

Part A: Concepts

Answer in complete sentences.

1. When you jump off a wall and land, you bend your knees instead of landing stiff-legged. Your change in momentum is the same either way. Use $F\Delta t = \Delta p$ to explain why bending your knees hurts less.

Stopping takes away the same momentum either way, so Δp (the impulse) is the same. Bending your knees makes the stop take **more time**. Since $F\Delta t = \Delta p$ is fixed, a larger Δt means a **smaller force** on your legs.

2. Show that a newton-second (N·s) is the same unit as a kilogram meter per second (kg·m/s). Hint: $1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$.

$1 \text{ N}\cdot\text{s} = (1 \text{ kg}\cdot\text{m}/\text{s}^2)(1 \text{ s}) = \mathbf{1 \text{ kg}\cdot\text{m}/\text{s}}$, because one of the seconds in s^2 cancels.

Part B: Calculations

Show knowns, equation, substitution, and answer with units. Right is positive.

3. A golf club hits a 0.0450 kg golf ball that is sitting at rest on a tee. The ball leaves the club at 60.0 m/s, and the contact lasts 0.000500 s. Find the change in the ball's momentum and the average force of the club on the ball.

Knowns: $m = 0.0450 \text{ kg}$, $v_i = 0 \text{ m/s}$, $v_f = +60.0 \text{ m/s}$, $\Delta t = 0.000500 \text{ s}$

Change in momentum: $\Delta p = m(v_f - v_i) = (0.0450 \text{ kg})(60.0 \text{ m/s} - 0) = \mathbf{+2.70 \text{ kg}\cdot\text{m/s}}$

Equation: $F = \Delta p / \Delta t$

Substitute: $F = (2.70 \text{ kg}\cdot\text{m/s}) / (0.000500 \text{ s})$

Answer: $\mathbf{F = 5.40 \times 10^3 \text{ N}}$ forward

4. A 1,200 kg car is moving at 20.0 m/s. The brakes apply a steady stopping force of $6.00 \times 10^3 \text{ N}$. How long does it take the car to stop?

Knowns: $m = 1,200 \text{ kg}$, $v_i = +20.0 \text{ m/s}$, $v_f = 0$, $F = -6.00 \times 10^3 \text{ N}$

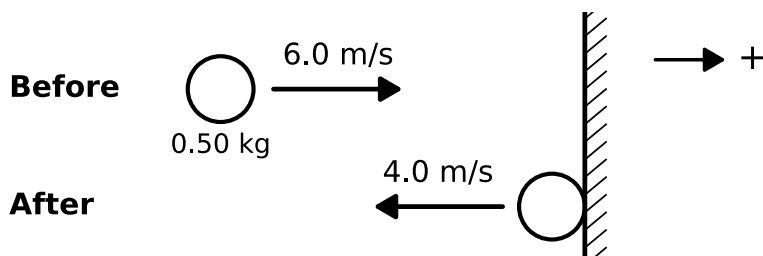
Change in momentum: $\Delta p = (1,200 \text{ kg})(0 - 20.0 \text{ m/s}) = -2.40 \times 10^4 \text{ kg}\cdot\text{m/s}$

Equation: $\Delta t = \Delta p / F$

Substitute: $\Delta t = (-2.40 \times 10^4 \text{ kg}\cdot\text{m/s}) / (-6.00 \times 10^3 \text{ N})$

Answer: $\mathbf{\Delta t = 4.00 \text{ s}}$

5. A 0.50 kg ball hits a wall moving right at 6.0 m/s and bounces straight back to the left at 4.0 m/s, as shown. The ball touches the wall for 0.020 s.



- Find the change in the ball's momentum. Watch the signs.
- Find the average force of the wall on the ball, with direction.

Knowns: $m = 0.50 \text{ kg}$, $v_i = +6.0 \text{ m/s}$, $v_f = -4.0 \text{ m/s}$, $\Delta t = 0.020 \text{ s}$

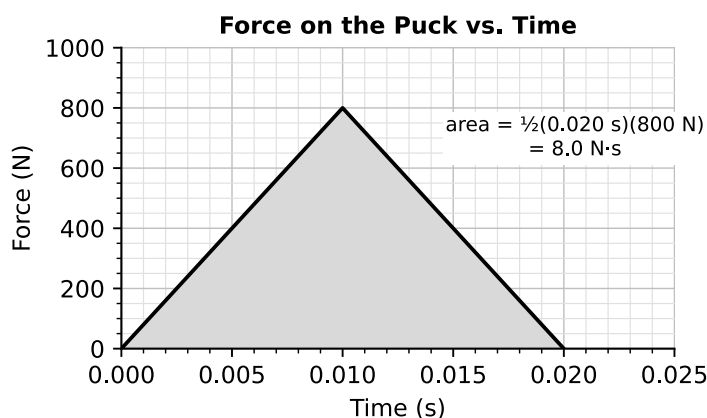
a. $\Delta p = m(v_f - v_i) = (0.50 \text{ kg})(-4.0 \text{ m/s} - 6.0 \text{ m/s}) = (0.50 \text{ kg})(-10.0 \text{ m/s}) = \mathbf{-5.0 \text{ kg}\cdot\text{m/s}}$

b. $F = \Delta p / \Delta t = (-5.0 \text{ kg}\cdot\text{m/s}) / (0.020 \text{ s}) = \mathbf{-250 \text{ N, or } 250 \text{ N to the left}}$

Bouncing changes the momentum more than just stopping would (-5.0 vs. $-3.0 \text{ kg}\cdot\text{m/s}$), so it takes a bigger force.

Part C: Force-Time Graphs

6. A hockey stick strikes a 0.16 kg puck that starts at rest. The graph shows the force on the puck.



- Find the impulse on the puck from the area under the graph.
- Find the puck's speed after it leaves the stick.
- A different stick gives the same impulse in 0.010 s. Sketch or describe how its graph would look.

a. The area is a triangle: $J = \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2}(0.020 \text{ s})(800 \text{ N}) = \mathbf{8.0 \text{ N}\cdot\text{s}}$

b. $J = \Delta p = m(v_f - 0)$, so $v_f = J/m = (8.0 \text{ N}\cdot\text{s}) / (0.16 \text{ kg}) = \mathbf{50. \text{ m/s}}$

c. A **taller, narrower** triangle with the same area: base 0.010 s and a peak of 1,600 N.