<table>
<thead>
<tr>
<th>Section/Objectives</th>
<th>Standards</th>
<th>Labs/Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chapter Opener</strong></td>
<td></td>
<td>Launch LAB: Compare Speeds, p. 37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foldables, p. 37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A data-collection lab using Probeware technology can be found in Probeware Labs, pp. 41–43</td>
</tr>
<tr>
<td><strong>Section 1 Describing Motion</strong></td>
<td>National Content Standards</td>
<td>Integrate Astronomy, p. 39</td>
</tr>
<tr>
<td></td>
<td>5–8: UCP.1, UCP.2, UCP.3, A.1, A.2, B.2</td>
<td>Applying Math: Calculating Speed, p. 40</td>
</tr>
<tr>
<td></td>
<td>9–12: UCP.1, UCP.2, UCP.3, A.1, A.2, B.4</td>
<td>Science Online, p. 41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MiniLAB: Describing the Motion of a Car, p. 42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Science Online, p. 43</td>
</tr>
<tr>
<td>1. <strong>Distinguish</strong></td>
<td></td>
<td>Integrate History, p. 48</td>
</tr>
<tr>
<td>between distance and</td>
<td></td>
<td>Visualizing Acceleration, p. 49</td>
</tr>
<tr>
<td>displacement.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. <strong>Explain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the difference between speed and velocity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. <strong>Interpret</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motion graphs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Section 2 Acceleration</strong></td>
<td>National Content Standards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5–8: UCP.1, UCP.2, UCP.3, A.1, A.2, B.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9–12: UCP.1, UCP.2, UCP.3, A.1, A.2, B.4</td>
<td></td>
</tr>
<tr>
<td>1. <strong>Identify</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>how acceleration, time, and velocity are related.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. <strong>Explain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>how positive and negative acceleration affect motion.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. <strong>Describe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>how to calculate the acceleration of an object.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Section 3 Motion and Forces</strong></td>
<td>National Content Standards</td>
<td>Science Online, p. 53</td>
</tr>
<tr>
<td></td>
<td>5–8: UCP.1, UCP.2, UCP.3, A.1, A.2, B.2, G.3</td>
<td>MiniLAB: Observing Inertia, p. 54</td>
</tr>
<tr>
<td></td>
<td>9–12: UCP.1, UCP.2, UCP.3, A.1, A.2, B.4, G.3</td>
<td>Lab: Force and Acceleration, p. 57</td>
</tr>
<tr>
<td>1. <strong>Explain</strong></td>
<td></td>
<td>Lab: Comparing Motion from Different Forces, pp. 58–59</td>
</tr>
<tr>
<td>how force and motion are related.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. <strong>Describe</strong></td>
<td></td>
<td><strong>Science and Language Arts:</strong></td>
</tr>
<tr>
<td>what inertia is and how it is related to Newton's first law of motion.</td>
<td></td>
<td>A Brave and Startling Truth, p. 60</td>
</tr>
<tr>
<td>3. <strong>Identify</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the forces and motion that are present during a car crash.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab Materials</td>
<td>Reproducible Resources</td>
<td>Section Assessment</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td><strong>Launch LAB:</strong> meterstick, stopwatch</td>
<td><strong>Chapter Fast File Resources</strong> Foldables Worksheet, p. 17 Directed Reading Overview, p. 19 Note-taking Worksheets, pp. 33–35</td>
<td><strong>Portfolio</strong> Differentiated Instruction, p. 43 <strong>Performance</strong> MiniLAB, p. 42 Applying Math, p. 40 Applying Math, p. 46</td>
</tr>
<tr>
<td><strong>MiniLAB:</strong> tape, toy car, stopwatch, pencil, meterstick</td>
<td><strong>Chapter Fast File Resources</strong> Transparency Activity, p. 44 MiniLAB, p. 3 Enrichment, p. 30 Reinforcement, p. 27 Directed Reading, p. 20 Lab Activity, pp. 9–12 Transparency Activity, pp. 47–48</td>
<td><strong>Portfolio</strong> Differentiated Instruction, p. 49 <strong>Performance</strong> Applying Math, p. 51 <strong>Content</strong> Section Review, p. 51</td>
</tr>
<tr>
<td><strong>MiniLAB:</strong> board, textbooks, stop block, small object, cart, rubber bands</td>
<td><strong>Chapter Fast File Resources</strong> Transparency Activity, p. 45 Enrichment, p. 31 Reinforcement, p. 28 Directed Reading, p. 21 Lab Activity, pp. 13–15</td>
<td><strong>Portfolio</strong> Activity, p. 55 <strong>Performance</strong> MiniLAB, p. 46 Applying Math, p. 56 <strong>Content</strong> Section Review, p. 56</td>
</tr>
<tr>
<td><strong>Lab:</strong> tape, paper clip, 10-N spring scale, large book, this science book, triple-beam or electronic balance</td>
<td><strong>Chapter Fast File Resources</strong> Transparency Activity, p. 46 MiniLAB, p. 4 Enrichment, p. 32 Reinforcement, p. 29 Directed Reading, pp. 21, 22 Lab Worksheets, pp. 5–6, 7–8</td>
<td><strong>Portfolio</strong> Activity, p. 55 <strong>Performance</strong> MiniLAB, p. 54 Applying Math, p. 56 <strong>Content</strong> Section Review, p. 56</td>
</tr>
</tbody>
</table>

---

**End of Chapter Assessment**

<table>
<thead>
<tr>
<th>Blackline Masters</th>
<th>Technology</th>
<th>Professional Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chapter Fast File Resources</strong></td>
<td>MindJogger Videoquiz</td>
<td>Performance Assessment in the Science Classroom (PASC)</td>
</tr>
<tr>
<td>Chapter Review, pp. 37–38  Chapter Tests, pp. 39–42</td>
<td>Virtual Labs CD-ROM</td>
<td></td>
</tr>
<tr>
<td><strong>Standardized Test Practice</strong></td>
<td>ExamView® Pro Testmaker</td>
<td></td>
</tr>
<tr>
<td>, pp. 12–15</td>
<td>TeacherWorks CD-ROM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interactive Chalkboard CD-ROM</td>
<td></td>
</tr>
</tbody>
</table>
**Chapter 2: Motion**

**Transparencies**

**Section Focus**

**Assessment**

**Teaching**

**Hands-on Activities**

This is a representation of key blackline masters available in the Teacher Classroom Resources. See Resource Manager boxes within the chapter for additional information.

**Key to Teaching Strategies**

The following designations will help you decide which activities are appropriate for your students.

- **L1** Level 1 activities should be appropriate for students with learning difficulties.
- **L2** Level 2 activities should be within the ability range of all students.
- **L3** Level 3 activities are designed for above-average students.
- **ELL** ELL activities should be within the ability range of English Language Learners.

**COOP LEARN** Cooperative Learning activities are designed for small group work.

**L5** Multiple Learning Styles logos, as described on page 12T, are used throughout to indicate strategies that address different learning styles.

**P** These strategies represent student products that can be placed into a best-work portfolio.

**PBL** Problem-Based Learning activities apply real-world situations to learning.
Chapter 2

What is probably being measured in the diagram above?

1. Rate of tire wear
2. Engine temperature
3. Speed

Horse 1

The horses on this carousel are accelerating because...

1. The speed of the horses is constantly changing.
2. The speed of the horses is constantly changing.*

Horse 2

Horse 3

Calculating acceleration

\[ \text{Acceleration} = \frac{\text{change in velocity}}{\text{time}} \]

1. \[ \text{Change in velocity} = \text{final velocity} - \text{initial velocity} \]

2. \[ \text{Change in velocity} = \text{instantaneous change in velocity} \]

3. \[ \text{Change in velocity} = \text{average change in velocity} \]

A distance-time graph displays motion of an object over time.

Speed is usually not constant; usually an object has a changing* speed.

Distance depends on an object's distance and direction compared to a starting point.

The greater a boulder's mass, the greater inertia it has.

1. \[ \text{Speed} = \frac{\text{distance}}{\text{time}} \]

2. \[ \text{Average speed} = \frac{\text{total distance}}{\text{total travel time}} \]

3. You can tell an object has moved because its velocity has changed.

A. \[ \text{acceleration} = \text{speed is increasing} \]

B. \[ \text{acceleration} = \text{speed is decreasing} \]

C. \[ \text{acceleration} = \text{speed is constant} \]

5. In which segment might the student be waiting for a traffic light?

6. The distance-time graph above shows the motion of a student walking to a convenience store for a loaf of bread and returning home. Use the graph to answer questions 1 through 5.

In which segment was the student moving at the slowest rate of speed?

1. During the first segment, the student was moving at the slowest rate of speed.

In which segment was the student moving at the fastest rate of speed?

1. During the second segment, the student was moving at the fastest rate of speed.

Part A. Vocabulary Review

1. Constant velocity occurs when an object's velocity decreases.
2. Equal forces acting in opposite directions.
3. Balanced forces.
4. Inertia is the tendency to resist change in motion.
5. Acceleration is the rate of change in velocity of an object.
6. Displacement depends on an object's distance and direction.
7. Average speed is indicated on the speedometer.
8. Instantaneous speed is the speed of motion when speed is changing.
9. The greatest acceleration?

Measuring motion requires using the graph and understanding the units on the axes.

The runners are staggered, with one runner up to advance beyond the other runners. Some athletes like the talented Michael Johnson have made this a favorite race that is equal to one lap around the running track. At the sound of a starting pistol, the athletes run the 400 m race. Athletes like the talented Michael Johnson have made this a favorite race that is equal to one lap around the running track. At the sound of a starting pistol, the athletes run the 400 m race. To complete the distance of 400 m on a track, the runners must run the 400 m race in 44.40 s. How would you describe the motion of one of the runners?
Describing Motion
Distance Versus Displacement
A vector quantity has both magnitude and direction, such as a displacement of 15 km east and a velocity of 7 m/s west. Scalar quantities have magnitude only, such as a distance of 5 km and a speed of 6 m/s. The terms distance and displacement have different meanings. Consider a car going around a round race-track. The distance the car travels can be read from its odometer, but the car's displacement is its straight-line distance and direction from its starting point. For each lap the odometer increases. But for each lap its displacement at first increases, and then decreases and becomes zero as it returns to the starting point. Speed and velocity also can be contrasted easily. The car traveling around the track may have a constant speed, but its velocity is constantly changing because its direction is constantly changing.

Acceleration
Acceleration, Speed, and Velocity
An object will move with constant velocity unless a force acts on it. A planet orbiting a star experiences the force of gravity between the star and the planet. This force causes the object to accelerate toward the star and not fly off in straight-line motion. So even though the planet moves with constant speed, it is accelerating.

Acceleration units show changes in velocity divided by time. If velocity is expressed as meters/second and time in seconds, then acceleration is expressed with units of meters per second per second. This is equivalent to m/s/s or (m/s × 1/s) or m/s².

Motion and Forces
Inertia and Mass
Astronauts in weightless conditions would still have a harder time moving a massive object like a bowling ball than moving a tennis ball. This is because the greater the mass of an object, the greater is its inertia. In the weightless condition, if the bowling ball were not moving, it would be just as hard to push it down as to pick it up.

Internet Resources
For additional content background, visit gpscience.com to:
- access your book online
- find references to related articles in popular science magazines
- access Web links with related content background
- access current events with science journal topics

Print Resources
Eyewitness: Force and Motion, by Peter Lafferty, Dorling Kindersley Publishing, 2000
Sports Science Projects: The Physics of Balls in Motion (Science Fair Success), by Madeline Goodstein, Enslow Publishers, Inc., 1999
Students may think that . . .

**Distance and displacement are the same thing.**

**Speed and velocity are the same thing.**

Students are familiar with scalar quantities and vector quantities, but terms such as *displacement* and *velocity* may cause confusion. Also, the term velocity is frequently used as though it were the same thing as speed. Finally, the terms *displacement* and *distance* sound similar, and this may cause confusion between them.

**Discussion**

Tell students that a turtle and a hare start a race at the same time. The turtle goes straight to the finish line. The hare starts off and deviates along the way. They both finish the race at the same time. Discuss which had the greatest average speed during the race.

**Activity**

- Draw the graphs on the right on the board. Explain that the distance-time graph and the displacement-time graph each show Samantha’s walking motion after she left her house.
- Ask students to supply a possible story to describe her motion. Ask them what she might be doing when the lines of both graphs are horizontal.
- Students should see that the distance-time graph and the displacement-time graph for the same motion look very different. In this case the distance traveled is how far Samantha actually walked. Her displacement shows how far she is from her house.
- A plausible story for both graphs is Samantha walks with constant speed directly away from her house, then rests a bit, and then walks with constant speed directly back to her house.

**Assess**

After completing the chapter, see *Identifying Misconceptions* in the Study Guide at the end of the chapter.
Chapter Vocabulary

distance, p. 39
displacement, p. 39
speed, p. 39
average speed, p. 42
instantaneous speed, p. 42
velocity, p. 44
acceleration, p. 47
force, p. 52
net force, p. 53
balanced force, p. 53
inertia, p. 54

Science Journal  Student responses will vary, but may include a roller coaster, bumper cars, and a Ferris wheel. The roller coaster and bumper car rides provide examples of quick velocity and acceleration changes. The Ferris wheel provides an example of constant speed but changing velocity and acceleration due to the constant change in direction of the passengers.

Science Journal  Write a paragraph describing three rides in an amusement park and how the rides cause you to move.

Taking the Plunge  You probably don't think of an amusement park as a physics laboratory. The fast speeds, quick turns, and plunging falls are a great place to study the laws of gravity and motion. In fact, engineers use these laws when they are designing and building amusement park rides.

Science Journal  Write a paragraph describing three rides in an amusement park and how the rides cause you to move.

Theme Connection

Stability and Change  An object will have a constant velocity unless the object is acted upon by an outside force.

Amusement Park Physics  The fast speeds, sharp turns, and plunging falls in amusement park rides may seem dangerous, but actually they are very safe. Engineers use the laws of motion to design the rides so that the passengers experience the thrill but they are not in danger of getting hurt.
Purpose
Use the Launch Lab to introduce students to the relationship between motion and speed.

**Kinesthetic**

**Preparation** Find a location outside where groups of students will have room to mark off their 10-m distances. Assign each group a specific location.

**Materials** meterstick, stopwatch, calculator

**Teaching Strategy** Stage a contest between the five students with the greatest speeds to determine the fastest student in the class. Post the top speeds on a classroom bulletin board.

**Think Critically**
Students would lose races with a cheetah, horse, or elephant. They would win races with a snake.

**Assessment**
Oral Have students infer a formula for determining the speed of moving objects. Use Performance Assessment in the Science Classroom, p. 89.

---

**Compare Speeds**
A cheetah can run at a speed of almost 120 km/h and is the fastest runner in the world. A horse can reach a speed of 64 km/h; an elephant’s top speed is about 40 km/h; and the fastest snake slithers at a speed of about 3 km/h. The speed of an object is calculated by dividing the distance the object travels by the time it takes it to move that distance. How does your speed compare to the speeds of these animals?

1. Use a meterstick to mark off 10 m.
2. Have your partner use a stopwatch to determine how fast you run 10 m.
3. Divide 10 m by your time in seconds to calculate your speed in m/s.
4. Multiply your answer by 3.6 to determine your speed in km/h.
5. **Think Critically** Write a paragraph in your Science Journal comparing your speed with the maximum speed of a cheetah, horse, elephant, and snake. Could you win a race with any of them?

**Identify Questions** Before you read the chapter, select a motion you can observe and write it under the left tab. As you read the chapter, write answers to the other questions under the appropriate tabs.
Bellringer

Section Focus Transparencies also are available on the Interactive Chalkboard CD-ROM.

Tie to Prior Knowledge

**Speed Limits**

Ask students to name the speed limits near their school, on the road in front of their homes, or on an interstate highway. Discuss with students the units, such as miles per hour and kilometers per hour, used in speed limits. Tell students they will learn about measuring speed in this section.

Caption Answer

**Figure 1** Its position relative to the mailbox changed.

**Motion**

Are distance and time important in describing running events at the track-and-field meets in the Olympics? Would the winners of the 5-km race and the 10-km race complete the run in the same length of time?

Distance and time are important. In order to win a race, you must cover the distance in the shortest amount of time. The time required to run the 10-km race should be longer than the time needed to complete the 5-km race because the first distance is longer. How would you describe the motion of the runners in the two races?

**Motion and Position**

You don’t always need to see something move to know that motion has taken place. For example, suppose you look out a window and see a mail truck stopped next to a mailbox. One minute later, you look out again and see the same truck stopped farther down the street. Although you didn’t see the truck move, you know it moved because its position relative to the mailbox changed.

A reference point is needed to determine the position of an object. In **Figure 1**, the reference point might be a tree or a mailbox. Motion occurs when an object changes its position relative to a reference point. The motion of an object depends on the reference point that is chosen. For example, the motion of the mail truck in **Figure 1** would be different if the reference point were a car moving along the street, instead of a mailbox.
Frame of Reference  After a reference point is chosen, a frame of reference can be created. A frame of reference is a coordinate system in which the position of the objects is measured. The $x$-axis and $y$-axis of the reference frame are drawn so that they intersect the reference point.

Distance  In track-and-field events, have you ever run a 50-m dash? A distance of 50 m was marked on the track or athletic field to show you how far to run. An important part of describing the motion of an object is to describe how far it has moved, which is distance. The SI unit of length or distance is the meter (m). Longer distances are measured in kilometers (km). One kilometer is equal to 1,000 m. Shorter distances are measured in centimeters (cm). One meter is equal to 100 centimeters.

Displacement  Suppose a runner jogs to the 50-m mark and then turns around and runs back to the 20-m mark, as shown in Figure 2. The runner travels 50 m in the original direction (north) plus 30 m in the opposite direction (south), so the total distance she ran is 80 m. How far is she from the starting line? The answer is 20 m. Sometimes you may want to know not only your distance but also your direction from a reference point, such as from the starting point. Displacement is the distance and direction of an object’s change in position from the starting point. The runner’s displacement in Figure 2 is 20 m north.

The length of the runner’s displacement and the distance traveled would be the same if the runner’s motion was in a single direction. If the runner ran from the starting point to the finish line in a straight line, then the distance traveled would be 50 m and the displacement would be 50 m north.

**How do distance and displacement differ?**

Speed  Think back to the example of the mail truck’s motion in Figure 1. You could describe the movement by the distance traveled and by the displacement from the starting point. You also might want to describe how fast it is moving. To do this, you need to know how far it travels in a given amount of time. Speed is the distance an object travels per unit of time.
**Activity**

**Different Rates** Review the concept of rate by having students measure their breathing rates. Discuss other rates, such as heart rate (pulse) and interest rates. Discuss the units that describe these rates and point out similarities in the units. They are all a number of something per time. **Logical-Mathematical**

**National Math Standards**

**Correlation to Mathematics Objectives**

1, 2, 9,

**Answers to Practice Problems**

1. about 27.4 s
2. 0.25 h or 15 min

**Activity**

**Speed Limits** Have each student make a table showing all of the speed limits between his or her home and school. The table should begin with the speed limit of the road outside the home and should also give the distance that speed limit is in effect. The table should then give the next speed limit and the distance it is in effect, and so on. Students can then use the formula \( t = \frac{d}{v} \) to determine the time it would take them to get to school if they traveled the exact speed limit all the way to school. **Logical-Mathematical**

**Use an Analogy**

**Lined Paper** Explain to students that using a reference point to describe motion is analogous to using lines on paper to write. The lines on the paper provide a reference point to keep your writing on a straight line. **Logical-Mathematical**

---

**Calculating Speed** Any change over time is called a rate. If you think of distance as the change in position, then speed is the rate at which distance is traveled or the rate of change in position.

**Speed Equation**

\[
\text{speed (in meters/second)} = \frac{\text{distance (in meters)}}{\text{time (in seconds)}}
\]

\[
s = \frac{d}{t}
\]

The SI unit for distance is the meter and the SI unit of time is the second (s), so in SI, units of speed are measured in meters per second (m/s). Sometimes it is more convenient to express speed in other units, such as kilometers per hour (km/h). **Logical-Mathematical**

---

**Calculating Speed**

**Solve a One-Step Equation**

**Calculating Speed** A car traveling at a constant speed covers a distance of 750 m in 25 s.

What is the car’s speed?

**Identify** known values and the unknown value

<table>
<thead>
<tr>
<th>Identify the known values:</th>
<th>Identify the unknown value:</th>
</tr>
</thead>
<tbody>
<tr>
<td>covers a distance of 750 m</td>
<td>What is the car’s speed?</td>
</tr>
<tr>
<td>in 25 s</td>
<td>( s = ? \ m/s )</td>
</tr>
</tbody>
</table>

**Solve** the problem

Substitute the given values of distance and time into the speed equation:

\[
s = \frac{d}{t} = \frac{750 \text{ m}}{25 \text{ s}} = 30 \text{ m/s}
\]

**Check** the answer

Does your answer seem reasonable? Check your answer by multiplying the time by the speed. The result should be the distance given in the problem.

---

**Practice Problems**

1. A passenger elevator operates at an average speed of 8 m/s. If the 60th floor is 219 m above the first floor, how long does it take the elevator to go from the first floor to the 60th floor?
2. A motorcyclist travels an average speed of 20 km/h. If the cyclist is going to a friend’s house 5 km away, how long does it take the cyclist to make the trip?

For more practice problems go to page 834, and visit gpscience.com/extra_problems.

---

**Cultural Diversity**

**The Olympics** Runners from all over the world participate in track and field events in the Olympics every four years. Have students research the winners and their times and speeds for a track event of their choice for the past five summer Olympics. They should combine their research into a bulletin board and creatively relate it to information in this chapter. **Logical-Mathematical**
Quick Demo

Car Ramps

Materials  three ramps of various lengths at least 2 m long, toy car, stopwatch, meterstick

Estimated Time 15 minutes

Procedure  Make three ramps of various lengths, each at least 2 m long. Have a volunteer start a toy car rolling down one of the ramps while another volunteer times the car’s motion with a stopwatch. Ask a third volunteer to measure the distance covered by the car. Write the distance traveled and time elapsed on the board. Repeat the activity with each of the three ramps. Have students determine the average speed for the three runs by dividing the total distance traveled by the total time.

Caption Answer

Figure 3  average speed over the entire motion or instantaneous speed at a given time

Discussion

Speed Units  Remind students that when the equation for speed is rearranged, we have \( t = \frac{d}{v} \). How do time units emerge from this equation?

\[
m \div \left( \frac{m}{s} \right) = m \times \frac{s}{m} = s
\]

Activity  In your Science Journal, describe how running fast benefits the survival of animals in the wild.

Motion with Constant Speed  Suppose you are in a car traveling on a nearly empty freeway. You look at the speedometer and see that the car’s speed hardly changes. If the car neither slows down nor speeds up, the car is traveling at a constant speed. If you are traveling at a constant speed, you can measure your speed over any distance interval.

Changing Speed  Usually speed is not constant. Think about riding a bicycle for a distance of 5 km, as in Figure 3. As you start out, your speed increases from 0 km/h to 20 km/h. You slow down to 10 km/h as you pedal up a steep hill and speed up to 30 km/h going down the other side of the hill. You stop for a red light, speed up again, and move at a constant speed for a while. Finally, you slow down and then stop. Checking your watch, you find that the trip took 15 min. How would you express your speed on such a trip? Would you use your fastest speed, your slowest speed, or some speed between the two?

Table 1  Examples of Units of Speed

<table>
<thead>
<tr>
<th>Unit of Speed</th>
<th>Examples of Uses</th>
<th>Approximate Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>km/s</td>
<td>rocket escaping Earth’s atmosphere</td>
<td>11.2 km/s</td>
</tr>
<tr>
<td>km/h</td>
<td>car traveling at highway speed</td>
<td>100 km/h</td>
</tr>
<tr>
<td>cm/yr</td>
<td>geological plate movements</td>
<td>2 cm/yr – 17 cm/yr</td>
</tr>
</tbody>
</table>

Science Journal

How far do they move? Have students calculate how far each object in Table 1 moves in one hour and put their calculations and their answers in their Science Journals. rocket: 40,320 km; car: 100 km; geological plate: 0.0002 cm – 0.002 cm Logical-Mathmatical

Curriculum Connection

Geography  Geographers use lines of latitude and longitude to help them describe displacement on Earth. Have students find out how early seafarers determined their latitude and longitude. To find their latitude they used the positions of the stars and the Sun. They had no way to determine longitude until an accurate chronometer was developed in the mid-1700s. Logical-Mathmatical Linguistic
**Purpose** Students will calculate the average speed and velocity of a car’s motion. [2]

**Materials** tape, toy car, stopwatch, pencil, meterstick

**Teaching Strategy** Try to use cars that will travel in a straight line when pushed gently.

**Analysis**

average speed = distance/time; The speed would be the same if the car traveled in the opposite direction.

**Assessment**

Process Have students use their observations to hypothesize why the car eventually comes to a rest. Use Performance Assessment in the Science Classroom, p. 93.

---

**Answer** possible responses: driving a car in town, riding a bicycle

**Discussion**

Lightning Strikes Have students use the information in the Applying Math activity to calculate how far a lightning strike is from them if they see the lightning strike 5 seconds before they hear the thunder. Write the solution on the board after the students have had a chance to solve the problem. \( v = \frac{d}{t}, \) therefore, \( d = vt; \) \( d = 330 \text{ m/s} \times 5 \text{ s} = 1,650 \text{ m} = 1.65 \text{ km} \) [2]

**Figure 4** The speed shown on the speedometer gives the instantaneous speed—the speed at one instant in time.

**Describing the Motion of a Car**

**Procedure**

1. Mark your starting point on the floor with tape.
2. At the starting line, give your toy car a gentle push forward. At the same time, start your stopwatch.
3. Stop timing when the car comes to a complete stop. Mark the spot on the floor at the front of the car with a pencil. Record the time for the entire trip.
4. Use a meterstick to measure the distance to the nearest tenth of a centimeter and convert it to meters.

**Analysis**

Calculate the speed. How would the speed differ if you repeated your experiment in exactly the same way but the car traveled in the opposite direction?

**Graphing Motion**

The motion of an object over a period of time can be shown on a distance-time graph. Time is plotted along the horizontal axis of the graph and the distance traveled is plotted along the vertical axis of the graph. If the object moves with constant speed, the increase in distance over equal time intervals is the same. As a result, the line representing the object’s motion is a straight line.

For example, the graph shown in Figure 5 represents the motion of three swimmers during a 30-min workout. The straight red line represents the motion of Mary, who swim with a constant speed of 80 m/min over the 30-min workout. The straight blue line represents the motion of Kathy, who swim with a constant speed of 60 m/min during the workout.

The graph shows that the line representing the motion of the faster swimmer is steeper. The steepness of a line on a graph is the slope of the line. The slope of a line on a distance-time graph equals the speed. A horizontal line on a distance-time graph has zero slope, and represents an object at rest. Because Mary has a larger speed than Kathy, the line representing her motion has a larger slope.

**Differentiated Instruction**

**Learning Disabled** Perform the calculations for determining average speed on the board to help students understand the process before doing it themselves. After you have done the procedure several times, ask students to do the calculations on their own. [2]
**Changing Speed** The green line represents the motion of Julie, who did not swim at a constant speed. She covered 400 m at a constant speed during the first 10 min, rested for the next 10 min, and then covered 800 m during the final 10 min. During the first 10 min, her speed was less than Mary’s or Kathy’s, so her line has a smaller slope. During the middle period her speed is zero, so her line over this interval is horizontal and has zero slope. During the last time interval she swam as fast as Mary, so that part of her line has the same slope.

**Plotting a Distance-Time Graph** On a distance-time graph, the distance is plotted on the vertical axis and the time on the horizontal axis. Each axis must have a scale that covers the range of numbers to be plotted. In Figure 5 the distance scale must range from 0 to 2,400 m and the time scale must range from 0 to 30 min. Then, each axis can be divided into equal time intervals to represent the data. Once the scales for each axis are in place, the data points can be plotted. After plotting the data points, draw a line connecting the points.

---

**Caption Answer**

On Julie’s graph there is a slope of zero between 10 min and 20 min which represents a speed of 0 m/min.

**Differentiated Instruction**

**English-Language Learners** Have students cut photos out of magazines showing some type of motion. Have students create a decorative collage of their photos.

---

**Virtual Labs**

**d = st** What is the relationship between distance, average speed, and time?
**Discussion**

**Velocity** Describe the velocity of an object that travels north 6.9 m in 3 s, then turns and travels south 2.8 m in 4 s. velocity \(= \frac{2.3}{3} \text{ m/s north} \) then \(0.7 \text{ m/s south} \)

**Logical-Mathematical**

**Reading Check**

**Answer** Velocity includes direction; speed does not.

**Activity**

**Changing Velocity** Swing a ball on a string around your head at a constant speed. Ask students whether the velocity of the ball is constant or changing. changing, because the direction varies **Visual-Spatial**

**Inquiry Lab**

**Controlling Motion**

**Purpose** To design a device that will control the motion of a marble and keep the marble in constant motion for exactly 3 minutes.

**Possible Materials** Students will choose their own materials. Suggestions: cardboard sheets, cardboard tubes, pizza delivery boxes, or plastic tubing

**Estimated Time** 2 class periods, outside class time may be required

**Teaching Strategy** Divide the class into small groups. Students can use a variety of schemes to keep their marble in motion. The goal is to keep the marble in motion exactly 3 min, so the students will have to fine-tune their devices. Encourage students to use gravity, springs, catapults, mouse traps, etc. to make their device fun.

For additional inquiry activities, see Science Inquiry Labs.

**Science Journal**

**Changing Velocity** Have students write brief paragraphs in their Science Journals describing several situations in which speed is constant but velocity is changing. a person walking up and down the aisles of a grocery store at constant speed, a glider moving up and down in the air at constant speed **Linguistic**

**Velocity**

You turn on the radio and hear the tail end of a news story about a hurricane, like the one in Figure 6, that is approaching land. The storm, traveling at a speed of 20 km/h, is located 100 km east of your location. Should you be worried?

Unfortunately, you don’t have enough information to answer that question. Knowing only the speed of the storm isn’t much help. Speed describes only how fast something is moving. To decide whether you need to move to a safer area, you also need to know the direction that the storm is moving. In other words, you need to know the velocity of the storm. Velocity includes the speed of an object and the direction of its motion.

Escalators like the one shown in Figure 7 are found in shopping malls and airports. The two sets of passengers pictured are moving at constant speed, but in opposite directions. The speeds of the passengers are the same, but their velocities are different because the passengers are moving in different directions.

Because velocity depends on direction as well as speed, the velocity of an object can change even if the speed of the object remains constant. For example, look at Figure 7. The race car has a constant speed and is going around an oval track. Even though the speed remains constant, the velocity changes because the direction of the car’s motion is changing constantly.

How are velocity and speed different?

The people on these two escalators have the same speed. However, their velocities are different because they are traveling in opposite directions.

The speed of this car might be constant, but its velocity is not constant because the direction of motion is always changing.

**Active Reading**

**ReQuest** Have students listen carefully as you read an interesting story or newsworthy item aloud. After the reading, students, alone or in groups, can formulate questions to discuss. Have students participate in a ReQuest related to motion and/or acceleration and the forces that are acting on the object. **Linguistic**
Motion of Earth’s Crust

Can you think of something that is moving so slowly you cannot detect its motion, yet you can see evidence of its motion over long periods of time? As you look around the surface of Earth from year to year, the basic structure of the planet seems the same. Mountains, plains, lakes, and oceans seem to remain unchanged over hundreds of years. Yet if you examined geological evidence of what Earth’s surface looked like over the past 250 million years, you would see that large changes have occurred. Figure 8 shows how, according to the theory of plate tectonics, the positions of landmasses have changed during this time. Changes in the landscape occur constantly as continents drift slowly over Earth’s surface. However, these changes are so gradual that you do not notice them.

About 250 million years ago, the continents formed a supercontinent called Pangaea.

Figure 8 Geological evidence suggests that Earth’s continents have moved slowly over time.

Pangaea began to separate into smaller pieces and by 66 million years ago, the continents looked like the figure above. The continents are still moving today.
Moving Continents  How can continents move around on the surface of Earth? Earth is made of layers, as shown in Figure 9. The outer layer is the crust, and the layer just below the crust is called the upper mantle. Together the crust and the top part of the upper mantle are called the lithosphere. The lithosphere is broken into huge sections called plates that slide slowly on the puttylike layers just below. If you compare Earth to an egg, these plates are about as thick as the eggshell. These moving plates cause geologic changes such as the formation of mountain ranges, earthquakes, and volcanic eruptions.

The movement of the plates also is changing the size of the oceans and the shapes of the continents. The Pacific Ocean is getting smaller while the Atlantic Ocean is getting larger. The movement of the plates also changes the shape of the continents as they collide and spread apart.

Plates move so slowly that their speeds are given in units of centimeters per year. In California, two plates slide past each other along the San Andreas Fault with an average relative speed of about 1 cm per year. The Australian Plate’s movement is one of the fastest, pushing Australia north at an average speed of about 17 cm per year.
Acceleration, Speed, and Velocity

You’re sitting in a car at a stoplight when the light turns green. The driver steps on the gas pedal and the car starts moving faster and faster. Just as speed is the rate of change of position, acceleration is the rate of change of velocity. When the velocity of an object changes, the object is accelerating.

Remember that velocity includes the speed and direction of an object. Therefore, a change in velocity can be either a change in how fast something is moving or a change in the direction it is moving. Acceleration occurs when an object changes its speed, its direction, or both.

Speeding Up and Slowing Down When you think of acceleration, you probably think of something speeding up. However, an object that is slowing down also is accelerating.

Imagine a car traveling through a city. If the speed is increasing, the car has positive acceleration. When the car slows down its speed is decreasing and the car has negative acceleration. In both cases the car is accelerating because its speed is changing.

Acceleration also has direction, just as velocity does. If the acceleration is in the same direction as the velocity, as in Figure 10, the speed increases and the acceleration is positive. If the speed decreases, the acceleration is in the opposite direction from the velocity, and the acceleration is negative for the car shown in Figure 10.

Figure 10 These cars are both accelerating because their speed is changing.

- The speed of this car is increasing. The car has positive acceleration.
- The speed of this car is decreasing. The car has negative acceleration.

Tie to Prior Knowledge

“Stepping on the Gas” Have a student explain the phrase “stepping on the gas.” Relate the function of the accelerator to the motion of a car.
Aircraft Carriers  The U.S. navy was not alone in the development of aircraft carriers. During World War I the British navy converted a merchant-ship hull into the first aircraft carrier with an unobstructed flight deck, the HMS Argus. The first U.S. carrier, the USS Langley, joined the fleet in March 1922. The Japanese built the first carrier from the keel up, the Hosyo. It entered service in December 1922.

Research  Have students research modern aircraft carriers including nuclear-powered carriers. Students can prepare a presentation to present to the class using the information they find.

Discussion

Acceleration  Tell students that, as in the case of speed and velocity, acceleration can be constant or changing, and one can measure instantaneous acceleration as well as average acceleration. Ask students to give examples of constant acceleration, instantaneous acceleration, and average acceleration. Constant acceleration: free fall; instantaneous acceleration: the acceleration of a falling rock after it has been falling for 3 s; average acceleration: final velocity of the falling rock when it hits the ground divided by the total time it was falling.

Calculating Acceleration  Acceleration is the rate of change in velocity. To calculate the acceleration of an object, the change in velocity is divided by the length of the time interval over which the change occurred. To calculate the change in velocity, subtract the initial velocity—the velocity at the beginning of the time interval—from the final velocity—the velocity at the end of the time interval. Let \( v_i \) stand for the initial velocity and \( v_f \) stand for the final velocity. Then the change in velocity is:

\[
\text{change in velocity} = \text{final velocity} - \text{initial velocity} = v_f - v_i
\]

Using this expression for the change in velocity, the acceleration can be calculated from the following equation:

\[
\text{acceleration (in meters/second}^2\text{)} = \frac{\text{change in velocity (in meters/second)}}{\text{time (in seconds)}}
\]

Recall that velocity includes both speed and direction. However, if the direction of motion doesn’t change and the object moves in a straight line, the change in velocity is the same as the change in speed. The change in velocity then is the final speed minus the initial speed.

The unit for acceleration is a unit for velocity divided by a unit for time. In SI units, velocity has units of m/s, and time has units of s, so acceleration has units of m/s².

Curriculum Connection

Physical Education  Most sports rely on the ability of people to make quick changes in acceleration. Have students find out some of the equipment used in different sports to make acceleration easier: starting blocks for runners and swimmers; cleats on shoes for runners, soccer players, football players, and baseball players; rubber-soled shoes for basketball players; special clothing for reducing wind resistance for all racers.

Feeling Acceleration  In the aerospace industry, the accelerations experienced by astronauts and pilots are often expressed as multiples of g. The acceleration, caused by gravity (g), acting on an object falling freely near Earth’s surface is about 9.8 m/s². Vertical accelerations as low as 3 g can cause pilots to black out.
Visualizing Acceleration

Have students examine the pictures and read the captions. Then ask the following questions.

In the graphs for A, B, and C, how are the slopes of the lines and the accelerations of the objects related? The slope of the line is positive if acceleration is positive, negative if acceleration is negative, and zero if there is no acceleration.

In the graph for B, what is the numerical value of the acceleration of the ball? The numerical value is the same as the acceleration due to gravity, 9.8 m/s².

What is the relation between the graphs for B and C? The acceleration of both balls is due to the pull of gravity. Graph B has a positive acceleration due to gravity or +9.8 m/s² and graph C has a negative acceleration due to gravity or −9.8 m/s².

Activity

Rap Songs  Have students work in pairs to make up rap songs containing descriptions of the relationship between different types of acceleration and their corresponding graphs. [L2]

Auditory-Musical

Differentiated Instruction

Challenge  Have students find out what type of information can be obtained by finding the area under a speed-time graph. Explain why this could be a useful tool for scientists. Construct a speed-time graph and find the distance traveled by the object. The numerical value of the area under a speed-time graph is the distance traveled by the object. [L3]

Visually Impaired  Have a student helper read the text for each graph. Have the helper move his or her finger along the graph while the other student gently lays his or her hand on top of the helper’s hand. This can help the visually-impaired student “see” the graph. [L3]
Visual Learning

Figure 13 Review with students the graphs in Figure 13. Then ask a volunteer to draw on the board the speed-time graph for a car that starts at 0 km/h, accelerates to 30 km/h over a period of 2 minutes, runs at 30 km/h for 10 minutes, then takes 30 seconds to stop. [2]

Quick Demo

Sphere Acceleration

Materials about 2 m of clear plastic tubing, small sphere that can freely roll through tubing

Estimated Time 10 minutes

Procedure Have two students hold the tubing in a U-shape. Put the sphere in one end of the tubing. Point out to the students that the sphere has positive acceleration as it rolls downhill in the tubing. The sphere has negative acceleration as it starts to go uphill in the tubing.

Answer They are accelerated.

LAB DEMONSTRATION

Purpose to demonstrate making a table and graph from distance-time measurements

Materials 8 socks, clock with second hand, meterstick

Preparation Mark a starting place where you have room to walk.

Procedure Start walking at the starting line. Have a student call out every 3 s. Begin walking slowly then steadily increase your speed. Drop a sock every 3 s. Measure the distance from the starting line to each sock. On the board, make a table and a distance-time graph of the data.

Expected Outcome The distance between socks will increase for each 3-second interval.

Assessment What is the slope of the line after 6 s? The slope will vary with the data. What does this show? the speed [2]

Calculating Positive Acceleration How is the acceleration for an object that is speeding up different from that of an object that is slowing down? Suppose the jet airliner in Figure 13 starts at rest at the end of a runway and reaches a speed of 80 m/s in 20 s. The airliner is traveling in a straight line down the runway, so its speed and velocity are the same. Because it started from rest, its initial speed was zero. Its acceleration can be calculated as follows:

\[ a = \frac{(v_f - v_i)}{t} = \frac{(80 \text{ m/s} - 0 \text{ m/s})}{20 \text{ s}} = 4 \text{ m/s}^2 \]

The airliner is speeding up, so the final speed is greater than the initial speed and the acceleration is positive.

Calculating Negative Acceleration Now imagine that the skateboarder in Figure 13 is moving in a straight line at a constant speed of 3 m/s and comes to a stop in 2 s. The final speed is zero and the initial speed was 3 m/s. The skateboarder’s acceleration is calculated as follows:

\[ a = \frac{(v_f - v_i)}{t} = \frac{(0 \text{ m/s} - 3 \text{ m/s})}{2 \text{ s}} = -1.5 \text{ m/s}^2 \]

The skateboarder is slowing down, so the final speed is less than the initial speed and the acceleration is negative. The acceleration always will be positive if an object is speeding up and negative if the object is slowing down.
Amusement Park Acceleration

Riding roller coasters in amusement parks can give you the feeling of danger, but these rides are designed to be safe. Engineers use the laws of physics to design amusement park rides that are thrilling, but harmless. Roller coasters are constructed of steel or wood. Because wood is not as rigid as steel, wooden roller coasters do not have hills that are as high and steep as some steel roller coasters have. As a result, the highest speeds and accelerations usually are produced on steel roller coasters.

Steel roller coasters can offer multiple steep drops and inversion loops, which give the rider large accelerations. As the rider moves down a steep hill or an inversion loop, he or she will accelerate toward the ground due to gravity. When riders go around a sharp turn, they also are accelerated. This acceleration makes them feel as if a force is pushing them toward the side of the car. Figure 14 shows the fastest roller coaster in the United States.

What happens when riders on a roller coaster go around a sharp turn?

Figure 14  This roller coaster can reach a speed of about 150 km/h in 4 s.

Summary

Acceleration, Speed, and Velocity
- Acceleration is the rate of change of velocity.
- A change in velocity occurs when the speed of an object changes, or its direction of motion changes, or both occur.
- The speed of an object increases if the acceleration is in the same direction as the velocity.
- The speed of an object decreases if the acceleration and the velocity of the object are in opposite directions.

Calculating Acceleration
- Acceleration can be calculated by dividing the change in velocity by the time according to the following equation:
  \[ a = \frac{v_f - v_i}{t} \]
- The SI unit for acceleration is m/s².
- If an object is moving in a straight line, the change in velocity equals the final speed minus the initial speed.

Self Check
1. Describe three ways to change the velocity of a moving car.
2. Determine the change in velocity of a car that starts at rest and has a final velocity of 20 m/s north.
3. Explain why streets and highways have speed limits rather than velocity limits.
4. Describe the motion of an object that has an acceleration of 0 m/s².
5. Think Critically  Suppose a car is accelerating so that its speed is increasing. Describe the plotted line on a distance-time graph of the motion of the car.

Applying Math
6. Calculate Time A ball is dropped from a cliff and has an acceleration of 9.8 m/s². How long will it take the ball to reach a speed of 24.5 m/s?
7. Calculate Speed A sprinter leaves the starting blocks with an acceleration of 4.5 m/s². What is the sprinter’s speed 2 s later?

Check for Understanding

Kinesthetic  Have students work in groups to discuss acceleration experienced by a tennis ball as it is dropped and bounces. Because the velocity of the ball changes direction as it bounces, students must include the direction of the ball’s motion when they calculate acceleration. If down is the positive direction, the ball’s acceleration is positive when it falls. When the ball rises, its velocity becomes less negative as it moves upward, so its acceleration is again positive. When the ball is in contact with the floor, its acceleration is negative as it slows down in the positive (down) direction, and then speeds up in the negative (up) direction. Have students make a labeled poster illustrating the tennis ball’s positive then negative acceleration cycle; a pattern that repeats itself with each bounce.

Process  Think about how motion is affected by gravitational acceleration. Water on Earth falls from a waterfall with an acceleration of 9.8 m/s². The gravity of Mars is four-tenths that of Earth. If water were on the surface of Mars, would water fall from a waterfall faster, more slowly, or at the same speed? more slowly  Use  Performance Assessment in the Science Classroom, p. 89.
Tie to Prior Knowledge

Changing Velocity  Ask students to describe things they could do to change the velocity of a soccer ball. Point out that in each case, they are using a push or a pull to change the ball’s motion. Tell students that pushes and pulls are forces, and this section discusses how forces change an object’s motion.  

Answer  Student answers will vary. Possible answer: force of gravity on a falling object.

Changing Motion  What happens to the motion of an object when you exert a force on it? A force can cause the motion of an object to change. Think of hitting a ball with a racket, as in Figure 15. The racket strikes the ball with a force that causes the ball to stop and then move in the opposite direction. If you have played billiards, you know that you can force a ball at rest to roll into a pocket by striking it with another ball. The force of the moving ball causes the ball at rest to move in the direction of the force. In these cases, the velocities of the ball and the billiard ball were changed by a force.

What is force?  Passing a basketball to a team member or kicking a soccer ball into the goal are examples of applying force to an object. A force is a push or pull. In both examples, the applied force changes the movement of the ball. Sometimes it is obvious that a force has been applied. But other forces aren’t as noticeable. For instance, are you conscious of the force the floor exerts on your feet? Can you feel the force of the atmosphere pushing against your body or gravity pulling on your body? Think about all the forces you exert in a day. Every push, pull, stretch, or bend results in a force being applied to an object.

Figure 15  This ball is hit with a force. The racket strikes the ball with a force in the opposite direction of its motion. As a result, the ball changes the direction it is moving.

Lab Worksheet, pp. 5–6, 7–8
Home and Community Involvement, p. 41
Earth Science Critical Thinking/Problem Solving, p. 9
Cultural Diversity, p. 63

Motion and Forces

Reading Guide

What You’ll Learn
- Explain how force and motion are related.
- Describe what inertia is and how it is related to Newton’s first law of motion.
- Identify the forces and motion that are present during a car crash.

Why It’s Important
Force and motion are directly linked—without force, you cannot have motion.

New Vocabulary
- force
- net force
- balanced force
- inertia

What is force?  Passing a basketball to a team member or kicking a soccer ball into the goal are examples of applying force to an object. A force is a push or pull. In both examples, the applied force changes the movement of the ball. Sometimes it is obvious that a force has been applied. But other forces aren’t as noticeable. For instance, are you conscious of the force the floor exerts on your feet? Can you feel the force of the atmosphere pushing against your body or gravity pulling on your body? Think about all the forces you exert in a day. Every push, pull, stretch, or bend results in a force being applied to an object.

Figure 15  This ball is hit with a force. The racket strikes the ball with a force in the opposite direction of its motion. As a result, the ball changes the direction it is moving.
Motion and Forces

Quick Demo
Upward and Downward Force

Materials: spring scale and objects with various masses

Estimated Time: 10 minutes

Procedure: Hold up a spring scale and hang objects of different masses from it. Have a student read the force required to hold up each object. Explain that the upward force exerted by the spring of the spring scale balances the downward gravitational force of the object.

Balanced Forces

Students often assume no motion means no force, but an object’s lack of motion is because the forces acting on it are balanced. Students also may assume that an object in motion has an external force acting on it. Explain that motion may be caused by unbalanced forces, or it may be the result of inertia.

Visual Learning

Tell students that the net force acting on an object is called the resultant force. In Figure 16A, the forces are equal and in opposite directions, so the resultant force is zero. In Figure 16B, you can calculate the resultant force by subtracting the smaller force from the larger one. How would you calculate the resultant force in Figure 16C?

Activity: Use inexpensive materials such as bars of soap to model the forces and movements along the fault lines. Share your models and demonstrations with your class.

Plate Tectonics

Scientists do not fully understand the driving force behind the movement of the plates. There appears to be three factors contributing to the movement of the plates: the pull of gravity, convection currents in the mantle, and thermal plumes or vertical columns of molten material in the mantle.
Inertia and Mass

The dirt bike in Figure 17 is sliding on the track. This sliding bike demonstrates the property of inertia. Inertia (ihr NUR shuh) is the tendency of an object to resist any change in its motion. If an object is moving, it will have uniform motion. It will keep moving at the same speed and in the same direction unless an unbalanced force acts on it. The velocity of the object remains constant unless a force changes it. If an object is at rest, it tends to remain at rest. Its velocity is zero unless a force makes it move.

Does a bowling ball have the same inertia as a table-tennis ball? Why is there a difference? You couldn’t change the motion of a bowling ball much by swatting it with a table-tennis paddle. However, you easily could change the motion of the table-tennis ball. A greater force would be needed to change the motion of the bowling ball because it has greater inertia. Why is this? Recall that mass is the amount of matter in an object, and a bowling ball has more mass than a table-tennis ball does. The inertia of an object is related to its mass. The greater the mass of an object is, the greater its inertia.

Newton’s Laws of Motion Forces change the motion of an object in specific ways. The British scientist Sir Isaac Newton (1642–1727) was able to state rules that describe the effects of forces on the motion of objects. These rules are known as Newton’s laws of motion. They apply to the motion of all objects you encounter every day such as cars and bicycles, as well as the motion of planets around the Sun.

Figure 17 This racer is skidding because of inertia. The bike tends to move in a straight line with constant speed despite the efforts of the rider to steer the bike around the curve.

Differentiated Instruction

Challenge Have students prepare a diagram showing the four forces acting on an ice-skater skating forward. Explain why the skater is able to move forward for a relatively long period of time. Possible answer: The four forces are gravity pulling down on the skater, the ice pushing up, the ice pushing forward in response to the skater’s push on the ice, and friction pulling the skater back. Since the ice provides relatively little friction, the skater’s inertia keeps him or her moving forward for a relatively long time.

Logical-Mathematical
Newton's First Law of Motion

Newton's first law of motion states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it. If an object is at rest, it stays at rest unless an unbalanced net force acts on it. Does this sound familiar? It is the same as the earlier discussion of inertia. This law is sometimes called the law of inertia. You probably have seen and felt this law at work without even knowing it. Figure 18 shows a billiard ball striking the other balls in the opening shot. What are the forces involved when the cue ball strikes the other balls? Are the forces balanced or unbalanced? How does this demonstrate the law of inertia?

What happens in a crash?

The law of inertia can explain what happens in a car crash. When a car traveling about 50 km/h collides head-on with something solid, the car crumples, slows down, and stops within approximately 0.1 s. Any passenger not wearing a safety belt continues to move forward at the same speed the car was traveling. Within about 0.02 s (1/50 of a second) after the car stops, unbelted passengers slam into the dashboard, steering wheel, windshield, or the backs of the front seats, as in Figure 19. They are traveling at the car's original speed of 50 km/h—about the same speed they would reach falling from a three-story building.
Before the string was cut, the force of gravity was pulling down on the book. The string exerted an equal upward force on the book. Since these forces were equal and opposite in direction, the book was at rest. After the string was cut, there was no upward force on the book. The force of gravity was not opposed, so the book fell to the floor. The net force allows the kite to overcome gravity and fly. The tension (force) in the string prevents the kite from flying away. The downward force of gravity exerts on the person. The belt loosens a little as it restrains the person, increasing the time it takes to slow the person down. This reduces the force exerted on the person. The safety belt also prevents the person from being thrown out of the car. Car-safety experts say that about half the people who die in car crashes would survive if they wore safety belts. Thousands of others would suffer fewer serious injuries.

Air bags also reduce injuries in car crashes by providing a cushion that reduces the force on the car’s occupants. When impact occurs, a chemical reaction occurs in the air bag that produces nitrogen gas. The air bag expands rapidly and then deflates just as quickly as the nitrogen gas escapes out of tiny holes in the bag. The entire process is completed in about 0.04 s.
If you stand at a stoplight, you will see cars stopping for red lights and then taking off when the light turns green. What makes the cars slow down? What makes them speed up? Can a study of unbalanced forces lead to a better understanding of these everyday activities?

Real-World Question

How does an unbalanced force on a book affect its motion?

Goals

- **Observe** the effect of force on the acceleration of an object.
- **Interpret** the data collected for each trial.

Materials

- tape
- this science book
- paper clip
- triple-beam balance
- 10-N spring scale
- *electronic balance
- large book
  *Alternate materials

Safety Precautions

Proper eye protection should be worn at all times while performing this lab.

Procedure

1. With a piece of tape, attach the paper clip to your textbook so that the paper clip is just over the edge of the book.
2. Prepare a data table with the following headings: Force, Mass.
3. If available, use a large balance to find the mass of this science book.
4. Place the book on the floor or on the surface of a long table. Use the paper clip to hook the spring scale to the book.
5. Pull the book across the floor or table at a slow but constant velocity. While pulling, read the force you are pulling with on the spring scale and record it in your table.
6. Repeat step 5 two more times, once accelerating slowly and once accelerating quickly. Be careful not to pull too hard. Your spring scale will read only up to 10 N.

Conclude and Apply

1. Organize the pulling forces from greatest to least for each set of trials. Do you see a relationship between force and acceleration? Explain your answer.
2. Explain how adding the second book changed the results.

Have students discuss with one another any differences in their results and possible reasons for the differences.

Assessment

Process Ask students to infer how the pulling force would be different if a book with less mass were pulled. **Less force would be required.** How would it be different if three of the science books were pulled? **More force would be required.**

Use **Performance Assessment in the Science Classroom**, p. 89.
Comparing Motion from Different Forces

Real-World Question
Think about a small ball. How many ways could you exert a force on the ball to make it move? You could throw it, kick it, roll it down a ramp, blow it with a large fan, etc. Do you think the distance and speed of the ball’s motion will be the same for all of these forces? Do you think the acceleration of the ball would be the same for all of these types of forces?

Form a Hypothesis
Based on your reading and observations, state a hypothesis about how a force can be applied that will cause the toy car to go fastest.

Test Your Hypothesis

Make a Plan
1. As a group, agree upon the hypothesis and decide how you will test it. Identify which results will confirm the hypothesis that you have written.
2. List the steps you will need to test your hypothesis. Be sure to include a control run. Be specific. Describe exactly what you will do in each step. List your materials.
3. Prepare a data table in your Science Journal to record your observations.

Goals
- Identify several forces that you can use to propel a small toy car across the floor.
- Demonstrate the motion of the toy car using each of the forces.
- Graph the position versus time for each force.
- Compare the motion of the toy car resulting from each force.

Possible Materials
small toy car
ramps or boards of different lengths
springs or rubber bands
string
stopwatch
meterstick or tape measure
graph paper

Safety Precautions

Possible Hypothesis
Students might hypothesize that the force of the spring will cause the car to go fastest.

Data Table:

<table>
<thead>
<tr>
<th>Force Used</th>
<th>Distance</th>
<th>Time</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Alternative Inquiry Lab

Real-World Connection
To make this Lab an Inquiry Lab, give the students more personal investment into the problem by connecting it to the real world. Tell the students that they are designing a race track for a new type of car racing. They are to design a new race track that will allow stock cars to break speed records in racing. Students should consider safe but innovative ways to increase the speeds of the race cars.
4. **Read** the entire experiment to make sure all steps are in logical order and will lead to a useful conclusion.

5. **Identify** all constants, variables, and controls of the experiment. Keep in mind that you will need to have measurements at multiple points. These points are needed to graph your results. You should make sure to have several data points taken after you stop applying the force and before the car starts to slow down. It might be useful to have several students taking measurements, making each responsible for one or two points.

**Follow Your Plan**

1. Make sure your teacher approves your plan before you start.
2. Carry out the experiment as planned.
3. While doing the experiment, record your observations and complete the data tables in your Science Journal.

**Analyze Your Data**

1. Graph the position of the car versus time for each of the forces you applied. How can you use the graphs to compare the speeds of the toy car?
2. Calculate the speed of the toy car over the same time interval for each of the forces that you applied. How do the speeds compare?

**Conclude and Apply**

1. Evaluate Did the speed of the toy car vary depending upon the force applied to it?
2. Determine For any particular force, did the speed of the toy car change over time? If so, how did the speed change? Describe how you can use your graphs to answer these questions.
3. Draw Conclusions Did your results support your hypothesis? Why or why not?

**Test Your Hypothesis**

**Possible Procedures** Position students with stopwatches at points along a track to determine when the car reaches there. One student will provide the initial force to the car by releasing a spring against it, tugging it with a string, etc.

**Teaching Strategy** Encourage students to provide a sufficient force to enable the car to travel the entire length of the track they have made.

**Expected Outcome** Although results will vary greatly, students should be able to determine the average speed of the car for each force.

**Analyze Your Data**

1. Some graphs will show a slight increase in speed. Others will show a decrease in speed.
2. Students should calculate the average speed using $v = \frac{d}{t}$.

**Error Analysis** Ask students to compare their results with other groups and discuss ways the differences could be minimized.

**Conclude and Apply**

1. Did the speed of the toy car vary depending upon the force applied to it?
2. For any particular force, did the speed of the toy car change over time? If so, how did the speed change? Describe how you can use your graphs to answer these questions.
3. Did your results support your hypothesis? Why or why not?

**Assessment**

**Process** Ask students to draw diagrams showing how friction, gravity, and inertia influenced the motion of the car. Use *Performance Assessment in the Science Classroom*, p. 127.

**Communicating Your Data**

Have students use graphics software to prepare a poster explaining their experiment and the results. Posters should contain sketches showing forces on the car. They might also include graphs of the data.

**Answers to Questions**

1. yes
2. Answers will vary.
3. Answers will depend on student hypotheses.
Understanding Literature

Descriptive Writing

Angelou is telling us that the power that people have to make changes for better lives is more significant than the universe and the special places people have built on Earth.

Respond to the Reading

1. small, lonely, minuscule, kithless, wayward, floating
2. people
3. Linking Science and Writing

Remind students that the Moon revolves around Earth. Therefore, their poems should describe how the Moon might see the Sun come and go as it moves around Earth.

Motion

In the Middle Ages, most people thought Earth stood still and that the sky moved around Earth. It is now known that the daily movement of the stars is due to Earth’s rotation on its axis. This can be proven by focusing a camera on the North Star and leaving the shutter open for several hours. At the same time that Earth rotates, it revolves around the Sun. Earth follows the Sun in its wanderings through the heavens. The Sun revolves around the center of the Milky Way. Earth, a satellite of the Sun, takes part in this journey.

A Brave and Startling Truth
by Maya Angelou

We, this people, on a small and lonely planet Traveling through casual space Past aloof stars, across the way of indifferent suns To a destination where all signs tell us It is possible and imperative that we learn A brave and startling truth …

When we come to it Then we will confess that not the Pyramids With their stones set in mysterious perfection … Not the Grand Canyon Kindled into delicious color By Western sunsets These are not the only wonders of the world …

When we come to it We, this people, on this minuscule and kithless1 globe … We this people on this mote2 of matter

When we come to it We, this people, on this wayward3, floating body Created on this earth, of this earth Have the power to fashion for this earth A climate where every man and every woman Can live freely without sanctimonious piety4 Without crippling fear

When we come to it We must confess that we are the possible We are the miraculous, the true wonder of the world That is when, and only when

We come to it.

Respond to the Reading

1. What adjectives does the poet use to describe Earth?
2. What does the poet believe are the true wonders of the world?
3. Linking Science and Writing

Write a six-line poem that describes Earth’s movement from the point of view of the Moon.

Sometime a person doesn’t need to see movement to know that something has moved. Even though we don’t necessarily see Earth’s movement, we know Earth moves relative to a reference point such as the Sun. If the Sun is the reference point, Earth moves because the Sun appears to change its position in the sky. The poem describes Earth’s movement from a reference point outside of Earth, somewhere in space.

Resources for Teachers and Students


Roller Coaster, by David Bennett, Chartwell Books, 1998

1 to be without friends or neighbors
2 small particle
3 wanting one’s own way in spite of the advice or wishes of another
4 a self-important show of being religious
Summary statements can be used by students to review the major concepts of the chapter.

### Section 1  Describing Motion

1. Motion is a change of position of a body. Distance is the measure of how far an object moved. Displacement is the distance and direction of an object’s change in position from the starting point.
2. A reference point must be specified in order to determine an object’s position.
3. The speed of an object can be calculated from this equation: 
   \[ s = \frac{d}{t} \]
4. The slope of a line on a distance-time graph is equal to the speed.
5. Velocity describes the speed and direction of a moving object.

### Section 2  Acceleration

1. Acceleration occurs when an object changes speed or changes direction.
2. An object speeds up if its acceleration is in the direction of its motion.
3. An object slows down if its acceleration is opposite to the direction of its motion.
4. Acceleration is the rate of change of velocity, and is calculated from this equation: 
   \[ a = \frac{v_f - v_i}{t} \]

### Section 3  Motion and Forces

1. A force is a push or a pull.
2. The net force acting on an object is the combination of all the forces acting on the object.
3. The forces on an object are balanced if the net force is zero.
4. Inertia is the resistance of an object to a change in motion.
5. According to Newton’s first law of motion, the motion of an object does not change unless an unbalanced net force acts on the object.

### Identification of Misconceptions

After students have done the activity on page F at the beginning of the chapter and completed the chapter, have them perform this activity.

**Materials** protractor, paper, ruler, string

**Procedure** Have each student use the protractor to draw a large circle and label four points 90 degrees apart A, B, C, and D. Have them place an object at point A, and tell them the object will travel around the circle. Their mission is to find the object’s distance traveled and displacement at points B, C, and D.

**Expected Outcome** Use the string to measure the circle or use the formula for a perimeter of a circle.
1. Both tell how distance changes with time. Velocity includes the direction.

2. Displacement is distance and direction from a starting point. Distance is how far an object has moved.

3. Both describe rate of change in position. Average speed refers to total distance moved divided by total time elapsed. Instantaneous speed refers to speed at a given point in time.

4. Balanced forces are forces on an object that cancel each other out. Net force is the sum of all forces acting on an object.

5. Force is a push or a pull that one body exerts on another. Inertia is the tendency of an object to resist change in motion.

6. Velocity is the speed and direction of an object. Acceleration is how the velocity changes with time.

7. Velocity is the speed and direction of an object. Instantaneous speed is how fast an object moves at a given point in time.

8. Force is a push or a pull. Net force is the sum of all forces acting on an object.

9. Force is a push or a pull. Acceleration is the change in velocity of an object.

10. Which of the following is a proper unit of acceleration?

   A) $s/km^2$
   B) $km/h$
   C) $m/s^2$
   D) $cm/s$

11. Which of the following is not used in calculating acceleration?

    A) initial velocity
    B) average speed
    C) time interval
    D) final velocity

12. In which of the following conditions does the car NOT accelerate?

    A) A car moves at 80 km/h on a flat, straight highway.
    B) The car slows from 80 km/h to 35 km/h.
    C) The car turns a corner.
    D) The car speeds up from 35 km/h to 80 km/h.

13. What is the tendency for an object to resist any change in its motion called?

    A) net force
    B) acceleration
    C) balanced force
    D) inertia

14. How can speed be defined?

    A) acceleration/time
    B) change in velocity/time
    C) distance/time
    D) displacement/time

15. Make a distance-time graph that shows the motion of both runners. What is the average speed of each runner? Which runner stops briefly? Over what time interval do they both have the same speed?
18. Copy and complete this concept map on motion.

19. Evaluate Which of the following represents the greatest speed: 20 m/s, 200 cm/s, or 0.2 km/s?
20. Recognize Cause and Effect Acceleration can occur when a car is moving at constant speed. What must cause this acceleration?
21. Explain why a passenger who is not wearing a safety belt will likely hit the windshield in a head-on collision.
22. Determine If you walked 20 m, took a book from a library table, turned around and walked back to your seat, what are the distance traveled and displacement?

23. Explain When you are describing the rate that a race car goes around a track, should you use the term speed or velocity to describe the motion?

24. Calculate Speed A cyclist must travel 800 km. How many days will the trip take if the cyclist travels 8 h/day at an average speed of 16 km/h?
25. Calculate Acceleration A satellite’s speed is 10,000 m/s. After 1 min, it is 5,000 m/s. What is the satellite’s acceleration?
26. Calculate Displacement A cyclist leaves home and rides due east for a distance of 45 km. She returns home on the same bike path. If the entire trip takes 4 h, what is her average speed? What is her displacement?
27. Calculate Velocity The return trip of the cyclist in question 13 took 30 min longer than her trip east, although her total time was still 4 h. What was her velocity in each direction?

28. Interpret a Graph Use the graph to determine which runner had the greatest speed.

29. Thinking Critically

19. 0.2 km/s
20. change in direction
21. The inertia of the unbelted passenger will cause the person to move forward.
22. distance traveled, 40 m; displacement, 0 m
23. speed, because the velocity is constantly changing due to the constant change of direction

30. Applying Math

17. Sally’s average speed is 2 m/s and Alonzo’s is 1 m/s. Alonzo stops briefly; they run at the same speed from 3 s to 4 s.

31. National Math Standards

1, 2, 5, 6, 9

24. time = 800 km/16 km/h = 50 h; at 8 h/day, total time is 6 days 2 hours
25. about —83.3 m/s²
26. 22.5 km/h; displacement is 0
27. Time there is 1.75 hours; time back is 2.25 hours; velocity there is 25.7 km/h; velocity back is — 20 km/h.
28. Runner 1 because of the greater slope on the graph
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Sound travels at a speed of 330 m/s. How long does it take for the sound of thunder to travel 1485 m?
   A. 45 s  
   B. 4.5 s  
   C. 4,900 s  
   D. 0.22 s

2. The graph shows how a cyclist’s speed changed over distance of 5 km. What is the cyclist’s average speed if the trip took 0.25 h?
   A. 2 km/h  
   B. 30 km/h  
   C. 20 km/h  
   D. 8 km/h

3. Once the trip was started, how many times did the cyclist stop?
   A. 0  
   B. 4  
   C. 2  
   D. 5

4. What was the fastest speed the cyclist traveled?
   A. 20 km/h  
   B. 30 km/h  
   C. 12 km/h  
   D. 10 km/h

5. A skier is going down a hill at a speed of 9 km/s. The hill gets steeper and her speed increases to 18 m/s in 3 s. What is her acceleration?
   A. 9 m/s²  
   B. 3 m/s²  
   C. 27 m/s²  
   D. 6 m/s²

6. Which of the following best describes an object with constant velocity?
   A. It is changing direction.  
   B. Its acceleration is increasing.  
   C. Its acceleration is zero.  
   D. Its acceleration is negative.

7. Which of the following is a force?
   A. friction  
   B. acceleration  
   C. inertia  
   D. velocity

8. What is Daisy’s average speed?
   A. 0.29 km/min  
   B. 5.30 km/min  
   C. 2.9 km/min  
   D. 3.4 km/min

9. Which runner has the fastest average speed?
   A. Daisy  
   B. Jane  
   C. Bill  
   D. Joe

10. The movement of the Australian plate pushes Australia north at an average speed of about 17 cm per year. What will Australia’s displacement be in meters in 1,000 years?
    A. 170 m north  
    B. 170 m south  
    C. 1,700 m north  
    D. 1,700 m south

Part 2 Short Response

11. Swimmer C is the fastest because the line representing her motion has the larger slope.

12. Swimmers B and C swim at constant speed because their motion is shown by straight lines. Swimmer A did not swim at a constant speed because between 10 and 20 minutes, her speed is zero.

13. You must also know the direction the storm is moving in order to plot its course. This allows you to predict where it will hit land and which people should evacuate.

14. The car could be accelerating if it is changing direction.

15. —2.2 m/s²

Part 3 Open Ended

16. You could speed up, slow down, or change direction.

17. If the object slows down and comes to a stop, its velocity is changing. According to the first law of motion, an unbalanced force must be acting on the object.

18. Possible answer: A box is at rest. You push on the box in one direction and someone else pushes with an equal force in the opposite direction.

19. plane speeds up: force exerted by engine is greater than air resistance, net force is in the forward direction; plane slows down: air resistance is greater than force exerted by engine, net force is in the backward direction.
20. Possible answer: at the Sun, because Earth and Jupiter move with respect to the Sun

21. The greater the mass of the car, the greater the stopping distance. The greater the mass of the car, the more inertia it has, and the harder it is to change its motion.

22. The speed of one car relative to the other is greater than the speed of that car relative to the ground.