CHAPTER

1

Constant velocity represents uniform motion.

Learning Expectations

By the end of this chapter, you will:

Relating Science to Technology, Society, and the Environment

- analyze, on the basis of research, a technology that applies concepts related to kinematics

Developing Skills of Investigation and Communication

- use appropriate terminology related to kinematics, including, but not limited to: time, distance, position, displacement, speed, and velocity
- analyze and interpret position-time and velocity-time graphs of motion in one dimension
- conduct an inquiry into the uniform and non-uniform linear motion of an object
- solve problems involving distance, position, and displacement

Understanding Basic Concepts

- distinguish between the terms constant, instantaneous, and average with reference to speed and velocity and provide examples to illustrate each term
- distinguish between, and provide examples of, scalar and vector quantities as they relate to the description of uniform and non-uniform motion

Many car drivers have become conscious of reducing gas consumption to save money and the environment. Hypermiling is a technique that drivers use to maximize fuel economy. Two criteria are extremely important for hypermiling. One is avoiding excessive braking and speeding, which can be done by keeping enough distance between your car and the car in front of you. The other criterion is driving your car at a reasonable constant speed. It has been found that constant speed is the best way to hypermile as it can reduce gas consumption significantly.

Some research and experience has shown that on a highway, if you drive at a constant speed close to 100 km/h, you can increase the distance travelled appreciably. While driving, it would be very difficult and unsafe for a car driver to maintain constant speed just by observing the speedometer on the dashboard. To facilitate this, most new cars have a system called cruise control or auto cruise (Figure 1.1). When this system is activated, it automatically controls the speed of the car and keeps it at a set constant value. On a highway, if the traffic allows, some drivers use it to drive at a constant speed and maintain a safe distance from the car in front. Both reduced braking and keeping a constant speed help in hypermiling, and can save a considerable amount of gas while protecting the environment from pollution.

Figure 1.1 Hypermiling dramatically reduces gas consumption in a car. One of the ways to implement hypermiling is using a cruise control system to maintain a constant speed.

1.1 Position, Motion, and Displacement

Section Summary

- Position is defined using a coordinate system with a reference point.
- Change in position is a proof of motion; and motion results in change in position.
- Distance is the length of the actual path travelled. It is a scalar quantity.
- Displacement is the straight line between the initial and final positions. It is a vector quantity.
- Position-time graphs give a lot of information about the motion of an object.

The physicists and engineers at NASA think about the motion of Earth when they are launching rockets (Figure 1.2). A surgeon thinks about blood flow and how to stop it while performing surgery. Imagine the amount of research that goes into designing a race car to make it safe and reliable to drive (Figure 1.3). Cars, washing machines, dryer, fans, etc. have become very important in our daily lives. Mechanical engineers design several movable things like robots, automobiles, and different kinds of machines by using physics principles. **Mechanics** is the field of physics in which we study the motion of objects. **Kinematics** explains the "what" and the "how" of motion.

Figure 1.2 A United Launch Alliance Delta II rocket being launched.

Figure 1.3 Race car in motion

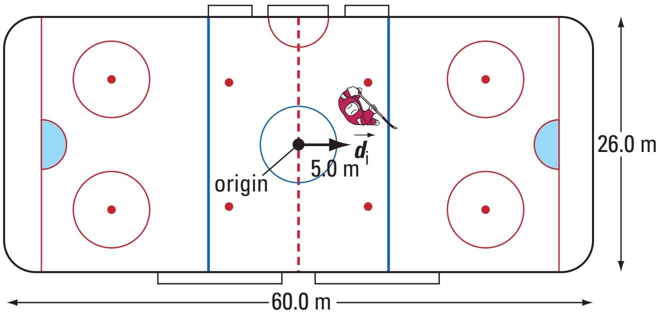

Figure 1.4 The player's position is 5.0 m [east of the origin] or simply 5.0 m [E]. The player is at a distance of 5.0 m from the origin.

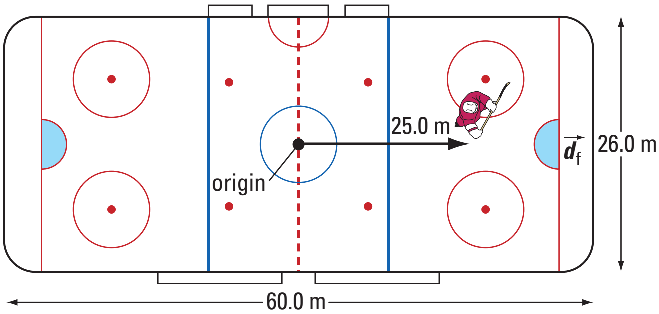

Figure 1.5 The player's position has changed. A change in position is called displacement.

Scalars and Vectors

In order to locate players on the ice during a hockey game, you need a reference system. In this case, select the centre of the ice as the reference point, also called the **origin**. You can then measure the straight-line distances, d, of players from the origin, such as 5.0 m. If you specify a distance and a direction from the origin along with the distance, then you define a player's **position**, $\vec{d}$, for example, 5.0 m [E] (Figure 1.4). The arrow over the variable indicates that the variable is a vector quantity. The number and unit are called the **magnitude** of the vector. Distance, which has a magnitude but no direction associated with it, is an example of a **scalar quantity**. **Vector quantities** have both magnitude and direction. Position is an example of a vector quantity.

If the player, initially 5.0 m [east of the origin], skates to the east end of the rink to the goal area, his position changes. It is now 25.0 m [east of the origin] or 25.0 m [E] (Figure 1.5). You can state that he has travelled a straight-line distance of 20.0 m, and has a displacement of 20.0 m [E] relative to his initial position.

Distance travelled is the length of the path taken to move from one position to another, regardless of direction. **Displacement**, $\Delta\vec{d}$, is the change in position. The player's displacement is written as

$$\Delta\vec{d} = 20.0 \text{ m [E]}$$

where Δ is the Greek letter delta that means "change in." Calculate the change in a quantity by subtracting the initial quantity from the final quantity. In algebraic notation, $\Delta R = R_f - R_i$. You can calculate the displacement of the player in the following manner:

$$\begin{aligned}\Delta\vec{d} &= \vec{d}_f - \vec{d}_i\\ &= 25.0 \text{ m [E]} - 5.0 \text{ [E]}\\ &= 20.0 \text{ m [E]}\end{aligned}$$

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Explore More

What is the difference between mass and weight as they relate to scalar and vector quantities?

Sign Conventions

How would you determine your final distance and displacement if you moved from a position 5.0 m [W] to a position 10.0 m [E] (Figure 1.6)?

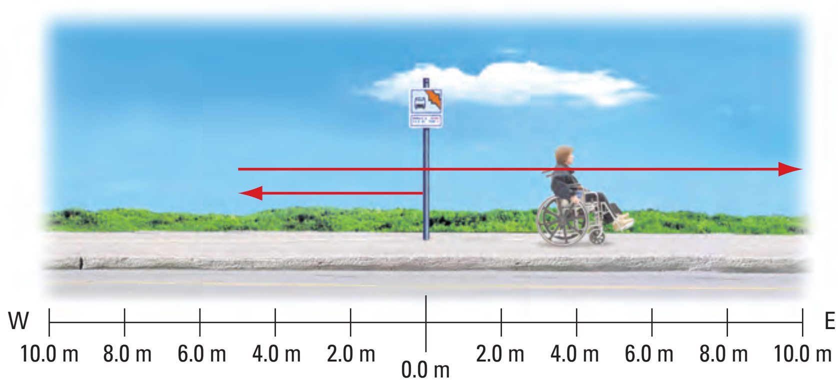

Figure 1.6 The person travels a distance of 5.0 m + 10.0 m = 15.0 m.

To calculate the distance travelled in the scenario on the previous page, you need to add the magnitudes of the two position vectors.

$$\begin{aligned}\Delta d &= 5.0 \text{ m} + 10.0 \text{ m} \\ &= 15.0 \text{ m}\end{aligned}$$

To find displacement, you need to subtract the initial position, $\vec{d}_i$, from the final position, $\vec{d}_f$. Let $\vec{d}_i$ = 5.0 m [W] and $\vec{d}_f$ = 10.0 m [E].

$$\begin{aligned}\Delta\vec{d} &= \vec{d}_f - \vec{d}_i \\ &= 10.0 \text{ m [E]} - 5.0 \text{ m [W]}\end{aligned}$$

Note that subtracting a vector is the same as adding its opposite, so the negative west direction is the same as the positive east direction.

$$\begin{aligned}\Delta\vec{d} &= 10.0 \text{ m [E]} - 5.0 \text{ m [W]} \\ &= +10.0 \text{ m [E]} + 5.0 \text{ m [E]} \\ &= +15 \text{ m [E]}\end{aligned}$$

Another way of solving for displacement is to designate the east direction as positive and the west direction as negative (Figure 1.7). The two position vectors become $\vec{d}_i$ = 5.0 m [W] = −5.0 m and $\vec{d}_f$ = 10.0 m [E] = +10.0 m.

Now calculate displacement:

$$\begin{aligned}\Delta\vec{d} &= \vec{d}_f - \vec{d}_i \\ &= +10.0 \text{ m} - (-5.0 \text{ m}) \\ &= +15.0 \text{ m}\end{aligned}$$

Since east is positive, the positive sign indicates that the person has moved 15.0 m east.

For all subsequent problems in this book, you will be using plus and minus signs to indicate direction. This method is more flexible for problem solving and easier to use.

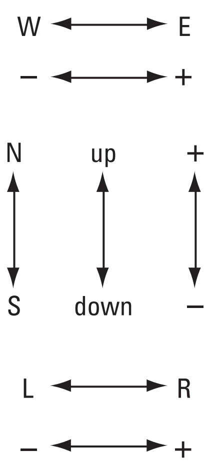

Figure 1.7 Let east be positive and west negative. Similarly, north, up, and right are usually designated as positive.

Concept Check

1. Figure 1.8 shows the surface of a rectangular table ABCD. Choose the corner labelled A as the starting position. Move the object following the arrow towards the corner labelled B. Continue moving the object along the side labelled BC until it reaches point P. Stop and measure the displacement (shown by the dotted arrow from A to P) and the distance covered (length AB + length BP).
   (a) Are the two measured quantities the same or different?
   (b) Repeat these steps by moving the object and following the arrows from A through B and C and stopping at Q. Are the two measured quantities the same or different?
   (c) Is (are) there any point(s) on the table where distance and displacement will be the same. Explain why?

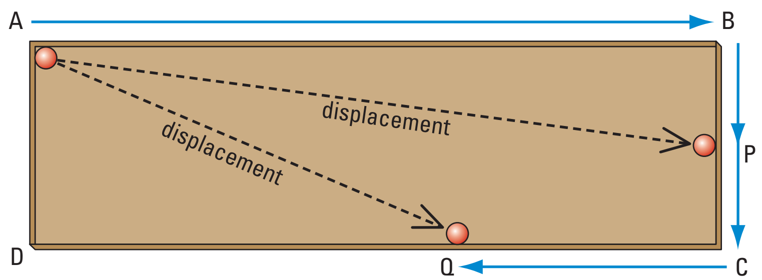

Figure 1.8 Distance and displacement

Example 1.1

A traveller initially standing 1.5 m to the right of the inukshuk moves so that she is 3.5 m to the left of the inukshuk (Figure 1.9). Determine the traveller's displacement algebraically
(a) using directions
(b) using plus and minus signs

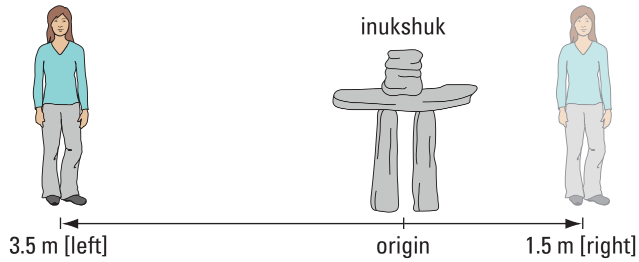

Figure 1.9

Given

Choose the inukshuk to be the reference point.

$\vec{d}_i$ = 1.5 m [right]

$\vec{d}_f$ = 3.5 m [left]

Required

displacement ($\Delta\vec{d}$)

Analysis and Solution

To find displacement, use the equation $\Delta\vec{d} = \vec{d}_f - \vec{d}_i$.

(a) $\Delta\vec{d} = \vec{d}_f - \vec{d}_i$
= 3.5 m [left] − 1.5 m [right]
= 3.5 m [left] − (−1.5 m [left])
= 3.5 m [left] + 1.5 m [left]
= 5.0 m [left]

(b) Consider right to be positive.

$\vec{d}_i$ = 1.5 m [right] = +1.5 m
d_f = 3.5 m [left] = −3.5 m
$\Delta\vec{d} = \vec{d}_f - \vec{d}_i$
= −3.5 m − (+1.5 m)
= −3.5 m − 1.5 m
= −5.0 m

The answer is negative, so the direction is left.

Paraphrase

The traveller's displacement is 5.0 m [left] of her initial position.

Note that the direction of *displacement* is relative to initial position, whereas the direction of *position* is relative to the designated origin, in this case, the inukshuk.

Practice Problems

1. Sprinting drills include running 40.0 m [N], walking 20.0 m [N], and then sprinting 100.0 m [N]. What is the sprinter's displacement from the initial position?
2. To perform a give and go, a basketball player fakes out the defence by moving 0.75 m [right] and then 3.50 m [left]. What is the player's displacement from the starting position?
3. While building a wall, a bricklayer sweeps the cement back and forth. If she swings her hand back and forth, a distance of 1.70 m, four times, calculate the distance and displacement her hand travels during that time.

Answers

1. 160.0 m [N]
2. 2.75 m [left]
3. 6.80 m, 0 m

Position-time Graphs

Position-time graphs give a visual representation of the motion of an object.

If the object is stationary, the graph is a horizontal line, as shown in Figure 1.10, because the position does not change with time.

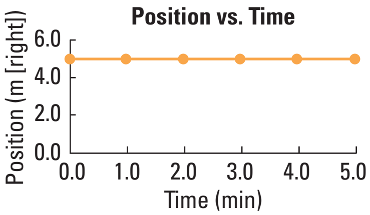

Figure 1.10 Position-time graph for a stationary object

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Suggested Activity

- A2 Quick Lab Overview on page 12

If an object goes through equal displacement in equal time intervals, the corresponding position-time graph is a straight line. This type of motion with no change in direction is called **uniform motion**. Figure 1.11 shows several examples of position-time graphs for a car travelling with uniform motion.

If the displacements that occur in equal time intervals are not equal, then the graph is not a straight line, but is a curve.

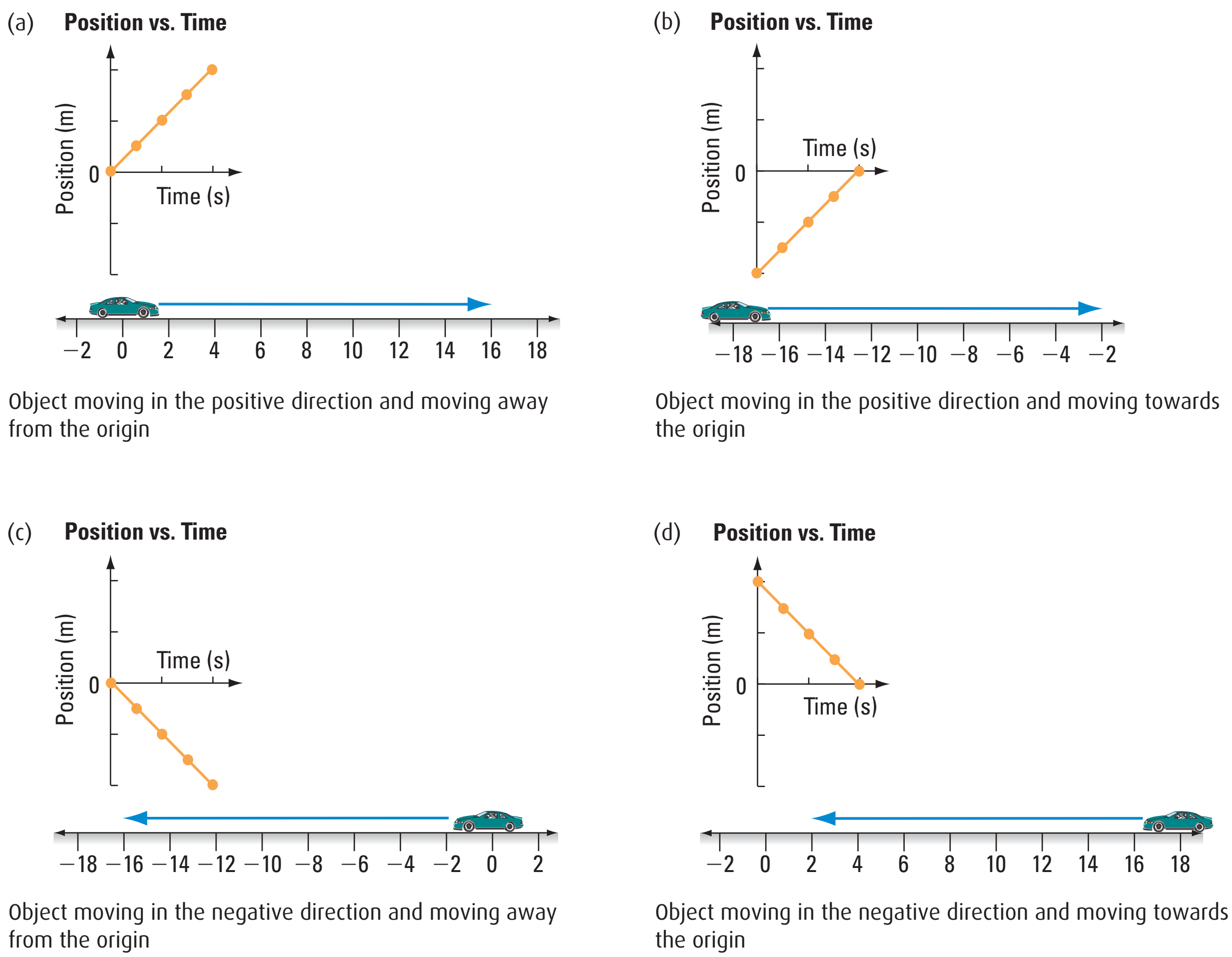


Figure 1.11 Position-time graphs for uniform motion

Concept Check

1. A person walks steadily from -18 km to 18 km, passing through the origin.
   (a) What do you think the position-time graph for the walk will look like?
   (b) Draw the position-time graph for the walk.
   (c) Are your answers in parts (a) and (b) the same or different? Explain.

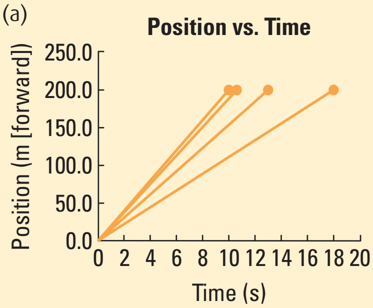
Practice Problems

1. A wildlife biologist measures how long it takes four animals to cover a displacement of 200 m [forward].
   (a) Graph the data from the table below.
   (b) From your graph, estimate how long it takes the Elk and Grizzly bear to cover 150 m.

Animal	Time Taken (s)
Elk	10.0
Coyote	10.4
Grizzly bear	18.0
Moose	12.9

Answers

1. (a)



(b) 7.5 s, 13.5 s

Example 1.2

At the end of the school day, student A and student B say goodbye and head in opposite directions, walking at constant rates. Student B heads west to the bus stop while student A walks east to her house. After 3.0 min, student A is 300 m [E] and student B is 450 m [W] (Figure 1.12). Graph the position of each student on one graph after 3.0 min.

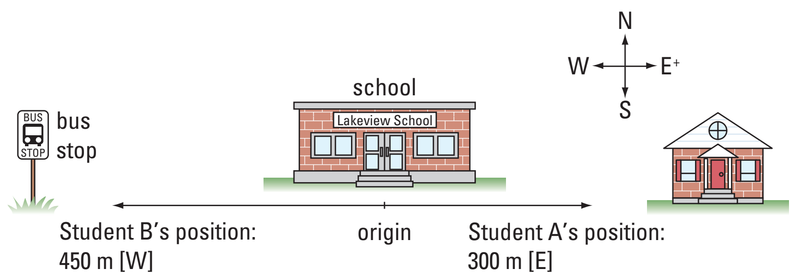


Figure 1.12

Given

Choose east to be positive.

$\Delta\vec{d}_A = 300 \text{ m [E]} = +300 \text{ m}$

$\Delta\vec{d}_B = 450 \text{ m [W]} = -450 \text{ m}$

$\Delta t = 3.0 \text{ min}$

Required

position-time graph

Analysis and Solution

Since east is the positive direction, plot student A's position (3.0 min, +300 m) above the time axis and student B's position (3.0 min, −450 m) below the time axis (Figure 1.13).

Paraphrase

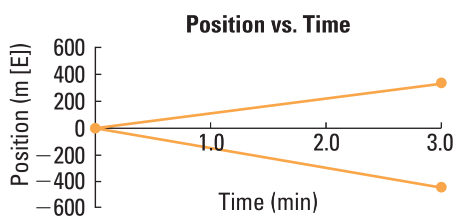


Figure 1.13

Example 1.3

Two rollerbladers, A and B, are having a race. B gives A a head start of 5.0 s (Figure 1.14). Each rollerblader moves with a uniform motion. Assume that the time taken to reach uniform motion is negligible. If A travels 100.0 m [right] in 20.0 s and B travels 112.5 m [right] in 15.0 s,
(a) graph the motions of both rollerbladers on the same graph.
(b) find the time, position, and displacement at which B catches up with A.

Given

Choose right to be positive.

$\Delta\vec{d}_A = 100.0$ m [right] $= 100.0$ m

$\Delta t_A = 20.0$ s

$\Delta\vec{d}_B = 112.5$ m [right] $= 112.5$ m

$\Delta t_B = 15.0$ s, started 5.0 s later

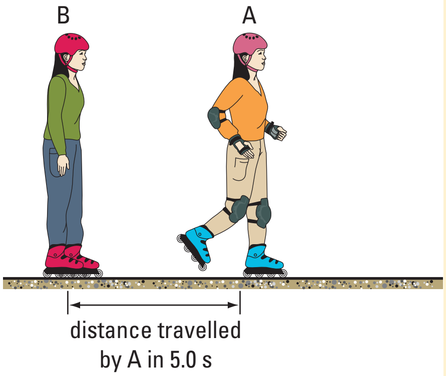


Figure 1.14

Required

(a) position-time graph
(b) time (Δt), position ($\vec{d}$), and displacement ($\Delta\vec{d}$) when B catches up with A

Analysis and Solution

(a) Assume that $t = 0.0$ s at the start of A's motion. Thus, the position-time graph of A's motion starts at the origin. A's final position is +100.0 m at 20.0 s.

The position-time graph for B's motion starts at 0.0 m and 5.0 s (because B started 5.0 s after A). B starts moving after 5.0 s for 15.0 s. Thus, at 20.0 s (5.0 s + 15.0 s), B's position is +112.5 m.

Each rollerblader travels with a constant velocity, so the lines connecting their initial and final positions are straight (Figure 1.15(a)).

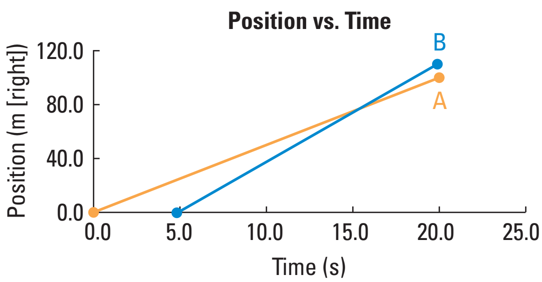


Figure 1.15(a)

(b) On the graph in Figure 1.15(a), look for a point of intersection. At this point, both rollerbladers have the same final position. From the graph, you can see that this point occurs at $t = 15.0$ s. The corresponding position is +75.0 m (Figure 1.15(b)).

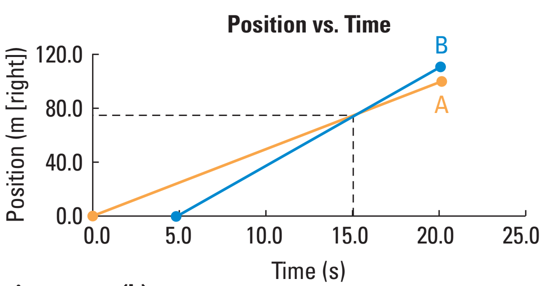


Figure 1.15(b)

Practice Problems

1. The two rollerbladers in Example 1.3 have a second race in which they each travel the original time and distance. In this race, they start at the same time, but B's initial position is 10.0 m left of A. Take the starting position of A as the reference.
   (a) Graph the motions of the rollerbladers.
   (b) Find the time, position, and B's displacement at which B catches up with A.

Answers

1. (b) $t = 4.0$ s
   $\vec{d} = 20.0$ m [right]
   $\Delta\vec{d} = 30.0$ m [right]

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Take It Further

Understanding how biological systems move is a branch of physics known as biomechanics. For automobile manufacturers, understanding how the human body moves during a car accident is very important. Today, crash test dummies are used to study, collect, and analyze data on how the human body moves during a vehicular collision. Research the history of crash test dummies.

To find B's displacement, find the change in position: $\Delta\vec{d} = \vec{d}_f - \vec{d}_i$. Both A and B started from the same position, $\vec{d}_i = 0$. Since they both have the same final position at the point of intersection, $\vec{d}_f = +75.0$ m.

$$\begin{aligned}\Delta\vec{d} &= +75.0\text{ m} - 0.0\text{ m}\\ &= +75.0\text{ m}\end{aligned}$$

The answer is positive, so the direction is to the right.

Paraphrase

(b) B catches up with A 15.0 s after A started. B's position and displacement are 75.0 m [right] of the origin.

A1 Skill Builder Activity

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Using a Motion Sensor

Activity Overview

In this Skill Builder, you learn how to set-up a motion sensor (Figure 1.16) and use it, with the aid of a computer, to collect data and plot graphs for a moving object.

Your teacher will give you a copy of the full activity.

Figure 1.16

DI Key Activity

A2 Quick Lab

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Video

Match a Graph

Purpose

To approximate the type of motion to the position-time graph provided.

Activity Overview

In this activity, your teacher will provide different position-time graphs. Using a motion sensor, you will move away from the sensor in such a way that the graph of the motion captured approximates each position-time graph (Figure 1.17).

Your teacher will give you a copy of the full activity.

Figure 1.17 Setup for the activity

Prelab Questions

Consider the questions below before beginning this activity.

1. What types of motion can objects undergo?

2. What are some words used to describe motion?

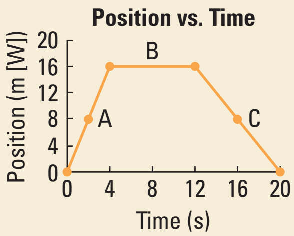
1.1 Check and Reflect

Key Concept Review

1. When an object is at rest, what can you say about its position, displacement, and distance?
2. For an object travelling with uniform motion, how does the displacement change over equal time intervals?
3. A camper kayaks 16 km [E] from a camping site, stops, and then paddles 23 km [W].
   (a) What is the camper's final position with respect to the campsite?
   (b) What is the total displacement of the camper?
   (c) What is the distance covered by the camper? Is it the same as the displacement? Explain.

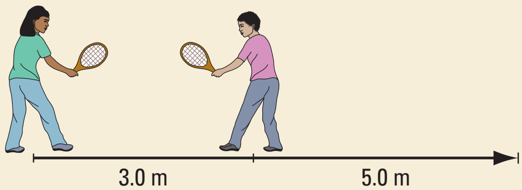
Connect Your Understanding

4. For the graph given below:
   (a) Describe the motion of the object in stages A, B, and C.
   (b) What is the displacement of the object at the end of each stage?
   (c) What is the total displacement (between the initial and final positions)?
   (d) What is the total distance covered?



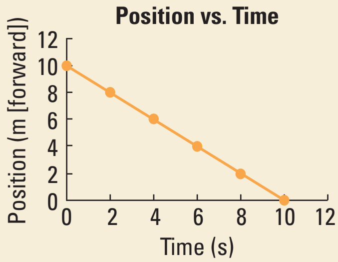
Question 4

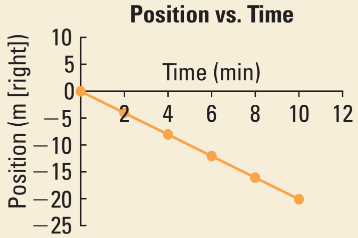
5. Below, two children play catch using an autuk (a type of sealskin racquet). Standing 3.0 m apart, the child on the right tosses the ball to the child on the left, and then moves 5.0 m [right] to catch the ball again. Determine the horizontal distance and displacement the ball travels from its initial position (ignore any vertical motion).

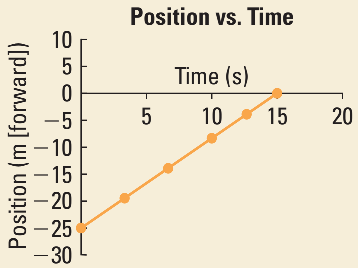


Question 5

6. For the graphs given below:
   (a) What is the displacement in each case?
   (b) Is it necessary that the position points for an object and its final displacement have the same sign? Explain using the graphs below.







Question 6

7. A person's displacement is 50.0 km [W]. What is his final position if he started at 5.0 km [E]?

Reflection

8. What do you know about the difference between distance and displacement that you did not know before?

For more questions, go to PHYSICS•SOURCE

1.2 Speed and Velocity

Section Summary

- The slope of a straight line position-time graph gives the velocity. The slope of the tangent at a point on a curved position-time graph gives the instantaneous velocity.
- Average speed is distance covered per unit time and average velocity is displacement per unit time.
- The direction of velocity can be stated using positive and negative signs.

Uniform Motion and Constant Speed

Table 1.1 displays the data for a golf ball's position from you at 1.0-s intervals. The position-time graph for this data is a straight line as shown in Figure 1.18. It shows that the golf ball moves steadily and uniformly.

Table 1.1 Position-time data

	Time (s)	Position (m [right])
t_0	0.0	0.0
t_1	1.0	1.0
t_2	2.0	2.0
t_3	3.0	3.0
t_4	4.0	4.0
t_5	5.0	5.0

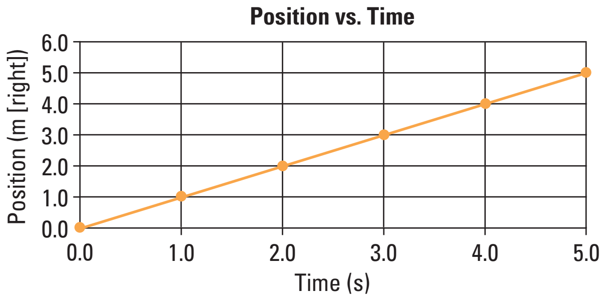


Figure 1.18 A position-time graph of a golf ball

In other words, we say that the golf ball has constant speed. **Speed** is defined as the distance covered per unit time. If the distances covered in every unit of time are the same, then the speed will be a constant. Speed is a scalar quantity.

Average Speed

You know by experience that when people are walking, biking, swimming, driving, or running, their speeds are not always the same at all times. They may speed up or slow down as they travel. This type of motion is **non-uniform motion**. Sometimes, it is helpful to know how fast or slow the overall motion was during these activities. **Average speed** is defined as the total distance covered divided by the total time taken.

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

The SI unit for average speed is m/s, but for automobiles, it is more common to use km/h. The common notation is v_{ave}. If you are on a 450 km road trip for 5 h, the average speed will be

$$\begin{aligned} v_{\text{ave}} &= \frac{450 \text{ km}}{5 \text{ h}} \\ &= 90 \text{ km/h} \end{aligned}$$

Average speed is a scalar quantity. If you use MapQuest, Google Maps, or a Global Positioning System (GPS) (Figure 1.19) to find the route of travel, you will find that it requires you to specify if you plan to travel via a highway or not. The reason for this is that it calculates the average speed with which you will be able to travel and gives you an approximate time that you will take to reach the destination.

The average speed of a jogger is 2.1 m/s. How far will he be able to run in 1.2 h? Give your answer in kilometres.

$$\begin{aligned} v_{\text{ave}} &= 2.1 \text{ m/s} \\ d &= ? \\ t &= 1.2 \text{ h} = 1.2 \cancel{\text{h}} \times \frac{3600 \text{ s}}{1 \cancel{\text{h}}} = 4320 \text{ s} \end{aligned}$$

Since, $v_{\text{ave}} = \dfrac{d}{t}$

$$\begin{aligned} d &= v_{\text{ave}} \times t \\ &= 2.1 \frac{\text{m}}{\cancel{\text{s}}} \times 4320 \cancel{\text{s}} \\ &= 9072 \text{ m} \end{aligned}$$

The jogger runs 9072 m or 9.1 km.

1.19 GPS systems can show you how to get to your destination.

Average Velocity

In addition to finding out how slow or how fast an object moves, it is also important to know in which direction this motion takes place. In this case, you would want to use displacement, which is a vector quantity, rather than distance, which is a scalar quantity. Displacement per unit time is called **velocity**. Velocity is a vector quantity that has the same direction as the displacement. If velocity is a calculated over a time interval rather than at an instant in time, it is called the **average velocity**. The SI unit for average velocity is m/s, though for cars the common unit is km/h.

$$\begin{aligned} \text{average velocity} &= \frac{\text{displacement}}{\text{time taken}} \\ \vec{v}_{\text{ave}} &= \frac{\vec{d}_{\text{f}} - \vec{d}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}} \\ &= \frac{\Delta \vec{d}}{\Delta t} \end{aligned}$$

PHYSICS•SOURCE

Explore More

The straight line on a position-time graph slopes up 8 m for every 1 s along the time axis. What is the velocity of the object? What type of motion is the object experiencing?

Concept Check

1. A student drives 5 km from home to the library and returns home. The total travel time is 15 min.
   (a) What was the student's average speed?
   (b) What is the average velocity?
   (c) Are the quantities in parts (a) and (b) the same or different? Why?

Practice Problems

1. A person runs 10.0 m [E] in 2.0 s, then 5.0 m [E] in 1.5 s, and finally 30.0 m [W] in 5.0 s. Find the person's average velocity.
2. Person A runs the 100-m dash in 9.84 s and then tags person B, who runs 200 m in 19.32 s. Person B then tags an out-of-shape person C, who runs 400 m in 1.90 min. Find the average velocity for the trio. Compare it to each individual's average velocity. Assume they are all running in a straight line.

Answers

1. 1.8 m/s [W]
2. 4.89 m/s [forward]
   A: 10.2 m/s [forward]; faster than the average velocity for the trio
   B: 10.4 m/s [forward]; faster than the average velocity for the trio
   C: 3.51 m/s [forward]; slower than the average velocity for the trio

Example 1.4

Find the average velocity of a student who jogs 750 m [E] in 5.0 min, does static stretches for 10.0 min, and then runs another 3.0 km [E] in 30.0 min.

Given

Choose east to be positive. Convert kilometres to metres.

$$\begin{aligned}
\Delta\vec{d}_1 &= 750\text{ m [E]} = +750\text{ m}\\
\Delta t_1 &= 5.0\text{ min}\\
\Delta\vec{d}_2 &= 0\text{ m}\\
\Delta t_2 &= 10.0\text{ min}\\
\Delta\vec{d}_3 &= 3.0\text{ km [E]}\\
&= +3.0\ \cancel{\text{km}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} = +3000\text{ m}\\
\Delta t_3 &= 30.0\text{ min}
\end{aligned}$$

Required

average velocity ($\vec{v}_{\text{ave}}$)

Analysis and Solution

First add the displacement values.

$$\begin{aligned}
\Delta\vec{d}_{\text{total}} &= \Delta\vec{d}_1 + \Delta\vec{d}_2 + \Delta\vec{d}_3\\
&= +750\text{ m} + 0\text{ m} + 3000\text{ m}\\
&= +3750\text{ m}
\end{aligned}$$

Then add the time intervals and convert to seconds. The total time elapsed is

$$\begin{aligned}
\Delta t_{\text{total}} &= \Delta t_1 + \Delta t_2 + \Delta t_3\\
&= 5.0\text{ min} + 10.0\text{ min} + 30.0\text{ min}\\
&= (45.0\ \cancel{\text{min}})\left(60\ \frac{\text{s}}{\cancel{\text{min}}}\right)\\
&= 2700\text{ s}
\end{aligned}$$

Average velocity equals total displacement divided by total time elapsed:

$$\begin{aligned}
\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t}\\
&= \frac{+3750\text{ m}}{2700\text{ s}}\\
&= +1.4\text{ m/s}
\end{aligned}$$

Since the answer is positive, the direction is east.

Paraphrase

The student's average velocity is 1.4 m/s [E].

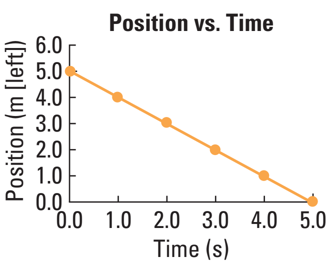


Figure 1.20 A position-time graph of a ball rolling back

Positive and Negative Average Velocity

Refer to Figure 1.20. By looking at this graph and the equation for average velocity more closely, you will observe that average velocity is actually the slope of this graph.

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

If we have a straight line position-time graph, you can find the average velocity by finding the slope. If the slope is positive, the average velocity will be positive. If the slope is negative, the average velocity is negative.

If an object is moving in the positive direction, $\vec{d}_f$ will be more than $\vec{d}_i$, and $\Delta\vec{d}$ will be positive. The slope and average velocity will also be positive. So a positive slope on a position-time graph indicates that an object is travelling in the positive direction, and with positive average velocity. In the same way, if the object is moving in the negative direction, $\vec{d}_i$ will be more than $\vec{d}_f$, and $\Delta\vec{d}$ will be negative. The slope and average velocity will also be negative. So a negative slope on a position-time graph indicates that an object is travelling in the negative direction, and with negative average velocity.

Zero Average Velocity

There are two ways in which the average velocity of an object can be zero. The first is when the object does not move at all for a period of time. The position of the object does not change and $\Delta\vec{d}$ will be zero and the average velocity will be zero. The other way may not be so obvious. Consider a train travelling from Toronto to Ottawa (Figure 1.21) in the morning and returning to Toronto in the evening. The total trip takes approximately 12 h. As the final position $\vec{d}_f$ of this train is the same as the initial position $\vec{d}_i$ (Toronto), this displacement ($\vec{d}_f - \vec{d}_i = \Delta\vec{d}$) will be zero. The average velocity for this trip will also be zero. This might sound very strange to you as the train has actually travelled and its speed was not zero at all times. Figure 1.22 describes this trip graphically. At 0 h and 12 h the train is in the same position.

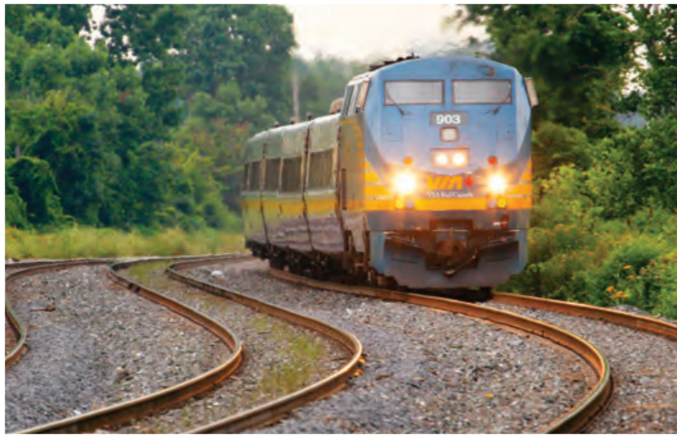


Figure 1.21 A train travelling between Toronto and Ottawa.

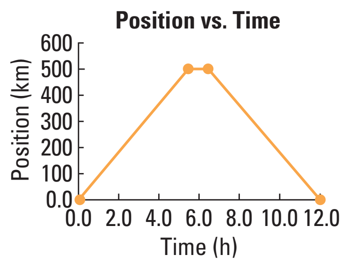


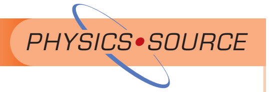
Figure 1.22 A position-time graph for the train

The conceptual reasoning for this problem is that for an observer in Toronto, the train was not displaced. He saw it in the morning and 12 h later when he returned to the station in the evening. For him, the train was still in the same position both times. This goes back to our original definition of motion, which is change in position. Zero average velocity can mean two things:

- that the object did not move at all, and
- that the object may have moved, but returned to the same position at the final time of observation.

Instantaneous Velocity

Although its average velocity is zero, we know that the train in the above example moved during the 12 h time period. To describe that motion, we need to define another concept called instantaneous velocity. **Instantaneous velocity** is the moment-to-moment measure of an object's velocity. Imagine recording the speed of the train once every second while it was moving. These data form a series of instantaneous velocities that describe the trip in detail. If the velocity of an object is a constant, then the instantaneous velocity is equal to its average velocity and the slope of the graph.



Suggested Activity

- A3 Quick Lab Overview on page 24

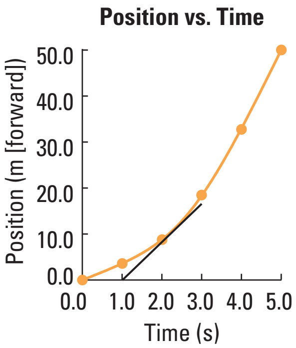


Figure 1.23 The tangent at 2.0 s

If the velocity changes every moment during the motion of an object, no portion of the position-time graph is a straight line.

Earlier in this section, you learned that determining the velocity of an object from a position-time graph requires calculating the slope of the position-time graph. But how can you obtain the slope of a curve? Remember that each point on the curve indicates the position of the object at an instant in time. To determine the velocity of an object at any instant, physicists use tangents. A **tangent** is a straight line that touches a curve at only one point (Figure 1.23). Each tangent on a curve has a unique slope, which represents the velocity at that instant. In order for the object to be at that position, at that time, it must have an instantaneous velocity equal to the slope of the tangent at that point. Determining the slopes of the tangents at different points on a position-time curve gives the instantaneous velocities at different times. Consider forward to be the positive direction.

Concept Check

1. What does the slope of a position-time graph represent?
2. Draw the approximate velocity-time graphs for the given position-time graphs.
3. Is the velocity changing in the graphs in Figure 1.24? Explain.

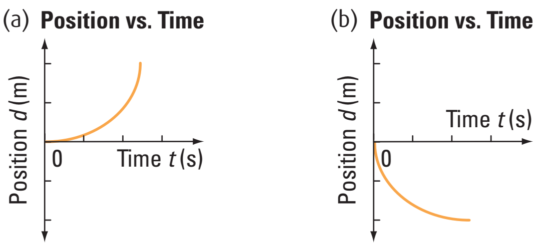


Figure 1.24

Example 1.5

The position-time data for an all-terrain vehicle (ATV) approaching a river are given in Table 1.2. Using these data,
(a) draw a position-time graph
(b) find the instantaneous velocities at 2.0 s, 3.0 s, and 5.0 s
(c) draw a velocity-time graph

Analysis and Solution

Designate the forward direction as positive.
(a) For the position-time graph, plot the data in Table 1.2 (Figure 1.25).

Table 1.2

Time (s)	Position (m [forward])
0.0	0.0
1.0	13.5
2.0	24.0
3.0	31.5
4.0	36.0
5.0	37.5

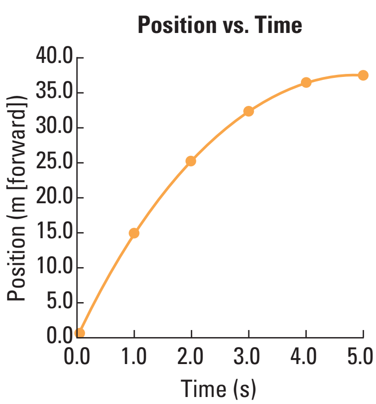


Figure 1.25

(b) Since the position-time graph is non-linear, find the slope of the tangent at 2.0 s, 3.0 s, and 5.0 s (Figures 1.26, 1.27, and 1.28).

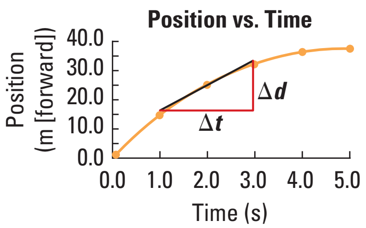


Figure 1.26

$$\begin{aligned} \text{slope} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{+32.5\ \text{m} - 15.5\ \text{m}}{3.0\ \text{s} - 1.0\ \text{s}} \\ &= \frac{+17.0\ \text{m}}{2.0\ \text{s}} \\ &= +8.5\ \text{m/s} \end{aligned}$$

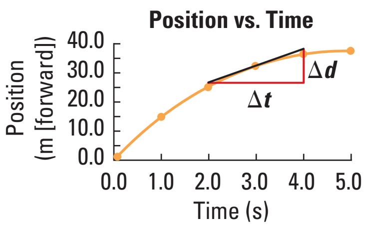


Figure 1.27

$$\begin{aligned} \text{slope} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{+37.0\ \text{m} - (+26.0\ \text{m})}{4.0\ \text{s} - 2.0\ \text{s}} \\ &= \frac{+11.0\ \text{m}}{2.0\ \text{s}} \\ &= +5.5\ \text{m/s} \end{aligned}$$

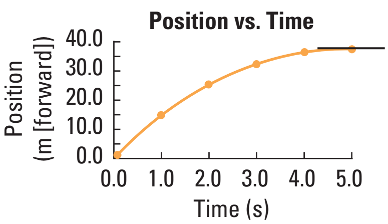


Figure 1.28

This tangent is a horizontal line, so its slope is zero.

Paraphrase

(c) The slopes of the tangents give the instantaneous velocities (Table 1.3). Positive signs mean that the direction is forward. Plot the data on a velocity-time graph (Figure 1.29).

Table 1.3

Time (s)	Velocity (m/s [forward])
2.0	8.5
3.0	5.5
5.0	0

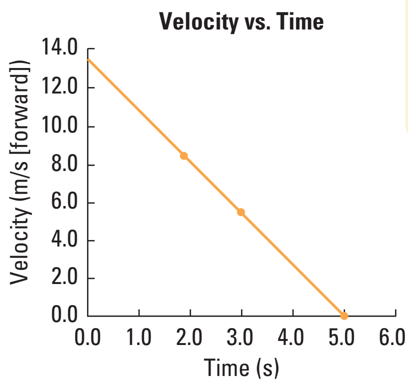


Figure 1.29

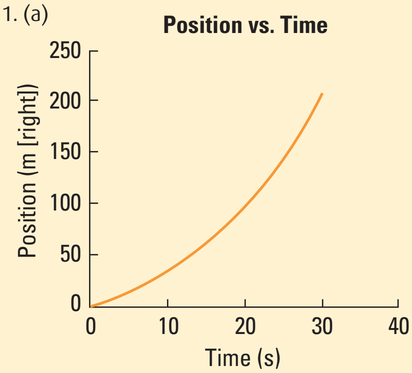
Practice Problems

1. (a) Using the data in the table, draw a position-time graph.
   (b) Draw a velocity-time graph from the position-time graph.

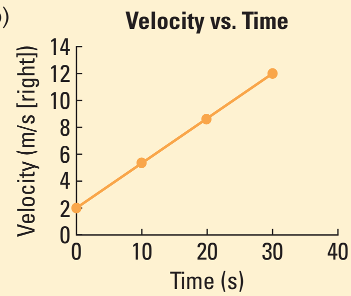
Time (s)	Position (m [right])
0.0	0.0
10.0	35.0
20.0	100.0
30.0	200.0

Answers

1. (a)



(b)

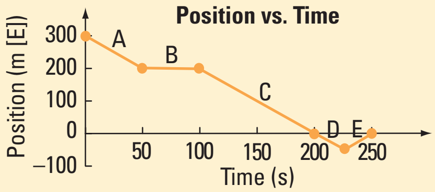


Conversion of Position-time Graphs to Velocity-time Graphs

You have learned that the slope of the straight line position-time graph will give the average velocity of that motion. In the next example, a straight line position-time graph is used to find velocity and draw the velocity-time graph.

Practice Problems

1. A girl is walking to her friend's house (the origin). She starts from her house, stops at a convenience store, and then walks past her friend's house. When she realizes that she has passed her friend's house, she returns to it. The position-time graph for the girl's walk is given below.



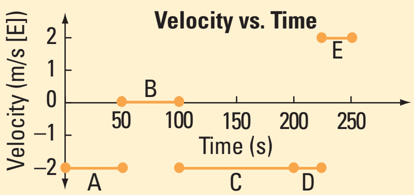
(a) What is the girl's velocity for each part (A, B, C, D, and E) of the walk?

(b) Draw the velocity-time graph for the girl's walk.

Answers

(a) A: −2 m/s, B: 0 m/s, C: −2 m/s, D: −2 m/s, E: 2 m/s

(b)



Example 1.6

A man is walking to his home (the origin). He starts from a nearby crossing, stops to talk to a neighbour, and then walks beyond his home. When he realizes that he has passed his house, he returns to it. For the man's walk, the position-time graph is given below (Figure 1.30). Draw the velocity-time graph for this position-time graph.

Analysis and Solution

For part A of the walk:

$$(\vec{v}_{\text{ave}})_{\text{A}} = \frac{\vec{d}_{\text{f}} - \vec{d}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$$
$$= \frac{10\ \text{m} - 20\ \text{m}}{5\ \text{s} - 0\ \text{s}}$$
$$= -2\ \text{m/s}$$

During the first 5 s, the man walks in the negative direction towards the origin with velocity −2 m/s.

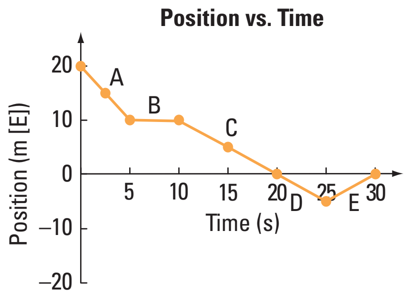


Figure 1.30 Slope of each part of the position-time graph gives the average velocity for that part

For part B of the walk:

$$(\vec{v}_{\text{ave}})_{\text{B}} = \frac{\vec{d}_{\text{f}} - \vec{d}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$$
$$= \frac{10\ \text{m} - 10\ \text{m}}{10\ \text{s} - 5\ \text{s}}$$
$$= 0\ \text{m/s}$$

Between 5 s and 10 s, the man is stationary.

For parts C and D of the walk:

$$(\vec{v}_{\text{ave}})_{\text{C, D}} = \frac{\vec{d}_{\text{f}} - \vec{d}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$$
$$= \frac{-5\ \text{m} - 10\ \text{m}}{25\ \text{s} - 10\ \text{s}}$$
$$= -1\ \text{m/s}$$

Between 10 s and 25 s, the man walks in the negative direction with the velocity of −1 m/s.

For part E of the walk:

$$(\vec{v}_{\text{ave}})_{\text{E}} = \frac{\vec{d}_{\text{f}} - \vec{d}_{\text{i}}}{t_{\text{f}} - t_{\text{i}}}$$
$$= \frac{0\ \text{m} - (-5\ \text{m})}{30\ \text{s} - 25\ \text{s}}$$
$$= 1\ \text{m/s}$$

During the last 5 s, the man walks in the positive direction and reaches the origin (his home).

Paraphrase

The velocity-time graph is shown in Figure 1.31.

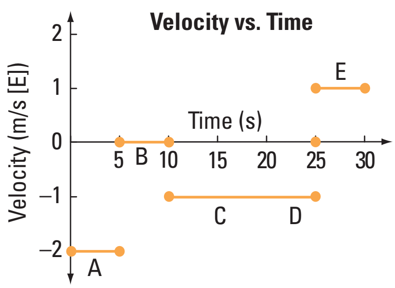


Figure 1.31 Velocity-time graph from position-time graph shown in Figure 1.30

Concept Check

1. If north is positive, sketch position-time and velocity-time graphs for an object
   (a) speeding up and going north
   (b) slowing down and going north
   (c) speeding up and going south
   (d) slowing down and going south

Finding Displacement from Velocity-time Graphs

Occasionally, due to a medical or other emergency, a pilot must turn an aircraft and land at the same or an alternate airport. Consider the graph for the uniform motion of a plane travelling east at 300 km/h for 2.0 h only to turn back west for 0.5 h to make an emergency landing (Figure 1.32). What is the plane's displacement for this time interval? The area under the velocity-time graph gives the displacement.

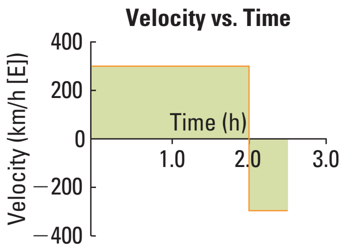


Figure 1.32 To calculate net displacement, add the areas above and below the time axis.

The shapes in Figure 1.32 are rectangles, so the area under the velocity time graph is $l \times w$ (length times width). In this case, find the sum of the areas above and below the time axis. Consider east to be positive. For eastward displacement, the area is above the time axis, so it is positive. For westward displacement, the area is below the time axis, so it is negative.

For eastward displacement (above the time axis),

$$\begin{aligned} \text{area} &= \Delta\vec{d} \\ &= \vec{v}\Delta t \\ &= \left(+300\ \frac{\text{km}}{\cancel{\text{h}}}\right)(2\ \cancel{\text{h}}) \\ &= +600\ \text{km} \end{aligned}$$

For westward displacement (below the time axis),

$$\begin{aligned} \text{area} &= \Delta\vec{d} \\ &= \vec{v}\Delta t \\ &= \left(-300\ \frac{\text{km}}{\cancel{\text{h}}}\right)(0.5\ \cancel{\text{h}}) \\ &= -150\ \text{km} \end{aligned}$$

To find the plane's net displacement, add the two areas.

Net displacement $= +600\ \text{km} + (-150\ \text{km}) = +450\ \text{km}$

Because the net area is positive, the plane's displacement is 450 km [E].

The slope of a position-time graph gives the velocity, and the area under a velocity-time graph gives displacement.

Example 1.7

From the graph in Figure 1.33, calculate displacement.

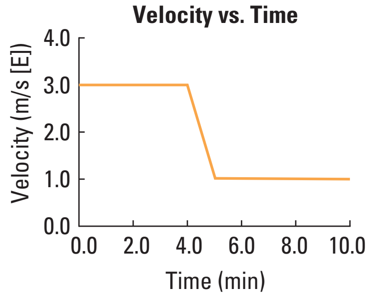


Figure 1.33

Analysis and Solution

For displacement, find the sum of the areas under the velocity-time graph (Figure 1.34). Designate east (above the time axis) as the positive direction. Convert minutes to seconds.

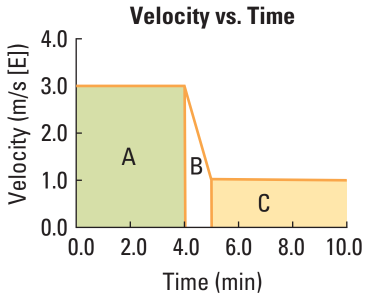


Figure 1.34

Region A:

$$\begin{aligned}\Delta\vec{d}_{\mathrm{A}} &= \vec{v}\Delta t\\ &= \left(+3.0\ \frac{\mathrm{m}}{\mathrm{s}}\right)\left(4.0\ \cancel{\mathrm{min}} \times \frac{60\ \mathrm{s}}{1\ \cancel{\mathrm{min}}}\right)\\ &= \left(+3.0\ \frac{\mathrm{m}}{\cancel{\mathrm{s}}}\right)(240\ \cancel{\mathrm{s}})\\ &= +720\ \mathrm{m}\end{aligned}$$

Region B:

$$\begin{aligned}\Delta\vec{d}_{\mathrm{B}} &= \frac{1}{2}(5.0\ \mathrm{min} - 4.0\ \mathrm{min})\left(\frac{60\ \mathrm{s}}{1\ \mathrm{min}}\right)\left(+3.0\ \frac{\mathrm{m}}{\mathrm{s}} - 1.0\ \frac{\mathrm{m}}{\mathrm{s}}\right) +\\ &\quad \left(+1.0\ \frac{\mathrm{m}}{\mathrm{s}}\right)(5.0\ \mathrm{min} - 4.0\ \mathrm{min})\left(\frac{60\ \mathrm{s}}{1\ \mathrm{min}}\right)\\ &= \frac{1}{2}(1.0\ \cancel{\mathrm{min}})\left(\frac{60\ \cancel{\mathrm{s}}}{1\ \cancel{\mathrm{min}}}\right)\left(+2.0\ \frac{\mathrm{m}}{\cancel{\mathrm{s}}}\right) + \left(+1.0\ \frac{\mathrm{m}}{\cancel{\mathrm{s}}}\right)(1.0\ \cancel{\mathrm{min}})\left(\frac{60\ \cancel{\mathrm{s}}}{1\ \cancel{\mathrm{min}}}\right)\\ &= \frac{1}{2}(120\ \mathrm{m}) + 60\ \mathrm{m}\\ &= +120\ \mathrm{m}\end{aligned}$$

Region C:

$$\begin{aligned}\Delta\vec{d}_{\mathrm{C}} &= \left(+1.0\ \frac{\mathrm{m}}{\mathrm{s}}\right)(10.0\ \mathrm{min} - 5.0\ \mathrm{min})\left(\frac{60\ \mathrm{s}}{1\ \mathrm{min}}\right)\\ &= \left(+1.0\ \frac{\mathrm{m}}{\cancel{\mathrm{s}}}\right)(5.0\ \cancel{\mathrm{min}})\left(\frac{60\ \cancel{\mathrm{s}}}{1\ \cancel{\mathrm{min}}}\right)\\ &= +300\ \mathrm{m}\end{aligned}$$

$$\begin{aligned}\Delta\vec{d} &= \Delta\vec{d}_{\mathrm{A}} + \Delta\vec{d}_{\mathrm{B}} + \Delta\vec{d}_{\mathrm{C}}\\ &= +720\ \mathrm{m} + 120\ \mathrm{m} + 300\ \mathrm{m}\\ &= +1140\ \mathrm{m}\\ &= +1.1 \times 10^{3}\ \mathrm{m}\end{aligned}$$

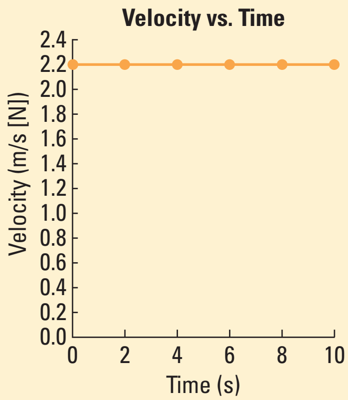
The answer is positive, so the direction of the displacement is east.

Paraphrase

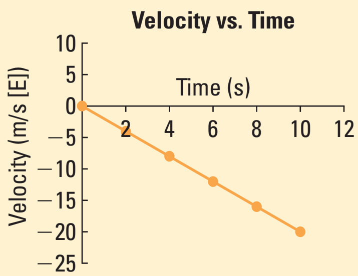
The displacement is 1.1×10^{3} m [E].

Practice Problems

1. Calculate the displacement from the graph.



2. Use the graph below to determine the displacement of the object.



Answers

1. 22 m [N]
2. -1.0×10^{2} m [E] or 1.0×10^{2} m [W]

Drawing Position-time Graphs from Velocity-time Graphs

You can use the information in a velocity-time graph to draw a position-time graph.

Consider the following trip. A family travelling from Calgary to go camping in Banff National Park moves at 18.0 m/s [forward] in a camper van. The van accelerates for 4.0 s until it reaches a velocity of 30.0 m/s [forward]. It continues to travel at this velocity for 25.0 s. When approaching a check stop, the driver brakes, bringing the vehicle to a complete stop in 15.0 s. The velocity-time graph for the trip is given in Figure 1.35. Sketch a position-time graph for this trip.

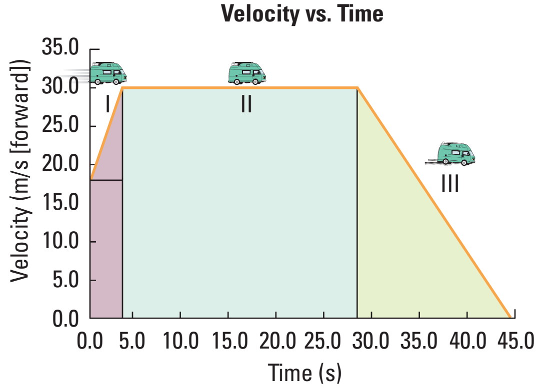


Figure 1.35 The complete graph of the van's motion

To sketch the position-time graph, find the area under the velocity-time graph. Consider forward to be positive. In the first part of the velocity-time graph (0.0–4.0 s), the area (displacement) is made up of a rectangle and a triangle. The displacement is positive because the areas are above the time-axis.

$$A = l \times w + \frac{1}{2}bh$$

$$\begin{aligned}\Delta\vec{d} &= \left(+18.0\ \frac{\text{m}}{\text{s}}\right)(4.0\ \text{s}) + \frac{1}{2}(4.0\ \text{s})\left(30.0\ \frac{\text{m}}{\text{s}} - 18.0\ \frac{\text{m}}{\text{s}}\right)\\ &= +96\ \text{m}\end{aligned}$$

Since the velocity is positive and is increasing, the corresponding position-time graph is curved upward. On the position-time graph, sketch a curve from the origin to the point $t = 4.0$ s and $d = 96$ m (Figure 1.36(a)).

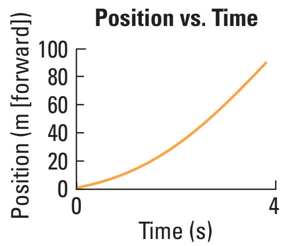


Figure 1.36(a) Part I of the trip

In the second part of the velocity-time graph (4.0–29.0 s), displacement is a rectangle. It is positive since the area is above the time-axis.

$$A = l \times w$$

$$\begin{aligned}\Delta\vec{d} &= \left(+30\ \frac{\text{m}}{\text{s}}\right)(29\ \text{s} - 4\ \text{s})\\ &= +750\ \text{m}\end{aligned}$$

Since the velocity-time graph has zero slope in this section, the car moves with constant velocity and the position-time graph is a straight line with a positive slope that extends from

$t = 4.0$ s and $d = +96$ m to
$t = 29.0$ s and $d = 96$ m $+$ 750 m $=$ 846 m (Figure 1.36(b))

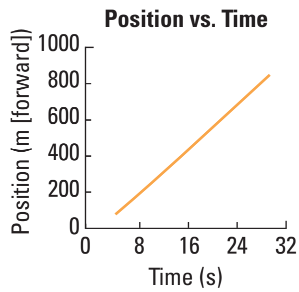


Figure 1.36(b) Part II of the trip

In the third part of the velocity-time graph (29.0–44.0 s), displacement is a triangle. It is positive since the area is above the time-axis.

$$A = \frac{1}{2}bh$$

$$\begin{aligned}\Delta d &= +\frac{1}{2}(44.0\ \text{s} - 29.0\ \text{s})\left(30.0\ \frac{\text{m}}{\text{s}}\right)\\ &= +225\ \text{m}\end{aligned}$$

Since the velocity-time graph has a negative slope, the slopes of the tangents of the position-time graph decrease (approach zero). The position-time graph is a parabola, from

$t = 29.0$ s and $d = +846$ m to
$t = 44.0$ s and $d = 846$ m $+$ 225 m $=$ 1071 m (Figure 1.36(c))

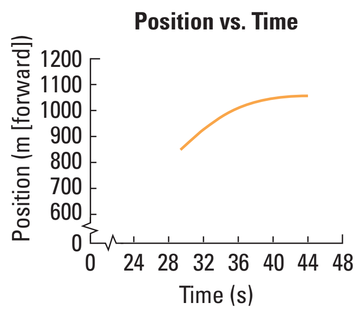


Figure 1.36(c) Part III of the trip

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Suggested Activity

- A4 Inquiry Activity Overview on page 24

Take It Further

In November 2004, at an altitude of 33 000 m, the X-43A recorded a speed of Mach 9. Research the term "Mach" as used to describe the speed of an object. How did this term originate? What is the difference between Mach and hypersonic? Write a brief summary of your findings.

The resulting position-time graph is shown in Figure 1.37.

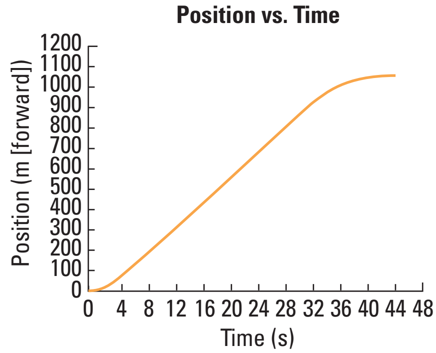

Figure 1.37 The complete position-time graph of the trip

A3 Quick Lab

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Instantaneous Velocity

Purpose

To understand curved position-time graphs and changes in velocity during the motion

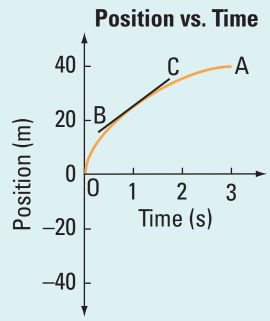

Figure 1.38

Activity Overview

In this Quick Lab, you will determine the slopes of the tangents to a number of points on a position-time graph (Figure 1.38). You will then use this data to draw the corresponding velocity-time graph.

Your teacher will give you a copy of the full activity.

Prelab Questions

Consider the questions below before beginning this activity.

1. Explain the difference between average velocity and instantaneous velocity.
2. When is it important to know the instantaneous velocity of a vehicle?

A4 Inquiry Activity

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REQUIRED SKILLS
- Measuring
- Analyzing patterns

Car Activity

Question

What are the speeds of two different toy cars? If one car is released 3.0 s after the other, where will they meet?

Activity Overview

In this activity, you will use ticker tape to determine the speeds of two different toy cars (Figure 1.39). You will then determine where the cars will meet if the faster car is released 3.0 s after the slower car.

Your teacher will give you a copy of the full activity.

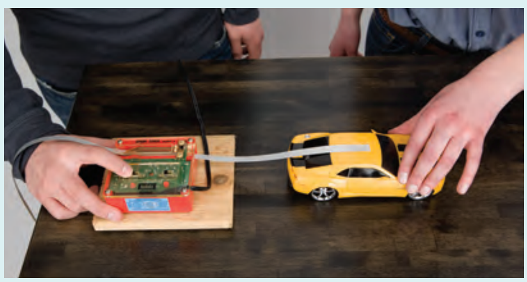


Figure 1.39 Setup for the activity

Prelab Questions

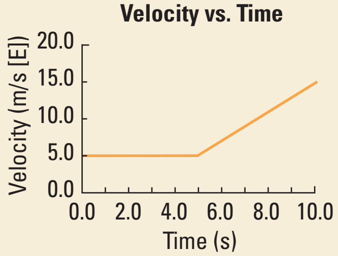
Consider the questions below before beginning this activity.

1. What does the slope of a position-time graph represent?
2. A position-time graph represents the motions of two cars. Which is the faster moving car? Explain.

1.2 Check and Reflect

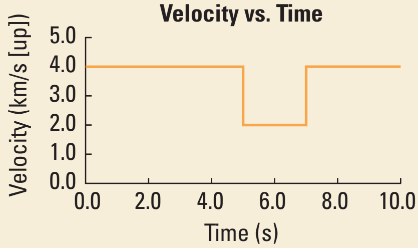
Key Concept Review

1. What is the relationship between the slope of a position-time graph and velocity?
2. If a velocity-time graph is a straight line with a non-zero slope, what kind of motion is the object undergoing?
3. Two friends start walking on a football field in the same direction. Person A walks twice as fast as person B. However, person B has a head start of 20.0 m. If person A walks at 3.0 m/s, find the distance between the two friends after walking for 20.0 s and determine who is ahead at this time. Sketch a position-time graph for both people.
4. A cyclist travels 11 km [N] from a refreshment stand, stops, and then travels 27 km [S]. What is the cyclist's final position with respect to the refreshment stand?
5. Sketch a position-time graph for a bear starting 1.2 m from a reference point, walking slowly away at constant velocity for 3.0 s, stopping for 5.0 s, backing up at half the speed for 2.0 s, and finally stopping.
6. Determine the displacement of the object whose motion is described by the following graph



Question 6

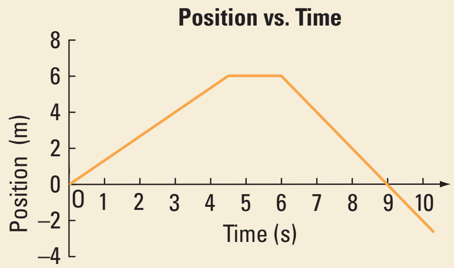
7. Calculate displacement from the velocity-time graph below.



Question 7

Connect Your Understanding

8. Two children on racing bikes start from the same reference point. Child A travels 5.0 m/s [right] and child B travels 4.5 m/s [right]. How much farther from the point of origin is child A than child B after 5.0 s?
9. Insect A moves 5.0 m/min and insect B moves 9.0 cm/s. Determine which insect is ahead and by how much after 3.0 min. Assume both insects are moving in the same direction.
10. Spotting a friend 5.0 m directly in front of you, walking 2.0 m/s [N], you start walking 2.25 m/s [N] to catch up. How long will it take for you to intercept your friend and what will be your displacement?
11. Two vehicles, separated by a distance of 450 m, travel in opposite directions toward a traffic light. When will the vehicles pass one another if vehicle A is travelling 35 km/h and is 300 m [E] of the traffic light while vehicle B is travelling 40 km/h? When will each vehicle pass the traffic light, assuming the light remains green the entire time?
12. A person runs 10.0 m [E] in 2.0 s, then 5.0 m [E] in 1.5 s, and finally 30.0 m [W] in 5.0 s.
    (a) Find the person's average velocity.
    (b) Draw the velocity-time graph.
13. For the graph given below:
    (a) Describe the motion of the object.
    (b) Draw the corresponding velocity-time graph.
    (c) Determine the object's displacement.



Question 13

Reflection

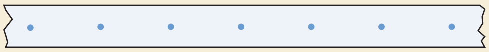
14. Explain why you think that it is important for you to learn about velocity.

For more questions, go to PHYSICS•SOURCE

CHAPTER REVIEW

Key Concept Review

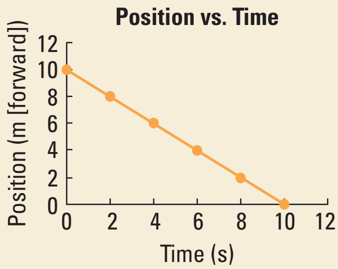
1. Compare and contrast distance and displacement. k
2. What is the significance of a reference point? k
3. Complete a position-time data table for the motion described by the ticker tape given below. k



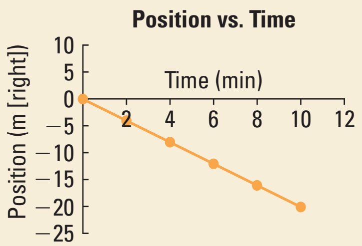
Question 3

4. Determine the velocity of each object whose motion is represented by the graphs below. k

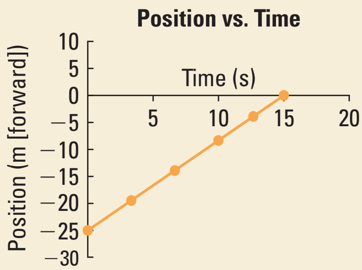
(a)



(b)

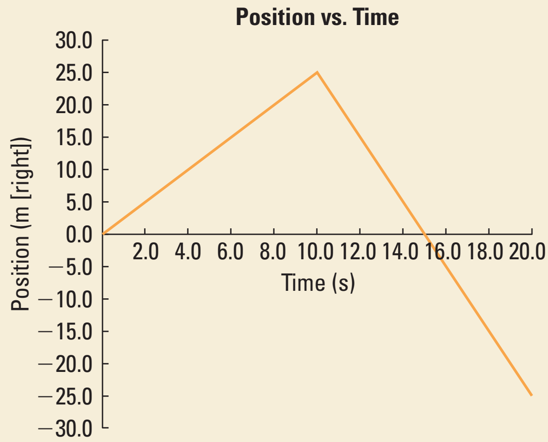


(c)



Question 4(a), (b), (c)

5. Sketch a position-time graph for a student
   (a) walking east to school with a constant velocity k
   (b) stopping at the school, which is 5 km east of home k
   (c) cycling home with a constant velocity k
6. What quantity of motion can be determined from the area under a velocity-time graph? k
7. Determine the average speed, average velocity, and net displacement from the position-time graph below. k



Question 7

8. Explain how a person standing still could have the same average velocity but different average speed than a person running around a circular track. t

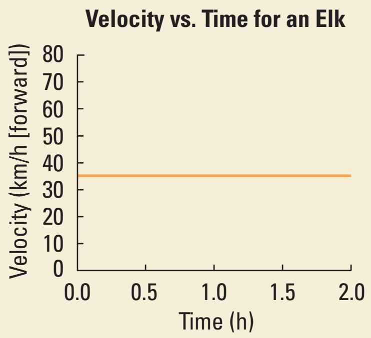
Connect Your Understanding

9. Draw a seating plan using the statements below.
   (a) Chad is 2.0 m [left] of Dolores. a
   (b) Ed is 4.5 m [right] of Chad. a
   (c) Greg is 7.5 m [left] of Chad. a
   (d) Hannah is 1.0 m [right] of Ed. a
   (e) What is the displacement of a teacher who walks from Greg to Hannah? a
10. A mosquito flies toward you with a velocity of 2.4 km/h [E]. If a distance of 35.0 m separates you and the mosquito initially, at what point (distance and time) will the mosquito hit your sunglasses if you are travelling toward the mosquito with a speed of 2.0 m/s and the mosquito is travelling in a straight path? a
11. In 1980, during the Marathon of Hope, Terry Fox ran 42 km [W] a day. Assuming he ran for 8.0 h a day, what was his average velocity in m/s? a

ACHIEVEMENT CHART CATEGORIES

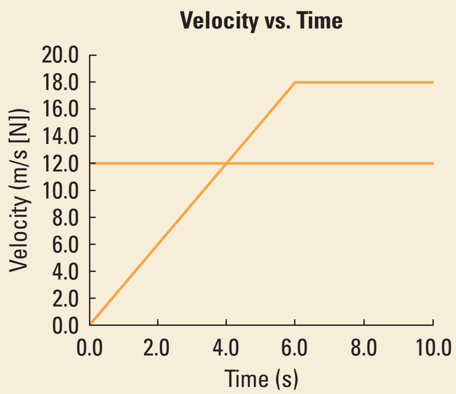
k Knowledge and understanding · t Thinking and investigation
c Communication · a Application

12. From the velocity-time graph below, determine how far an elk will travel in 30 min. a



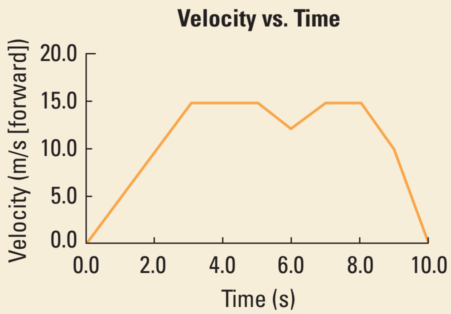
Question 12

13. Two cars pass one another while travelling on a city street. Using the velocity-time graph below, draw the corresponding position-time graph and determine when and where the two cars pass one another. Assume both cars start at position 0.0 m [N] and time 0.0 s. t



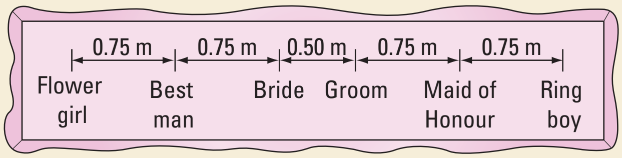
Question 13

14. Describe the motion of the truck from the velocity-time graph below. When is the truck at rest? travelling with a uniform velocity? c



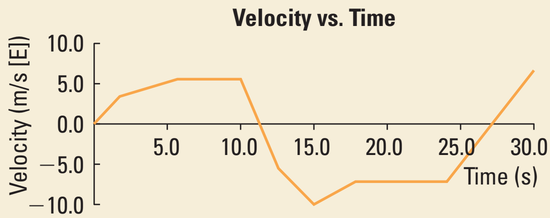
Question 14

15. Below is a seating plan for the head table at a wedding reception. Relative to the bride, describe the positions of the groom, best man, maid of honour, and flower girl. c



Question 15

16. Describe the motion of the object illustrated in the graph below. t



Question 16

17. Guy runs 100 m in 11.85 s, Jane runs 200 m in 24.12 s, and Terry runs 300 m in 39.18 s. Find the average velocity for the trio. Compare it to each individual's average velocity. Assume they are all running in a straight line. a

Reflection

18. (a) Describe one concept from this chapter that you found easy to understand. c

(b) Why do you think it was easy for you to understand? c

(c) Describe one concept from this chapter that you found challenging to understand. c

Unit Task Link

Designing a traffic light system is a very complex procedure. The timing of the green and red lights at any time is determined by the speed limit and the number of cars that are expected to pass through the intersection at that time. Explore and list the variables and factors that must be considered when designing a traffic light system. Share your ideas with the class.

For more questions, go to PHYSICS•SOURCE