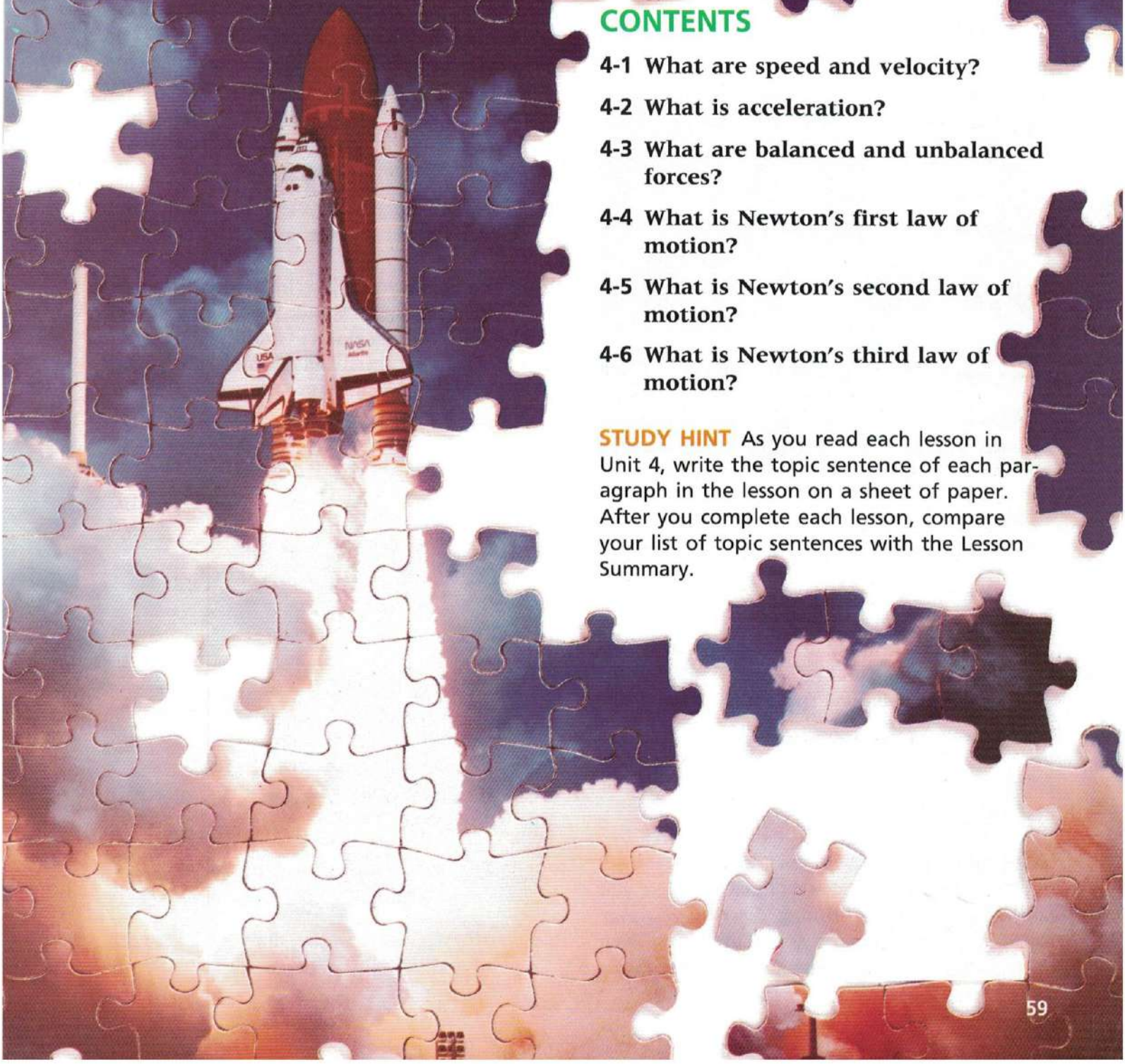
MOTION

UNIT 4



CONTENTS

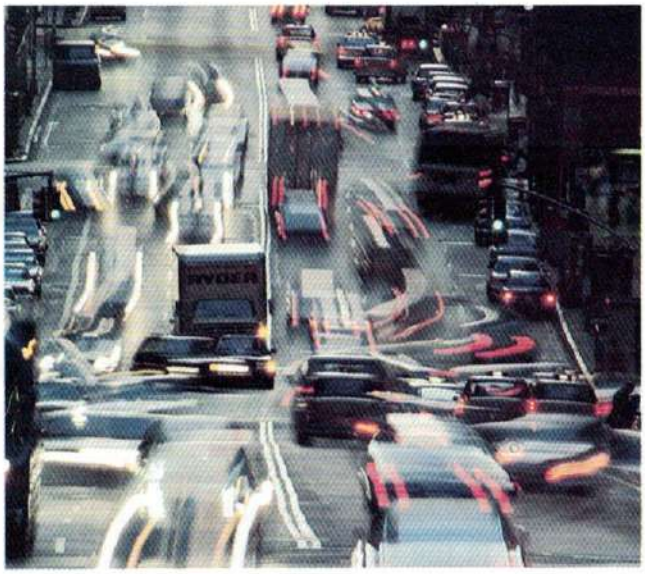
STUDY HINT As you read each lesson in Unit 4, write the topic sentence of each paragraph in the lesson on a sheet of paper. After you complete each lesson, compare your list of topic sentences with the Lesson Summary.

4-1 What are speed and velocity?

Objective ▸ Differentiate between speed and velocity.

TechTerms

- **motion:** change in position
- **speed:** distance traveled per unit of time
- **velocity** (vuh-LAHS-uh-tee): speed and direction



Motion and Speed Many of the things you see around you are in **motion.** Motion is a change in position. When you move from place to place, you cover a certain distance. Distance is measured in meters or kilometers. The time it takes you to cover a certain distance is called **speed.** If you travel 50 km in one hour, your speed is 50 km/hr. The equation for finding speed is

speed = distance/time

Calculate: At a speed of 80 km/hr, how far will you go in 3 hr?

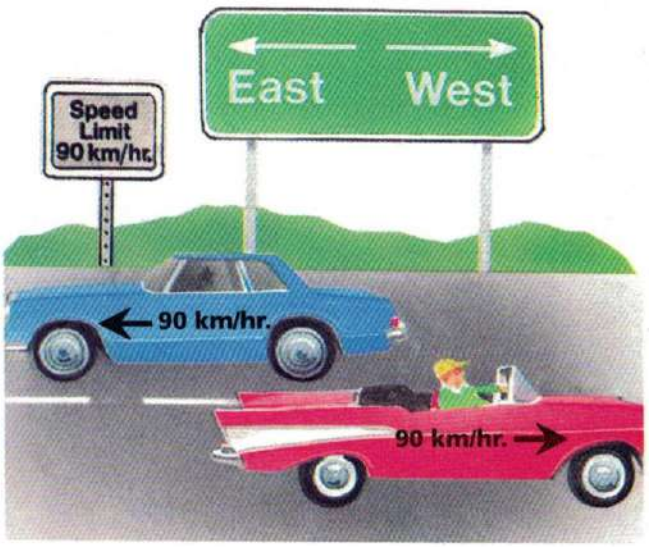
Average Speed When you travel, you do not move at the same speed at all times. Suppose you are taking a car trip. During the trip, you may speed up, slow down, or stop many times. Even though you moved at different speeds during your trip, you can find your average speed for the whole trip. The average speed is equal to the total distance traveled divided by the total time for the trip.

average speed = total distance/total time

The speedometer of a car tells you what your speed is at any instant. This speed is called the instantaneous (in-stun-TAY-nee-us) speed. The instantaneous speed can be faster, slower, or the same as the average speed. Average speed gives information about the speed for the whole trip. Instantaneous speed gives information about the speed at one instant during the trip.

Calculate: If you traveled 360 km in 6 hr, what was your average speed?

Velocity When you move from place to place, you move at a certain speed. You also move in a certain direction. **Velocity** (vuh-LAHS-uh-tee) tells you both the speed and direction of a moving object. People sometimes use the words "speed" and "velocity" as if they were the same. In science, however, velocity always includes speed and direction.



Contrast: What is the difference between speed and velocity?

4-2 What is acceleration?

Objective ▸ Explain how to calculate acceleration.

TechTerm

- **acceleration** (uk-sel-uh-RAY-shun): change in speed or direction

Changing Speed Speeding up and slowing down are changes in speed. Have you ever talked about the "pickup" of a car? This term describes how fast a car can reach a certain speed from a complete stop. When you step on the gas, the speed increases. When you step on the brake, the speed decreases. To find the change in speed, subtract the initial (i-NISH-ul), or starting, speed from the final speed. Suppose a car is moving at a speed of 4 m/sec. Ten seconds later its speed is 10 m/sec. The change in speed is 6 m/sec.

change in speed = final speed − initial speed
change in speed = 10 m/sec − 4 m/sec
change in speed = 6 m/sec

Predict: A car goes from 5 m/sec to 10 m/sec. What is its change in speed?

Acceleration When a car changes speed, it is accelerating. **Acceleration** (uk-sel-uh-RAY-shun) is a change in speed or direction. When a car speeds up, it is accelerating. When a car slows down, it is accelerating. Slowing down is sometimes called deceleration (dee-SEL-uh-ray-shun). A car is also accelerating when it goes around a curve or turns a corner.

Infer: Why is a car accelerating when it turns a corner?

Measuring Acceleration Acceleration describes how fast the speed of a moving object is changing. To find acceleration, you must know the change in speed and the time for the change to occur. The equation for calculating acceleration is

acceleration = change in speed/time
or
acceleration = (final speed − initial speed)/time

Suppose a car is stopped at a red light. When the light turns green, the car accelerates to a speed of 150 m/sec. The car takes 10 sec to reach this speed. What is its acceleration?

acceleration = (150 m/sec − 0 m/sec)/10 sec
acceleration = 150 m/sec/10 sec
acceleration = 15 m/sec/sec

The acceleration is 15 meters per second per second, or 15 m/sec/sec. This means that the car's speed increases 15 m/sec every second.

Infer: Why is the initial speed of the car 0 m/sec?

LESSON SUMMARY

- Motion is a change in position.
- Average speed is equal to the total distance traveled divided by the total time for the trip.
- Speed at any instant is called instantaneous speed.
- Velocity describes the speed and direction of a moving object.

CHECK *Complete the following.*

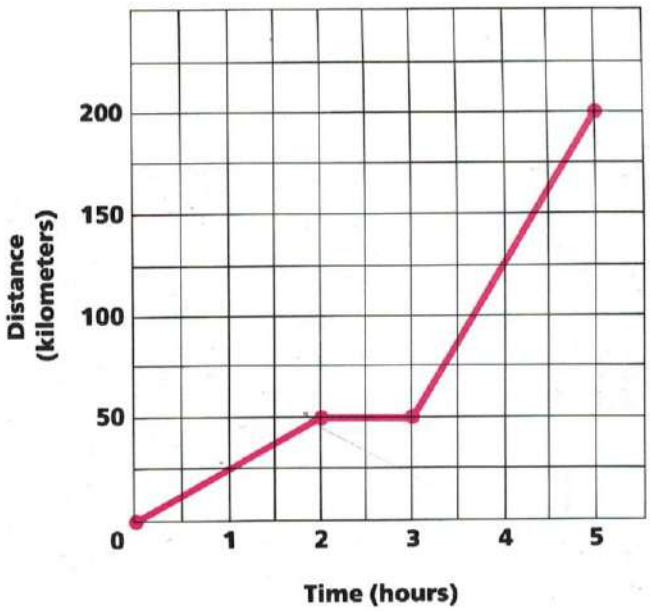
1. What is motion?
2. What is the formula for finding speed?
3. What is average speed?
4. What is instantaneous speed?
5. What does velocity tell you about a moving object?

APPLY *Complete the following.*

6. **Compare:** A truck is traveling east on a highway at 80 km/hr. What is its speed? What is its velocity?
7. **Analyze:** A highway speed limit is posted as 90 km/hr. Is this average speed or instantaneous speed? Explain your answer.

Skill Builder

Analyzing a Graph The distance an object travels in a certain amount of time can be shown on a graph. Look at the graph. It shows distance and time for a car trip. After 5 hr, the car has traveled 200 km. What was the average speed of the car? What was the speed of the car between the second and third hours of the trip? What was the average speed of the car during the last two hours?

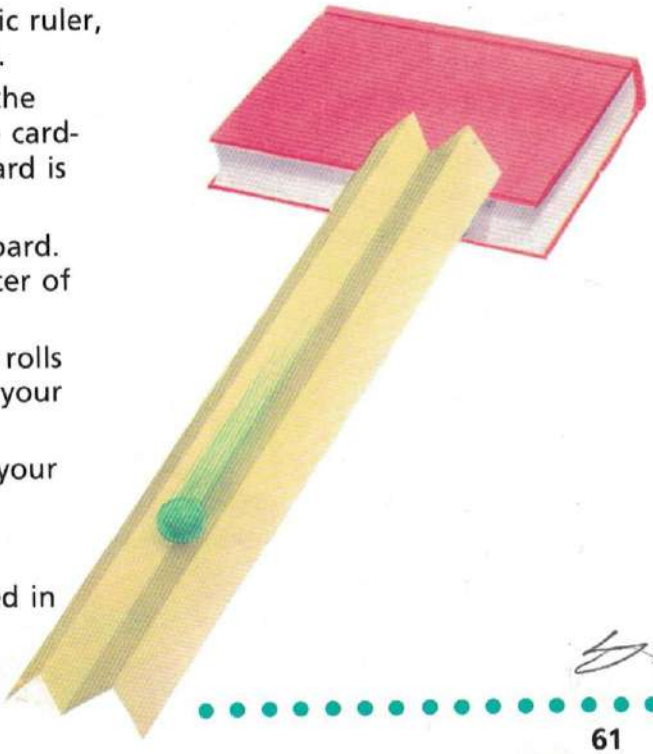


ACTIVITY

MEASURING AVERAGE SPEED

You will need a book, a piece of cardboard, a metric ruler, a watch or clock with a second hand, and a marble.

1. You will need about 1.5 m of floor space. Fold the piece of cardboard in half. Place one end of the cardboard on a book so that the end of the cardboard is raised 1.5 cm off the floor.
2. Hold the marble at the raised end of the cardboard. Release the marble and let it roll down the center of the cardboard and across the floor.
3. Measure the distance in centimeters the marble rolls from the end of the cardboard in 2 sec. Record your measurement in a table.
4. Repeat steps 2 and 3 three more times. Record your measurements.



Questions

1. What was the average distance the marble rolled in 2 sec?
2. What was the average speed of the marble?

4-3 What are balanced and unbalanced forces?

Objectives ▸ Identify balanced and unbalanced forces. ▸ Describe how unbalanced forces affect the motion of an object.

TechTerms

- **balanced forces:** forces that are equal in size but opposite in direction
- **force:** push or pull
- **unbalanced forces:** forces that cause a change in the motion of an object

Balanced Forces Any push or pull is a **force.** To describe a force, you must know two things. You must know the size of the force and the direction of the force. Suppose two teams are playing tug of war. Each team is pulling with equal force, but in opposite directions. Neither team can make the other team move.

Figure 1 Balanced forces

Forces that are equal in size but opposite in direction are called **balanced forces.** Balanced forces do not cause a change in motion. When balanced forces act on an object at rest, the object will not move. If you push against a wall, the wall pushes back with an equal but opposite force. Neither you nor the wall will move.

Predict: What effect will balanced forces have on a book?

Unbalanced Forces Forces that cause a change in the motion of an object are **unbalanced forces.** Unbalanced forces are not equal and opposite. Suppose that one of the teams in the tug of war pulls harder than the other team. The forces would no longer be equal. One team would be able to pull the other team in the direction of the larger force.

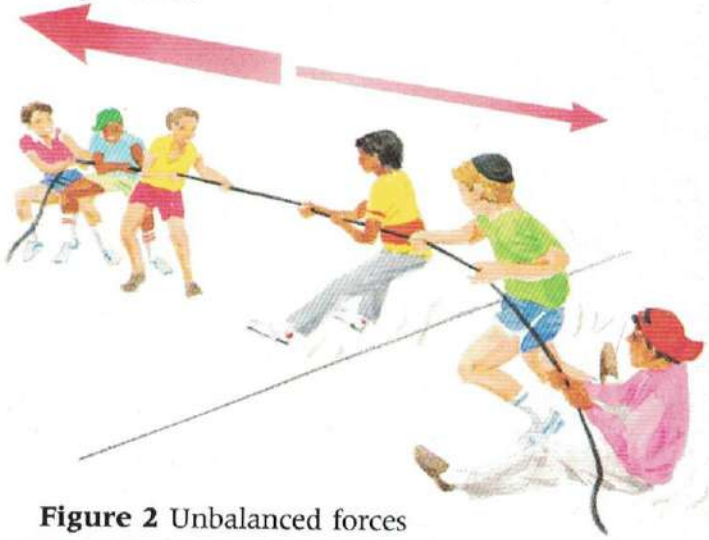


Figure 2 Unbalanced forces

Identify: What kinds of forces cause a change in motion?

Force and Motion Unbalanced forces can change the motion of an object in two ways.

- When unbalanced forces act on an object at rest, the object will move.
- When unbalanced forces act on a moving object, the velocity of the object will change. Remember that a change in velocity means a change in speed, direction, or both speed and direction.

Predict: What will happen when unbalanced forces act on a moving car?

LESSON SUMMARY

- Speeding up and slowing down are changes in speed.
- A car is accelerating when it speeds up, slows down, or changes direction.
- To find acceleration, you must know the change in speed and the time for the change to occur.

CHECK *Complete the following.*

1. Speeding up and slowing down are changes in _____ .
2. The starting speed of a car is called its _____ speed.
3. To find change in speed, subtract initial speed from _____ speed.
4. A change in speed or direction is called _____ .
5. Slowing down is called _____ .
6. To find acceleration, divide the change in speed by the _____ .

APPLY *Complete the following.*

7. **Infer:** Another name for deceleration is negative acceleration. Why do you think this term is used?
8. **Classify:** Which of the following are examples of acceleration?
   - **a.** a train sitting in the station
   - **b.** a train pulling out of the station
   - **c.** a train traveling at 100 km/hr on a straight stretch of track
   - **d.** a train going around a curve in the track
   - **e.** a train pulling into the station

Skill Builder

Interpreting Tables When an object falls to the ground, it accelerates as it falls. When it is released, its speed is zero. As it falls, its speed increases. The table shows how the speed of a falling object changes.

Time (seconds)	Speed (m/sec)
0	0
1	9.8
2	19.6
3	29.4
4	39.2
5	0

What is the object's acceleration from 0 to 1 sec? from 0 to 3 sec? from 2 sec to 4 sec? Based on your calculations, what can you say about the acceleration of a falling object?

CAREER IN PHYSICAL SCIENCE

AIRPLANE PILOT

An airplane pilot is trained to fly an airplane and to supervise the flight crew. The pilot is responsible for the safety of the passengers and crew. About half of all pilots are commercial airline pilots.

Many pilots fly their own airplanes for pleasure or for business. Test pilots fly experimental airplanes. They may test the effects of high speed or acceleration on the structure of the planes. Instructor pilots train other pilots. Special training is necessary to become an instructor pilot.

All pilots must have a high school education. Most employers also require a college degree. All pilots need a license issued by the Federal Aviation Administration (FAA).

LESSON SUMMARY

- Forces that are equal in size but opposite in direction are called balanced forces.
- Balanced forces do not cause a change in the motion of objects.
- Forces that cause a change in the motion of objects are called unbalanced forces.
- Unbalanced forces can change the motion of an object in two ways.

CHECK *Complete the following.*

1. A _____ is a push or a pull.
2. To describe a force, you must know its size and _____ .
3. Balanced forces are _____ in size but opposite in direction.
4. Unbalanced forces cause moving objects to change their _____ .
5. Balanced forces cannot change an object's _____ .

APPLY *Complete the following.*

6. **Analyze:** A skater is moving from east to west across a frozen pond. Her speed is 4 m/sec. Someone gives her a push. As a result of the push, her speed increases to 6 m/sec in the same direction.

   a. Is the push a balanced force or an unbalanced force? How do you know?

   b. In what direction was the push applied? How do you know?

Ideas in Action

IDEA: Balanced forces do not cause a change in motion. Unbalanced forces always cause a change in motion.

ACTION: Identify and describe different examples of balanced and unbalanced forces in your everyday life. Explain how you know if the forces are balanced or unbalanced.

LEISURE ACTIVITY

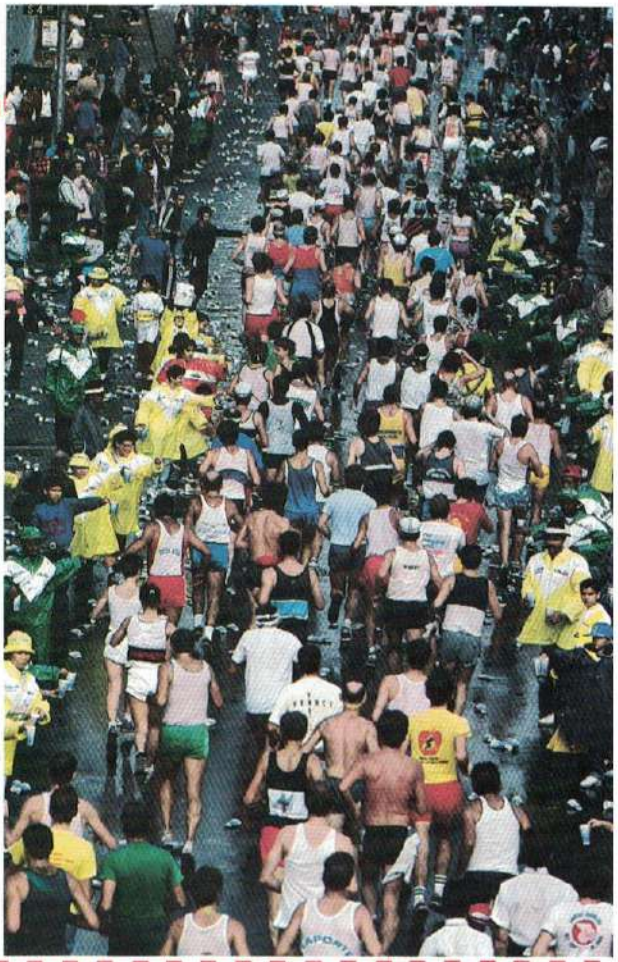
RUNNING

Running is one of the oldest of all sports. One of the great appeals of running is that it is open to people of all ages and all abilities. Many people run every day for their health and for enjoyment. Others take part in organized races.

One popular type of race for long-distance runners is the marathon (MAR-uh-thahn). A marathon covers a distance of 42.2 kilometers. New York City and Boston have marathons each year.

To prepare for a race, runners must train each day. Runners may begin their training as long as eight weeks before a race. All runners wear special shoes and must be in excellent health. Marathon runners must save their strength to complete the race. Beginners should be very careful. The main goal of a beginner should be just to finish the race at his or her own speed.

The benefits of running are a lowered pulse rate and an improved circulatory system. Runners also say that running improves their general feeling of well-being.

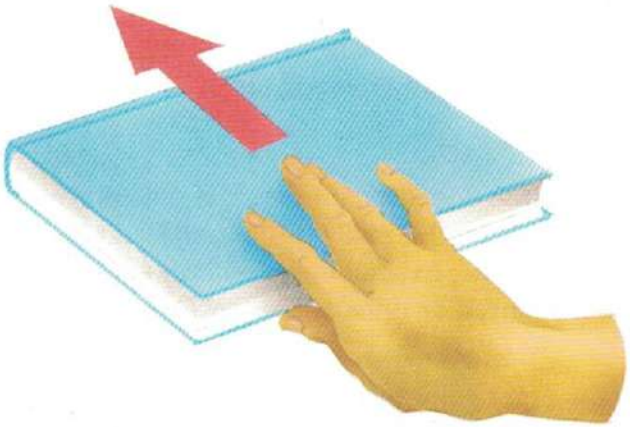


4-4 What is Newton's first law of motion?

Objective ▸ Describe Newton's first law of motion.

TechTerm

▸ **inertia** (in-UR-shuh): tendency of an object to stay at rest or in motion



Inertia Place a book on your desk. Does the book move? Unless you move the book, it will remain where you put it without moving. Imagine a spacecraft moving through space. When the engines are turned off, the spacecraft will coast through space at the same speed and in the same direction. The book and the spacecraft have **inertia** (in-UR-shuh). Because of inertia, an object at rest tends to stay at rest. An object in motion tends to keep moving at a constant speed in a straight line.

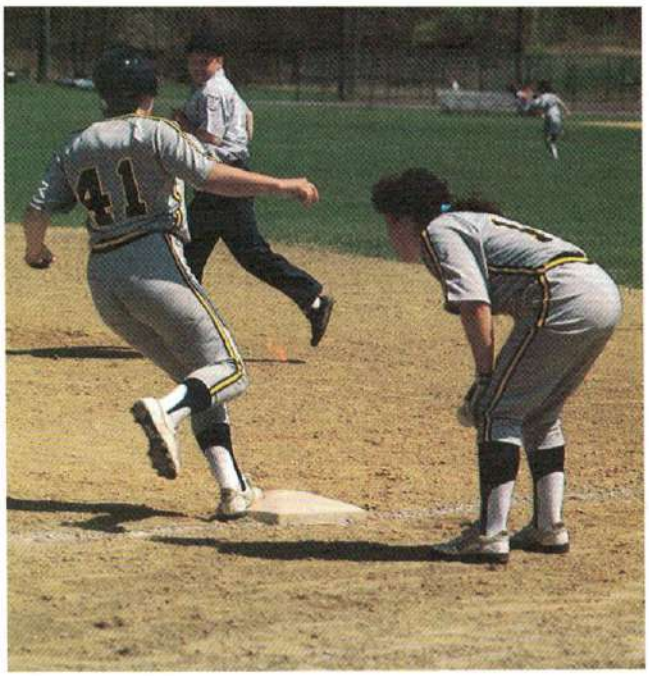
Identify: What causes a book on a table to remain at rest?

Newton's First Law Newton's first law of motion explains how inertia affects moving and nonmoving objects. Newton's first law states that an object will remain at rest or move at a constant speed in a straight line unless it is acted on by an unbalanced force.

According to Newton's first law, an unbalanced force is needed to move the book on your desk. You could supply the force by pushing the book. An unbalanced force is needed to change the speed or direction of the spacecraft. This force could be supplied by the spacecraft's engines.

Predict: According to Newton's first law of motion, what will happen to an object at rest if no unbalanced force acts on it?

Effects of Inertia You can feel the effects of inertia every day. Suppose you are riding in a car. What happens if the car comes to a sudden stop? Your body has inertia. When the car stops, you keep moving forward. What happens when the car starts moving? Because of inertia, your body tends to stay at rest when the car moves forward. In baseball, inertia tends to keep a player running in a straight line. So base runners have to "round" the bases instead of making sharp turns.



Explain: Why do you keep moving forward when your car stops suddenly?

4-5 What is Newton's second law of motion?

Objective ▸ Describe Newton's second law of motion.

TechTerm

- **newton:** unit of force equal to one kilogram-meter per second per second

Effects of Unbalanced Forces Unbalanced forces cause objects to accelerate. When an unbalanced force acts on an object, the motion of the object is changed. If the object is at rest, the force makes it move. If the object is in motion, the force changes its velocity. Any change in velocity is an acceleration.

Describe: What effect does an unbalanced force have on a moving object?

Force, Mass, and Acceleration The amount by which an object accelerates depends on two things. They are the size and direction of the force, and the mass of the object. If two forces act on the same object, the larger force will produce more acceleration than the smaller force. Suppose you apply the same amount of force to two objects with different masses. The object with the smaller mass will accelerate more than the object with the larger mass.

Identify: What two things affect the acceleration of an object?

Newton's Second Law The relationship among force, mass, and acceleration is explained by Newton's second law of motion. Newton's second law states that the unbalanced force acting on an object is equal to the mass of the object times its acceleration.

$$F = m \times a$$

In this equation, F is the force. The mass is m and the acceleration is a. Suppose the mass is measured in kilograms. The acceleration is measured in meters per second per second. Then the force is measured in **newtons** (N). A force of 1 N will accelerate a mass of 1 kg at 1 m/sec/sec. One newton of force is equal to one kilogram-meter per second per second (1 kg-m/sec/sec).

Define: What is 1 N of force equal to?

Figure 1 Equal masses, unequal forces

Figure 2 Unequal masses, equal forces

LESSON SUMMARY

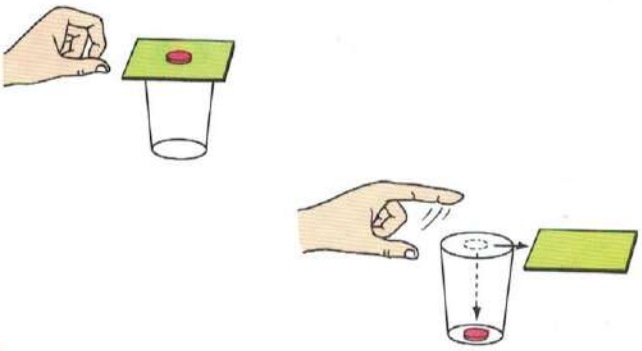
- Inertia is the tendency of an object to remain at rest or in motion.
- Newton's first law of motion states that an object will remain at rest or move at a constant speed in a straight line unless it is acted on by an unbalanced force.
- The effects of inertia can be felt every day.

CHECK *Complete the following.*

1. In space, a spacecraft with its engines turned off will move with constant speed in the same _____ .
2. A book will not move by itself because it has _____ .
3. A book will remain at rest unless it is acted on by an _____ force.
4. When a car stops suddenly, your body tends to keep moving _____ .
5. Base runners tend to run in a straight line because of _____ .
6. Newton's first law explains how inertia affects moving and _____ objects.

APPLY *Complete the following.*

7. **Analyze:** Look at the diagram. In terms of inertia, explain what happens when the card is flicked away.



8. **Predict:** Push a rollerskate across a smooth surface. Will the skate keep moving when you stop pushing? Explain.

Skill Builder

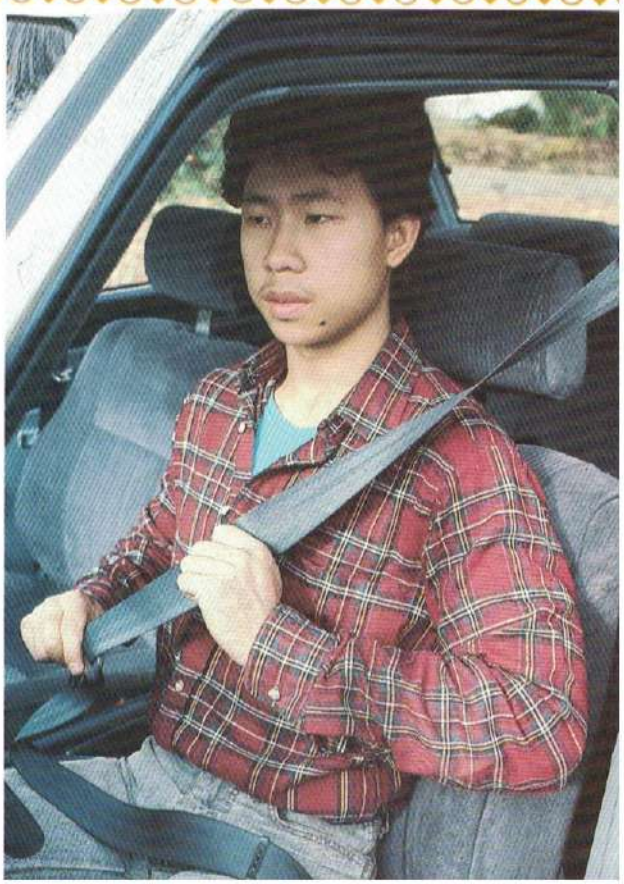
Building Vocabulary Look up the words "inert" and "inertia" in a dictionary. The Latin root for both these words is *iners*. What does this root word mean? How is the meaning of the root word related to the definitions of inert and inertia? What is an inert gas?

SCIENCE CONNECTION

SEAT BELTS

Seat belts could be called "anti-inertia" belts. A moving car has inertia. It tends to keep moving in a straight line, even if the driver's foot is not on the gas pedal. Everyone inside the car also has inertia. They are moving at the same speed as the car.

Suppose you are riding in a car. The driver is forced to step on the brakes suddenly. Inertia keeps you moving forward at the same speed as the car was moving. You will keep moving until something stops you. This might be the car's steering wheel, dashboard, or windshield. You might be hurt if you hit these parts of the car, unless you are wearing a seat belt. A seat belt keeps you from moving forward when the car stops suddenly. Seat belts can prevent serious injuries. You should always remember to "buckle up" when you get into a car.



LESSON SUMMARY

- Unbalanced forces cause objects to accelerate.
- The acceleration of an object depends on the mass of the object and the size and direction of the force acting on it.
- Newton's second law of motion describes the relationship among force, mass, and acceleration ($F = m \times a$).

CHECK *Complete the following.*

1. When it is acted on by an unbalanced force, an object will _____ .
2. When an unbalanced force acts on an object at rest, the object will _____ .
3. A change in velocity is called _____ .
4. A large force will cause _____ acceleration than a small force.
5. Newton's second law of motion states that force is equal to _____ times acceleration.
6. The _____ is a unit of force equal to 1 kg-m/sec/sec.
7. An object's acceleration depends on the size and direction of the force, and on the _____ of the object.

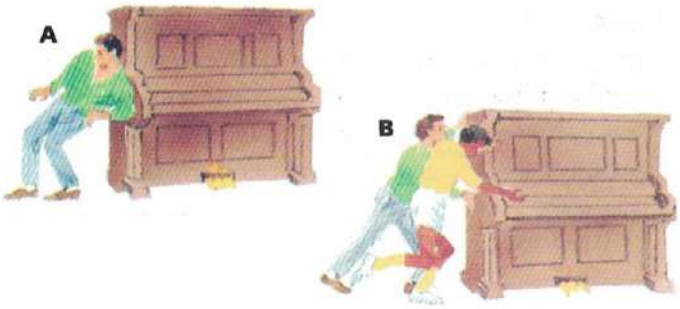
APPLY *Complete the following.*

Calculate: Use the equation $F = m \times a$ to answer the following. Show your calculations.

8. What force is needed to accelerate a 2-kg mass at 1 m/sec/sec?
9. How hard would you have to push a 50-kg skater to increase her speed by 2 m/sec/sec?
10. What is the mass of an object if a force of 10 N causes it to accelerate at 5 m/sec/sec?

Skill Builder

Interpreting a Diagram Look at the two diagrams. Will the acceleration of the piano be greater in A or in B? Use Newton's second law of motion to explain your answer.



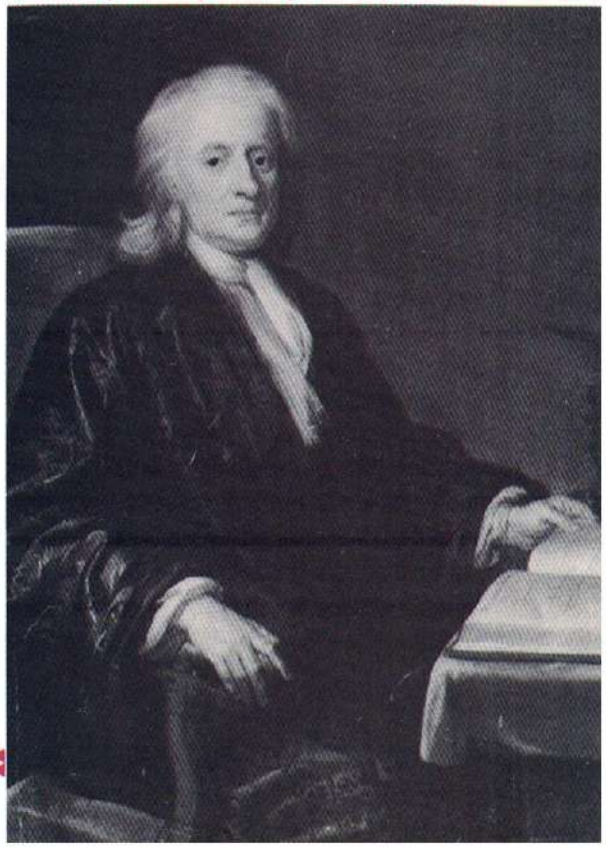
PEOPLE IN SCIENCE

SIR ISAAC NEWTON (1642–1727)

Isaac Newton was born in England on December 25, 1642. He was a physicist, an astronomer, and a mathematician. At the age of 45, Newton published his theories of motion and gravity. Newton's great book is usually called the *Principia*. It is considered one of the most important works in the history of science.

In the *Principia*, Newton explained his three laws of motion and his theory of gravitation. Newton also invented a branch of mathematics called "calculus" to help calculate motion using his three laws. Newton made many important discoveries about light and color.

Newton was a professor of mathematics at Cambridge University and a member of the Royal Society. He was knighted by Queen Anne in 1705. Newton once said about himself, "If I have seen further than others it is because I have stood on the shoulders of giants." What do you think Newton meant by this statement?



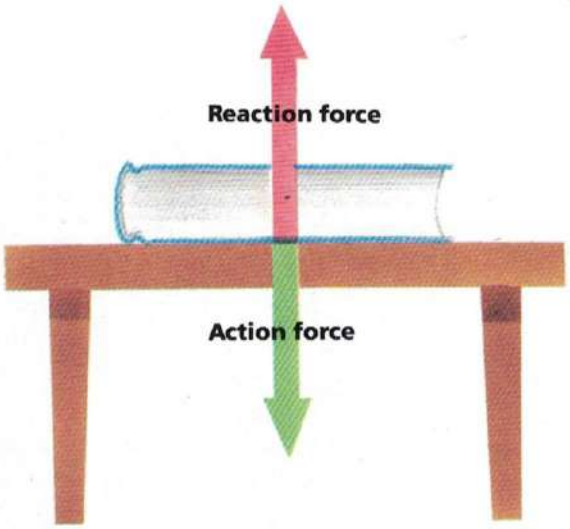
4-6 What is Newton's third law of motion?

Objective ▸ Describe Newton's third law of motion.

TechTerms

- **action force:** force acting in one direction
- **reaction force:** force acting in the opposite direction

Action and Reaction Forces always act in pairs. The two forces act in opposite directions. When you push on an object, the object pushes back with an equal force. Think of a pile of books on a table. The weight of the books exerts a downward force on the table. This is the **action force.** The table exerts an equal upward force on the books. This is the **reaction force.** Notice that the two forces act on different objects. The action force acts on the table. The reaction force acts on the books.



Contrast: How are action and reaction forces different?

Newton's Third Law Newton's third law of motion explains action and reaction forces. The third law states that for every action force, there is an equal and opposite reaction force. Imagine hitting a baseball. The bat exerts a force on the ball. This is the action force. The ball exerts an equal and opposite force on the bat. This is the reaction force.

State: What does Newton's third law of motion state?

Rocket Engines Newton's third law explains how rocket engines work. Hot gases are forced out of the back of the rocket. This is the action force. The gases exert an equal and opposite force on the rocket. This is the reaction force. The reaction force pushes the rocket upward.

Infer: Does the action force in a rocket engine act on the hot gases or on the rocket?

LESSON SUMMARY

- Forces always act in pairs.
- Newton's third law of motion states that for every action force, there is an equal and opposite reaction force.

  Newton's third law explains how rocket engines work.

CHECK *Write true if the statement is true. If the statement is false, correct the underlined term to make the statement true.*

1. Forces always act alone.
2. Books on a table exert an upward force on the table.
3. For every action force, there is an equal and opposite reaction force.
4. When you hit a baseball, the bat exerts a force on the ball.
5. In a rocket engine, the action force pushes the rocket upward.
6. Action forces and reaction forces always act on different objects.

APPLY *Complete the following.*

7. An object resting on a table weighs 100 N. With what force is the object pushing on the table? With what force is the table pushing on the object?
8. **Classify:** When you walk, your feet push against the ground. At the same time, the ground pushes against your feet. Which is the action force? Which is the reaction force?
9. **Hypothesize:** When you walk, you move forward. Does the earth move in the opposite direction? Explain your answer.

Health and Safety Tip

Newton's third law explains how many sports injuries are caused. The more force you use to hit a tennis ball, the more reaction force your arm receives from the racket. Every time your feet hit the ground when you are running, the ground hits your feet with an equal and opposite force. Use library references to find out how to protect yourself from sports injuries by wearing the proper equipment.

TECHNOLOGY AND SOCIETY

VENTURESTAR

In 1996, NASA started plans to develop a replacement for the space shuttle. The shuttle uses solid rocket boosters that are dropped over the ocean during launch. They must be recovered and rebuilt after each flight. The heat-resistant ceramic tiles must be checked and replaced after each flight. These are only two things that make the space shuttle very expensive. Each shuttle flight costs $500 million.

The replacement for the shuttle will be VentureStar, a wingless vehicle. VentureStar will lift off like a rocket and glide to a landing on a runway, much like the space shuttle. However, unlike the shuttle, VentureStar will not have booster rockets that have to be dropped. It will have a metal heat shield rather than individual ceramic tiles.

VentureStar will be able to do all the jobs the shuttle now does. But NASA also wants VentureStar for building and supporting a space station. NASA needs a vehicle that can carry people and heavy loads into space. VentureStar will do it at a lower cost than the shuttle. VentureStar will reduce costs of launching payloads into space by at least 80 percent, saving NASA billions of dollars.

UNIT 4 Challenges

STUDY HINT Before you begin the Unit Challenges, review the TechTerms and Lesson Summary for each lesson in this unit.

TechTerms

acceleration (62)
action force (70)
balanced forces (64)
force (64)
inertia (66)
motion (60)
newton (68)
reaction force (70)
speed (60)
unbalanced forces (64)
velocity (60)

TechTerm Challenges

Matching *Write the TechTerm that matches each description.*

1. speed and direction
2. change in speed or direction
3. push or pull
4. unit of force
5. change in position
6. distance traveled per unit of time

Applying Definitions *Explain the difference between the words in each pair. Write your answers in complete sentences.*

1. action force, reaction force
2. speed, velocity
3. balanced forces, unbalanced forces
4. force, acceleration
5. motion, inertia

Content Challenges

Multiple Choice *Write the letter of the term or phrase that best completes each statement.*

1. When you move from place to place, you are changing your
   a. mass. **b.** inertia. **c.** position. **d.** speed.
2. An unbalanced force causes a moving object to change
   a. speed. **b.** direction. **c.** neither speed nor direction. **d.** either speed or direction.
3. A car's speedometer tells you
   a. average speed. **b.** instantaneous speed. **c.** acceleration. **d.** velocity.
4. Balanced forces are always opposite in
   a. direction. **b.** size. **c.** size and direction. **d.** size or direction.
5. Velocity includes speed and
   a. acceleration. **b.** inertia. **c.** direction. **d.** force.
6. Average speed is equal to total distance divided by
   a. average distance. **b.** average time. **c.** instantaneous speed. **d.** total time.
7. Action forces and reaction forces are described by Newton's
   a. first law of motion. **b.** second law of motion. **c.** third law of motion. **d.** law of gravitation.
8. According to Newton's second law of motion, force is equal to mass times
   a. acceleration. **b.** speed. **c.** velocity. **d.** inertia.
9. The newton is a unit of
   a. speed. **b.** force. **c.** velocity. **d.** acceleration.

10. Inertia is described by Newton's
    a. first law of motion. **b.** second law of motion. **c.** third law of motion. **d.** law of gravitation.
11. To find a car's change in speed, subtract its final speed from its
    a. total speed. **b.** initial speed. **c.** average speed. **d.** instantaneous speed.
12. Acceleration is equal to change in speed divided by
    a. time. **b.** distance. **c.** final speed. **d.** initial speed.

Completion *Write the term or phrase that best completes each sentence.*

1. Speed is the distance traveled in a certain _____.
2. If an action force acts in one direction, the reaction force acts in the _____ direction.
3. In the equation $F = m \times a$, F equals the _____.
4. One newton of force is equal to _____.
5. Speed = _____/time.
6. Acceleration is a change in speed or _____.
7. Newton's third law of motion explains how _____ engines work.
8. Motion is a change in _____.
9. Slowing down is sometimes called _____, or negative acceleration.
10. Balanced forces are always _____ in size.
11. Forces always act in _____.
12. For every action force, there is an _____ reaction force.
13. Acceleration is equal to _____ divided by time.

Understanding the Features

Reading Critically *Use the feature reading selections to answer the following. Page numbers for the features are shown in parentheses.*

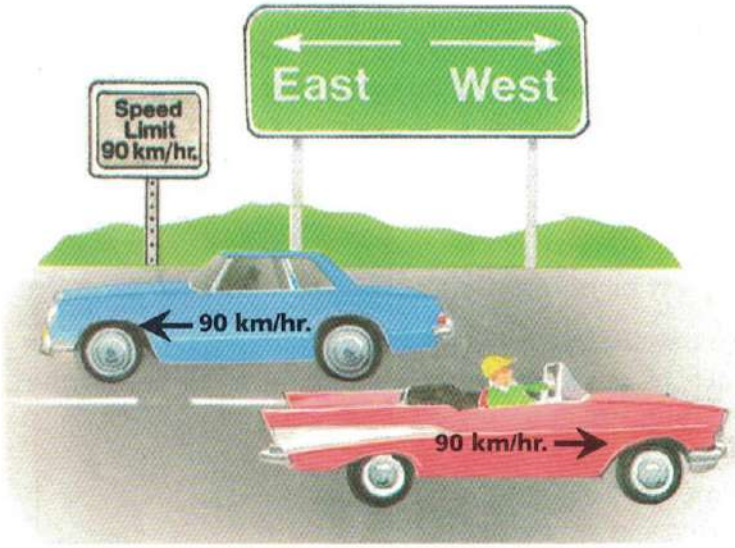
1. What is another possible name for seat belts? (67)
2. **Infer:** What is the distance of the New York City Marathon? (65)
3. How would VentureStar be different than the space shuttle? (71)
4. What is the name of the branch of mathematics invented by Isaac Newton? (69)
5. **Hypothesize:** Why do you think instructor pilots need special training? (63)

Concept Challenges

Critical Thinking *Answer the following questions in complete sentences.*

1. **Contrast:** What is the difference between average speed and instantaneous speed?
2. **Hypothesize:** When does an object have zero acceleration? Explain.
3. Two cars are stopped at a red light. When the light turns green, both cars accelerate to a speed of 150 m/sec. The first car takes 10 sec to reach this speed. The second car takes 20 sec. Which car has the greater acceleration? Explain.
4. An unbalanced force acts on a moving object. The object slows down. In what direction is the unbalanced force acting? How do you know?

Understanding a Diagram *Use the diagram to answer the questions.*



1. Does this diagram illustrate speed or velocity? Explain.
2. In what direction is the blue car traveling?
3. In what direction is the red car traveling?
4. What speed limit is shown in the diagram? Is this an average speed or an instantaneous speed?
5. If each car continues moving at an average speed of 90 km/hr. for two hours, how far will each car travel?
6. How much distance will separate the cars after 2 hours?

Finding Out More

1. The next time you ride in a car, close your eyes and try to sense changes in the speed and direction of the car. How can you tell if the car is accelerating? How can you tell if it is decelerating? How can you tell if it is changing direction? Write a report describing your observations.
2. Do library research to find out about different speed records. For example, what is the fastest land animal? What is the fastest airplane? Who is the fastest runner? Display your findings in the form of a chart comparing the speed records.
3. Scientists describe motion in terms of frames of reference. Find out what a frame of reference is. Why is it necessary to have a frame of reference when talking about motion? Explain your findings to the class.
4. At one time, scientists thought that an object could move at any speed. Albert Einstein discovered that there is a maximum speed in our universe. No object can move faster than this speed. Use your school library to find out what the maximum possible speed in our universe is.