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: $v_f = 0.800$ m/s
$v_i = 0$ m/s
$\Delta x = 1.00$ m

Unknown: $\Delta t = ?$

Use the equation for displacement with constant acceleration.

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

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?

Givens *Solutions*

8. $v_i = +245$ km/h

$a_{avg} = -3.0 \text{ m/s}^2$

$v_f = v_i - (0.200)\, v_i$

$$v_i = \left(245\,\frac{\text{km}}{\text{h}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{10^3\text{ m}}{1\text{ km}}\right) = +68.1\text{ m/s}$$

$$v_f = (1.000 - 0.200)\, v_i = (0.800)(68.1\text{ m/s}) = +54.5\text{ m/s}$$

$$\Delta t = \frac{v_f - v_i}{a_{avg}} = \frac{54.5\text{ m/s} - 68.1\text{ m/s}}{-3.0\text{ m/s}^2} = \frac{-13.6\text{ m/s}}{-3.0\text{ m/s}^2} = \boxed{4.5\text{ s}}$$

9. $\Delta x = 3.00$ km

$\Delta t = 217.347$ s

$a_{avg} = -1.72 \text{ m/s}^2$

$v_f = 0$ m/s

$$v_i = v_{avg} = \frac{\Delta x}{\Delta t} = \frac{3.00 \times 10^3\text{ m}}{217.347\text{ s}} = 13.8\text{ m/s}$$

$$t_{stop} = \frac{v_f - v_i}{a_{avg}} = \frac{0\text{ m/s} - 13.8\text{ m/s}}{-1.72\text{ m/s}^2} = \frac{-13.8\text{ m/s}}{-1.72\text{ m/s}^2} = \boxed{8.02\text{ s}}$$

10. $\Delta x = +5.00 \times 10^2$ m

$\Delta t = 35.76$ s

$v_i = 0$ m/s

$\Delta t' = 4.00$ s

$v_{max} = v_{avg} + (0.100)\, v_{avg}$

$$v_f = v_{max} = (1.100)v_{avg} = (1.100)\left(\frac{\Delta x}{\Delta t}\right) = (1.100)\left(\frac{5.00 \times 10^2\text{ m}}{35.76\text{ s}}\right) = +15.4\text{ m/s}$$

$$a_{avg} = \frac{\Delta v}{\Delta t'} = \frac{v_f - v_i}{\Delta t'} = \frac{15.4\text{ m/s} - 0\text{ m/s}}{4.00\text{ s}} = \boxed{+3.85\text{ m/s}^2}$$

II

Additional Practice 2C

1. $\Delta x = 115$ m

$v_i = 4.20$ m/s

$v_f = 5.00$ m/s

$$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(115\text{ m})}{4.20\text{ m/s} + 5.00\text{ m/s}} = \frac{(2)(115\text{ m})}{9.20\text{ m/s}} = \boxed{25.0\text{ s}}$$

2. $\Delta x = 180.0$ km

$v_i = 3.00$ km/s

$v_f = 0$ km/s

$$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(180.0\text{ km})}{3.00\text{ km/s} + 0\text{ km/s}} = \frac{360.0\text{ km}}{3.00\text{ km/s}} = \boxed{1.2 \times 10^2\text{ s}}$$

3. $v_i = 0$ km/h

$v_f = 1.09 \times 10^3$ km/h

$\Delta x = 20.0$ km

a. $$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(20.0 \times 10^3\text{ m})}{(1.09 \times 10^3\text{ km/h} + 0\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)}$$

$$\Delta t = \frac{40.0 \times 10^3\text{ m}}{(1.09 \times 10^3\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)} = \boxed{132\text{ s}}$$

$\Delta x = 5.00$ km

$v_i = 1.09 \times 10^3$ km/h

$v_f = 0$ km/h

b. $$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(5.00 \times 10^3\text{ m})}{(1.09 \times 10^3\text{ km/h} + 0\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)}$$

$$\Delta t = \frac{10.0 \times 10^3\text{ m}}{(1.09 \times 10^3\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)} = \boxed{33.0\text{ s}}$$

Givens | *Solutions*

4. $v_i = v_{avg} = 518$ km/h

$v_f = (0.600)\ v_{avg}$

$\Delta t = 2.00$ min

$$v_{avg} = \left(518\ \frac{\text{km}}{\text{h}}\right)\left(\frac{1\ \text{h}}{60\ \text{min}}\right)\left(\frac{10^3\text{m}}{1\ \text{km}}\right) = 8.63 \times 10^3\ \text{m/min}$$

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}[v_{avg} + (0.600)\ v_{avg}]\Delta t = \tfrac{1}{2}(1.600)(8.63 \times 10^3\ \text{m/min})(2.00\ \text{min})$$

$$\Delta x = 13.8 \times 10^3\ \text{m} = \boxed{13.8\ \text{km}}$$

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5. $\Delta t = 30.0$ s

$v_i = 30.0$ km/h

$v_f = 42.0$ km/h

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}(30.0\ \text{km/h} + 42.0\ \text{km/h})\left(\frac{1\text{h}}{3600\ \text{s}}\right)(30.0\ \text{s})$$

$$\Delta x = \tfrac{1}{2}\left(72.0\ \frac{\text{km}}{\text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)(30.0\ \text{s})$$

$$\Delta x = 3.00 \times 10^{-1}\ \text{km} = \boxed{3.00 \times 10^2\ \text{m}}$$

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6. $v_f = 96$ km/h

$v_i = 0$ km/h

$\Delta t = 3.07$ s

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}(0\ \text{km/h} + 96\ \text{km/h})\left(\frac{1\text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)(3.07\ \text{s})$$

$$\Delta x = \tfrac{1}{2}\left(96 \times 10^3\ \frac{\text{m}}{\text{h}}\right)(8.53 + \times 10^{-4}\ \text{h}) = \boxed{41\ \text{m}}$$

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7. $\Delta x = 290.0$ m

$\Delta t = 10.0$ s

$v_f = 0$ km/h $= 0$ m/s

$$v_i = \frac{2\Delta x}{\Delta t} - v_f = \frac{(2)(290.0\ \text{m})}{10.0\ \text{s}} - 0\ \text{m/s} = \boxed{58.0\ \text{m/s} = 209\ \text{km/h}}$$

(Speed was in excess of 209 km/h.)

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8. $\Delta x = 5.7 \times 10^3$ km

$\Delta t = 86$ h

$v_f = v_i + (0.10)\ v_i$

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

$$v_i\ (1.00 + 0.10) + v_i = \frac{2\Delta x}{\Delta t}$$

$$v_i = \frac{(2)(5.7 \times 10^3\ \text{km})}{(2.10)(86\ \text{h})} = \boxed{63\ \text{km/h}}$$

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9. $v_i = 2.60$ m/s

$v_f = 2.20$ m/s

$\Delta t = 9.00$ min

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}(2.60\ \text{m/s} + 2.20\ \text{m/s})(9.00\ \text{min})\left(\frac{60\ \text{s}}{\text{min}}\right) = \tfrac{1}{2}(4.80\ \text{m/s})(5.40 \times 10^2\ \text{s})$$

$$\Delta x = 1.30 \times 10^3\ \text{m} = \boxed{1.30\ \text{km}}$$

Additional Practice 2D

1. $v_i = 186$ km/h

$v_f = 0$ km/h $= 0$ m/s

$a = -1.5\ \text{m/s}^2$

$$\Delta t = \frac{v_f - v_i}{a} = \frac{0\ \text{m/s} - (186\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)}{-1.5\ \text{m/s}^2} = \frac{-51.7\ \text{m/s}}{-1.5\ \text{m/s}^2} = \boxed{34\ \text{s}}$$

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2. $v_i = -15.0$ m/s

$v_f = 0$ m/s

$a = +2.5\ \text{m/s}^2$

$v_i = 0$ m/s

$v_f = +15.0$ m/s

$a = +2.5$ m/s

For stopping:

$$\Delta t_1 = \frac{v_f - v_i}{a} = \frac{0\ \text{m/s} - (-15.0\ \text{m/s})}{2.5\ \text{m/s}^2} = \frac{15.0\ \text{m/s}}{2.5\ \text{m/s}^2} = 6.0\ \text{s}$$

For moving forward:

$$\Delta t_2 = \frac{v_f - v_i}{a} = \frac{15.0\ \text{m/s} - 0.0\ \text{m/s}}{2.5\ \text{m/s}^2} = \frac{15.0\ \text{m/s}}{2.5\ \text{m/s}^2} = 6.0\ \text{s}$$

$$\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 6.0\ \text{s} + 6.0\ \text{s} = \boxed{12.0\ \text{s}}$$