8.2 Average Velocity

Average velocity is the rate of change in position. Speed is the magnitude of the velocity. The slope of the best-fit line on a position-time graph is average velocity. The relationship between average velocity, displacement, and time interval is given by $\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$.

Words to Know

average velocity
speed
velocity

It is a beautiful, sunny, winter morning. Last night, 15 cm of fresh powder snow fell on your favourite ski hill. You stand happily at the base of the hill, waiting to be the first to carve your mark in the new snow.

British Columbia has some of the best skiing and snowboarding in the world. Our ski hills offer various methods to transport people safely and efficiently up and down the mountains. Gondolas, like those in Figure 8.16, are connected to one continuous loop of cable. Each gondola on that cable travels the same amount of distance in the same time interval.

Figure 8.16 These two gondolas have the same rate of change in distance but in different directions.

Did You Know?

Police instruments for detecting speeding vehicles include lasers, handheld radar devices, instruments mounted on police cars, and speed cameras. Some machines are able to track vehicles both approaching and receding and can track the fastest vehicle among a group of vehicles.

The Peak to Peak gondola at Whistler Blackcomb has the longest uninterrupted span in the world at 3024 m between supports. The gondola ride takes skiers 4.4 km from the peak of Whistler Mountain to the peak of Blackcomb in just over 11 min. The Skyride gondola ride at Grouse Mountain in North Vancouver takes 8 min for its passengers to go 3 km up or down the mountain.

Suppose you were asked which of the two gondola rides travels faster. You probably already understand that it takes less time to get to your destination when you travel faster. The slower you travel, the longer it takes to arrive. But how do we compare objects that travel different distances, in different directions, all with various time intervals? In this section, you will learn how to use displacement and time intervals to calculate the rate and direction of motion.

8-2A The Faster Car Wins

Find Out ACTIVITY

In order to compare motion, we usually consider how fast the objects move and the direction in which the objects travel. In this activity, you will observe which toy car is faster.

Materials

- masking tape
- 2 different toy cars (wind-up or friction)

What to Do

1. On your lab table or other flat surface, stick two strips of masking tape approximately 2 m apart to indicate the start and finish line of the race.
2. Place one car on each of the lines so that when released they will head opposite directions to complete the race.
3. Release both cars at the same time. Note that if you are using wind-up cars, you will need to wind them before you release them. Friction cars will need to be pulled back before they are released.
4. Watch the two cars closely after they are released and determine which car is moving faster.

What Did You Find Out?

1. How did you determine which car was travelling faster?
2. If you wanted to calculate how fast the cars were travelling, what data would you need to collect?
3. Both of these cars travelled the same distance, but did they have the same displacement? Explain.
4. What words could you use to describe how fast something is moving?

Speed and Velocity

You probably use the term *speed* to describe how fast an object moves. In the study of motion, **speed** (v) is the distance an object travels during a given time interval divided by the time interval. Speed is a scalar quantity. The SI unit for speed is metres per second (m/s).

If you want to describe both the speed and the direction of motion, you would use the term *velocity*. **Velocity** ($\vec{v}$) is the displacement of an object during a time interval divided by the time interval. In other words, velocity describes how fast an object's position is changing. The direction of the velocity is the same as the direction of the displacement. Because it includes direction, velocity is a vector quantity. The SI unit for velocity is metres per second (m/s).

Figure 8.17 These two escalators have the same speed but different velocities since they are travelling in opposite directions.

Same speed, different velocities

Objects travelling the same speed can have different velocities. The reason for the difference lies in the definitions of distance and displacement. Distance is measured along the actual path taken. Displacement, however, is always measured along a straight line joining the initial and final positions. For example, the people on the two escalators in Figure 8.17 are travelling the same speed, but they are travelling opposite directions. One of these directions must be given a negative sign, and therefore they have different velocities. Velocities change when magnitude or direction or both change.

Calculating the Slope of the Position-Time Graph

The motion of two joggers is shown in Figure 8.18A below as a motion diagram and in Figure 8.18B on the next page as a position-time graph. A position-time graph represents the motion of objects, and we can determine the velocity of the objects from the graph.

Suppose each jogger moves at a constant velocity. During equal time intervals, the position of the female jogger changes more than the position of the male jogger. Since her displacement for equal time intervals is greater than his, we can conclude that she is jogging faster than he is. In order to calculate how fast each jogger is moving, you need to know both the displacement and the time interval.

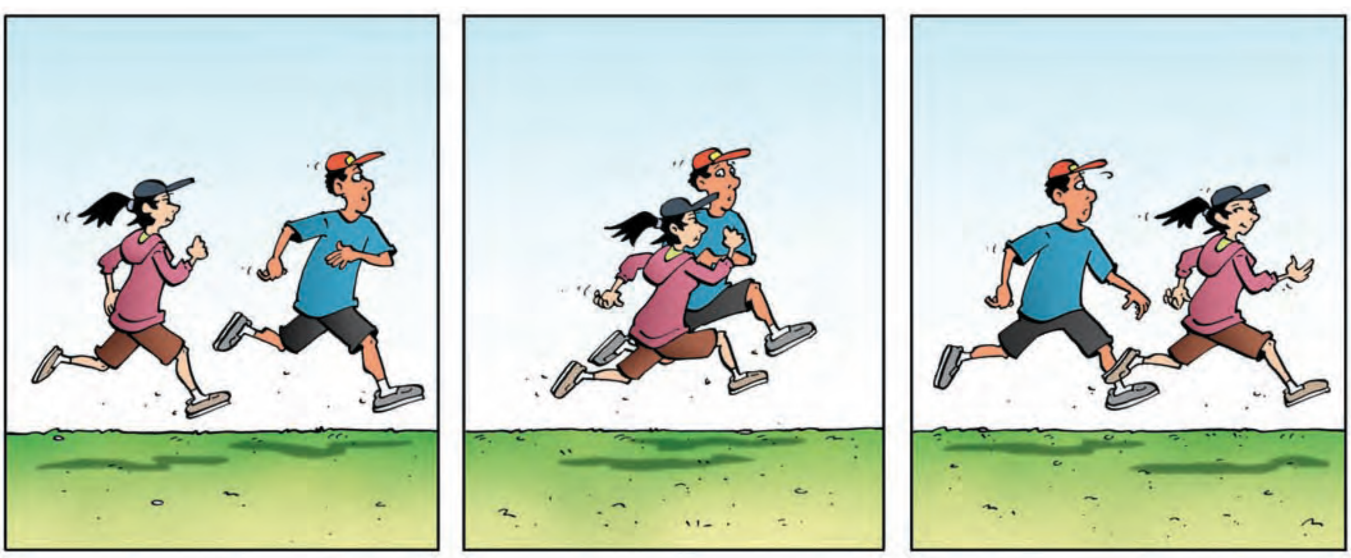


Figure 8.18A A motion diagram of two joggers. The female jogger is travelling faster than the male jogger.

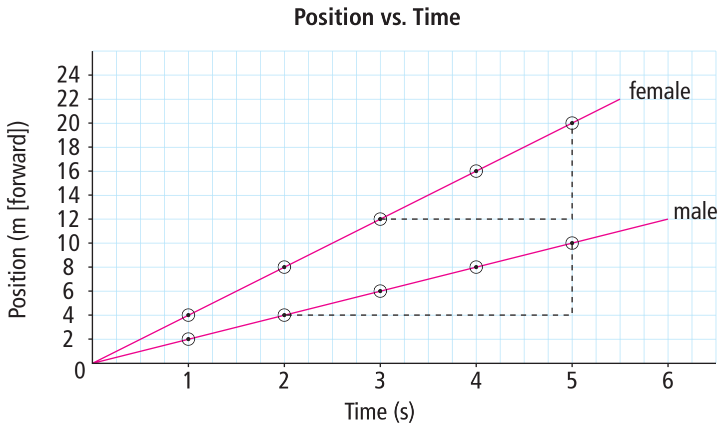


Figure 8.18B A position-time graph for two joggers. The female jogger is travelling faster than the male jogger.

Notice in Figure 8.18B that the slope of the female jogger's line is steeper than the slope of the male jogger's line. This is because she has a greater change in position (displacement) than he does during the same time interval. We can calculate and compare the slopes of each of these lines as follows.

Female jogger

$$\begin{aligned}\text{Slope} &= \frac{\Delta \vec{d}}{\Delta t}\\ &= \frac{(\vec{d}_f - \vec{d}_i)}{(t_f - t_i)}\\ &= \frac{(20\ \text{m} - 12\ \text{m})}{(5.0\ \text{s} - 3.0\ \text{s})}\\ &= \frac{8.0\ \text{m}}{2.0\ \text{s}}\\ &= 4.0\ \text{m/s}\end{aligned}$$

Male jogger

$$\begin{aligned}\text{Slope} &= \frac{\Delta \vec{d}}{\Delta t}\\ &= \frac{(\vec{d}_f - \vec{d}_i)}{(t_f - t_i)}\\ &= \frac{(10\ \text{m} - 4\ \text{m})}{(5.0\ \text{s} - 2.0\ \text{s})}\\ &= \frac{6.0\ \text{m}}{3.0\ \text{s}}\\ &= 2.0\ \text{m/s}\end{aligned}$$

Average Velocity

If we compare the two slopes in Figure 8.18B, the value of the female jogger's slope is greater than the value of the male jogger's slope. Since she was running faster than he was, we could assume that the slope might be related to the runner's speed. If we analyze the units of the slope calculation, metres per second (m/s), the slope shows on average how many metres the runner moved in one second. In other words, the slope of a position-time graph for an object is the object's average velocity.

Average velocity is the rate of change in position for a time interval. It would be almost impossible for a person to walk or run at a perfectly uniform rate. This is because many factors, such as wind or an uneven surface, may cause the person to slightly speed up or slow down. The concept of average velocity "smooths out" these changes.

It is a common error to consider average velocity to be the same as average speed. However, average velocity is a vector and includes a direction. Average speed is a scalar and does not include direction. The symbol $\vec{v}$ usually means the average velocity over a particular time interval. For clarity, $\vec{v}_{av}$ is used as a symbol for the average velocity.

Position-time graphs and average velocity

A position-time graph can contain positive, zero, and negative slopes, (Figure 8.19). If we designate moving away from the origin as positive, then a positive slope represents the average velocity of the object moving away from the origin. A horizontal line, which has zero slope, represents the object not moving. A negative slope represents the average velocity of the object moving back toward the origin. Table 8.2 summarizes this motion.

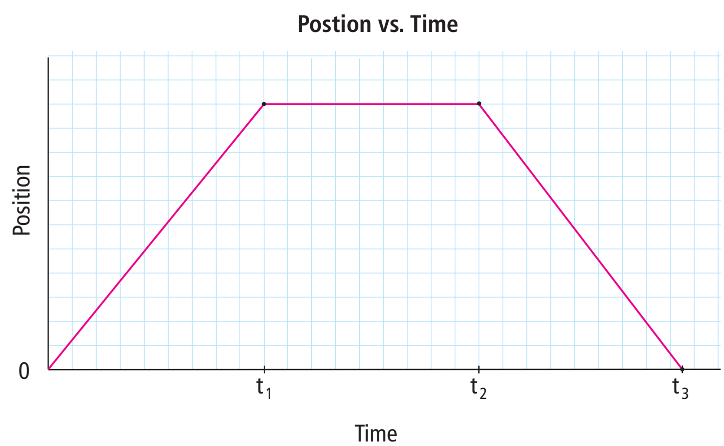


Figure 8.19 The slope of a position-time graph represents the object's average velocity.

Table 8.2 Average velocity of an object

Time interval	$t_1 - 0$	$t_2 - t_1$	$t_3 - t_2$
Velocity	Positive	Zero	Negative
Motion	Moving away from the origin at a uniform speed	Remaining stationary	Returning to the origin at a uniform speed

Reading Check

1. How is speed different from velocity?
2. How is the motion of an object with a positive velocity different from the motion of an object with a negative velocity?
3. What concept does the slope of a position-time graph represent?
4. On a position-time graph, line A has a greater slope than line B. What does this indicate about the average velocity of the two objects represented by line A and line B?
5. What does a zero slope on a position-time graph indicate about the object's average velocity?

8-2B Slope and the Position-Time Graph

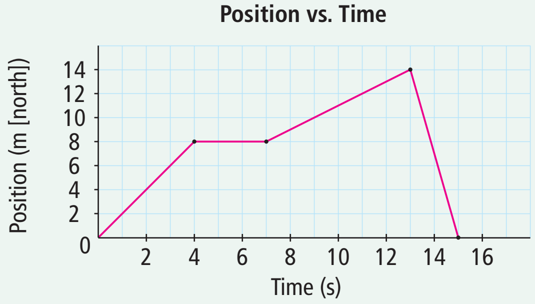
Think About It

In this activity, you will use an object's position-time graph to make inferences about the object's motion and calculate the object's average velocity.

What to Do

1. Copy the following table into your notebook. Give the table a title. Then use the table and graph to help you answer the questions that follow.

Time interval (s)	0 s to 4 s	4 s to 7 s	7 s to 13 s	13 s to 15 s
Velocity (positive, negative, or zero)				
Motion of the object				



2. For each of the time intervals indicated in your table, record whether the velocity of the object is positive, negative, or zero.
3. For each of the time intervals indicated in your table, what can you infer about the motion of the object? Record your inferences in the table.
4. Calculate the average velocity of the object for each of the following time intervals.
   (a) 0 s–4 s
   (b) 4 s–7 s
   (c) 7 s–13 s
   (d) 13 s–15 s

What Did You Find Out?

1. During what time interval was the object moving the fastest?
2. What direction was the object travelling when it was moving the fastest?

Converting between m/s and km/h

It is sometimes necessary to change from one unit of measurement into another. For example, the SI unit of measurement for both speed and velocity is metres per second (m/s). In daily life, kilometres per hour (km/h) is a common unit when representing both speed and velocity (Figure 8.20).

To convert a velocity given in km/h to m/s, you must first change kilometres to metres, then hours to seconds. Given that 1000 m = 1 km and 3600 s = 1 h, multiply by an appropriate distance conversion factor and then by a time conversion factor. For example, 55 km/h [W] becomes

$$\frac{55\ \cancel{\text{km}}}{1\ \cancel{\text{h}}} \times \frac{(1000\ \text{m})}{(1\ \cancel{\text{km}})} \times \frac{(1\ \cancel{\text{h}})}{(3600\ \text{s})} = 15\ \text{m/s [W]}$$

Notice that the units have been converted from km/h to m/s.

Figure 8.20 Speed zone limits are stated in kilometres per hour.

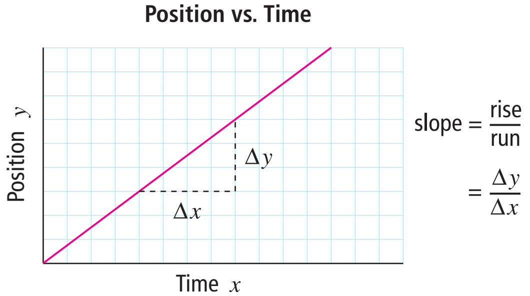


Figure 8.21 The slope of a straight line is the ratio of rise to run.

Calculating Average Velocity

In mathematics, we calculate the slope of a line as: slope = rise/run (Figure 8.21). On a graph, this would mean slope $= \frac{\triangle y}{\triangle x}$, where $\triangle y$ represents the change in the y-axis value and $\triangle x$ represents the change in the x-axis value. In other words, the slope of the line on a position-time graph is the displacement ($\triangle \vec{d}$) divided by the time interval ($\triangle t$).

$$\begin{aligned} \text{Slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{\triangle \vec{d}}{\triangle t} \end{aligned}$$

Since the slope of a position-time graph is the average velocity ($\vec{v}_{av}$), the relationship between the average velocity, displacement, and time shown in Figure 8.22 is given as:

$$\vec{v}_{av} = \frac{\triangle \vec{d}}{\triangle t}$$

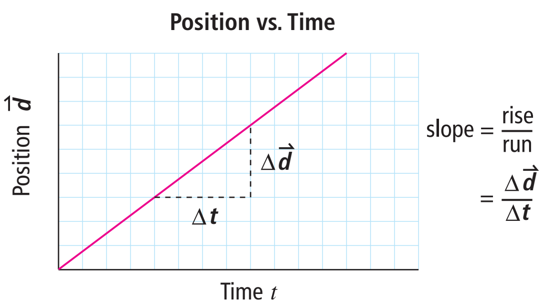


Figure 8.22 The slope of a straight line on a position-time graph is the ratio of displacement to time interval. The slope represents the average velocity.

By using this relationship, you can calculate the average velocity without analyzing a position-time graph. For example, suppose that it takes a sprinter 8.2 s to run forward 75.0 m. What is the sprinter's average velocity?

Given: $\triangle \vec{d} = +75.0 \text{ m}, \triangle t = 8.2 \text{ s}$

$$\begin{aligned} \vec{v}_{av} &= \frac{\triangle \vec{d}}{\triangle t} \\ &= \frac{+75.0 \text{ m}}{8.2 \text{ s}} \\ &= +9.1 \text{ m/s} \end{aligned}$$

The sprinter ran 9.1 m/s forward.

Did You Know?

A golf ball leaves the tee at over 250 km/h. The change in velocity from 0 km/h to 250 km/h occurs in 450 microseconds (0.00045 s), which is less time than it takes to blink your eye.

Calculating Displacement

The relationship $\vec{v}_{av} = \frac{\triangle \vec{d}}{\triangle t}$ can also be used to calculate the displacement or the time. For example, what is the displacement of a skateboarder who travels 3.5 m/s [W] for 12 s?

We will use a negative sign $(-)$ to indicate west [W].

$$\text{Given: } \vec{v}_{av} = -3.5 \text{ m/s}, \triangle t = 12 \text{ s}$$

$$\vec{v}_{av} = \frac{\triangle \vec{d}}{\triangle t}$$

$$\triangle \vec{d} = (\vec{v}_{av})(\triangle t)$$

$$= (-3.5 \text{ m/s})(12 \text{ s})$$

$$= -42 \text{ m}$$

Since the negative sign $(-)$ was used to indicate west, the skateboarder's displacement is 42 m [W].

Calculating Time

To find time, the equation can be rewritten as follows:

$$\vec{v}_{av} = \frac{\triangle \vec{d}}{\triangle t}$$

$$\triangle t = \frac{\triangle \vec{d}}{\vec{v}_{av}}$$

For example, if a cyclist travels south at 12 m/s, how long would it take the cyclist to travel 600 m [S]?

We will use a negative sign $(-)$ to indicate south.
Given: $\triangle \vec{d} = -600$ m and $\vec{v}_{av} = -12$ m/s

$$\triangle t = \frac{\triangle \vec{d}}{\vec{v}_{av}}$$

$$= \frac{(-600 \text{ m})}{(-12 \text{ m/s})}$$

$$= 50 \text{ s}$$

It takes the cyclist 50 s to travel 600 m.

Suggested Activity

Conduct an Investigation 8-2D on page 371
Conduct an Investigation 8-2E on page 372

Practice Problems

Try the following average velocity problems yourself.

1. What is the average velocity of a dog that runs 35 m [S] in 4.5 s?
2. If a baseball is thrown at 25 m/s toward home plate, what would be the ball's displacement after 0.65 s?
3. Two friends want to paddle their canoe 450 m across a lake. If they head across the lake at 2.5 m/s, how long does it take them to cross?

Answers

1. 7.8 m/s south
2. 16 m toward home plate
3. 180 s

Explore More

To find out more about shortcuts for converting units, go to **www.bcscience10.ca**.

Answers

1. 9.7 m/s
2. 56 km/h, 16 m/s
3. 520 m
4. (a) 6.0 km/h [W]
   (b) 1.7 m/s [W]
5. 67 m [E]
6. 11 s

Practice Problems

Try the following unit conversion problems yourself.

1. Convert 35 km/h to m/s.
2. A car's displacement is 42 km [S] after driving for 0.75 hours. What is the car's average velocity in km/h and m/s?
3. A car is travelling forward at 75 km/h. How far does the car travel in 25 s?
4. A person paddles a canoe 1.2 km [W] in 0.20 hours.
   (a) What is the average velocity of the canoe in km/h?
   (b) What is the average velocity of the canoe in m/s?
5. What is the displacement of a car travelling 48 km/h [E] during a 5.0 s time interval?
6. How many seconds would it take a cyclist, travelling at 25 km/h, to travel 75 m forward?

8-2C Determining Average Velocity — Think About It

In this activity, you will determine the average velocity by finding the slope of the best-fit line on a position-time graph.

Materials

- graph paper
- ruler
- calculator

What to Do

1. The following data was recorded for a student jogging. Copy this data table into your notebook. Give the data table a title.

Position (m [E])	0	7	15	20	26	35	42	49	56
Time (s)	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0

2. Draw and label a position-time graph.
3. Calculate the slope of your best-fit line.

What Did You Find Out?

1. Did the student jog with motion at a constant rate? Explain your answer.
2. Calculate the average velocity of the jogger.
3. (a) Write the equation for the best-fit line.
   (b) Use your equation to calculate the jogger's position after running for 25 s.

Science Skills

Go to Science Skill 5 for information about how to organize and communicate results with graphs.

8-2D What Is Its Velocity?

Design an INVESTIGATION

SkillCheck

- Observing
- Measuring
- Graphing
- Evaluating information

Materials

Any of:

- measuring tapes
- metre sticks
- stopwatches
- recording timers
- ticker tape
- motion sensors

In this activity, you will design and conduct an experiment to find the average velocity of an object of your choice.

Problem

Design and conduct an experiment to measure the average velocity of an object with nearly uniform motion.

Criteria

- Create a procedure that will allow you to determine the average velocity of your chosen object.
- Your analysis must include a data table, position-time graph, and calculations.

Design and Conduct

1. Choose an object that displays relatively uniform motion.
2. Write down your procedure for determining the object's average velocity. Have your teacher confirm that your procedure is safe and accurate before performing your experiment.
3. Collect all data and record in a titled data table.
4. Use a position-time graph to interpret your data.

Evaluate

1. What is the average velocity of your object? Show how you obtained your answer.
2. Was the object's motion perfectly uniform? Use your graph to justify your answer.
3. Describe any changes you would make to your procedure in order to improve your accuracy.

A volcanologist is using a radar gun to measure the speed of flowing lava. A similar type of radar gun is used to measure the speed of pitches in baseball.

8-2E Walk This Way

SkillCheck

- Measuring
- Controlling variables
- Graphing
- Working co-operatively

Materials

- 50 m tape measure
- 10 stopwatches
- 11 students

In order to find the average velocity of an object's motion, measurements of displacements during time intervals are required. The velocity of an object travelling in one direction must be opposite in sign to an object travelling in the other direction. On a position-time graph, this is represented as positive and negative slopes. In this activity, you will determine the average velocity of a person walking both forward and backward.

Question

How can a position-time graph be used to analyze the magnitude and direction of a person's average velocity?

Procedure

1. Copy the following data tables into your notebook. Give each data table a title.

Table 1

Walking Forward											
Position (m)	0	5	10	15	20	25	30	35	40	45	50
Time (s)	0										

Table 2

Walking Backward											
Position (m)	50	45	40	35	30	25	20	15	10	5	0
Time (s)	0										

2. On an open field, or in a long hallway, extend the 50 m tape measure in a straight line.
3. Place a student with a stopwatch at each of the positions indicated in Table 1, from 5 m to 50 m. There does not need to be a student with a stopwatch at the origin (0 m).
4. Place the student who is going to walk the 50 m at the origin (0 m).
5. On the command "Go," all students will start their stopwatches and the student who is going to walk will begin walking with as uniform a velocity as possible for the complete 50 m.
6. Students will stop their stopwatches when the walking student passes their position.

Inquiry Focus

7. The time on each student's stopwatch will be shared with the group and recorded in Table 1.
8. Place a student, with a stopwatch, at each of the positions indicated in Table 2, from 45 m to 0 m. There does not need to be a student with a stopwatch at the 50 m position.
9. Place the student who is going to walk backward at the 50 m position.
10. On the command "Go," all students will start their stopwatches and the student who is going to walk will begin walking backward with as uniform a velocity as possible for the complete 50 m.
11. Students will stop their stopwatches when the walking student passes their position.
12. The time on each student's stopwatch will be shared with the group and recorded in Table 2.
13. Clean up and put away the equipment you have used.

Analyze

1. On the same set of axes, plot a position-time graph for both sets of recorded data. Draw a best-fit line for each of your sets of data. Calculate the slope of each of your best-fit lines.
2. What is the average velocity of the student
   (a) walking forward?
   (b) walking backward?
3. Was the student's average speed faster when walking forward or when walking backward?

Conclude and Apply

1. What can you infer about whether the student's motion was perfectly uniform while walking forward or backward? Use your graph to justify your answer.

The Snowbirds Demonstration Team features more than 50 different formations and manoeuvres requiring precise changes in velocity. The head-on cross manoeuvre has a combined closing speed of approximately 1100 km/h.

Science Skills

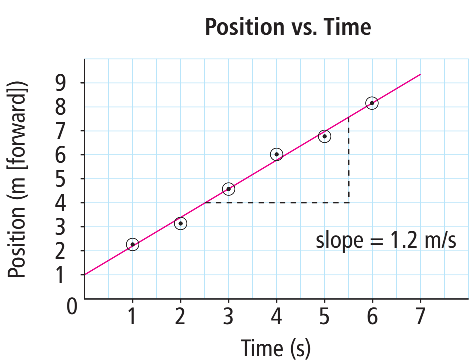
Go to Science Skill 5 for information about how to organize and communicate results with graphs.

Finding Relationships from Straight Line Graphs

A volcanologist tracks the position of the front of a lava flow at specific times as it travels forward in a straight line.

Time (s)	1.0	2.0	3.0	4.0	5.0	6.0
Position (m [forward])	2.2	3.3	4.6	5.9	6.9	8.2

When the data are plotted in a position-time graph, the slope shows that the lava's average velocity is 1.2 m/s forward. What other information does the graph show?



The *y*-intercept

The *y*-intercept is the location on the vertical axis where the graph line touches the *y*-axis. Not all graph lines must pass through the origin (0,0). On any graph, the *y*-intercept is the value on the *y*-axis when the value on the *x*-axis is zero. For the position-time graph shown above, the *y*-intercept is 1.0 m. This means that the lava front was located 1.0 m forward of the origin when timing began. This is information about the experiment that the graph shows but that the data table does not easily display.

The equation of the line

When the data are represented by a best-fit straight line, the two variables on the *x*-axis and the *y*-axis are directly proportional to each other. Directly proportional means, for example, as the value of one variable on the axis doubles, the value of the other axis doubles as well.

The equation of a straight line is given as $y = mx + b$, where y is the variable on the vertical axis, x is the variable on the horizontal axis, m is the slope, and b is the *y*-intercept. Using this general equation, we can write the equation for the directly proportional relationship between any two variables. The equation of the line for our position-time graph could be written as follows:

$$y = mx + b$$

$$\vec{d} = (1.2\ \text{m/s})t + 1.0\ \text{m}$$

where $\vec{d}$ represents the lava's position forward and t represents the time.

Using the equation of the line

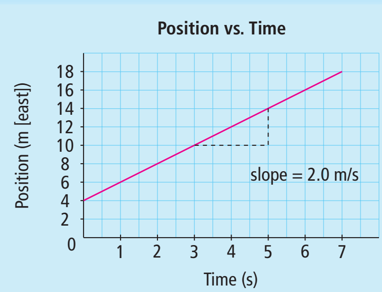
Interpolation is the process of estimating a value that is between two directly measured data points. Extrapolation is the process of estimating values that are beyond the measured data points. Interpolation and extrapolation are easily done from a equation of the line. For example, suppose we wanted to know the position of the lava front at 2.5 s. Rather than approximating from our graph, we can use the equation:

At $t = 2.5$ s

$$\begin{aligned}\vec{d} &= (1.2\ \text{m/s})t + 1.0\ \text{m}\\ &= (1.2\ \text{m/s})(2.5\ \text{s}) + 1.0\ \text{m}\\ &= 4.0\ \text{m}\end{aligned}$$

At 2.5 s, the lava front position is 4.0 m forward.

Questions



Use this graph to answer the questions.

1. What is the value of the *y*-intercept in this graph?
2. What equation represents the lava flow's motion?
3. Use your equation to determine the position of the front of the lava flow at 6.5 s.

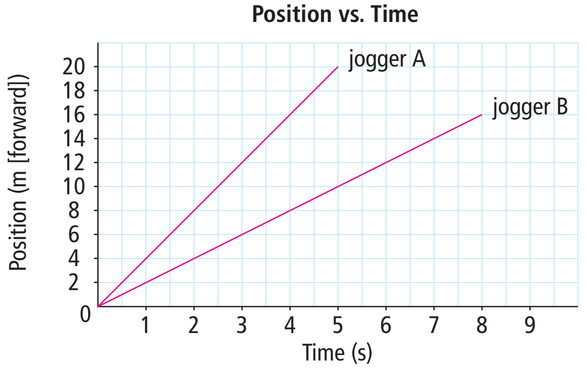
Check Your Understanding

Checking Concepts

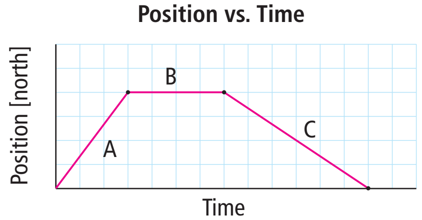
1. Two lines on a position-time graph represent the motion of two world-class sprinters. Line 1 has a steeper slope than line 2. How does the average velocity of the sprinter represented by line 1 compare to the average velocity of the sprinter represented by line 2?
2. What does the slope of the line on a position-time graph represent?
3. What are two common units for velocity?
4. Explain the difference between average speed and average velocity.
5. What is the mathematical relationship between average velocity ($\vec{v}_{av}$), displacement ($\Delta\vec{d}$), and time interval (Δt)?

Understanding Key Ideas

6. The motion of two joggers is recorded in the position-time graph below. Calculate the average velocity of jogger A and jogger B.



7. Given the position-time graph below, determine which segment of the graph represents each of the following.
   (a) zero velocity
   (b) positive slope
   (c) moving north with a uniform velocity
   (d) zero slope
   (e) moving south with a uniform velocity
   (f) negative slope



8. What is the average velocity of an arrow that travels 12 m [E] in 0.15 s?
9. What is the average velocity of a snail that crawls 0.25 m forward in 150 s?
10. If a canoe has an average velocity of 4.2 m/s [W], what is its displacement after 25 s?
11. A ball rolls across the floor with an average velocity of 6.0 m/s [S]. What is the ball's displacement after 12 s?
12. How long does it take to run forward 420 m if the runner's forward velocity is 6.0 m/s?
13. If sound travels at 350 m/s, how long does it take the sound to travel 110 m across a field?
14. Convert 45 km/h to m/s.
15. A car travels 45 km [N] in 0.70 h.
    (a) What is the car's average velocity in km/h?
    (b) What is the car's average velocity in m/s?
16. A horse is running forward at 42 km/h. What is the horse's displacement during a 3.0 s time interval?
17. The position of an object is recorded in the following data table.

Time	0.0 s	2.0 s	4.0 s
Position	3.0 m [N]	7.0 m [S]	3.0 m [S]

Calculate the average velocity for each of the following time intervals.
(a) 0.0 s–2.0 s
(b) 2.0 s–4.0 s
(c) 0.0 s–4.0 s

Pause and Reflect

Most major harbours have a 10 km/h speed limit for boats travelling in the harbour. Suppose you are sitting by the harbour and watching the motion of the boats. Describe a simple experiment you could perform to determine if a boat is exceeding the speed limit.

Chapter 8 Chapter Review

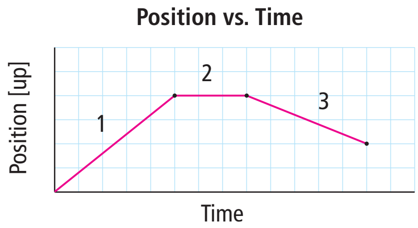
Prepare Your Own Summary

In this chapter, you investigated the relationship between average velocity, displacement, and time interval. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 11 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Terms Used to Describe Motion
2. Scalars and Vectors
3. Uniform Motion
4. Position-Time Graph
5. Calculating Average Velocity

Checking Concepts

1. How is a vector quantity different from a scalar quantity?
2. (a) Give an example of a scalar quantity.
   (b) Give an example of a vector quantity.
3. Explain which would be more useful to you if you needed to locate a buried treasure: the distance to the treasure or the position of the treasure.
4. Explain how it is possible to run a distance of 1.0 km and have zero displacement.
5. How do we determine a time interval?
6. What Greek letter represents the change in a quantity?
7. If a negative sign (−) is used to describe a soccer ball's direction of motion, what sign would you use if the ball were kicked in the opposite direction?
8. A ball travelling with uniform motion has a displacement of 6 m [E] during the first 2 s time interval. What would be the ball's displacement during the next 2 s time interval?
9. How is uniform motion represented on a position-time graph?
10. The following position-time graph represents the motion of an elevator. State which section of the graph describes:
    (a) the elevator at rest
    (b) the elevator moving downward
    (c) the elevator moving upward



11. Describe how you could use a position-time graph to determine average velocity.
12. The traffic sign at the beginning of a school zone reads "30 km/h." Is this sign a "speed zone" sign or a "velocity zone" sign? Explain your answer.
13. Suppose forward is assigned a positive sign (+). Describe the motion of an object whose velocity is:
    (a) positive
    (b) negative
14. State the mathematical relationship between average velocity, displacement, and time interval.
15. Copy and complete the following table in your notebook.

Concept	Symbol	Unit	Scalar or Vector?
Time interval			Scalar
Distance	*d*		
Displacement			
Speed		m/s	
Velocity			

16. The SI unit for average speed or average velocity is m/s. What is another common unit used for these two concepts?
17. Explain how you would convert 85 km/h to m/s.

Understanding Key Ideas

18. The motion of a canoe, leaving the dock, is recorded in the data table below. Use the data to draw a properly labelled position-time graph. Draw a best-fit line through the plotted points, and use your graph to answer the following questions.
(a) What is the average velocity of the canoe?
(b) What was the position of the canoe when the timer was started (t = 0 s)?

Time (s)	5	10	15	20	25	30	35	40	45	50
Position (m[E])	12	20	25	31	40	49	56	60	67	75

19. A boy rides his bicycle north with a uniform velocity of 5 m/s for 10 s. Then he stops for 15 s to adjust his helmet. Next, he pushes his bicycle south with a uniform velocity of 2 m/s for 20 s.
(a) Sketch a position-time graph that represents the bicycle's motion for the 45 s time interval.
(b) What is the displacement of the bike after the 45 s time interval?

20. A girl rides her bicycle 420 m south in a time of 47 s. What is her average velocity?

21. What is the average velocity of a sprinter who takes 8.8 s to run forward 75 m?

22. If you paddled a boat with an average velocity of 2.1 m/s south, what would be your displacement if you paddled for 120 s?

23. What would be the height of a hot-air balloon after 5.0 min if the balloon lifted off the ground with an average velocity of 0.75 m/s?

Applying Your Understanding

24. On April 12, 1980, Terry Fox dipped his artificial right leg into the Atlantic Ocean off the coast of St. John's, Newfoundland. This was the beginning of the Marathon of Hope. Terry Fox's goal was to run across Canada to raise money for cancer research. It was a journey that Canadians would never forget.

Terry Fox tried to run a minimum of 42 km each day. He set a goal of 42 km since that is the distance run during a marathon. Some days, when the weather was good and the road was flat, Fox would run up to 50 km. But other days, when the hills were steep or the weather was stormy, he was not able to complete his 42 km goal. On September 1, 1980, outside Thunder Bay, Ontario, Terry Fox was forced to stop. The cancer that had taken his leg had moved to his lungs. His shortest daily distance, 28 km, occurred on this final day.

In 143 days, Terry Fox ran 5373 km, more than halfway across Canada. Terry Fox died on June 28, 1981, but his legacy lives on.
(a) Was it likely that Terry Fox's average velocity was the same every day? Use evidence from the above reading to support your answer.
(b) On average, how far did Terry Fox run each day of his 143 day journey?
(c) If the average forward velocity of a runner is about 10 km/h, how many hours would it take to run the distance Terry Fox ran?

Pause and Reflect

In science, a model is anything that helps you better understand a scientific concept. How can uniform motion be a useful model for real motion if real motion is never quite uniform? In other words, if real motion is not uniform, why study uniform motion?