Momentum and Collisions

Problem C

STOPPING DISTANCE

PROBLEM

The largest nuts (and, presumably, the largest bolts) are manufactured in England. The nuts have a mass of 4.74×10^3 kg each, which is greater than any passenger car currently in production. Suppose one of these nuts slides along a rough horizontal surface with an initial velocity of 2.40 m/s to the right. If the force of friction acting on the nut is 6.8×10^3 N to the left, what is the change in the nut's momentum after 1.1 s? How far does the nut travel during its change in momentum?

SOLUTION

Given: $m = 4.74 \times 10^3$ kg

$\mathbf{v_i}$ = 2.40 m/s to the right = +2.40 m/s

$\mathbf{F} = 6.8 \times 10^3$ N to the left = -6.8×10^3 N

Δt = 1.1 s

Unknown: $\Delta\mathbf{p}$ = ? $\Delta\mathbf{x}$ = ?

Use the impulse-momentum theorem to calculate the change in momentum. Use the definition of momentum to find $\mathbf{v_f}$, and then use the equation for stopping distance to solve for $\Delta\mathbf{x}$.

$$\Delta\mathbf{p} = \mathbf{F}\Delta\mathbf{t} = (-6.8\times10^3\ \text{N})(1.1\ \text{s})$$

$$\Delta\mathbf{p} = -7.5\times10^3\ \text{kg}\bullet\text{m/s to the right, or } 7.5\times10^3\ \text{kg}\bullet\text{m/s to the left}$$

$$\Delta\mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i}$$

$$\mathbf{v_f} = \frac{\Delta\mathbf{p} + m\mathbf{v_i}}{m}$$

$$\mathbf{v_f} = \frac{-7.5\times10^3\ \text{kg}\bullet\text{m/s} + (4.74\times10^3\ \text{kg})(2.40\ \text{m/s})}{4.74\times10^3\ \text{kg}}$$

$$\mathbf{v_f} = \frac{-7.5\times10^3\ \text{kg}\bullet\text{m/s} + 1.14\times10^4\ \text{kg}\bullet\text{m/s}}{4.74\times10^3\ \text{kg}} = \frac{3900\ \text{kg}\bullet\text{m/s}}{4.74\times10^3\ \text{kg}}$$

$$\mathbf{v_f} = 0.82\ \text{m/s to the right}$$

$$\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \frac{1}{2}(2.40\ \text{m/s} + 0.82\ \text{m/s})(1.1\ \text{s}) = \frac{1}{2}(3.22\ \text{m/s})(1.1\ \text{s})$$

$$\Delta\mathbf{x} = 1.8\ \text{m/s to the right}$$

ADDITIONAL PRACTICE

1. **The most powerful tugboats in the world are built in Finland. These boats exert a force with a magnitude of 2.85×10^6 N. Suppose one of these tugboats is trying to slow a huge barge that has a mass of 2.0×10^7 kg and is moving with a speed of 3.0 m/s. If the tugboat exerts its maximum force for 21 s in the direction opposite to that in which the barge is moving,**

what will be the change in the barge's momentum? How far will the barge travel before it is brought to a stop? (Old Equation)

2. **In 1920, a 6.5×10^4 kg meteorite was found in Africa. Suppose a meteorite with this mass enters Earth's atmosphere with a speed of 1.0 km/s. What is the change in the meteorite's momentum if an average constant force of -1.7×10^6 N acts on the meteorite for 30.0 s? How far does the meteorite travel during this time?** (Find v_f, then Δx)
3. **The longest canoe in the world was constructed in New Zealand. The combined mass of the canoe and its crew of more than 70 people was 2.03×10^4 kg. Suppose the canoe is rowed from rest to a velocity of 5.00 m/s to the east, at which point the crew takes a break for 20.3 s. If a constant average retarding force of 1.20×10^3 N to the west acts on the canoe, what is the change in the momentum of the canoe and crew? How far does the canoe travel during the time the crew is not rowing?**
4. **The record for the smallest dog in the world belongs to a terrier who had a mass of only 113 g. Suppose this dog runs to the right with a speed of 2.00 m/s when it suddenly sees a mouse. The dog becomes scared and uses its paws to bring itself to rest in 0.80 s. What is the force required to stop the dog? What is the dog's stopping distance?**
5. In 1992, an ice palace estimated to be 4.90×10^6 kg was built in Minnesota. Despite this sizable mass, this structure could be moved at a constant velocity because of the small force of friction between the ice blocks of its base and the ice of the lake upon which it was constructed. Imagine moving the entire palace with a speed of 0.200 m/s on this very smooth, icy surface. Once the palace is no longer being pushed, it coasts to a stop in 10.0 s. What is the average force of kinetic friction acting on the palace? What is the palace's stopping distance?
6. *Steel Phantom* is a roller coaster in Pennsylvania that, like the *Desperado* in Nevada, has a vertical drop of 68.6 m. Suppose a roller-coaster car with a mass of 1.00×10^3 kg travels from the top of that drop without friction. The car then decelerates along a horizontal stretch of track until it comes to a stop. How long does it take the car to decelerate if the constant force acting on it is -2.24×10^4 N? How far does the car travel along the horizontal track before stopping? Assume the car's speed at the peak of the drop is zero.
7. **Two Japanese islands are connected by a long rail tunnel that extends horizontally underwater. Imagine a communication system in which a small rail car with a mass of 100.0 kg is launched by a type of cannon in order to transport messages between the two islands. Assume a rail car from one end of the tunnel has a speed of 4.50×10^2 m/s, which is just large enough for a constant frictional force of -188 N to cause the car to stop at the other end of the tunnel. How long does it take** (sec and min) **for the car to travel the length of the tunnel? What is the length of the tunnel?**