

Momentum and Collisions

Problem C**STOPPING DISTANCE****PROBLEM**

A high-speed train with a total mass of 9.25×10^5 kg travels north at a speed of 220 km/h. Suppose it takes 16.0 s of constant acceleration for the train to come to rest at a station platform. Calculate the force acting on the train during this time. What is the train's stopping distance.

SOLUTION

Given: $m = 9.25 \times 10^5$ kg
 $v_i = 220$ km/h to the north
 $v_f = 0$ km/h
 $\Delta t = 16.0$ s

Unknown: $F = ?$ $\Delta x = ?$

Use the impulse-momentum theorem to solve for F . Use the kinematic equation for Δx in terms of initial velocity, final velocity, and time to solve for Δx .

$$F\Delta t = \Delta p$$

$$F = \frac{\Delta p}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$$

$$F = \frac{(9.25 \times 10^5 \text{ kg})(0 \text{ km/h}) - (9.25 \times 10^5 \text{ kg})(220 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})}{16.0 \text{ s}}$$

$$F = \frac{-(9.25 \times 10^5 \text{ kg})(220 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})}{16.0 \text{ s}}$$

$$F = -3.5 \times 10^6 \text{ N} = \boxed{3.5 \times 10^6 \text{ N to the south}}$$

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

$$\Delta x = \frac{1}{2}(220 \text{ km/h} + 0 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})(16.0 \text{ s})$$

$$\Delta x = \boxed{490 \text{ m to the north}}$$

ADDITIONAL PRACTICE

1. A race car has a velocity of 382 km/h to the right. If the car's mass is 705 kg and the driver's mass is 65 kg, what force is needed to bring the car and driver to a stop in 12.0 s? What is the car's stopping distance?
2. The danger that space debris poses to spacecraft can be understood in terms of momentum. At 160 km above Earth's surface, any object will have a speed of about 7.82×10^3 m/s. Consider a meteoroid (a small orbiting rock) with a mass of 42 g. Suppose this meteoroid collides with a space shuttle and is brought to a full stop in 1.0×10^{-6} s. How large is the force that stops the meteoroid? By how much would the meteoroid dent the side of the shuttle?
3. A 63 kg astronaut drifting with 7.0 m/s to the right with respect to a spacecraft uses a jet pack to slow down. If it takes 14.0 s to come to a stop with respect to the spacecraft, what is the force exerted by the jet pack? How far does the astronaut travel before stopping?
4. A polar bear with a mass of 455 kg slides for 12.2 s across the surface of a frozen lake. If the coefficient of kinetic friction between the bear and the ice is 0.071, what is the change in the bear's momentum as it comes to a stop? How far does the polar bear slide?
5. A skyrocket that has consumed all of its fuel continues to move upward, slowed mostly by the force of gravity. If the rocket's mass is 75.0 g and it takes 1.2 s for the rocket to stop, what is the change in the rocket's momentum? What is the rocket's stopping distance?
6. A 4400 kg sailboat drifts in calm waters. The force of resistance that the water exerts on the ship is 2200 N to the left. What is the change in the ship's momentum after 8.0 s? If the ship's initial speed is 6.5 m/s, how far has the ship drifted?
7. A jet of water exerts a 25.0 N force on a type of sail that is attached to a small wagon. What is the magnitude of the change in the wagon's momentum after 7.00 s? If the wagon's mass is 14.0 kg and there are no other forces acting on it, how far will the wagon travel during the 7.00 s? Assume the wagon is initially at rest.
8. How long will it take a 2.30×10^3 kg truck to go from 22.2 m/s to a complete stop if acted on by a force of -1.26×10^4 N? What would be its stopping distance?

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9. Consider a Hornet jet landing on the flight deck of an aircraft carrier. The jet's mass is 1.35×10^4 kg and its initial velocity is 66.1 m/s to the west. If the force required to bring the jet to a stop is 4.00×10^5 N to the east, how long does it take the jet to come to rest? How far does the jet travel during its deceleration?
10. The surface of Jupiter's moon Europa is covered with ice. Suppose an ice boat moving with a speed of 14.5 m/s drifts to a stop. The boat's mass is 1.50×10^3 kg and the coefficient of kinetic friction between the boat's runners and the ice is 0.065. However, free-fall acceleration on Europa is only 1.305 m/s^2 . How long will it take the boat to stop? How far does the ice boat glide before stopping?