Chapter 1 Organizer

Section/Objectives	Standards: National	Standards: State/Local	Lab and Demo Planning
Chapter Opener	See page 14T for a key to the standards.		
Section 1.1 1. **Demonstrate** scientific methods. 2. **Use** the metric system. 3. **Evaluate** answers using dimensional analysis. 4. **Perform** arithmetic operations using scientific notation.	UCP.2, UCP.3, A.1, A.2, G.2		**Student Lab:** **Launch Lab,** p. 3: five pennies, tape **Mini Lab,** p. 8: five identical washers, spring, metric ruler **Teacher Demonstration:** **Quick Demo,** p. 5: solar cell, multimeter, sunny day
Section 1.2 5. **Distinguish** between accuracy and precision. 6. **Determine** the precision of measured quantities.	UCP.3, E.1, E.2		
Section 1.3 7. **Graph** the relationship between independent and dependent variables. 8. **Interpret** graphs. 9. **Recognize** common relationships in graphs.	UCP.2, UCP.3, A.1, A.2		**Student Lab:** **Additional Mini Lab,** p. 16: meterstick, string, four circular objects **Internet Physics Lab,** pp. 20–21: Internet access, watch or timer **Teacher Demonstration:** **Quick Demo,** p. 17: toy windup car or truck, meterstick, graph paper

Differentiated Instruction

L1 Level 1 activities should be appropriate for students with learning difficulties.

L2 Level 2 activities should be within the ability range of all students.

L3 Level 3 activities are designed for above-average students.

Legend — Transparency CD-ROM MP3 Videocassette DVD WEB

Reproducible Resources and Transparencies	Technology
	TeacherWorks™ includes: Interactive Teacher Edition ■ Lesson Planner with Calendar ■ Access to all Blacklines ■ Correlation to Standards ■ Web links
FAST FILE Chapters 1–5 Resources, Chapter 1 Transparency 1-1 Master, p. 23 Transparency 1-2 Master, p. 25 Study Guide, pp. 9–14 Section 1-1 Quiz, p. 15 Mini Lab Worksheet, p. 3 **Teaching Transparency 1-1** **Teaching Transparency 1-2** **Connecting Math to Physics**	**Interactive Chalkboard CD-ROM:** Section 1.1 Presentation **TeacherWorks™ CD-ROM**
FAST FILE Chapters 1–5 Resources, Chapter 1 Transparency 1-3 Master, p. 27 Study Guide, pp. 9–14 Section 1-2 Quiz, p. 16 **Teaching Transparency 1-3** **Connecting Math to Physics**	**Interactive Chalkboard CD-ROM:** Section 1.2 Presentation **TeacherWorks™ CD-ROM**
FAST FILE Chapters 1–5 Resources, Chapter 1 Transparency 1-4 Master, p. 29 Study Guide, pp. 9–14 Reinforcement, pp. 19–20 Enrichment, pp. 21–22 Section 1-3 Quiz, p. 17 Internet Physics Lab Worksheet, pp. 5–8 **Teaching Transparency 1-4** **Connecting Math to Physics** **Forensics Laboratory Manual,** pp. 7–10 **Forensics Laboratory Manual,** pp. 19–22 **Laboratory Manual,** pp. 1–4	**Interactive Chalkboard CD-ROM:** Section 1.3 Presentation **TeacherWorks™ CD-ROM** **Problem of the Week at physicspp.com**

Assessment Resources

FAST FILE Chapters 1–5 Resources, Chapter 1
Chapter Assessment, pp. 31–36

Additional Challenge Problems, p. 1
Physics Test Prep, pp. 1–2
Pre-AP Critical Thinking, pp. 1–2
Supplemental Problems, pp. 1–2

Technology

Interactive Chalkboard CD-ROM:
Chapter 1 Assessment
Exam*View*® Pro Testmaker CD-ROM
Vocabulary PuzzleMaker
TeacherWorks™ CD-ROM
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Chapter 1

A Physics Toolkit

Chapter Overview

Math is the language of physics, and students need to know how to use math as a tool to make the most of their studies. The first section familiarizes students with measurement and standards. It also distinguishes scientific law from scientific theory. In the second section, students learn about precision, accuracy, and uncertainty in measurement. Finally, students learn about graphing data and how equations and graphs reveal the relationship between variables.

Think About This

Physics research in the last 50 years has led to technological innovations in numerous areas affecting the lives of students, from the fields of medicine to home entertainment, from weather forecasting to air bags in cars. Examples include high-speed slide microscanners for detecting pathologies and the development of superconducting transistors—which has numerous applications, from X-ray astronomy to biological tagging.

▶ Key Terms

physics, p. 3
dimensional analysis, p. 6
significant digits, p. 7
scientific method, p. 8
hypothesis, p. 8
scientific law, p. 9
scientific theory, p. 10
measurement, p. 11
precision, p. 12
accuracy, p. 13
independent variable, p. 15
dependent variable, p. 15
line of best fit, p. 15
direct relationship, p. 16
quadratic relationship, p. 17
inverse relationship, p. 18

Chapter 1

A Physics Toolkit

What You'll Learn

- You will use mathematical tools to measure and predict.
- You will apply accuracy and precision when measuring.
- You will display and evaluate data graphically.

Why It's Important

The measurement and mathematics tools presented here will help you to analyze data and make predictions.

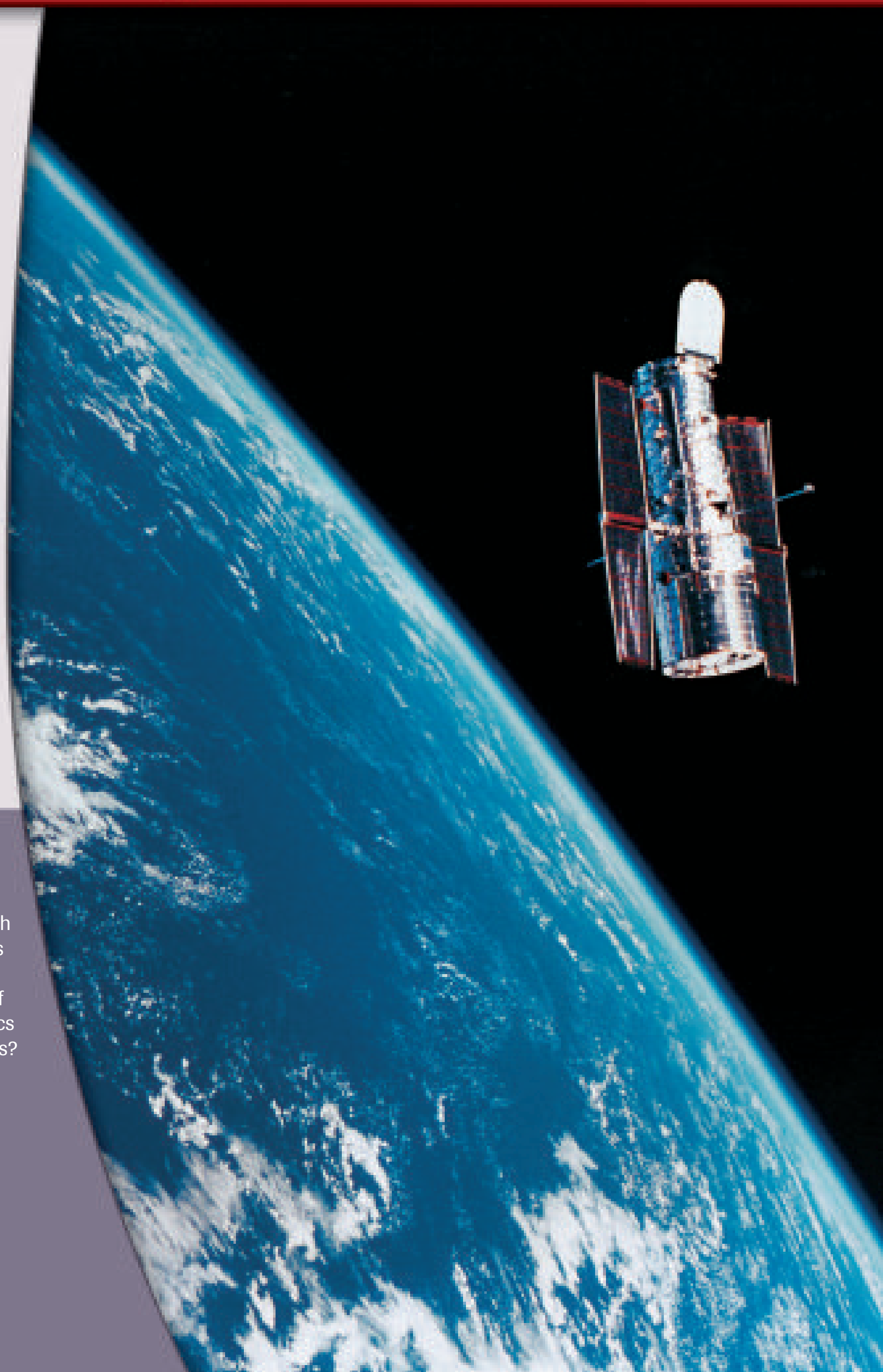
Satellites Accurate and precise measurements are important when constructing and launching a satellite—errors are not easy to correct later. Satellites, such as the *Hubble Space Telescope* shown here, have revolutionized scientific research, as well as communications.

Think About This ▶

Physics research has led to many new technologies, such as satellite-based telescopes and communications. What are some other examples of tools developed from physics research in the last 50 years?

Physics Online

physicspp.com



NASA

LAUNCH Lab

Purpose to explore the motion of falling objects

Materials five pennies, tape

Teaching Strategies

- Aristotle's teachings that heavier objects fall faster than lighter ones was predominant for nearly 1900 years, until Galileo's discoveries.
- Experiment with a greater difference in weight; use a 1-kg mass in place of the four pennies.
- Have students speculate about how dropping four pennies taped together is different from dropping four not taped together. If necessary guide the discussion so that they come to realize that there is no difference.

LAUNCH Lab

Do all objects fall at the same rate?

Question

How does weight affect the rate at which an object falls?

Procedure

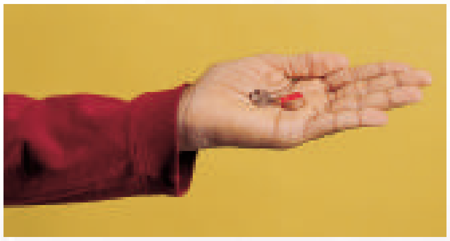
The writings of the Greek philosopher Aristotle included works on physical science theories. These were a major influence in the late Middle Ages. Aristotle reasoned that weight is a factor governing the speed of fall of a dropped object, and that the rate of fall must increase in proportion to the weight of the object.

1. Tape four pennies together in a stack.
2. Place the stack of pennies on your hand and place a single penny beside them.
3. **Observe** Which is heaviest and pushes down on your hand the most?
4. **Observe** Drop the two at the same time and observe their motions.

Analysis

According to Aristotle, what should be the rate of fall of the single penny compared to the stack? What did you observe?

Critical Thinking Explain which of the following properties might affect the rate of fall of an object: size, mass, weight, color, shape.



1.1 Mathematics and Physics

What do you think of when you see the word *physics?* Many people picture a chalkboard covered with formulas and mathematics: $E = mc^2$, $I = V/R$, $d = \frac{1}{2}at^2 + v_0t + d_0$. Perhaps you picture scientists in white lab coats, or well-known figures such as Marie Curie and Albert Einstein. Or, you might think of the many modern technologies created with physics, such as weather satellites, laptop computers, or lasers.

Objectives

- **Demonstrate** scientific methods.
- **Use** the metric system.
- **Evaluate** answers using dimensional analysis.
- **Perform** arithmetic operations using scientific notation.

Vocabulary

physics
dimensional analysis
significant digits
scientific method
hypothesis
scientific law
scientific theory

What is Physics?

Physics is a branch of science that involves the study of the physical world: energy, matter, and how they are related. Physicists investigate the motions of electrons and rockets, the energy in sound waves and electric circuits, the structure of the proton and of the universe. The goal of this course is to help you understand the physical world.

People who study physics go on to many different careers. Some become scientists at universities and colleges, at industries, or in research institutes. Others go into related fields, such as astronomy, engineering, computer science, teaching, or medicine. Still others use the problem-solving skills of physics to work in business, finance, or other very different disciplines.

Horizons Companies

- Observing that the times of fall are close to identical is relatively easy; measuring the speed at which objects fall is much harder. Galileo used inclined planes to slow vertical motion. Through many years of study measuring the time it takes for bodies to move various distances, Galileo found that the distance traveled by a falling body is proportional to the square of the time of descent.

Expected Results The penny and stack fall at the same time.

Analysis Aristotle would have predicted the rate of fall for the stack of pennies would be four times that of the single penny. When stacked, the four pennies fall just as they would if dropped right next to each other as single pennies.

Critical Thinking Air resistance affects the rate at which an object falls: it is related to object shape, air density, object density, object orientation, and speed of the object relative to the air.

Section 1.1

1 FOCUS

Bellringer Activity

Unit Systems Ask students to measure something—the length or width of the room, the width of a table—without using any formal measuring device. They will need to use their hand widths, foot lengths, or some similar unit to make this measurement. Then ask everyone in the class to report what they found. Discuss how difficult it is to compare results with all of these different unit systems. **L1 Kinesthetic**

Tie to Prior Knowledge

Units Students who have already taken chemistry should be somewhat familiar with SI and scientific notation, but this textbook does not presume any such prior knowledge.

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2 TEACH

Using Models

Equations Provide students with an example of how equations can be used to model a phenomenon. Have them interpret the meaning of the equation $V = IR$ presented in Example Problem 1. $V = IR$ means that *voltage* (measured in volts, V) is a product of the *current* (measured in amperes, A) and *resistance* (measured in ohms, Ω).
L2 Logical-Mathematical

Concept Development

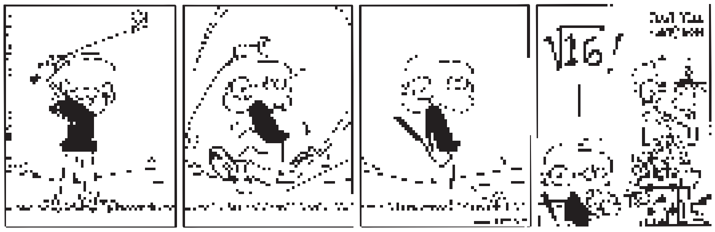
- **Equations** Example Problem 1 shows that $V = IR$ and that $R = V/I$. Ask students to provide you with an equation that solves for I. $I = V/R$
- **Controlling Current** Show students how to interpret the equation $I = V/R$. There are two ways to control current in a circuit, by varying either voltage, V, or resistance, R, (or both). **L2 Logical-Mathematical**

IN-CLASS Example

Question A 12-volt car battery is connected to a 3-ohm brake light. What is the current carrying energy to the lights?

Answer Use $I = V/R$, current = voltage divided by resistance (amperes = volts divided by ohms) and solve for I.
Known:
$I = \frac{12V}{3\Omega} = 4A$

Figure 1-1 Physicists use mathematics to represent many different phenomena—a trait sometimes spoofed in cartoons.



Mathematics in Physics

Physics uses mathematics as a powerful language. As illustrated in **Figure 1-1,** this use of mathematics often is spoofed in cartoons. In physics, equations are important tools for modeling observations and for making predictions. Physicists rely on theories and experiments with numerical results to support their conclusions. For example, think back to the Launch Lab. You can predict that if you drop a penny, it will fall. But how fast? Different models of falling objects give different answers to how the speed of the object changes, or on what the speed depends, or which objects will fall. By measuring how an object falls, you can compare the experimental data with the results predicted by different models. This tests the models, allowing you to pick the best one, or to develop a new model.

EXAMPLE Problem 1

Electric Current The potential difference, or voltage, across a circuit equals the current multiplied by the resistance in the circuit. That is, V (volts) = I (amperes) × R (ohms). What is the resistance of a lightbulb that has a 0.75 amperes current when plugged into a 120-volt outlet?

1 Analyze the Problem

- Rewrite the equation.
- Substitute values.

Known:	Unknown:
I = 0.75 amperes	R = ?
V = 120 volts	

2 Solve for the Unknown

Rewrite the equation so the unknown is alone on the left.

$V = IR$

$IR = V$ — Reflexive property of equality

$R = \frac{V}{I}$ — Divide both sides by I.

$= \frac{120 \text{ volts}}{0.75 \text{ amperes}}$ — Substitute 120 volts for V, 0.75 amperes for I.

$= 160$ ohms — Resistance will be measured in ohms.

Math Handbook
Isolating a Variable page 845

3 Evaluate the Answer

- **Are the units correct?** 1 volt = 1 ampere-ohm, so the answer in volts/ampere is in ohms, as expected.
- **Does the answer make sense?** 120 is divided by a number a little less than 1, so the answer should be a little more than 120.

1.1 Resource MANAGER

FAST FILE Chapters 1–5 Resources
Transparency 1–1 Master, p. 23
Transparency 1–2 Master, p. 25
Study Guide, pp. 9–14
Section 1–1 Quiz, p. 15
Mini Lab Worksheet, p. 3
Teaching Transparency 1-1
Teaching Transparency 1-2
Connecting Math to Physics

Technology
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Interactive Chalkboard CD-ROM
Exam*View*® Pro Testmaker CD-ROM
physicspp.com
physicspp.com/vocabulary_puzzlemaker

▶ PRACTICE Problems

Additional Problems, Appendix B

For each problem, give the rewritten equation you would use and the answer.

1. A lightbulb with a resistance of 50.0 ohms is used in a circuit with a 9.0-volt battery. What is the current through the bulb?
2. An object with uniform acceleration a, starting from rest, will reach a speed of v in time t according to the formula $v = at$. What is the acceleration of a bicyclist who accelerates from rest to 7 m/s in 4 s?
3. How long will it take a scooter accelerating at 0.400 m/s^2 to go from rest to a speed of 4.00 m/s?
4. The pressure on a surface is equal to the force divided by the area: $P = F/A$. A 53-kg woman exerts a force (weight) of 520 Newtons. If the pressure exerted on the floor is 32,500 N/m^2, what is the area of the soles of her shoes?

Does it make sense? Sometimes you will work with unfamiliar units, as in Example Problem 1, and you will need to use estimation to check that your answer makes sense mathematically. At other times you can check that an answer matches your experience, as shown in **Figure 1-2.** When you work with falling objects, for example, check that the time you calculate an object will take to fall matches your experience—a copper ball dropping 5 m in 0.002 s, or in 17 s, doesn't make sense.

The Math Handbook in the back of this book contains many useful explanations and examples. Refer to it as needed.

■ **Figure 1-2** What is a reasonable range of values for the speed of an automobile?

SI Units

To communicate results, it is helpful to use units that everyone understands. The worldwide scientific community and most countries currently use an adaptation of the metric system to state measurements. The Système International d'Unités, or SI, uses seven base quantities, which are shown in **Table 1-1.** These base quantities were originally defined in terms of direct measurements. Other units, called derived units, are created by combining the base units in various ways. For example, energy is measured in joules, where 1 joule equals one kilogram-meter squared per second squared, or 1 J = 1 kg·m^2/s^2. Electric charge is measured in coulombs, where 1 C = 1 A·s.

Table 1-1
SI Base Units

Base Quantity	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of a substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Mark E. Gibson

QUICK DEMO

Light and Solar Cells

Estimated Time 15 minutes

Materials solar cell, multimeter, sunny day

Procedure Ask students how they think the electricity generated by a solar cell is related to the amount of sunlight striking the surface. Once students have generated some theories, ask how they might be tested. Set up the multimeter to measure the current generated by the solar cell. Place the solar cell in direct sunlight, facing the Sun. Record the current. Cover various fractions of the cell's surface and record the corresponding currents. Do a brief data analysis, discuss the process used, and decide what conclusions could reasonably be drawn from the data.

▶ PRACTICE Problems

1. 0.18 ampere
2. 1.75 m/s^2
3. 10.0 s
4. 0.016 m^2

Teacher F.Y.I. — REAL-LIFE PHYSICS

Global Positioning Systems These systems allow sailors, hikers, and drivers to determine their locations on the surface of Earth to within a few meters. Remind students that the coordinates are three-dimensional. Ask students whether anyone has a GPS device. If so, ask the student to demonstrate it to the class.

Discussion

Question Why do scientists use the metric system, instead of the English or some other system?

Answer In the metric system, with its base of ten, it is easy to convert from one scale of measurements to another. For instance, it's much easier to convert from centimeters to meters than from inches to yards. L2

Concept Development

Unit Systems Ask students why it is important to have an agreed-upon system of units. For one thing, this makes comparisons between different groups easier. It also helps everyone get an idea of the magnitudes of various measurements. For instance, most students will have some idea of how fast 25 mph is. But do they know how fast 10 furlongs per fortnight is? As the course progresses, they will gain an idea of how fast 25 m/s is. L2

Reinforcement

Conversion Factors and Cubic Units Students can have trouble with conversion factors as they relate to cubic units. For example, students know that 100 cm equals 1 m. They may conclude that 100 cm^3 is equal to 1 m^3, rather than 1,000,000 cm^3 (1×10^6 cm^3) is equal to 1 m^3. Provide to the class a model of a 1 m^3-cube. Have students determine the volume of the cube in cm^3 and mm^3. From their calculations, have them create conversion factors.

Figure 1-3 The standards for the kilogram and meter are shown. The International Prototype Meter originally was measured as the distance between two marks on a platinum-iridium bar, but as methods of measuring time became more precise than those for measuring length, the meter came to be defined as the distance traveled by light in a vacuum in 1/299 792 458 s.

Scientific institutions have been created to define and regulate measures. The SI system is regulated by the International Bureau of Weights and Measures in Sèvres, France. This bureau and the National Institute of Science and Technology (NIST) in Gaithersburg, Maryland keep the standards of length, time, and mass against which our metersticks, clocks, and balances are calibrated. Examples of two standards are shown in **Figure 1-3.** NIST works on many problems of measurement, including industrial and research applications.

You probably learned in math class that it is much easier to convert meters to kilometers than feet to miles. The ease of switching between units is another feature of the metric system. To convert between SI units, multiply or divide by the appropriate power of 10. Prefixes are used to change SI units by powers of 10, as shown in **Table 1-2.** You often will encounter these prefixes in daily life, as in, for example, milligrams, nanoseconds, and gigabytes.

Table 1-2

Prefixes Used with SI Units

Prefix	Symbol	Multiplier	Scientific Notation	Example
femto-	f	0.000000000000001	10^{-15}	femtosecond (fs)
pico-	p	0.000000000001	10^{-12}	picometer (pm)
nano-	n	0.000000001	10^{-9}	nanometer (nm)
micro-	μ	0.000001	10^{-6}	microgram (μg)
milli-	m	0.001	10^{-3}	milliamps (mA)
centi-	c	0.01	10^{-2}	centimeter (cm)
deci-	d	0.1	10^{-1}	deciliter (dL)
kilo-	k	1000	10^{3}	kilometer (km)
mega-	M	1,000,000	10^{6}	megagram (Mg)
giga-	G	1,000,000,000	10^{9}	gigameter (Gm)
tera-	T	1,000,000,000,000	10^{12}	terahertz (THz)

Math Handbook
Dimensional Analysis
page 847

Dimensional Analysis

You can use units to check your work. You often will need to use different versions of a formula, or use a string of formulas, to solve a physics problem. To check that you have set up a problem correctly, write out the equation or set of equations you plan to use. Before performing calculations, check that the answer will be in the expected units, as shown in step 3 of Example Problem 1. For example, if you are finding a speed and you see that your answer will be measured in s/m or m/s^2, you know you have made an error in setting up the problem. This method of treating the units as algebraic quantities, which can be cancelled, is called **dimensional analysis.**

Dimensional analysis also is used in choosing conversion factors. A conversion factor is a multiplier equal to 1. For example, because 1 kg = 1000 g, you can construct the following conversion factors:

$$1 = \frac{1\ \text{kg}}{1000\ \text{g}} \qquad 1 = \frac{1000\ \text{g}}{1\ \text{kg}}$$

National Institute of Standards and Technology

PHYSICS PROJECT Activity

Ancient Standards All civilizations have had to develop standards for measuring. For example, in Mesopotamia (3500–1800 B.C.), workers built the first cities using *cubits,* measuring roughly the length of one's forearm from elbow to wrist bone (one cubit could range from 43–56 cm, or 17–22 in). Have students research measurement systems of various civilizations. Their reports should include advantages and disadvantages of the system, the units of measure, the rationale or origin of the unit, and their equivalent measure in SI. They also should convert some commonly measured items (for example, a football field) to provide additional perspective on the system. L2 **Linguistic**

Choose a conversion factor that will make the units cancel, leaving the answer in the correct units. For example, to convert 1.34 kg of iron ore to grams, do as shown below.

$$1.34\ \cancel{\text{kg}}\left(\frac{1000\ \text{g}}{1\ \cancel{\text{kg}}}\right) = 1340\ \text{g}$$

You also might need to do a series of conversions. To convert 43 km/h to m/s, do the following:

$$\left(\frac{43\ \cancel{\text{km}}}{1\ \cancel{\text{h}}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \text{s}}\right) = 12\ \text{m/s}$$

PRACTICE Problems

Additional Problems, Appendix B

Use dimensional analysis to check your equation before multiplying.

5. How many megahertz is 750 kilohertz?

6. Convert 5021 centimeters to kilometers.

7. How many seconds are in a leap year?

8. Convert the speed 5.30 m/s to km/h.

Significant Digits

Suppose you use a meterstick to measure a pen, and you find that the end of the pen is just past 14.3 cm. This measurement has three valid digits: two you are sure of, and one you estimated. The valid digits in a measurement are called **significant digits.** The last digit given for any measurement is the uncertain digit. All nonzero digits in a measurement are significant.

Are all zeros significant? No. For example, in the measurement 0.0860 m, the first two zeros serve only to locate the decimal point and are not significant. The last zero, however, is the estimated digit and is significant. The measurement 172,000 m could have 3, 4, 5, or 6 significant digits. This ambiguity is one reason to use scientific notation: it is clear that the measurement 1.7200×10^5 m has five significant digits.

Arithmetic with significant digits When you perform any arithmetic operation, it is important to remember that the result never can be more precise than the least-precise measurement.

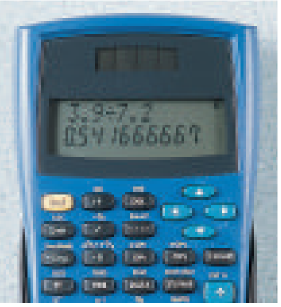
To add or subtract measurements, first perform the operation, then round off the result to correspond to the least-precise value involved. For example, 3.86 m + 2.4 m = 6.3 m because the least-precise measure is to one-tenth of a meter.

To multiply or divide measurements, perform the calculation and then round to the same number of significant digits as the least-precise measurement. For example, 409.2 km/11.4 L = 35.9 km/L, because the least-precise measure has three significant digits.

Some calculators display several additional digits, as shown in **Figure 1-4,** while others round at different points. Be sure to record your answers with the correct number of digits. Note that significant digits are considered only when calculating with measurements. There is no uncertainty associated with counting (4 washers) or exact conversion factors (24 hours in 1 day).

Math Handbook
Significant Digits
pages 833–836

Figure 1-4 This answer to 3.9 ÷ 7.2 should be rounded to two significant digits.



Horizons Companies

PRACTICE Problems

5. 0.75 MHz

6. 5.021×10^{-2} km

7. 31,622,400 s

8. 19.08 km/h

Reinforcement

Prefix Game Activity Write the metric prefixes that you intend to use frequently in your class on index cards. Make several sets. Divide the students into teams and give each team a set of the cards. Have each student on the team randomly select a card, then have a contest to see which team can line up its members most quickly according to the magnitude of the prefix on the card each member has drawn.
L1 Interpersonal

Concept Development

Rounding Students may have trouble rounding to the correct number of significant digits when a number is halfway between two numbers. Students should follow the following rules. (1) When the leftmost digit to be dropped is 5 followed by a nonzero number, that digit and any digits that follow are dropped. The last digit in the rounded number increases by one. For example, 8.7519 rounded to two significant figures equals 8.8. (2) If the digit to the right of the last significant figure is equal to 5 and 5 is not followed by a nonzero digit, look at the last significant figure. If it is odd, increase it by one; if even, do not round up. For example, 92.350 rounded to three significant figures equals 92.4 and 92.25 equals 92.2.

Teacher F.Y.I. CONTENT BACKGROUND

Solving for the Unknown Measuring and computing physical quantities requires the use of mathematics. Our modern system of mathematics owes a great deal to Hindu and Islamic mathematicians—and it's not just for the concept of zero and the Arabic numerals we use. Classical algebra developed over a period of 4000 years. The word *algebra* comes from the Arabic word *al-jabr,* meaning "the (science of) reuniting." The word *algorithm* is a corruption of the name of the mathematician Mohammed ibn Musa al-Khwarizmi, who wrote a definitive text on algebra in 830 A.D.; his contemporary, Abu Al-Battani, developed trigonometry.

PRACTICE Problems

9. a. 26.3 cm

b. 1600 m or 1.6 km

10. a. 2.5 g

b. 4.33 m

11. a. 320 cm^2 or 3.2×10^2 cm^2

b. 13.6 km^2

12. a. 1.22 g/mL

b. 4.1 g/cm^3

MINI LAB

Measuring Change

See page 3 of **FAST FILE Chapters 1–5 Resources** *for the accompanying Mini Lab Worksheet.*

Purpose to graph data and extrapolate from it

Materials five identical washers, spring, metric rule

Expected Results Students test their prediction by measuring the length of a spring with four and five washers, then plotting the data on the same graph.

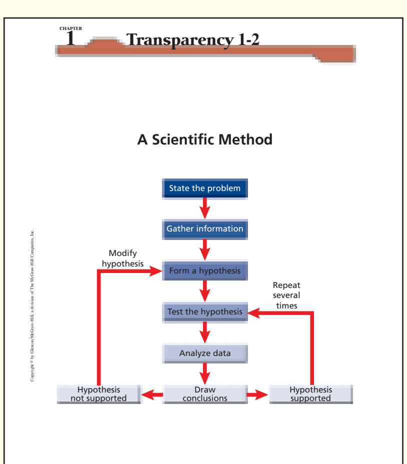
Analyze and Conclude

5. Length increases with mass. Line graph should slope up.

INTERACTIVE CHALKBOARD with Image Bank

PowerPoint® Presentations

Page 25, FAST FILE Chapters 1–5 Resources



PRACTICE Problems — Additional Problems, Appendix B

Solve the following problems.

9. a. 6.201 cm + 7.4 cm + 0.68 cm + 12.0 cm

b. 1.6 km + 1.62 m + 1200 cm

10. a. 10.8 g − 8.264 g

b. 4.75 m − 0.4168 m

11. a. 139 cm × 2.3 cm

b. 3.2145 km × 4.23 km

12. a. 13.78 g ÷ 11.3 mL

b. 18.21 g ÷ 4.4 cm^3

MINI LAB

Measuring Change

Collect five identical washers and a spring that will stretch measurably when one washer is suspended from it.

1. Measure the length of the spring with zero, one, two, and three washers suspended from it.

2. Graph the length of the spring versus the mass.

3. Predict the length of the spring with four and five washers.

4. Test your prediction.

Analyze and Conclude

5. Describe the shape of the graph. How did you use it to predict the two new lengths?

Scientific Methods

In physics class, you will make observations, do experiments, and create models or theories to try to explain your results or predict new answers, as shown in **Figure 1-5.** This is the essence of a **scientific method.** All scientists, including physicists, obtain data, make predictions, and create compelling explanations that quantitatively describe many different phenomena. The experiments and results must be reproducible; that is, other scientists must be able to recreate the experiment and obtain similar data. Written, oral, and mathematical communication skills are vital to every scientist.

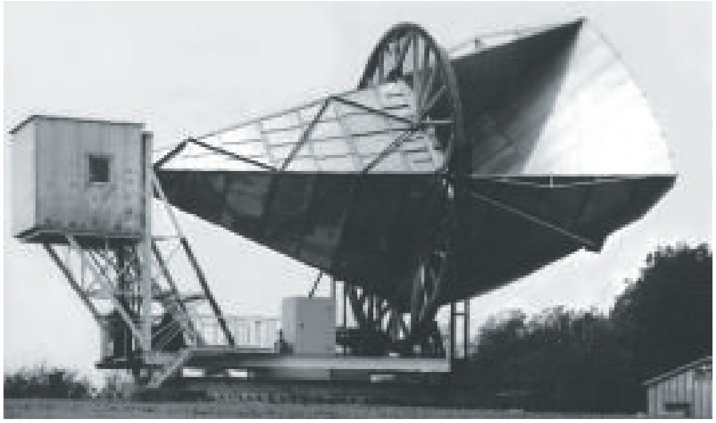
A scientist often works with an idea that can be worded as a **hypothesis,** which is an educated guess about how variables are related. How can the hypothesis be tested? Scientists conduct experiments, take measurements, and identify what variables are important and how they are related. For example, you might find that the speed of sound depends on the medium through which sound travels, but not on the loudness of the sound. You can then predict the speed of sound in a new medium and test your results.

Figure 1-5 These students are conducting an experiment to determine how much power they produce climbing the stairs **(a).** They use their data to predict how long it would take an engine with the same power to lift a different load **(b).**

Laura Sifferlin

HELPING STRUGGLING STUDENTS — Activity

The Scientific Method Many students carry with them the notion that a common series of steps is followed by all scientists. Inform students that scientists approach and solve problems with imagination, creativity, prior knowledge, and perseverance. These, of course, are the same methods used by all problem solvers. The lesson to be learned is that science is no different from other human endeavors when puzzles are investigated.



■ **Figure 1-6** In the mid-1960s, Arno Penzias and Robert Wilson were trying to eliminate the constant background noise in an antenna to be used for radio astronomy. They tested systems, duct-taped seams, and cleared out pigeon manure, but the noise persisted. This noise is now understood to be the cosmic microwave background radiation, and is experimental support for the Big Bang theory.

Models, laws, and theories An idea, equation, structure, or system can model the phenomenon you are trying to explain. Scientific models are based on experimentation. Recall from chemistry class the different models of the atom that were in use over time—new models were developed to explain new observations and measurements.

If new data do not fit a model, both are re-examined. **Figure 1-6** shows a historical example. If a very well-established model is questioned, physicists might first look at the new data: can anyone reproduce the results? Were there other variables at work? If the new data are born out by subsequent experiments, the theories have to change to reflect the new findings. For example, in the nineteenth century it was believed that linear markings on Mars showed channels, as shown in **Figure 1-7a.** As telescopes improved, scientists realized that there were no such markings, as shown in **Figure 1-7b.** In recent times, again with better instruments, scientists have found features that suggest Mars once had running and standing water on its surface, as shown in **Figure 1-7c.** Each new discovery has raised new questions and areas for exploration.

A **scientific law** is a rule of nature that sums up related observations to describe a pattern in nature. For example, the law of conservation of charge states that in the various changes matter can undergo, the electric charge before and after stays the same. The law of reflection states that the angle of incidence for a light beam on a reflective surface equals the angle of reflection. Notice that the laws do not explain why these phenomena happen, they simply describe them.

■ **Figure 1-7** Drawings of early telescope observations **(a)** showed channels on Mars; recent photos taken with improved telescopes do not **(b).** In this photo of Mars' surface from the *Mars Global Surveyor* spacecraft **(c),** these layered sedimentary rocks suggest that sedimentary deposits might have formed in standing water.

(t)Tom Pantages, (bc)NASA, (others)Photo Researchers

Identifying Misconceptions

Science and Scientists Find out what sort of preconceived notions your students may have about what science is and what sort of people do science. It is helpful to stress during the first few weeks of class that science is much more than looking up facts in a book. It is the process of testing one's knowledge by applying it to new situations. More importantly, science comes from a keen longing to know. It belongs to those who seek to know, who dare to ask, "Why?" and go to any lengths to find an answer.

ACTIVITY

■ **Measure from Afar** Galileo, with the aid of his telescope, was able to estimate the heights of mountains on the moon by estimating the lengths of the shadows. Ask a student to come to the front of the room to hold a shoe box and a 30-cm ruler so that the objects are on the white projection screen and pointing outward. Then use a flashlight to simultaneously make shadows of the two objects on the screen. Ask students to point out which object makes the longer shadow. The taller object Have students use ratios to compare measured dimensions of the objects and the shadows cast. Students should find that each shadow's length is proportional to the height of the object. **L2 Visual-Spatial**

Teacher F.Y.I. — CONTENT BACKGROUND

Galileo and Scientific Methods In 1609, Galileo Galilei (1564–1642) built a telescope powerful enough to explore the skies. He found that the Moon was neither a perfect nor a smooth sphere. In fact, the Moon had mountains, whose heights he could estimate from the shadows they cast. Through his telescope, Galileo also discovered that four moons circled the planet Jupiter, that the Milky Way was made up of more stars than anyone had imagined previously, and that Venus had phases similar to our Moon. As a result of this new perspective, Galileo was able to argue that Earth and the other planets circled the Sun.

Using Figure 1-8

Ask students to consider which theory they held about falling objects before studying physical science. What questions are raised by each new theory? **L2 Visual-Spatial**

3 ASSESS

Check for Understanding

Scientific Notation Give students a list of numbers in scientific notation and ask them to rank the numbers from least to greatest. Make sure to include some negative quantities and some with negative exponents. **L2 Logical-Mathematical**

Extension

Applications of Science Show students a laser pointer. Tell students that lasers and masers were developed because they looked like a wonderful way to demonstrate a particularly interesting property of matter-stimulated emission. Although today lasers have many useful applications, for many years lasers were called a solution in search of a problem. Divide the class into teams and ask each to come up with a list of applications of lasers today. Have students compare and validate their lists. **L2 Interpersonal**

Figure 1-8 Theories are changed and modified as new experiments provide insight and new observations are made. The theory of falling objects has undergone many revisions.

Greek philosophers proposed that objects fall because they seek their natural places. The more massive the object, the faster it falls.

↓ Revision

Galileo showed that the speed at which an object falls depends on the amount of time it falls, not on its mass.

↓ Revision

Galileo's statement is true, but Newton revised the reason why objects fall. Newton proposed that objects fall because the object and Earth are attracted by a force. Newton also stated that there is a force of attraction between any two objects with mass.

↓ Revision

Galileo's and Newton's statements still hold true. However, Einstein suggested that the force of attraction between two objects is due to mass causing the space around it to curve.

A **scientific theory** is an explanation based on many observations supported by experimental results. Theories may serve as explanations for laws. A theory is the best available explanation of why things work as they do. For example, the theory of universal gravitation states that all the mass in the universe is attracted to other mass. Laws and theories may be revised or discarded over time, as shown in **Figure 1-8.** Notice that this use of the word *theory* is different from the common use, as in "I have a theory about why it takes longer to get to school on Fridays." In scientific use, only a very well-supported explanation is called a theory.

1.1 Section Review

13. Math Why are concepts in physics described with formulas?

14. Magnetism The force of a magnetic field on a charged, moving particle is given by $F = Bqv$, where F is the force in kg·m/s^2, q is the charge in A·s, and v is the speed in m/s. B is the strength of the magnetic field, measured in teslas, T. What is 1 tesla described in base units?

15. Magnetism A proton with charge 1.60×10^{-19} A·s is moving at 2.4×10^{5} m/s through a magnetic field of 4.5 T. You want to find the force on the proton.

a. Substitute the values into the equation you will use. Are the units correct?

b. The values are written in scientific notation, $m\times10^{n}$. Calculate the 10^{n} part of the equation to estimate the size of the answer.

c. Calculate your answer. Check it against your estimate from part b.

d. Justify the number of significant digits in your answer.

16. Magnetism Rewrite $F = Bqv$ to find v in terms of F, q, and B.

17. Critical Thinking An accepted value for the acceleration due to gravity is 9.801 m/s^2. In an experiment with pendulums, you calculate that the value is 9.4 m/s^2. Should the accepted value be tossed out to accommodate your new finding? Explain.

Physics Online physicspp.com/self_check_quiz

1.1 Section Review

13. The formulas are concise and can be used to predict new data.

14. $1\ \frac{\text{kg}}{\text{A·s}^2}$

15. a. $F = Bqv = \left(4.5\ \frac{\text{kg}}{\text{A·s}^2}\right)(1.60\times10^{-19}\ \text{A·s})(2.4\times10^{5}\ \text{m/s})$; force will be measured in kg·m/s^2, which is correct.

b. 10^{-14}; the answer will be about 20×10^{-14}, or 2×10^{-13}.

c. 1.7×10^{-13} kg·m/s^2

d. The least-precise value is 4.5 T, with two significant digits, so the answer is rounded to two significant digits.

16. $v = \frac{F}{Bq}$

17. No. The value 9.801 m/s^2 has been established by many other experiments, and to discard the finding you would have to explain why they were wrong. There are probably some factors affecting your calculation, such as friction and how precisely you can measure the different variables.

1.2 Measurement

When you visit the doctor for a checkup, many measurements are taken: your height, weight, blood pressure, and heart rate. Even your vision is measured and assigned a number. Blood might be drawn so measurements can be made of lead or cholesterol levels. Measurements quantify our observations: a person's blood pressure isn't just "pretty good," it's 110/60, the low end of the good range.

What is a measurement? A **measurement** is a comparison between an unknown quantity and a standard. For example, if you measure the mass of a rolling cart used in an experiment, the unknown quantity is the mass of the cart and the standard is the gram, as defined by the balance or spring scale you use. In the Mini Lab in Section 1.1, the length of the spring was the unknown and the centimeter was the standard.

▶ **Objectives**

- **Distinguish** between accuracy and precision.
- **Determine** the precision of measured quantities.

▶ **Vocabulary**

measurement
precision
accuracy

Comparing Results

As you learned in Section 1.1, scientists share their results. Before new data are fully accepted, other scientists examine the experiment, looking for possible sources of error, and try to reproduce the results. Results often are reported with an uncertainty. A new measurement that is within the margin of uncertainty confirms the old measurement.

For example, archaeologists use radiocarbon dating to find the age of cave paintings, such as those from the Lascaux cave, in **Figure 1-9,** and the Chauvet cave. Radiocarbon dates are reported with an uncertainty. Three radiocarbon ages from a panel in the Chauvet cave are 30,940 ± 610 years, 30,790 ± 600 years, and 30,230 ± 530 years. While none of the measurements exactly match, the uncertainties in all three overlap, and the measurements confirm each other.

Figure 1-9 Drawings of animals from the Lascaux cave in France. By dating organic material in the cave, such as pigments and torch marks, scientists are able to suggest dates at which these cave paintings were made. Each date is reported with an uncertainty to show how precise the measurement is.

PhotoEdit

Section 1.2

1 FOCUS

Bellringer Activity

Measurement Technique Ask two students to act out taking a measurement. One should use good technique and one should make some fairly obvious errors. Ask the class which student's results would be more believable and why. **L2 Kinesthetic**

Tie to Prior Knowledge

Accuracy and Precision These are concepts students should be familiar with, even if they don't use the terms in a scientific way. Have students consider aspects of everyday experiences they might be able to measure, such as waiting for the bus, competing on the track, and building bookshelves. **L1**

2 TEACH

Discussion

Question Draw a cartoon of a beach. A sign says, "Pond Shallow—average depth 3 feet". A swimmer is standing on the shore. Ask students whether the swimmer could wade into water over his head. yes Ask students if the pond could be 30 ft deep in spots. yes Ask if the sign is useful or not.

Answer An average may not accurately convey the highest and lowest measurements. **L2 Logical-Mathematical**

1.2 Resource MANAGER

FAST FILE Chapters 1–5 Resources
- Transparency 1–3 Master, p. 27
- Study Guide, pp. 9–14
- Section 1–2 Quiz, p. 16

Teaching Transparency 1-3
Connecting Math to Physics

Technology
TeacherWorks™ CD-ROM
Interactive Chalkboard CD-ROM
Exam*View*® Pro Testmaker CD-ROM
physicspp.com
physicspp.com/vocabulary_puzzlemaker

Identifying Misconceptions

Unit Systems and Accuracy
Some students may think the metric system is more accurate than the English system because it is the one scientists choose to use. In truth, neither system is inherently more accurate than the other. **L2**

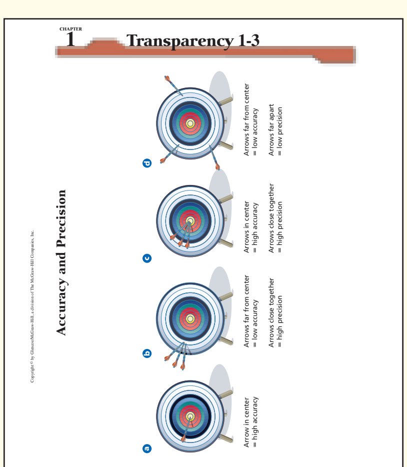
Using Figure 1-10

Have three to six students measure identical items, such as the width of a textbook or desk. Ask them to write down their measurements without announcing or comparing results. Their measurements will most likely vary slightly. Make a graph with uncertainty bars. Repeat with three groups, or three classes, to make
a graph similar to the one in Figure 1-10. **L2** **Kinesthetic**

Concept Development

Significance In common English *significant* means "important," while in science it means "measured." Nonsignificant digits are important as placeholders. A measurement of 8000 m has four important digits, but only one of them is significant.

Page 27, FAST FILE Chapters 1–5 Resources



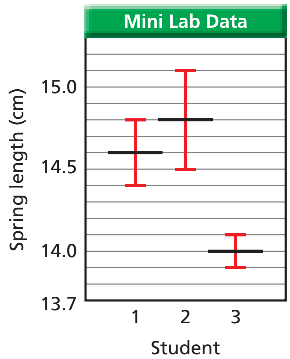


Figure 1-10 Three students took multiple measurements. Are the measurements in agreement? Is student 1's result reproducible?

Suppose three students performed the Mini Lab from Section 1.1 several times, starting with springs of the same length. With two washers on the spring, student 1 made repeated measurements, which ranged from 14.4 cm to 14.8 cm. The average of student 1's measurements was 14.6 cm, as shown in **Figure 1-10.** This result was reported as (14.6 ± 0.2) cm. Student 2 reported finding the spring's length to be (14.8 ± 0.3) cm. Student 3 reported a length of (14.0 ± 0.1) cm.

Could you conclude that the three measurements are in agreement? Is student 1's result reproducible? The results of students 1 and 2 overlap; that is, they have the lengths 14.5 cm to 14.8 cm in common. However, there is no overlap and, therefore, no agreement, between their results and the result of student 3.

Precision Versus Accuracy

Both precision and accuracy are characteristics of measured values. How precise and accurate are the measurements of the three students? The degree of exactness of a measurement is called its **precision.** Student 3's measurements are the most precise, within ± 0.1 cm. The measurements of the other two students are less precise because they have a larger uncertainty.

Precision depends on the instrument and technique used to make the measurement. Generally, the device that has the finest division on its scale produces the most precise measurement. The precision of a measurement is one-half the smallest division of the instrument. For example, the graduated cylinder in **Figure 1-11a** has divisions of 1 mL. You can measure an object to within 0.5 mL with this device. However, the smallest division on the beaker in **Figure 1-11b** is 50 mL. How precise were your measurements in the MiniLab?

The significant digits in an answer show its precision. A measure of 67.100 g is precise to the nearest thousandth of a gram. Recall from Section 1.1 the rules for performing operations with measurements given to different levels of precision. If you add 1.2 mL of acid to a beaker containing 2.4×10^2 mL of water, you cannot say you now have 2.412×10^2 mL of fluid, because the volume of water was not measured to the nearest tenth of a milliliter, but to 100 times that.

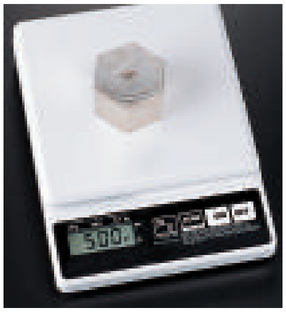
Figure 1-11 The graduated cylinder contains 41 ± 0.5 mL **(a)**. The flask contains 325 mL ± 25 mL **(b)**.

Teacher F.Y.I. **CONTENT BACKGROUND**

Significant Digits and Precision in Measurement The number of significant digits in a quantity ending in one or more zeros—such as 30 s, 60 W, or 100 km—is ambiguous. This can be avoided by writing 30 s and 3.0×10^1 s. Significant digits are the result of measurements, and students develop a sense of precision implied in a number. For example, a time interval written as 30 s is probably measured to ± 1 s, so there are two significant digits; 100 km is ± 1 km (3 significant digits). If 100 km is in a list of numbers such as 400 km, 600 km, 800 km, then it is more likely ± 10 km (two significant digits).

Accuracy describes how well the results of a measurement agree with the "real" value; that is, the accepted value as measured by competent experimenters. If the length of the spring that the three students measured had been 14.8 cm, then student 2 would have been most accurate and student 3 least accurate. How accurate do you think your measurements in the Mini Lab on page 8 were? What might have led someone to make inaccurate measurements? How could you check the accuracy of measurements?

A common method for checking the accuracy of an instrument is called the two-point calibration. First, does the instrument read zero when it should? Second, does it give the correct reading when it is measuring an accepted standard, as shown in **Figure 1-12?** Regular checks for accuracy are performed on critical measuring instruments, such as the radiation output of the machines used to treat cancer.



■ **Figure 1-12** Accuracy is checked by measuring a known value.

Techniques of Good Measurement

To assure accuracy and precision, instruments also have to be used correctly. Measurements have to be made carefully if they are to be as precise as the instrument allows. One common source of error comes from the angle at which an instrument is read. Scales should be read with one's eye directly above the measure, as shown in **Figure 1-13a.** If the scale is read from an angle, as shown in **Figure 1-13b,** you will get a different, and less accurate, value. The difference in the readings is caused by *parallax,* which is the apparent shift in the position of an object when it is viewed from different angles. To experiment with parallax, place your pen on a ruler and read the scale with your eye directly over the tip, then read the scale with your head shifted far to one side.

■ **Figure 1-13** By positioning the scale head on **(a),** your results will be more accurate than if you read your measurements at an angle **(b).** How far did parallax shift the measurement in b?

a

b

APPLYING PHYSICS

► **Distance to the Moon** For over 25 years, scientists have been accurately measuring the distance to the Moon by shining lasers through telescopes. The laser beam reflects off reflectors placed on the surface of the Moon by Apollo astronauts. They have determined that the average distance between the centers of Earth and the Moon is 385,000 km, and it is known with an accuracy of better than one part in 10 billion. Using this laser technique, scientists also have discovered that the Moon is receding from Earth at about 3.8 cm/yr. ◄

■ Using Figure 1-13

Ask students to look at an object in the distance with one eye shut. Have them position their thumbs at arm's length in front of the object so as to block it from view. Then have them view the object with the other eye shut, then the first. Ask them to tell you what happens to the object. It appears to shift. Explain that the farther the apparent shift, the closer the object is to the observer.
L2 Kinesthetic

Discussion

Question Show the results of a calculation on two different calculators, where one gives more decimal places on its readout than the other. Which is more accurate?

Answer The accuracy of the calculation has little (usually nothing) to do with the calculator. It is connected to the accuracy of the original readings. Just because a calculator gives more decimal places does not mean that its results are necessarily more accurate.
L2 Logical-Mathematical

Reinforcement

Significant Digits Ask students to write a four-digit number that has one zero that is not significant and one zero that is significant. After about 30 s, have each of them exchange papers with another student and evaluate. **L2**

APPLYING PHYSICS

► Retroreflectors were conceived in the 1960s by Montana State University physicist Kenneth Nordtvedt. Dr. Nordtvedt suggested to NASA that a series of reflectors on the surface of the Moon could be helpful in determining the exact distance between Earth and the Moon. NASA sent three arrays of 100 to 300 prisms to the Moon during three flights in the Apollo Moon-landing program. Two other arrays from the Soviet Union and France were delivered to the Moon aboard unmanned Lunakhod missions. ◄

DIFFERENTIATED INSTRUCTION — Activity

Visually Impaired Ask students to put the index finger of one hand on their noses and to extend the other arm as far as possible to the side. Tell them that this distance is approximately 1 m in length. Then have them feel the thickness of their little fingers and tell them this width is about 1 cm; the width of the fist is about 10 cm. Remind them that they will always have these distances handy to help them make estimates. **L2 Kinesthetic**

Critical Thinking

Average Accuracy Refer back to the cartoon you drew from p. 11, of the person at the shore. Ask students to discuss whether increasing the number of significant digits would have helped the situation. Even if the measurement were given as 3.0000 ft, the swimmer could still be in over his head, because the number was an average. L2

3 ASSESS

Check for Understanding

Accuracy Ask students to generate a list of real-world examples where it is important that measurements be done accurately and precisely. L2

Reteach

Simple Math Give the students the numbers 5.87 km and 1.2×10^{-2} km. Ask them to add, subtract, multiply, and divide them. L2

■ **Figure 1-14** A series of expeditions succeeded in placing a GPS receiver on top of Mount Everest. This improved the accuracy of the altitude measurement: Everest's peak is 8850 m, not 8848 m, above sea level.

The Global Positioning System, or GPS, offers an illustration of accuracy and precision in measurement. The GPS consists of 24 satellites with transmitters in orbit and numerous receivers on Earth. The satellites send signals with the time, measured by highly accurate atomic clocks. The receiver uses the information from at least four satellites to determine latitude, longitude, and elevation. (The clocks in the receivers are not as accurate as those on the satellites.)

Receivers have different levels of precision. A device in an automobile might give your position to within a few meters. Devices used by geophysicists, as in **Figure 1-14,** can measure movements of millimeters in Earth's crust.

The GPS was developed by the United States Department of Defense. It uses atomic clocks, developed to test Einstein's theories of relativity and gravity. The GPS eventually was made available for civilian use. GPS signals now are provided worldwide free of charge and are used in navigation on land, at sea, and in the air, for mapping and surveying, by telecommunications and satellite networks, and for scientific research into earthquakes and plate tectonics.

1.2 Section Review

18. Accuracy Some wooden rulers do not start with 0 at the edge, but have it set in a few millimeters. How could this improve the accuracy of the ruler?

19. Tools You find a micrometer (a tool used to measure objects to the nearest 0.01 mm) that has been badly bent. How would it compare to a new, high-quality meterstick in terms of its precision? Its accuracy?

20. Parallax Does parallax affect the precision of a measurement that you make? Explain.

21. Error Your friend tells you that his height is 182 cm. In your own words, explain the range of heights implied by this statement.

22. Precision A box has a length of 18.1 cm and a width of 19.2 cm, and it is 20.3 cm tall.

a. What is its volume?

b. How precise is the measure of length? Of volume?

c. How tall is a stack of 12 of these boxes?

d. How precise is the measure of the height of one box? of 12 boxes?

23. Critical Thinking Your friend states in a report that the average time required to circle a 1.5-mi track was 65.414 s. This was measured by timing 7 laps using a clock with a precision of 0.1 s. How much confidence do you have in the results of the report? Explain.

Physics Online physicspp.com/self_check_quiz

Bill Crouse

1.2 Section Review

18. As the edge of the ruler gets worn away over time, the first millimeter or two of the scale would also be worn away if the scale started at the edge.

19. It would be more precise but less accurate.

20. No, it doesn't change the fineness of the divisions on its scale.

21. His height would be between 181.5 and 182.5 cm. Precision of a measurement is one-half the smallest division on the instrument. The height 182 cm would range ±0.5 cm.

22. a. 7.05×10^3 cm^3

b. nearest tenth of a cm; nearest 10 cm^3

c. 243.6 cm

d. nearest tenth of a cm; nearest tenth of a cm

23. A result can never be more precise than the least precise measurement. The calculated average lap time exceeds the precision possible with the clock.

1.3 Graphing Data

A well-designed graph can convey information quickly and simply. Patterns that are not immediately evident in a list of numbers take shape when the data are graphed. In this section, you will develop graphing techniques that will enable you to display, analyze, and model data.

Objectives
- **Graph** the relationship between independent and dependent variables.
- **Interpret** graphs.
- **Recognize** common relationships in graphs.

Vocabulary

independent variable
dependent variable
line of best fit
linear relationship
quadratic relationship
inverse relationship

Identifying Variables

When you perform an experiment, it is important to change only one factor at a time. For example, **Table 1-3** gives the length of a spring with different masses attached, as measured in the Mini Lab. Only the mass varies; if different masses were hung from different types of springs, you wouldn't know how much of the difference between two data pairs was due to the different masses and how much to the different springs.

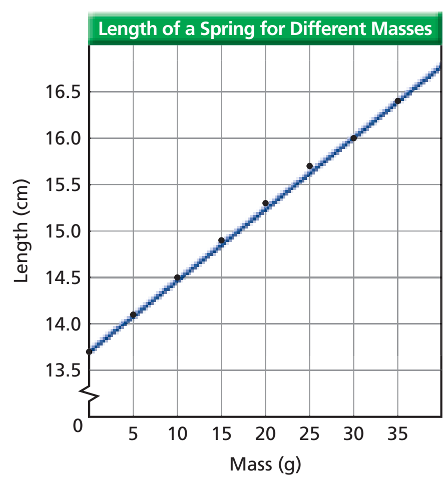
Table 1-3
Length of a Spring for Different Masses

Mass Attached to Spring (g)	Length of Spring (cm)
0	13.7
5	14.1
10	14.5
15	14.9
20	15.3
25	15.7
30	16.0
35	16.4

A *variable* is any factor that might affect the behavior of an experimental setup. The **independent variable** is the factor that is changed or manipulated during the experiment. In this experiment, the mass was the independent variable. The **dependent variable** is the factor that depends on the independent variable. In this experiment, the amount that the spring stretched depended on the mass. An experiment might look at how radioactivity varies with time, how friction changes with weight, or how the strength of a magnetic field depends on the distance from a magnet.

One way to analyze data is to make a line graph. This shows how the dependent variable changes with the independent variable. The data from Table 1-3 are graphed in black in **Figure 1-15.** The line in blue, drawn as close to all the data points as possible, is called a **line of best fit.** The line of best fit is a better model for predictions than any one point that helps determine the line. The problem-solving strategy on the next page gives detailed instructions for graphing data and sketching a line of best fit.

■ **Figure 1-15** The independent variable, mass, is on the horizontal axis. The graph shows that the length of the spring increases as the mass suspended from the spring increases.



Section 1.3

1 FOCUS

Bellringer Activity

Graphs First, show students a data table and a graph of the same data. Ask them to tell you which one they can understand more quickly. Second, show them a graph from some nonphysics context—something like number of sales versus hour of the day or number of cars through an intersection versus day of the week. Ask them what the graph represents and who might be interested in the information it conveys. Finally, show them a graph with no labels on the axes. Ask them what it represents. When they respond that they don't know, ask them why they can't tell; emphasize the importance of labeling. This activity can be expanded to show other graphs missing important elements. **L2 Visual-Spatial**

Tie to Prior Knowledge

Graphs Students have graphed equations in math classes before. They should be somewhat familiar with exponents and with equations for lines and parabolas. Students who have had chemistry should know about the importance of units.

2 TEACH

Identifying Misconceptions

Slope Show students an *x*-*y* graph of two parallel lines, with one line shorter than the other. Ask them which has a greater slope. Some may respond that the longer line has a greater slope, but inspection shows that the slopes in both graphs are the same. Mathematically, $\Delta y_1/\Delta x_1 = \Delta y_2/\Delta x_2$ **L2 Logical-Mathematical**

1.3 Resource MANAGER

FAST FILE Chapters 1–5 Resources
- Transparency 1–4 Master, p. 29
- Study Guide, pp. 9–14
- Reinforcement, pp. 19–20
- Enrichment, pp. 21–22
- Section 1–3 Quiz, p. 17
- Internet Physics Lab Worksheet, pp. 5–8

Teaching Transparency 1-4
Connecting Math to Physics

Technology
- TeacherWorks™ CD-ROM
- Interactive Chalkboard CD-ROM
- Exam*View*® Pro Testmaker CD-ROM
- physicspp.com
- physicspp.com/vocabulary_puzzlemaker

Using an Analogy

Steps and Slopes Point out to students how climbing steps is analogous to finding the slope. Use math to explain that "rise over run" is the same as $\Delta y/\Delta x$, where Δy is equal to the number of steps they climb up times the height of each step and Δx is the number of steps times the depth of each step. That is, Δx measures distance as the length along the x-axis.

Additional MINI LAB

How Far Around?

Purpose Give students practice with measurement, graphing, and graph interpretation.

Materials meterstick, string, four circular objects

Procedure Instruct the students to use a meterstick to measure the diameter of four circular objects and a string and meterstick to measure their circumferences. Instruct them to record their data in a table, then graph circumference versus diameter. The recorder should write a few sentences to summarize the graph. Explain the meaning of the slope of the graph. The slope is π; the ratio of C to d is constant.

Assessment Would the slope have been different if students had measured in different units? no

Using Figure 1-16

Ask students how the line graph in Figure 1-16 would change if the data had been measured and recorded in English units instead of metric units. The graph using English units would be the same shape but the numbers on the axes would be different. L2

PROBLEM-SOLVING Strategies

Plotting Line Graphs

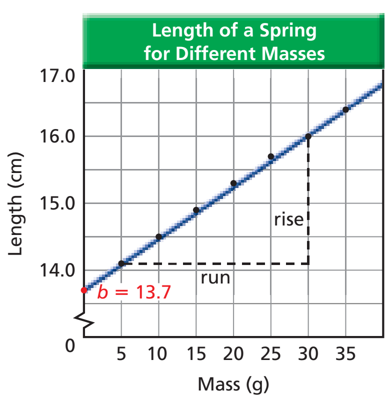
Connecting Math to Physics

Use the following steps to plot line graphs from data tables.

1. Identify the independent and dependent variables in your data. The independent variable is plotted on the horizontal axis, the x-axis. The dependent variable is plotted on the vertical axis, the y-axis.
2. Determine the range of the independent variable to be plotted.
3. Decide whether the origin (0, 0) is a valid data point.
4. Spread the data out as much as possible. Let each division on the graph paper stand for a convenient unit. This usually means units that are multiples of 2, 5, or 10.
5. Number and label the horizontal axis. The label should include the units, such as *Mass (grams).*
6. Repeat steps 2–5 for the dependent variable.
7. Plot the data points on the graph.
8. Draw the best-fit straight line or smooth curve that passes through as many data points as possible. This is sometimes called *eyeballing*. Do not use a series of straight line segments that connect the dots. The line that looks like the best fit to you may not be exactly the same as someone else's. There is a formal procedure, which many graphing calculators use, called the least-squares technique, that produces a unique best-fit line, but that is beyond the scope of this textbook.
9. Give the graph a title that clearly tells what the graph represents.

Math Handbook
Graphs of Relations
pages 848–852

■ **Figure 1-16** To find an equation of the line of best fit for a linear relationship, find the slope and y-intercept.



Linear Relationships

Scatter plots of data may take many different shapes, suggesting different relationships. (The line of best fit may be called a curve of best fit for nonlinear graphs.) Three of the most common relationships will be shown in this section. You probably are familiar with them from math class.

When the line of best fit is a straight line, as in Figure 1-15, the dependent variable varies linearly with the independent variable. There is a **linear relationship** between the two variables. The relationship can be written as an equation.

Linear Relationship Between Two Variables $y = mx + b$

Find the y-intercept, b, and the slope, m, as illustrated in **Figure 1-16.** Use points on the line—they may or may not be data points.

PHYSICS PROJECT Activity

Graphing Applications Ask students to go through newspapers or magazines to find examples of graphs that are trying to promote a product or viewpoint. Ask students to alter the graph somehow, such as modifying the scaling or the numbers on the axes to make a different visual impression. Ask students to write a short paragraph on how graphs can be designed with the purpose of misleading readers. L2 **Visual-Spatial**

The slope is the ratio of the vertical change to the horizontal change. To find the slope, select two points, A and B, far apart on the line. The vertical change, or rise, Δy, is the difference between the vertical values of A and B. The horizontal change, or run, Δx, is the difference between the horizontal values of A and B.

Slope $m = \frac{rise}{run} = \frac{\Delta y}{\Delta x}$

The slope of a line is equal to the rise divided by the run, which also can be expressed as the change in y divided by the change in x.

$$\text{In Figure 1-16: } m = \frac{(16.0 \text{ cm} - 14.1 \text{ cm})}{(30 \text{ g} - 5 \text{ g})}$$
$$= 0.08 \text{ cm/g}$$

If y gets smaller as x gets larger, then $\Delta y/\Delta x$ is negative, and the line slopes downward.

The y-intercept, b, is the point at which the line crosses the y-axis, and it is the y-value when the value of x is zero. In this example, $b = 13.7$ cm. When $b = 0$, or $y = mx$, the quantity y is said to vary directly with x.

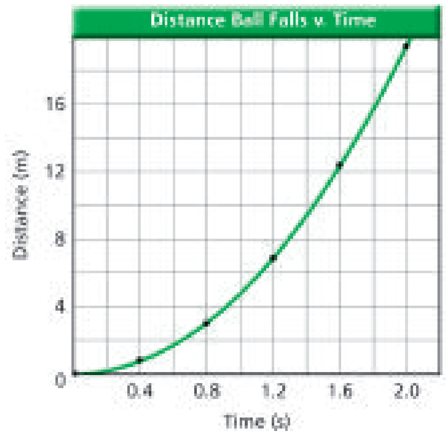


Figure 1-17 This graph indicates a quadratic, or parabolic, relationship.

Nonlinear Relationships

Figure 1-17 shows the distance a brass ball falls versus time. Note that the graph is not a straight line, meaning the relationship is not linear. There are many types of nonlinear relationships in science. Two of the most common are the quadratic and inverse relationships. The graph in Figure 1-17 is a **quadratic relationship,** represented by the following equation.

Quadratic Relationship Between Two Variables

$y = ax^2 + bx + c$

A quadratic relationship exists when one variable depends on the square of another.

Math Handbook
Quadratic Graphs page 852
Quadratic Equations page 846

A computer program or graphing calculator easily can find the values of the constants a, b, and c in this equation. In this case, the equation is $d = 5t^2$. See the Math Handbook in the back of the book for more on making and using line graphs.

CHALLENGE PROBLEM

An object is suspended from spring 1, and the spring's elongation (the distance it stretches) is X_1. Then the same object is removed from the first spring and suspended from a second spring. The elongation of spring 2 is X_2. X_2 is greater than X_1.

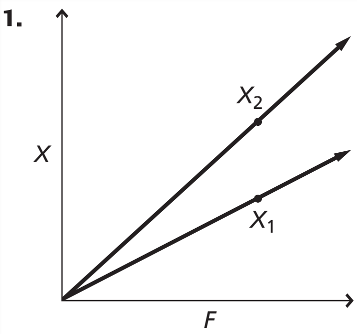
1. On the same axes, sketch the graphs of the mass versus elongation for both springs.
2. Is the origin included in the graph? Why or why not?
3. Which slope is steeper?
4. At a given mass, $X_2 = 1.6\ X_1$. If $X_2 = 5.3$ cm, what is X_1?

HELPING STRUGGLING STUDENTS Activity

Quadratic Relationships Give students several different sizes of cardboard squares. Have them measure the sides of each and compute the corresponding areas, then plot the area, A, as a function of the side length, x. Their line graphs will be parabolic curves. Have them compare their graphs to Figure 1-17 on page 17. Point out that the line graph shows the quadratic relationship, because one variable depends on the square of another. **L1 Kinesthetic**

CHALLENGE PROBLEM

1.



2. Yes; the origin corresponds to 0 elongation when the force is 0.
3. The slope for the second spring is steeper.
4. $X_2 = 1.6\ X_1$, $5.3 \text{ cm} = 1.6\ X_1$, $3.3 \text{ cm} = X_1$

QUICK DEMO

Types of Graphs

Estimated Time 15 minutes

Materials windup car or truck, meterstick, graph paper

Procedure Show students some sort of wind-up car or truck. Plot the distance that it travels as a function of the number of turns it is wound. From looking at the graph, have the students give their best guess as to what kind of relationship there is between the two (turns and distance). Is it linear, parabolic, inverse, or something else?

Reinforcement

Direct and Inverse Relationships Ask students to make a list of direct relationships and inverse relationships. After several minutes, ask a few students to write their ideas on the chalkboard and then lead a discussion for review. Make sure students state why they think a particular relationship is one or the other. **L2 Interpersonal**

Concept Development

Linear Relationships When discussing the slopes of graphs, the word "per" will come up frequently. Explain to the students that "per" means "for each" and get the students to articulate repeatedly what a particular slope means. For instance, ask students what 10 miles per gallon means. This means that for every one gallon of fuel used, the vehicle moves ten miles. **L2**

PRACTICE Problems

24. a. See Solutions Manual.

b. a straight line

c. The relationship is linear.

d. 19.3 g/cm^3

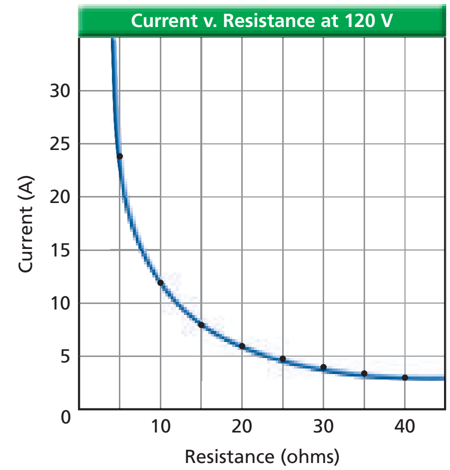
e. $m = (19.3\ \text{g/cm}^3)V$

f. The mass for each cubic centimeter of pure gold is 19.3 g.

Critical Thinking

Graphs for Predictions Physics is not the only area in which graphs can be used to make predictions. Ask students to consider other applications for graphing. As a class, have them describe numerous situations in which graphs could be used to make predictions. For example, plotting the average attendance at sporting events as a function of temperature can help the management of a stadium know how many vendors, ticket takers, and ushers they will need at an event. Plotting the average value of a stock index as a function of time of year can help brokers predict when to sell and when to buy. **L2 Interpersonal**

■ **Figure 1-18** This graph shows the inverse relationship between resistance and current. As resistance increases, current decreases.



The graph in **Figure 1-18** shows how the current in an electric circuit varies as the resistance is increased. This is an example of an **inverse relationship,** represented by the following equation.

Inverse Relationship $y = \frac{a}{x}$

A hyperbola results when one variable depends on the inverse of the other.

The three relationships you have learned about are a sample of the simple relations you will most likely try to derive in this course. Many other mathematical models are used. Important examples include sinusoids, used to model cyclical phenomena, and exponential growth and decay, used to study radioactivity. Combinations of different mathematical models represent even more complex phenomena.

PRACTICE Problems

Additional Problems, Appendix B

24. The mass values of specified volumes of pure gold nuggets are given in **Table 1-4.**

a. Plot mass versus volume from the values given in the table and draw the curve that best fits all points.

b. Describe the resulting curve.

c. According to the graph, what type of relationship exists between the mass of the pure gold nuggets and their volume?

d. What is the value of the slope of this graph? Include the proper units.

e. Write the equation showing mass as a function of volume for gold.

f. Write a word interpretation for the slope of the line.

Table 1-4
Mass of Pure Gold Nuggets

Volume (cm^3)	Mass (g)
1.0	19.4
2.0	38.6
3.0	58.1
4.0	77.4
5.0	96.5

CHALLENGE Activity

Filling a Beaker Give the students a large, graduated metric beaker and ask them to fill it using a slow trickle of water from a faucet. Have them repeat this with a fast flow of water. Tell the students that the volume of the beaker is measured in milliliters and the flow rate of the water can be measured in terms of milliliters per second. Ask the students to graph an inverse relationship associated with filling the beaker of water. Along with the graph, the students should identify the constant, the dependent variable, the independent variable, and the inverse relationship equation. **L3 Visual-Spatial**

■ **Figure 1-19** Computer animators use mathematical models of the real world to create a convincing fictional world. They need to accurately portray how beings of different sizes move, how hair or clothing move with a character, and how light and shadows fall, among other physics topics.

Predicting Values

When scientists discover relations like the ones shown in the graphs in this section, they use them to make predictions. For example, the equation for the linear graph in **Figure 1-16** is as follows:

$$y = (0.08\ \text{cm/g})x + 13.7\ \text{cm}$$

Relations, either learned as formulas or developed from graphs, can be used to predict values you haven't measured directly. How far would the spring in Table 1-3 stretch with 49 g of mass?

$$y = (0.08\ \text{cm/g})(49\ \text{g}) + 13.7\ \text{cm}$$
$$= 18\ \text{cm}$$

It is important to decide how far you can extrapolate from the data you have. For example, 49 kg is a value far outside the ones measured, and the spring might break rather than stretch that far.

Physicists use models to accurately predict how systems will behave: what circumstances might lead to a solar flare, how changes to a circuit will change the performance of a device, or how electromagnetic fields will affect a medical instrument. People in all walks of life use models in many ways. One example is shown in **Figure 1-19.** With the tools you have learned in this chapter, you can answer questions and produce models for the physics questions you will encounter in the rest of this textbook.

1.3 Section Review

25. Make a Graph Graph the following data. Time is the independent variable.

Time (s)	0	5	10	15	20	25	30	35
Speed (m/s)	12	10	8	6	4	2	2	2

26. Interpret a Graph What would be the meaning of a nonzero y-intercept to a graph of total mass versus volume?

27. Predict Use the relation illustrated in Figure 1-16 to determine the mass required to stretch the spring 15 cm.

28. Predict Use the relation in Figure 1-18 to predict the current when the resistance is 16 ohms.

29. Critical Thinking In your own words, explain the meaning of a shallower line, or a smaller slope than the one in Figure 1-16, in the graph of stretch versus total mass for a different spring.

Physics Online physicspp.com/self_check_quiz

0017_3949.ps

1.3 Section Review

25. See Solutions Manual.

26. There is a nonzero total mass when the volume of the material is zero. This could happen if the mass value includes the material's container.

27. 16 g

28. 7.5 A

29. The spring whose line has a smaller slope is stiffer, and therefore requires more mass to stretch it one centimeter.

3 ASSESS

Check for Understanding

Linear Graphs Ask each student to make a graph that shows a direct relationship. Ask students to put numerical values on the graph and to calculate the slope of the graph. After a few minutes, have them trade with a neighbor to check work. L2

Extension

Radius and Circumference Ask students to imagine a rope tied around Earth's equator and to assume that the surface is completely smooth all the way around ($C = 2\pi r$, let $r = 6400$ km). Then ask how far above the surface the rope would be if the amount of rope were increased by approximately 200 km. approximately 31 km (mathematical shortcut: divide the length added to the circumference, 200 km, by 2π) L3

PHYSICSLAB • Internet

Time Allotment
one laboratory period

Process Skills observe, measure, estimate, collect and organize data, identify variables

Safety Precautions none

Alternative Materials You could produce your own similar video to use in your classroom or use footage from a movie that has aerial footage, such as *Speed*. In this case, the distance between white lane stripes should be estimated.

Teaching Strategies

- **Have students form small groups so they can discuss their observations and point out features.**

Analyze

1. Answers will vary: Qualitative observations include color, relative speed (for example, fast), bumpy road, partly cloudy.
2. Answers will vary. Quantitative observations can include distance along the road between markers, number of vehicles seen, number of lanes, and number of striped lane markers.
3. Have students compare their graphs.
4. Answers will vary depending on the method used to measure the time for each vehicle to travel the two intervals between markers. Sample:
   v_{white} = distance/time
   = (0.644 km/28.0 s) (3600 s/h)
   = 82.8 km/h
   v_{grey} = (0.644 km/22.5 s) (3600 s/h)
   = 103 km/h

PHYSICSLAB • Internet

Benjamin Colman

Exploring Objects in Motion

Physics is a science that is based upon experimental observations. Many of the basic principles used to describe and understand mechanical systems, such as objects in linear motion, can be applied later to describe more complex natural phenomena. How can you measure the speed of the vehicles in a video clip?

QUESTION

What types of measurements could be made to find the speed of a vehicle?

Objectives

- **Observe** the motion of the vehicles seen in the video.
- **Describe** the motion of the vehicles.
- **Collect and organize data** on the vehicle's motion.
- **Calculate** a vehicle's speed.

Safety Precautions

Materials

Internet access is required.
watch or other timer

Procedure

1. Visit physicspp.com/internet_lab to view the Chapter 1 lab video clip.
2. The video footage was taken in the midwestern United States at approximately noon. Along the right shoulder of the road are large, white, painted rectangles. These types of markings are used in many states for aerial observation of traffic. They are placed at 0.322-km (0.2-mi) intervals.
3. **Observe** What type of measurements might be taken? Prepare a data table, such as the one shown on the next page. Record your observations of the surroundings, other vehicles, and markings. On what color vehicle is the camera located, and what color is the pickup truck in the lane to the left?
4. **Measure and Estimate** View the video again and look for more details. Is the road smooth? In what direction are the vehicles heading? How long does it take each vehicle to travel two intervals marked by the white blocks? Record your observations and data.

20

Sample Data

Vehicles are on a four-lane-wide freeway. The camera is in the white vehicle. The road appears to be bumpy as the camera moves up and down. The gray pickup truck passes on the left; it is moving faster and is speeding up. Surroundings: a partly cloudy day, with shadows toward the right; therefore, the vehicle is heading west. Three white markers are seen in the video. The third white marker occurs just before a white bridge is seen on the right. The bridge can be used to estimate the final position and the time for the pickup truck.

Data Table

Marker	Distance (km)	White Vehicle Time (s)	Gray Pickup Time (s)
0	0	0	0
1	0.322	14	12
2	0.644	28	22.5

Data Table

Marker	Distance (km)	White Vehicle Time (s)	Gray Pickup Time (s)

Analyze

1. Summarize your qualitative observations.
2. Summarize your quantitative observations.
3. **Make and Use Graphs** Graph both sets of data on one pair of axes.
4. **Estimate** What is the speed of the vehicles in km/s and km/h?
5. **Predict** How far will each vehicle travel in 5 min?

Conclude and Apply

1. **Measure** What is the precision of the distance and time measurements?
2. **Measure** What is the precision of your speed measurement? On what does it depend?
3. **Use Variables, Constants, and Controls** Describe the independent and the dependent variables in this experiment.
4. **Compare and Contrast** Which vehicle's graph has a steeper slope? What is the slope equal to?
5. **Infer** What would a horizontal line mean on the graph? A line with a steeper slope?

Going Further

Speed is distance traveled divided by the amount of time to travel that distance. Explain how you could design your own experiment to measure speed in the classroom using remote-controlled cars. What would you use for markers? How precisely could you measure distance and time? Would the angle at which you measured the cars passing the markers affect the results? How much? How could you improve your measurements? What units make sense for speed? How far into the future could you predict the cars' positions? If possible, carry out the experiment and summarize your results.

Real-World Physics

When the speedometer is observed by a front-seat passenger, the driver, and a passenger in the rear driver's-side seat, readings of 90 km/h, 100 km/h, and 110 km/h, respectively, are observed. Explain the differences.

Share Your Data

Design an Experiment Visit physicspp.com/internet_lab to post your experiment for measuring speed in the classroom using remote-controlled cars. Include your list of materials, your procedure, and your predictions for the accuracy of your lab. If you actually perform your lab, post your data and results as well.

Physics Online

To find out more about measurement, visit the Web site: physicspp.com

ALTERNATIVE INQUIRY LAB

To Make this Lab an Inquiry Lab: Alter the format to have students develop various techniques to measure the distance traveled, time, and speed of the vehicles more accurately. Ask students to think of ways they could change the experiment so it could be conducted in the real world. If time permits, allow them to test their procedures.

5. Answers will vary. Sample:

$$\begin{aligned} \textit{Distance}_{\text{white}} &= \textit{speed} \times \textit{time} \\ &= (0.0230\text{ km/s})(5 \times 60\text{ s}) \\ &= 6.9\text{ km} \end{aligned}$$

$$\begin{aligned} \textit{Distance}_{\text{gray}} &= \textit{speed} \times \textit{time} \\ &= (0.0286\text{ km/s})(5 \times 60\text{ s}) \\ &= 8.58\text{ km} \end{aligned}$$

Conclude and Apply

1. Answers will vary. The precision is one-half of the smallest measurement marks. The distance measurement is within ± 0.5 meter. The time measurement may be quite different depending on the method used. A stopwatch with one second increments will produce ± 0.5 second precision. A built-in timer on video playback software may have a precision of tenths or several hundredths of a second.
2. Precision depends on the precision of the measurements and their effect on the results of the calculation. The precision is ± 1 m/s.
3. Dependent variables: time; Independent variable: distance *Note:* This is reversed from what is typically measured in a speed-finding experiment.
4. The gray vehicle's graph has a steeper slope. The slope is equal to the speed of the vehicle, 28 m/s.
5. A horizontal line would mean that the vehicle is not moving. A line with a steeper slope would mean that the vehicle is traveling faster than the first vehicle.

Going Further

Answers will vary. Student responses should suggest protocols for ensuring accuracy, such as using evenly spaced markers. As for improving their measurements, rigging a motion detector to a digital chronometer has a far higher degree of accuracy than checking the second hand on a clock face.

Real-World Physics

Parallax creates the differences. The seats will not provide an accurate view of the speedometer. Looking straight at the speedometer will provide the most accurate reading.

Background

A computer can be described as a machine that can do anything with numbers. The fact that it uses binary numbers is irrelevant; what's important is that a number can be made to represent a color of a pixel (a tiny part of a picture), the pitch of a musical note, or a letter of the alphabet. Thus a computer can work with pictures, sounds, and text, besides doing arithmetic or geometry. The text assumes an understanding of binary numbers: if a musical note is represented by an 8-bit number, you can represent 256 (2^8) possible notes.

The construction of integrated circuits is more closely related to printing than to any sort of wiring. Think of a large picture that is reduced to microscopic size by looking at it through a reversed microscope. This picture is projected onto the chip, and then a photo-etching process is used to form the various structures.

Teaching Strategies

- Emphasize that software—such as e-mail programs, operating systems, video and audio "viewers"—conceals large math problems, such as the solution of large matrices and systems of differential equations.
- Some students may not be familiar with the internal parts of a computer. Use a computer or a diagram to explore the parts of a typical computer. Include in your discussion how the performance or capacity of the part is measured.

Activity

Consumer Electronics Have students examine the computing capabilities of some familiar electronic toys. The biggest and fastest computers used in many homes are video game consoles.

Future Technology

Computer History and Growth

Each pixel of the animations or movies you watch, and each letter of the instant messages you send presents your computer with several hundred equations. Each equation must be solved in a few billionths of a second—if it takes a bit longer, you might complain that your computer is slow.

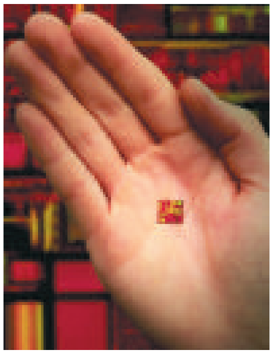
Early Computers The earliest computers could solve very complex arrays of equations, just as yours can, but it took them a lot longer to do so. There were several reasons for this. First, the mathematics of algorithms (problem-solving strategies) still was new. Computer scientists were only beginning to learn how to arrange a particular problem, such as the conversion of a picture into an easily-transmittable form, so that it could be solved by a machine.

UNIVAC 1, an early computer, filled an entire room.

Machine Size Second, the machines were physically large. Computers work by switching patterns of electric currents that represent binary numbers. A 16-bit machine works with binary numbers that are 16 bits long. If a 64-bit number must be dealt with, the machine must repeat the same operation four times. A 32-bit machine would have to repeat the operation only twice, thus making it that much faster. But a 32-bit machine is four times the size of a 16-bit machine; that is, it has four times as many wires and transistor switches, and even 8-bit machines were the size of the old UNIVAC shown above.

Moreover, current travels along wires at speeds no greater than about two-thirds the speed of light. This is a long time if the computer wires are 15 m long and must move information in less than 10^{-9} s.

Memory Third, electronic memories were extremely expensive. You may know that a larger memory lets your computer work faster. When one byte of memory required eight circuit boards, 1024 bytes (or 1 K) of memory was enormous. Because memory was so precious, computer programs had to be written with great cleverness. Astronauts got to the Moon with 64 K of memory in *Apollo's* on-board computers.



Processor chips used in today's computers are tiny compared to the old computer systems.

When Gordon Moore and others invented the integrated circuit around 1960, the size and cost of computer circuitry dropped drastically. Physically smaller, and thus faster, machines could be built and very large memories became possible. Today, the transistors on a chip are now smaller than bacteria.

The cost and size of computers have dropped so much that your cell phone has far more computing power than most big office machines of the 1970s.

Going Further

1. **Research** A compression protocol makes a computer file smaller and less prone to transmission errors. Look up the terms *.jpg*, *.mp3*, *.mpeg*, and *.midi* and see how they apply to the activities you do on your computer.
2. **Calculate** Using the example here, how long does it take for a binary number to travel 15 m? How many such operations could there be each second?

CORBIS

Going Further

1. These denote files that are mathematical representations of photographs (.jpg), musical selections (.mp3, .midi) or motion pictures (.mpeg). These representations are written in a very elaborate code that greatly reduces the amount of memory occupied by the song or picture.
2. velocity $= \frac{2}{3}(3\times10^8 \text{ m/s}) = 2\times10^8 \text{ m/s}$

   time $=$ distance/velocity $= \dfrac{15 \text{ m}}{2\times10^8 \text{ m/s}}$

   $= 7.5\times10^{-8}$ s

   $\dfrac{1}{7.5\times10^{-8}\text{ s}} = 13$ MHz, which is a fairly slow computer.

Study Guide

1.1 Mathematics and Physics

Vocabulary

- physics (p. 3)
- dimensional analysis (p. 6)
- significant digits (p. 7)
- scientific method (p. 8)
- hypothesis (p. 8)
- scientific law (p. 9)
- scientific theory (p. 10)

Key Concepts

- Physics is the study of matter and energy and their relationships.
- Dimensional analysis is used to check that an answer will be in the correct units.
- The result of any mathematical operation with measurements never can be more precise than the least-precise measurement involved in the operation.
- The scientific method is a systematic method of observing, experimenting, and analyzing to answer questions about the natural world.
- Scientific ideas change in response to new data.
- Scientific laws and theories are well-established descriptions and explanations of nature.

1.2 Measurement

Vocabulary

- measurement (p. 11)
- precision (p. 12)
- accuracy (p. 13)

Key Concepts

- New scientific findings must be reproducible; that is, others must be able to measure and find the same results.
- All measurements are subject to some uncertainty.
- Precision is the degree of exactness with which a quantity is measured. Scientific notation shows how precise a measurement is.
- Accuracy is the extent to which a measurement matches the true value.

1.3 Graphing Data

Vocabulary

- independent variable (p. 15)
- dependent variable (p. 15)
- line of best fit (p. 15)
- linear relationship (p. 16)
- quadratic relationship (p. 17)
- inverse relationship (p. 18)

Key Concepts

- Data are plotted in graphical form to show the relationship between two variables.
- The line that best passes through or near graphed data is called the line of best fit. It is used to describe the data and to predict where new data would lie on the graph.
- A graph in which data points lie on a straight line is a graph of a linear relationship. In the equation, m and b are constants.

$$y = mx + b$$

- The slope of a straight-line graph is the vertical change (rise) divided by the horizontal change (run) and often has a physical meaning.

$$m = \frac{rise}{run} = \frac{\Delta y}{\Delta x}$$

- The graph of a quadratic relationship is a parabolic curve. It is represented by the equation below. The constants a, b, and c can be found with a computer or a graphing calculator; simpler ones can be found using algebra.

$$y = ax^2 + bx + c$$

- The graph of an inverse relationship between x and y is a hyperbolic curve. It is represented by the equation below, where a is a constant.

$$y = \frac{a}{x}$$

Physics Online physicspp.com/vocabulary_puzzlemaker

Key Concepts

Summary statements can be used by students to review the major concepts of the chapter.

Physics Online

Visit physicspp.com
/self_check_quiz
/vocabulary_puzzlemaker
/chapter_test
/standardized_test

VOCABULARY PuzzleMaker

For additional help with vocabulary, have students access the Vocabulary PuzzleMaker online.

physicspp.com/vocabulary_puzzlemaker

Concept Mapping

30. See Solutions Manual.

Mastering Concepts

31. Identify a problem, gather information about it by observing and experimenting, analyze the information to arrive at an answer.

32. Mathematics allows you to be quantitative, to say "how fast", not just "fast".

33. The International System of Units, or SI, is a base 10 system of measurement that is the standard in science. The base units are the meter, kilogram, second, kelvin, mole, ampere, and candela.

34. The derived units are combinations of the base units.

35. a. Zeros are necessary to indicate the magnitude of the value, but there is no way of knowing whether or not the instrument used to measure the values actually measured the zeros. The zeros may serve only to locate the 1.

b. Write the number in scientific notation, including only the significant digits.

36. a. centimeter

b. millimeter

c. kilometer

37. $\frac{60\text{ min}}{1\text{ h}}$

38. a. 3.49×10^5 g

b. 2.87×10^5 J/cm^3

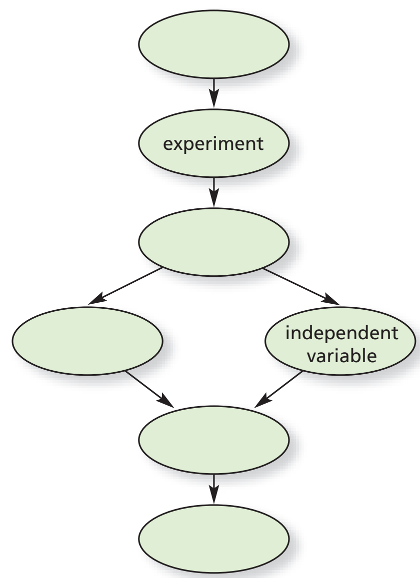
39. the precision of a measuring device, which is limited by the finest division on its scale

40. The final digit is estimated.

41. The most accurate measure is the measure closest to the actual distance.The odometer is probably more accurate as it actually covered the distance. The map is a model made from

Concept Mapping

30. Complete the following concept map using the following terms: *hypothesis, graph, mathematical model, dependent variable, measurement.*



Mastering Concepts

31. Describe a scientific method. (1.1)

32. Why is mathematics important to science? (1.1)

33. What is the SI system? (1.1)

34. How are base units and derived units related? (1.1)

35. Suppose your lab partner recorded a measurement as 100 g. (1.1)

a. Why is it difficult to tell the number of significant digits in this measurement?

b. How can the number of significant digits in such a number be made clear?

36. Give the name for each of the following multiples of the meter. (1.1)

a. $\frac{1}{100}$ m **b.** $\frac{1}{1000}$ m **c.** 1000 m

37. To convert 1.8 h to minutes, by what conversion factor should you multiply? (1.1)

38. Solve each problem. Give the correct number of significant digits in the answers. (1.1)

a. 4.667×10^4 g + 3.02×10^5 g

b. $(1.70\times10^2\text{ J}) \div (5.922\times10^{-4}\text{ cm}^3)$

39. What determines the precision of a measurement? (1.2)

40. How does the last digit differ from the other digits in a measurement? (1.2)

41. A car's odometer measures the distance from home to school as 3.9 km. Using string on a map, you find the distance to be 4.2 km. Which answer do you think is more accurate? What does *accurate* mean? (1.2)

42. How do you find the slope of a linear graph? (1.3)

43. For a driver, the time between seeing a stoplight and stepping on the brakes is called reaction time. The distance traveled during this time is the reaction distance. Reaction distance for a given driver and vehicle depends linearly on speed. (1.3)

a. Would the graph of reaction distance versus speed have a positive or a negative slope?

b. A driver who is distracted has a longer reaction time than a driver who is not. Would the graph of reaction distance versus speed for a distracted driver have a larger or smaller slope than for a normal driver? Explain.

44. During a laboratory experiment, the temperature of the gas in a balloon is varied and the volume of the balloon is measured. Which quantity is the independent variable? Which quantity is the dependent variable? (1.3)

45. What type of relationship is shown in **Figure 1-20?** Give the general equation for this type of relation. (1.3)

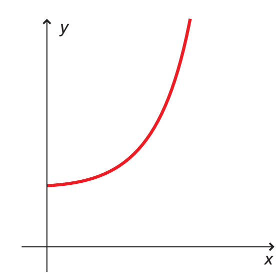


Figure 1-20

46. Given the equation $F = mv^2/R$, what relationship exists between each of the following? (1.3)

a. F and R

b. F and m

c. F and v

 For more problems, go to Additional Problems, Appendix B.

measurements, so your measurements from the map are more removed from the real distance.

42. The slope of a linear graph is the ratio of the vertical change to the horizontal change, or rise over run.

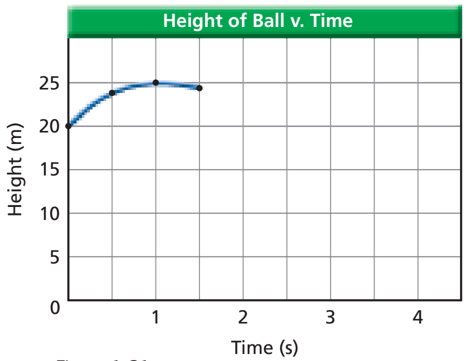
43. a. positive

b. Larger. The driver who was distracted would have a longer reaction time and thus a greater reaction distance at a given speed.

44. Temperature is the independent variable; volume is the dependent variable.

Applying Concepts

47. **Figure 1-21** gives the height above the ground of a ball that is thrown upward from the roof of a building, for the first 1.5 s of its trajectory. What is the ball's height at $t = 0$? Predict the ball's height at $t = 2$ s and at $t = 5$ s.



■ **Figure 1-21**

48. Is a scientific method one set of clearly defined steps? Support your answer.

49. Explain the difference between a scientific theory and a scientific law.

50. **Density** The density of a substance is its mass per unit volume.
a. Give a possible metric unit for density.
b. Is the unit for density a base unit or a derived unit?

51. What metric unit would you use to measure each of the following?
a. the width of your hand
b. the thickness of a book cover
c. the height of your classroom
d. the distance from your home to your classroom

52. **Size** Make a chart of sizes of objects. Lengths should range from less than 1 mm to several kilometers. Samples might include the size of a cell, the distance light travels in 1 s, and the height of a room.

53. **Time** Make a chart of time intervals. Sample intervals might include the time between heartbeats, the time between presidential elections, the average lifetime of a human, and the age of the United States. Find as many very short and very long examples as you can.

54. **Speed of Light** Two students measure the speed of light. One obtains $(3.001 \pm 0.001)\times10^8$ m/s; the other obtains $(2.999 \pm 0.006)\times10^8$ m/s.
a. Which is more precise?
b. Which is more accurate? (You can find the speed of light in the back of this textbook.)

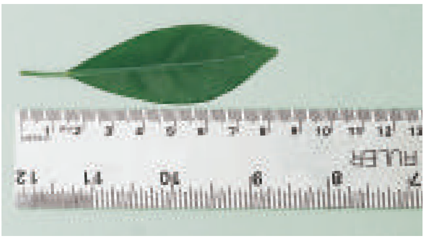
55. You measure the dimensions of a desk as 132 cm, 83 cm, and 76 cm. The sum of these measures is 291 cm, while the product is 8.3×10^5 cm^3. Explain how the significant digits were determined in each case.

56. **Money** Suppose you receive \$5.00 at the beginning of a week and spend \$1.00 each day for lunch. You prepare a graph of the amount you have left at the end of each day for one week. Would the slope of this graph be positive, zero, or negative? Why?

57. Data are plotted on a graph, and the value on the y-axis is the same for each value of the independent variable. What is the slope? Why? How does y depend on x?

58. **Driving** The graph of braking distance versus car speed is part of a parabola. Thus, the equation is written $d = av^2 + bv + c$. The distance, d, has units in meters, and velocity, v, has units in meters/second. How could you find the units of a, b, and c? What would they be?

59. How long is the leaf in **Figure 1-22?** Include the uncertainty in your measurement.



■ **Figure 1-22**

60. The masses of two metal blocks are measured. Block A has a mass of 8.45 g and block B has a mass of 45.87 g.
a. How many significant digits are expressed in these measurements?
b. What is the total mass of block A plus block B?
c. What is the number of significant digits for the total mass?
d. Why is the number of significant digits different for the total mass and the individual masses?

61. **History** Aristotle said that the speed of a falling object varies inversely with the density of the medium through which it falls.
a. According to Aristotle, would a rock fall faster in water (density 1000 kg/m^3), or in air (density 1 kg/m^3)?
b. How fast would a rock fall in a vacuum? Based on this, why would Aristotle say that there could be no such thing as a vacuum?

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Laura Sifferlin

Chapter 1 Assessment

45. quadratic; $y = ax^2 + bx + c$

46. **a.** inverse relationship
b. linear relationship
c. quadratic relationship

Applying Concepts

47. When $t = 0$ and $t = 2$, the ball's height will be about 20 m. When $t = 5$, the ball will have landed on the ground, so the height will be 0 m.

48. There is no definite order of specific steps. However, whatever approach is used, it always includes close observation, controlled experimentation, summarizing, checking, and rechecking.

49. A scientific law is a rule of nature, where a scientific theory is an explanation of the scientific law based on observation. A theory explains why something happens; a law describes what happens.

50. **a.** possible answers include g/cm^3, kg/m^3
b. derived unit

51. **a.** cm **b.** mm
c. m **d.** km

52. sample answer: radius of the atom, 5×10^{-11} m; virus, 10^{-7} m; thickness of paper, 0.1 mm; width of paperback book, 10.7 cm; height of a door, 1.8 m; width of town, 7.8 km; radius of Earth, 6×10^6 m; distance to Moon, 4×10^8 m

53. sample answer: half-life of polonium 194, 0.7 s; time between heartbeats, 0.8 s; time to walk between physics class and math class, 2.4 min; length of school year, 180 days; time between elections for the U.S. House of Representatives, 2 years; time between U.S. presidential elections, 4 years; age of the United States, (about) 230 years

54. **a.** $(3.001 \pm 0.001)\times10^8$ m/s
b. $(2.999 \pm 0.006)\times10^8$ m/s

55. In addition and subtraction, you ask what place the least precise measure is known to: in this case, to the nearest cm. So the answer is rounded to the nearest cm. In multiplication and division, you look at the number of significant digits in the least precise answer: in this case, 2. So the answer is rounded to 2 significant digits.

56. negative, because the change in vertical distance is negative for a positive change in horizontal distance

57. Zero. The change in vertical distance is zero. y does not depend on x.

58. The units in each term of the equation must be in meters because distance, d, is measured in meters. $av^2 = a(\text{m/s})^2$, so a is in s^2/m; $bv = b(\text{m/s})$, so b is in s^{-1}.

59. 8.3 cm $\pm$ 0.05 cm or 83 mm $\pm$ 0.5 mm

60. **a.** A: three; B: four
b. 54.32 g
c. four
d. When adding measurements, the precision matters: both masses are known to the nearest hundredth of a gram, so the total should be given to the nearest hundredth of a gram. Significant digits sometimes are gained when adding.

61. **a.** Lower density means faster speed, so the rock falls faster in air.
b. Because a vacuum would have a zero density, the rock should fall infinitely fast. Nothing can fall that fast.

62. A scientific theory has been tested and supported many times before it becomes accepted. A hypothesis is an idea about how things might work—it has much less support.

63. Newton's laws of motion, law of conservation of energy, law of conservation of change, law of reflection

64. Air resistance affects many light objects. Without controlled experiments, their everyday observations told them that heavier objects did fall faster.

65. As telescopes improved and later probes were sent into space, scientists gained more information about the surface. When the information did not support old hypotheses, the hypotheses changed.

66. $\pm$0.5 mL

Mastering Problems

1.1 Mathematics and Physics

67. **a.** 0.423 m
b. 6.2×10^{-12} m
c. 2.1×10^{4} m
d. 2.3×10^{-5} m
e. 2.14×10^{-4} m
f. 5.7×10^{-8} m

62. Explain the difference between a hypothesis and a scientific theory.

63. Give an example of a scientific law.

64. What reason might the ancient Greeks have had not to question the hypothesis that heavier objects fall faster than lighter objects? *Hint: Did you ever question which falls faster?*

65. Mars Explain what observations led to changes in scientists' ideas about the surface of Mars.

66. A graduated cylinder is marked every mL. How precise a measurement can you make with this instrument?

Mastering Problems

1.1 Mathematics and Physics

67. Convert each of the following measurements to meters.
a. 42.3 cm
b. 6.2 pm
c. 21 km
d. 0.023 mm
e. 214 μm
f. 57 nm

68. Add or subtract as indicated.
a. 5.80×10^{9} s + 3.20×10^{8} s
b. 4.87×10^{-6} m − 1.93×10^{-6} m
c. 3.14×10^{-5} kg + 9.36×10^{-5} kg
d. 8.12×10^{7} g − 6.20×10^{6} g

69. Rank the following mass measurements from least to greatest: 11.6 mg, 1021 μg, 0.000006 kg, 0.31 mg.

70. State the number of significant digits in each of the following measurements.
a. 0.00003 m
b. 64.01 fm
c. 80.001 m
d. 0.720 μg
e. 2.40×10^{6} kg
f. 6×10^{8} kg
g. 4.07×10^{16} m

71. Add or subtract as indicated.
a. 16.2 m + 5.008 m + 13.48 m
b. 5.006 m + 12.0077 m + 8.0084 m
c. 78.05 cm^2 − 32.046 cm^2
d. 15.07 kg − 12.0 kg

72. Multiply or divide as indicated.
a. $(6.2\times10^{18}\ \text{m})(4.7\times10^{-10}\ \text{m})$
b. $(5.6\times10^{-7}\ \text{m})/(2.8\times10^{-12}\ \text{s})$
c. $(8.1\times10^{-4}\ \text{km})(1.6\times10^{-3}\ \text{km})$
d. $(6.5\times10^{5}\ \text{kg})/(3.4\times10^{3}\ \text{m}^3)$

73. Gravity The force due to gravity is $F = mg$ where $g = 9.80\ \text{m/s}^2$.
a. Find the force due to gravity on a 41.63-kg object.
b. The force due to gravity on an object is 632 kg·m/s². What is its mass?

74. Dimensional Analysis Pressure is measured in pascals, where 1 Pa = 1 kg/m·s². Will the following expression give a pressure in the correct units?

$$\frac{(0.55\ \text{kg})(2.1\ \text{m/s})}{9.8\ \text{m/s}^2}$$

1.2 Measurement

75. A water tank has a mass of 3.64 kg when it is empty and a mass of 51.8 kg when it is filled to a certain level. What is the mass of the water in the tank?

76. The length of a room is 16.40 m, its width is 4.5 m, and its height is 3.26 m. What volume does the room enclose?

77. The sides of a quadrangular plot of land are 132.68 m, 48.3 m, 132.736 m, and 48.37 m. What is the perimeter of the plot?

78. How precise a measurement could you make with the scale shown in **Figure 1-23?**

Figure 1-23

79. Give the measure shown on the meter in **Figure 1-24** as precisely as you can. Include the uncertainty in your answer.

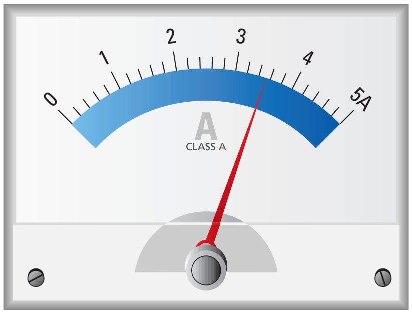

Figure 1-24

 For more problems, go to Additional Problems, Appendix B.
Horizons Companies

68. **a.** 6.12×10^{9} s **b.** 2.94×10^{-6} m
c. 1.250×10^{-4} kg **d.** 7.50×10^{7} g

69. 0.31 mg, 1021 μg, 0.000006 kg, 11.6 mg

70. **a.** 1 **b.** 4 **c.** 5
d. 3 **e.** 3 **f.** 1
g. 3

71. **a.** 34.7 m **b.** 25.022 m
c. 46.00 cm^2 **d.** 3.1 kg

80. Estimate the height of the nearest door frame in centimeters. Then measure it. How accurate was your estimate? How precise was your estimate? How precise was your measurement? Why are the two precisions different?

81. Base Units Give six examples of quantities you might measure in a physics lab. Include the units you would use.

82. Temperature The temperature drops from 24°C to 10°C in 12 hours.
- **a.** Find the average temperature change per hour.
- **b.** Predict the temperature in 2 more hours if the trend continues.
- **c.** Could you accurately predict the temperature in 24 hours?

1.3 Graphing Data

83. Figure 1-25 shows the masses of three substances for volumes between 0 and 60 cm^3.
- **a.** What is the mass of 30 cm^3 of each substance?
- **b.** If you had 100 g of each substance, what would be their volumes?
- **c.** In one or two sentences, describe the meaning of the slopes of the lines in this graph.
- **d.** What is the y-intercept of each line? What does it mean?

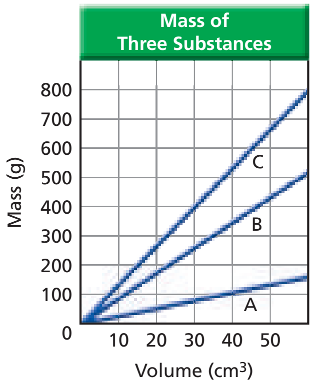

Figure 1-25

84. During a class demonstration, a physics instructor placed a mass on a horizontal table that was nearly frictionless. The instructor then applied various horizontal forces to the mass and measured the distance it traveled in 5 seconds for each force applied. The results of the experiment are shown in **Table 1-5.**

Table 1-5
Distance Traveled with Different Forces

Force (N)	Distance (cm)
5.0	24
10.0	49
15.0	75
20.0	99
25.0	120
30.0	145

- **a.** Plot the values given in the table and draw the curve that best fits all points.
- **b.** Describe the resulting curve.
- **c.** Use the graph to write an equation relating the distance to the force.
- **d.** What is the constant in the equation? Find its units.
- **e.** Predict the distance traveled when a 22.0-N force is exerted on the object for 5 s.

85. The physics instructor from the previous problem changed the procedure. The mass was varied while the force was kept constant. Time and distance were measured, and the acceleration of each mass was calculated. The results of the experiment are shown in **Table 1-6.**

Table 1-6
Acceleration of Different Masses

Mass (kg)	Acceleration (m/s^2)
1.0	12.0
2.0	5.9
3.0	4.1
4.0	3.0
5.0	2.5
6.0	2.0

- **a.** Plot the values given in the table and draw the curve that best fits all points.
- **b.** Describe the resulting curve.
- **c.** According to the graph, what is the relationship between mass and the acceleration produced by a constant force?
- **d.** Write the equation relating acceleration to mass given by the data in the graph.
- **e.** Find the units of the constant in the equation.
- **f.** Predict the acceleration of an 8.0-kg mass.

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72. a. 2.9×10^9 m^2
b. 2.0×10^5 m/s
c. 1.3×10^{-6} km^2
d. 1.9×10^2 kg/m^3

73. a. 408 kg·m/s^2
b. 64.5 kg

74. No; it is in kg/s^3

1.2 Measurement

75. 48.2 kg

76. 2.4×10^2 m^3

77. 362.1 m

78. ±0.5 g

79. 3.6 ± 0.1 A

80. A standard residential door frame height is about 80 inches, which is about 200 cm. The precision depends on the measurement instrument used.

81. Sample: distance, cm; volume, mL; mass, g; current, A; time, s; temperature, °C

82. a. 1.2°C/h
b. 8°C
c. No. Temperature is unlikely to continue falling sharply and steadily that long.

1.3 Graphing Data

83. a. (a) 80 g, (b) 260 g, (c) 400 g
b. (a) 36 cm^3, (b) 11 cm^3, (c) 7 cm^3
c. The slope represents the increased mass of each additional cubic centimeter of the substance.
d. The y-intercept is (0, 0). It means that when $V = 0$ cm^3, there is none of the substance present ($m = 0$ g)

84. a. See Solutions Manual.
b. a straight line
c. $d = 4.9F$
d. The constant is 4.9 and has units cm/N.
e. 108 cm or 110 cm using 2 significant digits

85. a. See Solutions Manual.
b. a hyperbola
c. Acceleration varies inversely with mass.
d. $a = 12/m$
e. kg·m/s^2
f. 1.5 m/s^2

86. a. See Solutions Manual.
b. a straight line
c. $m = 0.79V$
d. g/cm^3; density
e. 25.7 g

Mixed Review

87. 0.0034, 45.6, 1234

88. 80 meters is equivalent to about 260 feet, which would be very large. 10 meters would be a more reasonable value.

89. 162 shorts = 1.00 long

90. volume = 1.87×10^{-4} m^3, density = 8.87 g/cm^3

91. 5.4×10^{7} yr

92. 8.00 g/cm^3

Thinking Critically

93. The "right" question is one that points to fruitful research and to other questions that can be answered.

94. Volume of water is (140 cm)(60.0 cm)(34.0 cm) = 285,600 cm^3. Because the density of water is 1.00 g/cm^3, the mass of water in kilograms is 286 kg.

95. 0.0494 g/cm^3

96. mass of ball, footing, practice, and conditioning

97. 8.31 min; 43.2 min

Writing in Physics

98. Answers will vary.

99. For example, students might suggest that improved precision can lead to better observations.

86. During an experiment, a student measured the mass of 10.0 cm^3 of alcohol. The student then measured the mass of 20.0 cm^3 of alcohol. In this way, the data in **Table 1-7** were collected.

Table 1-7
The Mass Values of Specific Volumes of Alcohol

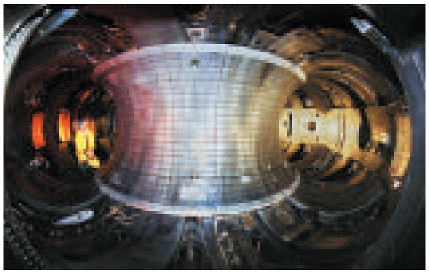
Volume (cm^3)	Mass (g)
10.0	7.9
20.0	15.8
30.0	23.7
40.0	31.6
50.0	39.6

a. Plot the values given in the table and draw the curve that best fits all the points.
b. Describe the resulting curve.
c. Use the graph to write an equation relating the volume to the mass of the alcohol.
d. Find the units of the slope of the graph. What is the name given to this quantity?
e. What is the mass of 32.5 cm^3 of alcohol?

Mixed Review

87. Arrange the following numbers from most precise to least precise
0.0034 m   45.6 m   1234 m

88. **Figure 1-26** shows the toroidal (doughnut-shaped) interior of the now-dismantled Tokamak Fusion Test Reactor. Explain why a width of 80 m would be an unreasonable value for the width of the toroid. What would be a reasonable value?



■ Figure 1-26

89. You are cracking a code and have discovered the following conversion factors: 1.23 longs = 23.0 mediums, and 74.5 mediums = 645 shorts. How many shorts are equal to one long?

90. You are given the following measurements of a rectangular bar: length = 2.347 m, thickness = 3.452 cm, height = 2.31 mm, mass = 1659 g. Determine the volume, in cubic meters, and density, in g/cm^3, of the beam. Express your results in proper form.

91. A drop of water contains 1.7×10^{21} molecules. If the water evaporated at the rate of one million molecules per second, how many years would it take for the drop to completely evaporate?

92. A 17.6-gram sample of metal is placed in a graduated cylinder containing 10.0 cm^3 of water. If the water level rises to 12.20 cm^3, what is the density of the metal?

Thinking Critically

93. Apply Concepts It has been said that fools can ask more questions than the wise can answer. In science, it is frequently the case that one wise person is needed to ask the right question rather than to answer it. Explain.

94. Apply Concepts Find the approximate mass of water in kilograms needed to fill a container that is 1.40 m long and 0.600 m wide to a depth of 34.0 cm. Report your result to one significant digit. (Use a reference source to find the density of water.)

95. Analyze and Conclude A container of gas with a pressure of 101 kPa has a volume of 324 cm^3 and a mass of 4.00 g. If the pressure is increased to 404 kPa, what is the density of the gas? Pressure and volume are inversely proportional.

96. Design an Experiment How high can you throw a ball? What variables might affect the answer to this question?

97. Calculate If the Sun suddenly ceased to shine, how long would it take Earth to become dark? (You will have to look up the speed of light in a vacuum and the distance from the Sun to Earth.) How long would it take the surface of Jupiter to become dark?

Writing in Physics

98. Research and describe a topic in the history of physics. Explain how ideas about the topic changed over time. Be sure to include the contributions of scientists and to evaluate the impact of their contributions on scientific thought and the world outside the laboratory.

99. Explain how improved precision in measuring time would have led to more accurate predictions about how an object falls.

 For more problems, go to Additional Problems, Appendix B.

Princeton Plasma Physics Laboratory

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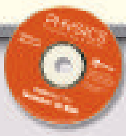

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Standardized Test Practice

Multiple Choice

1. Two laboratories use radiocarbon dating to measure the age of two wooden spear handles found in the same grave. Lab A finds an age of 2250 ± 40 years for the first object; lab B finds an age of 2215 ± 50 years for the second object. Which of the following is true?

- (A) Lab A's reading is more accurate than lab B's.
- (B) Lab A's reading is less accurate than lab B's.
- (C) Lab A's reading is more precise than lab B's.
- (D) Lab A's reading is less precise than lab B's.

2. Which of the following is equal to 86.2 cm?

- (A) 8.62 m
- (B) 0.862 mm
- (C) 8.62×10^{-4} km
- (D) 862 dm

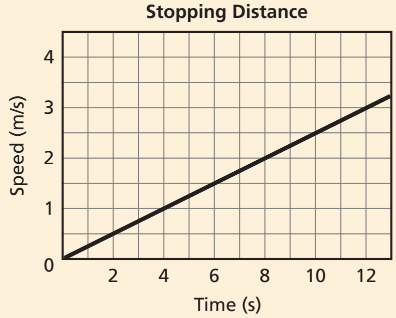
3. Jario has a problem to do involving time, distance, and velocity, but he has forgotten the formula. The question asks him for a measurement in seconds, and the numbers that are given have units of m/s and km. What could Jario do to get the answer in seconds?

- (A) Multiply the km by the m/s, then multiply by 1000.
- (B) Divide the km by the m/s, then multiply by 1000.
- (C) Divide the km by the m/s, then divide by 1000.
- (D) Multiply the km by the m/s, then divide by 1000.

4. What is the slope of the graph?

- (A) 0.25 m/s^2
- (B) 0.4 m/s^2
- (C) 2.5 m/s^2
- (D) 4.0 m/s^2

Stopping Distance



5. Which formula is equivalent to $D = \frac{m}{V}$?

- (A) $V = \frac{m}{D}$
- (B) $V = Dm$
- (C) $V = \frac{mD}{V}$
- (D) $V = \frac{D}{m}$

Extended Answer

6. You want to calculate an acceleration, in units of m/s^2, given a force, in N, and the mass, in g, on which the force acts. (1 N = 1 kg·m/s^2)

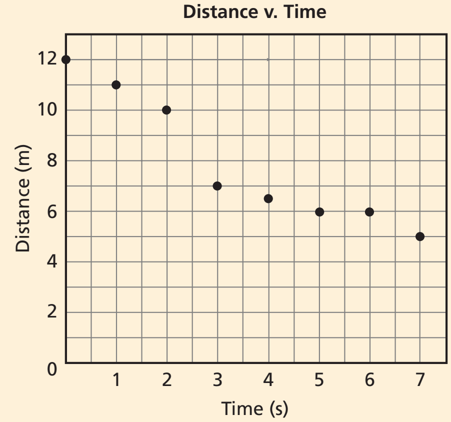
a. Rewrite the equation $F = ma$ so a is in terms of m and F.

b. What conversion factor will you need to multiply by to convert grams to kilograms?

c. A force of 2.7 N acts on a 350-g mass. Write the equation you will use, including the conversion factor, to find the acceleration.

7. Find an equation for a line of best fit for the data shown below.

Distance v. Time



✓Test-Taking TIP

Skip Around if You Can

You may want to skip over difficult questions and come back to them later, after you've answered the easier questions. This will guarantee more points toward your final score. In fact, other questions may help you answer the ones you skipped. Just be sure you fill in the correct ovals on your answer sheet.

Standardized Test Practice

Rubric

The following rubric is a sample scoring device for extended response questions.

Extended Response

Points	Description
4	The student demonstrates a thorough understanding of the physics involved. The response may contain minor flaws that do not detract from the demonstration of a thorough understanding.
3	The student demonstrates an understanding of the physics involved. The response is essentially correct and demonstrates an essential but less than thorough understanding of the physics.
2	The student demonstrates only a partial understanding of the physics involved. Although the student may have used the correct approach to a solution or may have provided a correct solution, the work lacks an essential understanding of the underlying physical concepts.
1	The student demonstrates a very limited understanding of the physics involved. The response is incomplete and exhibits many flaws.
0	The student provides a completely incorrect solution or no response at all.

Multiple Choice

1. C **2.** C **3.** B **4.** A **5.** A

Extended Answer

6. a. $a = \frac{f}{m}$

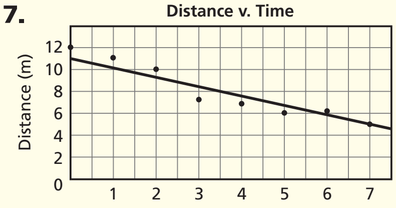
b. $\frac{1\text{ kg}}{1000\text{ g}}$

c. $a = \left(\frac{2.7\text{ kg·m/s}^2}{350\text{ g}}\right)\left(\frac{1000\text{ g}}{1\text{ kg}}\right)$

$= 7.7\text{ m/s}^2$

7.

Distance v. Time



$d = -\frac{6}{7}t + 11$