Answers

9. (a) 1.2×10^3 m
   (b) 32 s
   (c) 4.9×10^3 m
   (d) 2.2×10^2 m/s [45° below the horizontal]
10. (a) 2.4 s
    (b) 22 m
    (c) 18 m/s [60° below the horizontal]

Practice

Understanding Concepts

8. A field hockey ball is struck and undergoes projectile motion. Air resistance is negligible.
   (a) What is the vertical component of velocity at the top of the flight?
   (b) What is the acceleration at the top of the flight?
   (c) How does the rise time compare to the fall time if the ball lands at the same level from which it was struck?

9. A cannon is set at an angle of 45° above the horizontal. A cannonball leaves the muzzle with a speed of 2.2×10^2 m/s. Air resistance is negligible. Determine the cannonball's
   (a) maximum height
   (b) time of flight
   (c) horizontal range (to the same vertical level)
   (d) velocity at impact

10. A medieval prince trapped in a castle wraps a message around a rock and throws it from the top of the castle wall with an initial velocity of 12 m/s [42° above the horizontal]. The rock lands just on the far side of the castle's moat, at a level 9.5 m below the initial level (**Figure 14**). Determine the rock's
   (a) time of flight
   (b) width of the moat
   (c) velocity at impact

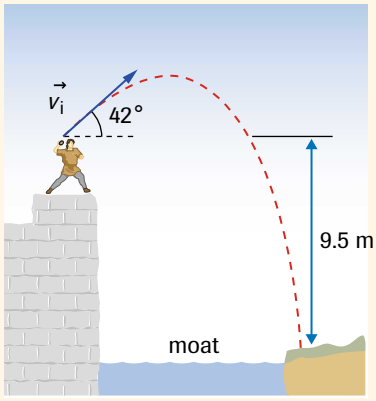

Figure 14
The situation for question 10

SUMMARY Projectile Motion

- A projectile is an object moving through the air in a curved trajectory with no propulsion system.
- Projectile motion is motion with a constant horizontal velocity combined with a constant vertical acceleration.
- The horizontal and vertical motions of a projectile are independent of each other except they have a common time.
- Projectile motion problems can be solved by applying the constant velocity equation for the horizontal component of the motion and the constant acceleration equations for the vertical component of the motion.

Section 1.4 Questions

Understanding Concepts

1. What is the vertical acceleration of a projectile on its way up, at the top of its trajectory, and on its way down?

2. (a) For a projectile with the launch point lower than the landing point, in what part of the flight is the magnitude of the velocity at a maximum? a minimum?
   (b) In what part of the flight is the magnitude of the velocity at a maximum, and in what part is it at a minimum, for a projectile with the launch point higher than the landing point?

3. A projectile launched horizontally moves 16 m in the horizontal plane while falling 1.5 m in the vertical plane. Determine the projectile's initial velocity.

4. A tennis player serves a ball horizontally, giving it a speed of 24 m/s from a height of 2.5 m. The player is 12 m from the net. The top of the net is 0.90 m above the court surface. The ball clears the net and lands on the other side. Air resistance is negligible.

(a) For how long is the ball airborne?
(b) What is the horizontal displacement?
(c) What is the velocity at impact?
(d) By what distance does the ball clear the net?

5. A child throws a ball onto the roof of a house, then catches it with a baseball glove 1.0 m above the ground, as in **Figure 15**. The ball leaves the roof with a speed of 3.2 m/s.
(a) For how long is the ball airborne after leaving the roof?
(b) What is the horizontal distance from the glove to the edge of the roof?
(c) What is the velocity of the ball just before it lands in the glove?

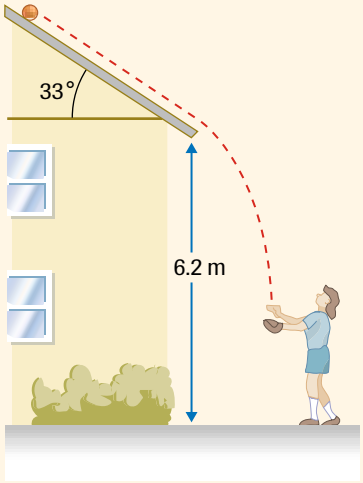

Figure 15

6. For a projectile that lands at the same level from which it starts, state another launch angle above the horizontal that would result in the same range as a projectile launched at an angle of 36°, 16°, and 45.6°. Air resistance is negligible.

7. During World War I, the German army bombarded Paris with a huge gun referred to, by the Allied Forces, as "Big Bertha." Assume that Big Bertha fired shells with an initial velocity of 1.1×10^3 m/s [45° above the horizontal].
(a) How long was each shell airborne, if the launch point was at the same level as the landing point?
(b) Determine the maximum horizontal range of each shell.
(c) Determine the maximum height of each shell.

8. An astronaut on the Moon, where $|\vec{g}| = 1.6$ m/s^2, strikes a golf ball giving the ball a velocity of 32 m/s [35° above the Moon's horizontal]. The ball lands in a crater floor that is 15 m below the level where it was struck. Determine
(a) the maximum height of the ball
(b) the time of flight of the ball
(c) the horizontal range of the ball

Applying Inquiry Skills

9. A garden hose is held with its nozzle horizontally above the ground (**Figure 16**). The flowing water follows projectile motion. Given a metre stick and a calculator, describe how you would determine the speed of the water coming out of the nozzle.

Figure 16
Projectile motion in the garden

10. Describe how you would build and test a device made of simple, inexpensive materials to demonstrate that two coins launched simultaneously from the same level, one launched horizontally and the other dropped vertically, land at the same instant.

Making Connections

11. In real-life situations, projectile motion is often more complex than what has been presented in this section. For example, to determine the horizontal range of a shot in shot put competitions, the following equation is used:

$$\Delta x = \Delta x_1 + \Delta x_2 + \Delta x_3$$

$$\Delta x = 0.30 \text{ m} + \frac{2v_i^2 \sin\theta \cos\theta}{g} + \frac{v_i \sin\theta \sqrt{v_i^2 \sin^2\theta + |2g\Delta y|}}{g}$$

where 0.30 m is the average distance the athlete's hand goes beyond the starting line, v_i is the magnitude of the initial velocity, θ is the angle of launch above the horizontal, Δy is the height above the ground where the shot leaves the hand, and g is the magnitude of the acceleration due to gravity (**Figure 17**).
(a) Determine the range of a shot released 2.2 m above the ground with an initial velocity of 13 m/s [42° above the horizontal].
(b) Compare your answer in (a) to the world record for the shot put (currently about 23.1 m).
(c) Why do you think the equation given here differs from the equation for horizontal range derived in this section?

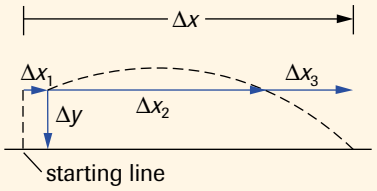

Figure 17