Problem F

FALLING OBJECT

PROBLEM

The famous Gateway to the West Arch in St. Louis, Missouri, is about 192 m tall at its highest point. Suppose Sally, a stuntwoman, jumps off the top of the arch. If it takes Sally 6.4 s to land on the safety pad at the base of the arch, what is her average acceleration? What is her final velocity?

SOLUTION

1. **DEFINE**

Given: $v_i = 0$ m/s

$\Delta y = -192$ m

$\Delta t = 6.4$ s

Unknown: $a = ?$

$v_f = ?$

2. **PLAN** **Choose an equation(s) or situation:** Both the acceleration and the final speed are unknown. Therefore, first solve for the acceleration during the fall using the equation that requires only the known variables.

$$\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

Then the equation for v_f that involves acceleration can be used to solve for v_f.

$$v_f = v_i + a\Delta t$$

Rearrange the equation(s) to isolate the unknown(s):

$$a = \frac{2(\Delta y - v_i \Delta t)}{\Delta t^2}$$

$$v_f = v_i + a\Delta t$$

3. **CALCULATE** **Substitute the values into the equation(s) and solve:**

$$a = \frac{(2)\left[(-192 \text{ m}) - \left(0 \frac{\text{m}}{\text{s}}\right)(6.4 \text{ s})\right]}{(6.4 \text{ s})^2} = -9.4 \frac{\text{m}}{\text{s}^2}$$

$$v_f = 0 \frac{\text{m}}{\text{s}} + \left(-9.4 \frac{\text{m}}{\text{s}^2}\right)(6.4 \text{ s}) = -6.0 \times 10^1 \frac{\text{m}}{\text{s}}$$

4. **EVALUATE** Sally's downward acceleration is less than the free-fall acceleration at Earth's surface (9.81 m/s^2). This indicates that air resistance reduces her downward acceleration by 0.4 m/s^2. Sally's final speed, 60 m/s, is such that, if she could fall at this speed at the beginning of her jump with no acceleration, she would travel a distance equal to the arch's height in just a little more than 3 s.

ADDITIONAL PRACTICE

1. **The John Hancock Center in Chicago is the tallest building in the United States in which there are residential apartments. The Hancock Center is 343 m tall. Suppose a resident accidentally causes a chunk of ice to fall from the roof. What would be the velocity of the ice as it hits the ground? Neglect air resistance.**
2. Brian Berg of Iowa built a house of cards 4.88 m tall. Suppose Berg throws a ball from ground level with a velocity of 9.98 m/s straight up. What is the velocity of the ball as it first passes the top of the card house?
3. **The Sears Tower in Chicago is 443 m tall. Suppose a book is dropped from the top of the building. What would be the book's velocity at a point 221 m above the ground? Neglect air resistance.**
4. **The tallest roller coaster in the world is the Desperado in Nevada. It has a lift height of 64 m. If an archer shoots an arrow straight up in the air and the arrow passes the top of the roller coaster 3.0 s after the arrow is shot, what is the initial speed of the arrow?**
5. **The tallest *Sequoia sempervirens* tree in California's Redwood National Park is 111 m tall. Suppose an object is thrown downward from the top of that tree with a certain initial velocity. If the object reaches the ground in 3.80 s, what is the object's initial velocity?**
6. **The Westin Stamford Hotel in Detroit is 228 m tall. If a worker on the roof drops a sandwich, how long does it take the sandwich to hit the ground, assuming there is no air resistance? How would air resistance affect the answer?**
7. **A man named Bungkas climbed a palm tree in 1970 and built himself a nest there. In 1994 he was still up there, and he had not left the tree for 24 years. Suppose Bungkas asks a villager for a newspaper, which is thrown to him straight up with an initial speed of 12.0 m/s. When Bungkas catches the newspaper from his nest, the newspaper's velocity is 3.0 m/s, directed upward. From this information, find the height at which the nest was built. Assume that the newspaper is thrown from a height of 1.50 m above the ground.**
8. Rob Colley set a record in "pole-sitting" when he spent 42 days in a barrel at the top of a flagpole with a height of 43 m. Suppose a friend wanting to deliver an ice-cream sandwich to Colley throws the ice cream straight up with just enough speed to reach the barrel. How long does it take the ice-cream sandwich to reach the barrel?
9. **A common flea is recorded to have jumped as high as 21 cm. Assuming that the jump is entirely in the vertical direction and that air resistance is insignificant, calculate the time it takes the flea to reach a height of 7.0 cm.**

Harder, so THINK!