Newton’s Laws of Motion

Includes:

Reproducible Student Pages

ASSESSMENT
- ✔ Chapter Tests
- ✔ Chapter Review

HANDS-ON ACTIVITIES
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- ✔ Laboratory Activities
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MEETING INDIVIDUAL NEEDS
- ✔ Directed Reading for Content Mastery
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- ✔ Reinforcement
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Hands-On Activities
Measuring Motion

Procedure
1. Measure a fixed distance such as the length of your driveway.
2. Use a watch to measure the time it takes you to stroll, rapidly walk, and run this distance.

Data and Observations

<table>
<thead>
<tr>
<th></th>
<th>Time 1 at Test Distance</th>
<th>Time 2 at Test Distance</th>
<th>Time 3 at Test Distance</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strolling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapidly walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
1. Calculate your speed in each case.
2. Use your results to predict how long it would take you to go 100 m by each method.
Observing the Laws of Motion

Procedure
1. Incline one end of a board to a height of 20 cm.
2. Lay a meterstick on the floor with one end flush to the board and place a softball where the board and meterstick meet.
3. Hold a baseball 10 cm up the slope and roll it into the softball. Measure the distance the softball is pushed. Record your measurements in the table provided.
4. Repeat step 3 from different heights.

Data and Observations

<table>
<thead>
<tr>
<th>Trial</th>
<th>Height</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
1. Compare the distances the baseball pushes the softball.

2. Use the laws of motion to explain your results.
LAB
Static and Sliding Friction

Lab Preview
Directions: Answer these questions before you begin the Lab.

1. What potential hazard do you think there might be from using the materials in this lab?

2. How do you think friction might affect Newton’s first law?

Static friction can hold an object in place when you try to push or pull it. Sliding friction explains why you must continually push on something to keep it sliding across a horizontal surface.

Real-World Question
How do the forces of static friction and sliding friction compare?

Materials
- spring scale
- block of wood or other material
- tape

Goals
- Observe static and sliding friction.
- Measure static and sliding frictional forces.
- Compare and contrast static and sliding friction.

Safety Precautions

Procedure
1. Attach a spring scale to the block and set it on the table. Experiment with pulling the block with the scale so you have an idea of how hard you need to pull to start it in motion and continue the motion.

2. Measure the force needed to just start the block in motion. This is the force of static friction. Record your measurements in the table.

3. Measure the force needed to keep the block moving at a steady speed. This is the force of sliding friction on the block. Record your measurement.

4. Repeat steps 2 and 3 on a different surface, such as carpet. Record your measurements in the table.

Data and Observations

<table>
<thead>
<tr>
<th>Force Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>To start block in motion</td>
</tr>
<tr>
<td>To keep block moving at steady speed</td>
</tr>
<tr>
<td>To start block on carpet</td>
</tr>
<tr>
<td>To keep block moving on carpet</td>
</tr>
</tbody>
</table>

Newton’s Laws of Motion 5
Analyze Your Data
1. **Compare** the forces of static friction and sliding friction on both horizontal surfaces. Which force is greater?

2. On which horizontal surface is the force of static friction greater?

3. On which surface is the force of sliding friction greater?

Conclude and Apply
1. **Draw Conclusions** Which surface is rougher? How do static and sliding friction depend on the roughness of the surface?

2. **Explain** how different materials affect the static and sliding friction between two objects.

Communicating Your Data
Compare your conclusions with those of other students in your class.

(continued)
Lab Preview

Directions: Answer these questions before you begin the Lab.

1. What materials might you use in this lab to create balanced and unbalanced forces?

2. What forces are at work when you write on a piece of paper? Are they balanced or unbalanced? Explain.

Newton’s laws tell you that to change the velocity of an object, there must be an unbalanced force acting on the object. Changing the velocity can involve changing the speed of the object, changing the direction of motion, or changing both.

Real-World Question
How can you apply an unbalanced force to an object? How does the motion change when you exert a force in different ways?

Form a Hypothesis
Predict how the motion of a block will change when different forces are applied to it. Consider both speed and direction.

Goals
- Describe how to create balanced and unbalanced forces on an object.
- Demonstrate forces that change the speed and the direction of an object’s motion.

Test Your Hypothesis

Make a Plan
1. Describe how you are going to exert forces on the block using the available materials.
2. List several different ways to exert forces or combinations of forces on the block. Think about how strong each force will need to be to change the motion of the block. Include at least one force or combination of forces that you think will not change the object’s motion.
3. Predict which forces will change the object’s direction, its speed, both, or neither. Are the forces balanced or unbalanced?

Check Your Plan
1. Make sure that your teacher approves your plans before going any further.
2. Compare your plans for exerting forces with those of others in your class. Discuss why each of you chose the forces you chose.
Hands-On Activities

Communicating Your Data

Compare your results with those of other students in your class. Discuss how different combinations of forces affect the motion of the objects.

Hands-On Activities

Follow Your Plan
1. Set up your model so that you can exert each of the forces that you listed.
2. Collect data by exerting each of the forces in turn and recording how each one affects the object’s motion.

Analyze Your Data
1. Identifying Variables For each of the forces or combinations of forces that you applied to the object, list all of the forces acting on the object. Was the number of forces acting always the same? Was there a situation when only a single force was being applied? Explain.

2. Record Observations What happened when you exerted balanced forces on the object? Were the results for unbalanced forces the same for different combinations of forces? Why or why not?

Conclude and Apply
1. Were your predictions correct? Explain how you were able to predict the motion of the block and any mistaken predictions you might have made.

2. Summarize Which of Newton’s laws of motion did you demonstrate in this lab?

3. Apply Suppose you see a pole that is supposed to be vertical, but is starting to tip over. What could you do to prevent the pole from falling over? Describe the forces acting on the pole as it starts to tip and after you do something. Are the forces balanced or unbalanced?

(continued)
An empty truck is driven to a warehouse and picks up a large load. As the truck leaves the warehouse, the driver notices that it takes longer to reach the speed limit on the highway than it did before when the truck was empty. How do you think Newton’s second law of motion applies to the truck driver’s observations?

**Strategy**
You will determine the relationship between the force applied to an object and the motion produced by the force.
You will observe and describe how an increase in mass affects the force required to move an object.
You will observe and describe how an increase in force affects the acceleration of an object.

**Materials**
- balance
- meterstick
- books, small (3)
- string (150 cm)
- 30-g weights with hole (30)
- large paper clip
- large paper clip
- masking tape (60 cm)
- stopwatch
- *large metal washers (30)
- *fishing sinkers, 1 oz (30)
- *clock with second hand
- *Alternate materials

**Procedure**
1. Use the balance to determine the mass of each book. Record these masses in Table 1 in the Data and Observations section. From this data, calculate the masses of books 1 and 2 together and of all three books together. Record these masses in the table.
2. Use the balance to determine the mass of 10 weights. Record that mass here.
   Mass of 10 weights ____________
   Divide the mass recorded by 10 to get the average mass of one weight.
   Mass of 1 weight ____________
3. Place a 60 cm strip of masking tape on a table. Mark the tape in centimeters.
4. Tie the two ends of string together to make a loop.
5. Place the loop of string inside the front cover of one of the books, as shown in Figure 1.
6. Place the book on a tabletop so that some of the string hangs over the edge of the table.
7. Unbend the paper clip to form an “S.” Hook one end of the paper clip to the loop of string hanging over the table edge.
8. Slide the book back so the spine of the book is at the 60 cm mark on the masking tape. Your setup should look like Figure 2.
9. Hang weights, one at a time, from the paper clip until the book begins to move toward the edge of the table. Do not let the book slide off the table.
10. Count the number of weights on the paper clip. Calculate the total mass of the weights and record this in Table 1.
11. Calculate the force acting on the book from the weights by multiplying the mass in grams times 0.0098 N/g. Record this force in Table 1.
12. Without removing the weights, slide the book back to the 60 cm mark. Release the book and use the stopwatch to measure the number of seconds it takes for the book to travel 50 cm (to move from the 60 cm mark to the 10 cm mark).

![Figure 1](image-url)
13. Calculate the acceleration caused by the force and record this in Table 1. The formula for calculating acceleration is given below. In the formula, $a$ stands for acceleration, $d$ stands for distance, and $t$ stands for time. (The distance for each trial is 50 cm, which equals 0.5 m.)

$$a = \frac{2d}{t^2}$$

14. Repeat steps 8 through 13 using 2 books. Place the second book on top of the book with the loop attached.

15. Repeat steps 8 through 13 using three books. Place the third book on top of the other two books.

16. Repeat steps 12 through 13 three times using one book. For the first trial, use the number of weights you used in step 10. For the second trial, use the number of weights you used for two books. For the third trial, use the number of weights you used for three books. Record the results in the Table 2.

**Data and Observations**

**Table 1**

<table>
<thead>
<tr>
<th>Mass of books (g)</th>
<th>Mass of weights (g)</th>
<th>Force on book(s) (N)</th>
<th>Time (s)</th>
<th>Acceleration (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Book 1 + 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Book 1, 2 + 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

<table>
<thead>
<tr>
<th>1 Book</th>
<th>Mass of weights (g)</th>
<th>Force on book (N)</th>
<th>Time (s)</th>
<th>Acceleration (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions and Conclusions

1. How does the force needed to move an object change when the mass of an object increases?

2. What happens to the acceleration of an object as the force applied to it increases?

3. Make a graph on the next page of the data from Table 2. Show the force on the x-axis and the acceleration produced on the y-axis. Use the graph to predict the acceleration that would be caused by a force of 0.5 N.

4. Use the data from Table 1 for the force \( F \) on one book and the acceleration \( a \) of the book to calculate the mass of one book using the formula \( F = ma \). The result you calculate should agree with the mass of the book you measured on the balance in step 1. How closely do your results agree? What might be some reasons your results might not agree?

Strategy Check

_____ Can you determine the relationship between the force applied to an object and the motion produced by force?

_____ Can you describe how an increase in mass affects the force required to move an object?

_____ Can you describe how an increase in force affects the acceleration of an object?
Action and Reaction

The two forces in an action-reaction pair must interact, act in opposite directions, act on different objects in the interaction, and be equal in magnitude. In a rocket, the action force is the force exerted by the rocket that pushes hot gases out the nozzle. The escaping gases cause a reaction force that moves the rocket in the opposite direction. In this activity, you can observe Newton's third law in action.

Strategy
You will make and use a model that illustrates Newton's third law of motion.
You will observe action and reaction related to Newton’s third law of motion.
You will identify the forces in an action and reaction.

Materials
- plastic drinking straw
- long balloons (2)
- scissors
- masking tape
- fishing line (3 m)
- table tennis ball
- chairs (2)

Procedure

Part A
1. Cut a drinking straw into two equal parts.
2. Slide the fishing line through each piece of straw.
3. Tie each end of the fishing line to the back of a chair. Move the chairs apart so that the fishing line is taut.
4. Move both pieces of straw to one end of the fishing line.
5. Inflate one of the balloons and hold the end closed.
6. Have a partner tape the balloon to the piece of straw farthest away from the chair with the open end of the balloon toward this chair, as shown in Figure 1.
7. Release the balloon and observe what happens. Record your observations in the table in the Data and Observations section.
8. Remove the balloon from the straw. Then repeat steps 5 through 7, but place the straws near the center of the fishing line.

Figure 1

[Diagram showing the experiment setup]
Laboratory Activity 2 (continued)

Part B
1. Repeat step 5 of Part A. Have a partner attach the balloon to a piece of straw near the center of the fishing line. Then have your partner attach a table tennis ball to another piece of straw. The ball should be behind the open end of the balloon, as shown in Figure 2.
2. Release the balloon and observe what happens. Record your observations in the table.
3. Remove the balloon and ball from the fishing line.

Part C
1. Blow up the balloon again and hold the end closed. Have a partner blow up a second balloon and hold its end closed.
2. Have another partner attach both balloons to straws near the center of the fishing line. Place the open end of one balloon near the closed end of the other balloon.
3. Release both balloons at the same time and observe what happens. Record your observations in the table.

Figure 2

Data and Observations

<table>
<thead>
<tr>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>One balloon (end of string)</td>
</tr>
<tr>
<td>One balloon (center of string)</td>
</tr>
<tr>
<td>Balloon and table tennis ball (center of string)</td>
</tr>
<tr>
<td>Two balloons (center of string)</td>
</tr>
</tbody>
</table>
Questions and Conclusions

1. In Part A, compare the direction of the escaping air with the direction of the balloon’s movement.

2. In Parts A and B, did the escaping air have to hit anything to make the balloon move? Explain.

3. In Part B, what effect did the escaping air have on the table tennis ball? Use Newton’s law to explain why the ball moved as it did.

4. Explain the movement of the second balloon in Part C.

Strategy Check

_____ Can you make and use a model that illustrates Newton’s third law of motion?

_____ Can you observe action and reaction related to Newton’s third law?

_____ Can you identify the forces in an action and reaction?
Newton’s Laws of Motion

Directions: Use this page to label your Foldable Start Up Activities at the beginning of the chapter.

Motion
First Law
Second Law
Third Law
Meeting Individual Needs
Directions: Complete the following sentences.
1. If you walk from your house to your friend’s house, the distance and direction between your house and your friend’s house is your ____________________.
2. The distance traveled divided by the time needed to travel the distance is ____________________.
3. Displacement divided by time is ____________________.
4. Forces that cancel each other out are ____________________.

Directions: Complete the concept map using the terms below. Some terms may be used more than once.

<table>
<thead>
<tr>
<th>force</th>
<th>second</th>
<th>first</th>
<th>equal</th>
<th>third</th>
</tr>
</thead>
</table>

According to

5. Newton’s law of motion
   an object in motion will stay in motion until a ____________ acts upon it

6. Newton’s law of motion
   an object acted upon by a ____________ will accelerate in the direction of that force

7. Newton’s law of motion

8. ____________

9. Newton’s law of motion
   forces always act in but opposite pairs

10. ____________
Directions: Write the term that matches each description in items 1 through 6 below on the spaces provided. Unscramble the boxed letters to spell the term that answers question 7.

1. A measure of an object’s tendency to remain at rest or continue at constant speed
2. How far something travels
3. How far something ends up from its starting place
4. A push or a pull
5. Forces that result in no change in an object’s motion
6. The force that resists motion
7. An object will remain at rest or move in a straight line with constant speed unless it is acted upon by a force. This is the definition of Newton’s first law of ________________________ .

Directions: Circle the term in parentheses that makes the statement correct.

8. (Velocity, Speed) is an object’s displacement divided by time.
9. (Displacement, Acceleration) is the change in an object’s velocity divided by the amount of time required for the change to occur.
10. A (force, motion) is a push or a pull.
11. When scientists need to measure force, they use the (newton, degree).
12. The first law of motion is sometimes called the law of (inertia, force).
Directions: For each of the following, write the letter of the choice that best completes the sentence.

1. When you exert a force on an object it exerts ______ force back on you.
   a. a stronger  
   b. the same

2. When volleyball players jump into the air, the primary force acting to make them land back on the ground is ______.
   a. mass  
   b. gravity

3. Forces always act in ______.
   a. pairs  
   b. singles

4. In a game of tug-o-war, the team that wins has exerted a greater ______ force.
   a. unbalanced  
   b. mass

5. When you are pushing on a large door, ______ friction keeps you from sliding backwards.
   a. unbalanced  
   b. static

6. ______ is determined by gravity.
   a. weight  
   b. mass

7. A component of inertia is ______.
   a. mass  
   b. friction

8. ______ friction causes a car tire to turn on the road.
   a. Static  
   b. Rolling

9. ______ friction keeps an object from moving when a force is applied.
   a. Static  
   b. Sliding

10. If the same force is applied to two different objects, the one with the ______ mass has a smaller acceleration.
    a. larger  
    b. smaller
Key Terms
Newton’s Laws of Motion

Directions: Complete the following sentences using the terms listed below.

unbalanced force first
third friction speed

1. A _______________ is a push or pull on an object.
2. When an object remains at rest or moves in a straight line with constant speed until it is acted upon by an unbalanced force, the _______________ law of motion is demonstrated.
3. A(n) _______________ force allows you to pick up your book bag.
4. The _______________ law of motion says that for every action there is an equal but opposite reaction.
5. _______________ is a way to measure the rate of motion.
6. If you are trying to ice skate and you fall, the _______________ was too great between your skates and the ice.

Directions: Unscramble the terms in italics to complete the sentences below. Write the terms on the lines provided.

7. A car travels down the road at 30 miles per hour in a northwest direction which means it has _______________.
8. A student walks west from the school to the bus stop and has a _______________ of 50 meters west.
9. The train slows down as it comes to the station producing _______________.
10. When you roll a ball along the ground the ball is experiencing _______________.
11. Acceleration = force/mass is an example of Newton’s _______________ law of motion.
12. _______________ is all around you.
13. _______________ forces will not change the motion of an object.
Instrucciones: Completa las oraciones.

1. Si caminas desde tu casa hasta la casa de tu amigo, la distancia y la dirección entre la casa de tu amigo y tu casa es ________________.

2. La distancia viajada dividida entre el tiempo necesario para viajar tal distancia es el(la) ________________.

3. El desplazamiento dividido entre el tiempo es ________________.

4. Las fuerzas que se cancelan mutuamente son ________________.

Instrucciones: Completa el mapa de conceptos usando los siguientes términos. Algunos términos se usan más de una vez.

<table>
<thead>
<tr>
<th>fuerza</th>
<th>segunda</th>
<th>primera</th>
<th>igual</th>
<th>tercera</th>
</tr>
</thead>
</table>

5. ley de movimiento

6. ___________

7. ley de movimiento

8. ___________

9. ley de movimiento

10. ___________

Según la

de Newton, un cuerpo en

movimiento

permanecerá en movimiento hasta que un(a)

actúe sobre él

un cuerpo

sobre el cual actúa un(a)

acelerará en la dirección de esa fuerza

las fuerzas siempre actúan en

pares

pero opuestos
Sección 1  •  El movimiento
Sección 2  •  La primera ley
de Newton

Instrucciones: Resuelve el crucigrama usando los términos aprendidos.

Horizontales
3. La posición final a partir de la posición inicial.
5. Fuerzas que no resultan en un cambio en el movimiento de un cuerpo.
6. La primera ley de ______ de Newton establece que un cuerpo permanecerá en reposo o se moverá en línea recta con rapidez constante, a menos que una fuerza actúe sobre él.

7. Medida de la tendencia de un cuerpo a permanecer en reposo o continuar moviéndose con rapidez constante.

Verticales
1. Empujón o jalón.
2. Rapidez en un momento dado.

Instrucciones: Encierra en un círculo el término en paréntesis que hace que cada oración sea verdadera.
8. (Velocidad/Rapidez) es el desplazamiento de un cuerpo dividido entre tiempo.
9. El (La) (desplazamiento/aceleración) es el cambio en la velocidad de un cuerpo dividido entre la cantidad de tiempo que tomó el cambio.
10. Un(a) (fuerza/movimiento) es un empujón o un jalón.
11. Cuando los científicos necesitan medir la fuerza, usan el (newton/grado).
12. La primera ley del movimiento se conoce como la ley de la (inercia/fuerza).
Las leyes del movimiento de Newton

Instrucciones: En cada una de las siguientes, escribe la letra del término que complete mejor cada oración.

1. Cuando ejerces fuerza sobre un cuerpo, el cuerpo ejerce una fuerza ______ contra ti.
   a. más fuerte       b. igual

2. Cuando los jugadores de vólibol brincan, la fuerza primaria que actúa sobre ellos hasta que caen de nuevo al suelo es la ______.
   a. masa       b. gravedad

3. Las fuerzas siempre actúan ______.
   a. en pares       b. por sí solas

4. En un juego de guerra de la cuerda, el equipo que gana es el que ejerció la mayor fuerza ______.
   a. desequilibrada       b. de masa

5. En un juego de guerra de la cuerda, el equipo que gana ejerció la fuerza ______ más grande.
   a. desequilibrada       b. estática

6. La gravedad determina el(la) ______.
   a. peso       b. masa

7. Una medida de la inercia es la ______.
   a. masa       b. fricción

8. La fricción ______ hace que las llantas de un auto den vuelta al viajar.
   a. estática       b. de rodamiento

9. La fricción ______ mantiene los cuerpos en su sitio cuando una fuerza actúa sobre ellos.
   a. estática       b. de deslizamiento

10. Si se aplica la misma fuerza a dos cuerpos distintos, el que tiene la masa ______ tendrá la menor aceleración.
    a. mayor       b. menor
Las leyes del movimiento de Newton

**Términos claves**

Las leyes del movimiento de Newton

**Instrucciones:** Completa las oraciones usando los siguientes términos.

- desequilibrada
- primera
- fuerza
- tercera
- fricción
- rapidez

1. Un(a) ____________________ es un empujón o un jalón.
2. La ____________________ ley del movimiento se demuestra cuando un cuerpo permanece en reposo o se mueve en línea recta con rapidez constante hasta que una fuerza desequilibrada actúa sobre él.
3. Una fuerza ____________________ te permite levantar la mochila.
4. La ____________________ ley del movimiento establece que para cada acción existe una reacción igual, pero opuesta.
5. La tasa de movimiento se mide mediante el(la) ____________________.
6. Si tratas de patinar sobre el hielo y te caes, el(la) ____________________ entre tus patines y el hielo era demasiado fuerte.

**Instrucciones:** Acomoda las letras de los términos en bastardilla para completar cada oración. Escribe los términos en las líneas de la izquierda.

7. Un auto viaja por un camino a 30 millas por hora en dirección noreste, lo que significa que tiene didvoleac.
8. Un alumno camina hacia el oeste desde la escuela a la estación del autobús y tiene un metoidpleazsnae de 50 metros al oeste.
10. Cuando haces rodar una pelota por el suelo, la pelota tiene fricción de merdaoiton.
11. Aceleración = fuerza/ masa es un ejemplo de la dugasen ley de Newton.
12. Experimentas neimotvomi a todo tu alrededor.
13. Las fuerzas sadarbiliuqe no cambian el movimiento de un cuerpo.
**Section 1**

**Motion**

**Directions:** Choose the term from Column II that best describes the examples in Column I. Some terms will not be used.

**Column I**

1. A dog is sitting beside the door of a house; five minutes later the dog is 10 m away from the door.
2. A car travels on the freeway for 1.75 h with its cruise control set at 80 km/h.
3. A wagon travels 4.6 km.
4. A hiker walks north at 5 km/h.
5. The speedometer of a car reads 55 km/h.
6. A horse speeds up, runs around a track, then slows and comes to a stop.
7. change in position
8. A school office worker leaves the office, delivers messages around the school, and ends up back where she started.

**Column II**

a. motion  b. relative motion  c. distance  
d. displacement  e. acceleration  
f. instantaneous speed  g. speed  
h. constant speed  i. average speed  j. velocity

**Directions:** Use the map to answer questions 9 through 12.

Jenna left home, walked around town, and ended at a park. The figure below shows the route of her walk.

9. What distance did Jenna walk? 

10. What was Jenna’s displacement? 

11. If Jenna covered the entire distance in 5 hours, what was her average speed? 

12. If Jenna started from rest and reached the corner of Oak St. and Main St. in 1.5 h and was walking with a velocity of 90 m/h, what was her acceleration between the start and corner A?
Newton’s First Law

Directions: In question 1, below, a code letter has been substituted for each letter of the alphabet. To find what the sentence says, use the following key to decode it. In the key, the code letters are shown directly below the alphabet letter they stand for. Write the correct letter directly above each code letter, then read the sentence.

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
| X | M | J | W | T | A | O | U | R | V | G | Q | D | Z | B | Y | I | E | P | N | H | C | S | L | F | K |

1. ____________

   X        M        B        W        F        E        T        D        X        R        Z        P        X        N        J        B        Z        P        N        X        Z        N

   C        T        G        B        J        R        N        F        H        Z        G        T        P        P        X        Z        H        Z        M        X        G        X        Z        J        T        W

   A        B        E        J        T        X        J        N        P        B        Z        R        N

2. Which law of motion does the above sentence state?

   __________________________________________________________________________

Directions: Answer the following questions on the lines provided.

3. What is a force?

   __________________________________________________________________________

   __________________________________________________________________________

4. Is it possible for an object not to be in motion and still have forces acting on it? Explain.

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________

5. What is inertia? How are mass and inertia related?

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________
Newton’s Second Law

Directions: Circle the term in parentheses that best completes the statement.

1. Gravity is a (force, mass, distance).

2. The friction involved in a wagon moving down a hill is (static, sliding, rolling) friction.

3. As the force acting on you increases, your acceleration (increases, decreases, remains the same).

4. The unit of force is the (meter, hertz, newton).

5. If you go to the moon, your mass (increases, decreases, remains the same).

6. As you glide across a frozen pond, (static, sliding, rolling) friction is acting on your skates.

7. If there is no change in force as you increase the mass a truck is carrying, its acceleration (increases, decreases, remains the same).

8. An ant falling from the roof of a house lands unharmed because of (gravity, static friction, air resistance).

Directions: If the following statements are true, write true. If the statements are false, replace the term or phrase in italics to make the statement true.

9. If you go to the moon, your weight would stay the same.

10. Given the same force, a baseball will accelerate faster than a tennis ball.

11. The force always acting on everything on Earth is gravity.

12. Rolling friction keeps a wagon from rolling until it is pushed.

Directions: Solve the following problems in the spaces provided.

13. A force of 40 N is exerted on a 10-kg box. What is the box’s acceleration?

14. What unbalanced force is required to accelerate a 1,500 kg-race car at 3.0 m/s²?

15. If a student has a mass of 90 kg, what is the student’s weight?
Newton’s Third Law

Directions: Study the drawing below of a boy holding a bucket and answer questions 1 through 4.

1. Identify two pairs of action-reaction forces involving the bucket.

2. What are the balanced forces acting on the bucket?

3. What happens if the hand-on-bucket force increases? Explain.

4. What could you do to increase the Earth-on-bucket force?

Directions: Find the mistakes in the statements below. Rewrite each statement correctly on the lines provided.

5. An action-reaction force pair acts on the same body.

6. When action-reaction force pairs come into being, the action force is created first.

7. Action-reaction forces always act in the same direction.

8. Forces act in unequal but opposite pairs.
Describing motion is something we do in many different ways. Most people use terms like “slowed down” or “really fast.” In science, other, more specific terms are used, for example, velocity and acceleration. Imagine a baseball announcer calling a game using scientific terms. You would probably understand what the players are doing, but you might have to explain it to someone not familiar with Newton’s laws.

Directions: In the following paragraph describing a home run, fill in the blanks using the correct scientific terms from the text. Remember that you are describing motion in scientific terms. Then answer the questions below.

The player comes to bat. He hits the ball over the fence. Just before he starts to run, his 1. __________________ is zero. As he runs around first base and heads for second base his 2. _______________ and his 3. _______________ increase. As he continues to run around the bases, his speed is constant, but he is still 4. ___________ because he is constantly changing 5. ___________. As he approaches home plate, he slows slightly, thus 6. _______________ by changing his 7. ___________. Back at home plate, he has run the full 8. _______________ of the diamond, but his 9. _______________ is zero.

Directions: Answer the questions on the lines provided.
10. In what ways did the runner’s velocity change?

__________________________________________________________________________
__________________________________________________________________________

11. How did you calculate the runner’s displacement?

__________________________________________________________________________
__________________________________________________________________________

12. If the runner had only managed a base hit and stopped at first base would he still have been accelerating as he stopped? Explain your answer.

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Crash-Test Dummies

More than one million people a year die in automobile crashes. Another 38 million are injured, with five million of those seriously or permanently hurt. While many people point to the lack of safety in cars, the real reason for the crashes is Newton’s first law of motion. Remember that an object will remain at rest or continue moving in a straight line unless acted upon by a force. This universal law is also called the law of inertia.

Inertia

Inertia, the tendency of an object to remain at rest or continue moving with constant velocity, is dependent upon the mass of the object. This is exactly the kind of situation that exists when you are a passenger in a car. You are an object with inertia. When the car is hit, a force acts upon it. Depending on the size of the force and several other factors, you might or might not be hurt.

It’s Only a Model

In an effort to make cars safer, automobile companies crash cars and study the effects of crashes on human bodies. Car makers want to build cars in which the crash force will not hurt the passengers or driver. It is not practical or legal to use real humans in these crashes, so a whole group of special human-like models called crash-test dummies have been created.

1. What is a crash-test dummy?

2. What feature does a crash-test dummy have to help scientists measure forces and their effects?

3. Why use crash-test dummies?

4. In terms of forces and inertia, why do you think it is important to have different sizes of crash test dummies?
Weight, Mass, and the Gold Rush

Gold has been precious to humans for thousands of years. A significant part of the history of the United States has to do with the discovery of gold. Many people grew rich from the huge amounts of gold discovered in California, Colorado, and Alaska. During the “gold rushes,” people from all over the world hurried to these areas to try to make their fortunes. Many banks that exist today were founded on the huge income from gold miners.

Gold Weight
The banks that purchased gold from the miners were extremely careful about weighing the gold. Gold is, after all, a form of money. In fact, one banking company purchased extraordinary scales from a well known company called Howard and Davis in Boston, Massachusetts. These scales had jeweled movements that weighed so precisely that no one ever disputed them. A problem arose, however, when the gold was weighed in different places. Remember that Earth’s mass produces the force of gravity. The closer an object is to the center of the Earth, the more it weighs. The farther it is from the center, the less it weighs.

Light Weights
When a bank in Denver, Colorado received a shipment of gold from San Francisco, California, it was always lighter than the paperwork said. And when a San Francisco bank received the gold from Colorado it was always heavy. The bank decided to send its scales along with its shipments, but the weights still varied.

How much does my gold weigh?
Only later was the problem understood. Because Denver was at a much higher altitude, the gold weighed less. The mass was still the same, but the weight was less. Eventually people realized that where the gold was weighed made a big difference in what the scales said. San Francisco was at sea level and Denver was at nearly 5,300 feet above sea level. This difference in altitude was enough to account for the difference in gold weight.

New Calculations
Now, mathematical calculations are used to make weights consistent. Newer scales and balances automatically correct for altitude and changes in the force of gravity. Should there be another gold rush, no longer would a miner at sea level make more money than a miner in the mountains for the same amount of gold.

1. What force affected the weight of gold between San Francisco and Denver?

2. What initial solution did the bankers come up with to try to make sure the gold was weighed correctly? Did it solve the problem?

3. How was this problem eventually solved?

4. Although the weight of the gold changed from one place to another, what stayed the same?

5. Do you think this means that two people with the same mass will weigh different amounts depending on where they live?
Nature contains many examples of Newton’s laws of motion in action. Some interesting animals that demonstrate Newton’s third law can be found under the sea.

**Newton Underwater**

The cephalopods are the group of animals that include the octopus, squid, nautilus, and a variety of other marine mollusks. They have tentacles and a well developed nervous system. Most important to Newton, however, would have been their water siphon. These animals have a special organ from which they can shoot water at a very high rate, which they use to propel themselves through the water.

**Using a Siphon to Move**

The nautilus is one example of an animal with this remarkable feature. The nautilus is a mollusk that lives in a coiled shell. The shell has compartments and makes an attractive display when cut in half. Mollusks produce a tissue called a mantle. The nautilus uses this mantle to form a tube that is on the side of its head. The tube can be filled with water. When the animal wants to move, it shoots water from the siphon.

**Equal Force Pairs**

The nautilus’s propulsion system is a good example of an action producing a reaction. As the water is quickly shot out of the siphon, the animal moves in the opposite direction. The water moves in one direction and the nautilus, in an equal and opposite reaction, moves in the other.

**An Equal and Opposite Reaction**

Squid also use this type of jet propulsion. Some squid have been measured by scientists as fast as 24 to 80 km/h. Cephalopods do not move only in one direction, but can move the siphon to any position necessary. However, it must always be pointed to the opposite of the direction in which they need to move. Whichever way the water spurts, the animal will go in the opposite direction. This type of motion is one of the reasons cephalopods are so hard to catch. They are very fast animals. So, while a squid, nautilus, or octopus has never heard of Sir Isaac Newton, they are good examples of his third law in action.

1. How does a cephalopod demonstrate Newton’s third law?

2. If a cephalopod wanted to turn right, which way would it point its siphon? Explain your answer.

3. If you were in the middle of a lake in a boat without an oar, do you think it would help you to have a bucket? Why or why not?
Section 1  Motion

A. Motion is a change in _________________.
   1. __________________—the entire path an object travels
   2. The distance and direction between starting and stopping positions
      is _____________________.
   3. __________________ motion—an object’s position change is described in terms of a
      reference point

B. __________________—distance traveled divided by the time needed to travel the distance, or
   speed = \( \frac{\text{distance}}{\text{time}} \)
   1. __________________—speed is the same at any given moment in time
   2. Speed at a particular instant in time is _____________________. speed.

C. __________________—displacement divided by time, or \( v = \frac{\text{displacement}}{\text{time}} \)
   1. Formula calculates ______________ velocity.
   2. Includes concept of __________________ as well as speed

D. Change in velocity divided by the time required for the change to occur
   is _____________________.
   1. Acceleration occurs when an object __________________ as well as speeds up.
   2. For an object traveling in a straight line, a change in ____________ can be used to calcu-
      late acceleration.
      a. Acceleration is final speed minus initial speed divided by ____________, or
         \[ \text{acceleration} = \frac{\text{final speed} - \text{initial speed}}{\text{time}} \]
      b. Initial speed is ____________ for objects at rest.
   3. __________________ or changing direction is also acceleration.
Section 2  Newton’s First Law

A. Laws of _______________ are sets of rules first stated by Isaac Newton.
   1. ______________—a push or pull with a size and direction
   2. ______________ force involves objects touching each other.
   3. ______________ forces include gravity, magnetism, and electricity.
   4. When scientists measure force, they use the _______________, abbreviated N.

B. ______________ law of motion—an object will remain at rest or move in a straight line with
   constant speed unless a force acts on it
   1. ______________ measures an object’s tendency to remain at rest or keep moving.
   2. Inertia is related to ______________; objects with more mass have more inertia.

C. Adding forces—sometimes ______________ one force acts on an object
   1. ______________ forces—forces that are equal but in opposite directions, canceling
      each other
   2. If one force is greater than another, a change in motion will result from the
      ______________ forces.
   3. An object acted on by an unbalanced force changes ______________.

Section 3  Newton’s Second Law

A. Second law of motion—an object acted on by an unbalanced force will ___________________
in the direction of the force.
   1. Acceleration equals force divided by mass, or \( a = \frac{\text{force}}{\text{mass}} \).
   2. Force is equal to the combination of all forces, or the ______________ force that acts on an
      object.

B. Second law can also be used to find ______________ if mass and acceleration are known.
   1. Near Earth’s surface, the force of gravity causes all objects to fall with the same
      ______________—9.8 m/s².
      a. For any object that is falling, the force of gravity ______________ mass times acceleration
due to gravity, or \( F = m \times (9.8 \text{ m/s}^2) \).
      b. Because weight is the force of gravity on an object, an object’s weight ______________
mass times acceleration due to gravity, or weight = \( m \times (9.8 \text{ m/s}^2) \).
2. Weight and mass are not the same thing.
   a. Weight changes when the acceleration due to ________________ changes.
   b. Mass remains the ______________ no matter what weight is.

C. ______________—a force that resists motion and is always present between two moving surfaces
   1. ______________ friction—keeps a stationary object from moving on a surface when a force is applied to the object
   2. ______________ friction—occurs when two surfaces slide past each other; slows down the moving object
   3. ______________ friction—friction between a surface and a wheel turns the wheel.
   4. Air ______________—typical action of air molecules on a forward-moving object, slowing its motion

Section 4  Newton’s Third Law

A. Third law of motion—______________ always act in equal but opposite pairs
   1. When a force is exerted on an object, the object exerts the ______________ amount of force.
   2. Third law of motion applies whether forces are contact or ________________.

B. Things move because action and reaction forces work on ________________ objects.
   1. Friction is a factor in the third law.
   2. Using the second law equation, the object with the larger mass has the smaller ________________ if the same force is applied.
   3. All objects in the universe exert a force on all others; however, differences in ________________ may make these forces unnoticeable.

C. The three laws of motion describe how any object moves when ______________ act on it.
Assessment
Newton’s Laws of Motion

Part A. Vocabulary Review

Directions: Use the clues below to complete the crossword puzzle.

Across
1. Distance traveled divided by the time of travel
3. Objects remain at constant velocity unless an unbalanced force acts
4. Forces on an object that do not cancel out
7. Force that opposes motion
9. Rate of change of velocity

Down
1. Acceleration equals force divided by mass
2. For every action there is an equal and opposite reaction
5. Distance and direction between starting and ending positions
6. Forces on an object that cancel each other out
7. A push or a pull
8. Rate of change of displacement
Part B. Concept Review

Directions: Circle the term that best completes the sentence.

1. If you drive from New York to San Francisco by way of Mt. Rushmore, Branson, MO, and Yellowstone National Park, your distance traveled is (greater than, less than, the same as) your displacement.

2. When your feet push on the floor so that you can walk across the room, you move but the floor doesn’t. The force of the floor on your feet is (greater than, less than, the same as) the force of your feet on the floor.

3. Standing still in a windstorm is an example of (static, sliding, rolling) friction between your feet and the ground.

4. To push a box across the floor takes more force than to push the same box on wheels across the floor. This shows that rolling friction is (greater than, less than, equal to) sliding friction.

5. In order to keep a race car going around a circular track at constant speed, (no force, a balanced force, an unbalanced force) is needed.

6. A reaction force is created (before, after, at the same time as) its action force.

Directions: Fill in the blank with the word that best completes the statement.

7. A crumpled piece of paper falls to the ground faster than a smooth piece because of ____________________.

8. When you push a book across your desk, the force of your hand is ____________________ the force of static friction.

9. The force needed to accelerate a bowling ball to a given velocity is ____________________ the force needed to accelerate a soccer ball to the same velocity.

Directions: Solve the following problems.

10. A car travels 528 km in 6 hours. Find its average speed.

11. The maximum acceleration of a fist in a karate punch is 3800 m/s². The mass of the fist is 0.70 kg. If the fist hits a wooden block, what force does the wood place on the fist?
Transparency Activities
Race cars must meet certain specifications in order for the different racing teams to compete fairly with one another. After that, it’s up to the driver to get the car around the track as quickly as possible.

1. Describe how a car’s movements change as it goes from a straight-away, through a turn, and back to a straightaway.
2. How is a car’s speed at a specific point on the track different from its average speed for the whole race?
3. During a race, a car might travel 200 miles. Where does it start and finish?
If you are familiar with speed skating, you may have seen short-track competitions like the one below. In short-track racing, skaters compete on a track about the size of a hockey rink. In this short race, there are four skaters in each heat.

1. What happens if a skater going in a straight line falls?
2. What happens if a skater falls in the middle of a turn?
3. Is it easier to walk on ice or asphalt? Why?
Bowling has a long history—stone bowling balls and pins have been found in Egyptian tombs dating to 5200 B.C. Today, bowling balls are made of rubber, polyester, or urethane; the pins are made of wood with a plastic coating; and the lanes consist of a slick coating on top of wood.

1. What factors affect the way the pins fall?
2. Sometimes bowlers make the ball curve. Why do they do this?
These firefighters are dousing a fire. Why does it take more than one person to aim the fire hose? The force of the water shooting out of the nozzle causes a reaction that can be pretty tough to control.

1. What happens when you step from a canoe or a small boat onto a dock?
2. Why can a garden hose be controlled by one person while a fire hose needs several?
3. How might the action of a fire hose might be similar to a rocket engine?
Newton’s Laws of Motion

Teaching Transparency Activity

Applied force

Newton’s Laws of Motion

Transparency Activities
Teaching Transparency Activity (continued)

1. Which of Newton’s laws of motion is built around the idea that for every action there is an opposite and equal reaction?

2. What is the formula that can be used with Newton’s second law of motion?

3. What is the force called when you kick a ball?

4. What unit do scientists use to measure force? What is the symbol for this unit?

5. When a moving bus suddenly stops, what happens to the passengers? Which law of motion does this illustrate?
Newton’s Laws of Motion

Directions: Carefully review the graph and answer the following questions.

1. How long did it take Bob to run 100 meters?
   A 10 s  C 12 s
   B 11 s  D 14 s

2. After 9 seconds, about how much farther had Bob run than Ray?
   F 15 m  G 20 m
   H 25 m  J 30 m

3. According to the graph, about how many seconds would it take Bob to run 200 meters?
   A 14 s
   B 16.5 s
   C 22 s
   D 28 s

4. A reasonable hypothesis based on these data is that ___.
   F Ray probably tripped in the middle of the race
   G Ray runs faster than Bob
   H at one point in the race, Bob’s speed was 0 m/s
   J after 5 seconds, Bob and Ray had run the same distance