Skill and Practice Worksheets

cpo science

CPO Focus on Physical Science
Skill and Practice Worksheets

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Contents

SKILL and PRACTICE

1.1

Using Your Textbook

Your textbook is a tool to help you understand and enjoy science. Colors, shapes, and symbols are used in the book to help you find information quickly. Take a few minutes to get familiar with these features—it will help you get the most out of your book all year long.

READ CPO Science

Part 1: The Introduction

Take a look at the introduction found at the beginning of your textbook. These pages are easy to find because they have a light blue background. Use these pages and the rest of your book to answer the questions below.

1. What color is used to identify Unit 5?

2. List five important vocabulary words for section 2.1.

3. What color is the box in which you found these vocabulary words?

4. What is the main idea of the first paragraph on page 246?

5. Where do you find section review questions?

6. What is the first key question for chapter 13?

7. What color is the box that outlines sample problems in the text?

8. List the three sections of questions in each Chapter Assessment.

Part 2: The Table of Contents

The Table of Contents is found after the introduction pages. Use it to answer the following questions.

1. How many units are in the textbook? List their titles.

2. Which unit will be the most interesting to you? Why?

3. At the end of each chapter is a two-page article called a "Connection" which describes an interesting application of topics in the chapter. Look at all the Connection titles and list the three that interest you most.

4. What is on the page after each Connection?

Part 3: Tools at the end of the text

At the back of the book, you will find tools to help you use the text. Use these tools to answer the questions.

1. What is the definition for velocity?

2. On what pages will you find information on chemical bonds?

3. On what page will you find information on the discovery of the solar system?

4. List one of the California standards that describes what you should know about motion by the end of this course.

Stopwatch Math

READ 📖 CPO Science

What do horse racing, competitive swimming, stock car racing, speed skating, many track and field events, and some scientific experiments have in common? The need for some sort of stopwatch, and people to interpret the data. For competitive athletes in speed-related sports, finishing times (and split times taken at various intervals of a race) are important to help the athletes gauge progress and identify weaknesses so they can adjust their training and improve their performance.

EXAMPLE ▶

Three girls ran the following times for one mile in their gym class: Julie ran **9:33.2** (nine minutes, 33.2 seconds), Maggie ran **9:44.24** (nine minutes, 44.24 seconds), and Mel ran **9:33.27** (nine minutes, 33.27 seconds). In what order did they finish?

The girl who came in first is the one with the fastest (smallest) time. Compare each time digit by digit, starting with the largest place-value. Here, that would be the minutes place:

There is a "9" in the minutes' place of each time, so next, compare the seconds' place. Since Maggie's time has larger numbers in the seconds' place (**44**) than Julie or Mel (**33**), her time is larger (slower) than the other two. We know Maggie finished third out of the three girls. Now, comparing Julie's time (**9:33.2**) to Mel's (**9:33.27**), it is helpful to rewrite Julie's time (**9:33.2**) so that it has the same number of places as Mel's. Julie's time needs one more digit, so adding a zero onto the end of her time, it becomes **9:33.20**. Notice that Mel's time is larger (slower) than Julie's (**27 > 20**). This means that Julie's time was fastest (smallest), so she finished first, followed by Mel, and Maggie's time was the slowest (largest).

PRACTICE ▶ ~~〰~~

1. Put each set of times in order from fastest to slowest.

    a. **5.5   5.05   5   5.2   5.15**

Fastest							Slowest

    b. **6:06.04   6:06   6:06.4   6:06.004**

Fastest							Slowest

2. The table below gives the winners and their times from eight USA track and field championship races in the men's 100 meter run. Rewrite the table so that the times are in order from fastest to slowest. Please include the times and the years. Please note that the "w" that occurs next to some times indicates that the time was wind aided.

Year	2005	2004	2003	2002	2001	2000	1999	1998
Time	10.08	9.91	10.11	9.88w	9.95w	10.01	9.97w	9.88w
Name	Justin Gatlin	Maurice Greene	Bernard Williams	Maurice Greene	Tim Montgomery	Maurice Greene	Dennis Mitchell	Tim Harden

Time								
Year								

3. The following times were recorded during an experiment with battery powered cars. Please put them in order from fastest to slowest.

   a.   1:22.4   1:24.007   1:25   1:22.04   1:23.117   1:23.2   1:24   1:33

Fastest							Slowest

   b.   1:18.3   1:20.22   1:21.003   1:20   1:17.99   1:21.2   1:18.22

Fastest						Slowest

   c.   1:25   1:24.99   1:24.099   1:25.001   1:24.9901   1:24.9899

Fastest					Slowest

4. Write a set of five times (in order from fastest to slowest) that are all between 26:15.2 and 26:15.24. Do not include the given numbers in your set.

SI Units

READ CPO Science

In the late 1700's, as scientists began to develop the ideas of physics and chemistry, they needed better units of measurements to communicate scientific data more efficiently. Scientists needed to prove their ideas with data based on measurements that other scientists could reproduce. A decimal system of units based on the meter as a standard length, the kilogram as a standard mass, and the liter as a standard volume was developed by the French. Today this system is known as the SI system, or metric system. The equations below show how the meter is related to other units in this system of measurements.

$$1 \text{ meter} = 100 \text{ centimeters}$$
$$1 \text{ cubic centimeter} = 1 \text{ cm}^3 = 1 \text{ milliliter}$$
$$1000 \text{ milliliters} = 1 \text{ liter}$$

The SI system is easy to use because all the units are based on factors of 10. In the English system, there are 12 inches in a foot, 3 feet in a yard, and 5,280 feet in a mile. In the SI system, there are 10 millimeters in a centimeter, 100 centimeters in a meter, and 1,000 meters in a kilometer. From the graphic, how many kilometers is it from the North Pole to the equator?
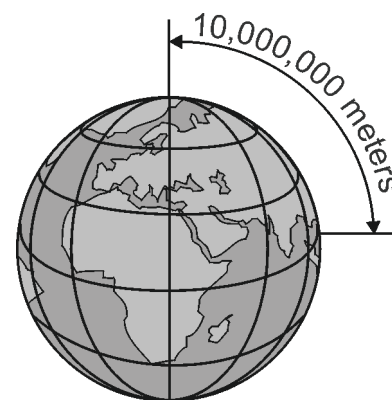
Answer: You need to convert 10,000,000 meters to kilometers. Since 1 meter = 0.001 kilometers, 0.001 is the multiplication factor. To solve, multiply 10,000,000 0.001 km = 10,000 km. So, it is 10,000 kilometers from the North Pole to the equator.

10,000,000 meters

These are the standard units of measurement that you will use in your scientific studies. The prefixes above are used with the base units when measuring very large or very small quantities.

When you are measuring:	Use this standard unit:	Symbol of unit
mass	kilogram	kg
length	meter	m
volume	liter	l
force	newton	N
temperature	degree Celsius	°C
time	second	s

You may wonder why the kilogram, rather than the gram, is called the standard unit for mass. This is because the mass of an object is based on how much matter it contains as compared to the standard kilogram made from platinum and iridium and kept in Paris. The gram is such a small amount of matter that if it had been used as a standard, small errors in reproducing that standard would be multiplied into very large errors when large quantities of mass were measured.

SKILL and PRACTICE

1.2

The following prefixes in the SI system indicate the multiplication factor to be used with the basic unit. For example, the prefix kilo- is a factor of 1,000. A kilometer is equal to 1,000 meters, and a kilogram is equal to 1,000 grams.

Prefix	kilo-	hecto-	deka-	Basic unit (no prefix)	deci-	centi-	milli-
Symbol	k	h	da	m, l, g	d	c	m
Multiplication Factor or Place-Value	1,000	100	10	1	0.1	0.01	0.001

EXAMPLES ▶

- How many centigrams are there in 24 grams?

  (1) Restate the question: 24 grams = _____ centigrams

  (2) Use the place value chart to determine the multiplication factor, and solve:

kilo	hecto	deka	meter, liter, or gram	deci	centi	milli
thousands	hundreds	tens	ones	tenths	hundredths	thousandths

Since we want to convert grams (ones place) to centigrams (hundredths place), count the number of places on the chart it takes to move from the ones place to get to the hundredths place. Since it takes 2 moves to the right, the multiplication factor is 100.

$24.00 \times 100 = 24.00. = 2,400$

move decimal two places to the right

Solution: multiply $24 \times 100 = 2,400$.

Answer: There are 2,400 centigrams in 24 grams.

- How many liters are there in 5,000 deciliters?

  (1) Restate the question: 5,000 deciliters (dl) = _____ liters (l)?

  (2) Use the place value chart to determine the multiplication factor, and solve:

Since we want to convert deciliters (tenths place) to liters (ones place), count the number of places on the chart it takes to move from the ones place to get to the hundredths place. Since it takes 1 move to the left, the multiplication factor is 0.1.

$5,000 \times 0.01 = 500.0. = 500$

move decimal one place to the left

Solution: multiply $5,000 \times 0.1 = 500$.

Answer: There are 500 liters in 5,000 deciliters.

- How many decimeters are in a dekameter?

  (1) Restate the question: 1 dam = _____ dm.

  (2) Use the place value chart to determine the multiplication factor, and solve:

Since we want to convert dekameters to decimeters, count the number of places on the chart it takes to move from the tens place (deka) to the tenths place (deci). It takes 2 moves to the right, so the multiplication factor is 100.

$1.00 \times 100 = 1.00. = 1$

move decimal two places to the right

Solution: multiply $1 \times 100 = 100$.

Answer: There are 100 decimeters in one dekameter.

- How many kilograms are equivalent to 520,000 centigrams?

  (1) Restate the question: 520,000 centigrams = _____ kilograms.

  (2) Determine the multiplication factor, and solve:

  Moving from the hundredths place (centi) to the thousands place (kilo) requires moving 5 places to the left, so the multiplication factor is 0.00001.

  $$520{,}000 \times 0.00001 = 5.2.0.0.0.0. = 5.2$$

  move decimal five places to the left

  Solution: Multiply $520{,}000 \times 0.00001 = 5.2$

  Answer: 5.2 kilograms are equivalent to 520,000 centigrams.

PRACTICE

1. How many grams are in a dekagram?

2. How many millimeters are there in one meter?

3. How many millimeters are in 6 decimeters?

4. Convert 4,200 decigrams to grams.

5. How many liters are equivalent to 500 centiliters?

6. Convert 100 millimeters to meters.

7. How many milligrams are equivalent to 150 dekagrams?

8. How many liters are equivalent to 0.3 kiloliters?

9. How many centimeters are in 65 kilometers?

10. Twelve dekagrams are equivalent to how many milligrams?

11. Seven hundred twenty centiliters is how many liters?

12. A fountain can hold 53,000 deciliters of water. How many kiloliters is this?

13. What is the name of a length that is 100 times larger than a millimeter?

14. How many times larger than a centigram is a dekagram?

15. Name the distance that is 10 times smaller than a centimeter.

SI-English Conversions

READ CPO Science

Even though the United States adopted the SI system in the 1800's, most Americans still use the English system (feet, pounds, gallons, etc.) in their daily lives. Because almost all other countries in the world, and many professions (medicine, science, photography, and auto mechanics among them) use the SI system, it is often necessary to convert between the two systems.

It is useful to be familiar with standard examples of measurements in both systems. Most people in the U.S. are very familiar with English system units due to household tasks and what is taught in elementary schools. Some examples of measurements in the metric system are:

One kilometer (1 km) is about two and a half times around a standard running track.
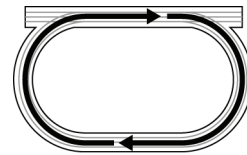
One centimeter (1 cm) is about the width of your little finger.

One kilogram (1 kg) is about the mass of a full one-liter bottle of drinking water.

One gram (1 g) is about the mass of a paper clip.

One liter (1 l) is a common size of a small bottle of drinking water.

One milliliter (1 mL) is about one droplet of liquid.

When precise conversions between the two systems are necessary, you will need to know the correct conversion factors given in the table below.

Table 1: English - SI measurement equivalents

Measurement	Equivalents
Length:	1 inch = 2.54 centimeters 1 kilometer ≈ 0.62 mile
Volume:	1 liter ≈ .106 quart
Mass:	1 ounce ≈ 28 grams 1 kilogram ≈ 2.2 pounds

EXAMPLES ▶

1. If we need to know the mass of a 50-pound bag of dog food in kilograms, we take the following steps:

    (1) Restate the question: 50 lb ≈ _____ kg

    (2) Find the conversion factor from the table: 1 kg ≈ 2.2 lb

    (3) Multiply the ratios making sure that the unwanted units cancel, leaving only the desired units (kilograms) in the answer:

    $$\frac{50 \text{ lb}}{1} \bullet \frac{1 \text{ kg}}{2.2 \text{ lb}} \approx \frac{50 \text{ kg}}{2.2} \approx 22.7272 \text{ kg} \approx 22.7 \text{ kg}$$

2. How many inches are equivalent to 99 centimeters?

    (1) Restate the question: 99 centimeters = _____ inches

    (2) Find the conversion factor from the table: 1 inch = 2.54 centimeters.

    (3) Multiply the ratios. Make sure the units cancel correctly to produce the desired type of unit in the answer.

    $$\frac{99 \text{ cm}}{1} \bullet \frac{1 \text{ in}}{2.54 \text{ cm}} = \frac{99 \text{ in}}{2.54} = 38.97638 \text{ in} \approx 39.0 \text{ inches}$$

3. An eighth grader is 5 feet 10 inches tall. We want to know how many centimeters that is without measuring.

    (1) Restate the question: 5 feet 10 inches = _____ centimeters

    (2) Convert units within one system if necessary: 5 feet 10 inches needs to be rewritten as either feet or inches. Since our conversion factor (from the table) is given as 1 inch = 2.54 centimeters, it makes sense to rewrite the quantity 5 feet 10 inches as some number of inches. First convert the number of feet (5) to inches, then add 10 inches. Since there are 12 inches in 1 foot, use that as your conversion factor to calculate:

    $$\frac{5 \text{ ft}}{1} \bullet \frac{12 \text{ in}}{1 \text{ ft}} = \frac{60 \text{ in}}{1} = 60 \text{ inches}$$

    Now add: 60 inches + 10 inches = 70 inches. 5 feet 10 inches = 70 inches. We now need to convert 70 inches to centimeters.

(3) Restate the question: 70 inches = _____ centimeters.

(4) Choose the correct conversion factor from the table. Here, we want to convert inches to centimeters, so use 1 inch = 2.54 centimeters.

(5) Multiply the ratios. Make sure the units cancel correctly to produce the desired type of unit in the answer.

$$\frac{70 \text{ in}}{1} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} = \frac{177.8 \text{ cm}}{1} = 177.8 \text{ cm}$$

PRACTICE

1. 7 km ≈ _____ mi

2. 115 g ≈ _____ oz

3. 2,000 lb. ≈ _____ kg

4. A 2-liter bottle of soda is about how many quarts?

5. A pumpkin weighs 5.4 pounds. What is its mass in grams?

6. Felipe biked 54 kilometers on Sunday. How many miles is this?

7. How many inches are in 72 meters? How many yards is this?

8. In a track meet, Julian runs the 800 meter dash, the 1600 meter run, and the opening leg of the 4 × 400 meter relay. How many miles is this altogether?

9. How many liters are equivalent to 1 gallon? (There a four quarts in a gallon.)

10. The mass of a large order of french fries is about 170 grams. What is its approximate weight in pounds?

Dimensional Analysis

READ CPO Science

Dimensional analysis is a way to find the correct label (also called units or dimensions) for the solution to a problem. In dimensional analysis, we treat the units the same way that we treat the numbers. For example, this problem shows how can you can "cancel" the sevens and then perform the multiplication:

$$\frac{3}{\cancel{7}} \bullet \frac{\cancel{7}}{8} = \frac{3}{8}$$

In some problems, there are no numerical cancellations to make, but you need to pay close attention to the units (or dimensions):

$$\frac{16 \text{ oz}}{1 \text{ lb}} \bullet 4 \text{ lb} = \frac{16 \bullet 4 \text{ oz} \bullet \cancel{lb}}{1 \cancel{lb}} = \frac{64 \text{ oz}}{1} = 64 \text{ oz}$$

The "lbs" may be cancelled either before or after the multiplication.

- The goal of dimensional analysis is to simplify a problem by focusing on the units of measurement (dimensions).

- Dimensional analysis is very useful when converting between units (like converting inches to yards, or converting between the metric and English systems of measurement).

EXAMPLE ▶

The eighth grade class is having a reward lunch for collecting the most food for a canned food drive. They have decided to order pizza. They are figuring two slices of pizza per student. Each pizza that will be ordered will have 12 slices. There are 220 students total in the eighth grade. How many pizzas should they order?

1. Determine what we want to find out: here, it is the number or whole pizzas needed to feed 220 eighth graders. It's important to remember that if the solution is to have the label "pizzas," "pizzas" should be kept in the numerator as the problem is set up.

2. Determine what we know. We know that they're planning 2 slices of pizza per student, that there are 12 slices in each pizza, and that there are 220 eighth graders.

3. Write what you know as fractions with units. Here, we have: $\frac{2 \text{ slices}}{\text{student}}$, $\frac{12 \text{ slices}}{\text{pizza}}$ and 220 students.

   Notice that in the fraction, $\frac{12 \text{ slices}}{\text{pizza}}$, "pizza" is in the denominator.

   Recall that (from step #1, above) "pizza" should be kept in the numerator, as it will be the label of the final

   solution. To correct this problem, just switch the numerator and denominator: $\frac{1 \text{ pizza}}{12 \text{ slices}}$.

4. Set up the problem by focusing on the units. Just writing the information as a multiplication problem, we have:

$$\frac{1 \text{ pizza}}{12 \text{ slices}} \cdot \frac{2 \text{ slices}}{\text{student}} \cdot \frac{220 \text{ students}}{1}$$

5. Calculate:
$$\frac{1 \text{ pizza}}{12 \text{ slices}} \cdot \frac{2 \text{ slices}}{\text{student}} \cdot \frac{220 \text{ students}}{1} = \frac{110 \text{ pizza} \cdot \text{slices} \cdot \text{students}}{3 \text{ slices} \cdot \text{students}} = 36\frac{2}{3} \text{ pizzas}$$

Therefore, 37 pizzas will need to be ordered.

Notice that canceling the units can be done either before or after the multiplication.

6. Check your solution for reasonableness: Since there are 12 slices in each pizza, and we're figuring that each student will eat 2 slices, one pizza will feed 6 students. It is expected that a little less than 40 pizzas would be needed. It does seem reasonable that 37 pizzas would feed 220 students.

PRACTICE

1. Multiply. Be sure to label your answers.

a. $\dfrac{\$12.00}{1 \text{ hr}} \cdot \dfrac{6 \text{ hr}}{1 \text{ day}}$

b. $\dfrac{2 \text{ lbs}}{1 \text{ person}} \cdot \dfrac{7 \text{ days}}{1 \text{ week}} \cdot \dfrac{15 \text{ people}}{1 \text{ day}}$

2. Use dimensional analysis to convert each. You may need to use a reference to find some conversion factors. Show all of your work.

a. 11 quarts to some number of gallons

b. 220 centimeters to some number of meters

c. 6000 inches to some number of miles

d. How many cups are there in 4 gallons?

3. Use dimensional analysis to find each solution. You may need to use a reference to find some conversion factors. Show all of your work.

a. Frank just graduated from eighth grade. Assuming exactly four years from now he will graduate from high school, how many seconds does he have until his high school graduation?

b. In 2005, Christian Cantwell won the US outdoor track and field championship shot put competition with a throw of 21.64 meters. How far is this in feet?

c. A recipe for caramel oatmeal cookies calls for 1.5 cups of milk. Sam is helping to make the cookies for the soccer and football teams plus the cheerleaders and marching band, and needs to multiply the recipe by twelve. How much milk (in quarts) will he need altogether?

d. How many football fields (including the 10 yards in each end zone) would it take to make a mile?

e. Corey's sister's car gets 30 miles on each gallon of gas. How many kilometers per gallon is this?

f. Convert your answer from (e) to kilometers per liter.

g. A car is traveling at a rate of 65 miles per hour. How many feet per second is this?

Reading Strategies (SQ3R)

READ CPO Science

Commonly, we read a science textbook as if we were watching a movie—we just sit there and expect to take it all in. Actually, reading a science book is more like playing a video game. You have to interact with it! This skill builder will teach you active strategies that will improve your reading and study skills. Remember—just like in video game playing—the more you practice these strategies, the more skilled you will become.

The **SQ3R** active reading method was developed in 1941 by Francis Robinson to help his students get the most out of their textbooks. Using the SQ3R method will help you interact with your text, so that you understand and remember what you read. "SQ3R" stands for:

- **Survey**
- **Question**
- **Read**
- **Recite**
- **Review**

Your student text has many features to help you organize your reading. These features are highlighted on page 2 through 26 of Chapter 1: Studying Physics and Chemistry. Open your text to those pages so that you can see the features for yourself.

Survey the chapter first.

- Skim the *introduction* on the first page of every chapter. Notice the *key questions*. The key questions are thought provoking and will engage you in the chapter. See if you can answer these questions after you have read the entire chapter.

- You will find *vocabulary* words in the blue box with the definition on the right side of the page. Vocabulary words will be scattered throughout the chapter. Write down any vocabulary words that are unfamiliar to you to help you recognize them later on.

- Next, skim the chapter to get an overview. Notice the *section numbers and titles*. These divide the chapter into major topics. The *subheadings* in each section outline important points. Vocabulary words are highlighted in bold. Tables, charts, and figures summarize important information throughout each section.

- Read the *section review* questions at the end of each section. The questions help you identify what you are expected to know when you finish your reading. You will also find *Challenge, Solve It, and/or Study Skills* boxes scattered throughout each section. These boxes provide you with an interesting way to learn more about information in the section.

- At the end of each chapter you will find a reading called the *Chapter Connection* and the *Chapter Activity*. Connections readings are like a magazine article with interesting science facts. Chapter connection articles always end with a set of engaging questions for you to answer to test your reading comprehension. The chapter activity is a hands-on project that you can do in school or at home. The activity will help you learn more about the information in the chapter.

- Carefully read the *Chapter Assessment* at the end of the chapter to see what kinds of questions you will need to be able to answer. Notice that it is divided into three subtitles, Vocabulary, Concepts, and Problems, and each is listed by chapter section.

SKILL and PRACTICE

1.2

Question what you see. Turn headings into questions.

- Look at each of the section headings and subheadings, found at the tops of pages in your text. Change each heading to a question by using words such as who, what, when, where, why, and how. For example, **Section 1.1: The Physical Science in Your Life** could become *What role does physical science play in your daily life?* The subheading **The physics of a car** could become *What is the physics of a car?* Write down each question and try to answer it. Doing this will help you pinpoint what you already know and what you need to learn as you read.

Read and look for answers to the questions you wrote.

- Pay special attention to the *sidenotes* in the left margin of each page. For example under the subheading **The physics of a car** the sidenotes are **Cars changed the way people live, Forces are described by physics,** and **Mass is also described by physics.** These phrases and short sentences are designed to guide you to the main idea of each paragraph. Also, note the sidebars and illustrations on the right side of the page with additional explanations and concepts. For example **Figure 1.3** on page 6 of your text illustrates how an otter's streamlined body reduces the force of water friction.

- Slow your reading pace when you come to a difficult paragraph. Read difficult paragraphs out loud. Copy a confusing sentence onto paper. These methods force you to slow down and allow you time to think about what the author is saying.

Recite concepts out loud.

- This step may seem strange at first, because you are asked to talk to yourself! But studies show that saying concepts out loud can actually help you to record them in your long-term memory.

- At the end of each section, stop reading. Ask yourself each of the questions you wrote in step two on the previous page. Answer each question out loud, in your own words. Imagine that you are explaining the concept to someone who hasn't read the text.

- You may find it helpful to write down your answers. By using your senses of seeing, hearing, and touch (when you write) as you learn, you create more memory paths in your brain.

Review it all.

- Once you have finished the entire chapter, go back and answer all of the questions that you wrote for each section. If you can't remember the answer, go back and reread that portion of the text. Recite and write the answer again.

- Next, reread the key questions at the beginning of the chapter. Can you answer these?

- Complete the section reviews and different parts of the chapter assessment at the end of the chapter. Use the glossary and index at the back of the book to help you locate specific definitions.

PRACTICE

The SQ3R method may seem time-consuming, but it works! With practice, you will learn to recognize the important concepts quickly.

Active reading helps you learn and remember what you have read, so you will have less to re-learn as you study for quizzes and tests.

Study Notes

READ

This skill builder will help you take notes while you read. Each paragraph in the text has a sidenote. Fill in the table as you read each section of your textbook. Use the information to study for tests!

- First, write in the number of the section that you are reading. For example, the first section of the text is 1.1. This is the first section in chapter 1 of the text.

- For each paragraph that you read, write the sidenote. Then, write a question based on this sidenote. As you read the paragraph, answer your own question!

- When you study, fold this paper so that the answers are hidden. Use separate paper to write answers to each of your questions. Then unfold this paper and check your work.

EXAMPLE ▶

An example of how to fill in the table:

Page number	Sidenote text	Question based on sidenote	Answer to question
52	Elements	What are elements?	An element is a pure substance that can't be broken down into other substances.

PRACTICE ▷〰

Section number: _____

Page number	Sidenote text	Question based on sidenote	Answer to question

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1.3

Section number: _____

Page number	Sidenote text	Question based on sidenote	Answer to question

James Prescott Joule

James Joule, known for the accuracy and precision of his work in a time when exactness of measurements was not held in high regard, demonstrated that heat is a form of energy. He studied the nature of heat and the relationship of heat to mechanical work. Joule has also been credited with finding the relationship between the flow of electricity through a resistance, such as a wire, and the heat given off from it, now known as Joule's Law. He is remembered for his work that led to the First Law of Thermodynamics (Law of Conservation of Energy).

The young student
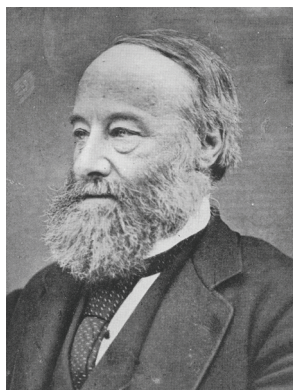
James Joule was born near Manchester, England on December 24, 1818. His father was a wealthy brewery owner. James injured his spine when he was young and as a result he spent a great deal of time indoors, reading and studying. When he became interested in science, his father built him a lab in the basement.

When James was fifteen years old, his father hired John Dalton, a leading scientist at the time, to tutor James and his brother, Benjamin. Dalton believed that a scientist needed a strong math background. He spent four years teaching the boys Euclidian mathematics. He also taught them the importance of taking exact measurements, a skill that strongly influenced James in his scientific endeavors.

Brewer first, scientist second

After their father became ill, James and Benjamin ran the family brewery. James loved the brewery, but he also loved science. He continued to perform experiments as a serious hobby. In his lab, he tried to make a better electric motor using electromagnets. James wanted to replace the old steam engines in the brewery with these new motors. Though he learned a lot about magnets, heat, motion, and work, he was not able to change the steam engines in the brewery. The cost of the zinc needed to make the batteries for the electric motors was much too high. Steam engines fired by coal were more cost efficient.

The young scientist

In 1840, when he was only twenty-two years old, James wrote what would later be known as Joule's Law. This law explained that electricity produces heat when it travels through a wire due to the resistance of the wire. Joule's Law is still used today to calculate the amount of heat produced from electricity.

By 1841, Joule focused most of his attention on the concept of heat. He disagreed with most of his peers who believed that heat was a fluid, called caloric. Joule argued that heat was a state of vibration caused by the collision of molecules. He showed that no matter what kind of mechanical work was done, a given amount of mechanical work always produced the same amount of heat. Thus, he concluded, heat was a form of energy. He established this kinetic theory nearly 100 years before others truly accepted that molecules and atoms existed.

On his honeymoon

In 1847, Joule married Amelia Grimes, and the couple spent their honeymoon in the Alps. Joule had always been fascinated by waterfalls. He had observed that water was warmer at the bottom of a waterfall than at the top. He believed that the energy of the falling water was transformed into heat energy. While he and his new bride were in the Alps, he tried to prove his theory. His experiment failed because there was too much spray from the waterfall, and the water did not fall the correct distance for his calculations to work.

From 1847–1854, Joule worked with a scientist named William Thomson. Together they studied thermodynamics and the expansion of gases. They learned how gases react under different conditions. Their law, named the Joule-Thomson Effect, explains that compressed gases cool when they are allowed to expand under the right conditions. Their work later led to the invention of refrigeration.

James Joule died on October 11, 1889. The international unit of energy is called the Joule in his honor.

Reading reflection

1. Why do you think that Joule's father built him a science lab when he was young?

2. What evidence is there that Joule had an exceptional education?

3. Why was Joule so interested in electromagnets?

4. Why would you consider Joule's early experiments with electric motors important even though he did not achieve his goal?

5. Explain Joule's Law in your own words.

6. Describe something Joule believed that contradicted the beliefs of his peers.

7. Describe the experiment that Joule tried to conduct on his honeymoon.

8. Name one thing that we use today that was invented as a result of his research.

9. What unit of measurement is named after him?

10. **Research:** Find out more information about one of Joule's more well-known experiments, and share your findings with the class. Try to find a picture of some of the apparatus that he used in his experiments. Suggested topics: galvanometer, heat energy, kinetic energy, mechanical work, conservation of energy, Kelvin scale of temperature, thermodynamics, Joule-Thomson Effect, electric welding, electromagnets, resistance in wires.

Creating Line Graphs

READD CPO Science

Line graphs allow you to present data in a form that is easy to understand. The parts of a line graph include:

1. **Data pairs:** Graphs are made using pairs of numbers. Each pair of numbers represents one data point on a graph. The first number in the pair represents the independent variable and is plotted on the *x*-axis. The second number represents the dependent variable and is plotted on the *y*-axis.

2. **Axis labels:** The label on the *x*-axis is the name of the independent variable. The label on the *y*-axis is the name of the dependent variable. Be sure to write the units of each variable in parentheses after its label.

3. **Scale:** The scale is the quantity represented per line on the graph. The scale of the graph depends on the number of lines available on your graph paper and the range of the data. Divide the range by the number of lines. To make the calculated scale easy-to-use, round the value to a whole number.

4. **Title:** The format for the title of a graph is: "Dependent variable name versus independent variable name."

PRACTICE ▷〜

1. For each data pair in the table, identify the independent and dependent variable. Then, rewrite the data pair according to the headings in the next two columns of the table The first two data pairs are done for you.

	Data pair (not necessarily in order)		Independent (x-axis)	Dependent (y-axis)
1	Temperature	Hours of heating	Hours of heating	Temperature
2	Stopping distance	Speed of a car	Speed of a car	Stopping distance
3	Number of people in a family	Cost per week for groceries		
4	Stream flow rate	Amount of rainfall		
5	Tree age	Average tree height		
6	Test score	Number of hours studying for a test		
7	Population of a city	Number of schools needed		

2. Using the variable range and number of lines, calculate the scale for an axis. The first two are done for you.

Variable range	Number of lines	Range ÷ Number of lines	Calculated scale	Adjusted scale
13	24	13 ÷ 24 =	0.54	1
83	43	83 ÷ 43 =	1.93	2
31	35			
100	33			
300	20			
900	15			

3. Here is a data set for you to plot as a graph. Follow these steps to make the graph.

   a. Place this data set in the table below. Each data point is given in the format of (x, y). The x- values represent time in minutes. The y-values represent distance in kilometers.
   (0, 5.0), (10, 9.5), (20, 14.0), (30, 18.5), (40, 23.0), (50, 27.5), (60, 32.0).

Independent variable (x-axis)	Dependent variable (y-axis)

   b. What is the range for the independent variable?

   c. What is the range for the dependent variable?

   d. Make your graph using the blank graph below. Each axis has twenty lines (boxes). Use this information to determine the adjusted scale for the x-axis and the y-axis.

   e. Label your graph. Add a label for the x-axis, y-axis, and provide a title.

   f. Draw a smooth line through the data points.

   g. Question: What is the position value after 45 minutes? Use your graph to answer this question.

   y-axis
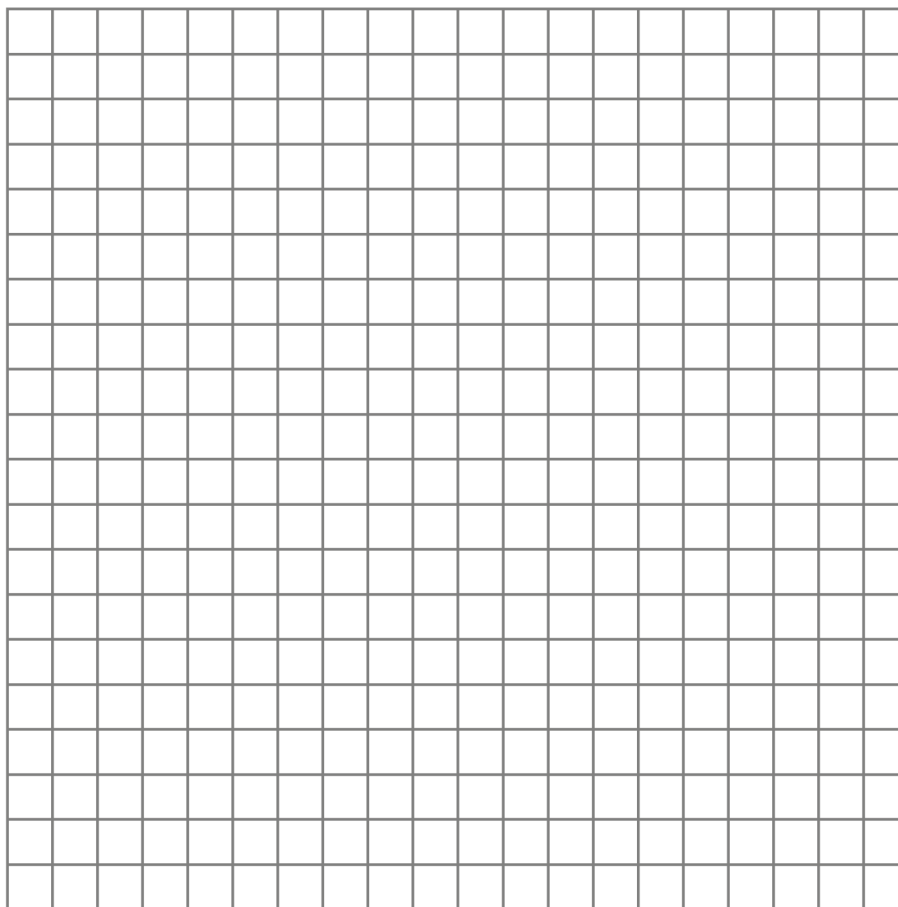
   x-axis

Measuring Angles with a Protractor

Measure each of these angles (A - Q) with a protractor. Record the angle measurements in the table below.
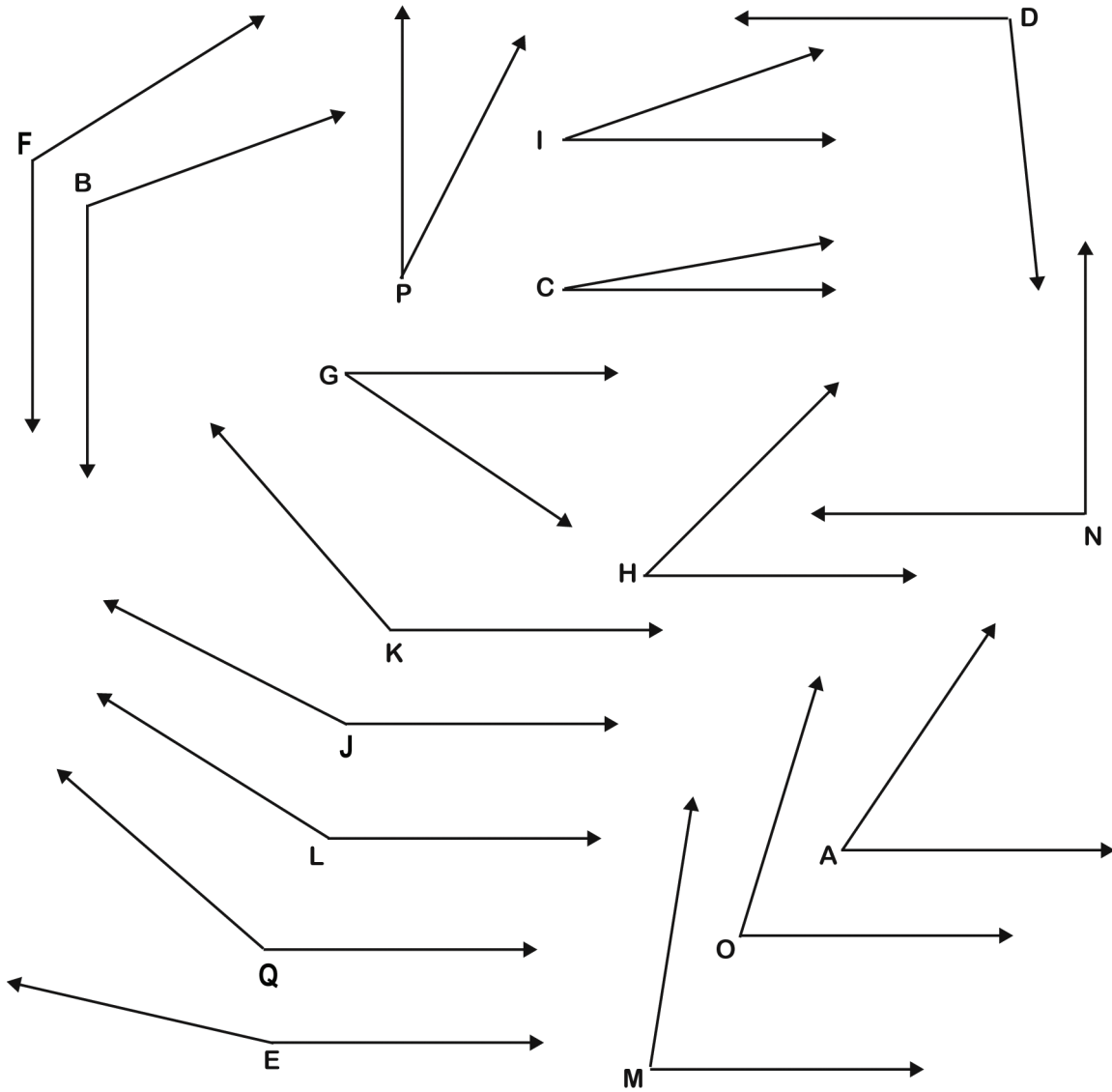
Letter	Angle		Letter	Angle
A			J	
B			K	
C			L	
D			M	
E			N	
F			O	
G			P	
H			Q	
I				

Solving Equations with One Variable

READ 📖 CPO Science

It is useful to know formulas for calculating different quantities. Often, the formulas are very straightforward. It's easy to calculate the volume of a rectangular solid when you know the formula:

Volume = V = length × width × height ($V = l \times w \times h$)

and the length, width, and height of the solid. It's a little more challenging when you know the volume, length, and width, but need to find the height. It then becomes necessary to solve an equation in order to determine the unknown (in this case, the height).

EXAMPLES ▶

1. The volume of a rectangular solid, with a length of 1.5 cm, is 10.98 cm^3. The width of the same solid is 1.2 cm. Find its height.

Explanation/Answer: use the formula $V = l \times w \times h$, and then plug in what is known, leaving the variable (h) for the unknown. Solve the equation for h to find the height.

The Work:	What's happening:
$V = l \times w \times h$	Formula
10.98 cm^3 = 1.5 cm × 1.2 cm × h	Plug in known values.
10.98 cm^3 = 1.8 cm^2 × h	Complete arithmetic, multiply 1.5 × 1.2
$\dfrac{10.98 \text{ cm}^3}{1.8 \text{ cm}^2} = \dfrac{1.8 \text{ cm}^2 \times h}{1.8 \text{ cm}^2}$	Divide both sides by 1.8 cm^2, to get h alone.
6.1 cm = 1 × h	Do the division; 10.98 cm^3 ÷ 1.8 cm^2 = 6.1 cm, 1.8 cm^2 ÷ 1.8 cm^2 = 1
6.1 cm = h	
Check the Work:	
$V = l \times w \times h$	
V = 1.5 cm × 1.2 cm × 6.1 cm	Multiply 1.5 cm × 1.2 cm × 6.1 cm. If the answer is 10.98 cm^3, the solution, h = 6.1 cm, is correct.
1.5 cm × 1.2 cm × 6.1 cm = 10.98 cm^3	The product does equal 10.98 cm^3, the solution is correct.
In summary:	

The height (h) of a rectangular solid whose volume is 10.98 cm^3, whose length is 1.5 cm, and whose width is 1.2 cm, is 6.1 cm.

2. The density of titanium is 4.5 g/cm^3. A titanium pendant's mass is 2.25 grams. Use the formula Density $= \dfrac{\text{mass}}{\text{volume}}$, or $D = \dfrac{m}{v}$, or to find its volume.

The Work:	What's happening:
$D = \dfrac{m}{v}$	Formula
$4.5 \text{ g/cm}^3 = \dfrac{2.25 \text{ g}}{V}$	Plug in known values.
$\dfrac{4.5 \text{g}}{1 \text{ cm}^3} = \dfrac{2.25 \text{ g}}{V}$	Rewrite 4.5 g/cm^3 as $\dfrac{4.5 \text{ g}}{1 \text{ cm}^3}$
$4.5 \text{ g} \times V = (2.25 \text{ g}) \times (1 \text{ cm}^3)$	Think of $\dfrac{4.5 \text{ g}}{1 \text{ cm}^3} = \dfrac{2.25 \text{ g}}{V}$ as a proportion. Then set the cross products equal
$4.5 \text{ g} \times V = 2.25 \text{ g} \times 1 \text{ cm}^3$	Do arithmetic: $2.25 \text{ g} \times 1\text{cm}^3 = 2.25 \text{ g} \times 1 \text{ cm}^3$
$\dfrac{4.5 \text{ g} \times V}{4.5 \text{ g}} = \dfrac{2.25 \text{ g} \times 1\text{cm}^3}{4.5 \text{ g}}$	Divide both sides of the equation by 4.5 g to get V alone.
$V = 0.5 \text{ cm}^3$	Do the division on each side. Remember to cancel units as well as divide the numbers.

Check the Work:	
$D = \dfrac{m}{v}$	
$4.5 \text{ g/cm}^3 = \dfrac{2.25 \text{ g}}{0.5 \text{ cm}^3}$	Divide $2.25 \div 0.5$. If the answer is 4.5 g/cm^3, the solution, $V = 0.5 \text{ cm}^3$, is correct.
$2.25 \div 0.5 = 4.5 \text{ g/cm}^3$	The quotient does equal 4.5 g/cm^3; therefore, the solution is correct.

In summary:

The volume of a titanium pendant whose mass is 2.25 grams is 4.5 g/cm^3.

Use the formula $V = l \times w \times h$ to set up and solve for the unknown in each.

1. Find the width (w) of a rectangular solid whose length is 12 mm, and whose height is 15 mm, if the volume of the solid is 720 mm^3.

2. Find the length of this rectangular solid whose volume is 0.12 m^3.

0.25 m

0.6 m

?
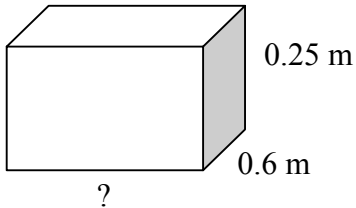
3. The length and width of a rectangular solid are 2.15 cm. Its volume is 36.98 cm^3. Find the height of this rectangular solid.

Use the formula $\text{Speed} = \dfrac{\text{distance}}{\text{time}}$**, or** $S = \dfrac{d}{t}$ **to set up and solve for the unknown in each.**
Here, speed is measured in meters/second (m/s), distance is measured in meters (m), and time is measured in seconds (s).

4. How far will a marble rolling at a speed of 0.25 m/s travel in 30 seconds?

5. Nate throws a paper wad to Ali who is sitting exactly 1.8 meters away. The paper wad was only in the air for 0.45 seconds. How fast was it traveling?

6. How long does it take a battery operated toy car to travel 3 meters at a speed of 0.1 m/s?

7. A dog is running 3.2 m/s. How long will it take him to go 100 meters?

Use the formula $\text{Density} = \dfrac{\text{mass}}{\text{volume}}$**, or** $D = \dfrac{m}{v}$**, to set up and solve for the unknown in each.**
Here, density (D) is measured in grams per cubic centimeter (g/cm3), mass (m) is measured in grams (g), and volume (V) is measured in cubic centimeters (cm3).

8. What is the density of a steel nail whose volume is 3.2 cm^3 and whose mass is 25 g?

9. Find the mass of a cork whose density is 0.12 g/cm^3 and whose volume is 9 cm^3?

10. An ice cube's volume is 4.9 cm^3. Find its mass if its density is 0.92 g/cm^3.

11. A solid plastic ball's mass is 225 g. The density of the plastic is 2.00 g/cm^3. What is the volume of the ball?

12. Find the volume of an ice cube whose mass is 2.08 g. See question #10 for the density of ice.

Use the formula: Force = pressure × area to set up and solve for each unknown.

Here, force is measured in Newtons (N), pressure is measured in Pascals (Pa), and area is measured in square meters (m2).Hint: 1 Pa = 1 N / m2.

EXAMPLE ▶

A drinking glass is sitting on the kitchen table. The glass has a weight of 2 N. Its base has an area of 0.005 m^2. How much pressure does the drinking glass exert on the table?

Explanation/Answer:

The Work:	What's happening:
Force = pressure × area	Formula
2 N = p × 0.005m^2	Plug in known values.
$\dfrac{2\ N}{0.005\ m^2} = \dfrac{p \times 0.005\ m^2}{0.005\ m^2}$	Divide both sides by 0.005 m^2 to get p alone.
400 N/m^2 = p × 1	Do the division; 2 N ÷ 0.005 m^2 = 400 N / m^2, 0.005 m^2 ÷ 0.005 m^2 = 1)
400 $Pa = p$	Rewrite 400 N/m^2 as 400 Pa, multiply; p × 1 = p.

In summary:

A drinking glass with a weight of 2 N and whose base has area 0.005 m^2 exerts 400 Pa of pressure on the table it sits on.

1. A tea kettle's base has an area of 0.008 m^2. It is puts 1,000 Pascals of pressure on the stove where it sits. What is the weight of the kettle?

2. A block of wood whose base has an area of 4 m^2 has a weight of 80 N. How much pressure does the block place on the floor on which it sits?

3. A sculpture's base has an area of 2.5 m^2. How much pressure does the sculpture place on the wooden display case where it sits, if it has a weight of 540 N?

4. A student is breaking class rules by standing on a chair. If her feet have a total area of 0.04 m^2, and her weight is 600 N, how much pressure is she putting on the chair?

What's the Scale?

READING CPO Science

Graphs allow you to present data in a form that is easy to understand. With a graph, you can see whether your data shows a pattern and you can picture the relationship between your variables.

The **scale** on a graph is the quantity represented per line on the graph. Your graph's scales will depend on what data you are plotting. Each of your graph's axes has its own separate scale. You need to be consistent with your scales. If one line on a graph represents 1 cm on the *x*-axis, it has to stay that way for the entire *x*-axis.

When figuring out the scale for your graph, you first need to know the **range**. When you want your axis to start at zero, your range is equal to your highest data value. Once you have the range, you can calculate the scale. Count the number of lines you have available on your graph paper. Now, divide the range by the number of lines. This number is your scale. Then you adjust your scale by rounding up to a whole number.

EXAMPLE ▶

Calculate the scales for the data set listed in the table below. Your graph paper is 20 boxes by 20 boxes.

Time (hours)	Amount of rainfall (mL)
5	5
10	11
15	21
20	28
25	37
30	59

Identify the variables.

1. Which is the independent variable?   Time is your independent variable; it goes on the *x*-axis.
   Which is the dependent variable?   Amount of rainfall is your dependent variable; it goes on the *y*-axis.

Find the ranges.

2. What is the range of data for the x-axis? 30 hours
   What is the range of data for the y-axis? 59 mL

Calculate the scales.

3. What is the scale for your *x*-axis?   30 hrs divided by 20 boxes = 1.5 hrs/box rounded up to 2 hrs/box
   Each line on the graph is equal to 2 hours.
   The *x*-axis will start at zero and go up to 40 hours, with each line counting as 2 hours.

   What is the scale for your *y*-axis?   59 mL divided by 20 boxes = 2.95 mL/box rounded up to 3 mL/box
   Each line on the graph is equal to 3 mL.
   The *y*-axis will start at zero and go up to 60 mL, with each line counting as 3 mL.

PRACTICE

1. Given the variable range and the number of lines, calculate the scale for an axis. Often the calculated scale is not an easy-to-use value. To make the calculated scale easy-to-use, round the value and write this number in the column with the heading "Adjusted scale." The first two are done for you.

Range from 0	Number of Lines	Range ÷ Number of Lines	Calculated scale	Adjusted scale (whole number)
14	10	14 ÷ 10 =	1.4	2
8	5	8 ÷ 5 =	1.6	2
1000	20	1000 ÷ 20 =		
547	15	547 ÷ 15 =		
99	30	99 ÷ 30 =		
35	12	35 ÷ 12 =		

2. Calculate the range and the scale for the x-axis starting at zero, given the following data pairs and a 30 box by 30 box piece of graph paper. Each data point is given in the format of (x, y): (1, 27), (30, 32), (20, 19), (6, 80), (15, 21).

3. Calculate the range and the scale for the y-axis starting at zero, given the following data pairs and a 10 box by 10 box piece of graph paper. Each data point is given in the format of (x, y): (1, 5), (2, 10), (3, 15), (4, 20), (5, 25).

4. Calculate the scale for both the x-axis and the y-axis of a graph using the data set in the table below. Your graph paper is 20 boxes by 20 boxes. Start both the x- and y-axis at zero.

   a. Which is the independent variable? Which is the dependent variable?

   b. What is the range of data for the x-axis? What is the range of data for the y-axis?

   c. What is the scale for your x-axis? What is the scale for your y-axis?

Day	Average Daily Temperature (°F)
1	67
3	68
5	73
7	66
9	70
11	64

SKILL and PRACTICE

2.1

Internet Research Skills

READD CPO Science

The Internet is a valuable tool for finding answers to your questions about the world. A search engine is like an on-line index to information on the World Wide Web. There are many different search engines to choose from. Search engines differ in how often they are updated, how many documents they contain in their index, and how they search for information. Your teacher may suggest several search engines for you to try.

EXAMPLE ▶

Search engines ask you to type a word or phrase into a box known as a *field*. Knowing how search engines work can help you pinpoint the information you need. However, if your phrase is too vague, you may end up with a lot of unhelpful information.

How could you find out who was the first woman to participate in a space shuttle flight?

First, put **key phrases** in quotation marks. You want to know about the "first woman" on a "space shuttle." Quotation marks tell the engine to search for those words together.

Second, if you only want websites that contain both phrases, **use a + sign** between them. Typing **"first woman" + "space shuttle"** into a search engine will limit your search to websites that contain both phrases.

If you want to broaden your search, use the word **or** between two terms. For example, if you type **"first female" or "first woman" + "space shuttle"** the search engine will list any website that contains either of the first two phrases, as long as it also contains the phrase "space shuttle."

You can narrow a search by using the word **not.** For example, if you wanted to know about marine mammals other than whales, you could type **"marine mammals" not "whales"** into the field. Please note that some search engines use the minus sign (-) rather than the word **not**.

1. If you wanted to find out about science museums in your state that are not in your own city or town, what would you type into the search engine?

2. If you wanted to find out which dog breeds are not expensive, what would you type into the search engine?

3. How could you research alternatives to producing electricity through the combustion of coal or natural gas?

READ CPO Science

The quality of information found on the Internet varies widely. This section will give you some things to think about as you decide which sources to use in your research.

1. **Authority:** How well does the author know the subject matter? If you search for "Newton's laws" on the Internet, you may find a science report written by a fifth grade student, and a study guide written by a college professor. Which website is the most authoritative source?
Museums, national libraries, government sites, and major, well-known "encyclopedia sources" are good places to look for authoritative information.

2. **Bias:** Think about the author's purpose. Is it to inform, or to persuade? Is it to get you to buy something? Comparing several authoritative sources will help you get a more complete understanding of your subject.

3. **Target audience:** For whom was this website written? Avoid using sites designed for students well below your grade level. You need to have an understanding of your subject matter at or above your own grade level. Even authoritative sites for younger students (children's encyclopedias, for example) may leave out details and simplify concepts in ways that would leave gaps in your understanding of your subject.

4. **Is the site up-to-date, clear, and easy to use?** Try to find out when the website was created, and when it was last updated. If the site contains links to other sites, but those links don't work, you may have found a site that is infrequently or no longer maintained. It may not contain the most current information about your subject. Is the site cluttered with distracting advertisements? You may wish to look elsewhere for the information you need.

1. What is your favorite sport or activity? Search for information about this sport or activity. List two sites that are authoritative and two sites that are not authoritative. Explain your reasoning. Finally, write down the best site for finding out information about your favorite sport.

2. Search for information about a physical science topic of your choice on the Internet (*i.e.*, "simple machines," "Newton's Laws," "Galileo"). Find one source that you would NOT consider authoritative. Write the key words you used in your search, the web address of the source, and a sentence explaining why this source is not authoritative.

3. Find a different source that is authoritative, but intended for a much younger audience. Write the web address and a sentence describing who you think the intended audience is.

4. Find three sources that you would consider to be good choices for your research here. Write two to three sentence description of each. Describe the author, the intended audience, the purpose of the site, and any special features not found in other sites.

Averaging

READ 📘 *CPO Science*

The most common type of average is called the mean. To find the mean, just add all the data, then divide the total by the number of items in the data set. This type of average is used daily by many people; teachers and students use it to average grades, meteorologists use it to average normal high and low temperatures for a certain date, and sports statisticians use it to calculate batting averages, among many other things.

EXAMPLE ▶

Seven students in Mrs. Ramos' homeroom have part time jobs on the weekends. Some of them baby sit, some mow lawns, and others help their parents with their businesses. They all listed their hourly wages to see how their own pay compares to that of the others. Here is the list: $11.00, $4.50, $12.20, $5.25, $8.77, $15.33, $5.75. What is the average (mean) hourly wage earned by students in Mrs. Ramos' homeroom?

1. Find the sum of the data: $11.00 + $4.50 + $12.20 + $5.25 + $8.77 + $15.33 + $5.75 = $62.80

2. Divide the sum ($62.80) by the number of items in the data set (7): $62.80 ÷ 7 ≈ $8.97

3. Solution: The average hourly wage of the students in Mrs. Ramos' homeroom is $8.97.

PRACTICE ▷━〜

1. Jill's test grades in science class so far this grading period are: 77%, 64%, 88%, and 82%. What is her average test grade so far?

2. The total team salaries in 2005 for teams in a professional baseball league are as follows: Team One, $63,015,833 (24 players); Team Two, $48,107,500 (24 players); Team Three, $81,029,500 (29 players); Team Four, $62,888,192 (22 players); Team Five, $89,487,426 (18 players). What is the average amount of money spent by a team in this league on players salaries in 2005?

3. During a weekend landscaping job, Raul worked 8 hours, Ben worked 15 hours, Michelle worked 22 hours, Rosa worked 5 hours, and Sammie worked 15 hours. What was the average number of hours worked by one person during this landscaping job? If each worker was paid $12.00 an hour, what was the average pay per person for the job?

4. The 8th grade girls basketball team at George Washington Carver Middle School played the team from Rockwood Valley Middle School last night. The Rockwood Valley team won, 53-37. Altogether, there were three girls who scored 11 points each, four who scored 8 points each, one who scored 6 points, two who scored 4 points each, four who scored 2 points each, three who scored one point each, and two girls who did not score at all. What is the average number of points scored by a player on either team?

5. During a weekend car trip that covered 220 miles each way, Rowan kept track of the price per gallon of regular unleaded gasoline at different gas stations along the way. Here is the list he kept: $2.79, $3.23, $3.99, $2.89, $3.09, $2.99, $2.97, $3.11, $2.88, $3.01, $3.00, $2.99. What was the average price per gallon of gas among the different gas stations on the list?

Preparing a Bibliography

READ CPO Science

When you write a research paper or prepare a presentation for your class, it is important to document your sources. A bibliography serves two purposes. First, a bibliography gives credit to the authors who wrote the material you used to learn about your subject. Second, a bibliography provides your audience with sources they can use if they would like to learn more about your subject.

This skill sheet provides bibliography formats and examples for research materials you may use when preparing science papers and presentations

EXAMPLES ▶

Books:

Author last name, First name. (Year published). *Title of book*. Place of publication: Name of publisher.

Vermeij, Geerat. (1997). *Privileged Hands: A Scientific Life*. New York: W.H. Freeman and Company.

Newspaper and Magazine Articles:

Author listed:

Author last name, First name. (Date of publication). Title of Article. *Title of Newspaper or Magazine*, page # or #'s.

Searcy, Dionne. (2006, March 20). Wireless Internet TV Is Launched in Oklahoma. *The Wall Street Journal*, p. B4.

Brody, Jane. (2006, February/March). 10 Kids' Nutrition Myth Busters. *Nick Jr Family Magazine*, pp. 72-73.

No author listed:

Title of article. (Date of publication). *Title of Newspaper or Magazine*, page # or #'s.

Chew on this: Gum may speed recovery. (2006, March 20). *St. Louis Post-Dispatch*, p.H2.

Adventures in Turning Trash into Treasure: (2006, April). *Reader's Digest*, p. 24.

Online Newspaper or Magazine:

Author listed:

Author last name, First name. (Date of publication). Title of Article. *Title of Newspaper or Magazine*, Retrieved date, from web address.

Dybas, Cheryl Lyn. (2006, March 20). Early Spring Disturbing Life on Northern Rivers. *The Washington Post*, Retrieved March 22, 2006, from www.washingtonpost.com.)

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Title of Article. (Date of publication). *Title of Newspaper or Magazine*. Retrieved date, from web address.

Comet mystery turns from hot to cold. (2006, March 20). *The Boston Globe*, retrieved March 22, 2006, from Boston.com.

Online document:

Author listed:

Author last name, author first name. (Date of publication). *Title of document*. Retrieved date, from web address.

Martinez, Carolina. (2006, March 9). *NASA's Cassini Discovers Potential Liquid Water on Enceladus*. Retrieved March 22, 2006, from http://www.nasa.gov/mission_pages/cassini/media/cassini-20060309.html

No Author listed:

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Scientific Processes

READ 📘

The scientific method is a process that helps you find answers to your questions about the world. The process starts with a question and your answer to the question based on experience and knowledge. This "answer" is called your hypothesis. The next step in the process is to test your hypothesis by creating experiments that can be repeated by other people in other places. If your experiment is repeated many times with the same results and conclusions, these findings become part of the body of scientific knowledge we have about the world.

Steps to the Scientific Method
1. Ask a question.
2. Formulate a hypothesis.
3. Design an experiment to test your hypothesis.
4. Conduct an experiment to test your hypothesis and collect the data
5. Analyze data.
6. Make a tentative conclusion.
7. Test your conclusion, or refine the question, and go through each step again.

• Read the following story. You will use this story to practice using the scientific method.

Maria and Elena are supposed to help their mom chill some soda by putting the cans into a large bucket filled with ice cubes, except that Maria forgot to fill the ice cube trays. Elena says that she remembers reading somewhere that hot water freezes faster than cold water. Maria is skeptical. She learned in her science class that the hotter the liquid, the faster the molecules are moving. Since hot water molecules have to slow down more than cold water molecules to become ice, Maria thinks that it will take hot water longer to freeze than cold water.
The girls decide to conduct a scientific experiment to determine whether it is faster to make ice cubes with hot water or cold water.

• Now, answer the following questions about the process they used to reach their conclusion.

PRACTICE ▷〜

Asking a question

1. What is the question that Maria and Elena want to answer by performing an experiment?

Formulate a hypothesis

2. What is Maria's hypothesis for the experiment? State why Maria thinks this is a good hypothesis.

Design and conduct an experiment

3. **Variables:** There are many variables that Maria and Elena must control so that their results will be valid. Name at least four of these variables.

4. **Measurements:** List at least two types of measurements that Maria and Elena must make during their experiment.

5. **Procedure:** If Maria and Elena want their friends to believe the results of their experiment, they need to conduct the experiment so that others could repeat it. Write a procedure that the girls could follow to answer their question.

Collect and analyze data

The girls conducted a carefully controlled experiment and found that after 3 hours and 15 minutes, the hot water had frozen solid, while the trays filled with cold water still contained a mixture of ice and water. They repeated the experiment two more times. Each time the hot water froze first. The second time they found that the the hot water froze in 3 hours and 30 minutes. The third time, the hot water froze in 3 hours and 0 minutes.

6. What is the average time that it took for hot water in ice cube trays to freeze?

7. Why is it a good idea to repeat your experiments?

Make a tentative conclusion

8. Which of the following statements is a valid conclusion to this experiment? Explain your reasoning for choosing a certain statement.

   a. Hot water molecules don't move faster than cold water molecules.

   b. Hot water often contains more dissolved minerals than cold water, so dissolved minerals must help water freeze faster.

   c. Cold water can hold more dissolved oxygen than hot water, so dissolved oxygen must slow down the rate at which water freezes.

   d. The temperature of water affects the rate at which it freezes.

   e. The faster the water molecules are moving, the faster they can arrange themselves into the nice, neat patterns that are found in solid ice cubes.

Test your conclusion or refine your question

Maria and Elena are pleased with their experiment. They ask their teacher if they can share their findings with their science class. The teacher says that they can present their findings as long as they are sure their conclusion is correct.

Here is where the last step of the scientific method is important. At the end of any set of experiments and before you present your findings, you want to make sure that you are confident about your work.

9. Let's say that there is a small chance that the results of the experiment that Maria and Elena performed were affected by the kind of freezer they used in the experiment. What could the girls do to make sure that their results were not affected by the kind of freezer they used?

10. Conclusion 8(b) suggests a possible reason why temperature affects the speed at which water freezes. Refine your original question for this experiment. In other words, create a question for an experiment that would prove or disprove conclusion (b).

Percent Error

When you do scientific experiments that involve measurements, your results may fit the trend that is expected. However, it is unlikely that the numbers will turn out exactly as expected.

In an experiment, you often make a prediction about an event's outcome, but find that your actual measured outcome is slightly different. The percent error (% Error) gives you a means to evaluate how far apart your prediction and measured values are.

Percent error is calculated as the absolute value of the difference between the predicted and measured values divided by the true value multiplied by 100, or:

$$\% \text{ Error} = \frac{|\text{measured value} - \text{predicted value}|}{\text{true value}} \times 100$$

Which value is the true value? That depends on your experiment design. If you want to evaluate how well a graph is able to predict an actual event (like how far a marble will travel or how long a car will take to travel down a ramp) then you use the measured value as the true value.

On the other hand, if you have carefully calculated how much product you should get in a chemical reaction, and you want to evaluate how carefully you made your measurements and followed the procedure, then you would use the predicted value as the true value.

Remember that with percent error, smaller is better. A perfect outcome would have zero percent error.

EXAMPLE ▶

Some students are conducting an experiment using a toy car with a track, timer, and photogates.

Their task is to determine how quickly the car will travel a given distance, and then to predict and test the last trip that the car takes. The table below shows the distances and times traveled by the car so far.

Distance from A to B (cm)	Time from A to B (sec)
10	0.3305
20	0.3380
40	0.3535
50	0.3610
60	?

Based on an estimation made from extending their graph, the students predict that it will take the car 0.3685 seconds to travel 60 centimeters. When the experiment was conducted three times, it took the car 0.3669, 0.3680, and 0.3694 seconds to make the trip. Calculate the percent of error based on the predicted and actual outcomes.

Answer/Explanation

The process:

1. Average the times recorded in the three 60-centimeter trials to use as the measured value in the formula.

2. Calculate percent error using the formula given above, using the average from (1) as the measured value.

The work:

1. Find the average:

$$\frac{0.3669 + 0.368 + 0.3694}{3} = \frac{1.1043}{3} = 0.3681$$

2. Calculate:

$$\% \text{ Error } = \frac{\text{measured value} - \text{predicted value}}{\text{true value}} \times 100$$

$$\% \text{ Error } = \frac{0.3681 - 0.3685}{0.3681} \times 100 = \frac{0.0004}{0.3981} \times 100 \approx 0.11\%$$

The Answer: The percent error in this particular experiment is 0.11%.

PRACTICE ▷

Use the method shown in the example to calculate the percent error in each. Part I: This table was constructed by a group of students conducting an experiment similar to the one in the example, but using a different incline. Complete the table using the average time calculated at each distance from the information provided in each question, and answer each.

Distance from A to B (cm)	Time from A to B (sec)
10	1.0050
20	1.8877
30	2.8000
40	3.7850
50	?
60	?
70	?
80	?
90	?

1. The lab group conducting these experiments decided to call themselves "the Science Sleuths." They graphed the data shown in the table and based on their graph, predicted that it would take the car 4.75 seconds to travel 50 centimeters. The three trials they conducted resulted in 4.802, 4.81, and 4.7 seconds. What is the percent error? Remember to update the table.

2. The Sleuths predict that the car will travel 60 centimeters in 5.795 seconds. Their trials gave times of 5.7702, 5.8, and 5.26 seconds. What is the percent error here?

3. For 70 centimeters, the trial runs resulted in 6.915, 6.808, and 7.0003 seconds. The Sleuths had predicted that it would take the car 6.815 seconds to cover the distance. Calculate the percent error.

4. The Sleuths' car took 7.9903, 7.9995, and 7.9047 seconds to travel 80 centimeters. They had predicted a time of 7.952 seconds. What is the percent error?

5. This time, the Sleuths predicted that it would take the car 9 seconds flat to cover the 90 centimeters it needed to travel. It actually took the car 8.9907, 9.0006, and 9.0507 seconds in each of three trials. Find the percent error.

6. Lisa was trying out for the track team at her middle school. The coach asked her to make predictions about how fast she could run each of the sprint events, then timed her in each event on three different days. All the information is shown in the table below. Calculate Lisa's percent error for her prediction in each event.

Event	Predicted time (s)	Actual times (s)
100 m	18.05	17.55
		18.94
		15.06
200 m	34.70	41.05
		38.22
		35.90
400 m	67.45	72.75
		65.10
		65.88

Calculate the percent error for each event:

a. 100 m

b. 200 m

c. 400 m

SKILL and
PRACTICE

2.2

Significant Differences in Measurement

READ 📖 CPO Science

When people conduct experiments (scientific, or otherwise), how can they be certain the results are accurate? The short answer is that they can never be certain the results are accurate. This is why experiments are usually performed multiple times, and then analyzed to determine the amount of the error. The error is estimated by calculating the largest difference between the average and a measured value. Once you know the amount of error, it can be used to determine whether two results can be considered the same. If two measurements or results differ by an amount that is less than or equal to the amount of error, they are considered to be the same.

EXAMPLE ▶

One hot summer day, Dave and Chris decided to have a toy boat race in their little sisters' wading pool. The boats are identical, except for the sails. Dave's boat has a rectangular sail, and Chris' boat has a triangular sail. They borrow their father's timer to get the most accurate measurement possible. They raced the boats 5 times. The results are given below.

Dave's Boat ([]) Time (seconds)	Chris' Boat (△) Time (seconds)
0.528	0.525
0.532	0.530
0.530	0.529
0.526	0.520
0.533	0.529

Chris claims that since his boat won every race; that proves that his boat is the faster boat. Is this correct?

In order to determine if Chris' claim is correct, you must decide if the times they have collected are significantly different. If there is no significant difference between the times of the boats, then there is no evidence to support that either boat is faster. Follow these steps to determine whether the difference is significant:

$$\text{Dave's boat's average time} = \frac{0.528 + 0.532 + 0.530 + 0.526 + 0.533}{5} = 0.530$$

$$\text{Chris' boat's average time} = \frac{0.525 + 0.530 + 0.529 + 0.520 + 0.529}{5} = 0.527$$

1. Find the average time it took each boat to complete the race course. Remember that the average is found by dividing the sum of a data set by the number of items in the data set.

2. Find the amount of error for each data set. To calculate the error, find the greatest difference between the average (found in #1) and any item in the data set.

   a. Find the error for Dave's boat: The difference between Dave's boat's average (0.530) and its slowest time (0.533) is 0.003; the difference between the average and the fastest time (0.526) is 0.004. The largest difference is 0.004, so the amount of error is ± 0.004.

b.   Find the error for Chris' boat: The difference between Chris' boat's average (0.527) and its slowest time (0.530) is 0.003; the difference between the average and the fastest time (0.520) is 0.007. The largest difference is 0.007, so the amount of error is ± 0.007.

3.   Determine whether the difference is significant. First, find the difference between the averages for each set of data. Here, the difference is found by subtracting the average time of Chris' boat (0.527) from the average time of Dave's boat (0.530). Since 0.530 - 0.527 = 0.003, and 0.003 is not greater than the amount of error found in #2, there is no significant difference between the two sets of data. In other words, scientifically, the data are the same. It is impossible to determine which boat is faster.

PRACTICE

1.   A toy car and a toy truck of about the same size are started down identical ramps. The distance traveled by each vehicle on each of four attempts is recorded below. Is it true that the truck will always travel farther than the car? [Hint: follow the steps explained in the example]

Toy Car Distance (m)	Toy Truck Distance (m)
1.57	1.77
1.45	1.90
1.55	1.85
1.48	2.00
Average	Average
Error	Error

2.   The water pressure in the sinks at Sean's house is constant. Sean wants to compare the water pressure in the kitchen sink with the water pressure in the bathroom sink. He does this by recording the amount of time it takes to fill a 1-cup measure with water from each sink. He performs this experiment a total of five times. Is it possible to determine which sink has the greatest water pressure (fills the cup the quickest)? If so, which sink has the greater water pressure?

Bathroom Sink Time (seconds)	Kitchen Sink Time (seconds)
3.42	3.12
3.50	3.15
3.45	3.12
3.49	3.10
3.47	3.13
Average	Average
Error	Error

3. After school one day, Antonio and Earnest were playing with a slingshot. Antonio's mother said it would be OK as long as they stayed in the back yard, and used only pencil erasers for ammunition. Antonio had a pink, rectangular eraser, while Earnest had a smaller white, square one. The table below shows the distance traveled by each eraser on 8 attempts. From only the given data, can you support (scientifically) Earnest's claim that his eraser will always go farther? Explain why or why not.

Antonio's (pink) eraser Distance (m)	Earnest's (white) eraser Distance (m)
3.12	3.20
3.20	3.75
3.55	3.22
3.04	3.05
3.48	3.58
3.60	3.63
3.16	3.18
3.35	3.41

4. While cleaning the kitchen sink one Saturday, Joanne noticed that her yellow sponge seemed to be a little heavier than the pink one when they were both saturated with water, even though when the sponges were dry, they seemed to have the same mass. Joanne found the mass of both sponges when they were dry. She was right, each sponge had a mass of 31.50 grams. She saturated each sponge with plain water several times, and recorded the data below. Does the data show (scientifically) that the yellow sponge absorbs more water than the pink one? Explain why or why not.

Yellow Sponge Mass (g)	Pink Sponge Mass (g)
94.25	75.62
93.45	75.60
92.40	75.55
92.22	75.50
92.20	75.00

5. At Valley View Middle School, the girls' 4 × 100 m relay team is set. Coach Davis still needs to determine who the fastest runner is, so she can decide in what order they should run. The four girls on the relay team run time trials twice each day for three days. Their times are given in the table below. Is it possible (scientifically speaking) to determine who is the fastest? If so, which girl is the fastest?

Tara Time (seconds)	Sammie Time (seconds)	Joan Time (seconds)	Lexy Time (seconds)
12.70	12.59	13.02	12.77
12.99	12.45	13.01	12.80
13.00	12.40	13.00	12.78
12.88	12.60	12.95	12.99
12.75	12.54	13.05	12.94
12.80	12.42	13.11	12.90

Science Vocabulary

READ 📘 CPO Science

One stumbling block for many science students is the number of new vocabulary words they encounter. Each field of science has its own body of terms, and there are many additional terms that are used in all the fields of science. However, few people are likely to run across these terms in their daily lives until they enter science classes in school. How do students master this new language? The same way they master any vocabulary— by looking to the roots!

Prefixes and *suffixes* play an important role in word structure. Prefixes are word parts that begin a word, and suffixes are word parts that end a word. These parts, also called *roots*, often have special meanings due to their use in other languages.

Prefixes and suffixes of words (and entire words themselves) in the English language are derived from other languages. Some of these languages like French are used in the world culture today and some languages belong to cultures long past. Latin and Greek are the two most common languages from which we derive pieces and parts of our words.

The study of languages provides tremendous benefit to understanding the meanings of words. Other languages provide us with greater understanding of our own language since the roots of many of the words come from these languages. For example, English, French, Italian, and Spanish all have Latin as a common ancestral language. Therefore, studying French, Italian, or Spanish increases the size of your vocabulary toolbox. Studying Latin (or Greek) is also a tremendous aid for mastery and comprehension of the English vocabulary.

EXAMPLE ▶

When you encounter a new word and are unsure of its meaning, find and isolate the prefix and suffix of the word. It may help to write the word on a separate sheet of paper and circle or underline these parts. The remaining, uncircled parts of the word may also have a special meaning. Now, study each part of the word and work towards understanding its meaning.

Example: Consider the word *blueberry*. There are two pieces to this word—the prefix *blue* and the suffix *berry*. Each of these word parts has its own meaning which, when combined with the other word part, gives the whole word its own, unique meaning. *Blue* denotes a color with which you are familiar. A *berry* is a small fruit that birds (and humans!) like to eat. Put them together, and you understand that *blueberry* probably means a small fruit that is colored blue! From your past experiences, you realize that this is a pretty good description of blueberries. Science words can be broken apart and analyzed in the same way to get an understanding of their meanings.

Below are some words you may encounter in a science class. For each word, circle the prefix and put a box around the suffix:

thermometer	electrolyte	monoatomic
volumetric	endothermic	spectroscope
prototype	convex	supersaturated

PRACTICE ▷⌒

The table below lists some prefixes and suffixes that are found in scientific vocabulary along with their respective meanings. Use this table to write a definition for the following terms.

Prefixes	Suffixes
homo – same, equal	*-escence* – to exist
poly – many	*-meter* – measure
hydro – water	*-ology* – the study of
lumen –- light	*-mer* – unit
spectro – a continuous range or full extent	*-geneous* – kind or type
hetero – different	

1. *hydrology* _____

2. *polymer* _____

3. *homogeneous* _____

4. *heterogeneous* _____

5. *luminescence* _____

6. *spectrometer* _____

Now, using a dictionary, look up the words for which you provided your own definition, and write the formal definitions in the spaces below:

1. *hydrology* _____

2. *polymer* _____

3. *homogeneous* _____

4. *heterogeneous* _____

5. *luminescence* _____

6. *spectrometer* _____

Using the table of prefixes and suffixes provided on the following page, write a word that corresponds to each of the following definitions:

Prefixes	Suffixes
thermo – heat	*-scope* – to view
mono – one	*-meter* – measure
tele – far	*-atomic* – indivisible unit
sono – sound, tone	*-graph, -gram* – something written

1. A device to measure heat or temperature: _____

2. A graph showing the loudness and frequencies of sounds: _____

3. Having only one type of "indivisible" unit: _____

4. A device used to view distant objects: _____

Look up the words you created in the dictionary. Write your words and the accepted definitions in the space below:

Word	Dictionary Definition

How closely did your definitions match the accepted ones found in the dictionary? Your definitions based on your understanding of the roots for the prefixes and suffixes likely provided you with good results. A thorough knowledge of prefixes and suffixes will be a tremendous help to you as you proceed through your science education and will enable you to better understand the written and spoken language you encounter in your daily life.

Temperature Scales

READ CPO Science

The Fahrenheit and Celsius temperature scales are commonly used scales for reporting temperature values. Scientists use the Celsius scale almost exclusively, as do many countries of the world. The United States relies on the Fahrenheit scale for reporting temperature information. You can convert information reported in degrees Celsius to degrees Fahrenheit or vice versa using conversion formulas.

Fahrenheit (°F) to Celsius (°C) conversion formula: $°C = \frac{5}{9}(°F - 32)$

Celsius (°C) to Fahrenheit (°F) conversion formula: $°F = \left(\frac{9}{5} \times °C\right) + 32$

EXAMPLES ▷

What is the Celsius value for 65° Fahrenheit?

Step 1: Subtract $\quad °C = \left(\frac{5}{9}\right)(65°F - 32)$

Step 2: Multiply $\quad °C = \left(\frac{5}{9}\right)(33) = (5 \times 33) \div 9$

Step 3: Divide $\quad °C = (165) \div 9$

$°C = 18.3$

200°C is the same temperature as what value on the Fahrenheit scale?

$$°F = \left(\frac{9}{5}\right)(200°C) + 32$$

Step 1: Multiply $\quad °F = [(9 \times 200°C) \div 5] + 32$

Step 2: Divide $\quad °F = [1800 \div 5] + 32$

Step 3: Add $\quad °F = 360 + 32$

$°F = 18.3$

PRACTICE ▷

1. For each of the problems below, show your calculations. Follow the steps from the examples above.

   a. What is the Celsius value for 212°F?

   b. What is the Celsius value for 98.6°F?

   c. What is the Celsius value for 40°F?

   d. What is the Celsius value for 10°F?

   e. What is the Fahrenheit value for 0°C?

   f. What is the Fahrenheit value for 25°C?

   g. What is the Fahrenheit value for 75°C?

212° ← water boils → ?

98.6° ← normal human body temp. → ?

? ← water freezes → 0°

FAHRENHEIT   **CELSIUS**
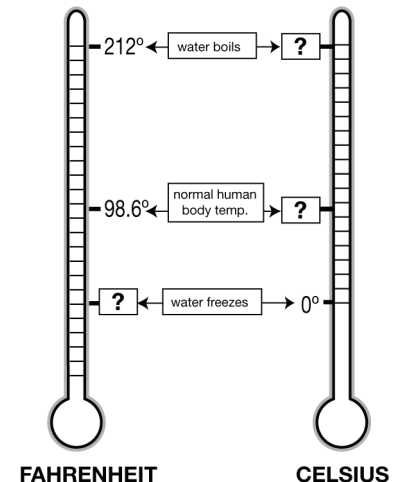
2. The weatherman reports that today will reach a high of 45°F. Your friend from Sweden asks what the temperature will be in degrees Celsius. What value would you report to your friend?

3. Your parents order an oven from England. The temperature dial on the new oven is calibrated in degrees Celsius. If you need to bake a cake at 350°F in the new oven, at what temperature should you set the dial?

4. A German automobile's engine temperature gauge reads in Celsius, not Fahrenheit. The engine temperature should not rise above about 225°F. What is the corresponding Celsius temperature on this car's gauge?

5. Your grandmother in Ireland sends you her favorite cookie recipe. Her instructions say to bake the cookies at 190.5°C. To what Fahrenheit temperature would you set the oven to bake the cookies?

6. A scientist wishes to generate a chemical reaction in his laboratory. The temperature values in his laboratory manual are given in degrees Celsius. However, his lab thermometers are calibrated in degrees Fahrenheit. If he needs to heat his reactants to 232°C, what temperature will he need to monitor on his lab thermometers?

7. You call a friend in Denmark during the winter holidays and say that the temperature in Boston is 15 degrees. He replies that you must enjoy the warm weather. Explain his comment using your knowledge of the Fahrenheit and Celsius scales. To help you get started, fill in this table. What is 15°F on the Celsius scale? What is 15°C on the Fahrenheit scale?

°F		°C
15°F	=	
	=	15°C

8. Challenge questions:

   a. A gas has a boiling point of -175°C. At what Fahrenheit temperature would this gas boil?

   b. A chemist notices some silvery liquid on the floor in her lab. She wonders if someone accidentally broke a mercury thermometer, but did not thoroughly clean up the mess. She decides to find out if the silver stuff is really mercury. From her tests with the substance, she finds out that the melting point for the liquid is 35°F. A reference book says that the melting point for mercury is -38.87°C. Is this substance mercury? Explain your answer and show all relevant calculations.

   c. It is August 1st and you are at a Science Camp in Florida. During an outdoor science quiz, you are asked to identify the temperature scale for a thermometer that reports the current temperature as 90. Is this thermometer calibrated for the Fahrenheit, or Celsius temperature scale? Fill in the table below to answer this question.

°F		°C
90°F	=	
	=	90°C

Specific Heat

READ CPO Science

Specific heat is the amount of thermal energy needed to raise the temperature of 1 gram of a substance 1°C.

The higher the specific heat, the more energy is required to cause a change in temperature. Substances with higher specific heats must lose more thermal energy to lower their temperature than do substances with a low specific heat. Some sample specific heat values are presented in the table below:

Material	Specific Heat (J/kg °C)
water (pure)	4,184
aluminum	897
silver	235
oil	1,900
concrete	880
gold	129
wood	1,700

Water has the highest specific heat of the listed types of matter. This means that water is slower to heat but is also slower to lose heat.

PRACTICE

Using the table above, solve the following heat problems.

1. If 100 joules of energy were applied to all of the substances listed in the table at the same time, which would heat up fastest? Explain your answer.

2. Which of the substances listed in the table would you choose as the best thermal insulator? A thermal insulator is a substance that requires a lot of heat energy to change its temperature. Explain your answer.

3. Which substance—wood or silver—is the better thermal conductor? A thermal conductor is a material that requires very little heat energy to change its temperature. Explain your answer.

4. Which has more thermal energy, 1 kg of aluminum at 20°C or 1 kg of gold at 20°C?

5. How much heat in joules would you need to raise the temperature of 1 kg of water by 5°C?

6. How does the thermal energy of a large container of water compare to a small container of water at the same temperature?

Density

READ

- The density of a substance does not depend on its size or shape. As long as a substance is homogeneous, the density will be the same. This means that a steel nail has the same density as a cube of steel or a steel girder used to build a bridge.

- The formula for density is: $density = \dfrac{mass}{volume}$

- One milliliter takes up the same amount of space as one cubic centimeter. Therefore, density can be expressed in units of g/mL or g/cm^3. Liquid volumes are most commonly expressed in milliliters, while volumes of solids are usually expressed in cubic centimeters.

- Density can also be expressed in units of kilograms per cubic meter (kg/m^3).

- If you know the density of a substance and the volume of a sample, you can calculate the mass of the sample. To do this, rearrange the equation above to find mass: $volume \times density = mass$

- If you know the density of a substance and the mass of a sample, you can find the volume of the sample. This time, you will rearrange the density equation to find volume: $volume = \dfrac{mass}{density}$

Steel density

Steel cube
Volume: 1.0 cm³
Mass: 7.8 g
Density: 7.8 g/cm³
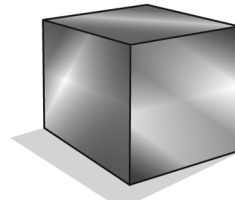
Nail
Volume: 1.6 cm³
Mass: 12.5 g
Density: 7.8 g/cm³

EXAMPLES ▶

Example 1: What is the density of a block of aluminum with a volume of 30.0 cm³ and a mass of 81.0 grams?

$$density = \frac{81.0 \text{ g}}{30.0 \text{ cm}^3} = \frac{2.70 \text{ g}}{cm^3}$$

Answer: The density of aluminum is 2.70 g/cm³.

Example 2: What is the mass of an iron horseshoe with a volume of 89 cm³? The density of iron is 7.9 g/cm³.

$$mass = 89cm^3 \times 7.9\frac{g}{cm^3} = 703 \text{ grams}$$

Answer: The mass of the horseshoe is 703 grams.

Example 3: What is the volume of a 525-gram block of lead? The density of lead is 11.3 g/cm³.

$$volume = \frac{525 \text{ g}}{11.3\frac{g}{cm^3}} = 46.5 \text{ cm}^3$$

Answer: The volume of the block is 46.5 cm³.

PRACTICE ▷~~~

1. A solid rubber stopper has a mass of 33.0 grams and a volume of 30.0 cm³. What is the density of rubber?

2. A chunk of paraffin (wax) has a mass of 50.4 grams and a volume of 57.9 cm³. What is the density of paraffin?

3. A marble statue has a mass of 6,200 grams and a volume of 2,296 cm³. What is the density of marble?

4. The density of ice is 0.92 g/cm³. An ice sculptor orders a one cubic meter block of ice. What is the mass of the block? Hint: 1 m³ = 1,000,000 cm³. Give your answer in grams and kilograms.

5. What is the mass of a pure platinum disk with a volume of 113 cm³? The density of platinum is 21.4 g/cm³. Give your answer in grams and kilograms.

6. The density of seawater is 1.025 g/mL. What is the mass of 1.000 liter of seawater in grams and in kilograms? (Hint: 1 liter = 1,000 mL)

7. The density of cork is 0.24 g/cm³. What is the volume of a 240-gram piece of cork?

8. The density of gold is 19.3 g/cm³. What is the volume of a 575-gram bar of pure gold?

9. The density of mercury is 13.6 g/mL. What is the volume of a 155-gram sample of mercury?

10. Recycling centers, for example, use density to help sort and identify different types of plastics so that they can be properly recycled. The table below shows common types of plastics, their recycling code, and density. Use the table to solve problems 10a -d.

Plastic name	Common uses	Recycling code	Density (g/cm³)	Density (kg/m³)
PETE	plastic soda bottles	1	1.38-1.39	1,380 - 1,390
HDPE	milk cartons	2	0.95-0.97	950 - 970
PVC	plumbing pipe	3	1.15-1.35	1,150 - 1,350
LDPE	trash can liners	4	0.92-0.94	920 - 940
PP	yogurt containers	5	0.90-0.91	900 - 910
PS	cd "jewel cases"	6	1.05-1.07	1,050 - 1,070

a. A recycling center has a 0.125 m³ box filled with one type of plastic. When empty, the box had a mass of 0.755 kilograms. The full box has a mass of 120.8 kilograms. What is the density of the plastic? What type of plastic is in the box?

b. A truckload of plastic soda bottles was finely shredded at a recycling center. The plastic shreds were placed into 55-liter drums. What is the mass of the plastic shreds inside one of the drums? Hint: 55 liters = 55,000 milliliters = 55,000 cm³.

c. A recycling center has 100 kilograms of shredded plastic yogurt containers. What volume is needed to hold this amount of shredded plastic? How many 10-liter (10,000 mL) containers do they need to hold all of this plastic? Hint: 1 m³ = 1,000,000 mL.

d. A solid will float in a liquid if it is less dense than the liquid, and sink if it is more dense than the liquid. If the density of seawater is 1.025 g/mL, which types of plastics would definitely float in seawater?

Slope from a Graph

READ CPO Science

To determine the slope of a line in a graph, first choose two points on the line. Then count how many steps up or down you must move to be on the same horizontal line as your second point. Multiply this number by the scale of your horizontal axis. For example, if your *x*-axis has a scale of 1 box = 20 cm, then multiply the number of boxes you counted by 20 cm.

Put the result along with the positive or negative sign as the top (numerator) of your slope ratio. Then count how many steps you must move right or left to land on your second point. Multiply the number of steps by the scale of your vertical axis. Place the results as the bottom (denominator) of your slope ratio. Then reduce the fraction of your ratio. This number is the slope of the line.

EXAMPLES ▶

A

The chosen points for Example A are (0, 0) and (3, 9). There are many choices for this graph, but only one slope. If you have the point (0, 0), you should choose it as one of your points.

It takes 9 vertical steps to move from (0, 0) to (0, 9). Put a 9 in the numerator of your slope ratio (or subtract 9 – 0). Then count the number of steps to move from (0, 9) to (3, 9). This is your denominator of your slope ratio. Again, you can do this by subtraction (3 - 0).

$$m = \frac{9}{3} = \frac{3}{1}$$

B

The two points that have been chosen for Example B are (0, 24) and (6, 15). Be careful of the scales on each of the axes.

It takes 3 vertical steps to go from (0, 24) to (0, 15). But each of these steps has a scale of 3. So you put a -9 into the numerator of the slope ratio. It is *negative* because you are moving down from one point to the other. Then count the steps over to (6, 15). There are 3 steps but each counts for 2 so you put a 6 into the denominator of the slope ratio.

$$m = \frac{-9}{6} = \frac{-3}{2}$$

PRACTICE ▶

Find the slope of the line in each of the following graphs:

Graph #1:   Graph #2:

m = _____   m = _____

Graph #3:

m =_____

Graph #4:

m =_____

Graph #5:

m =_____

Graph #6:

m =_____

Graph #7:

m = _____

Graph #8:

m = _____

Graph #9:

m = _____

Graph #10:

m = _____

Archimedes

Archimedes was a Greek mathematician who specialized in geometry. He figured out the value of pi and the volume of a sphere, and has been called "the father of integral calculus." During his lifetime, he was famous for using compound pulleys and levers to invent war machines that successfully held off an attack on his city for three years. Today he is best known for the Archimedes principle, which was the first explanation of how buoyancy works.

Archimedes' screw
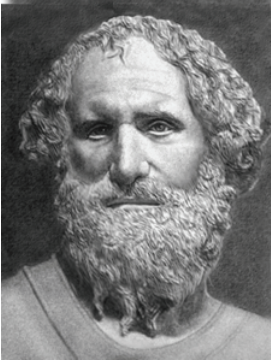
Archimedes was born in Syracuse, on Sicily (then an independent Greek city-state), in 287 B.C. His letters suggest he studied in Alexandria, Egypt, as a young man. Historians believe it was there that he invented a device for raising water by means of a rotating screw or spirally bent tube within an inclined hollow cylinder. The device known as Archimedes' screw is still used in many parts of the world.

"Eureka!"

A famous Greek legend says that King Hieron II of Syracuse asked Archimedes to figure out if his new crown was pure gold or if the craftsman had mixed some less expensive silver into it. Archimedes had to determine the answer without destroying the crown. He thought about it for days and then, as he lowered himself into a bath, the method for figuring it out struck him. The legend says Archimedes ran through the streets, shouting "Eureka!"—meaning "I have found it."

A massive problem

Archimedes realized that if he had equal masses of gold and silver, the denser gold would have a smaller volume. Therefore, the gold would displace less water than the silver when submerged.

Archimedes found the mass of the crown and then made a bar of pure gold with the same mass. He submerged the gold bar and measured the volume of water it

Equal Masses

Gold bar   Crown

The crown displaced more water
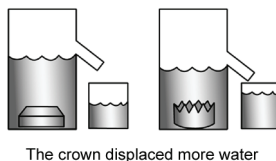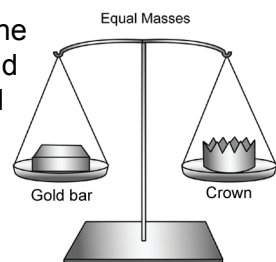
displaced. Next, he submerged the crown. He found the crown displaced more water than the gold bar had and, therefore, could not be pure gold. The gold had been mixed with a less dense material. Archimedes had confirmed the king's doubts.

Why do things float?

Archimedes wrote a treatise titled *On Floating Bodies*, further exploring **density** and **buoyancy**. He explained that an object immersed in a fluid is pushed upward by a force equal to the weight of the fluid displaced by the object. Therefore, if an object weighs more than the fluid it displaces, it will sink. If it weighs less than the fluid it displaces, it will float. This statement is known as the *Archimedes principle*. Although we commonly assume the fluid is water, the statement holds true for any fluid, whether liquid or gas. A helium balloon floats because the air it displaces weighs more than the balloon filled with lightweight gas.

Cylinders, circles, and exponents

Archimedes wrote several other treatises, including "On the Sphere and the Cylinder," "On the Measurement of the Circle," "On Spirals," and "The Sand Reckoner." In this last treatise, he devised a system of exponents that allowed him to represent large numbers on paper—up to 8×10^{63} in modern scientific notation. This was large enough, he said, to count the grains of sand that would be needed to fill the universe. This paper is even more remarkable for its astronomical calculations than for its new mathematics. Archimedes first had to figure out the size of the universe in order to estimate the amount of sand needed to fill it. He based his size calculations on the writings of three astronomers (one of them was his father). While his estimate is considered too small by today's standard, it was much, much larger than anyone had previously suggested. Archimedes was the first to think on an "astronomical scale."

Archimedes was killed by a Roman soldier during an invasion of Syracuse in 212 B.C.

Reading reflection

1. The boldface words in the article are defined in the glossary of your textbook. Look them up and then explain the meaning of each in your own words.

2. Imagine you are Archimedes and have to write your resume for a job. Describe yourself in a brief paragraph. Be sure to include in the paragraph your skills and the jobs you are capable of doing.

3. What was Archimedes' treatise "The Sand Reckoner" about?

4. Why does a balloon filled with helium float in air, but a balloon filled with air from your lungs sinks?

5. **Research** one of Archimedes' inventions and create a poster that shows how the device worked.

Buoyancy

READ 📖 CPO Science

When an object is placed in a fluid (liquid or gas), the fluid exerts an *upward force* upon the object. This force is called a **buoyant force**.

At the same time, there is an attractive force between the object and Earth, which we call the force of gravity. It acts as a *downward force*.

Buoyant force > Gravitational force		Buoyant force < Gravitational force
Object floats		Object sinks

EXAMPLES ▶

Example 1: A 13-newton object is placed in a container of fluid. If the fluid exerts a 60-newton buoyant (upward) force on the object, will the object float or sink?
Answer: Float. The upward buoyant force (60 N) is greater than the weight of the object (13 N).

Example 2: The rock weighs 2.25 newtons when suspended in air. In water, it appears to weigh only 1.8 newtons. Why?
Answer: The water exerts a buoyant force on the rock. This buoyant force equals the difference between the rock's weight in air and its apparent weight in water.

$$2.25 \text{ N} - 1.8 \text{ N} = 0.45 \text{ N}$$

The water exerts a buoyant force of 0.45 newtons on the rock.
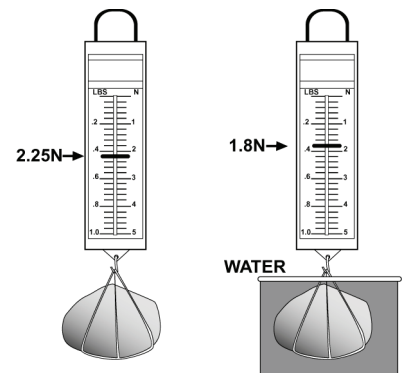
PRACTICE ▶

1. A 4.5-newton object is placed in a tank of water. If the water exerts a force of 4.0 newtons on the object, will the object sink or float?

2. The same 4.5-newton object is placed in a tank of glycerin. If the glycerin exerts a force of 5.0 newtons on the object, will the object sink or float?

3. You suspend a brass ring from a spring scale. Its weight is 0.83 N while it is suspended in air. Next, you immerse the ring in a container of light corn syrup. The ring appears to weigh 0.71 N. What is the buoyant force acting on the ring in the light corn syrup?

4. You wash the brass ring (from question 3) and then suspend it in a container of vegetable oil. The ring appears to weigh 0.73 N. What is the buoyant force acting on the ring?

5. Which has greater buoyant force, light corn syrup or the vegetable oil? Why do you think this is so?

6. A cube of gold weighs 1.89 N when suspended in air from a spring scale. When suspended in molasses, it appears to weigh 1.76 N. What is the buoyant force acting on the cube?

7. Do you think the buoyant force would be greater or smaller if the gold cube were suspended in water? Explain your answer.

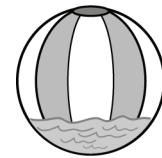# Archimedes Principle

READptember

More than 2,000 years ago, Archimedes discovered the relationship between buoyant force and how much fluid is displaced by an object. **Archimedes principle** states:

The buoyant force acting on an object in a fluid is equal to the weight of the fluid displaced by the object.

We can practice figuring out the buoyant force using a beach ball and a big tub of water. Our beach ball has a volume of 14,130 cm^3. The weight of the beach ball in air is 1.5 N.

If you put the beach ball into the water and don't push down on it, you'll see that the beach ball floats on top of the water by itself. Only a small part of the beach ball is underwater. Measuring the volume of the beach ball that is under water, we find it is 153 cm^3. Knowing that 1 cm^3 of water has a mass of 1 g, you can calculate the weight of the water displaced by the beach ball.

water displaced by floating ball
153 cm³
1.5N

153 cm^3 of water = 153 grams = 0.153 kg

weight = mass × force of gravity per kg = (0.153 kg) × 9.8 N/kg = 1.5 N

According to Archimedes principle, the buoyant force acting on the beach ball equals the weight of the water displaced by the beach ball. Since the beach ball is floating in equilibrium, the weight of the ball pushing down must equal the buoyant force pushing up on the ball. We just showed this to be true for our beach ball.

Have you ever tried to hold a beach ball underwater? It takes a lot of effort! That is because as you submerge more of the beach ball, the more the buoyant force acting on the ball pushes it up. Let's calculate the buoyant force on our beach ball if we push it all the way under the water. Completely submerged, the beach ball displaces 14,130 cm^3 of water. Archimedes principle tells us that the buoyant force on the ball is equal to the weight of that water:

14,130 cm³   **14,130 cm³**
(weighs 138 N)
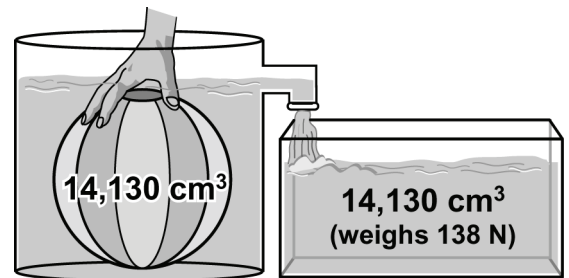
14,130 cm^3 of water = 14,130 grams = 14.13 kg

weight = mass × force of gravity per kg = (14.13 kg) × 9.8 N/kg = 138 N

If the buoyant force is pushing up with 138 N, and the weight of the ball is only 1.5 N, your pushing down on the ball supplies the rest of the force, 136.5 N.

EXAMPLE ▶

A 10-cm^3 block of lead weighs 1.1 N. The lead is placed in a tank of water. One cm^3 of water weighs 0.0098 N. What is the buoyant force on the block of lead?

Given	Solution
Weight of lead block = 1.1 N Volume of block = 10 cm^3	The lead displaces 10 cm^3 of water. buoyant force = weight of water displaced 10 cm^3 of water × 0.0098 N/cm^3 = 0.098 N
Looking for Buoyant force on the lead block	
Relationships 1 cm^3 of water weighs 0.0098 N.	

PRACTICE

1. A block of gold and a block of wood both have the same volume. If they are both submerged in water, which has the higher buoyant force?

2. A 100-cm^3 block of lead that weighs 11 N is carefully submerged in water. One cm^3 of water weighs 0.0098 N.

    a. What volume of water does the lead displace?

    b. How much does that volume of water weigh?

    c. What is the buoyant force on the lead?

    d. Will the lead block sink or float in the water?

3. The same 100-cm^3 lead block is carefully submerged in a container of mercury. One cm^3 of mercury weighs 0.13 N.

    a. What volume of mercury is displaced?

    b. How much does that volume of mercury weigh?

    c. What is the buoyant force on the lead?

    d. Will the lead block sink or float in the mercury?

4. According to problems 2 and 3, does an object's density have anything to do with whether or not it will float in a particular liquid? Justify your answer.

5. Based on the table of densities, explain whether the object would float or sink in the following situations:

material	density (g/ cm^3)
gasoline	0.7
gold	19.3
lead	11.3
mercury	13.6
molasses	1.37
paraffin	0.87
platinum	21.4

    a. A block of solid paraffin (wax) in molasses.

    b. A bar of gold in mercury.

    c. A piece of platinum in gasoline.

    d. A block of paraffin in gasoline.

Ernest Rutherford

Ernest Rutherford initiated a new and radical view of the atom. He explained the mysterious phenomenon of radiation as the spontaneous disintegration of atoms. He was the first to describe the atom's internal structure and performed the first successful nuclear reaction.

Ambitious immigrants
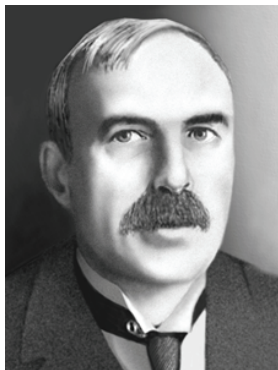
Ernest Rutherford was born in rural New Zealand on August 31, 1871. His father was a Scottish immigrant, his mother English. Both valued education and instilled a strong work ethic in their 12 children. Ernest enjoyed the family farm, but was encouraged by his parents and teachers to pursue scholarships. He first received a scholarship to a secondary school, Nelson College. Then, in 1890, after twice taking the qualifying exam, he received a scholarship to Canterbury College of the University of New Zealand.

Investigating radioactivity

After earning three degrees in his homeland, Rutherford traveled to Cambridge, England, to pursue graduate research under the guidance of the man who discovered the electron, J. J. Thomson. Through his research with Thomson, Rutherford became interested in studying radioactivity. In 1898 he described two kinds of particles emitted from radioactive atoms, calling them *alpha* and *beta* particles. He also coined the term *half-life* to describe the amount of time taken for radioactivity to decrease to half its original level.

An observer of transformations

Rutherford accepted a professorship at McGill University in Montreal, Canada, in 1898. It was there that he proved that atoms of a radioactive element could spontaneously decay into another element by expelling a piece of the atom. This was surprising to the scientific community—the idea that atoms could change into other atoms had been scorned as alchemy.

In 1908 Rutherford received the Nobel Prize in chemistry for "his investigations into the disintegration of the elements and the chemistry of radioactive substances." He considered himself a physicist and joked that, "of all the transformations I have seen in my lifetime, the fastest was my own transformation from physicist to chemist."

Exploring atomic space

Rutherford had returned to England in 1907, to Manchester University. There, he and two students bombarded gold foil with alpha particles. Most of the particles passed through the foil, but a few bounced back. They reasoned these particles must have hit denser areas of foil.

Rutherford hypothesized that the atom must be mostly empty space, through which the alpha particles passed, with a tiny dense core he called the nucleus, which some of the particles hit and bounced off. From this experiment he developed a new "planetary model" of the atom. The inside of the atom, Rutherford suggested, contained electrons orbiting a small nucleus the way the planets of our solar system orbit the sun.

'Playing with marbles'

In 1917, Rutherford made another discovery. He bombarded nitrogen gas with alpha particles and found that occasionally an oxygen atom was produced. He concluded that the alpha particles must have knocked a positively charged particle (which he named the *proton*) from the nucleus. He called this "playing with marbles" but word quickly spread that he had become the first person to split an atom. Rutherford, who was knighted in 1914 (and later elevated to the peerage, in 1931) returned to Cambridge in 1919 to head the Cavendish Laboratory where he had begun his research in radioactivity. He remained there until his death at 66 in 1937.

Reading reflection

1. What are alpha and beta particles? Use your textbook to find the definitions of these terms. Make a diagram of each particle; include labels in your diagram.

2. The term "alchemy" refers to early pseudoscientific attempts to transform common elements into more valuable elements (such as lead into gold). For one kind of atom to become another kind of atom, which particles of the atom need to be expelled or gained?

3. Make a diagram of the "planetary model" of the atom. Include the nucleus and electrons in your diagram.

4. Compare and contrast Rutherford's "planetary model" of the atom with our current understanding of an atom's internal structure.

5. Why did Rutherford say that bombarding atoms with particles was like "playing with marbles"? What subatomic particle did Rutherford discover during this phase of his work?

6. Choose one of Rutherford's discoveries and explain why it intrigues you.

Niels Bohr

Danish physicist Niels Bohr first proposed the idea that electrons exist in specific orbits around the atom's nucleus. He showed that when an electron falls from a higher orbital to a lower one, it releases energy in the form of visible light.

At home among ideas
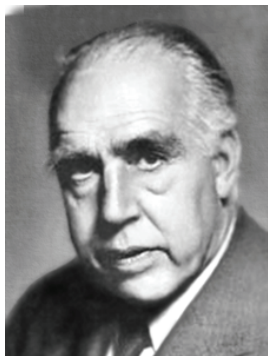
Niels Bohr was born October 7, 1885, in Copenhagen, Denmark. His father was a physiology professor at the University of Copenhagen, his mother the daughter of a prominent Jewish politician and businessman. His parents often invited professors over for dinners and discussions.

Niels and his sister and brother were invited to join this friendly exchange of ideas. (Niels and his brother also shared a passion for soccer, which they both played, and for which Harald, later a world-famous mathematician, was to win an Olympic silver medal.)

Bohr entered the University of Copenhagen in 1903 to study physics. Because the university had no physics laboratory, Bohr conducted experiments in his father's physiology lab. He graduated with a doctorate in 1911.

Meeting of great minds

In 1912, Bohr went to Manchester, England, to study under Ernest Rutherford, who became a lifelong friend. Rutherford had recently published his new planetary model of the atom, which explained that an atom contains a tiny dense core surrounded by orbiting electrons. Bohr began researching the orbiting electrons, hoping to describe their behavior in greater detail.

Electrons and the atom's chemistry

Bohr studied the quantum ideas of Max Planck and Albert Einstein as he attempted to describe the electrons' orbits. In 1913 he published his results. He proposed that electrons traveled only in specific orbits. The orbits were like rungs on a ladder — electrons could move up and down orbits, but did not exist in between the orbital paths. He explained that outer orbits could hold more electrons than inner orbits, and that many chemical properties of the atom were determined by the number of electrons in the outer orbit.

Bohr also described how atoms emit light. He explained that an electron needs to absorb energy to jump from an inner orbit to an outer one. When the electron falls back to the inner orbit, it releases that energy in the form of visible light.

An institute, then a Nobel Prize

In 1916, Bohr accepted a position as professor of physics at the University of Copenhagen. The university created the Institute of Theoretical Physics that Bohr directed for the rest of his life. In 1922, he was awarded the Nobel Prize in physics for his work in atomic structure and radiation.

In 1940, World War II spread across Europe and Germany occupied Denmark. Though he had been baptized a Christian, Bohr's family history and his own anti-Nazi sentiments made life difficult. In 1943, he escaped in a fishing boat to Sweden, where he convinced the king to offer sanctuary to all Jewish refugees from Denmark. The British offered him a position in England to work with researchers on the atomic bomb. A few months later, the team went to Los Alamos, New Mexico, to continue their work.

A warrior for peace

Although Bohr believed the creation of the atomic bomb was necessary in the face of the Nazi threat, he was deeply concerned about its future implications. He promoted disarmament efforts through the United Nations and won the first U.S. Atoms for Peace Award in 1957, the same year his son Aage shared the Nobel Prize in physics. He died in 1962 in Copenhagen.

Reading reflection

1. How did Niels Bohr's model of the atom compare with Ernest Rutherford's?

2. Name two specific contributions Bohr made to our understanding of atomic structure.

3. Make a drawing of Bohr's model of the atom.

4. In your own words describe how atoms emit light.

5. Why do you think Bohr was concerned with the future implications of his work on atomic bombs? Once you have answered this question, discuss your thoughts with a partner.

Marie and Pierre Curie

Marie and Pierre Curie's pioneering studies of radioactivity had a dramatic impact on the development of twentieth-century science. Marie Curie's bold view that uranium rays seemed to be an intrinsic part of uranium atoms encouraged physicists to explore the possibility that atoms might have an internal structure. Out of this idea the field of nuclear physics was born. Together the Curies discovered two radioactive elements, polonium and radium. Through Pierre Curie's study of how living tissue responds to radiation, a new era in cancer treatment was born.

The allure of learning

Marya Sklodowska was born on November 7, 1867, in Russian-occupied Warsaw, Poland. She was the youngest of five children of two teachers, her father a teacher of physics and mathematics, her mother also a singer and pianist. Marya loved school, and especially liked math and science. However, in Poland, as in much of the rest of the world, opportunities for higher education were limited for women. At 17, she and one of her sisters enrolled in an illegal, underground "floating university" in Warsaw.

After these studies, she worked for three years as a governess. Her employer allowed her to teach reading to the children of peasant workers at his beet-sugar factory. This was forbidden under Russian rule. At the same time, she took chemistry lessons from the factory's chemist, mathematics lessons from her father by mail, and studied on her own.

By fall 1891, Sklodowska had saved enough money to enroll at the University of Paris (also called the Sorbonne). She earned two master's degrees, in physics and mathematics. A Polish friend introduced Marie, as she was called in French, to Pierre Curie, the laboratory chief at the Sorbonne's Physics and Industrial Chemistry Schools.

The piezoelectric effect

Pierre Curie's early research centered on properties of crystals. He and his brother Jacques discovered the piezoelectric effect, which describes how a crystal will oscillate when electric current is applied. The oscillation of crystals is now used to precisely control timing in computers and watches and many other devices.

Pierre Curie and Marie Sklodowska found that despite their different nationalities and background, they had the same passion for scientific research and shared the desire to use their discoveries to promote humanitarian causes. They married in 1895.

Crystals and uranium rays

Pierre continued his pioneering research in crystal structures, while Marie pursued a physics doctorate. She chose uranium rays as her research topic. Uranium rays had been discovered only recently by French physicist Henri Becquerel. Becquerel's report explained that uranium compounds emitted some sort of ray that fogged photographic plates. Marie Curie decided to research the effect these rays had on the air's ability to conduct electricity. To measure this effect, she adapted a device that Pierre and Jacques Curie had invented 15 years earlier.

Marie Curie confirmed that the electrical effects of uranium rays were similar to the photographic effects that Becquerel reported—both were present whether the uranium was solid or powdered, pure or in compound, wet or dry, exposed to heat or to light. She concluded that the emission of rays by uranium was not the product of a chemical reaction, but could be something built into the very structure of uranium atoms.

Allies behind a revolutionary idea

Marie Curie's idea was revolutionary because atoms were still believed to be tiny, featureless particles. She decided to test every known element to see if any others would, like uranium, improve the air's ability to conduct electricity. She found that the element thorium had this property.

Pierre Curie decided to join Marie after she found that two different uranium ores (raw materials gathered from uranium mines) caused the air to conduct electricity much better than even pure uranium or thorium. They wondered if an undiscovered element might be mixed into each ore. They worked to separate the chemicals in the ores and found two

substances that were responsible for the increased conductivity. They called these elements polonium, in honor of Marie's native country, and radium, from the Greek word for ray.

A new field of medicine

While Marie Curie searched for ways to extract these pure elements from the ores, Pierre turned his attention to the properties of the rays themselves. He tested the radiation on his own skin and found that it damaged living tissue. As he published his findings, a whole new field of medicine developed, using targeted rays to destroy cancerous tumors and cure skin diseases. Unfortunately, both Curies became ill from overexposure to radiation.

Curies share the Nobel Prize

In June 1903, Madame Curie became the first woman in Europe to receive a doctorate in science. In December of that year, the Curies and Becquerel shared the Nobel Prize in physics. The Curies were honored for their work on the spontaneous radiation that Becquerel had discovered. Marie Curie called spontaneous radiation "radioactivity.") She was the first woman to win the Nobel in physics. And in 1904, her second daughter, Eve, was born. The elder daughter, Irene, was seven.

Tragedy intrudes

In April 1906, Pierre was killed by a horse-drawn wagon in a Paris street accident. A month later, the Sorbonne asked Madame Curie to take over her husband's position there. She agreed, in hopes of creating a state-of-the art research center in her husband's memory.

Marie Curie threw herself into the busy academic schedule of teaching and conducting research (she was the first woman to lecture, the first to be named professor, and the first to head a laboratory at the Sorbonne), and found time to work on raising money for the new center. The Radium Institute of the University of Paris opened in 1914 and Madame Curie was named director of its Curie Laboratory.

The scientist-humanitarian

In 1911, Curie received a second Nobel Prize (the first person so honored), this time in chemistry for her work in finding elements and determining the atomic weight of radium.

With the start of World War I in 1914, she turned her attention to the use of radiation to help wounded soldiers. Assisted by her daughter Irene, she created a fleet of 20 mobile x-ray units to help medics quickly determine and then treat injuries in the field. Next, she set up nearly 200 x-ray labs in hospitals and trained 150 women to operate the equipment.

Legacy continues

After the war, Curie went back to direct the Radium Institute, which grew to two centers, one devoted to research and the other to treatment of cancer. In July 1934, she died at 66 of radiation-induced leukemia. The next year, Irene Joliot-Curie and her husband, Frederic Joliot-Curie, were awarded the Nobel Prize in chemistry for their discovery of artificial radiation.

Reading reflection

1. Why might Marie Curie have been motivated to teach the children of beet workers? Recall that this was forbidden by Russian rule. Discuss your answer to this question with a partner.

2. What fundamental change in our understanding of the atom was brought about by the work of Marie Curie?

3. Describe how Marie and Pierre Curie discovered two elements.

4. Name at least three new fields of science that stem from the work of Marie and/or Pierre Curie.

5. **Research:** In your own words, describe Marie Curie as a role model for women in science. Use your library or the Internet to research how she worked to balance a scientific career and motherhood.

Rosalyn Sussman Yalow

Rosalyn Sussman Yalow and her research partner, Solomon Berson, developed radioimmunoassay, or RIA. This important medical diagnostic tool uses radioactive isotopes to trace hormones, enzymes, and medicines that exist in such low concentrations in blood that they were previously impossible to detect using other laboratory methods.

Encouraged and inspired

Rosalyn Sussman was born in 1921 in New York City. Neither of her parents attended school beyond eighth grade, but they encouraged Rosalyn and her older brother to value education. In the early grades, Rosalyn enjoyed math, but in high school her chemistry teacher encouraged her interest in science. She stayed in New York, studying physics and chemistry at Hunter College. After her graduation in 1941, she took a job as a secretary at Columbia University. There were few opportunities for women to attend graduate school, and Sussman hoped that by working at Columbia, she might be able to sit in on some courses.

A wartime opportunity

However, as the United States began drafting large numbers of men in preparation for war, universities began to accept women rather than close down. In fall 1941, Sussman arrived at the University of Illinois with a teaching assistantship in the School of Engineering, where she was the only woman. She specialized in the construction and use of devices for measuring radioactive substances. By January 1945 she had earned her doctorate, with honors, in nuclear physics, and married Aaron Yalow, a fellow student.

From medical physics to 'radioimmunoassay'

From 1946-50, Yalow taught physics at Hunter, which had only introduced it as a major her senior year and which now admitted men. In 1947, she also began working part time at the Veterans Administration Hospital in the Bronx, which was researching medical uses of radioactive substances.

In 1950 she joined the hospital full time and began a research partnership with Solomon A. Berson, an internist. Together they developed the basic science, instruments, and mathematical analysis necessary to use radioactive isotopes to measure tiny concentrations of biological substances and certain drugs in blood and other body fluids. They called their technique radioimmunoassay, or RIA. (Yalow also had two children by 1954.)

RIA helps diabetes research

One early application of RIA was in diabetes research, which was especially significant to Yalow because her husband was diabetic. Diabetes is a condition in which the body is unable to regulate blood sugar levels. This is normally accomplished through the release of a hormone called insulin from the pancreas. Using RIA, they showed that adult diabetics did not always lack insulin in their blood, and that, therefore, something must be blocking their insulin's normal action. They also studied the body's immune system response to insulin injected into the bloodstream.

Commercial applications, not commerce

RIA's current uses include screening donated blood, determining effective doses of medicines, detecting foreign substances in the blood, testing hormone levels in infertile couples, and treating certain children with growth hormones. Yalow and Berson changed theoretical immunology and could have made their fortunes had they chosen to patent RIA, but instead, Yalow explained, "Patents are about keeping things away from people for the purpose of making money. We wanted others to be able to use RIA." Berson died unexpectedly in 1972; Yalow had their VA research laboratory named after him, and lamented later that his death had excluded him from sharing the team's greatest recognition.

A rare Nobel winner

Yalow was awarded the Nobel Prize in Physiology or Medicine in 1977. She was only the second woman to win in that category, for her work on radioimmunoassay of peptide hormones.

Reading reflection

1. Rosalyn Yalow has said that Eve Curie's biography of her mother, Marie Curie, helped spark her interest in science. Compare the lives of these two scientists.

2. Describe radioimmunoassay in your own words.

3. What information about adult diabetes was discovered using RIA?

4. Find out more about the role of patents in medical research. Do you agree or disagree with Yalow's statement? Why?

Atoms, Isotopes, and Ions

READ 📖

You have learned that atoms contain three smaller particles called protons, neutrons, and electrons, and that the number of protons determines the type of atom. How can you figure out how many neutrons an atom contains, and whether it is neutral or has a charge? Once you know how many protons and neutrons are in an atom, you can also figure out its mass.

In this skill sheet, you will learn about **isotopes**, which are atoms that have the same number of protons but different numbers of neutrons. You will also learn about **ions**, which are atoms that have the same number of protons and different numbers of electrons.

EXAMPLE ▶

What are isotopes?

In addition to its atomic number, every atom can also be described by its mass number:

mass number = number of protons + number of neutrons

Atoms of the same element always have the same number of protons, but can have different numbers of neutrons. These different forms of the same element are called **isotopes**.

Sometimes the mass number for an element is included in its symbol. When the symbol is written in this way, we call it isotope notation. The isotope notation for carbon-12 is shown to the right. How many neutrons does an atom of carbon-12 have? To find out, simply take the mass number and subtract the atomic number: 12 - 6 = 6 neutrons.

mass number ← ⑫ C
atomic number ← ⑥
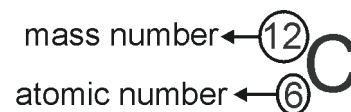
Hydrogen has three isotopes as shown below.
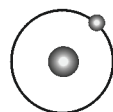
$^{1}_{1}H$
Protium
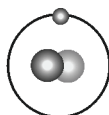
$^{2}_{1}H$
Deuterium
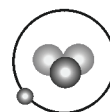
$^{3}_{1}H$
Tritium

1. How many neutrons does protium have? What about deuterium and tritium?

2. Use the diagram of an atom to answer the questions:

    a. What is the atomic number of the element?

    b. What is the name of the element?

    c. What is the mass number of the element?

    d. Write the isotope notation for this isotope.
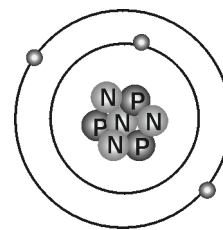
EXAMPLE ▶

What is the atomic mass?

If you look at a periodic table, you will notice that the atomic number increases by one whole number at a time. This is because you add one proton at a time for each element. The atomic mass however, increases by amounts greater than one. This difference is due to the neutrons in the nucleus. The value of the atomic mass reflects the abundance of the stable isotopes for an element that exist in the universe.

Atomic number — The number of protons → 47

Ag

Silver

107.87 ← Atomic mass increases by amounts greater than one

Since silver has an atomic mass of 107.87, this means that most of the stable isotopes that exist have a mass number of 108. In other words, the most common silver isotope is "silver-108." To figure out the most common isotope for an element, round the atomic mass to the nearest whole number.

3. Look up bromine on the periodic table. What is the most common isotope of bromine?

4. Look up potassium. How many neutrons does the most common isotope of potassium have?

EXAMPLE ▶

What are ions?

Sometimes, atoms will gain or lose one or more of their electrons. When this happens, the atoms are no longer neutral, but have a charge that is either positive or negative. Atoms that have a positive or negative charge are called **ions**. Ions always have a whole number for a charge and never a fraction. For example, a chlorine ion has a charge of -1, never -1.25 or -1.7.

You can determine the electric charge of an ion by simply comparing the number of protons and electrons. If there are more protons than electrons, then the ion has a positive charge that is equal to the number of extra protons. If there are more electrons than protons, then the ion has a negative charge that is equal to the number of extra electrons. For example:
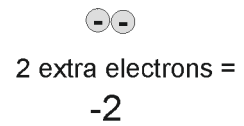
An oxygen atom has...

8 protons   **8** electrons

and

An oxygen ion has...

8 protons   **10** electrons

and
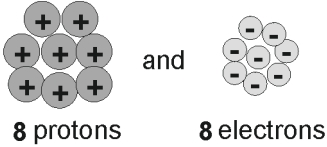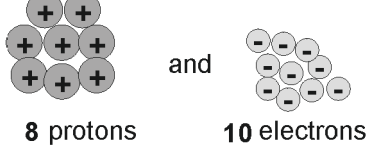
An oxygen ion's charge is...

2 extra electrons =

-2

5. A sodium ion has 11 protons and 10 electrons. What is its charge?

6. A magnesium ion has 12 protons and 10 electrons. What is its charge?

Albert Einstein

Albert Einstein revolutionized the way we view the physical world on an atomic scale.

Looking for "something deeply hidden"
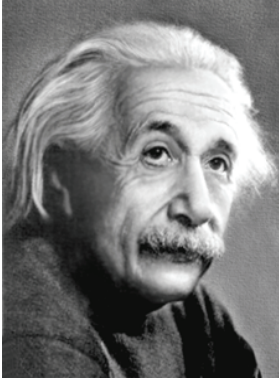
Albert Einstein was born in 1879 in Ulm, Germany, and his family moved several weeks later to Munich. He was a quiet child who spent hours building houses of cards and playing the violin. One story he told from his youth was of his first encounter with a magnetic compass: The needle seemed to him to be guided northward by an invisible force. He was convinced there had to be "something behind things, something deeply hidden." The search for that "something" occupied him until his death in 1955.

Einstein was not fond of school until he entered secondary school in Aarau, Switzerland (his family had moved to Italy). There he found first-rate laboratory facilities and teachers who nurtured his interest in science. He went on to attend the Swiss Federal Institute of Technology in Zurich and graduated in 1900 with a teaching degree. His first permanent job was as a technician in the Patent Office in Bern. Einstein enjoyed evaluating patent claims, but the best part of the position was the stability it provided. He spent his evenings reading and thinking about current issues in theoretical physics.

Stepping into the spotlight

In 1905, Einstein published three papers that radically changed the way scientists understood the physical world. Most work in theoretical physics is accomplished through discussions among scientists. But, Einstein wrote his paper without such discussions in relative isolation.

- The first described light as discrete bundles of **radiation**. Einstein's description formed the basis for much of **quantum mechanics**.

- The second paper proposed his **theory of special relativity**. While Einstein was not the first scientist to generate all of the pieces of this theory, he was the first to unify them.

- The third paper showed that Brownian motion (the erratic motion of microscopic particles in a fluid) provided physical evidence for the existence of atoms and molecules. Until Einstein's paper, scientists had only theoretical evidence of these tiny particles.

Einstein earned respect as one of Europe's leading scientific thinkers as a result of these papers. In 1909 he became a professor first in Zurich, then Prague, and eventually returned to Zurich. In 1914 he was appointed director of the Kaiser Wilhelm Physical Institute and professor at the University of Berlin.

Light bends in space

Einstein's interests turned toward a **theory of general relativity**, which showed how **inertia** and **gravity** are connected. His theory predicted that light from distant stars should be bent by the curvature of space near the sun. During a solar eclipse in 1919, his prediction was proven correct. In 1921, he was awarded the Nobel Prize in physics for his work on the **photoelectric effect**.

War and peace

During World War I, Einstein, a pacifist, refused to support Germany's war aims. In 1933, he left Germany to become a professor at Princeton University. In 1939, concerned about the rise of fascism, he decided force was necessary to face this threat. He sent a letter to President Franklin Roosevelt that urged the United States to develop an atomic bomb before Germany did. After the war, Einstein was a strong supporter of nuclear disarmament.

Unifying the forces of nature

Einstein's scientific interests in his later years focused on finding a unified field theory, which he hoped could integrate all the known forces in nature in a single equation that would show they were all manifestations of a single fundamental force. While he never managed to find what he was looking for, his work fascinates theoretical physicists to this day.

Reading reflection

1. Look up the definition of each boldface word in the article. Write down the definitions and be sure to credit your source.

2. Imagine that you knew Albert Einstein when he was growing up. Write a brief description of him as a young person.

3. How did each of Einstein's first three papers contribute to scientific understanding?

4. **Research** Brownian motion and prepare a demonstration for your classmates.

5. What event helped prove Einstein's prediction that light bends near the sun?

6. **Research** how scientists tested Einstein's theory of general relativity in 1919. Write a paragraph to explain their method.

7. The United States' involvement in World War II lasted from 1941-45. What important thing did Einstein do before the war?

8. After World War II, why do you think Einstein argued for nuclear disarmament?

9. Define the term "unified field theory" in your own words.

10. Which of Einstein's theories was most important? Why? Compare your answer to this question with others in your classroom or discussion group.

Structure of the Atom

READ 📖 CPO Science

Atoms are made of three tiny subatomic particles: protons, neutrons, and electrons. The protons and neutrons are grouped together in the nucleus, which is at the center of the atom. The chart below compares electrons, protons, and neutrons in terms of charge and mass.

	Occurrence	Charge	Mass (g)
⊖ **Electron**	found outside of nucleus	-1	9.109×10^{-28}
⊕ **Proton**	found in all nuclei	+1	1.673×10^{-24}
⚫ **Neutron**	found in almost all nuclei (exception: most H nuclei)	0	1.675×10^{-24}

Size and Structure of the Atom

Atom
Diameter = 10^{-10}m

⊕ **Proton**
⚫ **Neutron**
⊖ **Electron**

Nucleus
Diameter = 10^{-15}m

The **atomic number** of an element is the number of protons in the nucleus of every atom of that element.

Isotopes are atoms of the same element that have different numbers of neutrons. The number of protons in isotopes of an element is the same.

The **mass number** of an isotope tells you the number of protons plus the number of neutrons.

Mass number = number of protons + number of neutrons

EXAMPLE ▶

Carbon has three isotopes: carbon-12, carbon-13, and carbon-14. The atomic number of carbon is 6.

a. How many protons are in the nucleus of a carbon atom?	**Answer:** 6 protons; the atomic number indicates how many protons are in the nucleus of an atom. All atoms of carbon have 6 protons, no matter which isotope they are.
b. How many neutrons are in the nucleus of a carbon-12 atom?	**Answer:** 6 neutrons the mass number - the atomic number = the number of neutrons $12 - 6 = 6$
c. How many electrons are in a neutral atom of carbon-13?	**Answer:** 6 electrons All neutral carbon atoms have 6 protons and 6 electrons.
d. How many neutrons are in the nucleus of a carbon-14 atom?	**Answer:** 8 neutrons the mass number - the atomic number = the number of neutrons $14 - 6 = 8$

PRACTICE ▷

Use a periodic table of the elements to answer these questions.

1. The following graphics represent the nuclei of atoms. Using a periodic table of elements, fill in the table.

What the nucleus looks like	What is this element?	How many electrons does the neutral atom have?	What is the mass number?
(nucleus: N P P P N N N)			
(nucleus: P N / N P N P / P N P / N P N)			
(nucleus: P)			
(nucleus: N P N)			
(nucleus: P N / N P / N N P / N P)			

2. How many protons and neutrons are in the nucleus of each isotope?

   a. hydrogen-2 (atomic number = 1)

   b. scandium-45 (atomic number = 21)

   c. aluminum-27 (atomic number = 13)

   d. uranium-235 (atomic number = 92)

   e. carbon-12 (atomic number = 6)

3. Although electrons have mass, they are not considered in determining the mass number of an atom. Why?

4. A hydrogen atom has one proton, two neutrons, and no electrons. Is this atom an ion? Explain your answer.

5. An atom of sodium-23 (atomic number = 11) has a positive charge of +1. Given this information, how many electrons does it have? How many protons and neutrons does this atom have?

Dot Diagrams

READ CPO Science

You have learned that atoms are composed of protons, neutrons, and electrons. The electrons occupy energy levels that surround the nucleus in the form of an "electron cloud." The electrons that are involved in forming chemical bonds are called **valence electrons**. Atoms can have up to eight valence electrons. These electrons exist in the outermost region of the electron cloud often called the "valence shell."

The most stable atoms have eight valence electrons. When an atom has eight valence electrons, it is said to have a complete *octet*. Atoms will gain or lose electrons in order to complete their octet. In the process of gaining or losing electrons, atoms will form chemical bonds with other atoms. One method we use to show an atom's valence state is called a *dot diagram,* and you will be able to practice drawing these in the following exercise.

What is a dot diagram?

Dot diagrams are composed of two parts—the chemical symbol for the element and the dots surrounding the chemical symbol. Each dot represents one valence electron.

- If an element, such as oxygen (O), has six valence electrons, then six dots will surround the chemical symbol as shown to the right.

- Boron (B) has three valence electrons, so three dots surround the chemical symbol for boron as shown to the right.
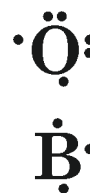
There can be up to eight dots around a symbol, depending on the number of valence electrons the atom has. The first four dots are single, and then as more dots are added, they fill in as pairs.

Using a periodic table, complete the following chart. With this information, draw a dot diagram for each element in the chart. Remember, only the valence electrons are represented in the diagram, not the total number of electrons.

| Element	Chemical symbol	Total number of electrons	Number of valence electrons	Dot diagram
Potassium	K			
Nitrogen	N			
Carbon	C			
Beryllium	Be			
Neon	Ne			
Sulfur	S			

READ CPO Science

Using dot diagrams to represent chemical reactivity

Once you have a dot diagram for an element, you can predict how an atom will achieve a full valence shell. For instance, it is easy to see that chlorine has one empty space in its valence shell. It is likely that chlorine will try to gain one electron to fill this empty space rather than lose the remaining seven. However, potassium has a single dot or electron in its dot diagram. This diagram shows how much easier it is to lose this lone electron than to find seven to fill the seven empty spaces. When the potassium loses its electron, it becomes *positively* charged. When chlorine gains the electron, it becomes *negatively* charged. Opposite charges attract, and this attraction draws the atoms together to form what is termed an **ionic bond**, a bond between two charged atoms or ions.
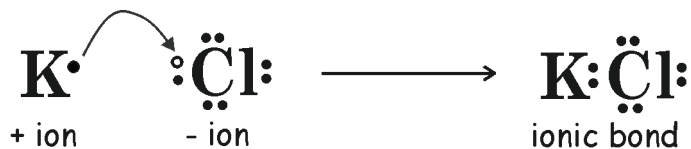
Because chlorine needs one electron, and potassium needs to lose one electron, these two elements can achieve a complete set of eight valence electrons by forming a chemical bond. We can use dot diagrams to represent the chemical bond between chlorine and potassium as shown above.

For magnesium and chlorine, however, the situation is a bit different. By examining the electron or Lewis dot diagrams for these atoms, we see why magnesium requires two atoms of chlorine to produce the compound, magnesium chloride, when these two elements chemically combine.
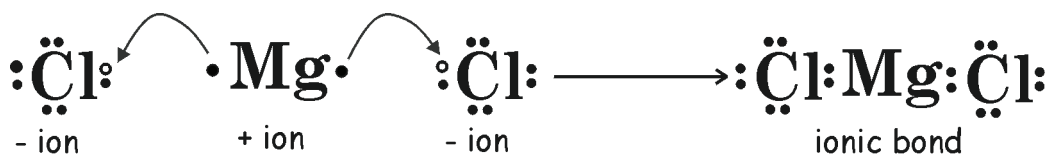
Magnesium can easily donate one of its valence electrons to the chlorine to fill chlorine's valence shell, but this still leaves magnesium unstable; it still has one lone electron in its valence shell. However, if it donates that electron to another chlorine atom, the second chlorine atom has a full shell, and now so does the magnesium.

The chemical formula for potassium chloride is KCl. This means that one unit of the compound is made of one potassium atom and one chlorine atom.

The formula for magnesium chloride is $MgCl_2$. This means that one unit of the compound is made of one magnesium atom and two chlorine atoms.

Now try using dot diagrams to predict chemical formulas. Fill in the table below:

Elements	Dot diagram for each element	Dot diagram for compound formed	Chemical formula
Na and F			
Br and Br			
Mg and O			

Chemical Formulas

PRACTICE
112m =
4 sec
8.2

READ CPO Science

Compounds have unique names that we use to identify them when we study chemical properties and changes. Chemists have devised a shorthand way of representing chemical names that provides important information about the substance. This shorthand representation for a compound's name is called a chemical formula. You will practice writing chemical formulas in the following activity.

What is a chemical formula?

Chemical formulas have two important parts: chemical symbols for the elements in the compound and subscripts that tell how many atoms of each element are needed to form the compound. The chemical formula for water, H_2O, tells us that a water molecule is made of the elements hydrogen (H) and oxygen (O) and that it takes two atoms of hydrogen and one atom of oxygen to build the molecule. For sodium nitrate, $NaNO_3$, the chemical formula tells us there are three elements in the compound: sodium (Na), nitrogen (N), and oxygen (O). To make a molecule of this compound, you need one atom of sodium, one atom of nitrogen, and three atoms of oxygen.

EXAMPLES ▶

How to write chemical formulas

How do chemists know how many atoms of each element are needed to build a molecule? For ionic compounds, oxidation numbers are the key. An element's oxidation number is the number of electrons it will gain or lose in a chemical reaction. We can use the periodic table to find the oxidation number for an element. When we add up the oxidation numbers of the elements in an ionic compound, the sum must be zero. Therefore, we need to find a balance of negative and positive ions in the compound for the molecule to form.

Example 1:

A compound is formed by the reaction between magnesium and chlorine. What is the chemical formula for this compound?

From the periodic table, we find that the oxidation number of magnesium is 2+. Magnesium loses 2 electrons in chemical reactions. The oxidation number for chlorine is 1-. Chlorine tends to gain one electron in a chemical reaction.

Remember that the sum of the oxidation numbers of the elements in a molecule will equal zero. This compound requires one atom of magnesium with an oxidation number of 2+ to combine with two atoms of chlorine, each with an oxidation number of 1-, for the sum of the oxidation numbers to be zero.

$$(2+) + 2(1-) = 0$$

To write the chemical formula for this compound, first write the chemical symbol for the positive ion (Mg) and then the chemical symbol for the negative ion (Cl). Next, use subscripts to show how many atoms of each element are required to form the molecule. When one atom of an element is required, no subscript is used. Therefore, the correct chemical formula for magnesium chloride is $MgCl_2$.

Example 2:

Aluminum and bromine combine to form a compound. What is the chemical formula for the compound they form?

From the periodic table, we find that the oxidation number for aluminum (Al) is 3+. The oxidation number for bromine (Br) is 1-. In order for the oxidation numbers of this compound to add up to zero, one atom of aluminum must combine with three atoms of bromine:

$$(3+) + 3(1-) = 0$$

The correct chemical formula for this compound, aluminum bromide, is $AlBr_3$.

PRACTICE

Practice writing chemical formulas for ionic compounds

Use the periodic table to find the oxidation numbers of each element. Then write the correct chemical formula for the compound formed by the following elements:

Element	Oxidation Number	Element	Oxidation Number	Chemical Formula for Compound
Potassium (K)		Chlorine (Cl)		
Calcium (Ca)		Chlorine (Cl)		
Sodium (Na)		Oxygen (O)		
Boron (B)		Phosphorus (P)		
Lithium (Li)		Sulfur (S)		
Aluminum (Al)		Oxygen (O)		
Beryllium (Be)		Iodine (I)		
Calcium (Ca)		Nitrogen (N)		
Sodium (Na)		Bromine (Br)		

Calculating Concentration of Solutions

READ CPO Science

What's the difference between regular and extra-strength cough syrup? Is the rubbing alcohol in your parents' medicine cabinet 70% isopropyl alcohol, or is it 90% isopropyl alcohol? The difference in these and many other pharmaceuticals is dependent upon the concentration of the solution. Chemists, pharmacists, and often consumers find it useful to distinguish between different concentrations of solutions. Remember that to calculate the percent concentration of a solution, use the formula:

$$\text{concentation} = \frac{\text{mass of solute}}{\text{total mass of solution}} \times 100\%$$

EXAMPLES ▷

1. What is the concentration of a solution made up of 12 grams of sugar, and 300 grams of water?

    Explanation/Answer: In this case, the solute is sugar (12 g), and the total mass of the solution is the mass of the sugar plus the mass of the water, (12 g + 300 g).
    Substituting into the formula, where c = the concentration, we have:

    $$c = \frac{12 \text{ g}}{12 \text{ g} + 300 \text{ g}} \times 100\% = \frac{12 \text{ g}}{312 \text{ g}} \times 100\% = 3.8\%$$

    The concentration of a solution made up of 12 grams of sugar and 300 grams of water is 3.8%

2. How many grams of salt and water are needed to create 150 grams of a solution with a concentration of 15% salt?

    Explanation/Answer: Here, we are given the concentration (15%) and the total mass of the solution (150 g). We are trying to find the mass of the solute (salt). Substituting into the same formula, where m is the mass of the salt, we have:

    $$15\% = \frac{m}{150 \text{ g}} \times 100\%, \text{ so } 0.15 = \frac{m}{150 \text{ g}}, \text{ and } 0.15 \times (150 \text{ g}) = m = 22.5 \text{g}$$

    Since the total mass of the solution is 150 grams, and we now know that 22.5 grams are salt, that leaves 150 – 22.5, or 127.5 grams of water.

    To make 150 grams of a solution with a concentration of 15% salt, you would need 22.5 grams of salt and 127.5 grams of water.

PRACTICE ▷〜

Find the **concentration** of each solution.

1. 5 grams of salt in 75 grams of water

2. 40 grams of cinnamon in 2,000 grams of flour

3. 1.5 grams of chocolate milk mix in 250 grams of 1% milk

Find the **mass of the solute** in each situation.

4. 1,000 grams of a 40% salt water solution

5. 30 grams of a 12.5% sugar water solution

6. 555 grams of a 25% sand and soil solution

Carefully read and answer each of the following questions.

7. Dawn is mixing 450 grams of dishwashing liquid with 600 grams of water to make a solution for her little brother to blow bubbles. What is the concentration of the dishwashing liquid?

8. How many grams of glucose are needed to prepare 250 grams of a 5% glucose solution?

9. Jill mixes 4 grams of vanilla extract into the 800 grams of cake batter she has prepared. What is the concentration of vanilla in her "solution" of cake batter?

10. **Challenge**: Find the amount of red food coloring (in grams) necessary to add to 50 grams of water to prepare a 15% solution of red food coloring in water.

Chemical Equations

READ CPO Science

Chemical symbols provide us with a shorthand method of writing the name of an element. Chemical formulas do the same for compounds. But what about chemical reactions? To write out, in words, the process of a chemical change would be long and tedious. Is there a shorthand method of writing a chemical reaction so that all the information is presented correctly and is understood by all scientists? Yes! This is the function of chemical equations. You will practice writing and balancing chemical equations in this skill sheet.

What are chemical equations?

Chemical equations show what is happening in a chemical reaction. They provide you with the identities of the reactants (substances entering the reaction) and the products (substances formed by the reaction). They also tell you how much of each substance is involved in the reaction. Chemical equations use symbols for elements and formulas for compounds. The reactants are written to the left of the arrow. Products go on the right side of the arrow.

$$H_2 + O_2 \rightarrow H_2O$$
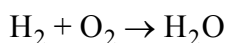
The arrow should be read as "yields" or "produces." This equation, therefore, says that hydrogen gas (H_2) plus oxygen gas (O_2) yields or produces the compound water (H_2O).

Write chemical equations for the following reactions:

Reactants	Products	Unbalanced Chemical Equation
Hydrochloric acid **HCl** and Sodium hydroxide **NaOH**	Water **H_2O** and Sodium chloride **NaCl**	
Calcium carbonate **$CaCO_3$** and Potassium iodide **KI**	Potassium carbonate **K_2CO_3** and Calcium iodide **CaI_2**	
Aluminum fluoride **AlF_3** and Magnesium nitrate **$Mg(NO_3)_2$**	Aluminum nitrate **$Al(NO_3)_3$** and Magnesium fluoride **MgF_2**	

READ

Conservation of atoms

Take another look at the chemical equation for making water:

$$2H_2 + O_2 \rightarrow 2H_2O$$
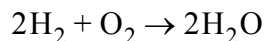
Did you notice that something has been added?

The large number in front of H_2 tells how many molecules of H_2 are required for the reaction to proceed. The large number in front of H_2O tells how many molecules of water are formed by the reaction. These numbers are called *coefficients*. Using coefficients, we can balance chemical equations so that the equation demonstrates conservation of atoms. The law of conservation of atoms says that no atoms are lost or gained in a chemical reaction. The same types and numbers of atoms must be found in the reactants and the products of a chemical reaction.

Coefficients are placed before the chemical symbol for single elements and before the chemical formula of compounds to show how many atoms or molecules of each substance are participating in the chemical reaction. When counting atoms to balance an equation, remember that the coefficient applies to all atoms within the chemical formula for a compound. For example, $5CH_4$ means that 5 atoms of carbon and 20 atoms (5×4) of hydrogen are contributed to the chemical reaction by the compound methane.

Balancing chemical equations

To write a chemical equation correctly, first write the equation using the correct chemical symbols or formulas for the reactants and products.

The displacement reaction between sodium chloride and iodine to form sodium iodide and chlorine gas is written as:

$$NaCl + I_2 \rightarrow NaI + Cl_2$$
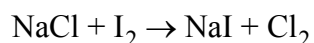
- Next, count the number of atoms of each element present on the reactant and product side of the chemical equation:

Reactant Side of Equation	Element	Product Side of Equation
1	Na	1
1	Cl	2
2	I	1

- For the chemical equation to be balanced, the numbers of atoms of each element must be the same on either side of the reaction. This is clearly not the case with the equation above. We need coefficients to balance the equation.

SKILL and
PRACTICE

10.1

- First, choose one element to balance. Let's start by balancing chlorine. Since there are two atoms of chlorine on the product side and only one on the reactant side, we need to place a "2" in front of the substance containing the chlorine, the NaCl.

$$2NaCl + I_2 \rightarrow NaI + Cl_2$$
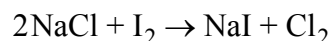
This now gives us two atoms of chlorine on both the reactant and product sides of the equation. However, it also give us two atoms of sodium on the reactant side! This is fine—often balancing one element will temporarily unbalance another. By the end of the process, however, all elements will be balanced.

We now have the choice of balancing either the iodine or the sodium. Let's balance the iodine. (It doesn't matter which element we choose.)

- There are two atoms of iodine on the reactant side of the equation and only one on the product side. Placing a coefficient of "2" in front of the substance containing iodine on the product side:

$$2NaCl + I_2 \rightarrow 2NaI + Cl_2$$
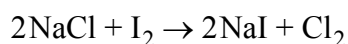
There are now two atoms of iodine on either side of the equation, and at the same time we balanced the number of sodium atoms!

In this chemical reaction, two molecules of sodium chloride react with one molecule of iodine to produce two molecules of sodium iodide and one molecule of chlorine. Our equation is balanced!

Balance the following equations using the appropriate coefficients. Remember that balancing one element may temporarily unbalance another. You will have to correct the imbalance in the final equation. Check your work by counting the total number of atoms of each element—the numbers should be equal on the reactant and product sides of the equation. Remember, the equations **cannot** be balanced by changing subscript numbers!

1. $Al + O_2 \rightarrow Al_2O_3$
2. $CO + H_2 \rightarrow H_2O + CH_4$
3. $HgO \rightarrow Hg + O_2$
4. $CaCO_3 \rightarrow CaO + CO_2$
5. $C + Fe_2O_3 \rightarrow Fe + CO_2$
6. $N_2 + H_2 \rightarrow NH_3$
7. $K + H_2O \rightarrow KOH + H_2$
8. $P + O_2 \rightarrow P_2O_5$
9. $Ba(OH)_2 + H_2SO_4 \rightarrow H_2O + BaSO_4$
10. $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + HF$
11. $KClO_3 \rightarrow KClO_4 + KCl$

Lise Meitner

Lise Meitner identified and explained nuclear fission, proving it was possible to split an atom.

Prepared to learn

Lise Meitner was born in Vienna on November 7, 1878, one of eight children; her father was among the first Jews to practice law in Austria. At 13, she completed the schooling provided to girls. Her father hired a tutor to help her prepare for a university education, although women were not yet allowed to attend.

The preparation was worthwhile. When the University of Vienna opened its doors to women in 1901, Meitner was ready. She found a mentor there in physics professor Ludwig Boltzmann, who encouraged her to pursue a doctoral degree. Physicist Otto Robert Frisch, Meitner's nephew, wrote that "Boltzmann gave her the vision of physics as a battle for ultimate truth, a vision she never lost."

Pioneer in radioactivity

In 1906 Meitner went to Berlin after earning her doctorate, only the second in physics awarded to a woman by the university. There was great interest in theoretical physics in Berlin. There she began a 30-year collaboration with chemist Otto Hahn. Together, they studied radioactive substances. One of their first successes was the development of a new technique for purifying radioactive material.

During World War I, Meitner volunteered as an X-ray nurse-technician with the Austrian army. She pioneered cautious handling techniques for radioactive substances, and when she was off duty, continued her work with Hahn.

Elemental discoveries

In 1917, they discovered the element protactinium. Afterward, Meitner was appointed head of the physics department at the Kaiser Wilhelm Institute for Chemistry in Berlin, where Hahn was head of the chemistry department. The two continued their study of radioactivity, and Meitner became the first to explain how conversion electrons were produced when gamma rays were used to remove orbital electrons.

Atomic-age puzzles

In 1934, when Enrico Fermi produced radioactive isotopes of uranium by neutron bombardment, he was puzzled by the products. Meitner, Hahn, and German chemist Fritz Strassmann began looking for answers.

Their research was interrupted when Nazi Germany annexed Austria in 1938 and restrictions on "non-Aryan" academics tightened. Meitner, though she had been baptized and raised a Protestant, went into exile in Sweden. She continued to correspond with her collaborators and suggested that they perform further tests on a product of the uranium bombardment.

When tests showed it was barium, the group was puzzled. Barium was so much smaller than uranium. Hahn wrote to Meitner that uranium "can't really break into barium … try to think of some other possible explanation."

Meitner and Frisch (who was also in Sweden) worked on the problem and proved that splitting the uranium atom was energetically possible. Using Neils Bohr's model of the nucleus, they explained how the neutron bombardment could cause the nucleus to elongate into a dumbbell shape. Occasionally, they explained, the narrow center of the dumbbell could separate, leaving two nuclei. Meitner and Frisch called this process *nuclear fission*.

Meitnerium honors achievement

In 1944, Hahn received the Nobel Prize in chemistry for the discovery of nuclear fission. Meitner's role was overlooked or obscured.

In 1966, she, Hahn, and Strassman shared the Enrico Fermi Award, given by President Lyndon B. Johnson and the Department of Energy. Meitner died two years later, just days before her 90th birthday. In 1992, element 109 was named *meitnerium* to honor her work.

Reading reflection

1. **Research:** Ludwig Boltzmann was an important mentor to Lise Meitner. Who was Boltzmann? Research and list one of his contributions to science.

2. What element did Meitner and Otto Hahn discover? Using the periodic table, list the atomic number and mass number of this element. Does this element have stable isotopes?

3. What is nuclear fission? Explain this event in your own words and draw a diagram showing how fission occurs in a uranium nucleus.

4. **Research** and describe at least two ways nuclear fission was used in the twentieth century.

5. Meitner did not receive the Nobel Prize for her work on nuclear fission, though she was honored in other ways. List how she was honored for her work in physics.

6. On a separate sheet of paper, compose a letter to the Nobel Prize Committee explaining why Meitner deserved this prize for her work. Be sure to explain your reasoning clearly and be sure to use formal language and good grammar in your letter.

Predicting Chemical Equations

READ [CPO Science]

Chemical reactions are the mechanism of chemical change. Elements and compounds enter into a reaction, and new substances are formed as a result. Often, we know the types of substances that entered the reaction and can tell what types of substance(s) were formed. Sometimes, though, it might be helpful if we could predict the products of the chemical reaction—know in advance what would be formed and how much of it would be produced. For certain chemical reactions, this is possible, using our knowledge of oxidation numbers, mechanics of chemical reactions, and balancing equations. In this skill sheet, you will practice writing a complete balanced equation for chemical reactions when only the identities of the reactants are known.

Chemical equations

Recall that chemical equations show the process of a chemical reaction. The equation reads from left to right with the reactants, separated from the products by an arrow that indicates "yields" or "produces."

In the chemical equation:

$$2Li + BaCl_2 \rightarrow 2LiCl + Ba$$
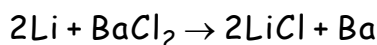
Two atoms of lithium combine with one molecule of barium chloride to yield two molecules of lithium chloride and one atom of barium. The equation fully describes the nature of the chemical change for this reaction.

For reactions such as the one above, a displacement reaction, we are generally capable of predicting the nature of the products in advance and write a completely balanced equation for the chemical change. To do this we must:

1. Predict the replacements for the reaction

In displacement reactions, one element is replaced by a similar element in a compound. The pattern for this replacement is easily predictable: if the element doing the replacing forms a positive ion, it replaces the element in the compound that forms a positive ion. If the substance doing the replacing forms a negative ion, it replaces the element in the compound that forms a negative ion. For the reaction described above, we could predict that the lithium would replace the barium in the compound barium chloride since both lithium and barium have positive oxidation numbers. The resulting product would pair lithium (1+) and chlorine (1-): the positive/negative combination required for ionic compounds.

2. Determine the chemical formula for the products

Once you have determined which elements will be swapped to form the products, you can use oxidation numbers and the fact that the sum of the oxidation numbers for an ionic compound must equal zero in order to determine the chemical formula for the reaction products.

3. Balance the chemical equation

Once you have determined the nature and formulas of the products for a chemical reaction, the final step is to write a balanced equation for the reaction.

EXAMPLE ▶

If beryllium (Be) combines with potassium iodide (KI) in a chemical reaction, what will be the identities of the products?

First, we decide which element of KI will be replaced by the beryllium. Since beryllium has an oxidation number of 2+, it replaces the element in KI that also has a positive oxidation number—the potassium (K^{1+}). It will therefore combine with the iodine to form a new compound.

Because beryllium has an oxidation number of 2+ and iodine's oxidation number is 1-, it is necessary for two atoms of iodine to combine with one atom of beryllium to form an electrically neutral compound. The resulting chemical formula for beryllium iodide is BeI_2.

In single-displacement reactions, the component of the compound that has been replaced by the uncombined reactant now stands alone and uncombined. The resulting products of this chemical reaction, therefore, are BeI_2 and K. Balancing the equation give us:

$$Be + 2KI \rightarrow BeI_2 + 2K$$
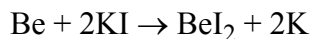
PRACTICE ▶

Predict replacements

1. If Na^{1+} were to combine with $CaCl_2$, what component of $CaCl_2$ would be replaced by the Na^{1+}?

2. If Fe^{2+} were to combine with K_2Br, what component of K_2Br would be replaced by the Fe^{2+}?

3. If Mg^{2+} were to combine with $AlCl_3$, what component of $AlCl_3$ would be replaced by the Mg^{2+}?

Predict product formulas

For the following combinations of reactants, predict the formulas of the products:

4. $Li + AlCl_3$

5. $K + CaO$

6. $F_2 + KI$

Predicting chemical equations for displacement reactions

Write complete balanced equations for the following combinations of reactants.

7. Ca and K_2S

8. Mg and Fe_2O_3

9. Li and NaCl

Classifying Reactions

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Chemical reactions may be classified into different groups according to the reactants and products. The five major groups of chemical reactions are summarized below.

Addition reactions - when two or more substances combine to make a new compound.

- *General equation*: $A + B \rightarrow AB$

- *Example*: When rust forms, iron reacts with oxygen to form iron oxide (rust).
  $4Fe_{(s)} + 3O_{2\,(g)} \rightarrow 2\,Fe_2O_{3\,(s)}$

Decomposition reactions - when a single compound is broken down to produce two or more smaller compounds.

- *General equation*: $AB \rightarrow A + B$

- *Example*: Water can be broken down into hydrogen and oxygen gases.
  $2H_2O_{(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$

Displacement reactions - when one element replaces another element in a compound.

- *General equation*: $A + BX \rightarrow AX + B$

- *Example*: When iron is added to a solution of copper chloride, iron replaces copper in the solution and copper falls out of the solution.
  $Fe_{(s)} + CuCl_{2\,(aq)} \rightarrow Cu_{(s)} + FeCl_{2\,(aq)}$

Precipitation reactions - when two dissolved compounds react to form two new compounds, one of which is not soluble and forms a precipitate.

- *General equation*: $AX + BY \rightarrow AY + BX$

- *Example*: When carbon dioxide gas is bubbled into lime water, a precipitate of calcium carbonate is formed along with water.
  $CO_{2\,(g)} + CaO_2H_{2\,(aq)} \rightarrow CaCO_{3\,(s)} + H_2O_{(l)}$

Combustion reactions - when a carbon compound reacts with oxygen gas to produce carbon dioxide and water vapor. Energy is released from the reaction.

- *General equation*: Carbon Compound $+ O_2 \rightarrow CO_2 + H_2O +$ energy

- *Example*: The combustion of methane gas.
  $CH_{4\,(g)} + 2O_2 \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$

EXAMPLE ▶

Classify the following reaction as addition, decomposition, displacement, precipitation, or combustion. Explain your answer.

$Mg_{(s)} + CuSO_{4\,(s)} \rightarrow MgSO_{4\,(aq)} + Cu_{(s)}$
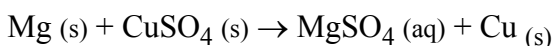
Answer: Displacement. Magnesium replaces copper in the compound.

PRACTICE ▷

Classify the reactions below as either: addition, decomposition, displacement, precipitation, or combustion. Explain your answers.

1. CO_2 (g) + H_2O (l) → H_2CO_3 (aq)

2. Cl_2 (g) + 2KI (aq) → 2KCl (aq) + I_2 (g)

3. H_2O_2 (l) → H_2O (l) + O_2 (g)

4. $MnSO_4$ (s) → MnO (s) + SO_3 (g)

5. $C_6H_{12}O_6$ (s) + $6O_2$ (g) → $6CO_2$ (g) + $6H_2O$ (g)

6. $CaCl_2$ (aq) + $2AgNO_3$ (aq) → $Ca(NO_3)_2$ (aq) + 2AgCl (s)

7. 2NaCl (aq) + $CuSO_4$ (aq) → Na_2SO_4 (aq) + $CuCl_2$ (s)

8. $CaCl_2$ (aq) + 2Na (s) → Ca (s) + 2NaCl (aq)

9. $CaCO_3$ (s) → CaO (s) + CO_2 (g)

10. C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (g)

Answer the following questions.

11. You mix two clear solutions. Instantly, you see a bright yellow precipitate form. What type of reaction did you just observe? Explain your answer.

12. What type of reaction occurs when you strike a match?

13. Solid sodium reacts violently with chlorine gas. The product formed in the reaction is sodium chloride, also known as table salt. What type of reaction is this? Explain your answer.

14. Hydrogen-powered cars burn hydrogen gas to produce water and energy. The reaction is:
$2H_2$ (g) + O_2 (g) → $2H_2O$ (g) + Energy
While this reaction can be classified as an addition reaction, it is sometimes referred to as combustion. What characteristics does this reaction share with other combustion reactions? How is it different?

Position on the Coordinate Plane

READD CPO Science

The way to describe any location in two dimensions is by using a flat surface called the **coordinate plane**. You can describe any **position** on the coordinate plane using two numbers called **coordinates**, which are shown in the form of (x, y). These coordinates are compared to a fixed reference point called the **origin**. The table below describes the x and y coordinates:

| Coordinate	Which axis is it on?	Which is the positive direction?	Which is the negative direction?
x	horizontal, called the *x*-axis	right or east	left or west
y	vertical, called the *y*-axis	up or north	down or south

EXAMPLE ▶

Your home is at the origin, and a park is located 2 miles north and 1 mile east of your home.

* Show your home and the park on a coordinate plane, and give the coordinates for each.
* After you go to the park, you drive 2 miles east and 1 mile north to the grocery store. What are the coordinates of the grocery store?

Solution

If your home is at the origin, it is given the coordinates (0, 0). By counting over 1 box from the origin in the positive *x*-direction and up 2 boxes in the positive *y*-direction, you can place the park on the coordinate plane. The park's coordinates are (+1 mile, +2 miles).

From the park, count over 2 more boxes in the positive *x*-direction and up one more 1 box in the positive *y*-direction to place the grocery store. That makes the grocery store's coordinates (+3 miles, +3 miles).
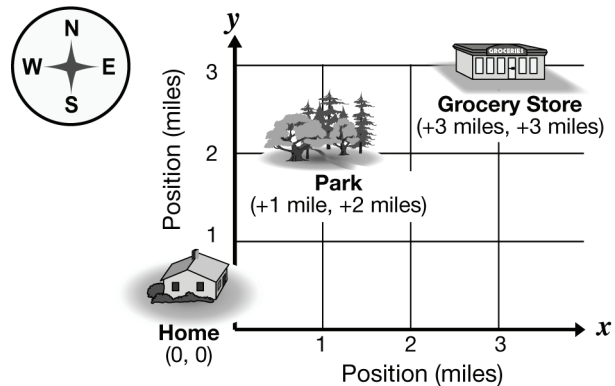
PRACTICE ▶

1. You are given directions to a friend's house from your school. They read: "Go east one block, turn north and go 4 blocks, turn west and go 1 block, then go south for 2 blocks." Using your school as the origin, draw a map of these directions on a coordinate plane. What are the coordinates of your friend's house?

2. A dog starts chasing a squirrel at the origin of a coordinate plane. He runs 20 meters east, then 10 meters north and stops to scratch. Then he runs 10 meters west and 10 meters north, where the squirrel climbs a tree and gets away.

   a. Draw the coordinate plane and trace the path the dog took in chasing the squirrel.

   b. Show where the dog scratched and where the squirrel escaped, and give coordinates for each.

3. Does the order of the coordinates matter? Is the coordinate (2, 3) the same as the coordinate (3, 2)? Explain and draw your answer on a coordinate plane.

Dimensional Analysis

READ [CPO Science]

Dimensional analysis is a way to find the correct label (also called units or dimensions) for the solution to a problem. In dimensional analysis, we treat the units the same way that we treat the numbers. For example, this problem shows how can you can "cancel" the sevens and then perform the multiplication:

$$\frac{3}{\cancel{7}} \cdot \frac{\cancel{7}}{8} = \frac{3}{8}$$

In some problems, there are no numerical cancellations to make, but you need to pay close attention to the units (or dimensions):

$$\frac{16 \text{ oz}}{1 \text{ lb}} \cdot 4 \text{ lb} = \frac{16 \cdot 4 \text{ oz} \cdot \cancel{\text{lb}}}{1 \cancel{\text{lb}}} = \frac{64 \text{ oz}}{1} = 64 \text{ oz}$$

The "lbs" may be cancelled either before or after the multiplication.

- The goal of dimensional analysis is to simplify a problem by focusing on the units of measurement (dimensions).

- Dimensional analysis is very useful when converting between units (like converting inches to yards, or converting between the metric and English systems of measurement.

EXAMPLE ▶

The eighth grade class is having a reward lunch for collecting the most food for a canned food drive. They have decided to order pizza. They are figuring two slices of pizza per student. Each pizza that will be ordered will have 12 slices. There are 220 students total in the eighth grade. How many pizzas should they order?

1. Determine what we want to find out: here, it is the number or whole pizzas needed to feed 220 eighth graders. It's important to remember that if the solution is to have the label "pizzas," "pizzas" should be kept in the numerator as the problem is set up.

2. Determine what we know. We know that they're planning 2 slices of pizza per student, that there are 12 slices in each pizza, and that there are 220 eighth graders.

3. Write what you know as fractions with units. Here, we have: $\frac{2 \text{ slices}}{\text{student}}$, $\frac{12 \text{ slices}}{\text{pizza}}$ and 220 students.

   Notice that in the fraction, $\frac{12 \text{ slices}}{\text{pizza}}$, "pizza" is in the denominator.

   Recall that (from step #1, above) "pizza" should be kept in the numerator, as it will be the label of the final solution. To correct this problem, just switch the numerator and denominator: $\frac{1 \text{ pizza}}{12 \text{ slices}}$.

4. Set up the problem by focusing on the units. Just writing the information as a multiplication problem, we have:

$$\frac{1 \text{ pizza}}{12 \text{ slices}} \bullet \frac{2 \text{ slices}}{\text{student}} \bullet \frac{220 \text{ students}}{1}$$

5. Calculate:
$$\frac{1 \text{ pizza}}{12 \text{ slices}} \bullet \frac{2 \text{ slices}}{\text{student}} \bullet \frac{220 \text{ students}}{1} = \frac{110 \text{ pizza} \bullet \text{slices} \bullet \text{students}}{3 \text{ slices} \bullet \text{students}} = 36\frac{2}{3} \text{ pizzas}$$

    Therefore, 37 pizzas will need to be ordered.

    Notice that canceling the units can be done either before or after the multiplication.

6. Check your solution for reasonableness: Since there are 12 slices in each pizza, and we're figuring that each student will eat 2 slices, one pizza will feed 6 students. It is expected that a little less than 40 pizzas would be needed. It does seem reasonable that 37 pizzas would feed 220 students.

PRACTICE

1. Multiply. Be sure to label your answers.

    a. $\dfrac{\$12.00}{1 \text{ hr}} \bullet \dfrac{6 \text{ hr}}{1 \text{ day}}$

    b. $\dfrac{2 \text{ lbs}}{1 \text{ person}} \bullet \dfrac{7 \text{ days}}{1 \text{ week}} \bullet \dfrac{15 \text{ people}}{1 \text{ day}}$

2. Use dimensional analysis to convert each. You may need to use a reference to find some conversion factors. Show all of your work.

    a. 11 quarts to some number of gallons

    b. 220 centimeters to some number of meters

    c. 6000 inches to some number of miles

    d. How many cups are there in 4 gallons?

3. Use dimensional analysis to find each solution. You may need to use a reference to find some conversion factors. Show all of your work.

    a. Frank just graduated from eighth grade. Assuming exactly four years from now he will graduate from high school, how many seconds does he have until his high school graduation?

    b. In 2005, Christian Cantwell won the US outdoor track and field championship shot put competition with a throw of 21.64 meters. How far is this in feet?

    c. A recipe for caramel oatmeal cookies calls for 1.5 cups of milk. Sam is helping to make the cookies for the soccer and football teams plus the cheerleaders and marching band, and needs to multiply the recipe by twelve. How much milk (in quarts) will he need altogether?

    d. How many football fields (including the 10 yards in each end zone) would it take to make a mile?

    e. Corey's sister's car gets 30 miles on each gallon of gas. How many kilometers per gallon is this?

    f. Convert your answer from (e) to kilometers per liter.

    g. A car is traveling at a rate of 65 miles per hour. How many feet per second is this?

Velocity and Speed

READrr CPO Science

Speed

To determine the speed of an object, you need to know the distance traveled and the time taken to travel that distance. However, by rearranging the formula for speed, $v = d/t$, you can also determine the distance traveled or the time it took for the object to travel that distance, if you know the speed. For example,

Equation...	Gives you...	If you know...
$v = d/t$	speed	distance and time
$d = v \times t$	distance	speed and time
$t = d/v$	time	distance and speed

Use the SI system to solve the practice problems unless you are asked to write the answer using the English system of measurement. As you solve the problems, include all units and cancel appropriately.

EXAMPLE ▶

Example 1: What is the speed of a cheetah that travels 112.0 meters in 4.0 seconds?

Looking for	Solution
Speed of the cheetah.	$$\text{speed} = \frac{d}{t} = \frac{112.0 \text{ m}}{4.0 \text{ s}} = \frac{28 \text{ m}}{\text{s}}$$
Given	
Distance = 112.0 meters	The speed of the cheetah is 28 meters per second.
Time = 4.0 seconds	
Relationship	
$$\text{speed} = \frac{d}{t}$$	

PRACTICE
112m = 4 sec
12.2

Example 2: There are 1,609 meters in one mile. What is this cheetah's speed in miles/hour?

Looking for	Solution
Speed of the cheetah in miles per hour.	$\dfrac{28 \text{ m}}{\text{s}} \times \dfrac{1 \text{ mile}}{1,609 \text{ m}} \times \dfrac{3,600 \text{ s}}{1 \text{ hour}} = \dfrac{63 \text{ miles}}{\text{hour}}$
Given	
Distance = 112.0 meters	The speed of the cheetah in miles per hour is
Time = 4.0 seconds	63 mph.
Relationships	
$$\text{speed} = \frac{d}{t}$$ and 1, 609 meters = 1 mile	

1. A bicyclist travels 60.0 kilometers in 3.5 hours. What is the cyclist's average speed?

Looking for	Solution
Given	
Relationships	

2. What is the average speed of a car that traveled 300.0 miles in 5.5 hours?

3. How much time would it take for the sound of thunder to travel 1,500 meters if sound travels at a speed of 330 m/s?

4. How much time would it take for an airplane to reach its destination if it traveled at an average speed of 790 kilometers/hour for a distance of 4,700 kilometers? What is the airplane's speed in miles/ hour?

5. How far can a person run in 15 minutes if he or she runs at an average speed of 16 km/hr?
   (HINT: Remember to convert minutes to hours.)

6. In problem 5, what is the runner's distance traveled in miles?

7. A snail can move approximately 0.30 meters per minute. How many meters can the snail cover in 15 minutes?

8. You know that there are 1,609 meters in a mile. The number of feet in a mile is 5,280. Use these equalities to answer the following problems:

   a. How many centimeters equals one inch?

   b. What is the speed of the snail in problem 7 in inches per minute?

9. Calculate the average speed (in km/h) of a car stuck in traffic that drives 12 kilometers in 2 hours.

10. How long would it take you to swim across a lake that is 900 meters across if you swim at 1.5 m/s?

    a. What is the answer in seconds?

    b. What is the answer in minutes?

11. How far will a you travel if you run for 10 minutes at 2 m/s?

12. You have trained all year for a marathon. In your first attempt to run a marathon, you decide that you want to complete this 26-mile race in 4.5 hours.

    a. What is the length of a marathon in kilometers (1 mile = 1.6 kilometers)?

    b. What would your average speed have to be to complete the race in 4.5 hours? Give your answer in kilometers per hour.

13. Suppose you are walking home after school. The distance from school to your home is five kilometers. On foot, you can get home in 25 minutes. However, if you rode a bicycle, you could get home in 10 minutes.

    a. What is your average speed while walking?

    b. What is your average speed while bicycling?

    c. How much faster you travel on your bicycle?

14. Suppose you ride your bicycle to the library traveling at 0.5 km/min. It takes you 25 minutes to get to the library. How far did you travel?

15. You ride your bike for a distance of 30 km. You travel at a speed of 0.75 km/ minute. How many minutes does this take?

16. A train travels 225 kilometers in 2.5 hours. What is the train's average speed?

17. An airplane travels 3,260 kilometers in 4 hours. What is the airplane's average speed?

18. A person in a kayak paddles down river at an average speed of 10 km/h. After 3.25 hours, how far has she traveled?

19. The same person in question 18 paddles upstream at an average speed of 4 km/h. How long would it take her to get back to her starting point?

20. An airplane travels from St. Louis, Missouri to Portland, Oregon in 4.33 hours. If the distance traveled is 2,742 kilometers, what is the airplane's average speed?

21. The airplane returns to St. Louis by the same route. Because the prevailing winds push the airplane along, the return trip takes only 3.75 hours. What is the average speed for this trip?

22. The airplane refuels in St. Louis and continues on to Boston. It travels at an average speed of 610 km/h. If the trip takes 2.75 hours, what is the flight distance between St. Louis and Boston?

23. The speed of light is about 3.00×10^5 km/s. It takes approximately 1.28 seconds for light reflected from the moon to reach Earth. What is the average distance from Earth to the moon?

24. The average distance from the sun to Pluto is approximately 6.10×10^9 km. How long does it take light from the sun to reach Pluto? Use the speed of light from the previous question to help you.

25. Now, make up three speed problems of your own. Give the problems to a friend to solve and check their work.

   a. Make up a problem that involves solving for average speed.

   b. Make up a problem that involves solving for distance.

   c. Make up a problem that involves solving for time.

READ CPO Science

Velocity

Speed and velocity do not have the same meaning to scientists. Speed is a *scalar quantity*, which means it can be completely described by its magnitude (or size). The magnitude is given by a number an a unit. For example, an object's speed may be measured as 15 meters per second.

Velocity is a *vector quantity*. In order to measure a vector quantity, you must know the both its magnitude and direction. The velocity of an object is determined by measuring both the *speed* and *direction* in which an object is traveling.

- If the speed of an object changes, then its velocity also changes.
- If the direction in which an object is traveling changes, then its velocity changes.
- A change in either speed, direction, or both causes a change in velocity.

You can use $\mathbf{v} = d/t$ to solve velocity problems in the same manner that you changed the form of the equation to solve speed problems in Part A. The boldfaced **v** is used to represent velocity as a vector quantity. The variables d and t are used for distance and time. **The velocity of an object in motion is equal to the distance it travels per unit of time in a given direction**.

EXAMPLES ▶

Example 1: What is the velocity of a car that travels 100.0 meters, northeast in 4.65 seconds?

Looking for	Solution
Velocity of the car.	$velocity = \dfrac{d}{t} = \dfrac{100.0 \text{ m}}{4.65 \text{ s}} = \dfrac{21.5 \text{ m}}{\text{s}}$
Given	
Distance = 100.0 meters	The velocity of the car is 21.5 meters per second, northeast.
Time = 4.65 seconds	
Relationship	
$velocity = \dfrac{d}{t}$	

PRACTICE
112m = 4 sec
12.2

Example 2: A boat travels with a velocity equal to 14.0 meters per second, east in 5.15 seconds. What distance in meters does the boat travel?

Looking for	Solution
Distance the boat travels.	
Given	$$\text{distance} = v \times t = \frac{14.0 \text{ m}}{\text{s}} \times 5.15 \text{ s} = 72.1 \text{ m}$$
Velocity = 14.0 meters per second, east	
Time = 5.15 seconds	The boat travels 72.1 meters.
Relationship	
$$\text{distance} = v \times t$$	

1. An airplane flies 525 kilometers north in 1.25 hours. What is the airplane's velocity?

Looking for	Solution
Given	
Relationship	

2. A soccer player kicks a ball 6.5 meters. How much time is needed for the ball to travel this distance if its velocity is 22 meters per second, south?

3. A cruise ship travels east across a river at 19.0 meters per minute. If the river is 4,250 meters wide, how long does it take for the ship to reach the other side?

4. Joaquin mows the lawn at his grandmother's home during the summer months. Joaquin measured the distance across his grandmother's lawn as 11.5 meters.

   a. If Joaquin mows one length across the lawn from east to west in 7.10 seconds, then what is the velocity of the lawnmower?

   b. Once he reaches the edge of the lawn, Joaquin turns the lawnmower around. He mows in the opposite direction but maintains the same speed. What is the velocity of the lawnmower?

5. A family drives 881 miles from Houston, Texas to Santa Fe, New Mexico for vacation. How long will it take the family to reach their destination if they travel at a velocity of 55.0 miles per hour, northwest?

6. A shopping cart is pushed 15.6 meters west across a parking lot in 5.2 seconds. What is the velocity of the shopping cart?

7. Katie and her best friend Liam play tennis every Saturday morning. When Katie serves the ball to Liam, it travels 9.5 meters south in 2.1 seconds.

   a. What is the velocity of the tennis ball?

   b. If the tennis ball travels at constant speed, what is its velocity when Liam returns Katie's serve?

8. A driver realizes that she is traveling in the wrong direction on a one-way street. She has already driven 3.5 meters at a velocity of 16 meters per second, east before deciding to make a U-turn. How long did it take for the driver to realize her error?

9. Juan's mother drives 12.5 miles southwest to her favorite shopping mall. What is the velocity of her automobile if she arrives at the mall in 7.25 minutes?

10. A bus is traveling at 79.7 kilometers per hour east, how far does the bus travel 1.45 hours?

11. A girl scout troop hiked 5.8 kilometers southeast in 1.5 hours. What was the troop's velocity?

12. A volcanologist noted that a lahar rushed down a mountain at 32.2 kilometers per hour, south. How far did the mud flow in 17.5 minutes?

SKILL and PRACTICE

12.3

Analyzing Graphs of Motion With Numbers

READ CPO Science

Speed can be calculated from position-time graphs and distance can be calculated from speed-time graphs. Both calculations rely on the familiar speed equation: $v = d/t$.

This graph shows position and time for a sailboat starting from its home port as it sailed to a distant island. By studying the line, you can see that the sailboat traveled 10 miles in 2 hours.

Position vs. Time

EXAMPLES ▶

- **Calculating speed from a position-time graph**

The speed equation allows us to calculate that the boat's speed during this time was 5 miles per hour.

$$v = d/t$$

$$v = 10 \text{ miles}/2 \text{ hours}$$

$$v = 5 \text{ miles/hour, read as 5 miles per hour}$$

This result can now be transferred to a speed-time graph. Remember that this speed was measured during the first two hours.

The line showing the boat's speed is horizontal because the speed was constant during the two-hour period.

Speed vs. Time

- **Calculating distance from a speed-time graph**

Here is the speed-time graph of the same sailboat later in the voyage. Between the second and third hours, the wind freshened and the sailboat gradually increased its speed to 7 miles per hour. The speed remained 7 miles per hour to the end of the voyage.

How far did the sailboat go during the six-hour trip? We will first calculate the distance traveled between the third and sixth hours.
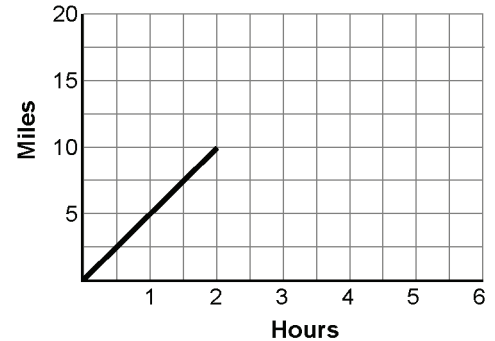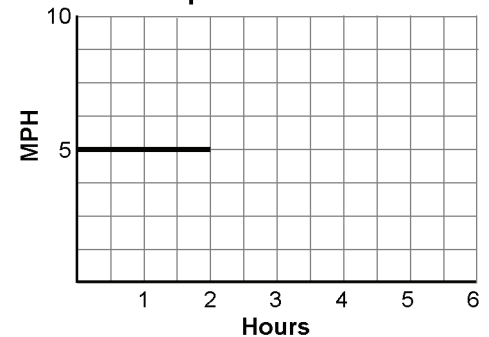
Speed vs. Time
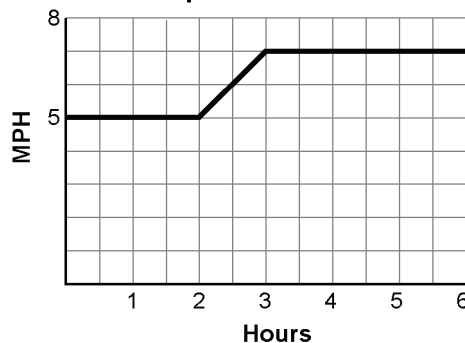
On a speed-time graph, distance is equal to the area between the baseline and the plotted line. You know that the area of a rectangle is found with the equation: $A = L \times W$. Similarly, multiplying the speed from the y-axis by the time on the x-axis produces distance. Notice how the labels cancel to produce miles:
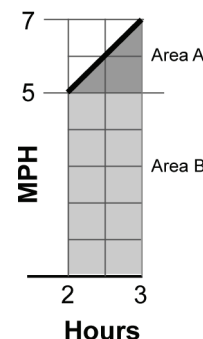
$$\text{speed} \times \text{time} = \text{distance}$$

$$7 \text{ miles/hour} \times (6 \text{ hours} - 3 \text{ hours}) = \text{distance}$$
$$7 \text{ miles/\sout{hour}} \times 3 \text{ \sout{hours}} = \text{distance} = 21 \text{ miles}$$

Now that we have seen how distance is calculated, we can consider the distance covered between hours 2 and 3.

The easiest way to visualize this problem is to think in geometric terms. Find the area of the triangle (Area A), then find the area of the rectangle (Area B), and add the two areas.

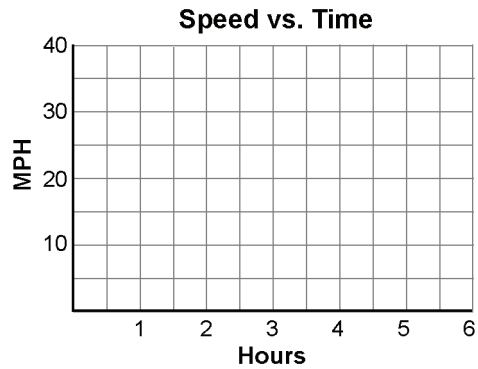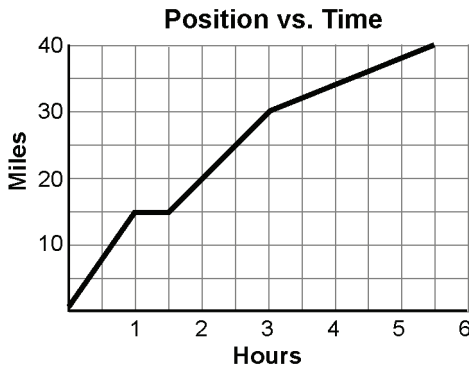| Area of triangle A Geometry formula	The area of a triangle is one-half the area of a rectangle.
	$\text{speed} \times \dfrac{\text{time}}{2} = \text{distance}$
	$(7 \text{ miles/hour} - 5 \text{ miles/hour}) \times \dfrac{(3 \text{ hours} - 2 \text{ hours})}{2} = \text{distance} = 1 \text{ mile}$
Area of rectangle B Geometry formula	$\text{speed} \times \text{time} = \text{distance}$
	$5 \text{ miles/hour} \times (3 \text{ hours} - 2 \text{ hours}) = \text{distance} = 5 \text{ miles}$
Add the two areas	$\text{Area A} + \text{Area B} = \text{distance}$
	$1 \text{ miles} + 5 \text{ mile} = \text{distance} = 6 \text{ miles}$

We can now take the distances found for both sections of the speed graph to complete our position-time graph:
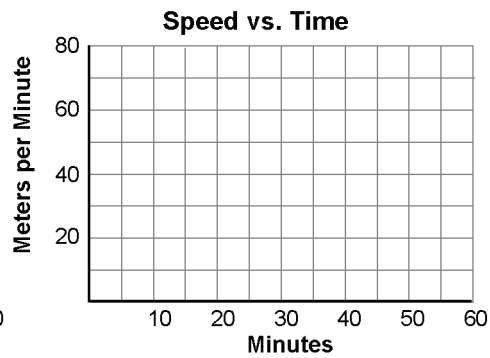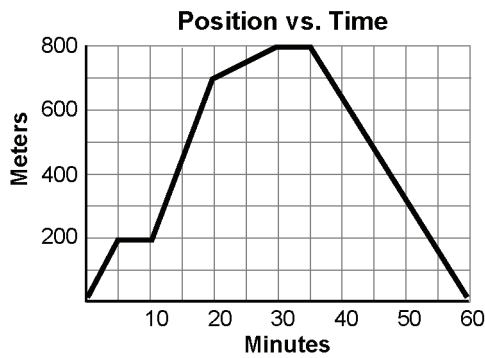

Position vs. Time
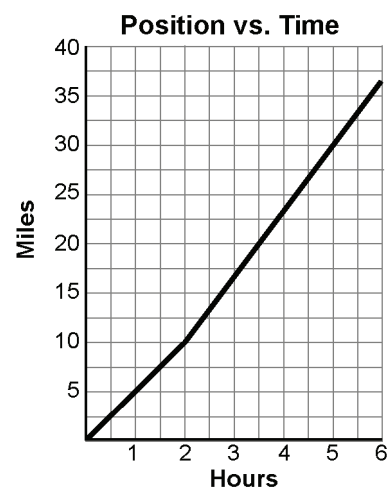
PRACTICE
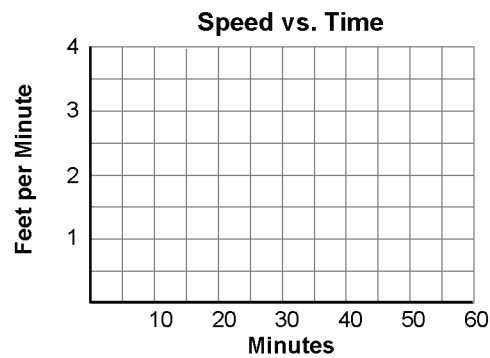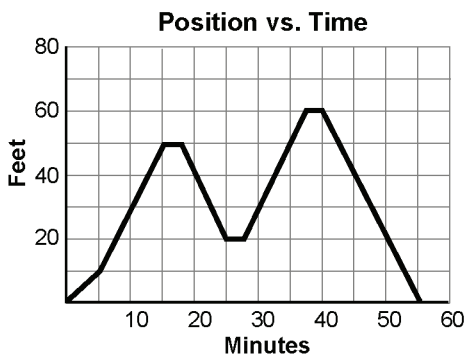
1. For each position-time graph, calculate and plot speed on the speed-time graph to the right.
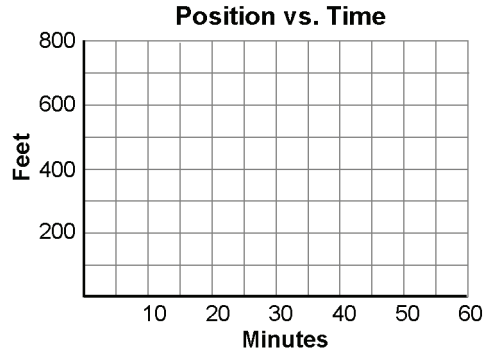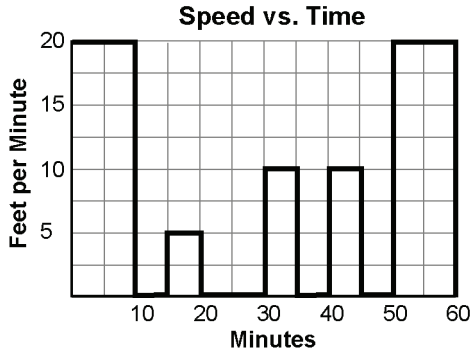
   a. The bicycle trip through hilly country

   Position vs. Time — Miles / Hours

   Speed vs. Time — MPH / Hours

   b. A walk in the park

   Position vs. Time — Meters / Minutes

   Speed vs. Time — Meters per Minute / Minutes

   c. Strolling up and down the supermarket aisles

   Position vs. Time — Feet / Minutes

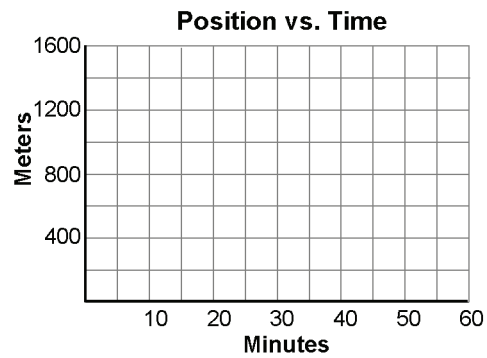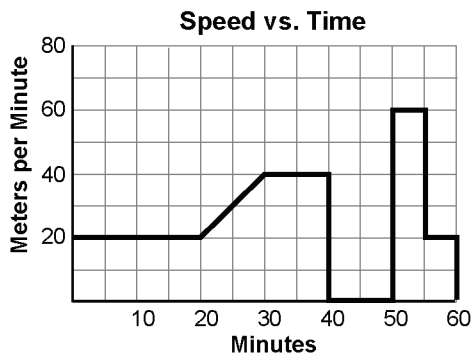   **Speed vs. Time** — Feet per Minute / Minutes

2. For each speed-time graph, calculate and plot the distance on the position-time graph to the right. For this practice, assume that movement is always away from the starting position.

a. The honey bee among the flowers

Speed vs. Time

Feet per Minute / Minutes

Position vs. Time

Feet / Minutes

b. Rover runs the street

Speed vs. Time

Meters per Minute / Minutes

Position vs. Time

Meters / Minutes

c. The amoeba

Speed vs. Time

Millimeters per Hour / Hours

Position vs. Time

Millimeters / Hours
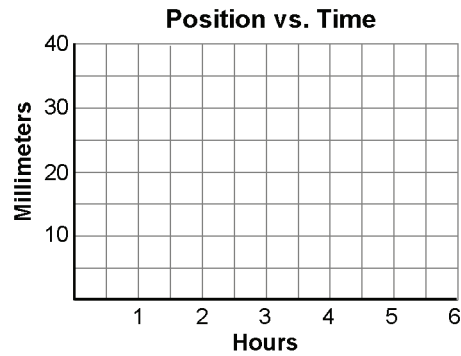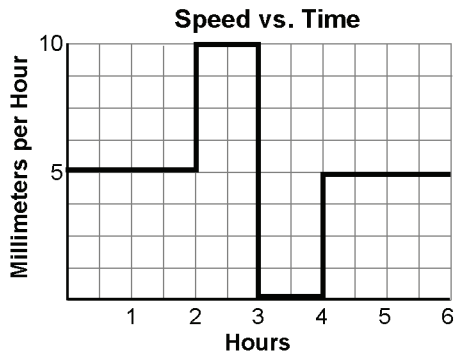
Analyzing Graphs of Motion Without Numbers

READ CPO Science

Position-time graphs

The graph at right represents the story of "The Three Little Pigs." The parts of the story are listed below.

- The wolf started from his house. The graph starts at the origin.
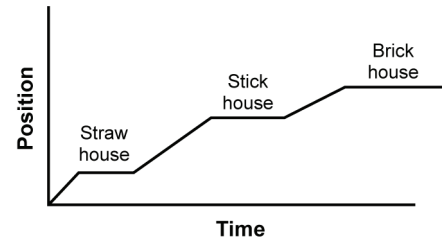- Traveled to the straw house. The line moves upward.
- Stayed to blow it down and eat dinner. The line is flat because position is not changing.
- Traveled to the stick house. The line moves upward again.
- Again stayed, blew it down, and ate seconds. The line is flat.
- Traveled to the brick house. The line moves upward.
- Died in the stew pot at the brick house. The line is flat.

The graph illustrates that the pigs' houses are generally in a line away from the wolf's house and that the brick house was the farthest away.

Position-time graph of the wolf in
The Three Little Pigs

Speed-time graphs

A speed-time graph displays the speed of an object over time and is based on position-time data. Speed is the relationship between distance (position) and time, $v = d/t$. For the first part of the wolf's trip in the position versus time graph, the line rises steadily. This means the speed for this first leg is constant. If the wolf traveled this first leg faster, the slope of the line would be steeper.

The wolf moved at the same speed toward his first two "visits." His third trip was slightly slower. Except for this slight difference, the wolf was either at one speed or stopped (shown by a flat line in the speed versus time graph).
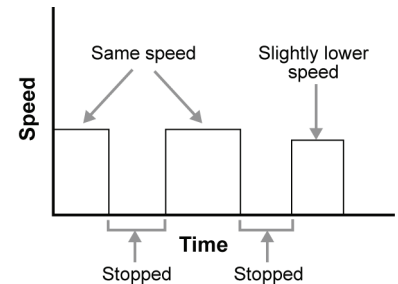
PRACTICE

Read the steps for each story. Sketch a position-time graph and a speed-time graph for each story.

1. Graph Red Riding Hood's movements according to the following events listed in the order they occurred:

- Little Red Riding Hood set out for Grandmother's cottage at a good walking pace.
- She stopped briefly to talk to the wolf.
- She walked a bit slower because they were talking as they walked to the wild flowers.
- She stopped to pick flowers for quite a while.
- Realizing she was late, Red Riding Hood ran the rest of the way to Grandmother's cottage.
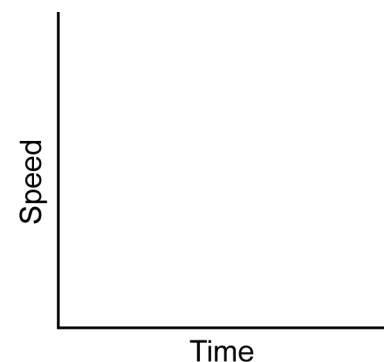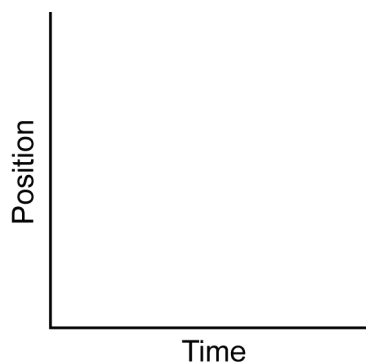
2. Graph the movements of the Tortoise and the Hare. Use two lines to show the movements of each animal on each graph. The movements of each animal is listed in the order they occurred.

- The tortoise and the hare began their race from the combined start-finish line. By the end of the race, the two will be at the same position at which they started.

- Quickly outdistancing the tortoise, the hare ran off at a moderate speed.

- The tortoise took off at a slow but steady speed.

- The hare, with an enormous lead, stopped for a short nap.

- With a startle, the hare awoke and realized that he had been sleeping for a long time.

- The hare raced off toward the finish at top speed.

- Before the hare could catch up, the tortoise's steady pace won the race with an hour to spare.
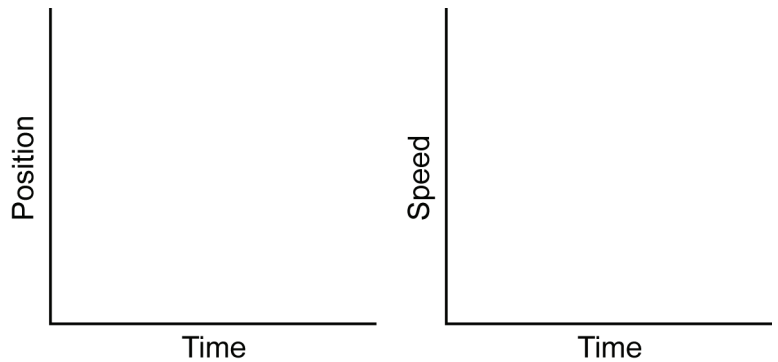
3. Graph the altitude of the sky rocket on its flight according to the following sequence of events listed in order.

- The skyrocket was placed on the launcher.

- As the rocket motor burned, the rocket flew faster and faster into the sky.

- The motor burned out; although the rocket began to slow, it continued to coast ever higher.

- Eventually, the rocket stopped for a split second before it began to fall back to Earth.

- Gravity pulled the rocket faster and faster toward Earth until a parachute popped out, slowing its descent.

- The descent ended as the rocket landed gently on the ground.
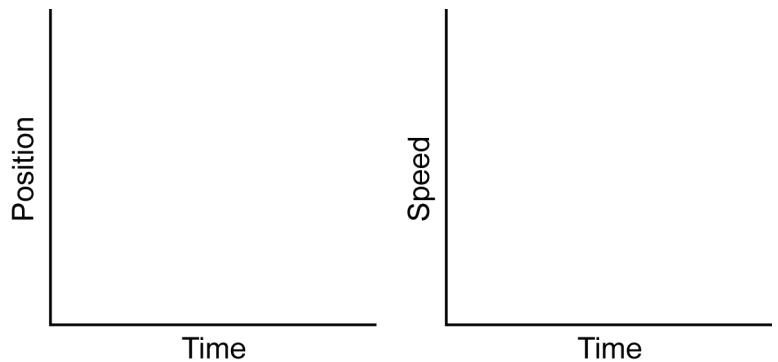
4. A story told from a graph: Tim, a student at Cumberland Junior High, was determined to ask Caroline for a movie date. Use these graphs of his movements from his house to Caroline's to write the story.

Calculating Slope from a Graph

READ CPO Science

To determine the slope of a line in a graph, first choose two points on the line. Then count how many steps up or down you must move to be on the same horizontal line as your second point. Multiply this number by the scale of your horizontal axis. For example, if your *x*-axis has a scale of 1 box = 20 cm, then multiply the number of boxes you counted by 20 cm.

Put the result along with the positive or negative sign as the top (numerator) of your slope ratio. Then count how many steps you must move right or left to land on your second poi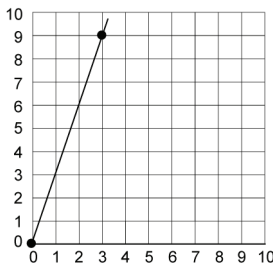nt. Multiply the number of steps by the scale of your vertical axis. Place the results as the bottom (denominator) of your slope ratio. Then reduce the fraction of your ratio. This number is the slope of the line.

EXAMPLES ▶

A

The chosen points for Example A are (0, 0) and (3, 9). (There are many choices for this graph, but only one slope. If you have the point (0, 0), you should choose it as one of your points.)

It takes 9 vertical steps to move from (0, 0) to (0, 9). Put a 9 in the numerator of your slope ratio (or put 9 – 0). Then count the number of steps to move from (0, 9) to (3, 9). This is your denominator of your slope ratio. Again, you can do this by subtraction (3 - 0).

$$m = \frac{9}{3} = \frac{3}{1}$$

B

The two points that have been chosen for Example B are (0, 24) and (6, 15). Be careful of the scales on each of the axes.

It takes 3 vertical steps to go from (0, 24) to (0, 15). But each of these steps has a scale of 3. So you put a -9 into the numerator of the slope ratio. It is *negative* because you are moving down from one point to the other. Then count the steps over to (6, 15). There are 3 steps but each counts for 2 so you put a 6 into the denominator of the slope ratio.

$$m = \frac{-9}{6} = \frac{-3}{2}$$

PRACTICE ▶

Find the slope of the line in each of the following graphs:

Graph #1:   Graph #2:

m = _____   m = _____

Graph #3:

m = _____

Graph #4:

m = _____

Graph #5:

m = _____

Graph #6:

m = _____

Graph #7:

m = _____

Graph #8:

m = _____

Graph #9:

m = _____

Graph #10:

m = _____

Chien-Shiung Wu

During World War II, Chinese-American physicist Chien-Shiung Wu played an important role in the Manhattan Project, the Army's secret work to develop the atomic bomb. In 1957, she overthrew what was considered an indisputable law of physics, changing the way we understand the weak nuclear force.
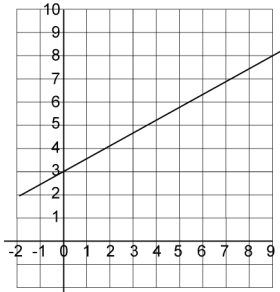
Determined to learn

Chien-Shiung Wu was born on May 31, 1912, in a small town outside Shanghai, China. Her father had opened the region's first school for young girls, which Chien-Shiung finished at age 10. She then attended a girls boarding school in Suzhou that had two sections—a teacher training school and an academic school with a standard Western curriculum. Chien-Shiung enrolled in teacher training, because tuition was free and graduates were guaranteed jobs.

Students from both sections lived in the dormitory, and as Chien-Shiung became friends with girls in the academic school, she learned that their science and math curriculum was more rigorous than hers. She asked to borrow their books and stayed up late teaching herself the material. She graduated first in her class and was invited to attend prestigious National Central University in Nanjing. There, she earned a bachelor's degree in physics and did research for two years. In 1936 Wu emigrated from China to the United States. She earned her doctorate from the University of California at Berkeley in 1940.

A key scientist in the Manhattan Project

Wu taught at Smith College and Princeton University until 1944, when she went to Columbia University as a senior scientist and researcher and was asked to join the Manhattan Project. There she helped develop the process to enrich uranium ore. In the course of the project, her renowned colleague Enrico Fermi turned to Wu for help with a fission experiment. A rare gas which she had studied in graduate school was causing the problem. With Wu's assistance, Fermi was able to solve the problem and continue his work.

Right and left in nature?

After the war, Wu continued her research in nuclear physics at Columbia. In 1956, she and two colleagues, Tsung-Dao Lee of Columbia and Chen Ning Yang of Princeton, reconsidered the *law of conservation of parity*. This law stated that nature does not distinguish between left and right in nuclear reactions. They wondered if the law might not be valid for interactions of subatomic particles involving the **weak nuclear force**.

Wu was a leading specialist in **beta decay**. She figured out a means of testing their theory. She cooled cobalt-60, a radioactive **isotope**, to 0.01 degree above absolute zero. Next, she placed the cobalt-60 in a strong magnetic field so that the cobalt nuclei lined up and spun along the same axis. She observed what happened as the cobalt-60 broke down and gave off electrons. According to the law of conservation of parity, equal numbers of electrons should have been given off in each direction. However, Wu found that many more electrons flew off in the direction opposite the spin of the cobalt-60 nuclei. She proved that in beta decay, nature does in fact distinguish between left and right.

Always a landmark achiever

Unfortunately, when Lee and Yang were awarded the Nobel Prize in physics in 1957, Wu's contribution to the project was overlooked. However, among her many honors and awards, she later received the National Medal of Science, the nation's highest award for science achievement. In 1973, she became the first female president of the American Physical Society. Wu died at 84 in 1997, leaving a husband and son who were both physicists.

Reading reflection

1. Use a dictionary to look up the meaning of each boldface word. Write a definition for each word. Be sure to credit your source.

2. How did Chien-Shiung Wu's work in graduate school help her with her work on the Manhattan Project?

3. From the reading, define *the law of conservation of parity* in your own words.

4. How many protons and neutrons does cobalt-60 have? List the nonradioactive isotopes of cobalt.

5. Briefly describe Wu's elegant experiment that proved that nature distinguishes between right and left.

6. **Research:** Wu was the first woman recipient of the National Medal of Science in physical science. Two other women have since received this award. Who were they and what did they do?

7. What are three questions that you have about Wu and her work?

8. Suggest some possible reasons why Wu did not receive the Nobel Prize for her work.

Mass versus Weight

READ CPO Science

What is the difference between mass and weight?

mass	weight
• Mass is a measure of the amount of matter in an object. Mass is not related to gravity.	• Weight is a measure of the gravitational force between two objects.
• The mass of an object does not change when it is moved from one place to another.	• The weight of an object does change when the amount of gravitational force changes, as when an object is moved from Earth to the moon.
• Mass is commonly measured in grams or kilograms.	• Weight is commonly measured in newtons or pounds.

Weightlessness: When a diver dives off of a 10-meter diving board, she is in free-fall. If she jumped off the board with a scale attached to her feet, the scale would read zero even though she is under the influence of gravity. She is "weightless" because her feet have nothing to push against. Similarly, astronauts and everything inside a space shuttle seem to be weightless because they are in constant free fall. The space shuttle moves at high speed, therefore, its constant fall toward Earth results in an orbit around the planet.

EXAMPLE ▶

• On Earth's surface, the force of gravity acting on one kilogram is 2.2 pounds. So, if an object has a mass of 2.0 kilograms, the force of gravity acting on that mass *on Earth* will be:

$$2.0 \text{ kg} \times \frac{2.2 \text{ pounds}}{\text{kg}} = 4.4 \text{ pounds}$$

• On the moon's surface, the force of gravity is about 0.37 pounds per kilogram. The same object, if it were carried to the moon, would have a mass of 2.0 kilograms, but its weight would be just 0.74 pounds.

$$2.0 \text{ kg} \times \frac{0.37 \text{ pounds}}{\text{kg}} = 0.74 \text{ pounds}$$

PRACTICE ▶

1. What is the weight (in pounds) of a 7.0-kilogram bowling ball on Earth's surface?

2. What is the weight (in pounds) of a 7.0-kilogram bowling ball on the surface of the moon?

3. What is the mass of a 7.0-kilogram bowling ball on the surface of the moon?

4. Would a balance function correctly on the moon? Why or why not?

Challenge Question

5. Take a bathroom scale into an elevator. Step on the scale.

   a. What happens to the reading on the scale as the elevator begins to move upward? to move downward?

   b. What happens to the reading on the scale when the elevator stops moving?

   c. Why does your weight appear to change, even though you never left Earth's gravity?

Equilibrium

READING 📖 CPO Science

When all forces acting on a body are balanced, the forces are in equilibrium. Here are free-body diagrams for you to use for practice working with equilibrium.

Remember that an unbalanced force results in acceleration. Therefore, the forces acting on an object that is not accelerating must be at balanced. These objects may be at rest, or they could be moving at a constant velocity. Either way, we say that the forces acting on these objects are in *equilibrium*.
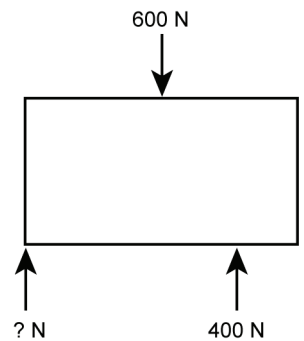
EXAMPLE ▶

What force is necessary in the free-body diagram at right to achieve equilibrium?

Looking for	**Solution**
The unknown force: **? N**	600 N = 400 N + **? N**
Given	600 N - 400 N = 400 N - 400 N + **? N**
600 N is pressing down on the box.	200 N = **? N**
400 N is pressing up on the box.	
Relationship	
You can solve equilibrium problems using simple equations: 600 N = 400 N + **? N**	

PRACTICE ▶

1. Supply the missing force necessary to achieve equilibrium.
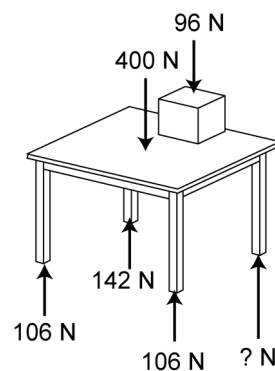
2. Supply the missing forces necessary to achieve equilibrium.
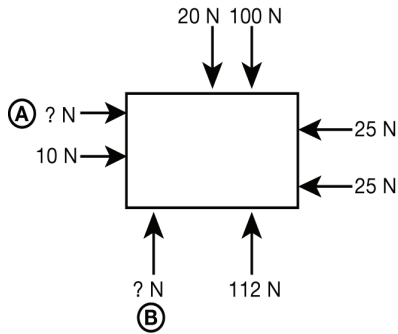
3. In the picture, a girl with a weight of 540 N is balancing on her bike in equilibrium, not moving at all. If the force exerted by the ground on her front wheel is 200 N, how much force is exerted by the ground on her back wheel?

540 N 200 N
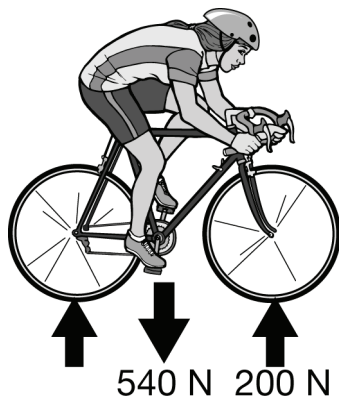
Challenge Question:

4. Helium balloons stay the same size as you hold them, but swell and burst as they rise to high altitudes when you let them go. Draw and label force arrows inside and/or outside the balloons on the graphic at right to show why the near Earth balloon does not burst, but the high altitude balloon does eventually burst. Hint: What are the forces on the inside of the balloon? What are the forces on the outside of the balloons?

HIGH ALTITUDE

NEAR EARTH

EARTH
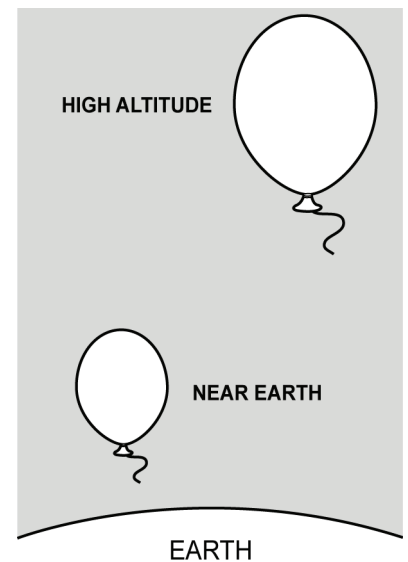
Isaac Newton

Isaac Newton is one of the most brilliant figures in scientific history. His three laws of motion are probably the most important natural laws in all of science. He also made vital contributions to the fields of optics, calculus, and astronomy.

Plague provides opportunity for genius
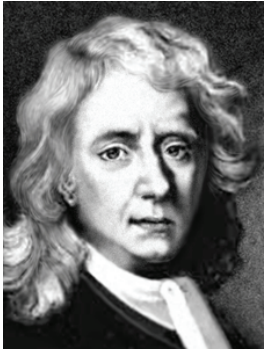
Isaac Newton was born in 1642 in Lincolnshire, England. His childhood years were difficult. His father died just before he was born. When he was three, his mother remarried and left her son to live with his grandparents. Newton bitterly resented his stepfather throughout his life.

An uncle helped Newton remain in school and in 1661, he entered Trinity College at Cambridge University. He earned his bachelor's degree in 1665.

Ironically, it was the closing of the university due to the bubonic plague in 1665 that helped develop Newton's genius. He returned to Lincolnshire and spent the next two years in solitary academic pursuit.

During this period, he made significant advances in calculus, worked on a revolutionary theory of the nature of light and color, developed early versions of his three laws of motion, and gained new insights into the nature of planetary motion.

Fear of criticism stifles scientist

When Cambridge reopened in 1667, Newton was given a minor position at Trinity and began his academic career. His studies in optics led to his invention of the reflecting telescope in the early 1670s. In 1672, his first public paper was presented, on the nature of light and color.

Newton longed for public recognition of his work but dreaded criticism. When another bright young scientist, Robert Hooke, challenged some of his points, Newton was furious. An angry exchange of words left Newton reluctant to make public more of his work.

Revolutionary law of universal gravitation

In the 1680s, Newton turned his attention to forces and motion. He worked on applying his three laws of motion to orbiting bodies, projectiles, pendulums, and free-fall situations. This work led him to formulate his famous law of universal gravitation.

According to legend, Newton thought of the idea while sitting in his Lincolnshire garden. He watched an apple fall from a tree. He wondered if the same force that caused the apple to fall toward the center of Earth (gravity) might be responsible for keeping the moon in orbit around Earth, and the planets in orbit around the sun.

This concept was truly revolutionary. Less than 50 years earlier, it was commonly believed that some sort of invisible shield held the planets in orbit.

Important contributor in spite of conflict

In 1687, Newton published his ideas in a famous work known as the *Principia*. He jealously guarded the work as entirely his. He bitterly resented the suggestion that he should acknowledge the exchange of ideas with other scientists (especially Hooke) as he worked on his treatise.

Newton left Cambridge to take a government position in London in 1696. His years of active scientific research were over. However, almost three centuries after his death in 1727, Newton remains one of the most important contributors to our understanding of how the universe works.

Reading reflection

1. Important phases of Newton's education and scientific work occurred in isolation. Why might this have been helpful to him? On the other hand, why is working in isolation problematic for developing scientific ideas?

2. Newton began his academic career in 1667. For how long was he a working scientist? Was he a very productive scientist? Justify your answer.

3. Briefly state one of Newton's three laws of motion in your own words. Give an explanation of how this law works.

4. Define the law of universal gravitation in your own words.

5. The orbit of a space shuttle is surprisingly like an apple falling from a tree to Earth. The space shuttle is simply moving so fast that the path of its fall is an orbit around our planet. Which of Newton's laws helps explain the orbit of a space shuttle around Earth and the orbit of Earth around the sun?

6. **Research:** Newton was outraged when, in 1684, German mathematician Wilhelm Leibniz published a calculus book. Find out why, and describe how the issue is generally resolved today.

Applying Newton's Laws of Motion

READ CPO Science

In the second column of the table below, write each of Newton's three laws of motion. Use your own wording. In the third column of the table, describe an example of each law. To find examples of Newton's laws, think about all the activities you do in one day.

Newton's laws of motion	Write the law here in your own words	Example of the law
The first law		
The second law		
The third law		

PRACTICE

1. When Jane drives to work, she always places her pocketbook on the passenger's seat. By the time she gets to work, her pocketbook has fallen on the floor in front of the passenger seat. One day, she asks you to explain why this happens in terms of physical science. What do you say?

2. You are waiting in line to use the diving board at your local pool. While watching people dive into the pool from the board, you realize that using a diving board to spring into the air before a dive is a good example of Newton's third law of motion. Explain how a diving board illustrates Newton's third law of motion.

3. You know the mass of an object and the force applied to the object to make it move. Which of Newton's laws of motion will help you calculate the acceleration of the object?

4. How many newtons of force are represented by the following amount: 3 kg·m/s^2 ?
   Select the correct answer (a, b, or c) and justify your answer.

   a. 6 newtons   b. 3 newtons   c. 1 newton

5. Your shopping cart has a mass of 65 kilograms. In order to accelerate the shopping cart down an aisle at 0.3 m/s^2, what force would you need to use or apply to the cart?

6. A small child has a wagon with a mass of 10 kilograms. The child pulls on the wagon with a force of 2 newtons. What is the acceleration of the wagon?

7. You dribble a basketball while walking on a basketball court. List and describe the pairs of action-reaction forces in this situation.

8. Pretend that there is no friction at all between a pair of ice skates and an ice rink. If a hockey player using this special pair of ice skates were to be gliding along on the ice at a constant speed and direction, what would be required for him to stop?

Acceleration

READ [CPO Science]

Acceleration is the rate of change in the speed of an object. To determine the rate of acceleration, you use the formula below. The units for acceleration are meters per second per second or m/s^2.

$$\text{Acceleration} = \frac{\text{Final speed} - \text{Beginning speed}}{\text{Time}}$$

$$a = \frac{v_2 - v_1}{t}$$

A positive value for acceleration shows speeding up, and negative value for acceleration shows slowing down. Slowing down is also called *deceleration*.

The acceleration formula can be rearranged to solve for other variables such as final speed (v_2) and time (t).

$$v_2 = v_1 + (a \times t)$$

$$t = \frac{v_2 - v_1}{a}$$

EXAMPLES ▶

1. A skater increases her velocity from 2.0 m/s to 10.0 m/s in 3.0 seconds. What is the skater's acceleration?

Looking for	Solution
Acceleration of the skater	
Given	
Beginning speed = 2.0 m/s	$\text{Acceleration} = \dfrac{10.0 \text{ m/s} - 2.0 \text{ m/s}}{3 \text{ s}} = 2.7 \text{ m/s}^2$
Final speed = 10.0 m/s	
Change in time = 3 seconds	
Relationship	The acceleration of the skater is 2.7 meters per
$a = \dfrac{v_2 - v_1}{t}$	second per second.

2. A car accelerates at a rate of 3.0 m/s^2. If its original speed is 8.0 m/s, how many seconds will it take the car to reach a final speed of 25.0 m/s?

Looking for	Solution
The time to reach the final speed.	$\text{Time} = \dfrac{25.0 \text{ m/s} - 8.0 \text{ m/s}}{3.0 \text{ m/s}^2} = 5.7 \text{ s}$
Given	
Beginning speed = 8.0 m/s; Final speed = 25.0 m/s	
Acceleration = 3.0 m/s^2	The time for the car to reach its final speed is
Relationship	5.7 seconds.
$t = \dfrac{v_2 - v_1}{a}$	

PRACTICE

1.   While traveling along a highway a driver slows from 24 m/s to 15 m/s in 12 seconds. What is the automobile's acceleration? (Remember that a negative value indicates a slowing down or deceleration.)

2.   A parachute on a racing dragster opens and changes the speed of the car from 85 m/s to 45 m/s in a period of 4.5 seconds. What is the acceleration of the dragster?

3.   The table below includes data for a ball rolling down a hill. Fill in the missing data values in the table and determine the acceleration of the rolling ball.

Time (seconds)	Speed (km/h)
0 (start)	0 (start)
2	3
	6
	9
8	
10	15

4.   A car traveling at a speed of 30.0 m/s encounters an emergency and comes to a complete stop. How much time will it take for the car to stop if it decelerates at -4.0 m/s^2?

5.   If a car can go from 0 to 60 mi/hr in 8.0 seconds, what would be its final speed after 5.0 seconds if its starting speed were 50 mi/hr?

6.   A cart rolling down an incline for 5.0 seconds has an acceleration of 4.0 m/s^2. If the cart has a beginning speed of 2.0 m/s, what is its final speed?

7.   A helicopter's speed increases from 25 m/s to 60 m/s in 5 seconds. What is the acceleration of this helicopter?

8.   As she climbs a hill, a cyclist slows down from 25 mi/hr to 6 mi/hr in 10 seconds. What is her deceleration?

9.   A motorcycle traveling at 25 m/s accelerates at a rate of 7.0 m/s^2 for 6.0 seconds. What is the final speed of the motorcycle?

10. A car starting from rest accelerates at a rate of 8.0 m/s. What is its final speed at the end of 4.0 seconds?

11. After traveling for 6.0 seconds, a runner reaches a speed of 10 m/s. What is the runner's acceleration?

12. A cyclist accelerates at a rate of 7.0 m/s^2. How long will it take the cyclist to reach a speed of 18 m/s?

13. A skateboarder traveling at 7.0 meters per second rolls to a stop at the top of a ramp in 3.0 seconds. What is the skateboarder's acceleration?

Newton's Second Law

14.2

READ [CPO Science]

- Newton's second law states that the acceleration of an object is directly related to the force on it, and inversely related to the mass of the object. You need more force to move or stop an object with a lot of mass (or *inertia*) than you need for an object with less mass.

- The formula for the second law of motion (first row below) can be rearranged to solve for mass and force.

What do you want to know?	What do you know?	The formula you will use
acceleration (*a*)	force (*F*) and mass (*m*)	$\text{acceleration} = \dfrac{\text{force}}{\text{mass}}$
mass (*m*)	acceleration (*a*) and force (*F*)	$\text{mass} = \dfrac{\text{force}}{\text{acceleration}}$
force (*F*)	acceleration (*a*) and mass (*m*)	$\text{force} = \text{acceleration} \times \text{mass}$

EXAMPLE ▷

- How much force is needed to accelerate a truck with a mass of 2,000 kilograms at a rate of 3 m/sec^2?

$$F = m \times a = 2{,}000 \text{ kg} \times 3 \text{ m/s}^2 = 6{,}000 \text{ kg-m/s}^2 = 6{,}000 \text{ N}$$

- What is the mass of an object that requires 15 N to accelerate it at a rate of 1.5 m/s^2?

$$m = \frac{F}{a} = \frac{15 \text{ N}}{1.5 \text{ m/s}^2} = \frac{15 \text{ kg-m/s}^2}{1.5 \text{ m/s}^2} = 10 \text{ kg}$$

PRACTICE ▷〰

1. What is the acceleration of a 2,000-kilogram truck if a force of 4,200 N is used to make it start moving forward?

2. What is the acceleration of a 0.30 kilogram ball that is hit with a force of 25 N?

3. How much force is needed to accelerate a 68 kilogram-skier at 1.2 m/s^2?

4. What is the mass of an object that requires a force of 30 N to accelerate at 5 m/s^2?

5. What is the force on a 1,000-kilogram elevator that is falling freely under the acceleration of gravity only?

6. What is the mass of an object that needs a force of 4,500 N to accelerate it at a rate of 5 m/s^2?

7. What is the acceleration of a 6.4 kilogram bowling ball if a force of 12 N is applied to it?

Ratio and Proportions

A recipe for Double Fudge Brownies

Ingredients:

$^3/_4$ c. sugar   2 eggs

6 tablespoons unsalted butter   1 teaspoon vanilla extract

2 tablespoons milk $^3/_4$ cup all-purpose flour

2 cups semi-sweet chocolate chips $^1/_3$ teaspoon baking soda

$^1/_4$ teaspoon salt   2 tablespoons confectioner's sugar

Makes 16 brownies.

EXAMPLES ▶

1. What is the ratio of milk to chocolate chips? $\frac{\text{2 tablespoons}}{\text{2 cups}}$

2. When we know the ratios, we can make proportions by setting two ratios equal to one another. This will help us to find missing answers.

   Suppose Patricia only needs 8 brownies and doesn't want any leftovers. Find out how much of each ingredient she needs. The original recipe will make 16 brownies. You will use the ratio of $^8/_{16} = ^1/_2$ to find the amount for each of the ingredients. Use cross-multiplication to solve the proportions.

For flour:

Step 1 $\dfrac{8}{16} = \dfrac{x}{3/4}$

Step 2 $8 \times \dfrac{3}{4} = 16x$

Step 3 $6 = 16x$

Step 4 $\dfrac{6}{16} = \dfrac{16x}{16}$

Step 5 $\dfrac{3}{8} = x$ Patricia needs $^3/_8$ cup of flour to make 8 brownies.

PRACTICE

1. What is the ratio of unsalted butter to eggs?

    For every _____ tablespoons of butter, you will need _____ eggs.

2. What is the ratio of flour to baking soda?

    For every _____ cups of flour, you will need _____ teaspoon of baking soda.

3. What is the ratio of salt to flour?
    For every _____ teaspoon(s) of salt, you will need _____ cups of flour

4. Find the correct amount of each ingredient to make 8 brownies ($^1/_2$ of the recipe).

Flour	$^3/_8$ cup
Sugar	
Butter	
Milk	
Chocolate chips	
Eggs	
Vanilla extract	
Baking soda	
Salt	
Confectioner's sugar	

5. Why are the eggs and confectioner's sugar easy to work with to make 8 brownies?

6. Patricia has a little extra of all the ingredients. How many brownies can be made using 3 cups of chocolate chips?

7. How much vanilla will she need when she makes the batch of brownies using 3 cups of chocolate chips?

Nicolaus Copernicus

Nicolaus Copernicus was a church official, mathematician, and influential astronomer. His revolutionary theory of a heliocentric (sun-centered) universe became the foundation of modern-day astronomy.

Wealth, education, and religion
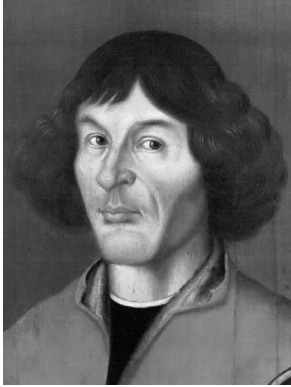
Nicolaus Copernicus was born on February 19, 1473 in Torun, Poland. Copernicus' father was a successful copper merchant. His mother also came from wealth. Being from a privileged family, young Copernicus had the luxury of learning about art, literature, and science.

When Copernicus was only 10 years old, his father died. Copernicus went to live his uncle, Lucas Watzenrode, a prominent Catholic Church official who became bishop of Varmia (now part of modern-day Poland) in 1489. The bishop was generous with his money and provided Copernicus with an education from the best universities.

From church official to astronomer

Copernicus lived during the height of the Renaissance period when men from a higher social class were expected to receive well-rounded educations. In 1491, Copernicus attended the University of Krakow where he studied mathematics and astronomy. After four years of study, his uncle appointed Copernicus a church administrator. Copernicus used his church wages to help pay for additional education.

In January 1497, Copernicus left for Italy to study medicine and law at the University of Bologna. Copernicus' passion for astronomy grew under the influence of his mathematics professor, Domenico Maria de Novara. Copernicus lived in his professor's home where they spent hours discussing astronomy.

In 1500, Copernicus lectured on astronomy in Rome. A year later, he studied medicine at the University of Padua. In 1503, Copernicus received a doctorate in canon (church) law from the University of Ferrara.

Observations with his bare eyes

After his studies in Italy, Copernicus returned to Poland to live in his uncle's palace. He resumed his church duties, practiced medicine, and studied astronomy. Copernicus examined the sky from a palace tower. He made his observations without any equipment. In the late 1500s, the astronomer Galileo used a telescope and confirmed Copernicus' ideas.

A heliocentric universe

In the 1500s, most astronomers believed that Earth was motionless and the center of the universe. They also thought that all celestial bodies moved around Earth in complicated patterns. The Greek astronomer Ptolomy proposed this geocentric theory more than 1000 years earlier.

However, Copernicus believed that the universe was heliocentric (sun-centered), with all of the planets revolving around the sun. He explained that Earth rotates daily on its axis and revolves yearly around the sun. He also suggested that Earth wobbles like a top as it rotates.

Copernicus' theory led to a new ordering of the planets. In addition, it explained why the planets farther from the sun sometimes appear to move backward (retrograde motion), while the planets closest to the sun always seem to move in one direction. This retrograde motion is due to Earth moving faster around the sun than the planets farther away.

Copernicus was reluctant to publish his theory and spent years rechecking his data. Between 1507 and 1515, Copernicus circulated his heliocentric principles to only a few astronomers. A young German mathematics professor, George Rheticus, was fascinated with Copernicus' theory. The professor encouraged Copernicus to publish his ideas. Finally, Copernicus published The Revolutions of the Heavenly Orbs near his death in 1543.

Years later, several astronomers (including Galileo) embraced Copernicus' sun-centered theory. However, they suffered much persecution by the church for believing such ideas. At the time, Church law held great influence over science and dictated a geocentric universe. It wasn't until the eighteenth century that Copernicus' heliocentric principles were completely accepted.

Reading reflection

1. How did Copernicus' privileged background help him become knowledgeable in so many areas of study?

2. Which people influenced Copernicus in his work as a church official and an astronomer?

3. How did Copernicus make his observations of the sky?

4. What did astronomers believe of the universe prior to the sixteenth century?

5. Describe Copernicus' revolutionary heliocentric theory of the universe.

6. Why did so many astronomers face persecution by the church for their beliefs in a heliocentric universe?

7. **Research:** Using the library or Internet, find out which organizations developed the Copernicus Satellite (OAO-3) and why it was used.

Galileo Galilei

Galileo Galilei was a mathematician, scientist, inventor, and astronomer. His observations led to advances in our understanding of pendulum motion and free fall. He invented a thermometer, water pump, military compass, and microscope. He refined a Dutch invention, the telescope, and used it to revolutionize our understanding of the solar system.

An incurable mathematician
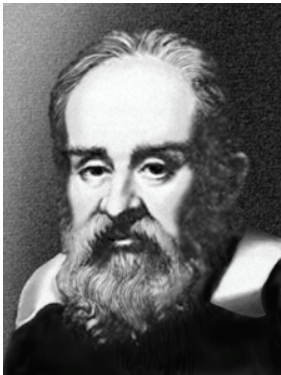
Galileo Galilei was born in Pisa, Italy, on February 15, 1564. His father, a musician and wool trader, hoped his son would find a more profitable career. He sent Galileo to a monastery school at age 11 to prepare for medical school. After four years there, Galileo decided to become a monk. The eldest of seven children, he had sisters who would need dowries in order to marry, and his father had planned on Galileo's support. His father decided to take Galileo out of the monastery school.

Two years later, he enrolled as a medical student at the University of Pisa, though his interests were mathematics and natural philosophy. Galileo did not really want to pursue medical studies. Eventually, his father agreed to let him study mathematics.

Seeing through the ordinary

Galileo was extremely curious. At 20, he found himself watching a lamp swinging from a cathedral ceiling. He used his pulse like a stopwatch and discovered that the lamp's long and short swings took the same amount of time. He wrote about this in an early paper titled "On Motion." Years later, he drew up plans for an invention, a pendulum clock, based on this discovery.

Inventions and experiments

Galileo started teaching at the University of Padua in 1592 and stayed for 18 years. He invented a simple thermometer, a water pump, and a compass for accurately aiming cannonballs. He also performed experiments with falling objects, using an inclined plane to slow the object's motion so it could be more accurately timed. Through these experiments, he realized that all objects fall at the same rate unless acted on by another force.

Crafting better telescopes

In 1609, Galileo heard that a Dutch eyeglass maker had invented an instrument that made things appear larger. Soon he had created his own 10-powered telescope. The senate in Venice was impressed with its potential military uses, and in a year, Galileo had refined his invention to a 30-powered telescope.

Star gazing

Using his powerful telescope, Galileo's curiosity now turned skyward. He discovered craters on the moon, sunspots, Jupiter's four largest moons, and the phases of Venus. His observations led him to conclude that Earth could not possibly be the center of the universe, as had been commonly accepted since the time of the Greek astronomer Ptolemy in the second century. Instead, Galileo was convinced that Polish astronomer Nicolaus Copernicus (1473-1543) must have been right: The sun is at the center of the universe and the planets revolve around it.

House arrest

The Roman Catholic Church held that Ptolemy's theory was truth and Copernican theory was heresy. Galileo had been told by the Inquisition in 1616 to abandon Copernican theory and stop pursuing these ideas.

Despite these threats, in February 1632, he published his ideas in the form of a conversation between two characters. He made the one representing Ptolemy's view seem foolish, while the other, who argued Copernicus's theory, seemed wise.

This angered the church, whose permission was needed for publishing books. Galileo was called to Rome before the Inquisition. He was given a formal threat of torture and so he abandoned his ideas that promoted Copernican theory. He was sentenced to house arrest, and lived until his death in 1642 watched over by Inquisition guards.

Reading reflection

1. What scientific information was presented in Galileo's paper "On Motion"?

2. **Research** one of Galileo's inventions and draw a diagram showing how it worked.

3. How were Galileo's views about the position of Earth in the universe supportive of Copernicus's ideas?

4. Imagine you could travel back in time to January 1632 to meet with Galileo just before he publishes his "Dialogue Concerning the Two Chief World Systems." What would you say to him?

5. In your opinion, which of Galileo's ideas or inventions had the biggest impact on history? Why?

Johannes Kepler

Johannes Kepler was a mathematician who studied astronomy. He lived at the same time as two other famous astronomers, Tycho Brahe and Galileo Galilei. Kepler is recognized today for his use of mathematics to solve problems in astronomy. Kepler explained that the orbit of Mars and other planets is an ellipse. In his most famous books he defended the sun-centered universe and his three laws of planetary motion.

Early years in Germany
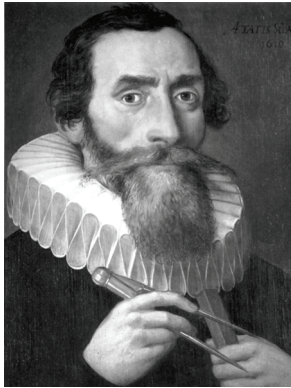
Johannes Kepler was born December 27, 1571, in Weil der Stadt, Wurttemburg, Germany, now called the "Gate to the Black Forest." He was the oldest of six children in a poor family. As a child he lived and worked in an inn run by his mother's family. He was sickly, nearsighted, and suffered from smallpox at a young age. Despite his physical condition, he was a bright student.

The first school Kepler attended was a convent school in Adelberg monastery. Kepler's original plan was to study to become a Lutheran minister. In 1589, Kepler received a scholarship to attend the University of Tubingen. There he spent three years studying mathematics, philosophy, and theology. His interest in math led him to take a mathematics teaching position at the Academy in Graz. There he began teaching and studying astronomy.

Influenced by Copernicus

At Tubingen, Kepler's professor, Michael Mastlin, introduced Kepler to Copernican astronomy. Nicholaus Copernicus (1473-1543), had published a revolutionary theory in, "On the Revolutions of Heavenly Bodies." Copernicus' theory stated that the sun was the center of the solar system. Earth and the planets rotated around the sun in circular orbits. At the time most people believed that Earth was the center of the universe.

Copernican theory intrigued Kepler and he wrote a defense of it in 1596, Mysterium Cosmographicum. Although Kepler's original defense was flawed, it was read by several other famous European astronomers of the time, Tycho Brahe (1546-1601) and Galileo Galilei (1546-1642).

Kepler published many books in which he explained how vision, optics, and telescopes work. His most famous work, though, dealt with planetary motion.

Working with Tyco Brahe

In 1600, Brahe invited Kepler to join him. Brahe, a Danish astronomer, was studying in Prague, Czechoslovakia. Every night for years Brahe recorded planetary motion without a telescope from his observatory. Brahe asked Kepler to figure out a scientific explanation for the motion of Mars. Less than two years later, Brahe died. Kepler was awarded Brahe's position as Imperial Mathematician. He inherited Brahe's collection of planetary observations to use to write mathematical descriptions of planetary motion.

Kepler's Laws of Planetary Motion

Kepler discovered that Mars' orbit was an ellipse, not a circle, as Copernicus had thought. Kepler published his first two laws of planetary motion in Astronomia Nova in 1609. The first law of planetary motion stated that planets orbit the sun in an elliptical orbit with the sun in one of the foci. The second law, the law of areas, said that planets speed up as their orbit is closest to the sun, and slow down as planets move away from the sun. Kepler published a third law, called the harmonic law, in 1619. The third law shows how a planet's distance from the sun is related to the amount of time it takes to revolve around the sun. His work influenced Isaac Newton's later work on gravity. Kepler's calculations were done before calculus was invented!

Other scientific discoveries

Kepler sent his book in 1609 to Galileo. Galileo's theories did not agree with Kepler's ideas and the two scientists never worked together. Despite his accomplishments, when Kepler died at age 59, he was poor and on his way to collect an old debt. It would take close to a century for his work to gain the recognition it deserved.

Reading reflection

1. Why was Copernicus' idea of the sun at the center of the solar system considered revolutionary?

2. Explain how Brahe helped Kepler make important discoveries in astronomy.

3. How was Kepler's approach to astronomy different than Brahe's and Galileo's?

4. Kepler discovered that Mars and other planets traveled in an ellipse around the sun. Does this agree with Copernicus' theory?

5. Describe Kepler's three laws of planetary motion.

6. Kepler observed a supernova in 1604. It challenged the way people at the time thought about the universe because people did not know the universe could change. When people have to change their beliefs about something because scientific evidence says otherwise, that is called a "paradigm shift." Find three examples in the text of scientific discoveries that led to a "paradigm shift."

Benjamin Banneker

Benjamin Banneker was a farmer, naturalist, civil rights advocate, self-taught mathematician, astronomer and surveyor who published his detailed astronomical calculations in popular almanacs. He was appointed by President George Washington as one of three surveyors of the territory that became Washington D.C.

Early times

Benjamin Banneker was born in rural Maryland in 1731. His family was part of a population of about two hundred free black men and women in Baltimore county. They owned a small farm where they grew tobacco and vegetables, earning a comfortable living.

A mathematician builds a clock

Benjamin's grandmother taught him to read, and he briefly attended a Quaker school near his home. Benjamin enjoyed school and was especially fond of solving mathematical riddles and puzzles. When he was 22, Benjamin borrowed a pocket watch, took it apart, and made detailed sketches of its inner workings. Then he carved a large-scale wooden model of each piece, fashioned a homemade spring, and built his own clock that kept accurate time for over 50 years.

A keen observer of the night sky

As a young adult, Benjamin designed an irrigation system that kept his family farm prosperous even in dry years. The Bannekers sold their produce at a nearby store owned by a Quaker family, the Ellicotts. There, Benjamin became friends with George Ellicott, who loaned him books about astronomy and mathematics.

Banneker was soon recording detailed observations of the night sky. He performed complicated calculations to predict the positions of planets and the timing of eclipses. From 1791 to 1797, Banneker published his astronomical calculations along with weather and tide predictions, literature, and commentaries in six almanacs. The almanacs were widely read in Maryland, Delaware, Pennsylvania, and Virginia, bringing Banneker a measure of fame.

A keen observer of nature

Banneker was also a keen observer of the natural world and is believed to be the first person to document the cycle of the 17-year cicada, an insect that exists in the larval stage underground for 17 years, and then emerges to live for just a few weeks as a loud buzzing adult.

Banneker writes Thomas Jefferson

Banneker sent a copy of his first almanac to then-Secretary of State Thomas Jefferson, along with a letter challenging Jefferson's ownership of slaves as inconsistent with his assertion in the Declaration of Independence that "all men are created equal." Jefferson sent a letter thanking Banneker for the almanac, saying that he sent it onto the Academy of Sciences of Paris as proof of the intellectual capabilities of Banneker's race. Although Jefferson's letter stated that he "ardently wishes to see a good system commenced for raising the condition both of [our black brethren's] body and mind," regrettably, he never freed his own slaves.

Designing Washington D.C.

In 1791, George Ellicott's cousin Andrew Ellicott asked him to serve as an astronomer in a large surveying project. George Ellicott suggested that he hire Benjamin Banneker instead. Banneker left his farm in the care of relatives and traveled to Washington, where he became one of three surveyors appointed by President George Washington to assist in the layout of the District of Columbia.

After his role in the project was complete, Banneker returned to his Maryland farm, where he died in 1806. Banneker Overlook Park, in Washington D.C., commemorates his role in the surveying project. In 1980, the U.S. Postal Service issued a stamp in Banneker's honor.

Reading reflection

1. Benjamin Banneker built a working clock that lasted 50 years. Why would his understanding of mathematics have been helpful in building the clock?

2. Identify one of Banneker's personal strengths. Justify your answer with examples from the reading.

3. Benjamin Banneker lived from 1731 to 1806. During his lifetime, he advocated equal rights for all people. Find out the date for each of the following "equal rights" events: (a) the Emacipation Proclamation, (b) the end of the Civil War, (c) women gain the right to vote, and (d) the desegregation of public schools (due to the landmark Supreme Court case, Brown versus the Board of Education).

4. Name three of Benjamin Banneker's lifetime accomplishments.

5. What do you think motivated Banneker during his lifetime? What are some possible reasons that he was persistent in his scientific work?

6. **Research:** Find a mathematical puzzle written by Banneker. Try to solve it with your class.

Touring the Solar System

READ CPO Science

What would a tour of our solar system be like? How long would it take? How much food would you have to bring on your tour? In this skill sheet, you will calculate the travel distances and times for a tour of the solar system. Your mode of transportation will be a space vehicle travelling at 250 meters per second or 570 miles per hour.

PRACTICE ▷〰

Part 1: Planets on the tour

Starting from Earth, the tour itinerary is: Earth to Mars to Saturn to Neptune to Venus and then back to Earth. The distances between each planet of the tour are provided in Table 1. The space vehicle travels at 250 meters per second or 900 kilometers per hour. Using this rate and the speed formula, find out how long it will take to travel each leg of the itinerary. An example for how to calculate how many hours it will take to travel from Earth to Mars is provided below. For the table, calculate the time in days and years as well.

Example: How many days will it take to travel from Earth to Mars? The distance from Earth to Mars is 78 million kilometers.

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$\text{time to travel from Earth to Mars} = \frac{78 \text{ million km}}{900 \dfrac{\text{km}}{\text{hour}}}$$

$$\text{time to travel from Earth to Mars} = 86{,}666 \text{ hours}$$

$$86{,}666 \text{ hours} \times \frac{1 \text{ day}}{24 \text{ hours}} = 3{,}611 \text{ days}$$

Table 1: Solar System Trip

Legs of the trip	Distance traveled for each leg (km)	Hours traveled	Days traveled	Years traveled
Earth to Mars	78,000,000			
Mars to Saturn	1,202,000,000			
Saturn to Neptune	3,070,000,000			
Neptune to Venus	4,392,000,000			
Venus to Earth	42,000,000			

Part 2: Provisions for the trip

A trip through the solar system is a science fiction fantasy. Answer the following questions as if such a journey were possible.

1. It is recommended that a person drink eight glasses of water each day. To keep yourself hydrated on your trip. How many glasses of water would you need to drink on the leg from Earth to Mars?

2. An average person needs 2,000 food calories per day. How many food calories will you need for the leg of the journey from Neptune to Venus?

3. Proteins and carbohydrates provide 4 calories per gram. Fat provides 9 calories per gram. Given this information, would it be more efficient to pack the plane full of foods that are high in fat or high in protein for the journey? Explain your answer.

4. You decide that you want to celebrate Thanksgiving each year of your travel. How many frozen turkeys will you need for the entire journey?

Part 3: Planning your trip for each planet

Section 15.1 of your student text presents a table that lists the properties of the nine planets. Use this table to answer the following questions.

1. On which planet would there be the most opportunities to visit a moon?

2. Which planets would require high-tech clothing to endure high temperatures? Which planets would require high-tech clothing to endure cold temperatures?

3. Which planet has the longest day?

4. Which has the shortest day?

5. On which planet would you have the most weight? How much would you weigh in newtons?

6. On which planet would you have the least weight? How much would you weigh in newtons? Use proportions to answer this question.

7. Which planet would take the longest time to travel around?

8. Which planet would require your spaceship to orbit with the fastest orbital speed? Explain your answer.

Gravity Problems

READ | CPO Science

An easy way to solve problems is to set them up as proportions. In this skill sheet, you will practice using proportions and learn more about the force of gravity on different planets.

PRACTICE

Comparing the force of gravity on the planets

Table 1 lists the force of gravity on each planet in our solar system. We can see more clearly how these values compare to each other using proportions. First, we assume that Earth's gravity is equal to "1." Then, we set up the proportion where "x" equals the force of gravity on another planet (in this case, Mercury) as compared to Earth.

$$\frac{1}{\text{Earth gravity}} = \frac{x}{\text{Mercury gravity}}$$

$$\frac{1}{9.8 \text{ N}} = \frac{x}{3.7 \text{ N}}$$

$$(1 \times 3.7 \text{ N}) = (9.8 \text{ N} \times x)$$

$$\frac{3.7 \text{ N}}{9.8 \text{ N}} = x$$

$$0.38 = x$$

Therefore, Mercury's force of gravity is a little more than a third of Earth's gravity.

Now, calculate the proportions for the remaining planets.

Table 1: The force of gravity on planet in our solar system

Planet	Force of gravity in newtons (N)	Value compared to Earth's gravity
Mercury	3.7	0.38
Venus	8.9	
Earth	9.8	1
Mars	3.7	
Jupiter	23.1	
Saturn	9.0	
Uranus	8.7	
Neptune	11.0	
Pluto	0.6	

How much does it weigh on another planet?

Use Table 1 to solve the following problems.

1. A cat weighs 8.5 pounds on Earth. How much would this cat weigh on Neptune?

2. A baby elephant weighs 250 pounds on Earth. How much would this elephant weigh on Saturn? Give your answer in newtons (4.48 newtons = 1 pound).

3. On Pluto, a baby would weigh 2.7 newtons. How much does this baby weigh on Earth? Give your answer in newtons and pounds.

4. Imagine that it is possible to travel to each planet in our solar system. After a space "cruise," a tourist returns to Earth. One of the ways he recorded his travels was to weigh himself on each planet he visited. Use the list of these weights on each planet to figure out the order of the planets he visited. On Earth he weighs 720 newtons. List of weights: 655 N; 1,872 N; 792 N; 36 N; and 661 N.

Challenge: Using the Universal Law of Gravitation

Here is an example problem that is solved using the equation for Universal Gravitation.

Equation of Universal Gravitation:

Mass 1 (kg) — Mass 2 (kg)

Force (N) — $$F = G \frac{m_1 m_2}{R^2}$$

Gravitational constant (6.67×10^{11} N-m²/kg²)

Distance between mass 1 and mass 2 (m)

Example

What is the force of gravity between Pluto and Earth? The mass of Earth is 6.0×10^{24} kg. The mass of Pluto is 1.3×10^{22} kg. The distance between these two planets is 5.76×10^{12} meters.

$$\text{Force of gravity between Earth and Pluto} = \left(\frac{6.67 \times 10^{-11} \text{N-m}^2}{\text{kg}^2} \right) \frac{(6.0 \times 10^{24}) \times (1.3 \times 10^{22})}{(5.76 \times 10^{12})^2}$$

$$\text{Force of gravity} = \frac{52.0 \times 10^{35}}{33.2 \times 10^{24}} = 1.57 \times 10^{11} \text{N}$$

Now use the equation for Universal Gravitation to solve this problem:

5. What is the force of gravity between Jupiter and Saturn? The mass of Jupiter is 6.4×10^{24} kg. The mass of Saturn is 5.7×10^{26} kg. The distance between Jupiter and Saturn is 6.52×10^{11} m.

Scientific Notation

A number like 43,200,000,000,000,000,000 (43 quintillion, 200 quadrillion) can take a long time to write, and an even longer time to read. Because they frequently encounter very large numbers like this one (and also very small numbers, such as 0.000000012, or twelve trillionths), scientists developed a shorthand method for writing these types of numbers. This method is called scientific notation. A number is written in scientific notation when it is written as the product of two factors, where the first factor is a number that is greater than or equal to 1, but less than 10, and the second factor is an integer power of 10. Some examples of numbers written in scientific notation are given in the table below:

Scientific Notation	Standard Form
4.32×10^{19}	43,200,000,000,000,000,000
1.2×10^{-8}	0.000000012
5.2777×10^{7}	52,777,000
$6.99 \ \ 10^{-5}$	0.0000699

EXAMPLES ▶

Rewrite numbers given in scientific notation in standard form.

- Express 4.25×10^{6} in standard form: $4.25 \times 10^{6} = 4,250,000$
  Move the decimal point (in 4.25) six places to the right. The exponent of the "10" is 6, giving us the number of places to move the decimal. We know to move it to the right since the exponent is a positive number.

$$4.25 \times 10^6 = 4.2.5.0.0.0.0. = 4,250,000$$
move decimal six
places to the right

- Express 4.033×10^{-3} in standard form: $4.033 \times 10^{-3} = 0.004033$
  Move the decimal point (in 4.033) three places to the left. The exponent of the "10" is negative 3, giving the number of places to move the decimal. We know to move it to the left since the exponent is negative.

$$4.033 \times 10^{-3} = 0.0.4.033 = 0.004033$$
move decimal three
places to the left

Rewrite numbers given in standard form in scientific notation.

- Express 26,040,000,000 in scientific notation: $26,040,000,000 = 2.604 \times 10^{10}$
  Place the decimal point in 2 6 0 4 so that the number is greater than or equal to one (but less than ten). This gives the first factor (2.604). To get from 2.604 to 26,040,000,000 the decimal point has to move 10 places to the right, so the power of ten is positive 10.

- Express 0.0001009 in scientific notation: $0.0001009 = 1.009 \times 10^{-4}$
  Place the decimal point in 1 0 0 9 so that the number is greater than or equal to one (but less than ten). This gives the first factor (1.009). To get from 1.009 to 0.0001009 the decimal point has to move four places to the left, so the power of ten is negative 4.

PRACTICE

1. Fill in the missing numbers. Some will require converting scientific notation to standard form, while others will require converting standard form to scientific notation.

	Scientific Notation	Standard Form
a.	6.03×10^{-2}	
b.	9.11×10^5	
c.	5.570×10^{-7}	
d.		999.0
e.		264,000
f.		761,000,000
g.	7.13×10^7	
h.		0.00320
i.		0.000040
j.	1.2×10^{-12}	
k.		42,000,000,000,000
l.		12,004,000,000
m.	9.906×10^{-2}	

2. Explain why the numbers below are not written in scientific notation, then give the correct way to write the number in scientific notation.

    Example: 0.06×10^5 is not written in scientific notation because the first factor (0.06) is not greater than or equal to 1. The correct way to write this number in scientific notation is 6.0×10^3.

    a. 2.004×1^{11}

    b. 56×10^{-4}

    c. 2×100^2

    d. 10×10^{-6}

3. Write the numbers in the following statements in scientific notation:

   a. The national debt in 2005 was about $7,935,000,000,000.

   b. In 2005, the U.S. population was about 297,000,000

   c. Earth's crust contains approximately 120 trillion (120,000,000,000,000) metric tons of gold.

   d. The mass of an electron is 0.000 000 000 000 000 000 000 000 000 000 91 kilograms.

   e. The usual growth of hair is 0.00033 meters per day.

   f. The population of Iraq in 2005 was approximately 26,000,000.

   g. The population of California in 2005 was approximately 33,900,000.

   h. The approximate area of California is 164,000 square miles.

   i. The approximate area of Iraq in 2005 was 169,000 square miles.

   j. In 2005, one right-fielder made a salary of $12,500,000 playing professional baseball.

Arthur Walker

Arthur Walker pioneered several new space-based research tools that brought about significant changes in our understanding of the sun and its corona. He was instrumental in the recruitment and retention of minority students at Stanford University, and he advised the United States Congress on physical science policy issues.

Not to be discouraged

Arthur Walker was born in Cleveland in 1936. His father was a lawyer and his mother a social worker. When he was 5, the family moved to New York. Arthur was an excellent student and his mother encouraged him to take the entrance exam for the Bronx High School of Science.

Arthur passed the exam, but when he entered school a faculty member told him that the prospects for a black scientist in the United States were bleak. Rather than allow him to become dissuaded from his aspirations, Arthur's mother visited the school and told them that her son would pursue whatever course of study he wished.

Making his mark in space

Walker went on to earn a bachelor's degree in physics, with honors, from Case Institute of Technology in Cleveland and, by 1962, his master's and doctorate from the University of Illinois. He then spent three years' active duty with the Air Force, where he designed a rocket probe and satellite experiment to measure **radiation** that affects satellite operation. This work sparked Walker's lifelong interest in developing new space-based research tools.

After completing his military service, Walker worked with other scientists to develop the first X-ray **spectrometer** used aboard a satellite. This device helped determine the temperature and composition of the sun's corona and provided new information about how matter and radiation interact in **plasma**.

Snapshots of the sun

In 1974, Walker joined the faculty at Stanford University. There he pioneered the use of a new multilayer mirror technology in space observations. The mirrors selectively reflected **X rays** of certain wavelengths, and enabled Walker to obtain the first high-resolution images showing different temperature regions of the solar atmosphere. He then worked to develop telescopes using the multilayer mirror technology, and launched them into space on rockets. The telescopes produced detailed photos of the sun and its corona. One of the pictures was featured on the cover of the journal *Science* in September 1988.

Corona
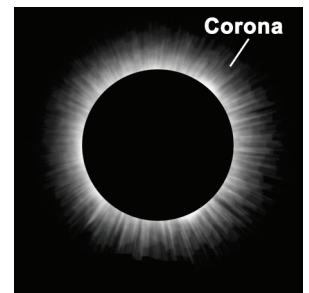
A model for student scientists

Walker was a mentor to many graduate students, including Sally Ride, who went on to become the first American woman in space. He worked to recruit and retain minority applicants to Stanford's natural and mathematical science programs. Walker was instrumental in helping Stanford University graduate more black doctoral physicists than any university in the United States.

At work in other orbits

Public service was important to Walker, who served on several committees of the National Aeronautics and Space Administration (NASA), National Science Foundation, and National Academy of Science, working to develop policy recommendations for Congress. He was also appointed to the presidential commission that investigated the 1986 space shuttle Challenger accident.

Walker died of cancer in April 2001.

Reading reflection

1. Use your textbook, an Internet search engine, or a dictionary to find the definition of each word in bold type. Write down the meaning of each word. Be sure to credit your source.

2. What have you learned about pursuing goals from Arthur Walker's biography?

3. Why is a spectrometer a useful device for measuring the temperature and composition of something like the sun's corona?

4. **Research:** Use a library or the Internet to find one of Walker's revolutionary photos of the sun and its corona. Present the image to your class.

5. **Research:** Use a library or the Internet to find more about the commission that investigated the explosion of the space shuttle Challenger in 1986. Summarize the commission's findings and recommendations in two or three paragraphs.

The Sun: A Cross-Section

D. Heat transfer through motion of hot gas

E. Heat transfer mainly through light energy

F. Nuclear fusion

A. Outer atmosphere 2,000,000°C

B. Inner atmosphere 5,000–10,000°C

C. Visible "surface" 5,500°C
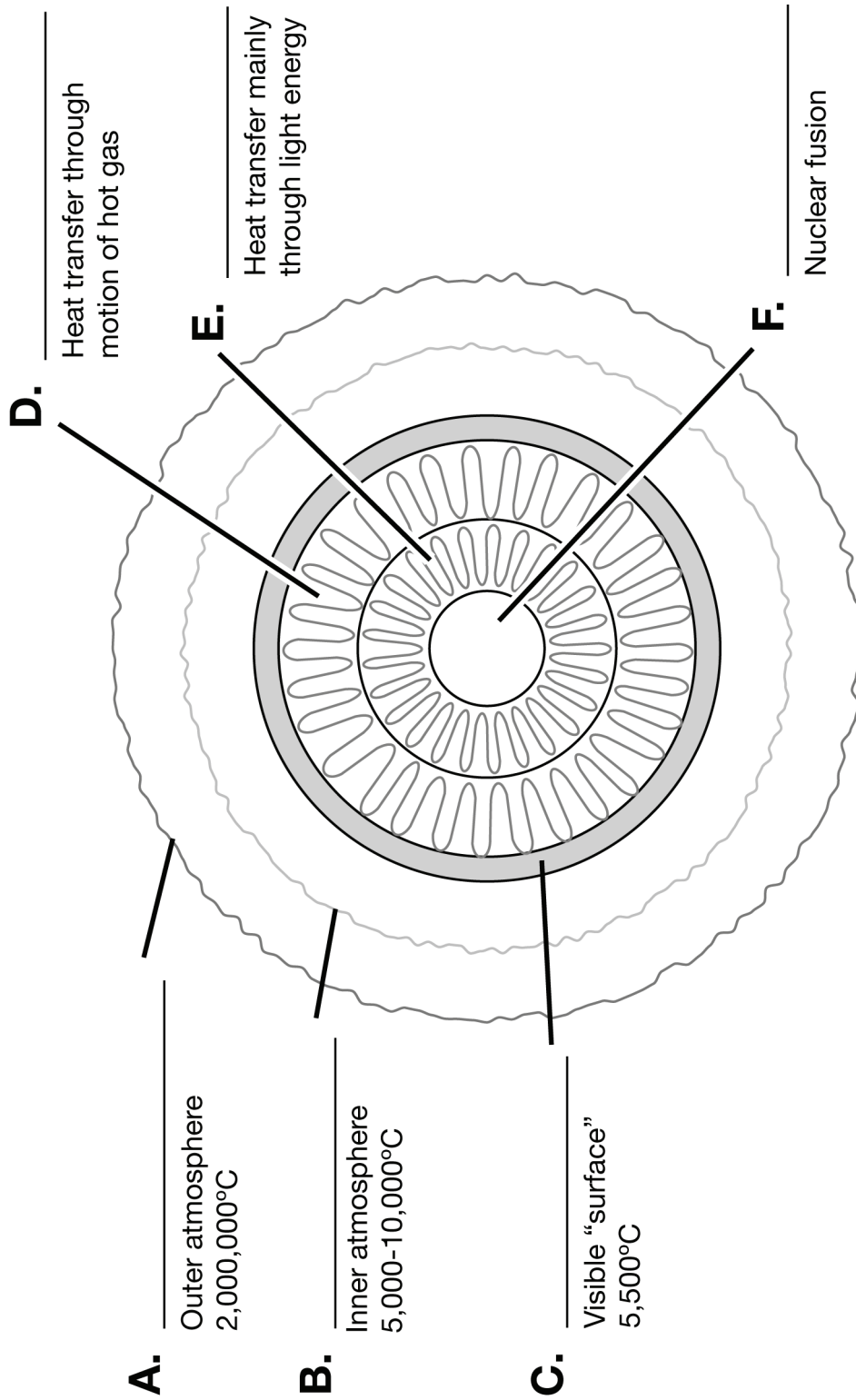
Understanding Light Years

How far is it from Los Angeles to New York? Pretty far, but it can still be measured in miles or kilometers. How far is it from Earth to the sun?   It's about one hundred forty-nine million, six hundred thousand kilometers (149,600,000, or 1.496×10^8 km). Because this number is so large, and many other distances in space are even larger, scientists developed bigger units in order to measure them. An Astronomical Unit (AU) is 1.496×10^8 km (the distance from Earth to the sun). This unit is usually what is used to measure distances within our solar system. To measure longer distances (like the distance between Earth and stars and other galaxies), the light year (ly) is used. A light year is the distance that light travels through space in one year, or 9.468×10^{12} km.

EXAMPLES ▶

1. **Converting light years (ly) to kilometers (km)**

   Earth's closest star (Proxima Centauri) is about 4.22 light years away. How far is this in kilometers?

   Explanation/Answer: Multiply the number of kilometers in one light year (9.468×10^{12} km/ly) by the number of light years given (in this case, 4.22 ly).

   $$\frac{(9.468 \times 10^{12}) \text{ km}}{1 \text{ ly}} \times 4.22 \text{ ly} \approx 3.995 \times 10^{13} \text{ km}$$

2. **Converting kilometers to light years**

   Polaris (the North Star) is about 4.07124×10^{15} km from the earth. How far is this in light years?

   Explanation/Answer: Divide the number of kilometers (in this case, 4.07124×10^{15} km) by the number of kilometers in one light year (9.468×10^{12} km/ly).

   $$4.07124 \times 10^{15} \text{ km} \div \frac{9.468 \times 10^{12} \text{ km}}{1 \text{ ly}} = \frac{4.07124 \times 10^{15} \text{ km}}{1} \times \frac{1 \text{ ly}}{9.468 \times 10^{12} \text{ km}} \approx 430 \text{ light years}$$

PRACTICE ▶

Convert each number of light years to kilometers.

1. 6 light years

2. 4.5×10^6 light years

3. 4×10^{-3} light years

Convert each number of kilometers to light years.

4. 5.06×10^{16} km

5. 11 km

6. 11,003,000,000,000 km

Solve each problem using what you have learned.

7. The second brightest star in the sky (after Sirius) is Canopus. This yellow-white supergiant is about 1.13616×10^{16} kilometers away. How far away is it in light years?

8. Regulus (one of the stars in the constellation Leo the Lion) is about 350 times brighter than the sun. It is 85 light years away from the earth. How far is this in kilometers?

9. The distance from earth to Pluto is about 28.61 AU from the earth. Remember that an AU $= 1.496 \times 108$ km. How many kilometers is it from Pluto to the earth?

10. If you were to travel in a straight line from Los Angeles to New York City, you would travel 3,940 kilometers. How far is this in AU's?

11. Challenge: How many AU's are equivalent to one light year?

Calculating Luminosity

READ CPO Science

You have learned that in order to understand stars, astronomers want to know their luminosity. *Luminosity* describes how much light is coming from the star each second. Luminosity can be measured in watts (W).

Measuring the luminosity of something as far away as a star is difficult to do. However, we can measure its brightness. *Brightness* describes the amount of the star's light that reaches a square meter of Earth each second. Brightness is measured in watts/square meter (W/m^2).

The brightness of a star depends on its luminosity and its distance from Earth. A star, like a light bulb, radiates light in all directions. Imagine that you are standing one meter away from an ordinary 100-watt incandescent light bulb. These light bulbs are about ten percent efficient. That means only ten percent of the 100 watts of electrical power is used to produce light. The rest is wasted as heat. So the luminosity of the bulb is about ten percent of 100 watts, or around 10 watts.

The brightness of this bulb is the same at all points one meter away from the bulb. All those points together form a sphere with a radius of one meter, surrounding the bulb.
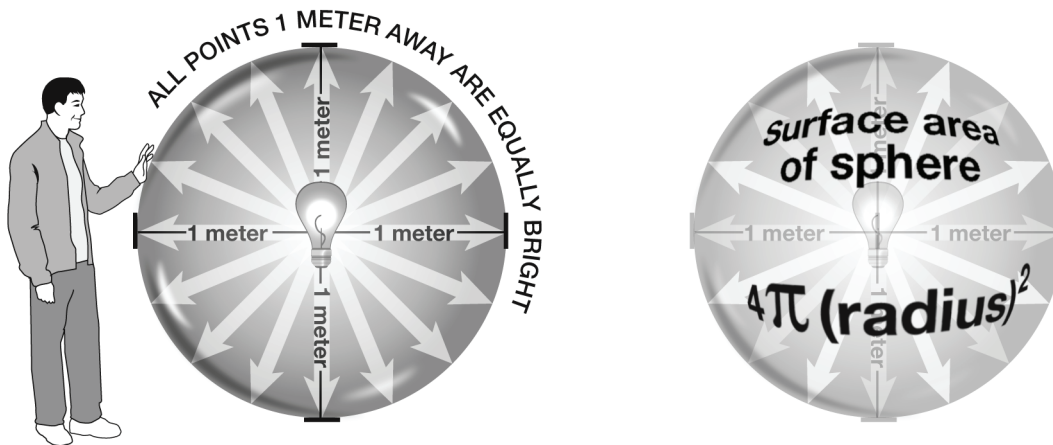
If you want to find the brightness of that bulb, you take the luminosity (10 watts) and divide it by the amount of surface area it has to cover—the surface area of the sphere. So, the formula for brightness is:

$$\text{brightness} = \frac{\text{luminosity}}{\text{surface area of sphere}} = \frac{\text{luminosity}}{4\pi(\text{radius})^2}$$

The brightness of the bulb at a distance of one meter is:

$$\frac{10 \text{ watts}}{4\pi(1 \text{ meter})^2} = \frac{10 \text{ watts}}{12.6 \text{ meter}^2} = 0.79 \text{ W/m}^2$$

Notice that the radius in the equation is the same as the distance from the bulb to the point at which we're measuring brightness. If you were standing 10 meters away from the bulb, you would use 10 for the radius in the equation. The surface area of your sphere would be $4\pi(100)$ or $1,256$ square meters! The same 10 watts of light energy is now spread over a much larger surface. Each square meter receives just 0.008 watts of light energy. Can you see why distance has such a huge impact on brightness?

If we know the brightness and the distance, we can calculate luminosity by rearranging the equation:

$$\text{luminosity } = \text{ brightness} \times \text{surface area of sphere} = \text{ brightness} \times 4\pi(\text{distance})^2$$

This is the same formula that astronomers use to calculate the luminosity of stars.

EXAMPLE ▷

You are standing 5 meters away from another incandescent light bulb. Using a light-meter, you measure its brightness at that distance to be 0.019 watts/meter². Calculate the luminosity of the bulb. Assuming this bulb is also about ten percent efficient, estimate how much electric power it uses (this is the wattage printed on the bulb).

Step 1: Plug the known values into the formula:

$$\text{luminosity } = \frac{0.019 \text{ watts}}{\text{meter}^2} \times \frac{4\pi(5 \text{ meters})^2}{1}$$

Step 2: Solve for luminosity:

$$\text{luminosity } = 0.019 \times 100\pi \text{ watts} = 6 \text{ watts}$$

Step 3: If the bulb is only about ten percent efficient, the electric power used must be about ten times the luminosity. The bulb must use about 10×6 watts, or 60 watts, of electric power.

PRACTICE ▷〜

1. Ten meters away from a flood lamp, you measure its brightness to be 0.024 W/m². What is the luminosity of the flood lamp? What is the electrical power rating listed on the bulb, assuming it is ten percent efficient?

2. You hold your light-meter a distance of one meter from the light bulb in your refrigerator. You measure the brightness to be 0.079 W/m². What is the luminosity of this light bulb? What is its power rating, assuming it is ten percent efficient?

3. **Challenge:** Finding the luminosity of the sun.

You can use the same formula to calculate the luminosity of the sun.

Astronomers have measured the average brightness of the sun at the top of Earth's atmosphere to be 1,370 W/m². This quantity is known as the *solar constant.*

We also know that the distance from Earth to the sun is 150 billion meters (or 1.5×10^{11} meters).

What is the luminosity of the sun?

Hints:

1. You may wish to rewrite the solar constant as 1.370×10^3 W/m².
2. $(10^{11})^2$ is the same as $10^{11} \times 10^{11}$. To find the product, add the exponents.
3. Don't forget to find the square of 1.5!

Edwin Hubble

Edwin Hubble was an accomplished academic that many astronomers credit with "discovering the universe."

A good student and even better athlete

Edwin Hubble was born on November 29, 1889, in Marshfield, Missouri. His family moved to Chicago when he was ten years old.

Hubble was an active, imaginative boy. He was an avid reader of science fiction. Jules Verne's adventure novels were among his favorite stories. Science fascinated Hubble, and he loved the way Verne wove futuristic inventions and scientific content into stories that took the reader on voyages to some strange and exotic destinations.

Hubble was a very good student and also an excellent athlete. In 1906 he set an Illinois state record for the high jump, and in that same season he took seven first place medals and one third place medal in a single high school track meet.

Focus turns to academics

Hubble continued his athletic success by participating in basketball and boxing at the University of Chicago. Eventually though, his studies became his primary focus. Hubble graduated with a bachelors degree in Mathematics and **Astronomy** in 1910.

Hubble was selected as a Rhodes Scholar and spent the next three years at the University of Oxford, in England. Instead of continuing his studies in math and science, he decided to pursue a law degree. He completed the degree in 1913 and returned to the United States. He set up a law practice in Louisville, Kentucky. However, it was a short lived law career.

Returning to Astronomy

It took Hubble less than a year to become bored with his law practice, and he returned to the University of Chicago to study astronomy. He did much of his work at the Yerkes Observatory, and received his Ph.D. in astronomy in 1917.

Hubble joined the army at this time and served a tour of duty in World War I. He attained the rank of Major. When he returned in 1919, he was offered a job by George Ellery Hale, the founder and director of Carnegie Institution's Mount Wilson Observatory, near Pasadena, California.

The best tool for the job

The timing could not have been better. The 100-inch Hooker telescope, the world's most powerful telescope at the time, had just been constructed. This telescope could easily focus images that were fuzzy, too dim, or too small to be seen clearly through other large telescopes.

The Hooker telescope enabled Hubble to make some astounding discoveries. Astronomers had believed that the many large fuzzy patches they saw through their powerful telescopes were huge gas clouds within our own Milky Way **galaxy**. They called these fuzzy patches "nebulae," a Greek word meaning "cloud."

Hubble's observations in 1923 and 1924 proved that while a few of these fuzzy objects were inside our galaxy, most were in fact entire galaxies themselves, not only separate from the Milky Way but millions of light years away. This greatly enlarged the accepted size of the universe, which many scientists at the time believed was limited to the Milky Way alone.

Another landmark discovery

Hubble also used **spectroscopy** to study galaxies. He observed that galaxies' spectral lines were shifting toward the red end of the spectrum, which meant they were moving away from each other. He showed that the farther away a galaxy was, the faster it was moving away from Earth. In 1929, Hubble and fellow astronomer Milton Humason announced that all observed galaxies are moving away from each other with a speed proportional to the distance between them. This became known as Hubble's Law, and it proved that the universe was expanding.

Albert Einstein visited Hubble and personally thanked him for this discovery, as it matched with Einstein's calculations, providing observable evidence confirming his predictions.

Hubble worked at the Wilson Observatory until his death in 1953. He is considered the father of modern **cosmology**. To honor him, scientists have named a space telescope, a crater on the moon, and an asteroid after him.

Reading reflection

1. Look up the definition of each boldface word in the article. Write down the definitions and be sure to credit your source.

2. **Research:** What is a Rhodes Scholarship?

3. **Research:** Why does a larger telescope allow astronomers to see more?

4. Imagine you knew Edwin Hubble. Describe how you think he may have felt when Albert Einstein came to visit and thank him for his discoveries.

5. **Research:** Before Hubble's discovery, people thought that the universe had always been about the same size. How did Hubble's discovery that the universe is currently expanding change scientific thought about the size of the universe *in the past*?

Answer Keys

Skill Sheet 1.1: Using Your Textbook

Part 1 answers:
1. Green
2. Variable, value, graph, independent variable, dependent variable
3. Blue
4. Motion in a line, on a plane, and in space
5. At the end of each section
6. What is a force?
7. Red
8. Vocabulary, concepts, problems

Part 2 answers:
1. There are six units: Physical Science and You, Properties of Matter, Atoms and the Periodic Table, Matter and Change, Motion and Force, Astronomy

2. Example answer: The astronomy unit will be the most interesting. I have a telescope and enjoy astronomy.
3. Example answer: Defy Gravity? It Can Be Done, Big Bear Solar Observatory, and Silly Putty: Solid or Liquid?
4. There is a chapter activity after each Connection.

Part 3 answers:
1. Speed with direction
2. 159, 163, and 202
3. 312
4. Example answer: Students know how to solve problems involving distance, time, and average speed.

Skill Sheet 1.2A: Stopwatch Math

1. Answers are:
   a. 5, 5.05, 5.15, 5.2, 5.5
   b. 6:06, 6:06.004, 6:06.04, 6:06.4
2. Answers are:

Time	9.88w	9.88w	9.91	9.95w
Year	2002	1998	2004	2001

Time	9.97w	10.01	10.08	10.11
Year	1999	2000	2005	2003

3. Answers are:
   a. 1:22.04, 1:22.4, 1:23.117, 1:23.2, 1:24, 1:24.007, 1:25, 1:33
   b. 1:17.99, 1:18.22, 1:18.3, 1:20, 1:20.22, 1:21.003, 1:21.2
   c. 1:24.099, 1:24.9899, 1:24.99, 1:24.9901, 1:25, 1:25.001
4. Infinitely many solutions possible.
   Example: 26:15.21, 26:15.215, 26:15.22, 26:15.225, 26:15.23

Skill Sheet 1.2B: SI Units

1. 10 g
2. 1000 mm
3. 600 mm
4. 420 g
5. 5 L
6. 0.1 m
7. 1,500,000
8. 300 L
9. 6,500,000 cm
10. 120,000 mg
11. 7.2 L
12. 530,000,000 kL
13. A decimeter is 100 times larger than a millimeter.
14. A dekagram is 1000 times larger than a centigram
15. millimeter

Skill Sheet 1.2C: SI-English Conversions

1. ≈ 4.34 mi
2. ≈ 4.11 oz
3. ≈ 909 kg
4. ≈ 2.12 qt
5. $\approx 2,454$ g
6. ≈ 33.5 km
7. 2835 in; 78 yd
8. ≈ 1.74 mi
9. ≈ 3.77 l
10. ≈ 0.38 lb

Skill Sheet 1.2D: Dimensional Analysis

1. Answers are:
   a. $72/day
   b. 210 lbs/week
2. Answers are:
   a. 2.75 gal
   b. 2.2 m
   c. ≈ 0.095 mile
   d. 64 c
3. Answers are:
   a. 126,144,000 sec
   b. ≈ 71 ft
   c. 4.5 qt
   d. $14 \, ^2/_3$ fields
   e. 50 km/gal
   f. ≈ 13.21 km/l
   g. 95.3 ft/sec

Skill Sheet 1.2E: SQ3R

No student responses are required.

Skill Sheet 1.3A: Study Notes

No student responses are required.

Skill Sheet 1.3B: James Joule

1. Perhaps because he thought that the pursuit of science was worthwhile.
2. His father hired one of the most famous scientists of his time to be a tutor for his sons.
3. His interest was based upon his desire to improve the brewery. He wanted to make a more efficient electric motor to replace the old steam engines that they had at the time.
4. His goal had been to replace the old steam engines with more efficient electric motors. He was not able to do that, however, he learned a great deal about electromagnets, magnetism, heat, motion, electricity, and work.
5. Electricity produces heat when it travels through a wire because of the resistance of the wire. Joule's Law also provided a formula so that scientists could calculate the exact amount of heat produced.

6. Joule believed that heat was a state of vibration caused by the collision of molecules. This contradicted the beliefs of his peers who thought that heat was a fluid.
7. Joule knew that the temperature of the water at the bottom of the waterfall was warmer than the water at the top of the waterfall. He thought that this was true because the energy produced by the falling water was converted into heat energy. He wanted to measure how far water had to fall in order to raise the temperature of the water by one degree. Joule used a large thermometer to measure the temperature at the top of the waterfall and the temperature at the bottom of the waterfall. The experiment failed because the water did not fall the right distance for his calculations and there was too much spray from the waterfall to read the instruments accurately.
8. Refrigeration
9. The joule is the international measurement for a unit of energy.
10. Answers will vary.

Skill Sheet 2.1A: Creating Line Graphs

1. Answers are:

Data pair not necessarily in order		Independent	Dependent
Temp.	Hours of heating	Hours of heating	Temp.
Stopping distance	Speed of a car	Speed of a car	Stopping distance
Number of people in family	Cost per week for groceries	Number of people in family	Cost per week for groceries
Stream flow	Rainfall	Amount of rainfall	Rate of stream flow
Tree age	Average tree height	Tree age	Average tree height
Test score	Number of hours studying for a test	Number of hours studying	Test score
Population of a city	Number of schools needed	Population of a city	Number of schools needed

2. Answers are:

Range	Number of lines	Range ÷ No. of lines	Calculated scale (per line)	Adj. scale (per line)
13	24	13 ÷ 24	0.54	1
83	43	83 ÷ 43	1.9	2
31	35	31 ÷ 35	0.88	1

Range	Number of lines	Range ÷ No. of lines	Calculated scale (per line)	Adj. scale (per line)
100	33	100 ÷ 33	3.03	5
300	20	300 ÷ 20	15	15
900	15	900 ÷ 15	60	60

3. Answers are:
   a. Table answers:

Independent variable	Dependent variable
0	5.0
10	9.5
20	14.0
30	18.5
40	23.0
50	27.5
60	32.0

   b. 60 minutes
   c. 27.0 kilometers
   d. Adjusted scale for the x-axis: 3 per line or 5 per line; adjusted scale for the y-axis: 1.5 per line or 2 per line

e. & f.
Graph of position (km) earned vs. time (min):

g. After 45 minutes, the position would be about 25.25 kilometers.

Position vs. Time

Time (min)
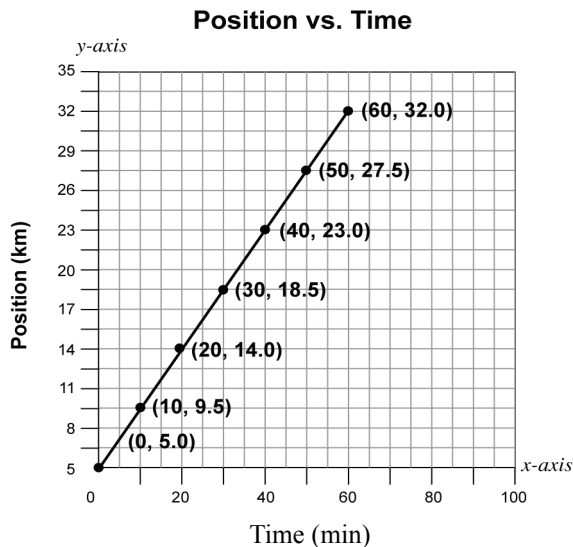
Skill Sheet 2.1B: Measuring Angles

Answers are:

Letter	Angle	Letter	Angle
A	56°	J	153°
B	110°	K	131°
C	10°	L	148°
D	96°	M	81°
E	167°	N	90°
F	122°	O	73°
G	34°	P	27°
H	45°	Q	139°
I	19°		

Skill Sheet 2.1C: Solving Equations With One Variable

Part 1 answers:
1. $w = 4$ mm
2. $l = 0.8$ m
3. $h \approx 8.0$ cm
4. $d = 7.5$ m
5. $s = 4$ m/s
6. $t = 30$ s
7. $t = 31.25$ s
8. $D = 7.8$ g/cm^3

9. $m = 1.08$ g
10. $m = 4.5$ g
11. $V = 112.5$ cm^3
12. $V \approx 2.26$ cm^3

Part 2 answers:
1. Force = 8 N
2. $p = 20$ Pa
3. $p = 216$ Pa
4. $p = 15,000$ Pa

Skill Sheet 2.1D: What's the Scale?

1. Answers are:

Range from 0	# of Lines	Range ÷ # of Lines	Calculated scale	Adj. scale (whole #)
14	10	14 ÷ 10 =	1.4	2
8	5	8 ÷ 5 =	1.6	2
1000	20	1000 ÷ 20 =	50	50

Range from 0	# of Lines	Range ÷ # of Lines	Calculated scale	Adj. scale (whole #)
547	15	547 ÷ 15 =	36.5	37
99	30	99 ÷ 30 =	3.3	4
35	12	35 ÷ 12 =	2.9	3

2. The range is 30 and the scale is 1 per line.

3. The range is 25 and the scale is 3 per line.
4. Answers are:
   Independent variable: Days; Dependent variable: Average

Temperature (°F)
Range for x-axis = 11; Range for y-axis = 73
Scale for x-axis = 1 day/box; Scale for y-axis = 4 °F/box

Skill Sheet 2.1E: Internet Research

Part 1 answers:
1. Example answer: "science museums" + "south carolina" not "columbia"
2. "dog breeds" not "expensive" (or) "dog breeds" + "inexpensive"
3. "producing electricity" not "coal" not "natural gas"

Part 2 answers:
1. Answers will vary. Sites that may be authoritative include non-profit sites (recognizable by having "org" as the extension in the web address) or government sites such as www.nasa.gov (recognizable by the "gov" extension address) or college/university websites (recognizable by the "edu" extension address). These sites often provide information to large, diverse groups and are not typically supported by advertising. Sites that are supported by advertising can be authoritative, but may be biased in the information presented. Another characteristic of authoritative sites are that they are actively updated on a regular basis.
2. Answers will vary. Reasons for why a source may not seem to be authoritative include: the author of the site is not affiliated with an organization and does not have obvious credentials, and the information seems to be one-sided. Many science topic searches will lead to student papers published on the Internet. These may contain mistakes, or they may have been written by a younger student.
3. Answers will vary. Intended audiences can be young children, pre-teens, teenagers, adults, or select groups of people (women, men, people who like dogs, etc.).
4. Answers will vary.

Skill Sheet 2.2A: Averaging

1. 78%
2. $68,905,690
3. Average hours per person = 13; average pay = $156
4. ≈ 4.7 points each
5. about $3.08 per gallon

Skill Sheet 2.2B: Bibliographies

No student responses are required.

Skill Sheet 2.2C: Scientific Processes

1. Maria and Elena's question is: Does hot water in an ice cube tray freeze faster than cold water in an ice cube tray?
2. Maria's hypothesis: Hot water will take longer to freeze into solid ice cubes than cold water, because the hot water molecules have to slow down more than cold water molecules to enter the solid state and become ice.
3. Examples of variables include:
   Amount of water in each ice cube tray "slot" must be uniform.
   Each ice cube tray must be made of same material, "slots" in all trays must be identical.
   Placement of trays in freezer must provide equal cooling.
   All "hot" water must be at the same initial temperature.
   All "cold" water must be at the same initial temperature.
4. Examples of measurements include:
   Initial temperature of hot water.
   Initial temperature of cold water.
   Volume of water to fill each ice cube tray "slot."
   Time taken for water to freeze solid.
5. Sample procedure in 9 steps:
   (1) Place 1 liter of water in a refrigerator to chill for 1 hour.
   (2) Boil water in pot on a stove (water will be 100°C).
   (3) Using pot holders, a kitchen funnel, and a medicine-measuring cup, carefully measure out 15 mL of boiling water into each slot in two labeled ice cube trays.
   (4) Remove chilled water from refrigerator, measure temperature.
   (5) Carefully measure 15 mL chilled water into each slot in two labeled ice cube trays.
   (6) Place trays on bottom shelf of freezer, along the back wall.
   (7) Start timer.
   (8) After 1/2 hour, begin checking trays every 15 minutes to see if solid ice has formed in any tray.
   (9) Stop timing when at least one tray has solid ice cubes in it.
6. The average time was 3 hours and 15 minutes.
7. Repeating experiments ensures the accuracy of your results. Each time you are able to repeat your results, you reduce the effect of sources of error in the experiment that may come from following a certain procedure, human error, or from the conditions in which the experiment is taking place.
8. The only valid conclusion that can be drawn is (d).
9. Maria and Elena could ask a few of their friends to repeat their experiment. This would mean that the experiment would be repeated in other places with other freezers. If their friends are able to repeat the girls' results, then the kind of freezer used can be eliminated as a factor that influenced the results.
10. A new question could be: Do dissolved minerals in water affect how fast water freezes?
    For further study: Ask student to come up with a plan to test the validity of statements b and c. Encourage your students to research methods for measuring dissolved minerals and oxygen in water.

Skill Sheet 2.2D: Percent Error

Table answers:

Distance from A to B (cm)	Time from A to B (s)
10	1.0050
20	1.8877
30	2.8000
40	3.7850
50	4.7707
60	5.6101
70	6.9078
80	7.9648
90	9.0140

1. $\approx 0.43\%$

2. $\approx 3.30\%$
3. $\approx 1.34\%$
4. $\approx 0.16\%$
5. $\approx 0.16\%$
6. Answers are:
    a. Avg. $\approx$ 17.18 s; percent error $\approx 5.06\%$
    b. Avg. = 38.39 s; percent error $\approx 9.61\%$
    c. Avg. = 67.91 s; percent error $\approx 0.68\%$

Skill Sheet 2.2E: Significant Differences in Measurement

1. Average ± error:
    toy car: 1.51 m ± 0.06
    toy truck: 1.88 m ± 0.12
    Difference: 0.37 (significant)
    Answer: Yes, the truck should always travel farther than the car.
2. Average ± error:
    bathroom sink: 3.47 s ± 0.05
    kitchen sink: 3.12 s ± 0.03
    Difference: 0.35 s (significant)
    Answer: The kitchen sink has the greater water pressure.
3. Average ± error:
    Antonio's eraser: 3.31 m ± 0.29
    Earnest's eraser: 3.38 m ± 0.37
    Difference: 0.07 m (not significant)
    Answer: It is not possible to support Earnest's claim that his eraser will always go farther, since there is no significant difference in the data.

4. Average ± error:
    yellow sponge: 92.90 g ± 1.35
    pink sponge: 74.45 g ± 0.45
    Difference: 18.45 g (significant)
    Answer: The data seems to show that the yellow sponge absorbs more water, since the difference between the averages is significant (>1.35).
5. Average ± error:
    Tara: 12.85 s ± 0.15
    Sammie: 12.50 s ± 0.10
    Joan: 13.02 s ± 0.09
    Lexy: 12.86 s ± 0.13
    Difference: the difference between Sammie and Tara (the next fastest girl) is ±0.35   (significant)
    Answer: Sammie is the fastest because the difference between Sammie's average and the next fastest girl (Tara) is ±0.35 , which is greater than the largest margin of error (0.15).

Skill Sheet 3.1: Science Vocabulary

Prefix is in bold and suffix is underlined:

thermometer   **electro**lyte   **mono**atomic

volumetric   **endo**thermic   **spectro**scope

prototype   **con**vex   **super**saturated

Answers may vary. Correct answers include:
1. The study of water
2. Many units
3. The same kind
4. Different kinds
5. Existing light
6. An instrument for measuring the full range of something

Dictionary definitions:
1. The science dealing with the properties, distribution, and circulation of water
2. A chemical compound formed by the union of small molecules, usually consisting of repeating units
3. Of the same kind, having uniform structure

4. Consisting of dissimilar ingredients
5. The emission of light (as by a chemical or physiological process)
6. An instrument for measuring spectra

Definitions based on prefixes and suffixes:
1. thermometer
2. sonogram
3. monoatomic
4. telescope

Word	Dictionary Definition
thermometer	An instrument for measuring temperature
sonogram	A graph that shows the loudness of sound at different frequencies
monoatomic	Containing only one type of atom

Word	Dictionary Definition
telescope	A cylindrical instrument for viewing distant objects

Skill Sheet 3.2A: Temperature Scales

1. Answers are:
   f. 100°C
   g. 37°C
   h. 4.4°C
   i. -12.2°C
   j. 32°F
   k. 77°F
   l. 167°F
2. 7.2°C
3. 177°C
4. 107°C
5. 375°F
6. 450°F
7. The table shows that the friend in Denmark thinks that the temperature is on the Celsius scale because 15°C is equal to 59°F, a warm temperature. However, 15°F is a cold temperature, equivalent to -9.4°C.

°F		°C
15°F	=	-9.4°C
59°F	=	15°C

8. **Challenge Questions:**
   a. -283°F
   b. 35°F = 1.6°C; this substance is not mercury, since its boiling point is not the same as that of mercury.
   c. The table shows that the thermometer must be calibrated in the Fahrenheit temperature scale. In Florida, in August, 90°F is a reasonable temperature. If the thermometer was calibrated in Celsius, it would be the equivalent of 194°C, which is a higher air temperature than would ever be found anywhere in the United States.

Skill Sheet 3.2B: Specific Heat

1. Gold would heat up the quickest because it has the lowest specific heat.
2. Pure water is the best insulator because it has the highest specific heat.
3. Silver is a better conductor of heat than wood because its specific heat is lower than that of wood.
4. Aluminum, because it has the higher specific heat.
5. $5°C \times 4,184 J/kg°C = 20,920$ J
6. At the same temperature, the larger mass of water contains more thermal energy.

Skill Sheet 4.1A: Density

1. 1.10 g/cm^3
2. 0.87 g/cm^3
3. 2.70 g/cm^3
4. 920,000 grams or 920 kilograms
5. 2,420 grams or 2.42 kilograms
6. 1,025 grams or 1.025 kilograms
7. 1,000 cm^3
8. 29.8 cm^3
9. 11.4 mL
10. Answers are:
    a. density = 960 kg/m^3, HDPE
    b. 76,000 grams or 76 kilograms
    c. The volume needed is 0.11 m^3; 11 10-liter containers would be needed to hold the plastic
    d. HDPE, LDPE, PP (PS would probably be suspended in seawater)

Skill Sheet 4.1B: Calculating Slope From a Graph

Numbers correlate to graph numbers:

1. $m = \frac{-3 \times 3}{6 \times 2} = \frac{-9}{12} = \frac{-3}{4}$

2. $m = \frac{-2 \times 3}{4 \times 2} = \frac{-3}{4}$

3. $m = \frac{5}{9}$

4. $m = \frac{4}{2} = 2$

5. $m = \frac{3}{3} = 1$

6. $m = \frac{-2}{2} = -1$

7. $m = 0$

8. $m = \frac{3}{4}$

9. $m = 2$

10. $m = \frac{-1}{2}$

Skill Sheet 4.2A: Archimedes

1. Density: a property that describes the relationship between a material's mass and volume. Buoyancy: A measure of the upward force a fluid exerts on an object.

2. Sample answer: I, Archimedes, have a wide variety of skills to offer. First, I am an inventor of problem-solving devices, including a device for transporting water upward. I have also

worked as a crime scene investigator for the king, uncovering fraud through scientific testing of materials. Furthermore, I am a writer with several treatises already published. I also have advanced skills in mathematics and can even estimate for you the number of grains of sand needed to fill the entire universe.

3. In the treatise entitled "The Sand Reckoner," Archimedes devised a system of exponents that allowed him to represent large numbers on paper—up to 8×10^{63} in modern scientific notation. This was large enough, he said, to count the grains of sand that would be needed to fill the universe. His assessment of the universe's size was an underestimate, but he was the first to think of the universe being so large.

4. A helium balloon floats in air because the air it displaces weighs more than the filled balloon. A balloon filled with air from someone's lungs sinks because the combined weight of the latex balloon and the air inside is greater than the weight of the air it displaces.

5. Inventions attributed to Archimedes include war machines (such as a lever used to turn enemy boats upside down), the Archimedes screw, compound pulley systems, and a planetarium. There is some debate about whether he invented a water organ and a system of mirrors and/or lenses to focus intense, burning light on enemy ships. Students can use the Internet or library to find more information and diagrams of the inventions.

Skill Sheet 4.2B: Buoyancy

1. Sink
2. Float
3. 0.12 N
4. 0.10 N
5. The light corn syrup has greater buoyant force than the vegetable oil.

6. 0.13 N
7. The buoyant force would be smaller if the gold cube were suspended in water. Student explanations may vary. A simple observation, such as "The water is thinner than the molasses" is acceptable, as well as the more sophisticated "The displaced water would weigh less than the displaced molasses" or "The water is less dense than the molasses."

Skill Sheet 4.2C: Archimedes Principle

1. If they are both submerged, then they both displace the same amount of water and have the same buoyancy force.
2. Answers are:
   a. 100 cm^3
   b. 0.98 N
   c. 0.98 N
   d. sink
3. Answers are:
   a. 100 cm^3
   b. 13 N

   c. 13 N
   d. float
4. In both cases, a material sinks in a fluid if it is more dense than the fluid. A material floats in a fluid if it is less dense than the fluid.
5. Answers are:
   a. Floats
   b. Floats
   c. Sinks
   d. Floats

Skill Sheet 6.1A: Ernest Rutherford

1. Alpha particle: a particle that has two protons and two neutrons (also known as a helium nucleus). Beta particle: An electron emitted by an atom when a neutron splits into a proton and an electron.


Alpha decay   **Beta decay**
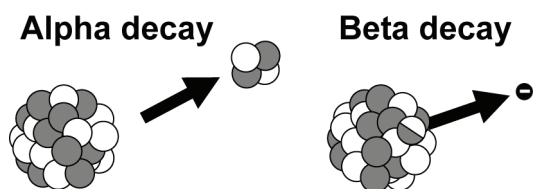
2. For one atom to turn into another kind of atom, the number of protons in the nucleus must change. This can happen when an alpha particle is ejected (two protons are lost then) or when a neutron splits into a proton and an electron (in that case the number of protons increases by one).
3. Diagram:

orbiting electron

e-

nucleus
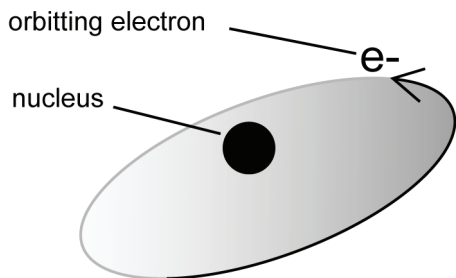
4. Rutherford's planetary model suggested that an atom consists of a tiny nucleus surrounded by a lot of empty space in which electrons orbit in fixed paths. Subsequent research has shown that electrons don't exist in fixed orbitals. The Heisenberg uncertainty principle tells us that it is impossible to know both an electron's position and its momentum at the same time. Scientists now discuss the probability that an electron will exist in a certain position. Computer models predict where an electron is most likely to exist, and three-dimensional shapes can be drawn to show the most likely positions. The sum of these shapes produces the charge-cloud model of the electron.
5. In the game of marbles, players "shoot" one marble at a group of marbles and then watch the deflection as collisions occur. This is a lot like what Rutherford was doing on a much, much smaller scale. Rutherford's comment is reflective of his typical self-deprecating humor. While "playing with marbles," he discovered the proton.
6. Answers will vary. Students may wish to write about one of the following discoveries: Rutherford first described two different kinds of particles emitted from radioactive atoms, calling them alpha and beta particles. He also proved that radioactive decay is possible. He developed the planetary model of the atom, and was the first to split an atom.

Skill Sheet 6.1B: Neils Bohr

1. Both Rutherford and Bohr described atoms as having a tiny dense core (the nucleus) surrounded by electrons in orbit. Bohr described the nature of the electrons' orbits in much greater detail.

2. Niels Bohr described atoms as existing in specific orbital pathways, and explained how atoms emit light.

3. In the Bohr's model of the atom, the electrons are in different energy levels. Bohr's model of the atom at right:

4. An electron absorbs energy as it jumps from an inner orbit to an outer one. When the electron falls
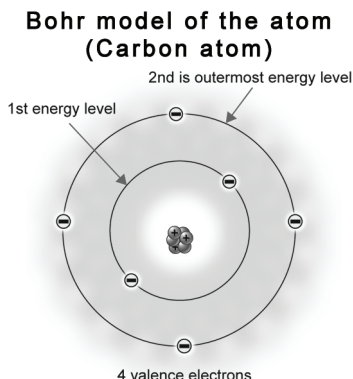
back to the inner orbit, it releases the absorbed energy in the form of visible light.

5. Answers will vary. You may wish to ask students to research world events from the end of World War II to Bohr's death in 1962. Students should look for events that may have raised concerns in Bohr's mind about the potential use/misuse of nuclear weapons. They might also choose to research Bohr's own comments on the subject.

Bohr model of the atom (Carbon atom)

2nd is outermost energy level
1st energy level
4 valence electrons

Skill Sheet 6.1C: Marie and Pierre Curie

1. Sample answer: Marie (or Marya, as she was called) had a strong desire to learn and had completed all of the schooling available to young women in Poland. She was part of an illegal "underground university" that helped young women prepare for higher education. Perhaps her own thirst for knowledge fueled her empathy for the peasant children, who were also denied the right to an education.

2. Marie Curie proposed that uranium rays were an intrinsic part of uranium atoms, which encouraged physicists to explore the possibility that atoms might have an internal structure.

3. Marie and Pierre worked with uranium ores, separating them into individual chemicals. They discovered two substances that increased the conductivity of the air. They named the new substances polonium and radium.

4. Answers include nuclear physics, nuclear medicine, and radioactive dating.

5. Marie Curie thought carefully about how to balance her scientific career and the needs of her children. When the children were young, Pierre's father lived with the family and took care of the children while their parents were working. Marie spent a great deal of time finding schools that best fit the individual needs of her children and at one point set up an alternative school where she and several friends took turns tutoring their children. When her daughters were in their teens, Marie included them in her professional activities when possible. Irene, for example, helped her mother set up mobile x-ray units for wounded soldiers during the war.

Skill Sheet 6.1D: Rosalyn Yalow

1. There are some striking similarities in the lives of Rosalyn Yalow and Marie Curie. As young women, both were outstanding math and science students. Even though Yalow was 54 years younger than Marie Curie, both faced limited higher education opportunities because they were women. Undaunted, each earned a doctorate degree in physics. Both Yalow and Curie's research focused on radioactive materials. Curie's work was at the forefront of discovery of how radiation works, while Yalow's work was to develop a new application of radiation. Both women were particularly interested in the medical uses of radiation. Each was committed to using their scientific discoveries to promote humanitarian causes. Both women won Nobel Prizes for their work (Marie Curie won two!).

2. RIA is a technique that uses radioactive molecules to measure tiny amounts of biological substances (like hormones) or certain drugs in blood or other body fluids.

3. Using RIA, they showed that adult diabetics did not always lack insulin in their blood, and that, therefore, something must be blocking their insulin's normal action. They also studied the body's immune system response to insulin injected into the bloodstream.

4. The issue of patents in medical research remains a hotly debated issue in our society. Proponents of patents, especially for new drugs, claim that because very few new drugs make it through the extensive safety and effectiveness trials required for FDA approval, research costs are very high. Patents, they claim, are the only means of recouping these research costs. On the other side of the issue, critics say that the profit motive drives research into certain types of medicines—tending to be drugs for chronic illnesses, so that patients will take the drugs for a long time. Research into drugs (like new antibiotics) that are generally taken only for a short period of time tends to be less of a priority. You may wish to have students research the pros and cons of the patent system and write a position paper or hold a class discussion or debate on the topic.

Skill Sheet 6.1E: Atoms, Isotopes, and Ions

Part 1 answers:

1. protium has 0 neutrons; deuterium has 1 neutron; tritium has 2 neutrons

2. Answers are:
   a. 3
   b. Lithium
   c. 7
   d. $^{7}_{3}Li$

Part 2 answers:

3. Bromine-80

4. Potassium-39 has 20 neutrons.

Part 3 answers:

5. +1

6. +2

Skill Sheet 6.2A: Albert Einstein

1. Students can use their textbook glossary, a standard English dictionary, or an Internet search engine to find the definitions.
   radiation: the flow of energy through space; alpha and beta radiation (from radioactive decay) are forms of radiation based on moving particles.
   quantum mechanics: the branch of physics that deals with the world at the atomic scale.
   theory of special relativity: a theory that describes what happens to matter, energy, time, and space at speeds close to the speed of light.
   theory of general relativity: describes gravity by stating that the presence of mass changes the shape of space-time—objects in orbit move in a straight line through curved space.
   inertia: the resistance of a body to change in its state of motion.
   gravity (acceleration due to): an acceleration of an object due to gravitational field strength; on Earth, it equals 9.8 m/sec^2.
   photoelectric effect: effect observed when light incident to certain metal surfaces causes electrons to be emitted.

7. Young Albert Einstein, according to his family, was quiet and thoughtful. His sister described the concentration and perseverance with which he built elaborate card houses. He was a slow talker who paused to think carefully about what he would say. He loved classical music and enjoyed playing the violin. He did not enjoy his early schooling very much.

8. Einstein's first paper formed the basis for quantum mechanics. The second paper unified pieces of special relativity into a unified theory. The third paper provided physical evidence for atoms.

9. Brownian motion was first observed by British botanist Robert Brown in 1827. He observed through a microscope that pollen grains suspended in water appeared to move erratically. He thought maybe it was because they were alive, but then found that ground glass and other non-living materials exhibited the same motion. He published his results in 1828. Eighty years later Einstein explained that the erratic motion was due to water molecules bumping into the small particles. Brownian motion can be demonstrated by suspending pollen grains (scraped from the anther of a lily flower, available year-round from a florist shop), graphite scraped from a #2 pencil, or talcum powder in water. Place several drops of the suspension in a cavity microscope slide and observe under a microscope.

2. A solar eclipse

3. Scientists tested Einstein's theory of relativity by photographing a solar eclipse on November 8, 1919 from locations in Brazil and the African island of Principe. If Einstein's theory were correct, light from a cluster of stars called the Hyades behind the dimmed sun should be bent into the gravitational dimple created by the sun, making the stars appear slightly out of alignment. The photographs confirmed Einstein's predictions. While some scientists debated the accuracy of this method and doubted Einstein's theory, conclusive evidence was provided by the European Space Agency's Hipparcos satellite, which in the years between 1989 and 1993 charted the positions of the stars with great precision and confirmed Einstein's prediction that gravity bends light.

4. Einstein wrote a letter to President Franklin about the importance of developing an atomic bomb before Germany did.

5. Einstein was concerned about nuclear proliferation and the destructive possibilities of nuclear weapons.

6. Sample answer: A unified field theory is an equation which would show that the fundamental forces in nature are all manifestations of a single basic force.

7. Answers will vary. Encourage students to back up their stated choice with scientific or historical evidence.

Skill Sheet 6.2B: Structure of the Atom

1. Answers are:

What is this element?	How many electrons does the neutral atom have?	What is the mass number?
lithium	3	7
carbon	6	12
hydrogen	1	1
hydrogen (a radioactive isotope, 3H, called tritium)	1	3
beryllium	4	9

2. Answers are:
   a. hydrogen-2: 1 proton, 1 neutron
   a. scandium-45: 21 protons, 24 neutrons
   b. aluminum-27: 13 protons, 14 neutrons
   c. uranium-235: 92 protons, 143 neutrons
   d. carbon-12: 6 protons, 6 neutrons

3. Most of an atom's mass is concentrated in the nucleus. The number of electrons and protons is the same but electrons are so light they contribute very little mass. The mass of the proton is 1,835 times the mass of the electron. Neutrons have a bit more mass than protons, but the two are so close in size that we usually assume their masses are the same.

4. Yes, it has a proton (+1) and no electrons to balance charge. Therefore, the overall charge of this atom (now called an ion) is +1.

5. This sodium atom has 10 electrons, 11 protons, and 12 neutrons.

Skill Sheet 8.2A: Dot Diagrams

Part 1 answers:

Element	Chemical Symbol	Total Electrons	No. of Valence Electrons	Dot Diagram
Potassium	K	19	1	K·
Nitrogen	N	7	5	·N̈·
Carbon	C	6	4	·C̈·
Beryllium	Be	4	2	Be·
Neon	Ne	10	8	:N̈e:
Sulfur	S	16	6	·S̈:

Part 2 answers:

Elements	Dot Diagram for Each Element	Dot Diagram for Compound Formed	Chemical Formula
Na and F	Na· ·F̈:	Na:F̈:	NaF
Br and Br	·B̈r: ·B̈r:	:B̈r:B̈r:	Br_2
Mg and O	Mg· ·Ö:	Mg:Ö:	MgO

Skill Sheet 8.2B: Chemical Formulas

Answers:

Element	Oxidation No.	Element	Oxidation No.	Chemical Formula for Compound
Potassium (K)	1+	Chlorine (Cl)	1-	KCl
Calcium (Ca)	2+	Chlorine (Cl)	1-	$CaCl_2$
Sodium (Na)	1+	Oxygen (O)	2-	Na_2O
Boron (B)	3+	Phosphorus (P)	3-	BP
Lithium (Li)	1+	Sulfur (S)	2-	Li_2S
Aluminum (Al)	3+	Oxygen (O)	2-	Al_2O_3
Beryllium (Be)	2+	Iodine (I)	1-	BeI_2
Calcium (Ca)	2+	Nitrogen (N)	3-	Ca_3N_2
Sodium (Na)	1+	Bromine (Br)	1-	NaBr

Skill Sheet 9.1: Calculating Concentration of Solutions

1. 6.3%
2. 2.0%
3. 6.0%
4. 400 g salt
5. 3.75 g sugar
6. 139 g sand
7. 43%
8. 12.5 g
9. 0.5%
10. **Challenge:** 8.3 g red food coloring

Skill Sheet 10.1: Chemical Equations

Part 1 answers:

Reactants	Products	Unbalanced Chemical Equation
Hydrochloric acid HCl and Sodium hydroxide NaOH	Water H_2O and Sodium chloride NaCl	$HCl + NaOH \rightarrow NaCl + H_2O$
Calcium carbonate $CaCO_3$ and Potassium iodide KI	Potassium carbonate K_2CO_3 Calcium iodide CaI_2	$CaCO_3 + KI \rightarrow K2CO_3 + CaI_2$
Aluminum fluoride AlF_3 and Magnesium nitrate $Mg(NO_3)_2$	Aluminum nitrate $Al(NO_3)_3$ and Magnesium fluoride MgF_2	$AlF_3 + Mg(NO_3)_2 \rightarrow Al(NO_3)_3 + MgF_2$

Part 2 answers:

1. $4Al + 3O_2 \rightarrow 2Al_2O_3$
2. $CO + 3H_2 \rightarrow H_2O + CH_4$
3. $2HgO \rightarrow 2Hg + O_2$
4. $CaCO_3 \rightarrow CaO + CO_2$
5. $3C + 2Fe_2O_3 \rightarrow 4Fe + 3CO_2$
6. $N_2 + 3H_2 \rightarrow 2NH_3$
7. $2K + 2H_2O \rightarrow 2KOH + H_2$
8. $4P + 5O_2 \rightarrow 2P_2O_5$
9. $Ba(OH)_2 + H_2SO_4 \rightarrow 2H_2O + BaSO_4$
10. $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$
11. $4KClO_3 \rightarrow 3KClO_4 + KCl$

Skill Sheet 10.2A: Lise Meitner

1. Ludwig Boltzmann was a pioneer of statistical mechanics. He used probability to describe how properties of atoms (like mass, charge, and structure) determine visible properties of matter (like viscosity and thermal conductivity).

2. They discovered protactinium. Its atomic number is 91 and atomic mass is 231.03588. It has 20 isotopes. All are radioactive.

3. The graphic at right illustrates fission (n = a neutron):
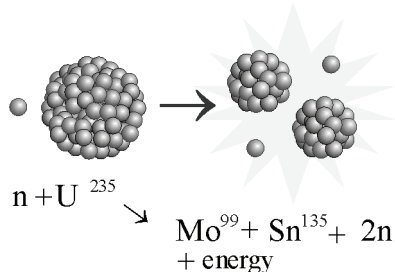
4. Some topics students may research and describe include nuclear power plants, nuclear weapons, nuclear-

$n + U^{235}$

$Mo^{99} + Sn^{135} + 2n$
$+ energy$

powered submarines or aircraft carriers.

5. Meitner's honors included the Enrico Fermi award, and element 109, meitnerium, named in her honor.

6. Students should include the following pieces of evidence in their letters:
   Meitner suggested tests to perform on the product of uranium bombardment.
   Meitner proved that splitting the uranium atom was energetically possible.
   Meitner explained how neutron bombardment caused the uranium nucleus to elongate and eventually split.

Skill Sheet 10.2B: Predicting Chemical Equations

1. Ca
2. K
3. Al
4. Al + LiCl
5. Ca + K_2O
6. I_2 + KF
7. $Ca + K_2S \rightarrow 2K + CaS$
8. $3Mg + Fe_2O_3 \rightarrow 3MgO + 2Fe$
9. $Li + NaCl \rightarrow Na + LiCl$

## Skill Sheet 11.1: Classifying Reactions

1. Addition. Two substances combine to make a new compound.
2. Displacement. Clorine replaces potassium in the compound.
3. Decomposition. A single compound is broken into two substances.
4. Decomposition. A single compound is broken into two substances.
5. Combustion. A carbon compound reacts with oxygen to produce carbon dioxide and water.
6. Precipitation. Two solutions are mixed and a solid is one of the products.
7. Precipitation. Two solutions are mixed and a solid is one of the products.
8. Displacement. Sodium replaces calcium in the compound.
9. Decomposition. A single compound is broken into two substances.
10. Combustion. A carbon compound reacts with oxygen to produce carbon dioxide and water.
11. This is a precipitation reaction because a solid forms from two solutions.
12. A combustion reaction.
13. Addition reaction because two substances form a single compound.
14. The reaction is similar to a combustion reaction because a substance (hydrogen) reacts with oxygen and energy is produced. So is water. It is different because carbon is not involved in the reaction.

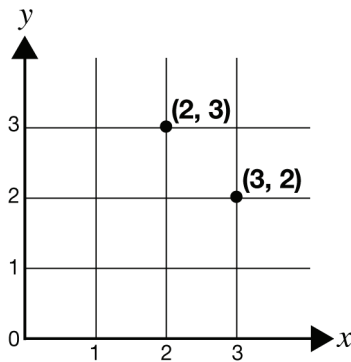## Skill Sheet 12.1: Position on the Coordinate Plane

1.
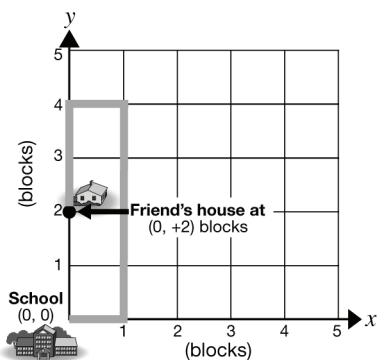
2.
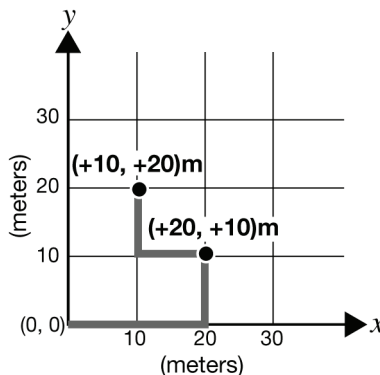
3. Yes the order does matter. The coordinate (2, 3) shows a point that is 2 to the right and 3 up, while the coordinate (3, 2) shows a point that is 3 to the right and 2 up.

Skill Sheet 12.2A: Dimensional Analysis

1. Answers are:
   a. $72/day
   b. 210 lbs/week
2. Answers are:
   a. 2.75 gal
   b. 2.2 m
   c. ≈ 0.095 mile
   d. 64 c

3. Answers are:
   a. 126,144,000 sec
   b. ≈ 71 ft
   c. 4.5 qt
   d. $14 \, ^2/_3$ fields
   e. 50 km/gal
   f. ≈ 13.21 km/l
   g. 95.3 ft/sec

Skill Sheet 12.2B: Velocity

Part 1 answers:
1. 17 km/hr
2. 55 mph
3. 4.5 seconds
4. 5.9 hours; 490 mph
5. 4.0 km
6. 2.5 miles
7. 4.5 meters
8. Answers are:
   a. 2.54 cm/inch
   b. 12 inches/min
9. 6 km/hr
10. Answers are:
    a. 600 seconds
    b. 10 minutes
11. 1,200 meters
12. Answers are:
    a. 42 km
    b. 9.2 km/hr
13. Answers are:
    a. 0.2 km/min
    b. 0.5 km/min
    c. 0.3 km/min faster by bicycle
14. 12.5 km
15. 40 minutes
16. 90 km/hr
17. 815 km/hr or 800 km/hr

18. 32.5 km or 33 km
19. 8 hours
20. 633 km/hr
21. 731 km/hr
22. 1,680 km
23. 3.84×10^5 km
24. 2.03×10^4 seconds
25. Answers for 25 (a) - (c) will vary. Having students write their own problems will further develop their understanding of how to solve speed problems.
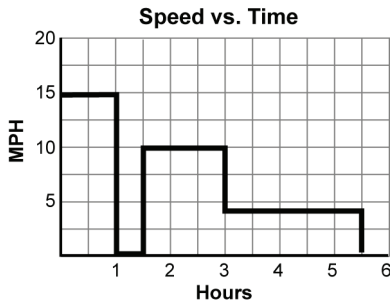
Part 2 answers:
1. 420 km/hr, north
2. 0.30 seconds
3. 224 minutes
4. Answers are:
   a. 1.62 m/s, west
   b. 1.62 m/s, east
5. 16.0 hours
6. 3.0 m/s, west
7. Answers are:
   a. 4.5 m/s, south
   b. 4.5 m/s, north
8. 0.22 second
9. 1.72 miles/min, southwest
10. 116 kilometers
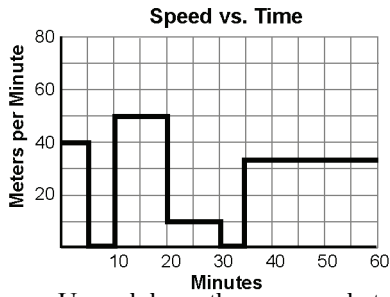11. 3.9 km/hr, southeast
12. 564 kilometers

Skill Sheet 12.3A: Analyzing Graphs of Motion with Numbers
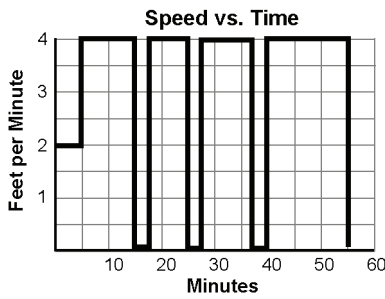
1. Answers are:
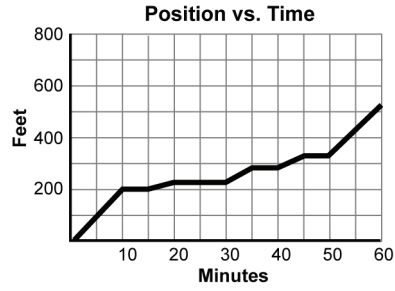
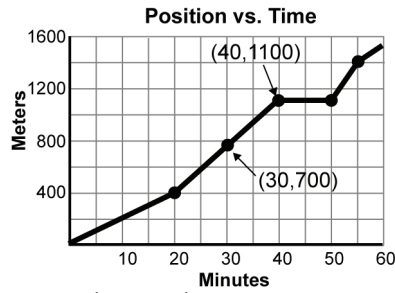a. The bicycle trip through hilly country.

Speed vs. Time

b. A walk in the park.

Speed vs. Time

c. Up and down the supermarket aisles.

Speed vs. Time

2. Answers are:

a. The honey bee among the flowers.

Position vs. Time

b. Rover runs the street.

Position vs. Time

(40,1100)

(30,700)

c. The amoeba.

Position vs. Time

1.
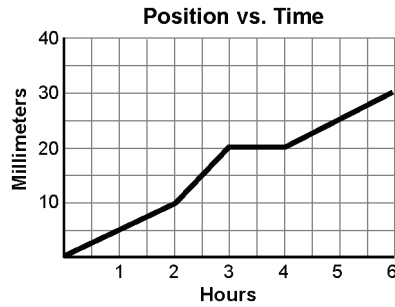
Skill Sheet 12.3B: Analyzing Graphs of Motion without Numbers

1. Little Red Riding Hood. Graph Little Red Riding Hood:

2. The Tortoise and the Hare. Use two lines to graph both the tortoise and the hare:

3. The Skyrocket. Graph the altitude of the rocket:
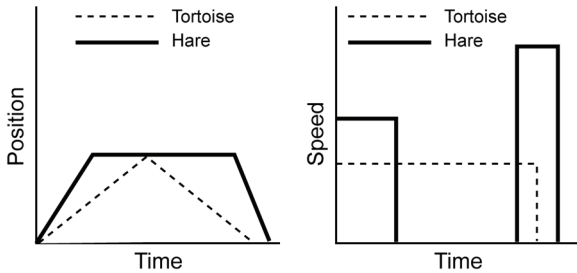
4. Each student story will include elements that are controlled by the graphs and creative elements that facilitate the story. Only the graph-controlled elements are described here.

   a. The line begins and ends on the baseline, therefore Tim must start from and return to his house.

   b. The line rises toward the first peak as a downward curved line that becomes horizontal. This indicates that Tim's pace toward Caroline's house slowed to a stop.

   c. Then the line rises steeply to the first peak. This indicates that after his stop, Tim continues toward Caroline's house faster than before.

   d. The first peak is sharp, indicating that Tim did not spend much time at Caroline's house on first arrival.

e. The line then falls briefly, turns to the horizontal, and then rises to a second peak. This indicates that Tim left, paused, and then returned quickly to Caroline's house.

1. The line then remains at the second peak for a long time, then drops steeply to the baseline. This indicates that after spending a long time at Caroline's house, Tim probably ran home.

Skill Sheet 12.3C: Calculating Slope From a Graph

Numbers correlate to graph numbers:

1. $m = \frac{-3 \times 3}{6 \times 2} = \frac{-3}{4}$

2. $m = \frac{-2 \times 3}{4 \times 2} = \frac{-3}{4}$

3. $m = \frac{5}{9}$

4. $m = \frac{4}{2} = 2$

5. $m = \frac{3}{3} = 1$

6. $m = \frac{-2}{2} = -1$

7. $m = 0$

8. $m = \frac{3}{4}$

9. $m = 2$

10. $m = \frac{-1}{2}$

Skill Sheet 13.1A: Chien-Shiung Wu

1. *Weak nuclear force:* One of the fundamental forces in the atom that governs certain processes of radioactive decay. It is weaker than both the electric force and the strong nuclear force. If you leave a solitary neutron outside the nucleus, the weak force eventually causes it to break into a proton and an electron. The weak force does not play an important role in a stable atom, but comes into action in certain cases when atoms break apart.
   Beta decay: a radioactive transformation in which a neutron splits into a proton and an electron. The electron is emitted as a beta particle and the proton stays in the nucleus, increasing the atomic number by one.
   Isotope: Forms of the same element that have different numbers of neutrons and different mass numbers.
2. When Enrico Fermi was having difficulty with a fission experiment, he turned to Wu for assistance. She recognized the cause of the problem: a rare gas she had studied in graduate school. Because she was familiar with the behavior of the gas she was able to help Fermi get on with his work.
3. The law of conservation of parity stated that in nuclear reactions, there should be no favoring of left or right. In beta decay, for example, electrons should be ejected to the left and to the right in equal numbers.
4. Cobalt-60 has 27 protons and 33 neutrons. There is only one stable isotope of cobalt, cobalt-59.
5. Wu cooled cobalt-60 to less than one degree above absolute zero, then placed the material in a strong magnetic field so that all the cobalt nuclei lined up and spun along the same axis. As the radioactive cobalt broke down and gave off electrons, Wu observed that far more electrons flew off in the direction opposite the spin of the nuclei. She proved that the law of conservation of parity does not hold true in all cases.
6. Margaret Burbridge, professor of astronomy, UCLA-awarded the National Medal of Science in the physical sciences in 1983. Citation: "For leadership in observational astronomy. Her spectroscopic investigations have provided crucial information about the chemical composition of stars and the nature of quasi-stellar objects."
   Vera C. Rubin, staff member, astronomy, Carnegie Institute of Washington-awarded the National Medal of Science in the physical sciences in 1993. Citation: "For her pioneering research programs in observational cosmology which demonstrated that much of the matter in the universe is dark and for significant contributions to the realization that the universe is more complex and more mysterious than had been imagined."
7. Answers may vary. Some interesting questions to research include:
   What are some other experiments or projects Wu undertook during the course of her career?
   Did she ever return to her home country?
   What advice would she give young people who wish to become scientists?
8. Unfortunately, the contributions of women to science were often overlooked. When the prize was awarded to Lee and Yang, playwright Clare Booth Luce commented, "When Dr. Wu knocked out that principle of parity, she established the principle of parity between men and women."

Skill Sheet 13.1B: Mass vs. Weight

1. 15 pounds
2. 2.6 pounds
3. 7.0 kilograms
4. Yes, a balance would function correctly on the moon. The unknown mass would tip the balance one-sixth as far as it would on Earth, but the masses of known quantity would tip the balance one-sixth as far in the opposite direction as they did on Earth. The net result is that it would take the same amount of mass to equalize the balance on the moon as it did on Earth. (In the free fall environment of the space shuttle, however, the masses wouldn't stay on the balance, so the balance would *not* work).
5. Answers are:

a. As the elevator begins to accelerate upward, the scale reading is greater than the normal weight. As the elevator accelerates downward, the scale reads less than the normal weight.
b. When the elevator is at rest, the scale reads the normal weight.
c. The weight appears to change because the spring is being squeezed between the top and the bottom of the scale. When the elevator accelerates upward, it is as if the bottom of the scale is being pushed up while the top is being pushed down. The upward force is what causes the spring to be compressed more than it is normally. When the elevator accelerates downward, the bottom of the scale

provides less of a supporting force for the feet to push against. Therefore, the spring is not compressed as much and the scale reads less than the normal weight.

Skill Sheet 13.2: Equilibrium

1. 142 N
2. A is 40 N; B is 8 N
3. 340 N
4. From the outside of a balloon, two forces act inward. The elastic membrane of the balloon and the pressure of Earth's atmosphere work together to balance the outward force of the helium compressed inside. Together with the elastic force, atmospheric pressure near Earth's surface applies enough force to maintain this equilibrium, but as the balloon rises, atmospheric pressure decreases. Although the inward force supplied by the elastic membrane remains unchanged, the decreasing atmospheric pressure force causes an imbalance with the outward force of the contained helium and the balloon expands. At some point, the membrane of the balloon reaches its elastic limit and bursts.
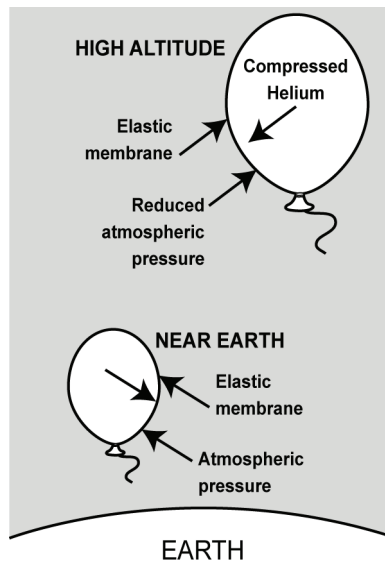
Skill Sheet 14.1: Isaac Newton

1. The isolation due to the Plague allowed Newton to focus on his scientific work, free from the distractions of university life. However, most scientists learn a great deal from discussing their ideas with peers. Collaboration also enables experimental scientists to test a greater number of hypotheses.
2. Newton was an active member of the scientific community at Cambridge for just under 30 years. In that time, he made great strides in understanding light and optics, planetary motion, universal gravitation, and calculus. He made extraordinary contributions to many scientific fields during those years.
3. Example answer: Newton's first law says that unless you apply an unbalanced force to an object, the object will keep on doing what is was doing in the first place. So a rolling ball will keep on rolling until an unbalanced force changes its motion, while a ball that is not moving will stay still unless acted on by an unbalanced force.
4. Example answer: The law of universal gravitation says that the force of attraction between two objects is directly related to the masses of the objects and inversely related to the distance between them.
5. Newton's law of universal gravitation.
6. Newton claimed that 20 years earlier, he had invented the material that Leibnitz published. Newton accused Leibnitz of plagiarism. Most historians today agree that the two developed the material independently, and therefore they are known as co-discoverers.

Extra information: The famous legend of Newton's apple tells of Newton sitting in his garden in Linconshire in 1666, watching an apple fall from a tree. He later noted that "In the same year, I began to think of gravity extending to the orb of the moon." However, he did not make public his musings about gravity until the 1680's, when he formulated his law of universal gravitation.

Skill Sheet 14.2A: Applying Newton's Laws

Table answers are:

Newton's laws of motion	Write the law here in your own words	Example of the law
The first law	An object will continue moving in a straight line at constant speed unless acted upon by an outside force.	A seat belt in a car prevents you from continuing to move forward when your car suddenly stops. The seat belt provides the "outside force."

Newton's laws of motion	Write the law here in your own words	Example of the law
The second law	The acceleration (a) of an object is directly proportional to the force (F) on an object and inversely proportional to its mass (m). The formula that represents this law is $$a = \frac{F}{m}$$	A bowling ball and a basketball, if dropped from the same height at the same time, will fall to Earth in the same amount of time. The resistance of the heavier ball to being moved due to its inertia is balanced by the greater gravitational force on this ball.
The third law	For every action force there is an equal and opposite reaction force.	When you push on a wall, it pushes back on you.

1. The purse continues to move forward and fall off of the seat whenever the car comes to a stop. This is due to Newton's first law of motion which states that objects will continue their motion unless acted upon by an outside force. In this case, the floor of the car is the stopping force for the purse.
2. Newton's third law of motion states that forces come in action and reaction pairs. When a diver exerts a force down on the diving board, the board exerts an equal and opposite force upward on the diver. The diver can use this force to allow himself to be catapulted into the air for a really dramatic dive or cannonball.
3. Newton's second law
4. The correct answer is b. One newton of force equals 1 kilogram-meter/second^2. These units are combined in Newton's second law of motion: F = mass × acceleration.
5.

$$\frac{0.3 \text{ m}}{\text{sec}^2} = \frac{F}{65 \text{ kg}}$$

$$F = \frac{0.3 \text{ m}}{\text{sec}^2} \times 65 \text{ kg} = 19.5 \text{ kg} \cdot \frac{\text{m}}{\text{sec}^2}$$

6.

$$a = \frac{2 \text{ N}}{10 \text{ kg}} = \frac{\dfrac{2 \text{ kg} \cdot \text{m}}{\text{sec}^2}}{10 \text{ kg}} = 0.2 \frac{\text{m}}{\text{sec}^2}$$

7. The hand pushing on the ball is an action force. The ball provides a push back as a reaction force. The ball then provides an action force on the floor and the floor pushes back in reaction. Another pair of forces occurs between your feet and the floor.
8. A force

Skill Sheet 14.2B: Acceleration

1. -0.75 m/sec^2
2. -8.9 m/sec^2
3. Answers are:

Time (seconds)	Speed (km/h)
0 (start)	0 (start)
2	3
4	6
6	9
8	12
10	15
The acceleration of the ball is 1.5 km/hr/s.	

4. 7.5 seconds
5. 88 mph
6. 22 m/s
7. 7 m/s^2
8. -1.9 mi/hr/s
9. 67 m/s
10. 32 m/s
11. 1.7 m/s^2
12. 2.6 seconds
13. -2.3 m/s^2

Skill Sheet 14.2C: Newton's Second Law

1. 2.1 m/s^2
2. 83 m/s^2
3. 82 N
4. 6 kg
5. 9800 N
6. 900 kg
7. 1.9 m/s^2

Skill Sheet 15.1A: Ratios and Proportions

1. 6 tablespoons; 2 eggs
2. $^3/_4$ cup; $^1/_3$ teaspoon
3. $^1/_4$ teaspoon; $^3/_4$ cup
4. Table answers:

Sugar	$^3/_8$ cup
Butter	3 tablespoons
Milk	1 tablespoon
Chocolate chips	1 cup

Eggs	1 egg
Vanilla extract	$^1/_2$ teaspoon
Baking soda	$^1/_6$ teaspoon
Salt	$^1/_8$ teaspoon
Confectioner's sugar	1 tablespoon

5. To make 16 brownies, you need two eggs and 2 tablespoons of sugar. Therefore, to make 8 brownies, you only need 1 of each unit for each ingredient: 1 egg and 1 tablespoon of sugar.

6. Since 8 brownies requires 1 cup of chocolate chips, 3 cups of chocolate chips will make 24 brownies.

7. 1.5 teaspoons vanilla is needed to make 24 brownies.

Skill Sheet 15.1B: Copernicus

1. Being from a privileged family, young Copernicus had the luxury of learning about art, literature, and science. When Copernicus was only 10 years old, his father died. Copernicus went to live his uncle who was generous with his money and provided Copernicus with an education from the best universities. Copernicus lived during the height of the Renaissance period when men from a higher social class were expected to receive well-rounded educations.

2. Copernicus' uncle, Lucas Watzenrode, was a prominent Catholic Church official who became bishop of Varmia in 1489. After Copernicus finished four years of study at the University of Krakow, Watzenrode appointed Copernicus a church administrator. Copernicus used his church wages to help pay for additional education. While studying at the University of Bologna, Copernicus' passion for astronomy grew under the influence of his mathematics professor, Domenico Maria de Novara. Copernicus lived in his professor's home where they spent hours discussing astronomy.

3. Copernicus examined the sky from a tower in his uncle's palace. He made his observations without any equipment.

4. Prior to the 1500s, most astronomers believed that Earth was motionless and the center of the universe. They also thought that all celestial bodies moved around Earth in complicated patterns. The Greek astronomer Ptolomy proposed this geocentric theory more than 1000 years earlier.

5. Copernicus believed that the universe was heliocentric (sun-centered), with all of the planets revolving around the sun. He explained that Earth rotates daily on its axis and revolves yearly around the sun. He also suggested that Earth wobbles like a top as it rotates. Copernicus' theory led to a new ordering of the planets. In addition, it explained why the planets farther from the sun sometimes appear to move backward (retrograde motion), while the planets closest to the sun always seem to move in one direction. This retrograde motion is due to Earth moving faster around the sun than the planets farther away.

6. At the time, Church law held great influence over science and dictated a geocentric universe.

7. The Copernicus Satellite, or Orbiting Astronomical Observatory 3 (OAO-3) was a collaborative project of both the United States' National Aeronautics and Space Administration (NASA) and the United Kingdom's Science and Engineering Research Council (SERC). The satellite operated from August 1972 to February 1981. The main experiment on the satellite was a Princeton University ultraviolet (UV) telescope. An x-ray astronomy experiment created by the University College London/Mullard Space Science Laboratory was also onboard. The Copernicus Satellite gathered a series of high-resolution ultraviolet spectral scans of over 500 objects, most of them being bright stars.

Skill Sheet 15.1C: Galileo

1. "On Motion" described how a pendulum's long and short swings take the same amount of time.

2. Galileo's many inventions include the thermometer, water pump, military compass, microscope, telescope, and pendulum clock. Information and illustrations of the inventions can be found using the Internet or library.

3. Galileo observed the motion of Jupiter's moons and realized that despite what Ptolemy said, heavenly bodies do not revolve exclusively around Earth. He also realized that his observation of the phases of Venus showed that Venus was revolving around the sun, not around Earth. Galileo therefore concluded that Copernicus' assertion that the sun, not Earth, was at the center must be correct.

4. Answers will vary. Students might suggest that Galileo use a less abrasive approach to convince people that the Copernican view is correct.

5. Galileo's telescope is the most likely student response, because it so profoundly changed our understanding of the solar system. However, students may choose another invention as long as they provide valid reasons for their decision.

Skill Sheet 15.1D: Johann Kepler

1. Copernicus' idea that the sun was at the center of the solar system was revolutionary because people believed Earth was the center of the universe.

2. Brahe helped Kepler make his important discoveries in several ways. Brahe invited Kepler to come and work with him. He asked Kepler to solve the problem of Mars' orbit. When Brahe died, Kepler gained all of his observational records. Kepler also got Brahe's job.

3. Kepler used mathematics to solve problems in astronomy. For this reason, Kepler is considered a theoretical positional astronomer. Brahe was an observational astronomer. He made and recorded the motion of planets and the stars in the night sky without a telescope. Galileo was also an observational astronomer. He used and improved the telescope, but he was not a mathematician.

4. Kepler's discovery that Mars traveled in an elliptical orbit was different than Copernicus' theory which said planets traveled in circular orbits.

5. Kepler's three laws of planetary motion are:
   • Planets orbit the sun in an elliptical orbit with the sun in one of the foci.
   • The law of areas says that planets speed up as they travel in their orbit closer to the sun and they slow down as they travel in their orbit farther away from the sun.
   • The harmonic law says that a planet's distance from the sun is mathematically related to the amount of time it takes the planet to revolve around the sun.

6. Three examples of a paradigm shift:
   • Copernicus' theory that the sun and not Earth was the center of the solar system.
   • Kepler's discovery that planets orbit the sun in an elliptical and not a circular path.
   • Newton's laws of gravitational attraction.

Skill Sheet 15.1E Benjamin Banneker

1. An understanding of gear ratios was necessary for building the clock. He used geometry skills to figure out how to create a large-scale model of each tiny piece of the watch he examined.
2. Personal strengths identified from the reading include strong spacial skills (building the clock), creativity and problem solving skills (irrigation system), curiosity and attention to detail (astronomical observations, cicada observations, and almanac), concern for others (letter to Jefferson).
3. Dates are as follows:
   a. 1863
   b. 1865
   c. 1920
   d. 1954
4. Any three of the following answers is correct. Banneker's accomplishments include:
   a. Designed an irrigation system
   b. Documented cycle of 17-year cicada
   c. Published detailed astronomical calculations in popular almanacs

d. Served as surveyor of territory that became Washington D.C.
5. Banneker evidently had a strong innate curiosity about the natural world. He was passionate about improving the welfare of the black men and women in the United States and his letter to Jefferson stated that he hoped his scientific work would be seen as proof that people of all races are created equal.
6. Banneker's puzzles can be found on several web sites. Using an Internet search engine, look for "Benjamin Banneker" + puzzle. Some of the sites publish the answers while others do not. Here is one of Banneker's puzzles taken from the web site www.thefriendsofbanneker.org. Note that the puzzle was written in the 1700's and from Banneker's personal journals.
THE PUZZLE ABOUT TRIANGLES
"Suppose ladder 60 feet long be placed in a Street so as to reach a window on the one side 37 feet high, and without moving it at bottom, will reach another window on the other side of the Street which is 23 feet high, requiring the breadth of the Street." [No solution recorded in historic records.]

Skill Sheet 15.1F: Touring the Solar System

Part 1 answers:

Legs of the trip	Distance travelled for each leg (km)	Hours travelled	Days travelled	Years travelled
Earth to Mars	78,000,000	86,666	3,611	9.9
Mars to Saturn	1,202,000,000	1,335,600	55,648	152
Saturn to Neptune	3,070,000,000	3,411,100	142,130	389
Neptune to Venus	4,392,000,000	4,880,000	203,330	557
Venus to Earth	42,000,000	46,667	1,944	5.3

Part 2 answers:

1.

$$\frac{8 \text{ glasses}}{1 \text{ day}} \times 3{,}611 \text{ days} = 28{,}888 \text{ glasses of water}$$

2.

$$\frac{2{,}000 \text{ food calories}}{1 \text{ day}} \times 203{,}330 \text{ days} = 406{,}660{,}000 \text{ food calories}$$

3. Pack foods high in fat for the journey because you get more calories per gram than from proteins and carbohydrates and you want a payload minimum.
4. Your entire trip will take 1,113 years, so you will need that many turkeys.

Part 3 answers:

1. Jupiter; it has 39 moons.
2. Venus has the hottest surface temperature; Pluto has the coldest surface temperature.
3. Venus; it takes 243 Earth days to rotate once around its axis.
4. Jupiter has the shorter day; it takes 0.41 Earth days to rotate.
5. Jupiter; it has the strongest gravitational force. You will weigh 2.36 times your Earth weight in Newtons.
6. Pluto; It has the weakest gravitational force. You will weigh 0.06 times your Earth weight in Newtons.
7. Jupiter; it has the largest diameter of 142,796 km.
8. Jupiter; it has the strongest gravitational force, therefore the spaceship must orbit at a fast speed to balance the gravitational force pulling the spaceship towards Jupiter's surface.

Skill Sheet 15.1G: Gravity Problems

Table 1 answers:

Planet	Force of gravity in Newtons (N)	Value compared to Earth's gravity
Mercury	3.7	0.38
Venus	8.9	0.91
Earth	9.8	1
Mars	3.7	0.38
Jupiter	23.1	2.36
Saturn	9.0	0.92
Uranus	8.7	0.89
Neptune	11.0	1.12
Pluto	0.6	0.06

1. 9.5 pounds on Neptune
2. 1,029 newtons on Saturn
3. The baby weighs 44.1 Newtons on Earth which is equal to 9.8 pounds.
4. Venus, Jupiter, Neptune, Pluto, then Saturn
5. Answer:

$$\text{Gravity} = \left(\frac{6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2}{\text{kg}^2}\right) \frac{\left(6.4 \times 10^{24}\right)\left(5.7 \times 10^{26}\right)}{\left(6.52 \times 10^{11}\right)^2}$$

$$= 5.72 \times 10^{17} \text{ N}$$

Skill Sheet 16.1A: Scientific Notation

1. Answers are:

	Scientific Notation	Standard Form
a.		0.0603

	Scientific Notation	Standard Form
b.		911,000
c.		0.000 000 557

	Scientific Notation	Standard Form
d.	9.99×10^2	
e.	2.64×10^5	
f.	7.61×10^8	
g.		71,300,000
h.	3.2×10^{-3}	
i.	4×10^{-5}	
j.		0.000 000 000 001 2
k.	4.2×10^{13}	
l.	1.2004×10^{10}	
m.		0.09906

2. Answers are:

a. 1^{11} is not a power of 10; 2.004×10^0
b. 56 is not less than 10; 5.6×10^{-3}
c. 100^2 not a power of 10; 2×10^4
d. 10 is not less than 10; 1×10^{-5}

3. Answers are:
a. 7.935×10^{12}
b. 2.97×10^8
c. 1.2×10^{14}
d. 9.1×10^{-31}
e. 3.3×10^{-4}
f. 2.6×10^7
g. 3.39×10^7
h. 1.64×10^5
i. 1.69×10^5
j. 1.25×10^7

Skill Sheet 16.1B: Arthur Walker

1. You may wish to have students compare and contrast their definitions with those of a student who used a different source. Discuss with the class the value of using a variety of sources and the importance of crediting these sources.
2. Walker didn't allow prejudice to dissuade him from pursuit of his goals. As a result he made important contributions to science and society. He also spent time and energy helping other members of minority groups achieve their own goals.
3. A spectrometer separates light into spectral lines. Each element has its own unique pattern of lines, so scientists use the patterns to identify the ions in the corona. Temperature can be determined by the colors seen in the corona. For example, red indicates cooler areas, while bluish light indicates a very hot area.
4. Magazines and journals that may have one of Walker's photographs can be found at public and university libraries. You might suggest that students contact a reference librarian for assistance.
5. The committee found that the accident was caused by a failure in a seal of the right solid rocket booster. They also made nine specific recommendations of changes to be made

to the space shuttle program prior to another flight. These steps included:
a. Redesign the solid rocket boosters.
b. Upgrade the space shuttle landing system.
c. Create a crew escape system that would allow astronauts to parachute to safety in certain situations.
d. Improve quality control in both NASA and contractor manufacturing.
e. Reorganize the space shuttle program to place astronauts in key decision-making roles.
f. Revoke any waivers to current safety standards, especially those related to launches in poor weather conditions.
g. Open the review of a mission's technical issues to independent government agencies.
h. Set up an extensive open review system to evaluate issues related to each particular mission.
i. Provide a means of anonymous, reprisal-free reporting of space shuttle safety concerns by any NASA employee or contractor.

Skill Sheet 16.1C: The Sun: A Cross-Section

A. Corona
B. Chromosphere
C. Photosphere
D. Convection zone
E. Radiation zone
F. Core

Skill Sheet 16.1D: Understanding Light Years

1. 5.7×10^{13} km
2. 4.3×10^{19} km
3. 3.8×10^{10} km
4. 5,344 ly
5. 1.16×10^{-12} ly
6. 1.16 ly
7. 1200 ly
8. 8.0478×10^{14} km
9. 4,280,056,000 km, or 4.28×10^9 km
10. 0.000026336 AU, or 2.6×10^{-5} AU
11. 63,288 AU

Skill Sheet 16.1E: Calculating Luminosity

1. luminosity = 30 watts
   power rating on bulb = 300 watts
2. luminosity = 1 watt
   power rating on bulb = 10 watts
3. Challenge:
luminosity $= 1.370 \times 10^3 (4\pi)(1.5 \times 10^{11})^2$
$= 1.370 \times 10^3 (4\pi)(2.25 \times 10^{22})$

$= 39 \times 10^{25}$
$= 3.9 \times 10^{26}$ watts

Skill Sheet 17.1 Edwin Hubble

1. Answers are:
- astronomy - the study of matter in outer space, especially the positions, dimensions, distribution, motion, composition, energy, and evolution of celestial bodies and phenomena.
- galaxy - a group of stars, dust, gas, and other objects held together by gravitational forces.
- spectroscopy - a method of studying an object by examining the visible light and other electromagnetic waves it creates.
- cosmology - the astrophysical study of the history, structure, and constituent dynamics of the universe.

2. Outstanding students from around the world are nominated for the prestigious Rhodes scholarship. Rhodes Scholars are invited to study at the University of Oxford in England. Only about 90 students are selected each year. This scholarship is awarded by the Rhodes Trust, a foundation set up by Cecil Rhodes in 1902.

3. A larger telescope allows more light to be collected by the mirrors and/or lenses of the telescope. More light allows for a clearer image, which can then be magnified to show greater detail.

4. Example answer: Edwin was incredibly excited today. Albert Einstein came to visit him, and he even thanked him for all of his hard work. It's almost unbelievable! The most celebrated scientist of our lifetime came to visit him. Just to be associated with Einstein is an honor, let alone be thanked by him. Edwin works very hard, and he must be very proud of his new discoveries that have changed the world of astronomy.

5. The fact that the universe is expanding implies that it must have been smaller in the past than it is today. The expanding universe implies that the universe must have had a beginning. This idea led to the development of the Big Bang theory, which says that the universe exploded outward from a single point smaller than an atom into the vast expanse of today's universe.