### Motion in Two Dimensions

<table>
<thead>
<tr>
<th>Mini Lab Worksheet</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics Lab Worksheet</td>
<td>5</td>
</tr>
<tr>
<td>Chapter 6 Study Guide</td>
<td>9</td>
</tr>
<tr>
<td>Section 6.1 Quiz</td>
<td>15</td>
</tr>
<tr>
<td>Section 6.2 Quiz</td>
<td>16</td>
</tr>
<tr>
<td>Section 6.3 Quiz</td>
<td>17</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>19</td>
</tr>
<tr>
<td>Enrichment</td>
<td>21</td>
</tr>
<tr>
<td>Teaching Transparency Masters and Worksheets</td>
<td>23</td>
</tr>
<tr>
<td>Chapter 6 Assessment</td>
<td>31</td>
</tr>
</tbody>
</table>
Over the Edge

Obtain two balls, one twice the mass of the other.

1. **Predict** which ball will hit the floor first when you roll them over the surface of a table and let them roll off the edge.

2. **Predict** which ball will hit the floor furthest from the table.

3. **Explain** your predictions.

4. **Test** your predictions.

**Analyze and Conclude**

5. Does the mass of the ball affect its motion? Is mass a factor in any of the equations for projectile motion?
On Target

In this activity, you will analyze several factors that affect the motion of a projectile and use your understanding of these factors to predict the path of a projectile. Finally, you will design a projectile launcher and hit a target a known distance away.

Question
What factors affect the path of a projectile?

Objectives
- Formulate models and then summarize the factors that affect the motion of a projectile.
- Use models to predict where a projectile will land.

Procedure
1. Brainstorm and list as many factors as you are able to think of that may affect the path of a projectile.
2. Create a design for your projectile launcher and decide what object will be your projectile shot by your launcher.
3. Taking the design of your launcher into account, determine which two factors are most likely to have a significant effect on the flight path of your projectile.
4. Check the design of your launcher and discuss your two factors with your teacher and make any necessary changes to your setup before continuing.
5. Create a method for determining what effect these two factors will have on the path of your projectile.

6. Have your teacher approve your method before collecting data.

### Data Table 1

<table>
<thead>
<tr>
<th>Launch Angle (deg)</th>
<th>Distance Projectile Travels (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Data Table 2

<table>
<thead>
<tr>
<th>Distance Rubber Band is Pulled Back (cm)</th>
<th>Distance Projectile Travels (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analyze

1. **Make and Use Graphs** Make graphs of your data to help you predict how to use your launcher to hit a target.

2. **Analyze** What are the relationships between each variable you have tested and the distance the projectile travels?

Conclude and Apply

1. What were the main factors influencing the path of the projectile?

2. **Predict** the conditions necessary to hit a target provided by the teacher.

3. **Explain** If you have a perfect plan and still miss the target on your first try, is there a problem with the variability of the laws of physics? Explain.

4. **Launch** your projectile at the target. If you miss, make the necessary adjustments and try again.
Going Further

1. How might your data have varied if you did this experiment outside? Would there be any additional factors affecting the motion of your projectile?

2. How might the results of your experiment be different if the target were elevated above the height of the launcher?

3. How might your experiment differ if the launcher were elevated above the height of the target?

Real-World Physics

1. When a kicker attempts a field goal, do you think it is possible for him to miss because he kicked it too high? Explain.

2. If you wanted to hit a baseball as far as possible, what would be the best angle to hit the ball?
Motion in Two Dimensions

Vocabulary Review

For each definition on the left, write the letter of the matching item.

1. a force directed toward the center of a circle  
   a. projectile  
   b. trajectory  
   c. uniform circular motion  
   d. centripetal acceleration  
   e. centripetal force

2. an object shot through the air  

3. the movement of an object at a constant speed around a circle with a fixed radius  

4. acceleration that always points toward the center of a circle  

5. a projectile’s path through space

Section 6.1  Projectile Motion

In your textbook, read about projectile motion on pages 147–152. Refer to the diagram to answer questions 1–3. Use complete sentences.

1. How would the path of the ball appear to an observer at Position A?

2. How would the path of the ball appear to an observer at Position B?

3. How would the path of the ball appear to an observer at Position C?
Answer the following questions. Use complete sentences.

4. Describe the motion of a projectile in terms of horizontal and vertical vectors. Which vectors change, which remain constant, and why?

5. Two rocks are thrown from a cliff. One is thrown horizontally at a speed of 25 m/s. The other is dropped straight down. Which stone will hit the ground first? Why?

---

Answer the following questions. Show your calculations.

6. A plane drops a rescue capsule from an altitude of 8500 m.
   a. How long does it take for the capsule to fall to Earth, assuming air resistance is negligible?
   
   b. What is the vertical component of the rescue capsule’s velocity when it hits the ground? Assume that air resistance is negligible. You may want to draw a diagram to help you answer the question.
c. If the plane is traveling with a horizontal speed of 483 km/h when the capsule is released, what is the horizontal distance between the point at which the capsule is released and the point at which the capsule strikes the ground? Draw a diagram to help you answer the question.

Section 6.2 Uniform Circular Motion

In your textbook, read about uniform circular motion on page 153.

Answer the following questions. Use complete sentences.

1. What are the two conditions necessary for an object to be in uniform circular motion?

2. Why is a particle in uniform circular motion not moving at a constant velocity?

3. Use Newton’s laws to explain how you know that an object in uniform circular motion must be experiencing a force.

4. Use Newton’s laws to explain how you know that an object in uniform circular motion is being accelerated.
5. An object in uniform circular motion is at position \( r_1 \) at the beginning of a time interval and position \( r_2 \) at the end of the time interval. Write an algebraic expression that describes the object’s average velocity during this time interval. You may want to draw a diagram to help you answer the question.

6. The object described in the Question 5 has a velocity vector \( v_1 \) at the beginning of the time interval and \( v_2 \) at the end of the time interval. Write an algebraic expression that describes the object’s average acceleration during this time interval.

In your textbook, read about uniform circular motion on page 153.

Answer the following questions. Use complete sentences.

7. For each situation below, what provides the force that causes centripetal acceleration? You may want to draw a diagram to help you answer some of the questions.

   a. a ball on a string swinging in a circle in uniform circular motion

   b. a satellite moving around Earth in uniform circular motion

   c. a car driving in a circle in uniform circular motion

   d. a person on a carnival ride that has hanging baskets that are whirled around horizontally in uniform circular motion

8. What is the relationship between the centripetal acceleration of an object in uniform circular motion and the object’s velocity?
9. What is the relationship between the centripetal acceleration of an object in uniform circular motion and the radius of the object’s motion?

Complete questions 10–12 in the table below.

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Radius</th>
<th>Centripetal Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(v)</td>
<td>(r)</td>
<td>(a_c)</td>
</tr>
<tr>
<td>(v)</td>
<td>(2r)</td>
<td></td>
</tr>
<tr>
<td>(2v)</td>
<td>(r)</td>
<td>10. (a = _\times a_c)</td>
</tr>
<tr>
<td>(2v)</td>
<td>(2r)</td>
<td>11. (a = _\times a_c)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12. (a = _\times a_c)</td>
</tr>
</tbody>
</table>

Section 6.3 Relative Velocity

In your textbook, read about relative velocity on pages 157–159.

Answer the following questions. Show your calculations.

1. A person walks along a moving sidewalk at a rate of 3 m/s in the same direction the sidewalk is moving. The sidewalk moves at a rate of 2 m/s. You may want to draw a diagram of the relative velocities to help you answer the questions.

   a. What is the person’s velocity relative to the moving sidewalk?

   b. What is the sidewalk’s velocity relative to the ground?

   c. What is the person’s velocity relative to the ground?
2. The person in question 1 turns around and walks in the opposite direction at 3 m/s. You may want to draw a diagram of the relative velocities to help you answer the questions.
   a. What is the person’s velocity relative to the moving sidewalk?
   b. What is the sidewalk’s velocity relative to the ground?
   c. What is the person’s velocity relative to the ground?

3. An airplane is moving north at 800 km/h relative to the ground. A person on the plane walks toward the back of the plane at a speed of 2.5 m/s. What direction is the person moving relative to the ground?

4. A boat travels west at 5.0 m/s. John jogs from the right side of the boat to the left side at a rate of 5.0 m/s.
   a. What direction is John moving relative to the water?
   b. Draw a vector diagram that illustrates John’s motion relative to the boat, the boat’s motion relative to the water, and John’s motion relative to the water. Indicate which direction is north.
1. Use Newton’s laws to explain the horizontal acceleration of a projectile.

2. Use Newton’s laws to explain the vertical acceleration of a projectile.

3. A projectile fired up into the air at an angle has a range of 235 m and a flight time of 47 s. You may want to draw a diagram to help you answer the following questions.

   a. What is the horizontal component of the projectile's velocity?

   b. What is the maximum height of the projectile?

   c. Calculate \( v_{iy} \) for the projectile.
1. Why is an object in uniform circular motion experiencing centripetal acceleration?

2. Why does centrifugal force not actually exist?

3. Objects A and B are in uniform circular motion and both have a tangential velocity of 11.5 m/s.
   a. If the period of Object A is 2.4 s and the period of Object B is 1.2 s, what is the ratio of the radius of Object A's motion to the radius of Object B's motion?

   b. If the radius of Object A's motion is 3.0 m and the radius of Object B's motion is 1.0 m, what is the ratio of Object A's acceleration to Object B's acceleration?
1. How does the concept of relative velocity refine the concept of velocity?
   
2. Why are vectors important to the concept of relative velocity?
   
3. The compass of an airplane indicates that the airplane is heading north and is moving at an airspeed of 230 km/h. The wind is blowing east at 55 km/h.
   
   a. What is the velocity of the plane with respect to the ground?
   
   b. How many degrees east of north is the plane’s velocity with respect to the ground?
Problem
How can you use coins and a ruler to identify the forces that affect the trajectory of projectiles?

Procedure
1. In a room with a wood or tile floor, place two nickels a few centimeters apart near the edge of a table.
2. Place a ruler behind the coins, parallel to the edge of the table.
3. Keeping the ruler parallel to the edge of the table, use the ruler to push the coins off the table.
4. Listen for the sound of the coins hitting the floor, and note where they strike the floor.
5. Repeat the exercise, varying the force you use to launch the coins.
6. Now place the ruler behind the coins, but at an angle to the edge of the table.
7. With one finger, hold the end of the ruler near the edge of the table in place.
8. With the other hand, pivot the ruler around and knock the coins off the table.
9. Repeat steps 4 and 5.

Results
1. What happened when you launched the coins by pushing the ruler? Describe the coins’ trajectories. How did varying the force affect the outcome?

2. Draw a motion diagram showing the trajectory of the coins with two different forces.
3. What happened when you launched the coins by pivoting the ruler? Describe the coins’ trajectories. How did varying the force affect the outcome?

________________________________________________________________________

________________________________________________________________________

4. Draw motion diagrams showing the trajectory of the coins with two different forces.


5. What does this exercise demonstrate about horizontal and vertical components of an object’s motion?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Walking on the Moon

On Earth, acceleration due to gravity is about 9.8 m/s². Acceleration due to gravity is determined by the magnitude of the gravitational force on the surface of Earth, which is in turn determined by Earth’s mass and radius.

As you may know, objects weigh less on the Moon than on Earth. This is true because even though the moon’s radius is about one fourth Earth’s radius, it has only about 12 percent of Earth’s mass (7.36×10²² kg versus Earth’s 5.98×10²⁴ kg). Thus the force of gravity on the surface of the Moon is much smaller than it is on the surface of Earth. This difference in the force of gravity explains why, in videotapes of the Moon, astronauts seem to float when they walk.

Acceleration due to gravity on the surface of the Moon is about 1.7 m/s², less than one fifth of the acceleration due to gravity on the surface of Earth. Thus the vertical component of projectile motion on the Moon is different from the vertical component of projectile motion on Earth. The path of a projectile on the Moon still makes a parabola, but it is a broader parabola than the projectile would follow on Earth.

1. A basketball star is able to jump to a height of 1.0 m above the ground. On Earth, how long will he be in the air? You may want to draw a diagram of the forces acting on the basketball player to help you answer the question.

2. What is the basketball player’s initial vertical velocity?
3. If the basketball player leapt directly upward with the same initial velocity on the Moon, how long would he be in the air?

4. What would be the maximum height of the jump in Question 3?

5. A football player kicks a football with an initial velocity of 17.0 m/s at 39.0° above the horizontal on the Moon.
   a. What is the maximum height the football will reach?
   
   b. How far away will the football land?
The Trajectory of a Projectile
The Trajectory of a Projectile

1. At what point is the magnitude of the ball’s velocity vector the smallest? Why?

2. What can be said about the relationship between the vertical component of the ball’s velocity at the moment it leaves the ground and the moment it returns to the ground?

3. What can be said about the relationship between the horizontal component of the ball’s velocity at the moment it leaves the ground and the moment it returns to the ground?

4. For each graph below, draw a line that represents the appropriate position of the ball as a function of time.
Vertical and Horizontal Projectiles

1. How do the vertical velocities of the two trajectories compare?

2. How does the acceleration of the two balls compare?

3. How does the red ball’s horizontal motion affect its vertical motion?

4. How do you know that the vertical velocity of both balls is greater near the bottom of the figure than it is at the top of the figure?

5. How do you know that the horizontal velocity of the red ball is constant from the top of its fall to the bottom?
Uniform Circular Motion

1. What are the conditions necessary for an object to be in uniform circular motion?

2. Do all of the objects pictured fulfill these conditions?

3. A speck of dust on the CD is in uniform circular motion. What provides the force that keeps the dust in uniform circular motion?

4. Assuming that all of the objects have approximately the same velocity, which of the pictured objects most likely has the greatest period and which has the smallest period? How do you know?
Ground Speed = Air Speed + Wind Speed

Ground Speed = Air Speed − Wind Speed

Copyright © Glencoe/McGraw-Hill, a division of The McGraw-Hill Companies, Inc.
Relative Velocity

1. Does the airplane have a greater ground speed when the wind blows with the plane or against the plane?

2. If the wind speed in the top figure increased, what would happen to the plane’s ground speed?

3. If the wind speed in the top figure decreased, what would happen to the plane’s ground speed?

4. If the wind speed in the bottom figure increased, what would happen to the plane’s ground speed?

5. If the wind speed in the bottom figure decreased, what would happen to the plane’s ground speed?

6. When an airplane is landing, it must have a relatively slow ground speed. However, at lower air speeds, the lift generated by the wings is less. Which of the figures shows the best situation for landing? Why?
§ Chapter Assessment

Motion in Two Dimensions

Understanding Physics Concepts

Circle the letter of the choice that best completes the statement or answers the question.

1. The horizontal and vertical components of a projectile's velocity are _____.
   a. directly proportional  
   b. inversely proportional  
   c. independent of each other  
   d. equal

2. The horizontal acceleration of a projectile after it is fired is _____.
   a. dependent on the vertical acceleration  
   b. directly proportional to acceleration due to gravity  
   c. constant  
   d. zero

3. Neglecting air resistance, the initial horizontal velocity of a projectile is _____ its final horizontal velocity.
   a. greater than  
   b. less than  
   c. equal to  
   d. directly proportional to

4. For a receiver to catch a football at chest level, the quarterback must aim the football _____ the receiver's chest.
   a. directly at  
   b. above  
   c. below  
   d. to the side of

5. How far does an object in uniform circular motion travel during one period?
   a. \(2\pi r\)  
   b. \(\pi r^2\)  
   c. \(\frac{v^2}{r}\)  
   d. \(2\pi \sqrt{\frac{r}{a_c}}\)

6. An object in uniform circular motion has an acceleration that is _____.
   a. in a direction tangential to the circle  
   b. toward the center of the circle  
   c. away from the center of the circle  
   d. zero

7. The velocity vector for an object in uniform circular motion is _____.
   a. directed away from the center of the circle  
   b. directed toward the center of the circle  
   c. tangential to the circle  
   d. proportional to the radius of the circle
8. When a problem has multiple frames of reference, _____ is used to determine relative velocity.
   a. magnitude  
   b. multiplication  
   c. vector addition  
   d. algebra

Answer the following questions. Show your calculations. You may find a diagram helpful in answering the questions.

9. A punter kicks a football at an angle of 45° to the ground. The football has an initial velocity of 25 m/s.
   a. How long is the football in the air?
   
   b. How far does the football travel horizontally?
   
   c. What is the maximum height of the football?

10. A car moving at 30.0 km/h rounds a bend in the road that has a radius of 21.2 m. What is the centripetal acceleration of the car?

11. A boat moves north at a speed of 2.7 m/s across a river that flows west at a rate of 1.2 m/s. What is the boat’s velocity relative to the riverbank?
Thinking Critically

Refer to the graphs to answer questions 1–5. Use complete sentences.

1. The graphs above show position versus time for the first half of a projectile’s flight. Which graph shows horizontal position and which shows vertical position? How do you know?

2. What do the slopes of the graphs represent?

3. What would a line graph of vertical velocity versus time look like?

4. What would a line graph of horizontal velocity versus time look like?

5. At what point on the position-time graph does the projectile have its maximum vertical speed? At what point does it have its minimum vertical speed?
Answer the following questions. Show your calculations.

6. A 0.150-kg rubber stopper is attached to the end of a 1.00-m string and is swung in a circle.
   a. If the stopper makes 0.85 rev/s, what is the force the string exerts on the stopper?

   b. If the rubber stopper is swung 2.3 m above the ground and released, how far from the point it
      was released will it fall to the ground?

7. A person on a ferry walks at a speed of 2.0 m/s. The ferry’s velocity is 5.0 m/s north.
   a. In which direction should the person walk to have the maximum possible velocity relative to a
      person standing on the dock? What is the velocity?

   b. In which direction should the person walk to have the smallest possible velocity relative to a
      person standing still on the dock? What is the velocity?

   c. If the person is walking south, what is the velocity relative to a person on the dock strolling at
      1.0 m/s south? (Hint: Is the velocity toward the strolling person more or less than the velocity
      toward a stationary person on the dock?)
Applying Physics Knowledge

Answer the following questions. Show your calculations.

1. A remote-control car with a constant velocity drives off the top of a wall that is 10.0 m high and lands 4.60 m from the base of the wall.
   a. Draw a diagram of the problem. Label the known and unknown quantities.
   b. What is the car’s velocity before it drives off the top of the wall?
   c. What is the car’s vertical velocity at impact?
   d. How far from the base of the wall would the remote-control car have landed if it had been subject to acceleration due to gravity on the Moon (1.7 m/s²)?
2. An 82.0-kg person rides on a carnival ride in a 45.0-kg basket supported by a single chain. When the ride reaches its top speed, the basket moves at a constant speed in a horizontal circle with a radius of 7.10 m. At this point, the chain supporting the basket is at a 45.0° angle to the vertical. You may want to draw a diagram to help you answer the questions.

a. At top speed, what are the vertical and horizontal components of the tension in the chain? (Hint: The vertical component of the tension equals the weight it supports.)

b. What is the centripetal acceleration of the basket and its passenger?

c. What is the speed of the basket and its passenger?

d. How long does it take the basket to make one complete circle?

3. Lois and Leo are riding their unicycles side by side. They are heading east at a speed of 3.5 m/s. Lois tosses a large beach ball over to Leo with a velocity of 0.76 m/s north. What is the velocity of the beach ball relative to the ground?
9. An adult exerts a force of 25 N to pull a child 350 m across the snow on a sled. If the rope that joins the sled is at an angle of 30.0° above the horizontal, how much work is done in pulling the sled?

10. A shelf stocker lifts a 7.5-kg carton from the floor to a height of 0.70 m, carries it 45 m at constant speed across the store and places it on a shelf 1.5 m above the floor. How much work does the worker accomplish?

11. At what speed can a 120-W motor lift a 2800-N load?

12. A mover uses a force parallel to the ramp of 720.0 N to push a 370.0-kg piano on wheels up a ramp onto a stage. The ramp is 8.00 m long, and the stage is 1.50 m above the floor.
   a. How much work does the mover do?
   b. If the ramp is 94% efficient, what is the output work of the ramp?
Chapter 6

Mini Lab Worksheet

Over the Edge

1. Answers will vary. However, students should suggest that the two balls will strike the floor at the same time.

2. Answers will vary. However, students should suggest that the two balls land the same distance from the table.

3. Provided the predictions are correct, the appropriate explanation is that the trajectory of a projectile is independent of its mass.

Analyze and Conclude

5. No, mass is not a factor in this experiment. Mass does not appear in any of the equations that describe projectile motion.

Physics Lab Worksheet

On Target

Data Table 1

<table>
<thead>
<tr>
<th>Launch Angle (deg)</th>
<th>Distance Projectile Travels (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>70</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>0</td>
</tr>
</tbody>
</table>

Data Table 2

<table>
<thead>
<tr>
<th>Distance Rubber Band Is Pulled Back (cm)</th>
<th>Distance Projectile Travels (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>36</td>
</tr>
<tr>
<td>0.5</td>
<td>55</td>
</tr>
<tr>
<td>1.0</td>
<td>141</td>
</tr>
<tr>
<td>1.5</td>
<td>182</td>
</tr>
<tr>
<td>2.0</td>
<td>236</td>
</tr>
</tbody>
</table>

Analyze

1. The answers below show an example of typical data for this experiment using a rubber band launcher.
2. The farther back the rubber band is stretched, the farther the range. As the angle changes, the range also changes. The maximum range occurs at approximately 45°.

Conclude and Apply
1. The launch speed and angle are major factors affecting the range of the trajectory.
2. Answers will vary.
3. The laws that govern physics are not subject to the same systematic and random error that students have in making measurements and following procedures.
4. No answer required.

Going Further
1. If this experiment is done outside, wind might play a significant role by affecting the path of the projectile in flight.
2. If the target is elevated above the launcher, you may need to have either a higher angle or greater launch speed in order to reach the target.
3. If the launcher is elevated above the target, you may need to decrease the launch angle or to decrease the launch speed in order to hit the target.

Real-World Physics
1. A field-goal kicker can never kick the ball too high over the cross bar; he can, however, kick it with too great a launch angle to get the required distance.
2. If you ignore air resistance, the ball should be hit at an angle of 45°; otherwise, it should be hit at an angle slightly less than 45°.

Study Guide

Section 6-1
Projectile Motion
1. To an observer at Position A, the ball would appear to move straight up and then straight down.
2. To an observer at Position B, the ball would appear to move in a straight line.
3. To an observer at Position C, the ball’s path would appear as in the diagram (as a parabola).
4. Throughout its flight, a projectile is constantly being accelerated toward the ground, even when it is moving upward. Thus, the vertical vector of a projectile’s flight first points upward and shrinks until the projectile reaches its maximum height, at which point the projectile has no vertical component to its motion. The vertical vector then points to the ground and grows larger until the projectile returns to Earth. The horizontal vector always points along the ground and has the same magnitude throughout the projectile’s flight.
5. Both stones will hit the ground at the same time because the horizontal component of their velocities is independent of the vertical component. They both start out with zero vertical velocity and they both undergo the same acceleration due to gravity.
6. a. Since it is dropped from rest aboard the airplane, \( v_i = 0 \) m/s and \( y_f = 0 \) m.
   \[
y_f = y_i + v_i t - \frac{1}{2} at^2
   \]
   \[
t = \sqrt{\frac{2y_f}{g}} = \sqrt{\frac{2(8500 \text{ m})}{9.80 \text{ m/s}^2}} = 42 \text{ s}
   \]
   \[
v_f = \sqrt{v_i^2 + 2gy} = \sqrt{2(9.80 \text{ m/s}^2)(8500 \text{ m})}
   = 410 \text{ m/s}
   \]
   b. \( d = v_i t = (134 \text{ m/s})(42 \text{ s}) = 5600\text{ m} \)

Answer Key

Copyright © Glencoe/McGraw-Hill, a division of The McGraw-Hill Companies, Inc.
Section 6-2
Uniform Circular Motion

1. The object must be moving in a circle with a fixed radius and the object must be moving at a constant speed.
2. While speed is a directionless quantity, velocity is a vector and therefore any change in direction indicates a change in velocity.
3. Newton's first law states that a body moving at a constant velocity will continue moving at a constant velocity unless a force acts on that body. Since an object in uniform circular motion has a changing velocity, it must be experiencing a force.
4. Newton's second law states that when a force acts on a mass, that force causes acceleration along the same axis that the force is applied. As shown in Question 3, an object in uniform circular motion must be experiencing a force since it has a changing velocity. Therefore, that force must be causing the object to accelerate along the same axis as the force.
5. \[ \ddot{v} = \frac{\Delta r}{\Delta t} \text{ or } \ddot{v} = \frac{r_2 - r_1}{t_2 - t_1} \]
6. \[ \ddot{a} = \frac{\Delta v}{\Delta t} \text{ or } \ddot{a} = \frac{v_2 - v_1}{t_2 - t_1} \]
7. a. the string
   b. the force of gravity
   c. the force of friction between the tires and the pavement
   d. the chain on which the basket hangs
8. The centripetal acceleration is directly proportional to the square of the velocity.
9. The centripetal acceleration is inversely proportional to the radius of rotation.

Section 6-3
Relative Velocity

1. a. 3 m/s
   b. 2 m/s
   c. 5 m/s
2. a. 3 m/s
   b. 2 m/s
   c. 1 m/s
3. north
4. a. southwest
   b. 

Section 6-1 Quiz

1. Newton’s second law states that when a force is applied to an object, the object will accelerate along the same axis that the force is applied. Assuming that air resistance is negligible, no forces act on a projectile along the horizontal axis and therefore the object has no horizontal component to its acceleration other than the initial force.
2. The force of gravity acts along the vertical axis of a projectile’s flight. This force is constant and thus the acceleration the projectile experiences along the vertical axis is constant and is equal to the acceleration due to gravity.
3. a. \[ d = vt \]
   \[ v = \frac{d}{t} = \frac{235 \text{ m}}{47 \text{ s}} = 5.0 \text{ m/s} \]
   b. As the projectile travels up and then down again, it reaches its maximum height at the midway point of its path,
   \[ t = \frac{47 \text{ s}}{2} = 24 \text{ s} \]
   \[ v_f = -\frac{1}{2} at^2 = -\frac{1}{2} (-9.80 \text{ m/s}^2)(24 \text{ s})^2 \]
   \[ = 2800 \text{ m} \]
c. The final velocity for the projectile is \( v_{fy} = 0 \) m/s, since it stops at its maximum height and begins to fall. A calculation is only necessary for this midway path as the projectile returns to Earth at the same velocity at which it was fired.

\[
v_{fy} = v_{iy} + at = -(-9.80 \text{ m/s}^2)(24 \text{ s}) = 240 \text{ m/s}
\]

Section 6-2 Quiz

1. The velocity vector of an object in uniform circular motion is constantly changing. The sum of any two velocity vectors for the object point toward the center of the circle, so the velocity is constantly changing direction toward the center of the circle. Since an object only changes its velocity when it is acted upon by a force and since a force causes acceleration, the object's changing velocity indicates that it is accelerating and the change in direction of velocity indicates that it is accelerating toward the center of the circle.

2. Centrifugal force is believed by some to be an outward force that exists when an object is in uniform circular motion. However, if the centripetal force that keeps an object in uniform circular motion is suddenly removed, the object does not fly outward away from the center of the circle. It moves along a line tangential to the circle. Thus, there is no centrifugal force.

3. a. \[
T = \frac{2\pi r}{v}
\]
\[
r = \frac{TV}{2\pi}
\]
\[
\frac{r_A}{r_B} = \frac{\left(\frac{T_A v}{2\pi}\right)}{\left(\frac{T_B v}{2\pi}\right)} = \frac{T_A}{T_B} = \frac{2.4 \text{ s}}{1.2 \text{ s}} = 2.0
\]

Section 6-3 Quiz

1. Velocity is always relative to a frame of reference. Saying that an object is moving at a rate of 10 m/s is an incomplete description of its movement. While an object may be moving at 10 m/s with reference to the ground, it is moving much faster within the solar system as Earth moves around the Sun. Thus, relative velocity is a way to specify the frame of reference you are using when solving a problem.

2. First, velocity is a vector quantity. Second, when more than one frame of reference is involved in a problem, the vectors of the velocities in each frame of reference must be added. Therefore, vectors are the tools that allow us to solve problems that involve relative velocities.

3. a. \[
\frac{\nu}{g} = \nu_{p/a}^2 + \nu_{a/g}^2
\]
\[
\nu_{p/g} = \sqrt{\frac{\nu_{p/a}^2 + \nu_{a/g}^2}{(230 \text{ km/h})^2 + (55 \text{ km/h})^2}}
\]
\[
= \frac{240 \text{ km/h}}{230 \text{ km/h}}
\]

b. \[
\theta = \tan^{-1}\left(\frac{\nu_{a/g}}{\nu_{p/a}}\right)
\]
\[
= \tan^{-1}\left(\frac{55 \text{ km/h}}{230 \text{ km/h}}\right)
\]
\[
= 13^\circ
\]
Chapter 6 Reinforcement

Horizontal and Vertical Components
of Motion

Results

1. No matter what the force, both coins had the same trajectory and hit the floor at the same time.

2. The coins had different trajectories. The coin closer to the moving end of the ruler landed further from the edge of the table. However, both coins hit the ground at the same time. When the force was varied, the distance between the locations where the coins landed increased, but the coins still hit the ground at the same time.

3. It demonstrates that the horizontal and vertical components of an object’s motion are independent of one another.

4. Diagrams may vary, but the consistent point should be that while the horizontal vectors change according to the forces used, the vertical components should be similar in all figures.

5. This exercise should demonstrate the independent nature of the horizontal and vertical components of an object’s motion.

Chapter 6 Enrichment

Walking on the Moon

1. Calculating the time it takes the player to fall from the maximum height, \( y_i = 1.0 \text{ m} \) and \( v_i = 0 \text{ m/s} \), to the ground,

\[
y_f = y_i + v_i t - \frac{1}{2} at^2
\]

\[
t = \sqrt{\frac{2y_i}{g}} = \sqrt{\frac{2(1.0 \text{ m})}{9.80 \text{ m/s}^2}} = 0.45 \text{ s}
\]

\[
t_{\text{flight}} = 2t = 2(0.45 \text{ s}) = 0.90 \text{ s}
\]

2. \( y_f = y_i + v_i t - \frac{1}{2} at^2 \)

\[
v_i = \frac{y_f + \frac{1}{2}at^2}{t}
\]

\[
= \frac{1.0 \text{ m} + \frac{1}{2}(9.80 \text{ m/s}^2)(0.45 \text{ s})^2}{0.45 \text{ s}}
\]

\[
= 4.4 \text{ m/s}
\]

3. \( v_f = v_i + at \)

\[
t = -\frac{v_i}{a} = -\frac{4.4 \text{ m/s}}{(-1.7 \text{ m/s}^2)} = 2.6 \text{ s}
\]

\[
t_{\text{flight}} = 2t = 2(2.6 \text{ s}) = 5.2 \text{ s}
\]

4. \( y_f = y_i + v_i t - \frac{1}{2} at^2 = (4.4 \text{ m/s})(2.6 \text{ s}) \\
- \frac{1}{2}(1.7 \text{ m/s}^2)(2.6 \text{ s})^2 = 5.7 \text{ m} \\

5. a. \( v_{yi} = v_i (\sin \theta) = (17.0 \text{ m/s})(\sin 39.0^\circ) = 10.7 \text{ m/s} \)

\[
v_y = v_{yi} + at = v_{yi} - gt
\]

\[
t = \frac{v_{yi} - v_y}{g} = \frac{10.7 \text{ m/s} - 17.0 \text{ m/s}}{-1.7 \text{ m/s}^2} = 3.7 \text{ s}
\]

\[
y_f = y_i + v_i t - \frac{1}{2}at^2 = (10.7 \text{ m/s})(3.7 \text{ s}) \\
- \frac{1}{2}(1.7 \text{ m/s}^2)(3.7 \text{ s})^2 = 28 \text{ m}
\]

b. \( v_{xi} = v_i (\cos \theta) = (17.0 \text{ m/s})(\cos 39.0^\circ) = 13.2 \text{ m/s} \)

\[
t_{\text{flight}} = 2t = 2(3.7 \text{ s}) = 7.4 \text{ s}
\]

\[
d = ut = (13.2 \text{ m/s})(7.4 \text{ s}) = 98 \text{ m}
\]
Transparency Worksheet 6-1

The Trajectory of a Projectile

1. The magnitude of the ball’s velocity is the smallest at the ball’s maximum height because the magnitude of the horizontal component of the ball’s velocity is zero.

2. The two velocities are equal in magnitude and opposite in direction.

3. The two velocities are equal in magnitude and in direction.

4. The horizontal intervals between each two pictures of the red ball are identical. Since the intervals represent identical time periods, the horizontal velocity of the red ball must be constant.

Transparency Worksheet 6-2

Vertical and Horizontal Projectiles

1. The trajectories have the same vertical velocity at each point.

2. Both balls fall with the same acceleration.

3. The horizontal motion of the red ball does not affect its vertical motion.

4. The vertical interval between successive pictures of the balls is greater near the bottom of the figure. Since the time interval between each two pictures is the same, the vertical velocity of the balls must have increased.

5. The horizontal intervals between each two pictures of the red ball are identical. Since the intervals represent identical time periods, the horizontal velocity of the red ball must be constant.

Transparency Worksheet 6-3

Uniform Circular Motion

1. The object must be moving in a circle with a fixed radius, and it must be moving at a constant speed.

2. Yes, all of the objects pictured are in uniform circular motion.

3. The speck of dust is kept in uniform circular motion by the force of friction.

4. The CD has the smallest radius and therefore probably has the smallest period. The car has the greatest radius and therefore probably has the greatest period.

Transparency Worksheet 6-4

Relative Velocity

1. The plane has a greater ground speed when the wind blows with the plane.

2. If the wind speed in the top figure increased, the plane’s ground speed also would increase.

3. If the wind speed in the top figure decreased, the plane’s ground speed also would decrease.

4. If the wind speed in the bottom figure increased, the plane’s ground speed would decrease.

5. If the wind speed in the bottom figure decreased, the plane’s ground speed would increase.

6. The bottom figure shows the best situation for landing because there would be enough air speed for the wings to generate lift, but the head wind would lower the plane’s ground speed.
Chapter Assessment

Motion in Two Dimensions

Understanding Physics Concepts
1. c
2. d
3. c
4. b
5. a
6. b
7. c
8. c
9. a. \(v_y = v_1 \sin \theta = (25 \text{ m/s} \sin 45°) = 18 \text{ m/s}\)
   \[ t = \frac{v_y - v_y}{g} = \frac{18 \text{ m/s} - 25 \text{ m/s}}{-9.80 \text{ m/s}^2} = 0.71 \text{ s} \]
   \[ t_{\text{flight}} = 2t = 2(0.71 \text{ s}) = 1.4 \text{ s} \]
   b. \(v_{ix} = v_1 \cos \theta = (25 \text{ m/s} \cos 45°) = 18 \text{ m/s}\)
   
   \[ d = vt = (18 \text{ m/s})(1.5 \text{ s}) = 27 \text{ m} \]
   c. \(y_f = y_i + v_i t + \frac{1}{2}at^2 = (18 \text{ m/s})(0.71 \text{ s}) + \frac{1}{2}(9.80 \text{ m/s}^2)(0.71 \text{ s})^2 = 15 \text{ m} \]
10. \(v = (3.00 \times 10^4 \text{ m/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = 8.33 \text{ m/s} \)
   \[ a_c = \frac{v^2}{r} = \frac{(8.33 \text{ m/s})^2}{21.2 \text{ m}} = 3.28 \text{ m/s}^2 \]
11. \(v_{b/r} = v_{b/w} + v_{w/r} \)
   \[ v_{b/w}^2 = v_{b/w}^2 + v_{w/r}^2 \]
   \[ v_{b/r} = \sqrt{v_{b/w}^2 + v_{w/r}^2} = \sqrt{(2.7 \text{ m/s})^2 + (1.2 \text{ m/s})^2} = 3.0 \text{ m/s} \]

Chapter Assessment

Thinking Critically
1. Graph A shows vertical position versus time. The curve in Graph A is consistent with the fact that vertical speed changes. Graph B shows horizontal position versus time. Horizontal speed is constant for a projectile and horizontal position will therefore increase constantly. Graph B is linear and increases throughout the entire time interval.

2. The slopes of the graphs represent the instantaneous velocities (vertical and horizontal) of the projectile.
3. It would look like a straight line that begins with a large value and decreases constantly over the given time interval until it reaches zero.
4. It would be a horizontal line that does not increase or decrease over the given time interval.
5. The projectile has its maximum vertical speed at \(t = 0\), immediately after it is fired. It reaches its minimum vertical speed at the maximum height of its trajectory.
6. a. \(T = \frac{1}{0.85 \text{ rev/s}} = 1.2 \text{ s} \)
   \[ F = ma_c = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2(0.150 \text{ kg})(1.00 \text{ m})}{(1.2 \text{ s})^2} = 4.1 \text{ N} \]
   b. \(y_f = y_i + v_i t - \frac{1}{2}at^2 \)
   \[ t = \sqrt{\frac{2y_i}{g}} = \sqrt{\frac{2(2.3 \text{ m})}{9.80 \text{ m/s}^2}} = 0.68 \text{ s} \]
   \[ v^2 = \frac{4\pi^2 r}{T^2} \]
   \[ v_x = \frac{2\pi r}{T} = \frac{2\pi(1.00 \text{ m})}{1.2 \text{ s}} = 5.2 \text{ m/s} \]
   \[ d = v_x t = (5.2 \text{ m/s})(0.68 \text{ s}) = 3.5 \text{ m} \]
7. a. The person should walk north toward the front of the boat. In this direction, the velocity of the boat and the velocity of the person will add to give the maximum value, \(v = 5.0 \text{ m/s} + 2.0 \text{ m/s} = 7.0 \text{ m/s} \)
   b. The person should walk south toward the rear of the boat. In this direction, the velocity of the person will be subtracted from the forward velocity of the boat for the minimum value, \(v = 5.0 \text{ m/s} - 2.0 \text{ m/s} = 3.0 \text{ m/s} \)
   c. Defining Person 1 as the person walking on the boat and Person 2 as the person walking along the dock,
   \[ v_{\text{person1/person2}} + v_{\text{person2/dock}} = v_{\text{person1/dock}} \]
   \[ v_{\text{person1/person2}} = v_{\text{person1/dock}} - v_{\text{person2/dock}} = 3.0 \text{ m/s} - 1.0 \text{ m/s} = 2.0 \text{ m/s} \]
Applying Physics Knowledge

1. a. 

![Diagram of a car](image)

b. \( y_f = y_i + v_i t - \frac{1}{2}at^2 \)
\[
t = \sqrt{\frac{2y_f}{g}} = \sqrt{\frac{2(10.0 \text{ m})}{9.80 \text{ m/s}^2}} = 1.43 \text{ s}
\]
\[v = \frac{d}{t} = \frac{4.60 \text{ m}}{1.43 \text{ s}} = 3.22 \text{ m/s} \]

c. \( y_f = y_i + v_i t - \frac{1}{2}at^2 \)
\[v_i = \frac{y_f + \frac{1}{2}at^2}{t} = \frac{10.0 \text{ m} + \frac{1}{2}(9.80 \text{ m/s}^2)(1.43 \text{ s})^2}{1.43 \text{ s}} = 14.0 \text{ m/s} \]

d. \( y_f = y_i + v_i t - \frac{1}{2}at^2 \)
\[
t = \sqrt{\frac{2y_f}{g}} = \sqrt{\frac{2(10.0 \text{ m})}{1.7 \text{ m/s}^2}} = 3.4 \text{ s}
\]
\[d = vt (3.22 \text{ m/s})(3.4 \text{ s}) = 11 \text{ m} \]

2. a. vertical: \( F_y = mg = (82.0 \text{ kg} + 45.0 \text{ kg}) \)
\[ \frac{9.80 \text{ m/s}^2}{} = 1240 \text{ N} \]

horizontal: \( \tan \theta = \frac{F_x}{F_y} \)
\[ F_x = F_y \tan \theta = (1240 \text{ N})(\tan 45.0^\circ) = 1240 \text{ N} \]

b. \( F_{net} = \sqrt{F_x^2 + F_y^2} \)
\[ = \sqrt{(1240 \text{ N})^2 + (1240 \text{ N})^2} = 1750 \text{ N} \]
\[ a_c = \frac{F_{net}}{m} = \frac{1750 \text{ N}}{82.0 \text{ kg} + 45.0 \text{ kg}} = 13.8 \text{ m/s}^2 \]

c. \( a_c = \frac{v^2}{r} \)
\[ v = \sqrt{ra_c} = \sqrt{(7.10 \text{ m})(13.8 \text{ m/s}^2)} = 9.89 \text{ m/s} \]

d. \( a_c = \frac{4\pi^2r}{T^2} \)
\[ T = 2\pi \sqrt{\frac{r}{a_c}} = 2\pi \sqrt{\frac{7.10 \text{ m}}{13.8 \text{ m/s}^2}} = 4.51 \text{ s} \]

3. \( v = \sqrt{v_x^2 + v_y^2} \)
\[ = \sqrt{(3.5 \text{ m/s})^2 + (0.76 \text{ m/s})^2} = 3.6 \text{ m/s} \]
\[ \theta = \tan^{-1} \left( \frac{v_y}{v_x} \right) = \tan^{-1} \left( \frac{0.76 \text{ m/s}}{3.5 \text{ m/s}} \right) \]
\[ = 12^\circ \text{ north of east} \]

Chapter 7

Mini Lab

Analyze and Conclude

3. When the cup is dropped, the water stays in the cup.

4. There is no pressure between the falling cup and the water inside it. Both the cup and the water are being accelerated the same by gravity. The water and cup are in apparent weightlessness.

Physics Lab

Sample Data

See below for table.

<table>
<thead>
<tr>
<th>Object</th>
<th>e</th>
<th>d (cm)</th>
<th>Measured A</th>
<th>Measured P</th>
<th>Measured e</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>0</td>
<td>0.00</td>
<td>10.0</td>
<td>10.0</td>
<td>0</td>
<td>1/M</td>
</tr>
<tr>
<td>Earth</td>
<td>0.017</td>
<td>0.33</td>
<td>10.0</td>
<td>9.9</td>
<td>0.15</td>
<td>12%</td>
</tr>
<tr>
<td>Pluto</td>
<td>0.25</td>
<td>4.0</td>
<td>12.4</td>
<td>7.6</td>
<td>0.24</td>
<td>4.0%</td>
</tr>
<tr>
<td>Comet</td>
<td>0.70</td>
<td>8.2</td>
<td>173</td>
<td>2.7</td>
<td>0.73</td>
<td>4.3%</td>
</tr>
</tbody>
</table>