Holt Physics

Problem 2A

AVERAGE VELOCITY AND DISPLACEMENT

PROBLEM

The fastest fish, the sailfish, can swim 1.2×10^2 km/h. Suppose you have a friend who lives on an island 16 km away from the shore. If you send a message using a sailfish as a messenger, how long will it take for the message to reach your friend?

SOLUTION

Given: $v_{avg} = 1.2 \times 10^2$ km/h

$\Delta x = 16$ km

Unknown: $\Delta t = ?$

Use the definition of average speed to find Δt.

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Rearrange the equation to calculate Δt.

$$\Delta t = \frac{\Delta x}{v_{avg}}$$

$$\Delta t = \frac{16 \text{ km}}{\left(1.2 \times 10^2 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)} = \frac{16 \text{ km}}{2.0 \text{ km/min}}$$

$$= \boxed{8.0 \text{ min}}$$

ADDITIONAL PRACTICE

1. The Sears Tower in Chicago is 443 m tall. Joe wants to set the world's stair climbing record and runs all the way to the roof of the tower. If Joe's average upward speed is 0.60 m/s, how long will it take Joe to climb from street level to the roof of the Sears Tower?
2. An ostrich can run at speeds of up to 72 km/h. How long will it take an ostrich to run 1.5 km at this top speed?
3. A cheetah is known to be the fastest mammal on Earth, at least for short runs. Cheetahs have been observed running a distance of 5.50×10^2 m with an average speed of 1.00×10^2 km/h.
   - **a.** How long would it take a cheetah to cover this distance at this speed?
   - **b.** Suppose the average speed of the cheetah were just 85.0 km/h. What distance would the cheetah cover during the same time interval calculated in (a)?

4. A pronghorn antelope has been observed to run with a top speed of 97 km/h. Suppose an antelope runs 1.5 km with an average speed of 85 km/h, and then runs 0.80 km with an average speed of 67 km/h.

a. How long will it take the antelope to run the entire 2.3 km?
b. What is the antelope's average speed during this time?

5. Jupiter, the largest planet in the solar system, has an equatorial radius of about 7.1×10^4 km (more than 10 times that of Earth). Its period of rotation, however, is only 9 h, 50 min. That means that every point on Jupiter's equator "goes around the planet" in that interval of time. Calculate the average speed (in m/s) of an equatorial point during one period of Jupiter's rotation. Is the average velocity different from the average speed in this case?

6. The peregrine falcon is the fastest of flying birds (and, as a matter of fact, is the fastest living creature). A falcon can fly 1.73 km downward in 25 s. What is the average velocity of a peregrine falcon?

7. The black mamba is one of the world's most poisonous snakes, and with a maximum speed of 18.0 km/h, it is also the fastest. Suppose a mamba waiting in a hide-out sees prey and begins slithering toward it with a velocity of +18.0 km/h. After 2.50 s, the mamba realizes that its prey can move faster than it can. The snake then turns around and slowly returns to its hide-out in 12.0 s. Calculate

a. the mamba's average velocity during its return to the hideout.
b. the mamba's average velocity for the complete trip.
c. the mamba's average speed for the complete trip.

8. In the Netherlands, there is an annual ice-skating race called the "Tour of the Eleven Towns." The total distance of the course is 2.00×10^2 km, and the record time for covering it is 5 h, 40 min, 37 s.

a. Calculate the average speed of the record race.
b. If the first half of the distance is covered by a skater moving with a speed of $1.05v$, where v is the average speed found in (a), how long will it take to skate the first half? Express your answer in hours and minutes.

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Holt Physics

Problem 2B

AVERAGE ACCELERATION

PROBLEM

In 1977 off the coast of Australia, the fastest speed by a vessel on the water was achieved. If this vessel were to undergo an average acceleration of 1.80 m/s^2, it would go from rest to its top speed in 85.6 s. What was the speed of the vessel?

SOLUTION

Given: $a_{avg} = 1.80 \text{ m/s}^2$

$\Delta t = 85.6 \text{ s}$

$v_i = 0 \text{ m/s}$

Unknown: $v_f = ?$

Use the definition of average acceleration to find v_f.

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t}$$

Rearrange the equation to calculate v_f.

$$v_f = a_{avg}\Delta t + v_i$$

$$v_f = \left(1.80 \frac{\text{m}}{\text{s}^2}\right)\left(85.6 \text{ s}\right) + 0 \frac{\text{m}}{\text{s}}$$

$$= 154 \frac{\text{m}}{\text{s}}$$

$$= \left(154 \frac{\text{m}}{\text{s}}\right)\left(\frac{3.60 \times 10^3 \text{ s}}{1\text{h}}\right)\left(\frac{1 \text{ km}}{10^3 \text{m}}\right)$$

$$= \boxed{554 \frac{\text{km}}{\text{h}}}$$

ADDITIONAL PRACTICE

1. If the vessel in the sample problem accelerates for 1.00 min, what will its speed be after that minute? Calculate the answer in both meters per second and kilometers per hour.

2. In 1935, a French destroyer, *La Terrible,* attained one of the fastest speeds for any standard warship. Suppose it took 2.0 min at a constant acceleration of 0.19 m/s^2 for the ship to reach its top speed after starting from rest. Calculate the ship's final speed.

3. In 1934, the wind speed on Mt. Washington in New Hampshire reached a record high. Suppose a very sturdy glider is launched in this wind, so that in 45.0 s the glider reaches the speed of the wind. If the glider undergoes a constant acceleration of 2.29 m/s^2, what is the wind's speed? Assume that the glider is initially at rest.

4. In 1992, Maurizio Damilano, of Italy, walked 29 752 m in 2.00 h.

a. Calculate Damilano's average speed in m/s.

b. Suppose Damilano slows down to 3.00 m/s at the midpoint in his journey, but then picks up the pace and accelerates to the speed calculated in (a). It takes Damilano 30.0 s to accelerate. Find the magnitude of the average acceleration during this time interval.

5. South African frogs are capable of jumping as far as 10.0 m in one hop. Suppose one of these frogs makes exactly 15 of these jumps in a time interval of 60.0 s.

a. What is the frog's average velocity?

b. If the frog lands with a velocity equal to its average velocity and comes to a full stop 0.25 s later, what is the frog's average acceleration?

6. In 1991 at Smith College, in Massachusetts, Ferdie Adoboe ran 1.00×10^2 m backward in 13.6 s. Suppose it takes Adoboe 2.00 s to achieve a velocity equal to her average velocity during the run. Find her average acceleration during the first 2.00 s.

7. In the 1992 Summer Olympics, the German four-man kayak team covered 1 km in just under 3 minutes. Suppose that between the starting point and the 150 m mark the kayak steadily increases its speed from 0.0 m/s to 6.0 m/s, so that its average speed is 3.0 m/s.

a. How long does it take to cover the 150 m?

b. What is the magnitude of the average acceleration during that part of the course?

8. The highest speed ever achieved on a bicycle was reached by John Howard of the United States. The bicycle, which was accelerated by being towed by a vehicle, reached a velocity of +245 km/h. Suppose Howard wants to slow down, and applies the brakes on his now freely moving bicycle. If the average acceleration of the bicycle during braking is –3.0 m/s^2, how long will it take for the bicycle's velocity to decrease by 20.0 percent?

9. In 1993, bicyclist Rebecca Twigg of the United States traveled 3.00 km in 217.347 s. Suppose Twigg travels the entire distance at her average speed and that she then accelerates at –1.72 m/s^2 to come to a complete stop after crossing the finish line. How long does it take Twigg to come to a stop?

10. During the Winter Olympic games at Lillehammer, Norway, in 1994, Dan Jansen of the United States skated 5.00×10^2 m in 35.76 s. Suppose it takes Jansen 4.00 s to increase his velocity from zero to his maximum velocity, which is 10.0 percent greater than his average velocity during the whole run. Calculate Jansen's average acceleration during the first 4.00 s.

Holt Physics

Problem 2C

DISPLACEMENT WITH CONSTANT ACCELERATION

PROBLEM

In England, two men built a tiny motorcycle with a wheel base (the distance between the centers of the two wheels) of just 108 mm and a wheel's measuring 19 mm in diameter. The motorcycle was ridden over a distance of 1.00 m. Suppose the motorcycle has constant acceleration as it travels this distance, so that its final speed is 0.800 m/s. How long does it take the motorcycle to travel the distance of 1.00 m? Assume the motorcycle is initially at rest.

SOLUTION

Given: $v_f = 0.800 \text{ m/s}$

$v_i = 0 \text{ m/s}$

$\Delta x = 1.00 \text{ m}$

Unknown: $\Delta t = ?$

Use the equation for displacement with constant acceleration.

$$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$$

Rearrange the equation to calculate Δt.

$$\Delta t = \frac{2\Delta x}{v_f + v_i}$$

$$\Delta t = \frac{(2)(1.00 \text{ m})}{0.800 \frac{\text{m}}{\text{s}} + 0 \frac{\text{m}}{\text{s}}} = \frac{2.00}{0.800} \text{ s}$$

$$= \boxed{2.50 \text{ s}}$$

ADDITIONAL PRACTICE

1. In 1993, Ileana Salvador of Italy walked 3.0 km in under 12.0 min. Suppose that during 115 m of her walk Salvador is observed to steadily increase her speed from 4.20 m/s to 5.00 m/s. How long does this increase in speed take?

2. In a scientific test conducted in Arizona, a special cannon called HARP (High Altitude Research Project) shot a projectile straight up to an altitude of 180.0 km. If the projectile's initial speed was 3.00 km/s, how long did it take the projectile to reach its maximum height?

3. The fastest speeds traveled on land have been achieved by rocket-powered cars. The current speed record for one of these vehicles is about 1090 km/h, which is only 160 km/h less than the speed of sound in air. Suppose a car that is capable of reaching a speed of

1.09×10^3 km/h is tested on a flat, hard surface that is 25.0 km long. The car starts at rest and just reaches a speed of 1.09×10^3 km/h when it passes the 20.0 km mark.

a. If the car's acceleration is constant, how long does it take to make the 20.0 km drive?

b. How long will it take the car to decelerate if it goes from its maximum speed to rest during the remaining 5.00 km stretch?

4. In 1990, Dave Campos of the United States rode a special motorcycle called the *Easyrider* at an average speed of 518 km/h. Suppose that at some point Campos steadily decreases his speed from 100.0 percent to 60.0 percent of his average speed during an interval of 2.00 min. What is the distance traveled during that time interval?

5. A German stuntman named Martin Blume performed a stunt called "the wall of death." To perform it, Blume rode his motorcycle for seven straight hours on the wall of a large vertical cylinder. His average speed was 45.0 km/h. Suppose that in a time interval of 30.0 s Blume increases his speed steadily from 30.0 km/h to 42.0 km/h while circling inside the cylindrical wall. How far does Blume travel in that time interval?

6. An automobile that set the world record for acceleration increased speed from rest to 96 km/h in 3.07 s. How far had the car traveled by the time the final speed was achieved?

7. In a car accident involving a sports car, skid marks as long as 290.0 m were left by the car as it decelerated to a complete stop. The police report cited the speed of the car before braking as being "in excess of 100 mph" (161 km/h). Suppose that it took 10.0 seconds for the car to stop. Estimate the speed of the car before the brakes were applied. (REMINDER: Answer should read, "speed in excess of . . .")

8. Col. Joe Kittinger of the United States Air Force crossed the Atlantic Ocean in nearly 86 hours. The distance he traveled was 5.7×10^3 km. Suppose Col. Kittinger is moving with a constant acceleration during most of his flight and that his final speed is 10.0 percent greater than his initial speed. Find the initial speed based on this data.

9. The polar bear is an excellent swimmer, and it spends a large part of its time in the water. Suppose a polar bear wants to swim from an ice floe to a particular point on shore where it knows that seals gather. The bear dives into the water and begins swimming with a speed of 2.60 m/s. By the time the bear arrives at the shore, its speed has decreased to 2.20 m/s. If the polar bear's swim takes exactly 9.00 min and it has a constant deceleration, what is the distance traveled by the polar bear?

Holt Physics

Problem 2D

VELOCITY AND DISPLACEMENT WITH CONSTANT ACCELERATION

PROBLEM

Some cockroaches can run as fast as 1.5 m/s. Suppose that two cockroaches are separated by a distance of 60.0 cm and that they begin to run toward each other at the same moment. Both insects have constant acceleration until they meet. The first cockroach has an acceleration of 0.20 m/s^2 in one direction, and the second one has an acceleration of 0.12 m/s^2 in the opposite direction. How much time passes before the two insects bump into each other?

SOLUTION

1. DEFINE

Given: $a_1 = 0.20$ m/s^2 (first cockroach's acceleration)
$v_{i,1} = 0$ m/s (first cockroach's initial speed)
$a_2 = 0.12$ m/s^2 (second cockroach's acceleration)
$v_{i,2} = 0$ m/s (second cockroach's initial speed)
$d = 60.0$ cm $= 0.60$ m (initial distance between the insects)

Unknown: $\Delta x_1 = ?$ $\Delta x_2 = ?$ $\Delta t = ?$

2. PLAN

Choose an equation(s) or situation: Use the equation for displacement with constant acceleration for each cockroach.

$$\Delta x_1 = v_{i,1}\Delta t + \frac{1}{2}a_1\Delta t^2$$

$$\Delta x_2 = v_{i,2}\Delta t + \frac{1}{2}a_2\Delta t^2$$

The distance the second cockroach travels can be expressed as the difference between the total distance that initially separates the two insects and the distance that the first insect travels.

$$\Delta x_2 = d - \Delta x_1$$

Rearrange the equation(s) to isolate the unknown(s): Substitute the expression for the first cockroach's displacement into the equation for the second cockroach's displacement using the equation relating the two displacements to the initial distance between the insects.

$$\Delta x_2 = d - \Delta x_1 = d - \left(v_{i,1}\Delta t + \frac{1}{2}a_1\Delta t^2\right)$$

$$= v_{i,2}\Delta t + \frac{1}{2}a_2\Delta t^2$$

The equation can be rewritten to express Δt in terms of the known quantities. To simplify the calculation, the terms involving the initial speeds, which are both zero, can be removed from the equations.

$$d - \frac{1}{2}a_1\Delta t^2 = \frac{1}{2}a_2\Delta t^2$$

$$\Delta t = \sqrt{\frac{2d}{a_1 + a_2}}$$

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

$$\Delta t = \sqrt{\frac{(2)(0.60 \text{ m})}{0.20 \frac{\text{m}}{\text{s}^2} + 0.12 \frac{\text{m}}{\text{s}^2}}} = \sqrt{\frac{1.2 \text{ m}}{0.32 \text{ m/s}^2}} = \boxed{1.9 \text{ s}}$$

4. EVALUATE The final speeds for the first and second cockroaches are 0.38 m/s and 0.23 m/s, respectively. Both of these values are well below the maximum speed for cockroaches in general.

ADDITIONAL PRACTICE

1. In 1986, the first flight around the globe without a single refueling was completed. The aircraft's average speed was 186 km/h. If the airplane landed at this speed and accelerated at -1.5 m/s^2, how long did it take for the airplane to stop?

2. In 1976, Gerald Hoagland drove a car over 8.0×10^2 km in reverse. Fortunately for Hoagland and motorists in general, the event took place on a special track. During this drive, Hoagland's average velocity was about -15.0 m/s. Suppose Hoagland decides during his drive to go forward. He applies the brakes, stops, and then accelerates until he moves forward at same speed he had when he was moving backward. How long would the entire reversal process take if the average acceleration during this process is $+2.5$ m/s^2?

3. The first permanent public railway was built by George Stephenson and opened in Cleveland, Ohio, in 1825. The average speed of the trains was 24.0 km/h. Suppose a train moving at this speed accelerates -0.20 m/s^2 until it reaches a speed of 8.0 km/h. How long does it take the train to undergo this change in speed?

4. The winding cages in mine shafts are used to move workers in and out of the mines. These cages move much faster than any commercial elevators. In one South African mine, speeds of up to 65.0 km/h are attained. The mine has a depth of 2072 m. Suppose two cages start their downward journey at the same moment. The first cage quickly attains the maximum speed (an unrealistic situation), then proceeds to descend uniformly at that speed all the way to the bottom. The second cage starts at rest and then increases its speed with a constant acceleration of magnitude 4.00×10^{-2} m/s^2. How long will the trip take for each cage? Which cage will reach the bottom of the mine shaft first?

5. In a 1986 bicycle race, Fred Markham rode his bicycle a distance of 2.00×10^2 m with an average speed of 105.4 km/h. Markham and the bicycle started the race with a certain initial speed.
   a. Find the time it took Markham to cover 2.00×10^2 m.
   b. Suppose a car moves from rest under constant acceleration. What is the magnitude of the car's acceleration if the car is to finish the race at exactly the same time Markham finishes the race?

6. Some tropical butterflies can reach speeds of up to 11 m/s. Suppose a butterfly flies at a speed of 6.0 m/s while another flying insect some distance ahead flies in the same direction with a constant speed. The butterfly then increases its speed at a constant rate of 1.4 m/s^2 and catches up to the other insect 3.0 s later. How far does the butterfly travel during the race?

7. Mary Rife, of Texas, set a women's world speed record for sailing. In 1977, her vessel, *Proud Mary*, reached a speed of 3.17×10^2 km/h. Suppose it takes 8.0 s for the boat to decelerate from 3.17×10^2 km/h to 2.00×10^2 km/h. What is the boat's acceleration? What is the displacement of the *Proud Mary* as it slows down?

8. In 1994, a human-powered submarine was designed in Boca Raton, Florida. It achieved a maximum speed of 3.06 m/s. Suppose this submarine starts from rest and accelerates at 0.800 m/s^2 until it reaches maximum speed. The submarine then travels at constant speed for another 5.00 s. Calculate the total distance traveled by the submarine.

9. The highest speed achieved by a standard nonracing sports car is 3.50×10^2 km/h. Assuming that the car accelerates at 4.00 m/s^2, how long would this car take to reach its maximum speed if it is initially at rest? What distance would the car travel during this time?

10. Stretching 9345 km from Moscow to Vladivostok, the Trans-Siberian railway is the longest single railroad in the world. Suppose the train is approaching the Moscow station at a velocity of +24.7 m/s when it begins a constant acceleration of –0.850 m/s^2. This acceleration continues for 28 s. What will be the train's final velocity when it reaches the station?

11. The world's fastest warship belongs to the United States Navy. This vessel, which floats on a cushion of air, can move as fast as 1.7×10^2 km/h. Suppose that during a training exercise the ship accelerates +2.67 m/s^2, so that after 15.0 s its displacement is $+6.00 \times 10^2$ m. Calculate the ship's initial velocity just before the acceleration. Assume that the ship moves in a straight line.

12. The first supersonic flight was performed by then Capt. Charles Yeager in 1947. He flew at a speed of 3.00×10^2 m/s at an altitude of more than 12 km, where the speed of sound in air is slightly less than 3.00×10^2 m/s. Suppose Capt. Yeager accelerated 7.20 m/s^2 in 25.0 s to reach a final speed of 3.00×10^2 m/s. What was his initial speed?

13. Peter Rosendahl rode his unicycle a distance of 1.00×10^2 m in 12.11 s. If Rosendahl started at rest, what was the magnitude of his acceleration?

14. Suppose that Peter Rosendahl began riding the unicycle with a speed of 3.00 m/s and traveled a distance of 1.00×10^2 m in 12.11s. What would the magnitude of Rosendahl's acceleration be in this case?

15. In 1991, four English teenagers built an electric car that could attain a speed 30.0 m/s. Suppose it takes 8.0 s for this car to accelerate from 18.0 m/s to 30.0 m/s. What is the magnitude of the car's acceleration?

Holt Physics

Problem 2E

FINAL VELOCITY AFTER ANY DISPLACEMENT

PROBLEM

In 1970, a rocket-powered car called *Blue Flame* achieved a maximum speed of 1.00 (10^3 km/h (278 m/s). Suppose the magnitude of the car's constant acceleration is 5.56 m/s^2. If the car is initially at rest, what is the distance traveled during its acceleration?

SOLUTION

1. DEFINE

Given: $v_i = 0$ m/s

$v_f = 278$ m/s

$a = 5.56$ m/s^2

Unknown: $\Delta x = ?$

2. PLAN

Choose an equation(s) or situation: Use the equation for the final velocity after any displacement.

$$v_f^2 = v_i^2 + 2a\Delta x$$

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

$$\Delta x = \frac{v_f^2 - v_i^2}{2a}$$

3. CALCULATE

Substitute the values into the equation(s) and solve:

$$\Delta x = \frac{\left(278\,\frac{\text{m}}{\text{s}}\right)^2 - \left(0\,\frac{\text{m}}{\text{s}}\right)^2}{(2)\left(5.56\,\frac{\text{m}}{\text{s}^2}\right)} = \boxed{6.95 \times 10^3\ \text{m}}$$

4. EVALUATE

Using the appropriate kinematic equation, the time of travel for *Blue Flame* is found to be 50.0 s. From this value for time the distance traveled during the acceleration is confirmed to be almost 7 km. Once the car reaches its maximum speed, it travels about 16.7 km/min.

ADDITIONAL PRACTICE

1. In 1976, Kitty Hambleton of the United States drove a rocket-engine car to a maximum speed of 965 km/h. Suppose Kitty started at rest and underwent a constant acceleration with a magnitude of 4.0 m/s^2. What distance would she have had to travel in order to reach the maximum speed?

2. With a cruising speed of 2.30×10^3 km/h, the French supersonic passenger jet Concorde is the fastest commercial airplane. Suppose the landing speed of the Concorde is 20.0 percent of the cruising speed. If the plane accelerates at –5.80 m/s^2, how far does it travel between the time it lands and the time it comes to a complete stop?

3. The Boeing 747 can carry more than 560 passengers and has a maximum speed of about 9.70×10^2 km/h. After takeoff, the plane takes a certain time to reach its maximum speed. Suppose the plane has a constant acceleration with a magnitude of 4.8 m/s^2. What distance does the plane travel between the moment its speed is 50.0 percent of maximum and the moment its maximum speed is attained?

4. The distance record for someone riding a motorcycle on its rear wheel without stopping is more than 320 km. Suppose the rider in this unusual situation travels with an initial speed of 8.0 m/s before speeding up. The rider then travels 40.0 m at a constant acceleration of 2.00 m/s^2. What is the rider's speed after the acceleration?

5. The skid marks left by the decelerating jet-powered car *The Spirit of America* were 9.60 km long. If the car's acceleration was –2.00 m/s^2, what was the car's initial velocity?

6. The heaviest edible mushroom ever found (the so-called "chicken of the woods") had a mass of 45.4 kg. Suppose such a mushroom is attached to a rope and pulled horizontally along a smooth stretch of ground, so that it undergoes a constant acceleration of +0.35 m/s^2. If the mushroom is initially at rest, what will its velocity be after it has been displaced +64 m?

7. Bengt Norberg of Sweden drove his car 44.8 km in 60.0 min. The feature of this drive that is interesting is that he drove the car on two side wheels.

a. Calculate the car's average speed.

b. Suppose Norberg is moving forward at the speed calculated in (a). He then accelerates at a rate of –2.00 m/s^2. After traveling 20.0 m, the car falls on all four wheels. What is the car's final speed while still traveling on two wheels?

8. Starting at a certain speed, a bicyclist travels 2.00×10^2 m. Suppose the bicyclist undergoes a constant acceleration of 1.20 m/s^2. If the final speed is 25.0 m/s, what was the bicyclist's initial speed?

9. In 1994, Tony Lang of the United States rode his motorcycle a short distance of 4.0×10^2 m in the short interval of 11.5 s. He started from rest and crossed the finish line with a speed of about 2.50×10^2 km/h. Find the magnitude of Lang's acceleration as he traveled the 4.0×10^2 m distance.

10. The lightest car in the world was built in London and had a mass of less than 10 kg. Its maximum speed was 25.0 km/h. Suppose the driver of this vehicle applies the brakes while the car is moving at its maximum speed. The car stops after traveling 16.0 m. Calculate the car's acceleration.

Holt Physics

Problem 2F

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:

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

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

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^2, 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.

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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.