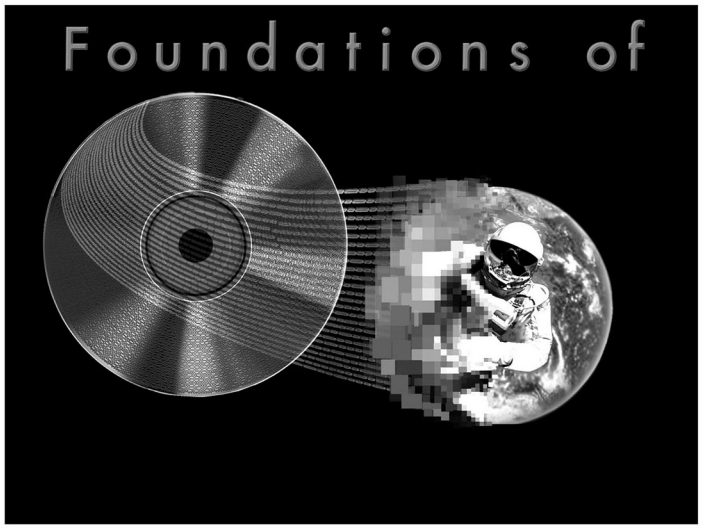

Physics

Tom Hsu, Ph.D.

Investigations

cpo science

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CPO Science
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About the Author

Dr. Thomas C. Hsu is a nationally recognized innovator in science and math education and the founder of CPO Science (formerly Cambridge Physics Outlet). He holds a Ph.D. in Applied Plasma Physics from the Massachusetts Institute of Technology (MIT), and has taught students from elementary, secondary and college levels across the nation. He was nominated for MIT's Goodwin medal for excellence in teaching and has received numerous awards from various state agencies for his work to improve science education. Tom has personally worked with more than 12,000, K-12 teachers and administrators and is well known as a consultant, workshop leader and developer of curriculum and equipment for inquiry-based learning in science and math. With CPO Science, Tom has published textbooks in physical science, integrated science, Earth and space science, and also written fifteen curriculum investigation guides that accompany CPO Science equipment. Along with the CPO Science team, Tom is always active, developing innovative new tools for teaching and learning science, including an inquiry-based chemistry text.

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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.
	**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

Section title reference from the student text

Section number referenced from the student text

Unit topic

Icon representing unit topic

Key question

Major learning objectives for the investigation

Explanation of investigation content

Illustrations and charts that support content

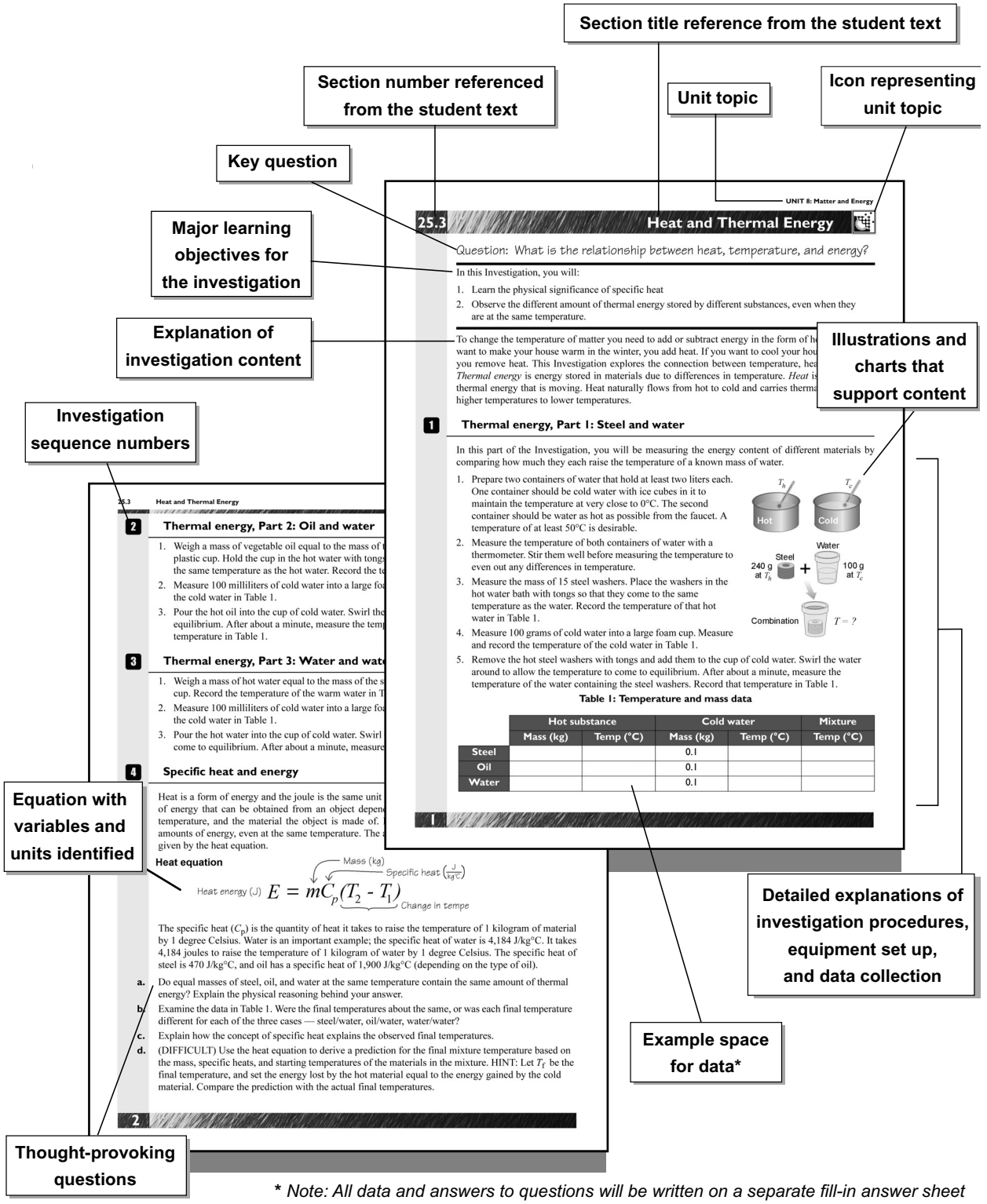
Investigation sequence numbers

Equation with variables and units identified

Detailed explanations of investigation procedures, equipment set up, and data collection

Example space for data*

Thought-provoking questions



UNIT 8: Matter and Energy

25.3 Heat and Thermal Energy

Question: What is the relationship between heat, temperature, and energy?

In this Investigation, you will:

1. Learn the physical significance of specific heat
2. Observe the different amount of thermal energy stored by different substances, even when they are at the same temperature.

To change the temperature of matter you need to add or subtract energy in the form of h
want to make your house warm in the winter, you add heat. If you want to cool your hou
you remove heat. This Investigation explores the connection between temperature, hea
Thermal energy is energy stored in materials due to differences in temperature. *Heat* is
thermal energy that is moving. Heat naturally flows from hot to cold and carries therma
higher temperatures to lower temperatures.

1 Thermal energy, Part 1: Steel and water

In this part of the Investigation, you will be measuring the energy content of different materials by comparing how much they each raise the temperature of a known mass of water.

1. Prepare two containers of water that hold at least two liters each. One container should be cold water with ice cubes in it to maintain the temperature at very close to 0°C. The second container should be water as hot as possible from the faucet. A temperature of at least 50°C is desirable.
2. Measure the temperature of both containers of water with a thermometer. Stir them well before measuring the temperature to even out any differences in temperature.
3. Measure the mass of 15 steel washers. Place the washers in the hot water bath with tongs so that they come to the same temperature as the water. Record the temperature of that hot water in Table 1.
4. Measure 100 grams of cold water into a large foam cup. Measure and record the temperature of the cold water in Table 1.
5. Remove the hot steel washers with tongs and add them to the cup of cold water. Swirl the water around to allow the temperature to come to equilibrium. After about a minute, measure the temperature of the water containing the steel washers. Record that temperature in Table 1.

Table 1: Temperature and mass data

	Hot substance		Cold water		Mixture
	Mass (kg)	Temp (°C)	Mass (kg)	Temp (°C)	Temp (°C)
Steel			0.1		
Oil			0.1		
Water			0.1		

1

25.3 Heat and Thermal Energy

2 Thermal energy, Part 2: Oil and water

1. Weigh a mass of vegetable oil equal to the mass of t
plastic cup. Hold the cup in the hot water with tongs
the same temperature as the hot water. Record the te
2. Measure 100 milliliters of cold water into a large foa
the cold water in Table 1.
3. Pour the hot oil into the cup of cold water. Swirl the
equilibrium. After about a minute, measure the temp
temperature in Table 1.

3 Thermal energy, Part 3: Water and wate

1. Weigh a mass of hot water equal to the mass of the s
cup. Record the temperature of the warm water in T
2. Measure 100 milliliters of cold water into a large foa
the cold water in Table 1.
3. Pour the hot water into the cup of cold water. Swirl
come to equilibrium. After about a minute, measure

4 Specific heat and energy

Heat is a form of energy and the joule is the same unit
of energy that can be obtained from an object depend
temperature, and the material the object is made of.
amounts of energy, even at the same temperature. The
given by the heat equation.

Heat equation

Heat energy (J) $E = mC_p(T_2 - T_1)$ (Mass (kg); Specific heat $\left(\frac{J}{kg°C}\right)$; Change in tempe)

The specific heat (C_p) is the quantity of heat it takes to raise the temperature of 1 kilogram of material by 1 degree Celsius. Water is an important example; the specific heat of water is 4,184 J/kg°C. It takes 4,184 joules to raise the temperature of 1 kilogram of water by 1 degree Celsius. The specific heat of steel is 470 J/kg°C, and oil has a specific heat of 1,900 J/kg°C (depending on the type of oil).

a. Do equal masses of steel, oil, and water at the same temperature contain the same amount of thermal energy? Explain the physical reasoning behind your answer.
b. Examine the data in Table 1. Were the final temperatures about the same, or was each final temperature different for each of the three cases — steel/water, oil/water, water/water?
c. Explain how the concept of specific heat explains the observed final temperatures.
d. (DIFFICULT) Use the heat equation to derive a prediction for the final mixture temperature based on the mass, specific heats, and starting temperatures of the materials in the mixture. HINT: Let T_F be the final temperature, and set the energy lost by the hot material equal to the energy gained by the cold material. Compare the prediction with the actual final temperatures.

2

** 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.