Glencoe Science

Chapter Resources

Forces

Includes:

Reproducible Student Pages

ASSESSMENT
✓ Chapter Tests
✓ Chapter Review

HANDS-ON ACTIVITIES
✓ Lab Worksheets for each Student Edition Activity
✓ Laboratory Activities
✓ Foldables—Reading and Study Skills activity sheet

MEETING INDIVIDUAL NEEDS
✓ Directed Reading for Content Mastery
✓ Directed Reading for Content Mastery in Spanish
✓ Reinforcement
✓ Enrichment
✓ Note-taking Worksheets

TRANSPARENCY ACTIVITIES
✓ Section Focus Transparency Activities
✓ Teaching Transparency Activity
✓ Assessment Transparency Activity

Teacher Support and Planning
✓ Content Outline for Teaching
✓ Spanish Resources
✓ Teacher Guide and Answers

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**Additional Assessment Resources available with Glencoe Science:**

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- **Interactive Chalkboard**
- **The Glencoe Science Web site at: gpscience.com**
- An interactive version of this textbook along with assessment resources are available online at: mhln.com
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Hands-On Activities
Comparing Friction

Procedure
1. Place an ice cube, rock, eraser, wood block, and square of aluminum foil at one end of a metal or plastic tray.
2. Slowly lift the end of the tray with the items.
3. Have a partner use a metric ruler to measure the height at which each object slides to the other end of the tray. Record the heights in the table below.

Data and Observations

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Height at which the object slid off the tray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice cube</td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td></td>
</tr>
<tr>
<td>Eraser</td>
<td></td>
</tr>
<tr>
<td>Wood block</td>
<td></td>
</tr>
<tr>
<td>Aluminum foil</td>
<td></td>
</tr>
</tbody>
</table>

Analysis
1. List the height at which each object slid off the tray.

2. Why did the objects slide off at different heights?

3. What type of friction acted on each object?
Mini LAB  

Observing Centripetal Force

**Procedure**
1. Thread a string about 1 m long through the holes of a plastic, slotted, golf ball.
2. Swing the ball in vertical circle.
3. Swing the ball at different speeds and observe the motion of the ball and the tension in the string.

**Analysis**
1. What force does the string exert on the ball when the ball is at the top, sides, and bottom of the swing?

2. How does the tension in the string depend on the speed of the ball?
Measuring the Effects of Air Resistance

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

1. Why is the symbol for a sharp object included in the safety precautions for this lab?

2. What are the ways in which you are permitted to change the shape of your last piece of paper?

If you dropped a bowling ball and a feather from the same height on the Moon, they would both hit the surface at the same time. All objects dropped on Earth are attracted to the ground with the same acceleration. But on Earth, a bowling ball and feather will not hit the ground at the same time. Air resistance slows the feather down.

Real-World Question
How does air resistance affect the acceleration of falling objects?

Materials
- meterstick
- masking tape
- paper (4 sheets of equal size)
- stopwatch
- scissors

Goals
- Measure the effect of air resistance on sheets of paper with different shapes.
- Design and create a shape from a piece of paper that maximizes air resistance.

Safety Precautions

Procedure
1. Measure a height of 2.5 m on the wall and mark the height with a piece of masking tape.
2. Have one group member drop the flat sheet of paper from the 2.5-m mark. Use the stopwatch to time how long it takes for the paper to reach the ground. Record your time in Table 1.
3. Crumple a sheet of paper into a loose ball and repeat step 2.
4. Crumple a sheet of paper into a tight ball and repeat step 2.
5. Use scissors to shape a piece of paper so that it will fall slowly. You may cut, tear, or fold your paper into any design you choose.

Data and Observations
Table 1

<table>
<thead>
<tr>
<th>Effects of Air Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper type</td>
</tr>
<tr>
<td>Flat paper</td>
</tr>
<tr>
<td>Loosely crumpled paper</td>
</tr>
<tr>
<td>Tightly crumpled paper</td>
</tr>
<tr>
<td>Your paper design</td>
</tr>
</tbody>
</table>
Conclude and Apply
1. Compare the falling times of the different sheets of paper.

2. Infer the relationship between the falling time and the acceleration of each sheet of paper.

3. Explain why the different-shaped papers fell at different speeds.

4. Explain how your design maximized the effect of air resistance on your paper’s gravitational acceleration.

5. Infer why a sky diver will fall in a spread-eagle position before opening her parachute.

Communicating Your Data
Compare your paper design with the designs created by your classmates. As a class, compile a list of characteristics that increase air resistance.
Lab Preview

Directions: Answer these questions before you begin the Lab.

1. What is Newton’s third law of motion?

2. What remains constant in this experiment?

Many scientists hypothesize that dinosaurs became extinct 65 million years ago when an asteroid collided with Earth. The asteroid’s diameter was probably no more than 10 km. Earth’s diameter is more than 12,700 km. How could an object that size change Earth’s climate enough to cause the extinction of animals that had dominated life on Earth for 140 million years? The asteroid could because it may have been traveling at a velocity of 50 m/s, and had a huge amount of momentum. The combination of an object’s velocity and mass will determine how much force it can exert. Explore how mass and velocity determine an object’s momentum during this activity.

Real-World Question
How do the mass and velocity of a moving object affect its momentum?

Materials
- meterstick
- softball
- racquetball
- tennis ball
- baseball
- stopwatch
- masking tape
- balance

Goals
- Observe and calculate the momentum of different balls.
- Compare the results of collisions involving different amounts of momentum.

Safety Precautions

Procedure
1. Use the balance to measure the mass of the racquetball, tennis ball, and baseball. Record these masses in the data table in the Data and Observations section.
2. Use your meterstick to measure a 2-m distance on the floor. Mark this distance with two pieces of masking tape.
3. Place the softball on one piece of tape. Starting from the other piece of tape, slowly roll the racquetball toward the center of the softball.
4. Use a stopwatch to time how long it takes the racquetball to roll the 2-m distance and hit the soft ball. Record this time in the data table.
5. Measure the distance the racquetball moved the softball. Record this distance in the data table.
6. Repeat steps 3–5, rolling the racquetball quickly.
7. Repeat steps 3–5, rolling the tennis ball slowly, and then quickly.
8. Repeat steps 3–5, rolling the baseball slowly, and then quickly.
Data and Observations

Momentum of Colliding Balls

<table>
<thead>
<tr>
<th>Action</th>
<th>Time</th>
<th>Velocity</th>
<th>Mass</th>
<th>Momentum</th>
<th>Distance Softball Moved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Racquetball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rolled slowly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Racquetball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rolled quickly</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>3. Tennis ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rolled slowly</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>4. Tennis ball</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>rolled quickly</td>
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<tr>
<td>5. Baseball</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>rolled slowly</td>
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<tr>
<td>6. Baseball</td>
<td></td>
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<tr>
<td>rolled quickly</td>
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</tbody>
</table>

Analyze Your Data

1. Calculate the momentum of each type of ball and action using the formula \( p = mv \). Record your calculations in the data table.

2. Graph the relationship between the momentum of each ball and the distance the softball was moved.

Conclude and Apply

1. Infer from your graph how the distance the softball moves after each collision depends on the momentum of the ball that hits it.

2. Explain how the motion of the balls, after they collide, can be determined by Newton's laws of motion.

Communicating Your Data

Compare your graph with the graphs made by other students in your class. Discuss why the graphs might look different.
Laboratory Activity

Projectile Motion

What do a volleyball, baseball, tennis ball, soccer ball, and football have in common? Each is used in a sport and each is a projectile after it is tapped, thrown, kicked, or hit. A projectile is any object that is thrown or shot into the air. If air resistance is ignored, the only force acting on a projectile is the force of gravity.

The path followed by a projectile is called a trajectory. Figure 1a shows the shape of the trajectory of a toy rocket. Because the force of gravity is the only force acting on it, the toy rocket has an acceleration of 9.80 m/s² downward. However, the motion of the projectile is upward and then downward. Figure 1b shows the size and direction of the vertical velocity of a toy rocket at different moments along its trajectory. The rocket’s velocity upward begins to decrease immediately after launch and the rocket begins to slow down. The rocket continues to slow down. And then, for an instant at the highest point of its trajectory, it stops moving because its velocity upward is zero. As the rocket begins to fall, its velocity begins to increase downward.

As you can see, the shape of the upward trajectory of the rocket is a mirror-image of the shape of its downward trajectory. Can the trajectory of a toy rocket be used to learn something about the motion of a projectile? In this experiment you will find out.

Strategy
You will measure the flight times of a projectile. You will analyze the flight times of a projectile.

Materials
- toy water rocket and launcher
- bucket of water
- 3 stopwatches

Hands-On Activities
Laboratory Activity 1 (continued)

Procedure
1. Wear goggles during this experiment.
2. Fill the water rocket to the level line shown on the rocket’s body. Always fill the rocket to the same level during each flight in the experiment.
3. Attach the pump/launcher to the rocket as shown in the manufacturer’s directions.
4. Pump the pump/launcher 10 times. **CAUTION:** Do not exceed 20 pumps or the maximum number suggested by the manufacturer, whichever is lower. Be sure to hold the rocket and pump/launcher so that the rocket is not directed toward yourself or another person.
5. Launch the rocket vertically. Predict the time for the rocket to rise to its highest point, and the time for it to fall back to Earth. Now predict these times if the rocket is pumped 15 times. Record your predictions as time up and time down in the Data and Observations section.
6. Retrieve the rocket. Fill the rocket with water as in step 2. Pump the pump/launcher 10 times. Record the number of pumps in Table 1.
7. At a given signal to the timers, launch the rocket. Your teacher will have timers measure specific parts of the flight using stopwatches. Record the values measured by the timers as total time, time up, and time down in Table 1.
8. Repeat steps 6 and 7 twice.
9. Repeat steps 6 and 7 three more times, increasing the number of pumps to 15 for each launch. **CAUTION:** Do not exceed the maximum number of pumps suggested by the manufacturer.

Data and Observations
1. Calculate the average total time, time up, and average time down for the two sets of launches. Record these values in Table 2.
2. Use Graph 1 to construct a bar graph comparing the average time up, average total time, and average time down for the two sets of launches. Plot the number of pumps used in each set of launches on the x-axis and the three average times (up, total, down) on the y-axis. Label the x-axis **Number of pumps** and the y-axis **Time (s)**. Clearly label the average time up, average total time, and average time down for each set of launches.

10 pumps—Prediction of time up: ______; time down ______
15 pumps—Prediction of time up: ______; time down ______

Table 1

<table>
<thead>
<tr>
<th>Number of pumps</th>
<th>Total time (s)</th>
<th>Time up (s)</th>
<th>Time down (s)</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>
Laboratory Activity 1 (continued)

Table 2

<table>
<thead>
<tr>
<th>Number of pumps</th>
<th>Average total time (s)</th>
<th>Average time up (s)</th>
<th>Average time down (s)</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Graph 1
Laboratory Activity 1 (continued)

Questions and Conclusions
1. How well did your predictions agree with the measured times?

2. Do your graphs support the statement that the time for a projectile to reach its highest point is equal to the time for the projectile to fall back to Earth? Explain.

3. Why was the number of pumps used to launch the rocket kept the same during each set of launches?

4. Why would you expect the flight times to be greater for the launches that were done using 15 pumps than those that were done with 10 pumps?

Strategy Check
_____ Can you measure and analyze the flight times of a projectile?
_____ Can you predict the trajectory of a projectile?
As you know, you can increase the speed of a shopping cart by pushing harder on its handles. You can also increase its speed by pushing on the handles for a longer time. Both ways will increase the momentum of the cart. How is the momentum of an object related to the time that a force acts on it? In this experiment, you will investigate that question.

**Strategy**
You will observe the effect of a net force on a cart.
You will measure the velocity of the cart at various times.
You will determine the momentum of the cart.
You will relate the momentum of the cart and the time during which the force acted on it.

**Materials**
- utility clamp
- ring stand
- 2 plastic-coated wire ties (1 short, 1 long)
- pulley
- metric balance
- momentum cart
- 2–3 rubber bands
- 1-m length of string
- 100-g mass
- 3–4 books
- plastic foam sheet
- meterstick
- masking tape
- stopwatch/timer
- felt-tip marker

**Procedure**
1. Attach the utility clamp to the ring stand. Using the short plastic-coated wire tie, attach the pulley to the clamp.
2. Use the metric balance to find the mass of the cart. Record this value in the Data and Observations section on the line provided.
3. Wrap the rubber bands around the cart lengthwise.
4. Tie one end of the string around the rubber bands as shown in Figure 1. Tie a loop at the opposite end of the string. Pass the string over the pulley.
5. Wrap the long plastic-coated wire tie securely around the 100-g mass. Attach the mass to the loop on the string with the wire tie.
6. Place the ring stand near the edge of the table. Adjust the position of the pulley so that the string is parallel to the table top as shown in Figure 2. Be sure that the 100-g mass can fall freely to the floor. Place several heavy books on the base of the ring stand.
7. Place a plastic foam sheet beneath the mass.
8. Pull the cart back until the 100-g mass is about 80 cm above the foam sheet. Have your lab partner place a strip of masking tape on the table marking the position of the front wheels. Release the cart. Observe the motion of the cart. Record your observations on a separate sheet of paper. **CAUTION:** *Have your partner stop the cart before it runs into the pulley.*

9. Using the marker, label the strip of masking tape *Starting Line*. Use the meterstick to measure a distance of 0.20 m from the starting line. Place a strip of masking tape on the table to mark this distance. Be sure to have the strip of masking tape parallel to the starting line. Label the strip of masking tape 0.20 m. Measure and label distances of 0.40 m and 0.60 m in the same manner. See Figure 3.

10. Pull the cart back with one hand until its front wheels are on the starting line. Hold the stopwatch in the other hand. Release the cart and immediately start the stopwatch. Measure the time for the front wheels to cross the 0.20-m line. **CAUTION:** *Have your partner stop the cart before it reaches the pulley.* Record the distance and time values as Trial 1 in Table 1.
11. Repeat step 10 twice. Record the values as Trials 2 and 3.
12. Repeat steps 10 and 11 to measure the time for the front wheels to cross the 0.40-m and 0.60-m lines.

Data and Observations

Table 1

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Average time (s)</th>
<th>Average velocity (m/s)</th>
<th>Final velocity (m/s)</th>
<th>Momentum (g·m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Graph 1
Laboratory Activity 2 (continued)

1. Calculate the average times for the cart to travel 0.20 m, 0.40 m, and 0.60 m. Record these values in Table 2.
2. Calculate the average velocity for each distance by dividing distance traveled by average time. Record these values in Table 2.
3. Because the cart started from rest and had a constant force acting on it, the velocity of the cart at a given distance from the starting line is equal to twice its average velocity for that distance. That is, the velocity of the cart as it crossed the 0.20-m line is twice the value of the average velocity that you calculated for 0.20 m. Calculate the velocity of the cart as it crossed the 0.20-m line, the 0.40-m line, and the 0.60-m line. Record these values in Table 2.
4. Calculate the momentum of the cart as it crossed the 0.20-m, 0.40-m, and 0.60-m lines by multiplying the mass of the cart by its velocity. Record these values in Table 2.
5. Use Graph 1 to make a graph of your data. Plot the average time on the \(x\)-axis and the momentum on the \(y\)-axis. Label the \(x\)-axis \(\text{Time (s)}\) and the \(y\)-axis \(\text{Momentum (P)}\).

Step 1. Mass of cart: ______ g  
Step 8. Observation of motion of a cart: 

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Questions and Conclusions

1. What force caused the cart to accelerate?

2. Why was it necessary to have a constant force acting on the cart?

3. What is the value of the momentum of the cart before you released it?

4. What does your graph indicate about how momentum is related to the time that a constant force acts on an object?

5. Why does a shot-putter rotate through a circle before releasing the shot?

---

Strategy Check

______ Can you measure the velocity and determine the momentum of a cart?  
______ Can you explain the relationship between the momentum of a cart and the time during which the force acted on it?
Forces

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

Static Friction

Sliding Friction

Rolling Friction

the force that opposes the motion of two surfaces sliding past each other

the friction between a rolling object and the surface on which it rolls

the friction between two surfaces that are not moving past each other
Meeting Individual Needs
Directions: Fill in the blanks using the terms listed below.

rolling  static  momentum  gravitational
sliding  conservation of momentum  weight
ma  mv  opposite  downward
frictional  centripetal

I. Newton's Second Law

A. defined as: net force acting on an object causes the object to accelerate in the
direction of the net force; \( F = \) ____________________

B. types of forces

1. ____________________ which opposes motion
   a. ____________________—when neither object is moving
   b. ____________________—when one object is sliding across another
   c. ____________________—when one object is rolling across another

2. ____________________ which occurs between any two objects
   a. ____________________ is the gravitational force exerted on an object
      by Earth
   b. an object that is shot or thrown follows a ____________________
      path because of the force of gravity pulling it

3. ____________________ which causes an object to move in a circle

II. Newton's Third Law

A. defined as: to every action force there is an equal and ____________________
   reaction force

B. ____________________: a property a moving object has because of its mass
   and velocity; \( p = \) ____________________

C. ____________________ : momentum transfers from one
   object to another with the total momentum being conserved
Directions: In the blank at the left, write the letter of the term that correctly completes each statement.

1. Every object in the universe exerts a force on every other object. This force is called ______.
   a. friction  
   b. gravity

2. The measure of the gravitational force exerted by Earth on an object is the object’s ______.
   a. weight  
   b. mass

3. The amount of gravitational force between two objects depends on their ______.
   a. color and density  
   b. mass and distance

4. Weight is measured in units called ______.
   a. newtons  
   b. kilograms

5. The greater an object’s ______, the stronger the gravitational force on it.
   a. mass  
   b. velocity

6. Mass is measured in units called ______.
   a. newtons and kilonewtons  
   b. grams and kilograms

7. A weight reading on a scale shows the ______ exerted by the scale.
   a. upward force  
   b. downward force

8. Earth exerts a stronger gravitational force than the moon because Earth has more ______.
   a. mass  
   b. density

9. The masses of your hand and your notebook are quite small, so the force of attraction between them is ______.
   a. zero  
   b. weak

10. An object transported from the surface of Earth to the surface of the Moon has its weight ______.
    a. decreased  
    b. stay the same
Directions: Choose the term from the list below that is best described by each statement. Write the term to the left of each statement.

<table>
<thead>
<tr>
<th>conservation of momentum</th>
<th>reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton’s third law of motion</td>
<td>momentum</td>
</tr>
<tr>
<td>velocity</td>
<td>mass</td>
</tr>
<tr>
<td>action</td>
<td></td>
</tr>
</tbody>
</table>

1. When one object exerts a force on a second object, the second object exerts a force that is equal in size and opposite in direction.

2. The backward “kick” of a rifle that is fired is an example of a(n) ______ force.

3. The total amount of momentum of a group of objects does not change unless outside forces act on the objects.

4. Air rushing out of the neck of a balloon causes the balloon to move. The air that comes from the balloon is an example of a(n) ______ force.

5. In the equation \( p = m \times v \), \( p \) represents ______.

6. Momentum has direction because ______ has direction.

7. Momentum is a property a moving object has because of its ______ and velocity.

Directions: Think for a minute about Newton’s third law of motion. Can you remember any event when you experienced this law? If so, draw a diagram below to show the action-reaction forces. If you can’t remember an event that you experienced, try to think up one and draw it below.

8.
Key Terms

Forces

Directions: Determine whether the italicized term makes each statement true or false. If the statement is true, write the word true in the blank. If the statement is false, write in the blank the term that makes the statement true.

1. Objects fall toward Earth at a rate of 9.8 m/s² because of centripetal force.
2. \( F = ma \) represents Newton’s second law of motion.
3. Acceleration toward the center of a curved or circular path is called gravitational acceleration.
4. In \( p = mv \), \( p \) represents position.
5. The force of gravity acting upon an object is the object’s mass.
6. Friction is the force that opposes motion between surfaces that touch each other.
7. To every action force there is an equal and opposite reaction force is the law of conservation of momentum.
8. According to the law of conservation of momentum, momentum lost equals momentum gained.
9. The force keeping a ball on a string moving in a circle is rolling friction.
10. Anything that is thrown or shot through the air is weightless.
11. Microwelds are the source of momentum between two surfaces pressed together.
12. Air resistance acts in the opposite direction to that of an object in motion.
13. Terminal velocity is the highest velocity that a falling object will reach.
Instrucciones: Llena los espacios en blanco usando los términos de la siguiente lista.

rodante  | estática  | momento
deslizante  | conservación del momento  | gravitatoria
ma  | mv  | opuestas  | peso
fricción  | centrípeta  | descendente

I. Segunda ley de Newton
A. se define como: fuerza neta que actúa sobre un cuerpo y lo hace acelerar en la dirección de la fuerza neta; \( F = \) _________________
B. tipos de fuerzas
1. _________________ la cual se opone al movimiento
   a. _________________ - cuando ninguno de los dos cuerpos se mueve
   b. _________________ - cuando un cuerpo se desliza sobre otro
   c. _________________ - cuando un cuerpo rueda a lo largo de otro
2. _________________ la cual ocurre entre cualquier par de cuerpos
   a. _________________ es la fuerza de gravedad que la Tierra ejerce sobre un cuerpo
   b. un cuerpo que se dispara o se lanza sigue una trayectoria _________________ porque la fuerza de gravedad lo empuja hacia abajo.
3. _________________, mediante la cual un cuerpo se mueve en un círculo.

II. Tercera ley de Newton
A. se define como: por cada fuerza de acción existe una fuerza de reacción igual y _________________
B. _________________: propiedad que posee un cuerpo en movimiento debido a su masa y velocidad; \( p = \) _________________
C. _________________: el momento se transfiere de un cuerpo a otro y el total del momento se conserva
Sección 1 • La segunda ley de Newton

Sección 2 • La gravedad

Instrucciones: Escribe en los espacios en blanco, la letra del término que complete correctamente cada oración.

1. Todos los objetos en el universo ejercen una fuerza sobre todos los otros objetos. Esta fuerza se llama ______.
   a. fricción  b. gravedad

2. La medida de la fuerza gravitatoria que ejerce la Tierra sobre un cuerpo es el(la) ______ del cuerpo.
   a. peso  b. masa

3. La fuerza gravitatoria entre dos objetos depende de su ______.
   a. color y densidad  b. masa y distancia

4. El peso se mide en unidades llamadas ______.
   a. newtons  b. kilogramos

5. Entre más grande es la ______, de un cuerpo, más fuerte es su fuerza gravitatoria.
   a. masa  b. velocidad

6. La masa se mide en unidades llamadas ______.
   a. newtons y kilonewtons  b. gramos y kilogramos

7. El peso que se mide en una balanza muestra la ______ que hace la escala.
   a. fuerza ascendente  b. fuerza descendente

8. La Tierra ejerce una fuerza gravitatoria mayor que la Luna porque la Tierra tiene más ______.
   a. masa  b. densidad

9. La masa de tus manos y tu cuaderno es pequeña, por lo que la fuerza de atracción entre ellos es ______.
   a. cero  b. débil

10. Un objeto que se lleva de la superficie de la Tierra a la superficie de la Luna muestra que su peso ______.
    a. disminuye  b. permanece igual
Las fuerzas

**Sección 3 ▶ La tercera ley de Newton**

**Instrucciones:** Escoge el término de la lista de abajo que describe cada oración. Escribe el término a la izquierda de la oración.

<table>
<thead>
<tr>
<th>conservación del momento</th>
<th>reacción</th>
</tr>
</thead>
<tbody>
<tr>
<td>tercera ley del movimiento de Newton</td>
<td>momento</td>
</tr>
<tr>
<td>velocidad</td>
<td>masa</td>
</tr>
</tbody>
</table>

1. Cuando un cuerpo ejerce una fuerza sobre otro cuerpo, la fuerza es igual en magnitud a la que recibe pero en dirección opuesta.

2. El golpe hacia atrás de un rifle cuando se dispara es un ejemplo de la fuerza de ______.

3. La cantidad total de momento de un grupo de cuerpos no cambia a menos que fuerzas externas actúen sobre los cuerpos.

4. Cuando el aire escapa por el cuello de un globo, el globo se mueve. El aire que sale del globo es un ejemplo de una fuerza ______.

5. En la ecuación $p = m \times v$, $p$ representa ______.

6. El momento tiene dirección porque el(la) ______ tiene dirección.

7. El momento es una propiedad que un cuerpo en movimiento tiene debido a su ______ y su velocidad.

**Instrucciones:** Piensa en la tercera ley del movimiento de Newton. ¿Recuerdas algún evento cuando experimentaste esta ley? Si es así, haz un diagrama que muestre las fuerzas de acción y reacción. Si no te acuerdas de ninguna experiencia personal, imagina una y dibújala enseguida.

8.
Instrucciones: Determina si el término en bastardilla hace verdadero el enunciado. Si el enunciado es verdadero, escribe **verdadero** en el blanco. Si es falso, escribe el término que haga verdadero el enunciado.

1. Los cuerpos caen hacia la Tierra a una razón de 9.8 m/s² debido a la **fuerza centrípeta**.
2. \( F = ma \) representa la **segunda ley de movimiento de Newton**.
3. La aceleración hacia el centro de una trayectoria curva o circular se llama aceleración **gravitatoria**.
4. En \( p = mv \), \( p \) representa **posición**.
5. La fuerza de gravedad que actúa sobre un cuerpo es la **masa** del cuerpo.
6. La **fricción** es la fuerza que se opone al movimiento entre dos superficies en contacto.
7. Para cada fuerza de acción hay una fuerza de reacción igual y opuesta es **la ley de conservación del momento**.
8. Según **la ley de conservación del momento**, el momento perdido es igual al momento ganado.
9. La fuerza que permite que una bola adherida a una cuerda que se mueve en círculos es la **fricción de rodamiento**.
10. Cualquier cosa que se lance o se dispare en el aire es **ingrávida**.
11. Las microsoldaduras son la fuente de **momento** entre dos superficies presionadas una contra la otra.
12. La resistencia del aire actúa en dirección **opuesta** a la de un objeto en movimiento.
13. La velocidad terminal es la **máxima** velocidad que alcanza un cuerpo que cae.
**Newton’s Second Law**

**Directions:** Use the equation \( F = m \times a \) to solve the following problems. Show your calculations in the spaces provided.

1. How much force is needed to accelerate a 1000-kg car at a rate of 3 m/s\(^2\)?

2. If a 70-kg swimmer pushes off a pool wall with a force of 250 N, at what rate will the swimmer accelerate from the wall?

3. A weightlifter raises a 200-kg barbell with an acceleration of 3 m/s\(^2\). How much force does the weightlifter use to raise the barbell?

4. A dancer lifts his partner above his head with an acceleration of 2.5 m/s\(^2\). The dancer exerts a force of 200 N. What is the mass of the partner?

**Directions:** Answer the following questions on the lines provided.

5. What does Newton’s second law of motion state?

6. What two factors affect the rate of acceleration of an object?

7. What are the three types of friction and when does each apply?
Gravity

Directions: Answer the following questions on the lines provided.

1. What is gravity? ____________________________________________________________________

2. What are two things that the amount of gravitational force between two objects depends on? ____________________________________________________________________

3. Why does Earth exert a stronger gravitational force than the Moon? ____________________________________________________________________

4. If an object weighs 40 N on Earth, would it weigh more than 40 N on the Moon? Explain. ____________________________________________________________________

Directions: Use the diagrams below to complete the following questions.

5. What is the centripetal force that allows a car to move around a sharp curve in a roadway? ____________________________________________________________________

6. Draw an arrow on the bottom diagram to show the movement of the car if the centripetal force of the road and car is not enough to overcome the car’s inertia when it reaches point B. ____________________________________________________________________

7. Explain how you know the car is accelerating when it reaches point A in the first diagram. ____________________________________________________________________
The Third Law of Motion

Directions: Use the illustrations to answer the following questions.

1. Draw an arrow on Figure A to show the direction the cannon will move when the cannonball is fired.
2. Draw arrows on Figure B to show the direction the oars must move to propel the boat forward.
3. Does the arrow you drew on Figure A represent an action force or a reaction force?
4. Do the arrows you drew on Figure B represent an action force or a reaction force?
5. If the force that propels the cannonball forward is 500 N, how much force will move the cannon backward? Explain.

Directions: Solve the following problems.

6. What is the momentum of a 2-kg toy truck that moves at 10 m/s?
7. What is the momentum of a 2000-kg truck that moves at 10 m/s?
8. Which truck has more momentum? Why?
Friction and the Curve Ball

The curve ball was invented by a young pitcher named Arthur “Candy” Cummings. Although Cummings first threw the curve ball during a game while pitching for the Brooklyn Excelsiors in 1867, he actually invented his technique many years before. As a boy, Cummings loved baseball and practiced his pitching on the beach near his New England home. He threw clam shells instead of a baseball and found that by holding and releasing the shells in a certain way he could make them curve.

Did It Really Curve?
He was given the title “inventor of the curve ball” by the Baseball Hall of Fame. In his historical performance, Cummings snapped his wrist at the exact moment when he released the ball. This caused it to arch and fly past the batter to land in the catcher’s mitt. People couldn’t believe it. Nobody knew for sure whether the ball really curved or just looked like it did.

More than 100 years later in 1982, the Massachusetts Institute of Technology (MIT) proved once and for all that a baseball thrown like Cummings threw it does, indeed, curve. Why does it curve? It’s all about friction.

The snap action of the pitcher’s wrist puts a spin on the ball. And that spin changes the friction between the air and the ball. After it’s thrown, parts of the ball experience more air friction and parts of the ball experience less. A curved path results from the ball moving toward the least amount of friction.

Specifically, one movement of the pitcher’s wrist when the ball is released causes a top spin, making the top of the ball move forward against the air (more friction) and the bottom move in the same direction as the air (less friction). Like any curve ball, the ball curves toward the least amount of friction: downward.

Spin It Sideways
In addition to topspin, a pitcher’s wrist can also produce a counter-clockwise spin or a clockwise spin. When a curveball is thrown by a right-handed pitcher the ball spins counter-clockwise. The right side of the baseball experiences less air friction, and the ball curves to the left, or away from a right handed hitter.

When a curveball is thrown by a left-handed pitcher, the ball spins clockwise. The left side of the baseball experiences less air friction, and the ball curves to the right, or away from left-handed batters.

1. What effect might the stitches on a baseball have on the path of a baseball?

2. Do you think a baseball curves better at the top of a high mountain or down on a flat plain? Explain.

3. Describe how the type of spin given to a baseball by a pitcher influences the path of the baseball.
**Finding Acceleration Due to Gravity (g)**

Acceleration due to gravity \((g)\) can be found by swinging a pendulum. The time it takes for a pendulum to swing depends on \(g\). An equation for the time \((T)\) it takes for a pendulum to make one complete swing is:

\[
T = 2\pi \sqrt{\frac{l}{g}} \quad \text{or} \quad g = \frac{4\pi^2 l}{T^2}
\]

In this equation, \(l\) is the length of the pendulum. This formula works best when small swings are used. Look at the diagram.

All of the mass of the pendulum is concentrated at the end of the string called the bob. The bob is a metal sphere hung by a fine thread. The pendulum’s length is the distance from the point where the thread is held to the center of the bob. Make a pendulum using a thread and a metal bob. Follow the procedure below and answer the questions.

**Procedure**
1. The thread can have any convenient length. Measure \(l\) accurately to 0.80 m.
2. Start the pendulum swinging with small swings. Time at least 20 or more complete swings.
3. Divide the total time by the number of swings completed in that time to find the time \((T)\) of one swing.
4. Repeat this procedure at least two more times. Release the bob from the same point as before.
5. Find the average value of \(T\) for your trials.
6. Substitute your averaged \(T\) value and your \(l\) value into the equation to find \(g\).

**Questions and Conclusions**
1. What value did you get for \(g\)? What is the accepted value for \(g\)?
2. What is your percentage error? Find percentage error by using the following formula:

\[
\frac{\text{accepted value} - \text{your value}}{\text{accepted value}} \times 100
\]

3. Which of your measurements do you think was the least accurate?
4. Why did you need to use 20 or more swings of the pendulum instead of just one swing to find the time of the pendulum?
Coach Rogers had 6 positions to fill on his football team. In order to be considered for a particular position, the players had to meet certain physical criteria, Table 1. Coach Rogers had obtained data on each player that he planned to use in assigning players to positions, Table 2. Determine each player’s mass from his weight. Assume $a = 9.8 \text{ m/s}^2$. Use your knowledge of Newton’s laws to assign the players to the positions for which they are best suited.

### Table 1

<table>
<thead>
<tr>
<th>Position</th>
<th>Description/Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>Stops other players from crossing the scrimmage line. Requires great strength in a short distance.</td>
</tr>
<tr>
<td>Back</td>
<td>Runs with a football. Requires speed and agility.</td>
</tr>
<tr>
<td>End</td>
<td>May block as a lineman or act as a pass receiver. Requires both speed and strength.</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Player</th>
<th>Weight</th>
<th>Mass</th>
<th>Time/36–m dash</th>
<th>Speed at finish line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen</td>
<td>833 N</td>
<td></td>
<td>4.51 s</td>
<td>16.0 m/s</td>
</tr>
<tr>
<td>Terry</td>
<td>735 N</td>
<td></td>
<td>4.40 s</td>
<td>16.4 m/s</td>
</tr>
<tr>
<td>Frank</td>
<td>911 N</td>
<td></td>
<td>4.82 s</td>
<td>15.0 m/s</td>
</tr>
<tr>
<td>Dave</td>
<td>825 N</td>
<td></td>
<td>4.71 s</td>
<td>15.3 m/s</td>
</tr>
<tr>
<td>Bob</td>
<td>1010 N</td>
<td></td>
<td>4.90 s</td>
<td>14.7 m/s</td>
</tr>
<tr>
<td>Carlos</td>
<td>931 N</td>
<td></td>
<td>4.60 s</td>
<td>15.7 m/s</td>
</tr>
</tbody>
</table>

Assuming mass indicates strength, select two players for each position. Assign each player to a position. Explain your selection in terms of Newton’s laws.

### Table 3

<table>
<thead>
<tr>
<th>Position</th>
<th>Player</th>
<th>Reasoning</th>
</tr>
</thead>
</table>

Assuming their accelerations remained the same, how many kilograms would Dave have to gain to exert the same force at the finish line as Allen? (Hint: Determine $a$ for each boy using $v = v_0 + at$, where $v_0 = 0$ because the players started from a rest position. Then use $F = ma$ to solve for $m$.)
Forces

Section 1  Newton’s Second Law

A. Force and motion are ___________________.
   1. An object will have greater ______________________ if a greater force is applied to it.
   2. The _______________ of an object and the force applied to it affect acceleration.

B. Newton’s second law of motion connects force, mass, and acceleration in the equation
   
   \[ \text{acceleration equals net force \overline{\text{mass}}} \]

C. ______________—force that opposes motion between two surfaces that are touching each other
   1. __________________, areas where surface bumpers stick together, are the source of friction.
   2. Friction between two surfaces that are not moving past each other is called _____________ friction.
   3. ______________ friction—force that opposes the motion of two surfaces sliding past each other
   4. Friction between a rolling object and the surface it rolls on is called ________________ friction.

D. _________________ opposes the motion of objects that move through the air.
   1. The ______________ of air resistance depends on an object’s shape, size, and speed.
   2. __________________—forces on a falling object are balanced and the object falls with constant speed

Section 2  Gravity

A. Law of _________________—any two masses exert an attractive force on each other
   1. __________________ is one of the four basic forces that also include the electromagnetic force, the strong nuclear force, and the weak nuclear force.
   2. Gravity is a ________________ force that gives the universe its structure.

B. Due to _______________, all objects fall with the same acceleration regardless of mass.
C. ______________—gravitational force exerted on an object
   1. Weight ______________ as an object moves away from Earth.
   2. Weight results from a force; ______________ is a measure of how much matter an
      object contains.

D. Objects in the space shuttle ______________ because they have no force supporting them.

E. ______________ have horizontal and vertical velocities due to gravity, and follow a
   curved path.

F. Acceleration toward the center of a curved path is called **centripetal acceleration**; it is caused
   by **centripetal ______________**, an unbalanced force.

**Section 3    The Third Law of Motion**

A. **Newton’s third law of motion**—to every action force there is an equal
   and ______________ reaction force
   1. Action-reaction forces act on ______________ objects and differ from balanced
      forces.
   2. ______________ is based on Newton’s third law of motion.

B. Before it was discovered, the existence of the planet ______________ was predicted based
   on gravitational forces and Newton’s laws.

C. ______________—related to how much force is needed to change an object’s motion;
   momentum equals mass times velocity.

D. Law of conservation of momentum—momentum can be ______________ between
   objects; momentum is not lost or gained in the transfer.
Assessment
**Part A. Vocabulary Review**

**Directions:** In the space at the left, write the term from the list that correctly completes each statement.

<table>
<thead>
<tr>
<th>gravity</th>
<th>weight</th>
<th>distance</th>
<th>newtons</th>
<th>momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td>terminal velocity</td>
<td>Newton’s second law of motion</td>
<td>projectile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>centripetal force</td>
<td>Newton’s third law of motion</td>
<td>centripetal acceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>air resistance</td>
<td>conservation of momentum</td>
<td>sliding friction</td>
<td>static friction</td>
<td></td>
</tr>
</tbody>
</table>

1. The phrase “to every action there is an equal and opposite reaction” is ______.
2. The largest velocity reached by a falling object is its ______.
3. A ball thrown across a football field is an example of a(n) ______.
4. When an object moves in a circle, ______ acts to accelerate the object toward the center of that circle.
5. When a car travels around a curve in the road, ______ helps to keep the car traveling in a curved path.
6. The force exerted by air on a moving object is called ______.
7. A net force acting on an object causes the object to accelerate in the direction of the force; this is ______.
8. A property of a moving object resulting from its mass and velocity is ______.
9. According to the ______, when a bowling ball strikes the pins, the momentum lost by the bowling ball is equal to the momentum gained by the pins.
10. ______ is the force that every object in the universe exerts on every other object.
11. An object’s ______ is the measure of the force of gravity on that object.
12. The amount of gravitational force between two objects depends on their masses and the ______ between them.
13. Weight is measured in units called ______, while mass is measured in units called grams and kilograms.
14. Two surfaces that are not moving past each other have ______.
15. ______ causes a box you are pushing across the floor to stop when you stop pushing.
Chapter Review (continued)

Part B. Concept Review

1. In the diagram at the right, a satellite is shown orbiting Earth. Add three arrows to the diagram to indicate the effects of a. inertia, b. gravity, and c. the path you predict results from the effects of inertia and gravity. Label the arrows a, b, and c.

2. Complete the diagrams below by indicating the path of the ball in each situation.

   a. The ball is placed on the edge of a table and allowed to fall to the floor.
   b. The ball is rolled rapidly across the table and falls onto the floor.

3. The balls in the figure above have the same mass. If the balls are dropped from the table at the same time, which ball will hit the floor first?

4. If a 2-kg ball is thrown through the air at 20 m/s, what is the momentum of the ball?

5. Why would a flat sheet of paper and a wad of paper with the same mass not fall through the air at the same rate?

6. When is something weightless?

7. What are the three types of friction and how are they different?
Transparency Activities
In 1999, Krishna Gopal Shrivastava of India set an unverified world record by pulling a ship with a mass of 244,000 kg with his teeth! His efforts can teach us about force, mass, and acceleration.

1. What would happen if the man were pulling a small rowboat instead of a large ship?
2. When he stops pulling, will the ship stop moving? Explain.
3. What direction is the ship moving? Why?
There is no up or down in orbit. If not secured, objects simply float here and there. Planes like NASA’s KC-135, the “Vomit Comet,” are able to briefly simulate the conditions of being in orbit.

1. On Earth, how can you tell up from down?
2. If a scale floated by and an astronaut stood on it, what would the scale say?
It takes more than one firefighter to aim a fire hose. The force of the water shooting out of the nozzle causes a reaction that can be difficult to control.

1. Describe what happens if you step from a canoe or small boat onto a dock.
2. Does a garden hose need more than one person to hold it? What’s the difference between a garden hose and a fire hose?
3. What would happen if the firefighters dropped the hose?
Teaching Transparency  
Activity

Stationary and Falling Elevator
1. What force gives the universe its structure?

2. What happens to the gravitational attraction between two objects as they move further apart?

3. In the top picture on the transparency, what object exerts an upward force on the boy?

4. In the second picture, what has happened to the reading on the scale? Why?

5. If the elevator is in free fall, what will the scale read?

6. What is the mass (in kg) of a person who weighs 637 N?
Directions: Carefully review the table and answer the following questions.

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass on Earth</th>
<th>Weight on Earth</th>
<th>Mass on Moon</th>
<th>Weight on Moon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronaut</td>
<td>90 kg</td>
<td>882 N</td>
<td>90 kg</td>
<td>149.4 N</td>
</tr>
<tr>
<td>Flashlight</td>
<td>1 kg</td>
<td>9.8 N</td>
<td>1 kg</td>
<td>1.7 N</td>
</tr>
<tr>
<td>Lunar Rover</td>
<td>650 kg</td>
<td>6370 N</td>
<td>650 kg</td>
<td>1079 N</td>
</tr>
<tr>
<td>Moon rocks</td>
<td>22 kg</td>
<td>215.6 N</td>
<td>22 kg</td>
<td>36.5 N</td>
</tr>
</tbody>
</table>

1. According to this information, which object has a weight on the Moon greater than 1000 newtons?
   A Astronaut   C Lunar Rover
   B Flashlight  D Moon rocks

2. Astronauts discovered how much easier it is to lift objects on the Moon. The weight of these objects on the Moon is due to ___.
   F Earth’s gravity
   G the Moon’s gravity
   H Earth’s revolution
   J the Moon’s rotation

3. According to the table, which object weighs the LEAST?
   A Astronaut   C Lunar Rover
   B Flashlight  D Moon rocks

4. Based on the data in the table, about how many times greater is the weight of these objects on Earth than on the Moon?
   F two times   H six times
   G four times  J eight times