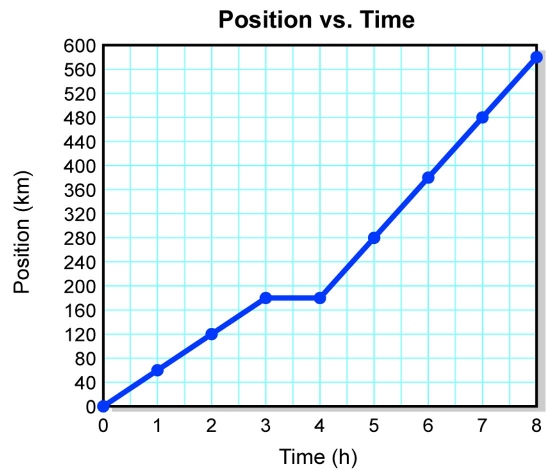
Distance and time graphs



Graphs A graph is a picture that shows how two variables are related. Graphs are easier to read than tables of numbers, so they are often used to display data collected during an experiment. The graph to the right shows distance and time measurements taken during a long trip in a car.

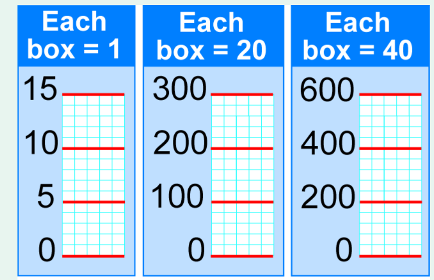
The independent variable By convention, or common agreement, graphs are drawn with the *independent variable* on the horizontal or *x*-axis. In the graph above, time is the independent variable. We say it is independent because we are free to decide the times when we take measurements. The graph shows that measurements were taken every hour.

The dependent variable The *dependent variable* goes on the vertical or *y*-axis. Distance is the dependent variable because the distance depends on the time. If a time interval other than one hour had been chosen, the distance measurements would be different.

1.2 Section Review

1. List two common systems of units and give examples of distance measurements for each.
2. Explain the two meanings in physics of the word "time."
3. If you wait in a long line for 1 hour and 10 minutes, how many seconds have you waited?
4. List the steps you should follow when making a graph.

How to make a graph



Letting each box = 40 fits the biggest data point (580 km)

1. Decide which variable to put on the *x*-axis and which to put on the *y*-axis.
2. Make a scale for each axis by counting boxes to fit your largest value for each axis. Count by multiples of 1, 2, 5, 10, or a larger number if needed. Write the numbers on each axis at evenly spaced intervals and label each axis with its corresponding variable and unit.
3. Plot each point by finding the *x*-value and tracing the graph upward until you get to the right *y*-value. Draw a dot for each point.
4. Draw a smooth curve that shows the pattern of the points.
5. Create a title for your graph.

1.3 Speed

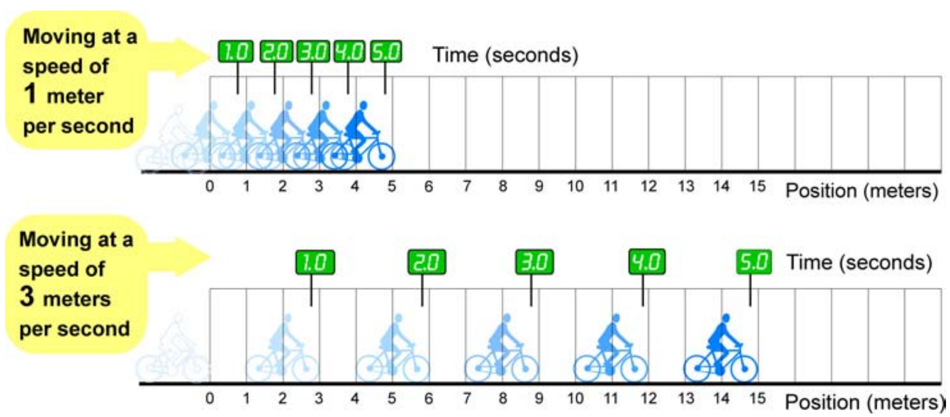
Nothing in the universe stays still. A book on a table appears to be sitting still, but Earth is moving in its orbit around the sun at a speed of 66,000 miles per hour. You and the book move with Earth. Speed is an important concept in physics and saying that something is "fast" is not descriptive enough to accurately convey its speed. A race car may be fast compared with other cars, but it is slow compared with a jet airplane. In this section, you will learn a precise definition of speed.

Speed

An example of speed

Consider a bicycle moving along the road. The diagrams below show the positions of two bicycles at different times. To understand the concept of speed, think about the following two questions.

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



The precise meaning of speed

The **speed** of a bicycle is the distance it travels divided by the time it takes. At 1 m/sec, a bicycle travels one meter each second. At 3 m/sec, it travels three meters each second. Both bicycles in the diagram are moving at **constant speed**. Constant speed means the same distance is traveled every second.

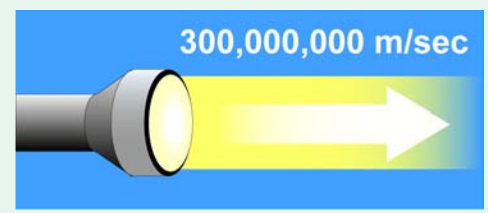
Vocabulary

speed, constant speed

Objectives

- ✓ *Define speed.*
- ✓ *Express an object's speed using various units.*
- ✓ *Calculate speed, distance, or time given two of the three quantities.*
- ✓ *List the steps for solving physics problems.*

The speed limit of the universe



The fastest speed in the universe is the speed of light. Light moves at 300 million meters per second (3×10^8 m/sec). If you could make light travel in a circle, it would go around the Earth 7 $^1/_2$ times in one second! We believe the speed of light is the ultimate speed limit in the universe.

Calculating speed

Speed is distance divided by time

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

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

Average speed

Speed is calculated by dividing the distance traveled by the time taken. For example, if you drive 150 kilometers in 1.5 hours (Figure 1.17), then the average speed of the car is 150 kilometers divided by 1.5 hours, which is equal to 100 kilometers per hour.

What does "per" mean?

The word "per" means "for every" or "for each." The speed of 100 kilometers per hour is short for saying 100 kilometers *for each* hour. You can also think of "per" as meaning "divided by." The quantity before the word per is divided by the quantity after it. For example, 150 kilometers divided by 1.5 hours (or per every 1.5 hours) equals 100 miles per hour.

Units for speed

Since speed is a ratio of distance over time, the units for speed are a ratio of distance units over time units. In the metric system, distance is measured in centimeters, meters, or kilometers. If distance is in kilometers and time in hours, then speed is expressed in kilometers per hour (km/h). Other metric units for speed are centimeters per second (cm/sec) and meters per second (m/sec). Speed is also commonly expressed in miles per hour (mph). Table 1.2 shows different units commonly used for speed.

$$\frac{\text{150 kilometers}}{\text{1.5 hours}} = \text{100 kilometers (km/h)}$$

Figure 1.17: *A driving trip with an average speed of 100 km/h.*

Table 1.2: ***Common units for speed***

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

Relationships between distance, speed, and time

Mixing up distance, speed, and time

A common type of question in physics is: "How far do you go if you drive for two hours at a speed of 100 km/h?" You know how to get speed from time and distance. How do you get distance from speed and time? The answer is the reason mathematics is the language of physics. A mathematical description of speed in terms of distance and time can easily be rearranged while preserving the original connections between variables.

Calculating speed

Let the letter *v* stand for "speed," the letter *d* stand for "distance traveled," and the letter *t* stand for "time taken." If we remember that the letters stand for those words, we can now write a mathematically precise definition of speed.

SPEED

Speed (m/sec) → $$v = \frac{d}{t}$$

d ← *Distance traveled* (meters)

t ← *Time taken* (seconds)

There are three ways to arrange the variables that relate distance, time, and speed. You should be able to work out how to get any one of the three variables if you know the other two (Figure 1.18).

Using formulas

Remember that the words or letters stand for the values that the variables have. For example, the letter *t* will be replaced by the actual time when we plug in numbers for the letters. You can think about each letter as a box that will eventually hold a number. Maybe you do not know yet what the number will be. Once we get everything arranged according to the rules, we can fill the boxes with the numbers that belong in each one. The last box left will be our answer. The letters (or variables) are the labels that tell us which numbers belong in which boxes.

Why *v* is used to represent speed

When we represent speed in a formula, we use the letter *v*. If this seems confusing, remember that *v* stands for *velocity*.

It is not important for this chapter, but there is a technical difference between speed and velocity. Speed is a single measurement that tells how fast you are going, such as 80 kilometers per hour. Velocity means you know both your speed and the *direction* you are going. If you tell someone you are going 80 km/h directly south, you are telling them your velocity. If you say only that you are going 60 mph, you are telling them your speed.

Forms of the speed equation

Equation	gives you	if you know
$v = d \div t$	speed	distance and time
$d = vt$	distance	speed and time
$t = d \div v$	time	distance and speed

Figure 1.18: *Different forms of the speed equation.*