary pendulum clocks. To make a pendulum clock accurate, the period must be set so that a certain number of periods equals a convenient measure of time. For example, you could design a clock with a pendulum that has a period of 1 second. The gears in the clock mechanism would then have to turn the second hand 1/60th of a turn per swing of the pendulum.

a. Using your data, design and construct a pendulum that you can use to accurately measure a time interval of 30 seconds. Test your pendulum clock against the Timer set to stopwatch mode.

b. Mark on your graph the period you chose for your pendulum.

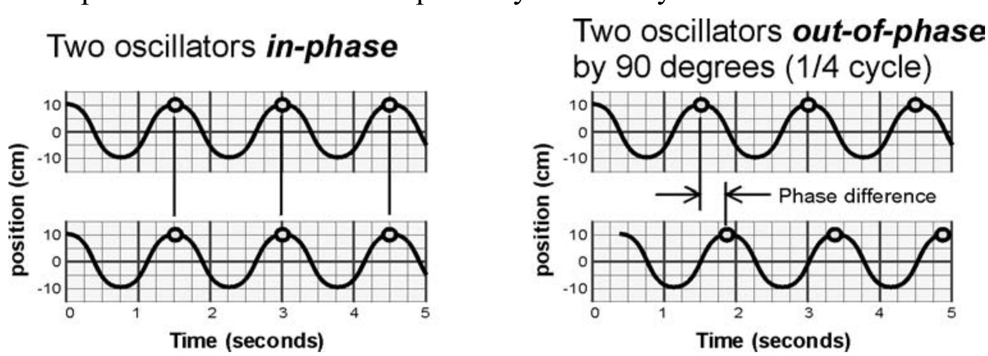
c. How many cycles did your pendulum complete in 30 seconds?

d. If mass does not affect the period, why is it important that the pendulum in a clock be heavy?

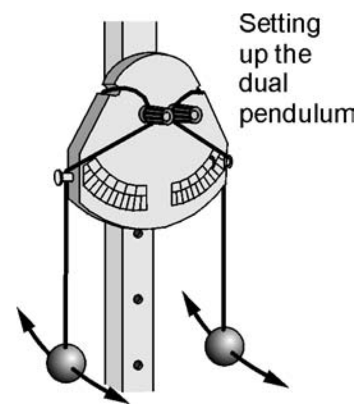
e. Calculate the percent error in your prediction of time from your pendulum clock.

6 Phase

The concept of *phase* is important when comparing one oscillator with another. Suppose you observe two identical pendulums, with exactly the same period. If you start them together, their graphs would look like the picture on the left (below). You would describe the two pendulums as being *in phase* because their cycles are aligned and each one is always at the same place at the same time. If one pendulum is started later than the other, their cycles would be *out of phase.* The graphs on the right (below) show two pendulums that are out of phase by 1/4 of a cycle.



1. Set up a dual pendulum as shown in the diagram. The strings wrap over and around the pegs on either side of the pendulum hanger. The two pendulums swing alongside the pole as shown.
2. Make the string lengths equal for both pendulums. See if you can make them swing in phase, and then out of phase by one-half cycle (180 degrees).
3. Set the pendulums to different lengths. Start them in phase and see what happens to the phase as they keep swinging.
4. Can you construct a pair of pendulums where one has twice the period of the other? Try it.



a. What is the relationship between the lengths of the strings if one pendulum has twice the period of the other?

b. Describe how the phase of the pendulums in step 3 changes over time.