Projectile Motion Problems

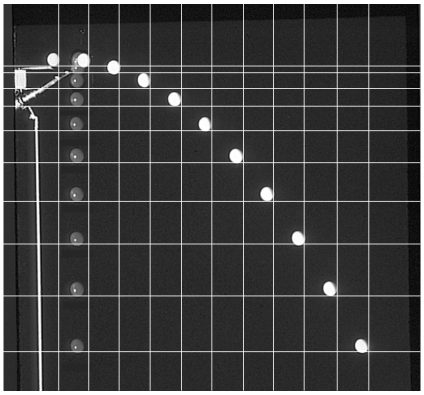

Figure 4
These two balls reached the lowest position at the same instant even though one was projected horizontally. Both balls had an initial vertical velocity of zero, and both experienced free fall.

Projectile motion is best understood when the horizontal and vertical components of an object's motion are considered independently. A projectile follows a parabolic trajectory to the ground. Once the projectile is in motion, only the force of gravity acts on the object (assuming no other forces are acting). Thus, the force of gravity is the net force and acts vertically downward. According to Newton's second law of motion, the object's acceleration is also vertically downward and equals 9.8 m/s^2. The vertical motion of a projectile consists of a uniform downward acceleration in the vertical plane and uniform motion (constant velocity) in the horizontal plane. Since no forces act horizontally, there is no horizontal acceleration.

Figure 4 on page 42 of the textbook shows two balls as they fall to the ground. The ball on the left falls vertically downward, while the ball on the right is projected and has some horizontal motion. A grid has been superimposed on the stroboscopic photograph. Note that the ball on the right stays in the same position relative to the vertical lines of equal time intervals. This indicates that the horizontal component of the ball's motion is uniform. Both balls remain adjacent to the horizontal lines, which become progressively farther apart as the balls fall. This indicates that both balls are experiencing the same vertical acceleration due to gravity. The grid lines are constructed once the balls' positions are identified in each successive image. The time interval between images is constant in this stroboscopic photograph.

Question

Look at the reproduction of **Figure 4** and determine (a) the flash rate of the stroboscope and (b) the projection speed of the ball on the right. Assume that the acceleration of gravity is 9.8 m/s^2, and the diameter of the ball is 2.0 cm.

Projectile Motion Problems, Solution

Question

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Solution

(a) To determine the flash rate of the stroboscope, consider the vertical motion of the ball on the left. Its position at time zero is at the top of the flight, just as the ball begins to descend. The last image in the figure occurs nine images later, a distance of 0.50 m as measured directly from the photograph and scaling the image using the ball's diameter of 2.0 cm. The time interval from the first image to the last image is, therefore, nine times the period of the flash of the stroboscope. Using the initial speed of zero ($v_i = 0$ m/s), an acceleration of 9.8 m/s^2 ($a = 9.8$ m/s^2), and a distance of 0.50 m ($\Delta d = 0.50$ m), the time interval for the entire flight is determined using the expression:

$$\Delta d = v_i \Delta t + \frac{a(\Delta t)^2}{2}$$

$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

$$= \sqrt{\frac{2(0.50 \text{ m})}{9.8 \text{ m/s}^2}}$$

$$\Delta t = 0.32 \text{ s}$$

Since the total time for the ball to fall is 0.32 s, the time interval between images is the period of the stroboscope:

$$T = \frac{0.32 \text{ s}}{9}$$

$$T = 3.5 \times 10^{-2} \text{ s}$$

From the period, the frequency can be determined:

$$f = \frac{1}{T}$$

$$= \frac{1}{3.5 \times 10^{-2} \text{ s}}$$

$$f = 28 \text{ Hz}$$

Thus, the frequency of the stroboscope is 28 Hz.

(continued)

(b) To determine the projection speed of the ball on the right, consider its horizontal motion. Using the diameter of the ball (2.0 cm) and scaling accordingly, the horizontal distance travelled by the ball across the nine images is 54 cm.

The horizontal component of the ball's speed is constant, and is determined as follows:

$$v = \frac{\Delta d}{\Delta t}$$
$$= \frac{0.54 \text{ m}}{0.32 \text{ s}}$$
$$v = 1.7 \text{ m/s}$$

Thus, the projection speed of the ball on the right is 1.7 m/s.

