1.2 Time and Distance

Measurement is a key skill and concept in physical science. In this section, you will learn about measuring two fundamental properties of the universe: time and distance.

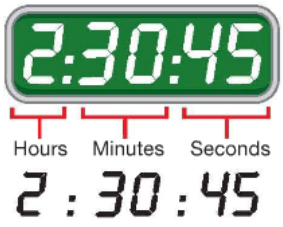
Time

Time in science We often want to know how things change over time. For example, a car rolls down a hill over time. A hot cup of coffee cools down over time. The laws of physical science tell us how things change over time.

What time is it? Time is used two ways (Figure 1.6). One way is to identify a particular moment in the past or in the future. For example, saying your 18th birthday party will be on January 1st, 2012 at 2:00 p.m. identifies a particular moment in the future for your party to start. This is the way "time" is usually used in everyday conversation.

How much time? The second way is to describe a *quantity* of time. The question "How much time?" is asking for a quantity of time. A quantity of time is also called a *time interval*. Any calculation involving time that you do in physical science will always use time intervals, *not* time of day.

Time in seconds



Many problems in science use time in seconds. For calculations, you might need to convert hours and minutes into seconds. For example, the timer (left) shows 2 hours, 30 minutes, and 45 seconds.

How many total seconds does this time interval represent? There are 60 seconds in a minute, so multiply 30 minutes by 60 to get 1,800 seconds. There are 3,600 seconds in an hour, so multiply 2 hours by 3,600 to get 7,200 seconds. Add up all the seconds to get your answer: 45 + 1,800 + 7,200 = 9,045 seconds.

Figure 1.6: *There are two different ways to understand time.*

CHALLENGE

What is your reaction time?

Sit at a table and rest your arm on the table, with your hand hanging off the edge. Have a friend dangle a metric ruler just above your thumb and index finger. When your friend drops the ruler, catch it quickly between your thumb and finger. Record the centimeter mark where you caught the ruler. Approximate reaction times are: 0.10 seconds for 5 cm, 0.14 s for 10 cm, 0.18 s for 15 cm, 0.20 s for 20 cm, 0.23 s for 25 cm, and 0.25 s for 30 cm.

Do several trials and discuss.

Distance

What is distance?

Distance is the amount of space between two points (Figure 1.7). You can also think of distance as how far apart two objects are. You probably have a good understanding of distance from everyday experiences, like the distance from your house to school, or the distance between your city and the next town. The concept of distance in physics is the same, but the actual distances might be much larger or much smaller than anything you measure in everyday life.

Distance is measured in units of length

Distance is measured in units of **length**. The English System uses inches, feet, yards, and miles for length units. One foot equals 12 inches. Do you know how many feet are in a yard? There are three feet in a yard. How many yards are in a mile? There are 1,760 yards in a mile. These numbers are not easy to remember. The SI units of length are much easier to use, because they are based on powers of ten, and the prefixes tell you something about the unit value. For example, the prefix *centi-* means one hundredth, so you know that a centimeter is 100 times smaller than a meter. There are 100 centimeters in a meter. The word *inch* does not tell you anything about how it is related to a foot. There are 12 inches in a foot, but you wouldn't know that from the unit name!

SI distance unit

The **meter** is a basic SI distance unit. In 1791, a meter was defined as one ten-millionth of the distance from the North Pole to the equator (Figure 1.8). Today a meter is defined more accurately using the speed of light. The meter was used as a starting point for developing the other SI units.

Useful prefixes

Prefixes are added to the names of basic SI units. Prefixes describe very small or very large measurements. There are many SI unit prefixes, but the following three (Table 1.3) are commonly used with meters to measure distance.

Table 1.3: Common Distance Prefixes

Prefix	Prefix + meter	Compared to 1 Meter
kilo-	kilometer	1,000 times bigger
centi-	centimeter	100 times smaller
milli-	millimeter	1,000 times smaller

VOCABULARY

distance - the amount of space between two points.

length - a measured distance.

meter - a basic SI unit of length.

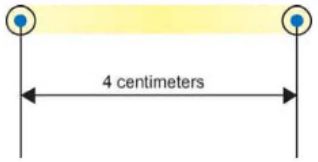


Figure 1.7: *Distance is the amount of space between two points.*

Figure 1.8: *In 1791, a meter was defined as 1/10,000,000 of the distance from Earth's North Pole to the equator. Today, a meter is defined more accurately as the distance that light travels in a fraction of a second.*

The meter stick A meter stick is a good tool for measuring ordinary lengths in the laboratory. A meter stick is 1 meter long and is divided into millimeters and centimeters. Figure 1.9 shows a meter stick next to objects of different lengths. Can you see how the meter stick is used to measure the length shown for each object?

Using a centimeter ruler Using a meter stick or a centimeter ruler to make distance or length measurements is easy. Each centimeter is divided into ten smaller units, called millimeters. Try using the centimeter rulers below to find the measurement of the length of each object. Check your answers in the sidebar answer box.

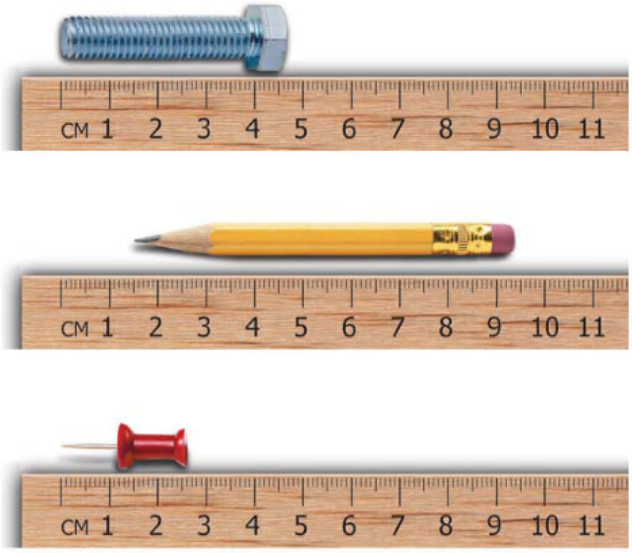


Figure 1.9: *Reading a meter stick.*

SOLVE FIRST LOOK LATER

The measurements are:
bolt: 4.70 cm
pencil: 7.90 cm
pushpin: 2.60 cm

Units of distance in space

What is a light year?

Astronomers have developed units other than kilometers and meters to measure the vast distances in space. You may have heard of *light years* (ly), an astronomical term. Even though the name might sound like it, this unit does not measure time. One **light year** is equal to the *distance* that light travels through space in one year.

Calculating a light year

In space, light travels at the amazing speed of about 300,000 km/s. How far will light travel in 1 year? We can calculate the distance light travels in 1 year by multiplying the speed of light (300,000 km/s) by time (1 year). To get the correct answer, we must convert years into seconds since the value for the speed of light contains seconds. There are 31,536,000 seconds in 1 year! Here's how to find the distance of 1 light year, in kilometers:

$$\begin{aligned} 1 \text{ light year} &= \text{speed of light} \times \text{time} \\ &= 300{,}000 \text{ km/s} \times 31{,}536{,}000 \text{ s} \\ &= 9{,}460{,}000{,}000{,}000 \text{ km} \\ &= 9.46 \times 10^{12} \text{ km} \end{aligned}$$

Light years are useful to astronomers

Light years are more useful to astronomers than kilometers. For example, the distance from the brightest star in the sky, Sirius, to Earth is about 83,200,000,000,000 or 8.32×10^{13} km. That distance is equal to about 8.8 light years. You can see that it is much easier to express the distance from Earth to Sirius in light years than it is to describe the distance in kilometers (Figure 1.10).

What is a parsec?

A **parsec** (*par*allax of one arc*sec*ond, symbol *pc*) is another unit of length used by astronomers. A parsec is about 3.26 light years. If you read a popular science magazine or watch a science show about astronomy, you will see astronomical distances expressed in *light years*. If you read a technical, scholarly journal article on astronomy, you will see the unit parsec used instead of light years. For example, a star's absolute brightness is defined as the brightness that star would have if it were 10 parsecs from Earth. Ten parsecs is about 32.6 light years. A parsec is a unit derived by using geometry and trigonometry to describe the position and distance of objects in space, relative to Earth.

VOCABULARY

light year - the distance that light travels through space in one year. One light year is equal to 9.46×10^{12} km.

parsec - An astronomical distance equal to about 3.26 light years.

Object	Distance from Earth (ly)
Sirius (brightest star in the sky)	8.8
Betelgeuse (appears as a red star in the sky)	700
Crab Nebula (remnant of an exploded star)	4,000
Andromeda galaxy (a huge group of billions of stars)	2.5 million

Figure 1.10: *Distance of some space objects from Earth in light years.*

Section 1.2 Review

1. What are two different ways to understand time? Explain and give examples.
2. How many minutes are there in 1.5 hours? Don't forget to show your work!
3. Convert 330 minutes to hours. Show your work.
4. Men in the age group of 18–34 years need to be able to run a marathon in 3 hours and 10 minutes to qualify for the Boston Marathon. How many seconds is this? Show your work!
5. Study the table in Figure 1.11 to answer the following questions.
   a. Which movies are longer than 2 hours?
   b. Which (if any) movies are longer than 3 hours?
   c. Convert the running time of *Gone with the Wind* to hours and minutes.
   d. Does any movie have a running time of less than 1.5 hours? If so, which one(s)?
6. Your teacher says, "There are 100 centimeters in a meter, and this fact is revealed in the unit's name (centimeter). There are 3 feet in 1 yard, but this fact is not revealed in the unit's name (yard)." Explain what your teacher means by this.
7. Which is larger? Copy each pair of measurements and circle the length that is the longest for each pair.
   a. 42 mm or 10 cm
   b. 15 mm or 0.15 cm
   c. 10 mm or 2 cm
8. Regulus, the brightest star in the constellation Leo, is approximately 77 light years from Earth. Which year did Regulus give off the light you see when you look at the star today?

Movie	Running Time (min)
Casablanca	102
Citizen Kane	119
Gone with the Wind	222
E.T. the Extraterrestrial	115
Jaws	124
King Kong (2005)	188
Titanic (1997)	194
Back to the Future	116

Figure 1.11: *Question 5.*