12.1 Distance and Time

The concepts of distance and time are so commonplace that we take them for granted. We know the distances to different places (Figure 1) and we know the time that class begins and ends. We have units for distance and we have units for time. In addition, we have different needs for accuracy. A game of basketball with a bunch of friends ends when everyone wants to stop, while a championship game ends exactly when the buzzer goes!

LEARNING TIP

Skim (read quickly) to get a general sense of Chapter 12. Consider information gathered from the title, headings, figures, words in bold, and sample problems. What do you expect to learn in this chapter?

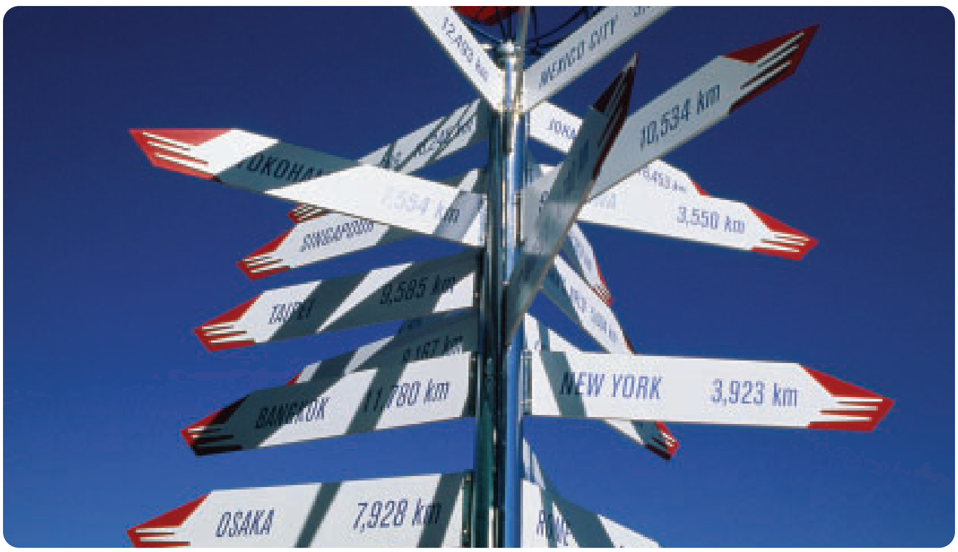

Figure 1 This signpost marks the distance from Canada Place in Vancouver to places all around the world.

Distance

The space between two points is the distance. Distances are commonly measured in units of metres. Historically, the metre was defined as one ten-millionth of the distance from the North Pole to the equator through Paris. Today, it is defined as the distance travelled by light in empty space during a time of 0.000 000 003 s. We use the metre to indicate not only the size of an object but also how far the object travelled. For example, consider the situation shown in Figure 2. John wants to visit his grandmother who lives on the opposite side of the lake. He can either cross the lake using a boat, or he can walk along the shore.

Distances can vary greatly in size. For example, the distance between tracks on a CD is 1.6×10^{-6} m, or 1.6 μm. Although this seems small, the diameter of a hydrogen atom is about ten thousand times smaller: about 10^{-10} m. On the other extreme, the distance to the Sun is 1.5×10^{9} m. The distance to Proxima Centauri, the nearest star to our solar system, is 4.0×10^{16} m. The distances in space are so large that astronomers use units of light-years to measure them. A light-year is the distance that light travels in one year and is equal to 9.46×10^{15} m. This means that Proxima Centauri is 4.22 light-years away from Earth.

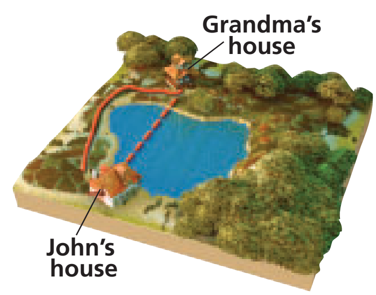

Figure 2 The distance to Grandma's house depends on the path that John takes.

TRY THIS: *Standards of Measurement*

Skills Focus: observing, predicting, analyzing, communicating

In this activity, you will measure lengths using commonplace objects.

Materials: a variety of objects (for example, desk, pencil, beaker, and classroom door), tickertape or string

1. Choose a commonplace object to be the basis for measuring distances. The width of the thumb at the base of the nail has already been chosen for the inch. However, you could use another part of your body (e.g., finger width/length, arm length, etc.) or another object (this textbook, your pen, a dime, a hockey stick, etc.).
2. Create a name for the base unit of your measuring system. For example, the thumb width is called the inch. However, the name of the base and the unit could be the same. For example, the Swedish word "tum" and the French word "pouce" both mean inch and thumb.
3. Use your measuring object to measure the lengths of other objects. For convenience, you may transfer the length of your base unit to tickertape or string for measuring. If the object is smaller than your base unit, you will have to devise a means to measure or estimate fractional units.

A. Which length was the easiest to measure? Why?

B. Which length was the most difficult to measure? Why?

C. Compare your measurements for the length of each object on the list with your classmates. For each object, decide which base unit created by the class was most suitable.

D. What was the basis for choosing the most suitable unit?

E. How could you measure the width of a page of this text using your unit?

Figure 3 The Gastown Steam Clock in Vancouver was built in 1977, and is the world's only steam powered clock.

Time

Most people have an intuitive understanding of time. We speak of how soon an event will take place compared with the present time or how much time has passed since an event occurred. Time can also mean the reading on a clock (Figure 3) or the difference between two clock readings. Time is measured in different units including years, days, hours, minutes, and seconds. In general, time is the duration of an event.

To emphasize that time is a duration, it is often referred to as a **time interval** and given the symbol Δt. The symbol Δ is the Greek letter *delta*, and represents change. Therefore, the symbol Δt combines the symbols for change (Δ) and time (t) together to mean "change in time."

Time and Distance

Time and distance are fundamental to our understanding of the natural world around us. These quantities can be used by themselves, for example, in using distance measurements to determine area or volume. By combining time and distance we can determine speed. Often we combine them with other quantities, such as mass, to describe quantities such as density, force, or energy.

Period and Frequency

One of the early proposals for defining distance was to make the base unit equal to the length of a pendulum that had a period of one second. A period (T) is the time interval between two repeating events. For example, the period of a pendulum is the time interval needed for a complete swing (both back-and-forth swings, or one cycle). The period of a pendulum does not depend on the mass of the bob or on the amplitude (the amount the pendulum is pulled to the side) if the amplitude is small. A period is measured in units of time.

Frequency is related to period. Frequency (f) is the number of cycles that occur in a specific time interval. For example, the frequency of a pendulum might be 15 cycles per minute. The SI unit for frequency is the hertz (Hz), which is equal to one cycle per second.

Since frequency is the number of occurrences per second, and period is the time per occurrence, they are reciprocals of each other, which can be written as

$$T = \frac{1}{f} \quad \text{or} \quad f = \frac{1}{T}$$

where T is the period (in s) and f is the frequency (in Hz). The occurrence or event that is repeating is often circular so frequency is often referred to as revolutions per second or cycles per second. Therefore, three cycles per second is equal to 3 Hz and 45 revolutions per second is 45 Hz. GO

SAMPLE PROBLEM 1

Determine Period and Frequency

Ann counted 7 pulses in her wrist in 6.0 s. What are the period and frequency of her heart beat?

Solution

Determine the period.

$$T = \frac{6.0\ \text{s}}{7\ \text{pulses}} = 0.86\ \text{s}$$

There are two possible methods to determine the frequency.

Method A

$$f = \frac{7\ \text{pulses}}{6.0\ \text{s}}$$

$$f = 1.2\ \text{Hz}$$

Method B

$$T = \frac{1}{f}$$

$$f = \frac{1}{T} = \frac{1}{0.86\ \text{s}}$$

$$f = 1.2\ \text{Hz}$$

The period is 0.86 s and the frequency is 1.2 Hz.

Practice

Five waves wash up on shore in 60 s. Determine their period and frequency.

Did You KNOW?

The Father of Standard Time

Can you imagine what life would be like if every city followed its own time—for example, if Vancouver was about ten minutes later than Victoria? This is what it would be like if Canadian engineer Sir Sandford Fleming (1827–1915) had not invented the system of standard time. His idea divided the world into 24 time zones measured against the time set in Greenwich, England. Fleming's standard time revolutionized travel and is still used today.

To learn more about period and frequency, go to **www.science.nelson.com** GO

STUDY TIP

There are many ways to improve your chances of remembering new material. One way is to plan an immediate review after each class and to build a review into each study session.

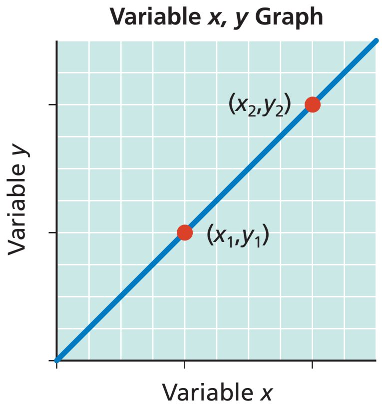

Figure 4 Graphing two variables that are directly related produces a straight line, which can then be used to calculate the slope.

Graphs and the Slope of a Line

Many quantities, including distance and time, and period and frequency, have mathematical relationships. If we graph two quantities that are directly related, such as x and y, we will get a straight line (Figure 4). The angle, or steepness, of the line is known as the **slope** of the line. In science, the x-axis is very often time. Therefore, the slope tells us what happens to the y variable as a function of time.

To calculate the slope, we divide the rise (along the y-axis) by the run (along the x-axis) using any two points on the line (x_1, y_1) and (x_2, y_2).

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{y_2 - y_1}{x_2 - x_1}$$

In the following activity, you will use a graph and the slope of the line to see how the period of a pendulum is related to its length. In section 12.3, we will look at how graphs can help us understand the relationship between distance and time.

TRY THIS: Length of a Pendulum with a Period of One Second

Skills Focus: observing, conducting, recording, analyzing, communicating

In this activity, you will determine the length of a pendulum with a period of one second.

Materials: pendulum (string, bob, retort stand, and clamp), stopwatch or clock with a second hand

1. Make a pendulum with a length of 1 m. Using a small amplitude swing, measure the time interval needed for 10 cycles (complete swings) of the pendulum (Figure 5).

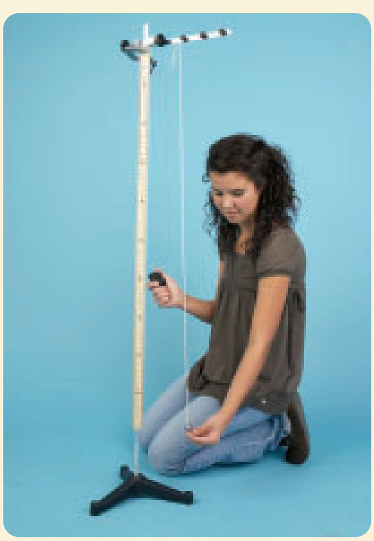

Figure 5

2. Copy Table 1 into your notebook and record the time. Divide the time by 10 to determine the period of the pendulum and record it in the table.

Table 1 Data Table

Length (cm)	Time (s)	Period (s)	Square root of length ($\sqrt{cm}$)
100	10		
80			
60			

3. Repeat step 2 for different pendulum lengths.
4. Although the period of a pendulum increases with the length of the pendulum, it is not a direct relationship. The period is related to the square root of the length of the pendulum. The last column of your table is for the square root of the length of the pendulum ($\sqrt{cm}$).

A. Estimate what pendulum length would have a period of 1 s.

B. Plot the data on a graph with period as a function of length. Draw a line through the data. Use the graph to estimate the length of a pendulum with a period of 1 s.

C. Plot a graph with period as a function of the square root of the length. Draw a line of best fit. Use the graph to estimate the length of a pendulum with a period of 1 s.

D. Why would this last estimate of length be more accurate than either of the first two estimates?

E. Calculate the slope of the line of the graph made in part C.

12.1 CHECK YOUR Understanding

1. There are different units used to measure time. Which unit would most commonly be used to measure the following?
   (a) your age
   (b) the duration of a Grade 10 Science class
   (c) the time an Olympic athlete needs to run 100 m
   (d) the time needed to fly from Vancouver to Paris
   (e) the duration of the summer holiday from school
2. Write a definition of distance in your own words.
3. The metre was originally defined as a fraction of the distance from the North Pole to the equator. What problems would this definition of the metre create for people?
4. A rectangular field is 1.5 km long and 700 m wide (Figure 6). An asphalt road goes around the outside of the field and a dirt path cuts across the field. A student wants to go from A to B on the field. Path *x* goes along the road and is shown in red; path *y* is shown in blue. Which path has the shorter distance? By how much is this path shorter?

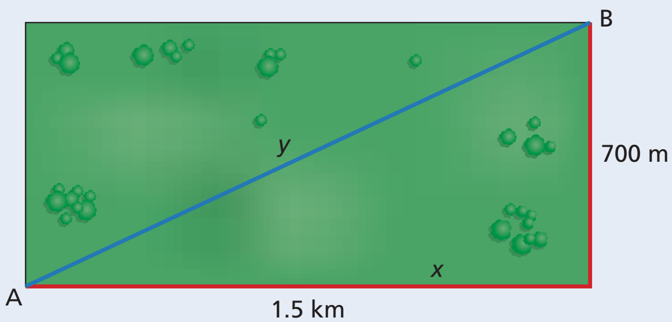

Figure 6

5. Why is time often referred to as a time interval in science?
6. Grandpa Adams took a nap from 2:32 p.m. until 3:19 p.m. How many seconds was Grandpa asleep?
7. Two points or locations are needed to measure distance. What two things are needed to measure a time interval?
8. A woodpecker taps 8 times on a tree in 2 s. What are the period and the frequency of the tapping?
9. Two children are playing on a teeter-totter (seesaw) in a park. They each move up and down 9 times in 25 s. Determine the period and frequency of their movement on the teeter-totter.
10. A bee's wings beat with a frequency of 200 Hz (Figure 7). What is the period of a beat of the bee's wings?

Figure 7