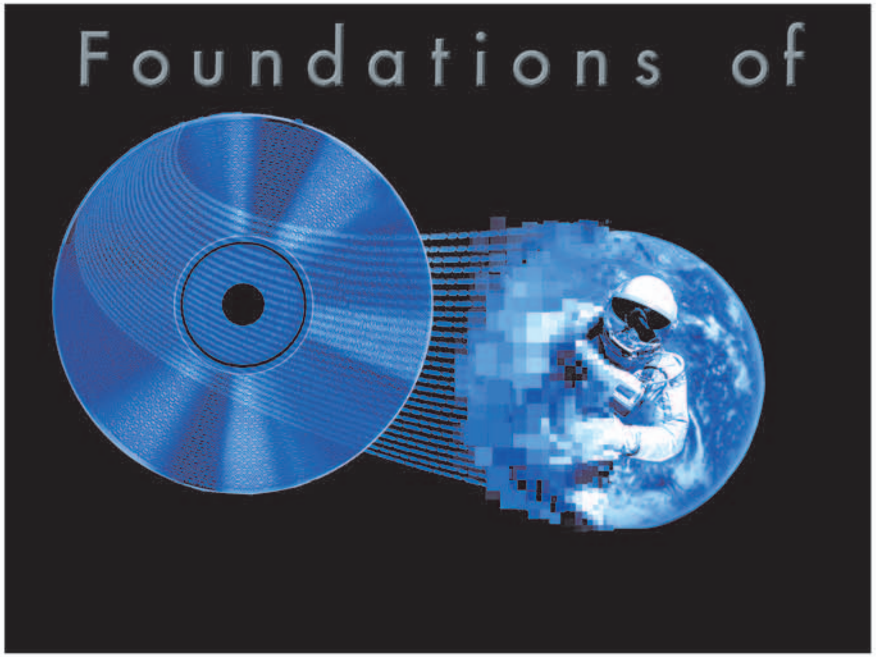

Physics

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First Edition
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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.

Foundations of Physics, First Edition

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Science Through Discovery

The whole of science is nothing more than a refinement of everyday thinking.
Albert Einstein

In many learning situations, you are expected to study prescribed materials and come up with correct answers by yourself. In science, you usually read the information and then experiment in a laboratory to visualize what you read. With the *Foundations of Physics Program* you will find that science is experienced through carrying out investigations and solving problems.

What you learn in school should be connected to what you see in the world. These connections will contribute to your success in learning physics. You will learn to observe how and why something happens by observing an action and then connecting your observations to the natural laws of science. In your life, you will need to ask insightful questions, plan, organize your work, look for and analyze information, try out an idea and if it doesn't work, try again. Physics teaches you how to problem solve, analyze observed actions, and test their ideas.

The *Foundations of Physics* program provides you the opportunity to analyze ideas, formulate questions, find your own ways to solve problems, and work with other students.

About the Physics Student Text

Foundations of Physics is an inquiry-centered program that combines the best attributes of “conceptual” and mathematical approaches to learning physics. Direct observation comes first; you will discover firsthand what happens. Each new concept is introduced through connections to real world applications, either in the lab or though the reading in the text. Theoretical information through the readings is provided to give you the “how” and “why.” What you learn from the investigations and reading will show how fundamental concepts explain a wide range of phenomena. An application at the end of each chapter pulls concepts together to connect topics in the chapter to the real world.

The text emphasizes conceptual understanding and is written in a clear, informal and reader-friendly style. Margin notes provide an outline to aid you in finding the main ideas and concepts. Because we learn in different ways, nearly every concept is presented in words and through graphs, charts and tables. Conceptual knowledge is supported by basic mathematical techniques found in math topics such as algebra. You learn to use important equations as a means to analyze data and solve quantitative problems. Many example problems are provided through a problem solving technique to help you to learn how to approach a word problem and solve it.

Foundations of Physics contains Nine Units and has Thirty One Chapters. Each Chapter is divided into three Sections. You will notice that many of the important concepts are repeated in different ways, equations are highlighted with an explanation for each symbol and example problems are solved for you. Applications that follow each Chapter (with the exception of the first and last Chapters) explain how physics is used in practical ways.

Student Text Main Components

Main text: In addition to reading about science concepts and skills, you will discover brief stories about important inventions, real world connections, environmental issues, and interesting facts.

Chapter pages: Each chapter starts with two pages that outline what you will learn in the chapter. These pages provide you with a brief summary, the key questions for each Investigation, vocabulary, and learning goals.

Review questions: After each section, there are review questions that evaluate what you have learned and support you and your teacher in choosing what needs to be reviewed and which concepts to discuss further.

Glossary: The glossary is where you will find the meaning of words that describe important science concepts and essential vocabulary. You can also find references to important people who are discussed in your reading.

Index: This section helps you find more specific topic information by giving page numbers that refer to the topic. You can use the index while studying to find information.

Reference tables: The inside back cover of the book is a quick reference for physical constants, variable names, and scientific notation.

Student Text Pages

Sidenotes (idea headers): In the left margin of each page you will find phrases, short sentences, and questions to guide you in understanding the most important ideas. These sidenotes will also help you skim the text and quickly find information when you are reviewing and studying for tests.

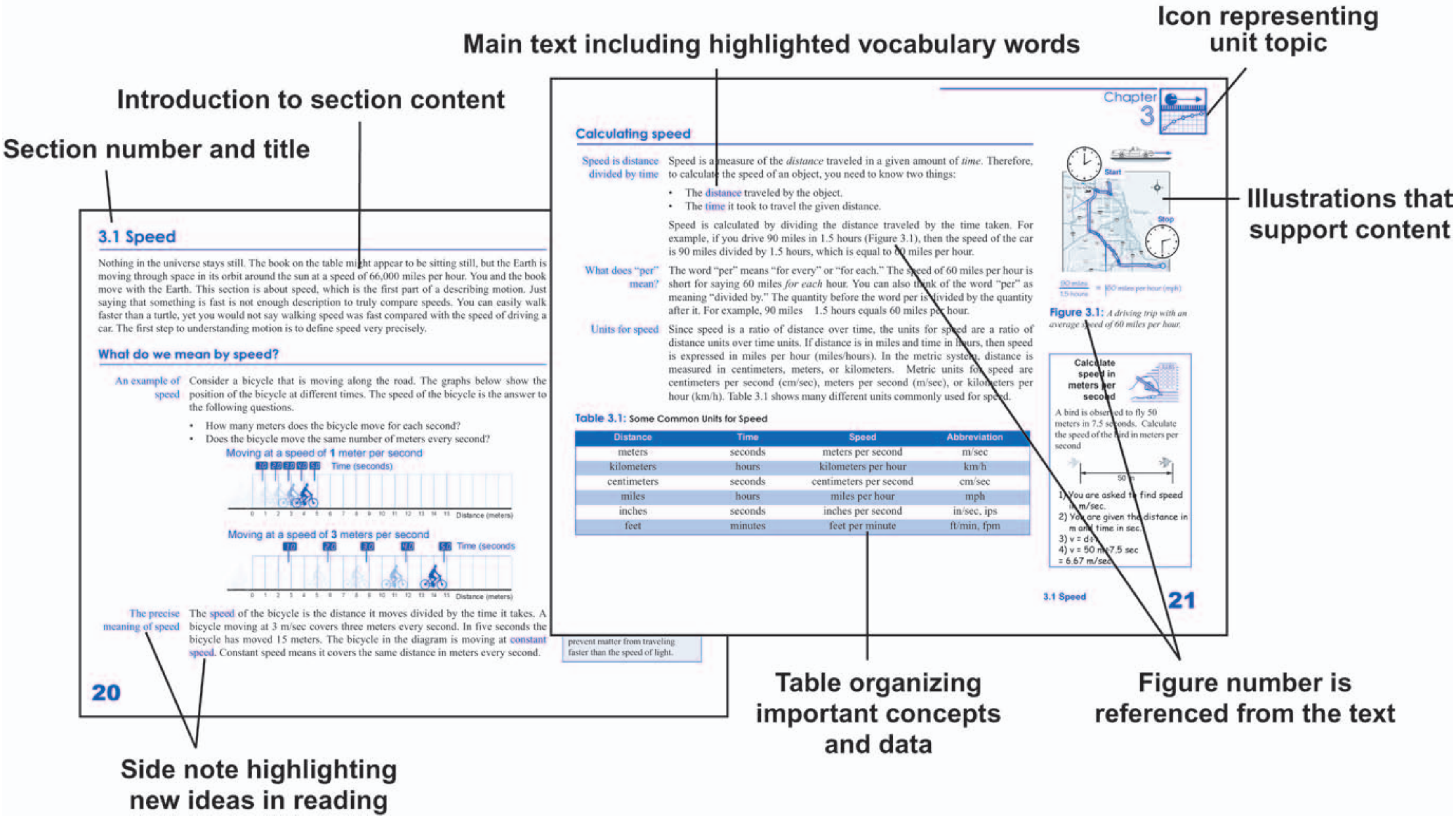
Illustrations: Use the illustrations, graphs, charts, and data tables to help you understand the reading. These reading tools help most students improve their understanding of the key concepts.

Vocabulary words: The vocabulary words are highlighted in blue. You need to understand their meanings to be successful in science and will find the same vocabulary used in many contexts and repeated throughout the text. The definitions can be found in the glossary.

Data tables: These tables will help you understand complex information, organize numerical data, and provide examples of how to collect and present data.

Figure number/captions: As you are reading, notice the references to the word *Figure* followed by a number. These figures are found on the right side of the page in the form of an illustration, picture, or chart. The figure number indicates which figure goes with the text you are reading and gives you another way to understand the information in the reading.

STUDENT TEXT PAGES



3.1 Speed

Nothing in the universe stays still. The book on the table might appear to be sitting still, but the Earth is moving through space in its orbit around the sun at a speed of 66,000 miles per hour. You and the book move with the Earth. This section is about speed, which is the first part of a describing motion. Just saying that something is fast is not enough description to truly compare speeds. You can easily walk faster than a turtle, yet you would not say walking speed was fast compared with the speed of driving a car. The first step to understanding motion is to define speed very precisely.

What do we mean by speed?

An example of speed

Consider a bicycle that is moving along the road. The graphs below show the position of the bicycle at different times. The speed of the bicycle is the answer to the following questions.

- How many meters does the bicycle move for each second?
- Does the bicycle move the same number of meters every second?

Moving at a speed of 1 meter per second

Moving at a speed of 3 meters per second

The precise meaning of speed

The speed of the bicycle is the distance it moves divided by the time it takes. A bicycle moving at 3 m/sec covers three meters every second. In five seconds the bicycle has moved 15 meters. The bicycle in the diagram is moving at constant speed. Constant speed means it covers the same distance in meters every second.

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prevent matter from traveling faster than the speed of light.

Chapter 3

Calculating speed

Speed is distance divided by time

Speed is a measure of the *distance* traveled in a given amount of *time*. Therefore, to calculate the speed of an object, you need to know two things:

- The distance traveled by the object.
- The time it took to travel the given distance.

Speed is calculated by dividing the distance traveled by the time taken. For example, if you drive 90 miles in 1.5 hours (Figure 3.1), then the speed of the car is 90 miles divided by 1.5 hours, which is equal to 60 miles per hour.

What does "per" mean?

The word "per" means "for every" or "for each." The speed of 60 miles per hour is short for saying 60 miles *for each* hour. You can also think of the word "per" as meaning "divided by." The quantity before the word per is divided by the quantity after it. For example, 90 miles 1.5 hours equals 60 miles per hour.

Units for speed

Since speed is a ratio of distance over time, the units for speed are a ratio of distance units over time units. If distance is in miles and time in hours, then speed is expressed in miles per hour (miles/hours). In the metric system, distance is measured in centimeters, meters, or kilometers. Metric units for speed are centimeters per second (cm/sec), meters per second (m/sec), or kilometers per hour (km/h). Table 3.1 shows many different units commonly used for speed.

Table 3.1: Some Common Units for Speed

Distance	Time	Speed	Abbreviation
meters	seconds	meters per second	m/sec
kilometers	hours	kilometers per hour	km/h
centimeters	seconds	centimeters per second	cm/sec
miles	hours	miles per hour	mph
inches	seconds	inches per second	in/sec, ips
feet	minutes	feet per minute	ft/min, fpm

Figure 3.1: *A driving trip with an average speed of 60 miles per hour.*

Calculate speed in meters per second

A bird is observed to fly 50 meters in 7.5 seconds. Calculate the speed of the bird in meters per second

1) You are asked to find speed in m/sec.
2) You are given the distance in m and time in sec.
3) v = d/t
4) v = 50 m/7.5 sec = 6.67 m/sec

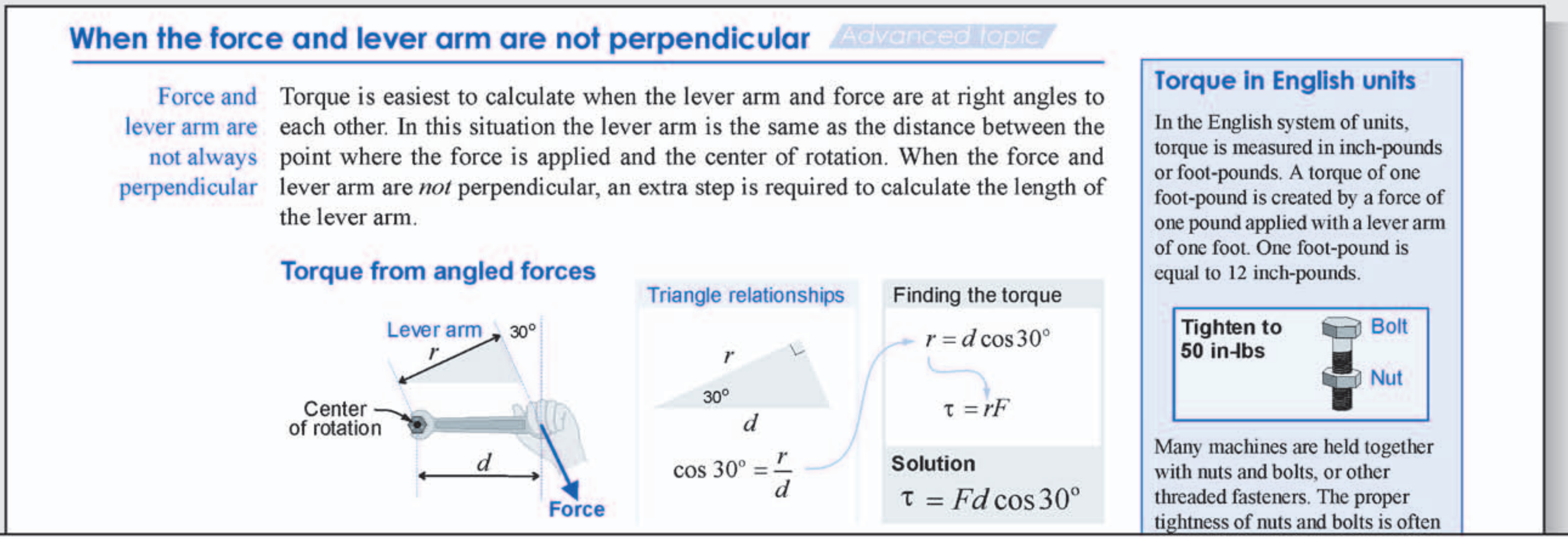
3.1 Speed 21

Topics and degree of difficulty

A high school physics course covers many different topics. The philosophy of how we chose topics is described below.

- The topics in this book cover the complete content for a standards-based introductory course in physics, with an emphasis on practical application of physics to real technology.
- Topics start with practical concepts developed through hands-on investigation, then proceed to theory. For example, we start with circuits that can be built with wires and batteries. Only after you have completed a thorough investigation and discussed of circuits do we proceed to the more difficult and abstract treatment of electric charges and fields.
- We excluded historical information in the text that was not necessary for the understanding of the concepts. While the history of physics is important, it is not necessary to learn and apply physics to real world problems. History is covered in our ancillary materials.
- Practical physics such as music, heat transfer, electronics, and the strength of materials is presented as well as more traditional theoretical material such as forces and fields.

The text contains far more material than we expect anyone to teach in a one year course. This provides a variety of choices of topics for your teacher to cover. Some of the topics selected are more advanced than others and may be skipped without affecting the overall flow of a course. The advanced topics are indicated with the Advanced topic icon on the header of the page. Advanced topics include calculations that are more difficult or outside the normal scope of an introductory course.



When the force and lever arm are not perpendicular (Advanced topic)

Force and lever arm are not always perpendicular

Torque is easiest to calculate when the lever arm and force are at right angles to each other. In this situation the lever arm is the same as the distance between the point where the force is applied and the center of rotation. When the force and lever arm are *not* perpendicular, an extra step is required to calculate the length of the lever arm.

Torque from angled forces

Torque in English units

In the English system of units, torque is measured in inch-pounds or foot-pounds. A torque of one foot-pound is created by a force of one pound applied with a lever arm of one foot. One foot-pound is equal to 12 inch-pounds.

Many machines are held together with nuts and bolts, or other threaded fasteners. The proper tightness of nuts and bolts is often

Investigation Text

The Investigations lab manual provides a series of 87 hands-on investigations, one for each of the 87 content sections of the text ((excluding the introduction and conclusion). This is a true inquiry-based approach to teaching physics: most of the investigations are performed before you read the corresponding section in the student text. Concepts are discovered and explored rather than proven or demonstrated. The equipment, lab manual and text were designed together to seamlessly reinforce your learning. Graphics in the text and lab manual precisely match what you use and see in the lab. Content development in the text is structured around lab experiences. In this way, you see and explore natural laws of science while you read about how they work.

Familiar things happen, and mankind does not bother about them. It requires a very unusual mind to undertake the analysis of the obvious.
Alfred North Whitehead

Features of the Investigation

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

Data tables: Data tables help you collect and organize 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 what you be able to do after completing the Investigation.

Brief introduction: This information helps you understand why the exercise is important to complete and, in most cases, how it connects to other sections of your reading.

Icons and section title: The icon is a reminder of the unit that you are studying. The section title corresponds to the reading in your student text.

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 and to explain your findings.

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 written responses. At times your teacher may collect this data to compile class results. You can also use the sheets to reinforce your reading in your student text.

INVESTIGATION PAGES

Section title reference from the student text

Section number referenced from the student text

Key question

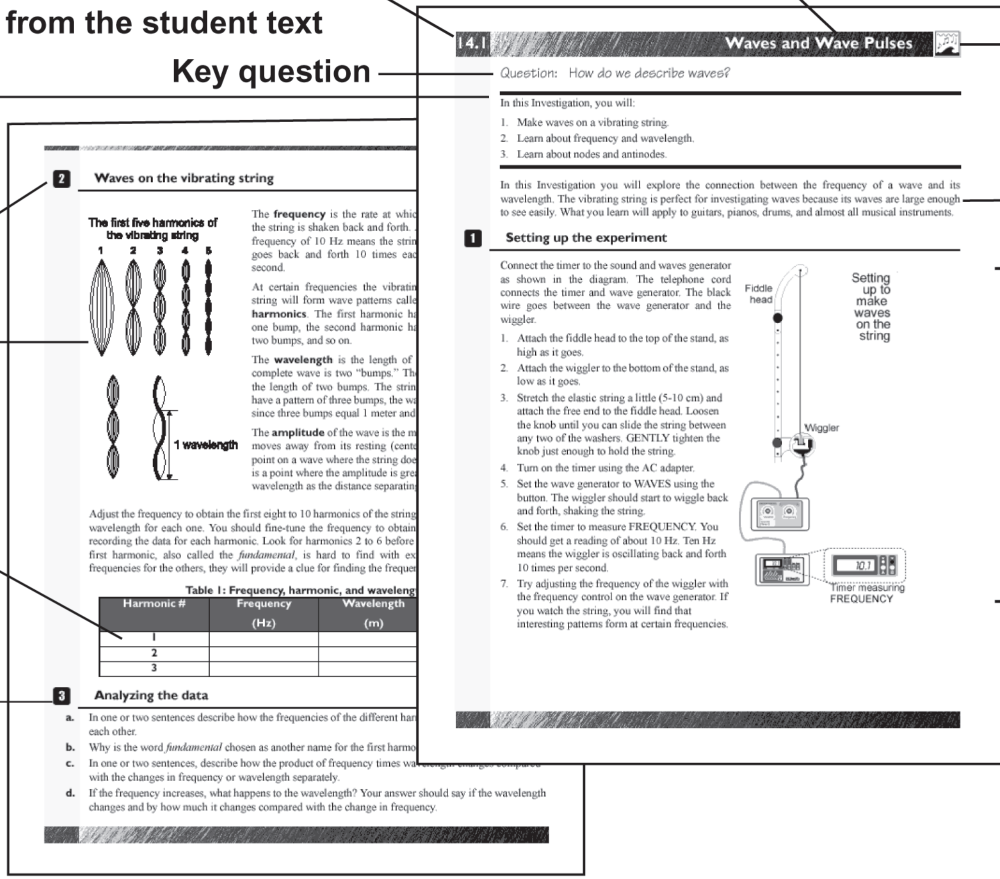
Major learning objective for the Investigation

Investigation sequence numbers

Illustrations and charts that support content

Example space for data*

Thought-provoking question



Icon representing unit topic

Explanation of Investigation content

Detailed explanations of Investigation procedures, equipment setup, and data collection

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

Student Text Chapter Pages

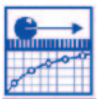
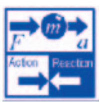
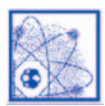
Each *Unit* is comprised of three *Chapters* and one application. Each chapter has a front page called a Chapter page. This page outlines the objectives or major topics that will be covered and the most important vocabulary. It is important to refer back to these pages to check to see if you have understood information about each topic. Features of the Chapter Pages include:

Learning objectives: These goals are the major ideas that you will explore throughout the chapter. You should check this list by going back and re-reading to make sure you can explain each of these concepts in writing or to another person.

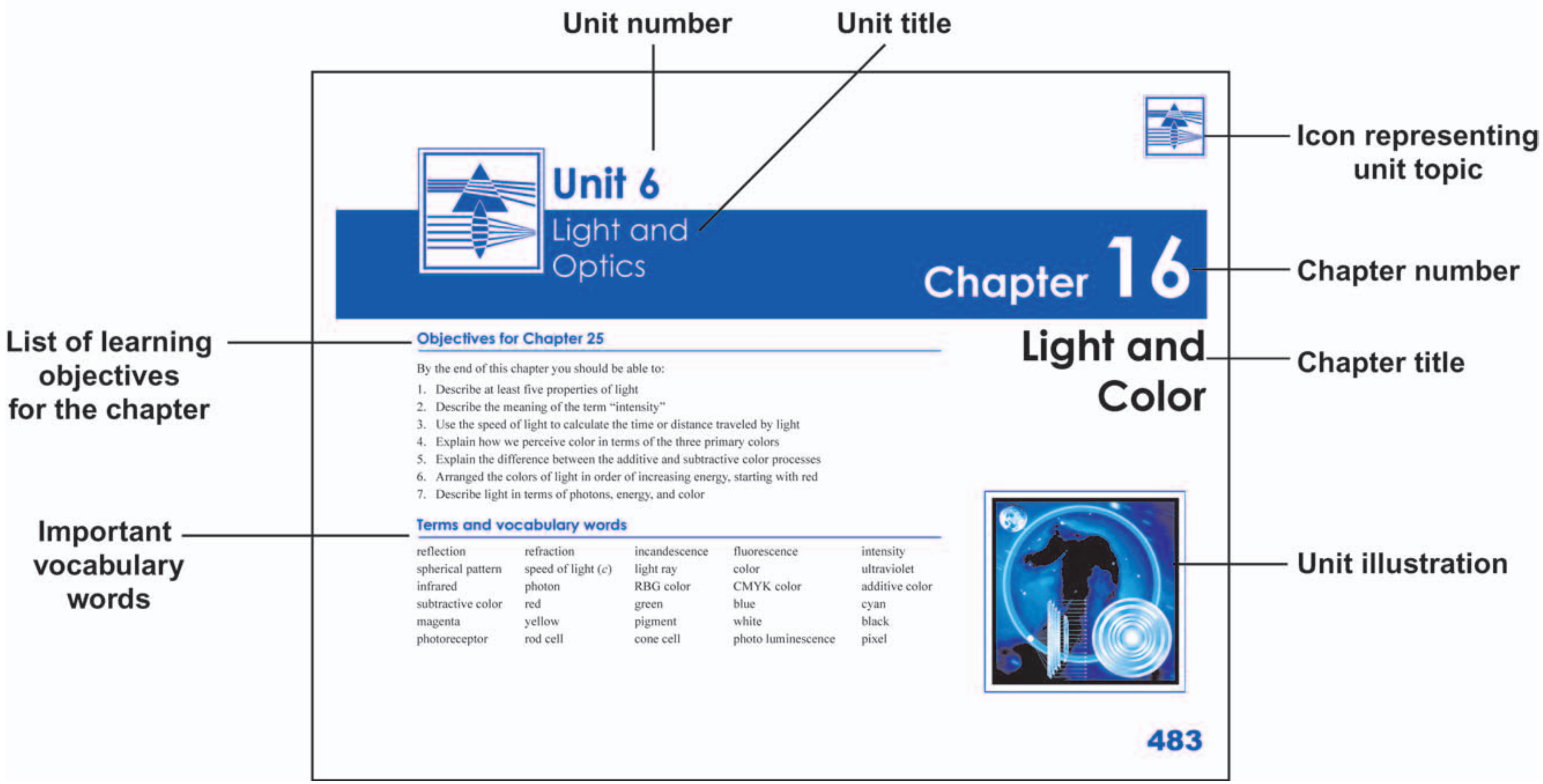
Vocabulary: The list of vocabulary words at the beginning of the chapter will familiarize you with the words in the chapter. Understanding the science vocabulary will help you learn the concepts in the readings. Reviewing the vocabulary list to identify terms that you are familiar with is a good way to begin each chapter.

Unit Icons Guide

Unit icons are used to identify what unit topic you are studying. You will see these icons with the chapter number on the right-hand chapter page and on the Investigation right hand corners.

	Unit One: Measurement and Motion		Unit Six: Light and Optics
	Unit Two: Motion and Force in One Dimension		Unit Seven: Electricity and Magnetism
	Unit Three: Motion and Force in 2 and 3 Dimensions		Unit Eight: Matter and Energy
	Unit Four: Energy and Momentum		Unit Nine: The Atom
	Unit Five: Waves and Sound		Chapter 31: The Edge of Physics

CHAPTER PAGES



Unit 6
Light and Optics

Chapter 16

Light and Color

Objectives for Chapter 25

By the end of this chapter you should be able to:

1. Describe at least five properties of light
2. Describe the meaning of the term "intensity"
3. Use the speed of light to calculate the time or distance traveled by light
4. Explain how we perceive color in terms of the three primary colors
5. Explain the difference between the additive and subtractive color processes
6. Arranged the colors of light in order of increasing energy, starting with red
7. Describe light in terms of photons, energy, and color

Terms and vocabulary words

reflection	refraction	incandescence	fluorescence	intensity
spherical pattern	speed of light (*c*)	light ray	color	ultraviolet
infrared	photon	RBG color	CMYK color	additive color
subtractive color	red	green	blue	cyan
magenta	yellow	pigment	white	black
photoreceptor	rod cell	cone cell	photo luminescence	pixel

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