Section 1: Measuring Motion

Preview

Key Ideas

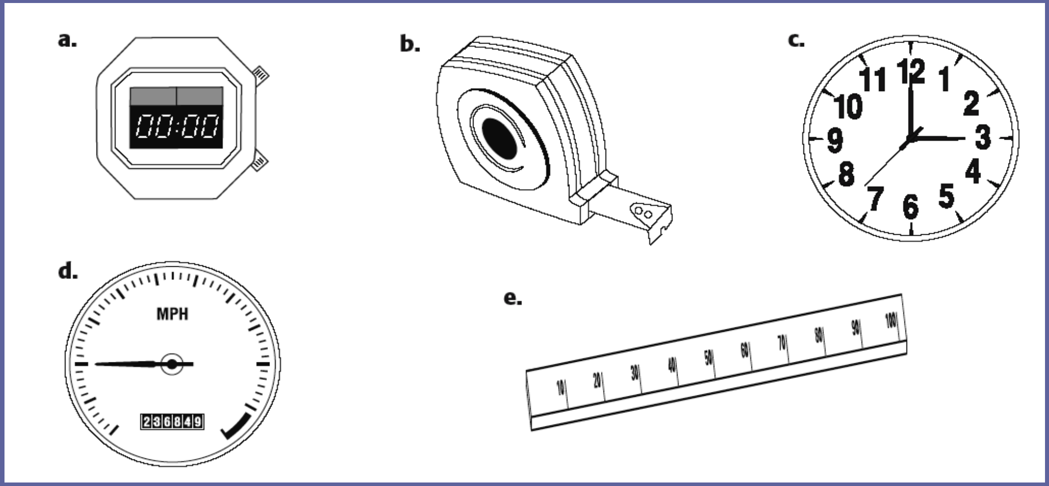
- How is a frame of reference used to describe motion?
- What is the difference between speed and velocity?
- What do you need to know to find the speed of an object?
- How can you study speed by using graphs?

Bellringer

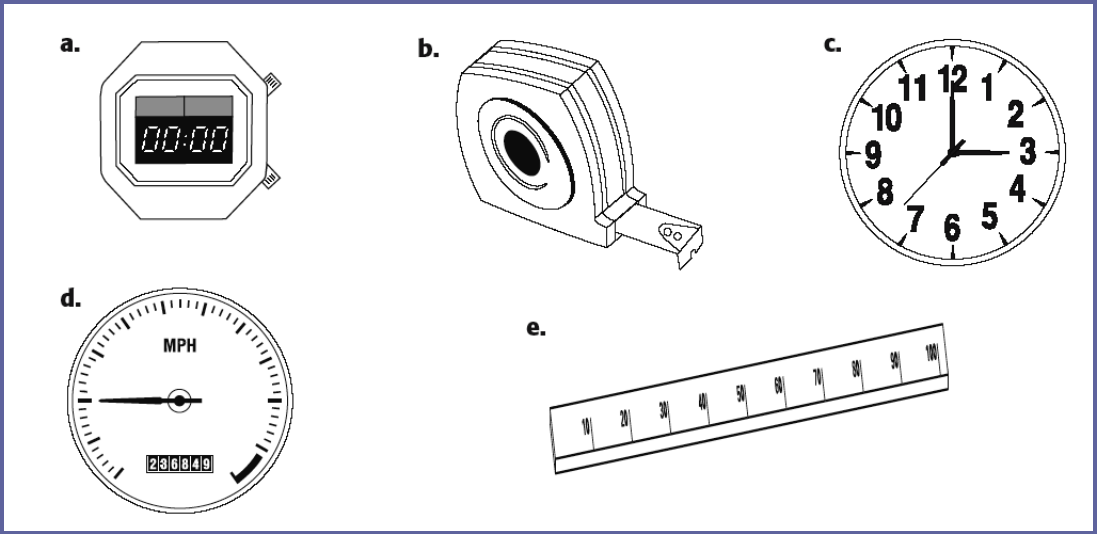
Everybody knows what motion is, but how do you measure it?

- One way is to measure distance, or how far something goes during a motion.
- Another is to measure time, or how long a motion takes to occur.
- A third way is to measure speed, or how fast something is moving.

Each of the devices shown below can be used to measure some aspect of motion.



Bellringer, *continued*



1. For each of the devices above, indicate whether it measures distance, time, or speed.
2. For each of the devices above, indicate which of the following units are possible for a measurement: meters (m), seconds (s), or meters per second (m/s).

Observing Motion

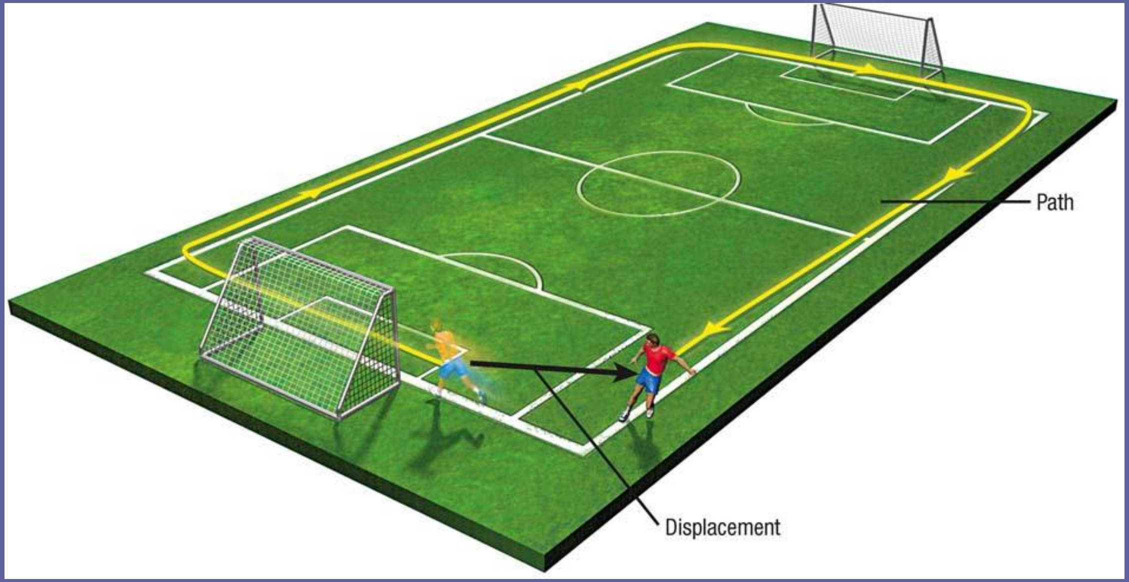
- How is a frame of reference used to describe motion?

- When an object changes position with respect to a frame of reference, the object is in motion.

- **motion:** an object's change in position relative to a reference point
- **frame of reference:** a system for specifying the precise location of objects in space and time

Observing Motion, *continued*

- Distance measures the path taken.
- Displacement is the change of an object's position.
  - **displacement:** the change in position of an object
  - always includes direction
- In the diagram:
  - yellow line = distance
  - black arrow = displacement



Speed and Velocity

- What is the difference between speed and velocity?
- Speed tells us how fast an object moves, and velocity tells us both the speed and the direction that the object moves.

- **speed:** the distance traveled divided by the time interval during which the motion occurred
- **velocity:** the speed of an object in a particular direction

Speed and Velocity, *continued*

- Velocity is described relative to a reference point.
  - Direction is described as positive or negative along the line of motion.
  - By convention, up and right are usually positive, and left and down are negative.
- Combined velocities determine the resultant velocity.

Calculating Speed

- What do you need to know to find the speed of an object?

- To calculate speed, you must measure two quantities: the distance traveled and the time it took to travel that distance.

Calculating Speed, *continued*

- Average speed is calculated as distance divided by time.

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ or } v = \frac{d}{t}$$

- SI unit for speed: meters per second (m/s)
- *constant speed*: equal distances in equal amounts of time
- *instantaneous speed:* the speed at a given time

Math Skills

Velocity

Metal stakes are sometimes placed in glaciers to help measure a glacier's movement. For several days in 1936, Alaska's Black Rapids glacier surged as swiftly as 89 meters per day down the valley. Find the glacier's velocity in m/s. Remember to include direction.

1. List the given and the unknown values.

Given: *time, t* = 1 day

distance, d = 89 m down the valley

Unknown: *velocity, v* = ? (m/s and direction)

Math Skills, *continued*

2a. Perform any necessary conversions.

To find the velocity in meters per second, the value for time must be in seconds.

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ or } v = \frac{d}{t}$$

t = 86 400 s = 8.64×10^4 s

Math Skills, *continued*

2b. Write the equation for speed.

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{ or } v = \frac{d}{t}$$

3. Insert the known values into the equation, and solve.

$$v = \frac{d}{t} = \frac{89 \text{ m}}{8.64 \times 10^4 \text{ s}} \quad \text{(For velocity, include direction.)}$$

$$\boxed{v = 1.0 \times 10^{-3} \text{ m/s down the valley}}$$

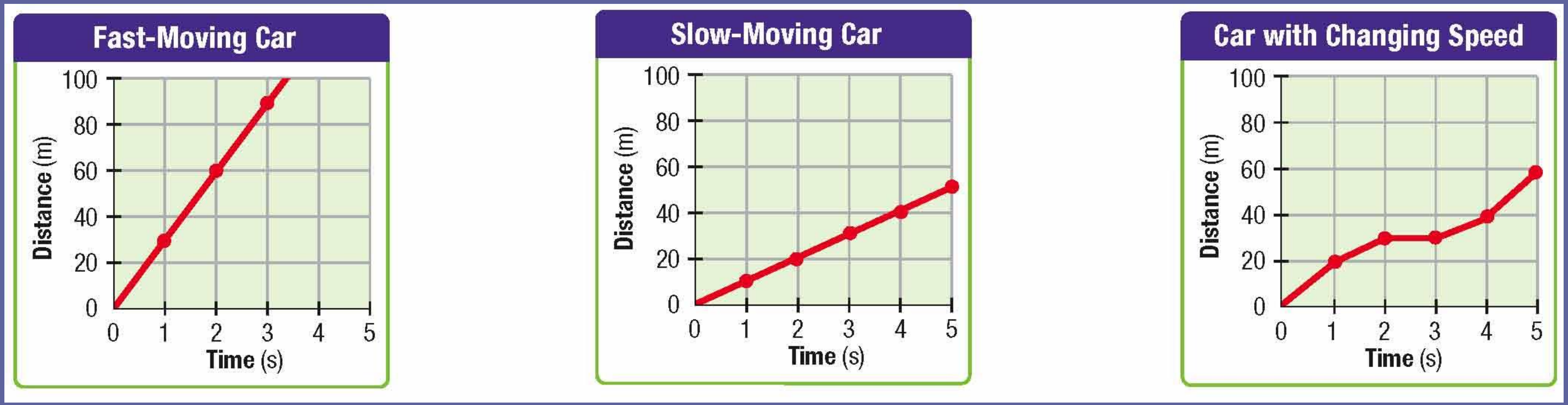
Graphing Motion

- How can you study speed by using graphs?

- You can plot a graph showing distance on the vertical axis and time on the horizontal axis.

Graphing Motion, *continued*

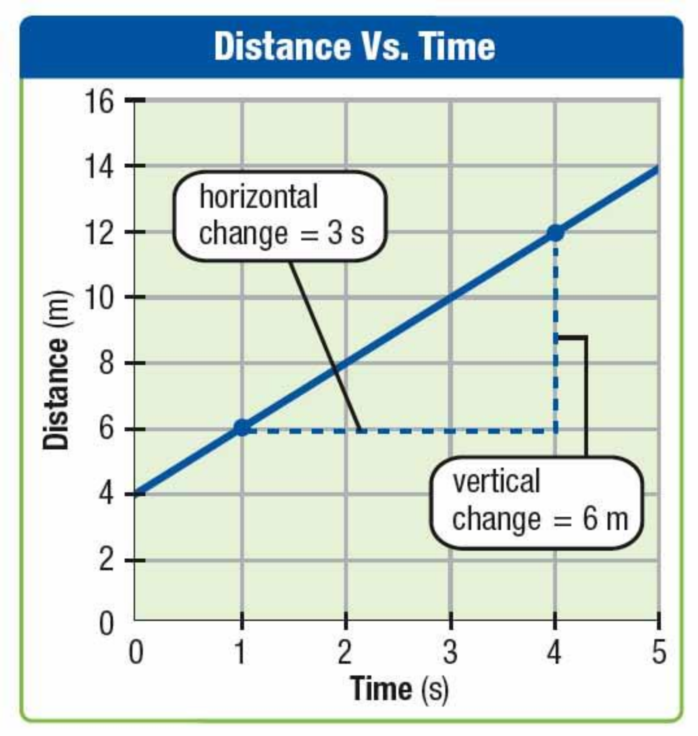
- Motion can be studied using a distance vs. time graph.
  - time (*x*-axis) = independent variable
  - distance (*y*-axis) = dependent variable
- The slope of a distance vs. time graph equals speed.



Graphing Skills

Calculating Slope

The slope of a straight line equals the vertical change divided by the horizontal change. Determine the slope of the blue line shown in the distance vs. time graph.



Graphing Skills, *continued*

1. **Choose two points that you will use to calculate the slope.**

   Point 1: t = 1 s and d = 6 m

   Point 2: t = 4 s and d = 12 m

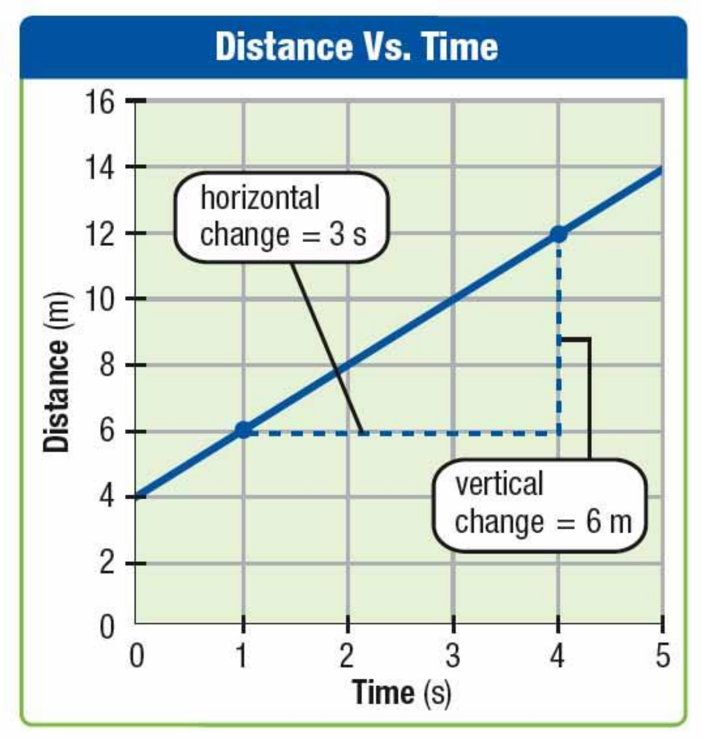
2. **Calculate the vertical change and the horizontal change.**

   vertical change = 12 m – 6 m = 6 m

   horizontal change = 4 s – 1 s = 3 s

3. **Divide the vertical change by the horizontal change.**

   slope = 6 m /3 s = 2 m/s



Section 2: Acceleration

Preview

Key Ideas

- What changes when an object accelerates?
- How do you calculate the acceleration of an object moving in a straight line?
- How can a graph be used to find acceleration?

Bellringer

In your study of velocity, you learned it involves both the speed of an object and the direction that the object is traveling.

1. Which of the following examples shows a change in velocity? Remember a change in velocity can be either a change in speed or a change in the direction of motion. Briefly explain your answers.

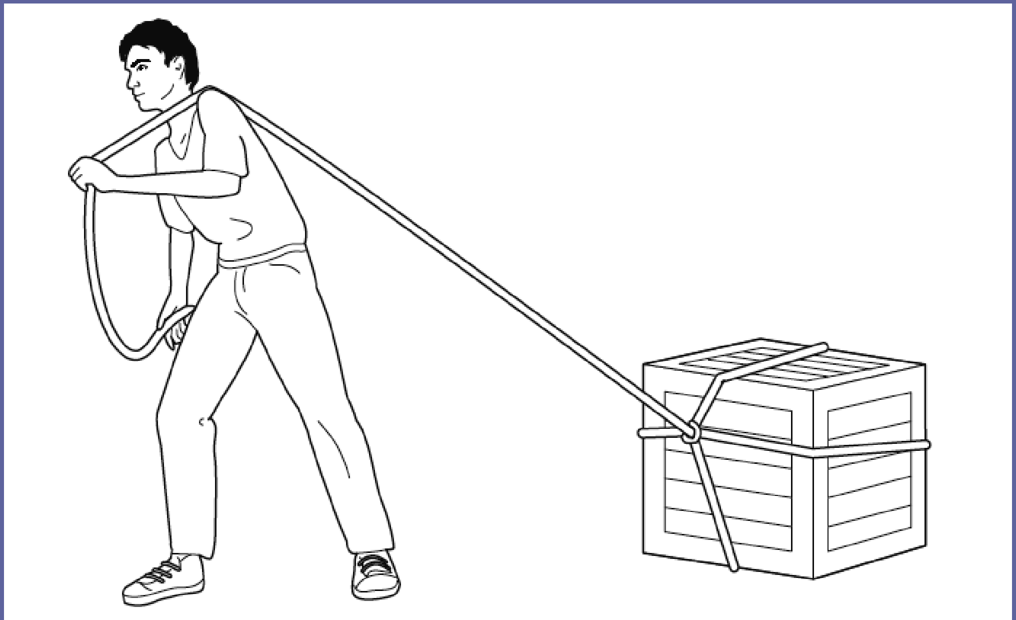
a. a car coming to a stop at a stop sign

b. a book sitting on a desk

c. a yo-yo in motion

d. a bicyclist making a left-hand turn at exactly 15 km/h

Bellringer, *continued*



2. In the picture shown above, a student pulls on a box with a rope. If the box is originally not moving, will its velocity increase or stay the same? In which direction (if any) will the velocity be after the student pulls on the box with the rope?

Acceleration and Motion

- What changes when an object accelerates?
- When an object undergoes acceleration, its velocity changes.

- **acceleration:** the rate at which velocity changes over time; an object accelerates if its speed, direction, or both change

Acceleration and Motion, *continued*

- Acceleration can be a change in speed.
  - An increase or decrease in speed is an acceleration.

- Acceleration can also be a change in direction.
  - A motorcyclist who rides around the inside of a large barrel is constantly accelerating.
  - A person riding a Ferris wheel at an amusement park is accelerating.

- The acceleration that occurs in circular motion is known as *centripetal acceleration.*

Calculating Acceleration

- How do you calculate the acceleration of an object moving in a straight line?

- The average acceleration over a given time interval can be calculated by dividing the change in the object's velocity by the time over which the change occurs.

- $$\text{average acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

- $$a = \frac{v_f - v_i}{t} = \frac{\Delta v}{t}$$

Back Next Preview Main

 Credits License Agreement

Calculating Acceleration, *continued*

- Acceleration is the rate at which velocity changes.
  - In this book, for straight-line motion, a positive acceleration means that the object’s velocity is increasing—the object is speeding up.
  - Negative acceleration means that the object’s velocity is decreasing—the object is slowing down.
  - SI units of acceleration = meters per second per second (m/s/s), or m/s^2

Math Skills

Acceleration

A flowerpot falls off a second-story windowsill. The flowerpot starts from rest and hits the sidewalk 1.5 s later with a velocity of 14.7 m/s. Find the average acceleration of the flowerpot.

1. List the given and the unknown values.

Given: *time, t* = 1.5 s

initial velocity, v_i = 0 m/s

final velocity, v_f = 14.7 m/s down

Unknown: *acceleration, a* = ? (m/s^2 and direction)

Math Skills, *continued*

2. Write the equation for acceleration.

$$acceleration = \frac{final\ velocity - initial\ velocity}{time} = \frac{v_f - v_i}{t}$$

3. Insert the known values into the equation, and solve.

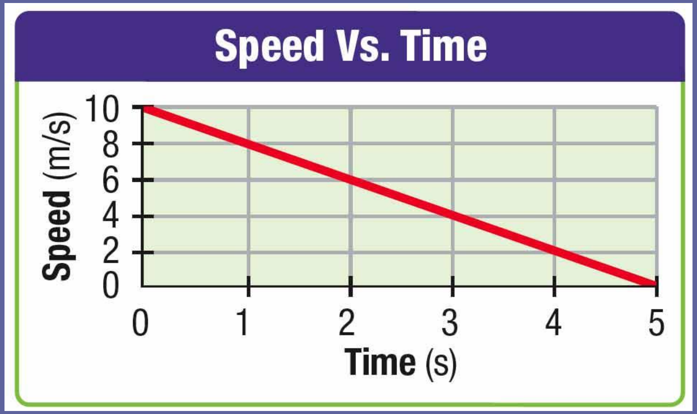
$$a = \frac{v_f - v_i}{t} = \frac{14.7\ \text{m/s} - 0\ \text{m/s}}{1.5\ \text{s}}$$

$$a = \frac{14.7\ \text{m/s}}{1.5\ \text{s}} = \boxed{9.8\ \text{m/s}^2\ \text{down}}$$

Graphing Accelerated Motion

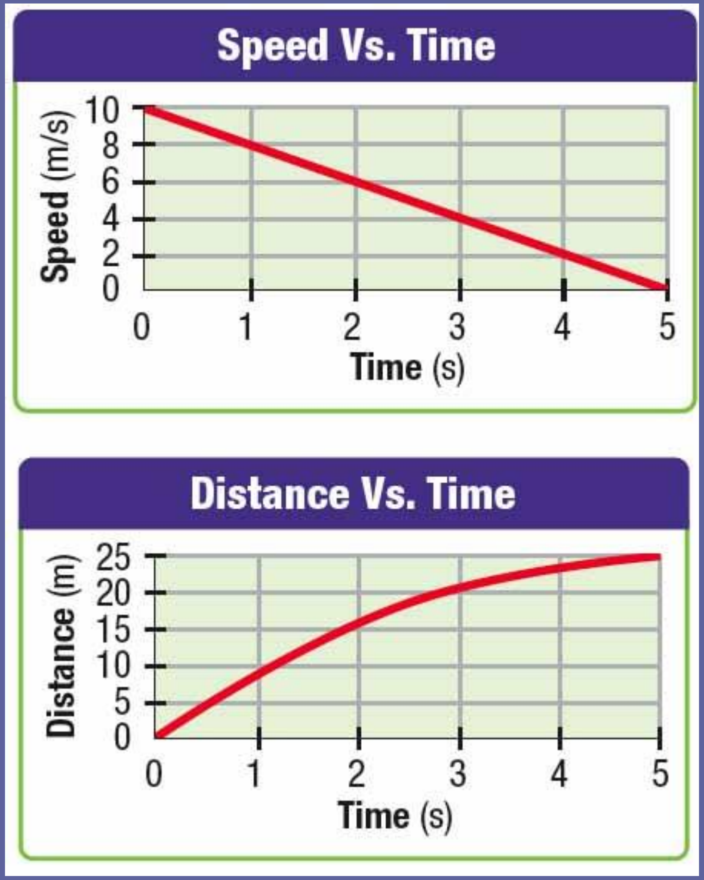
- How can a graph be used to find acceleration?

- The slope of a straight line on a speed vs. time graph is equal to the acceleration.



Graphing Accelerated Motion, *continued*

- Acceleration can also be seen on a distance vs. time graph.
  - The distance vs. time graph is not a straight line when the velocity is not constant.
  - This curved line indicates that the object is under acceleration



Graphing Skills

Graphing Acceleration

A bus traveling on a straight road at 20 m/s uniformly slows to a stop over 20 s. The bus remains stopped for 20 s, then accelerates at a rate of 1.5 m/s^2 for 10 s, and then continues at a constant speed. Graph speed vs. time for 60 s. What is the bus's final speed?

1. **Determine the *x*-axis and the *y*-axis of your graph.**

   The *x*-axis will indicate time, *t*, measured in s. The *y*-axis will indicate speed, *v*, measured in m/s.

Graphing Skills, *continued*

2. Starting from the origin, graph each section of the motion.

A. Draw and connect the first two points:

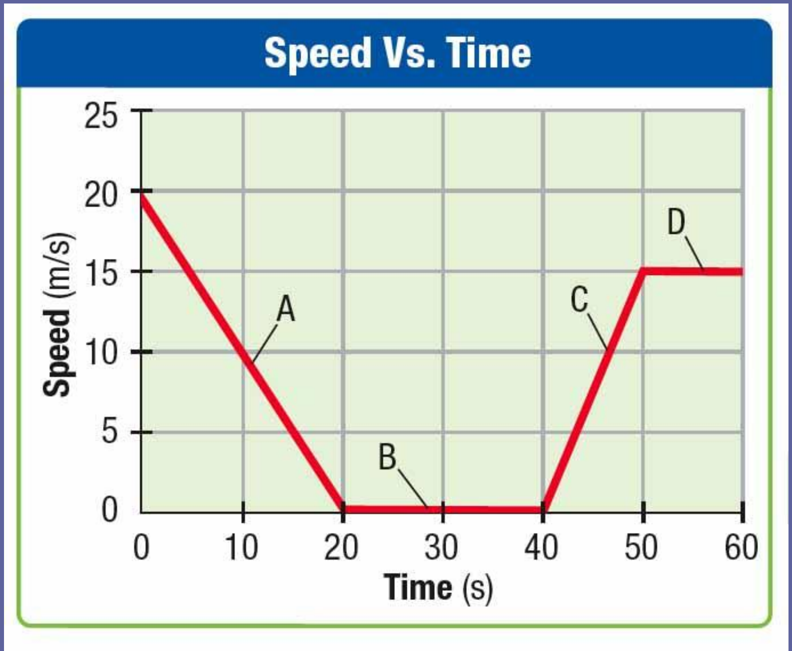
t = 0 s, v = 20 m/s

t = 20 s, v = 0 m/s

B. Draw a horizontal line from t = 20 s to t = 40 s at v = 0 m/s.

C. Starting at t = 40 s and v = 0 m/s, draw a line with a slope of 1.5 m/s^2.

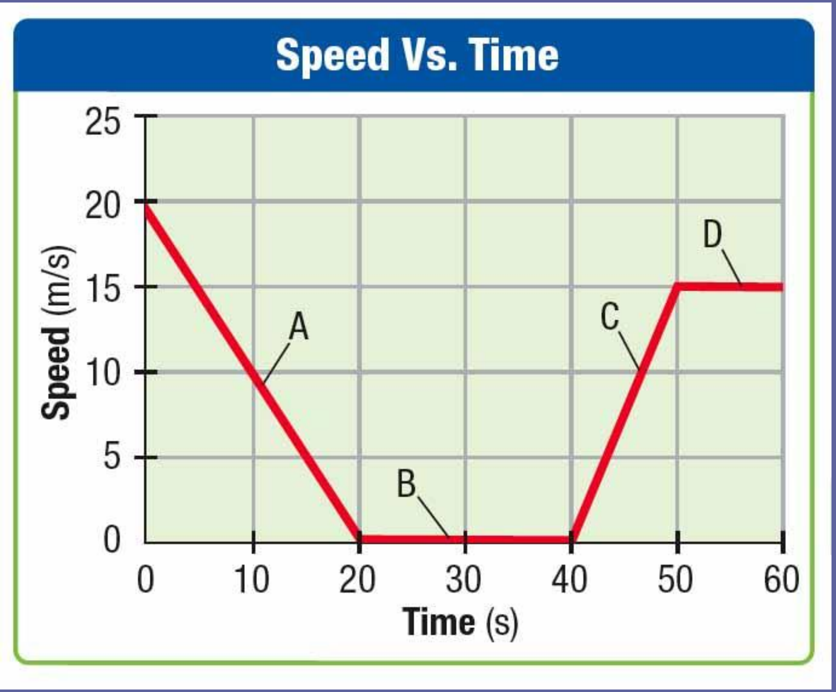
D. Draw a horizontal line from t = 50 s to t = 60 s at v = 15 m/s.



Graphing Skills, *continued*

3. Read the graph to find the final speed.

At time t = 60 s, the speed is 15 m/s.



Section 3: Motion and Force

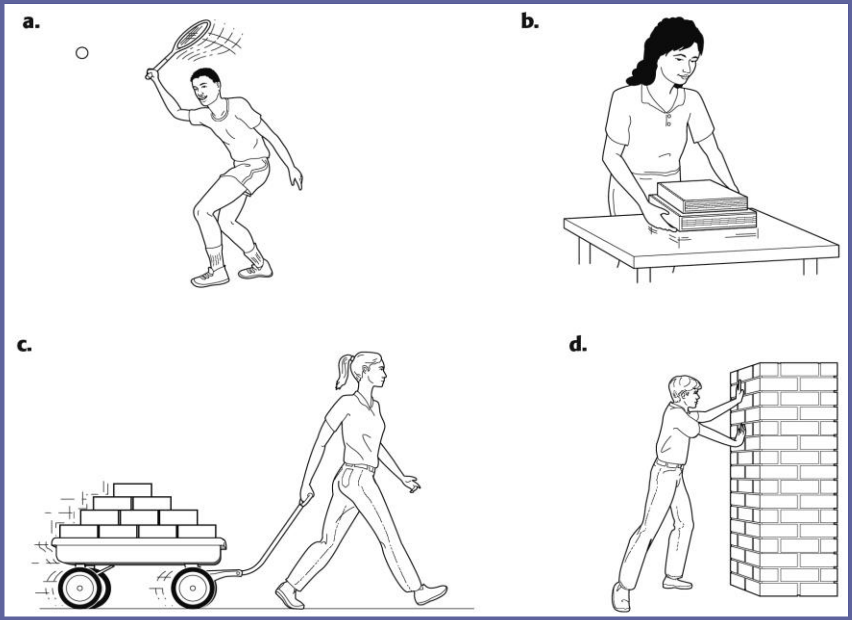
Preview

Key Ideas

- What do scientists identify as the fundamental forces of nature?
- What happens when there is a net force acting on an object?
- What force always opposes motion?
- Why is friction sometimes necessary?

Bellringer

In some cases, an applied force is balanced by an opposite force, and there is no change in motion. In other cases, an applied force is not balanced by an opposite force, and the result is acceleration in the direction of the applied force. Look at the following illustrations, and identify the forces and motion in each one.



Bellringer, *continued*

1. In one drawing, no motion is likely to occur. Which drawing is it?
2. In which diagram are the forces clearly balanced? How does this relate to your answer to item 1? If more force is exerted by the person, does the opposite force increase to match the new force, stay the same, or decrease?
3. Suppose there is enough friction in the wheels of the wagon in diagram c to balance the force with which the wagon is pulled. How will this affect the motion of the wagon?

Fundamental Forces

- What do scientists identify as the fundamental forces of nature?
- These forces are the force of gravity, the electromagnetic force, the strong nuclear force, and the weak nuclear force.
  - The strong and weak nuclear forces act only over a short distance.
  - The force of gravity is a force that you feel every day.
  - Other everyday forces, such as friction, are a result of the electromagnetic force.

Fundamental Forces, *continued*

- Fundamental forces vary in strength.
  - The fundamental forces vary widely in strength and the distance over which they act.
- Forces can act through contact or at a distance.
  - Pushes and pulls are examples of *contact forces.*
  - *Field forces* (like the force of gravity) do not require that the objects touch each other.
  - Both contact and field forces can cause an object to move or to stop moving.

Balanced and Unbalanced Forces

- What happens when there is a net force acting on an object?
- Whenever there is a net force acting on an object, the object accelerates in the direction of the net force.

- *net force:* the combination of all forces acting on an object

Balanced and Unbalanced Forces, *continued*

- Balanced forces do not change motion.
  - Forces are balanced when the net force is zero.
  - Example: For a light hanging from the ceiling (at rest), the upward force due to tension in the cord balances the downward force of gravity.

Balanced and Unbalanced Forces, *continued*

- Unbalanced forces do not cancel completely.
  - Forces are unbalanced when the net force is greater than zero.
  - The object will accelerate in the direction of the net force.
  - Example: If you push a box to the east and your friend pushes the box to the north, the box will accelerate in a northeasterly direction.

The Force of Friction

- What force always opposes motion?
- The force of friction always opposes the motion.

- **friction:** a force that opposes motion between two surfaces that are in contact

The Force of Friction, *continued*

- Static friction is greater than kinetic friction.
  - **static friction:** the force that resists the initiation of sliding motion between two surfaces that are in contact and at rest
  - **kinetic friction:** the force that opposes the movement of two surfaces that are in contact and are moving over each other

The Force of Friction, *continued*

- Not all kinetic friction is the same.
  - *sliding friction:* when objects slide past each other
  - *rolling friction:* when a rounded object rolls over a flat surface
  - in general, rolling friction < sliding friction

Friction and Motion

- Why is friction sometimes necessary?
- Friction is necessary for many everyday tasks to work correctly.

Friction and Motion, *continued*

- Unwanted friction can be lowered.
  - using low-friction materials, such as nonstick coatings on cooking pans
  - using *lubricants,* such as motor oil, wax, and grease
- Helpful friction can be increased.
  - scattering sand on icy roads to keep cars from skidding
  - wearing textured batting gloves when playing baseball to make it easier to grip the bat

Friction and Motion, *continued*

- Cars could not move without friction.
  - Without friction between the tires and the road, the tires would not be able to push against the road and the car would not move forward.
  - The force pushing the car forward must be greater than the force of friction that opposes the car's motion.
  - Because of friction, a constant force must be applied to a car just to keep it moving at the same speed.

Friction and Motion, *continued*