

Impulse, momentum and force-time graphs

AP Physics 1 (algebra-based) · Worksheet answers

Each answer shows the formula, the substitution with signs and the final result in bold. Check your sign convention first; if your magnitude is right but the sign differs, make sure you chose the positive direction consistently.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 4

Problem 1 Momentum of moving objects

- $p = mv = 1200 \times 15 = \mathbf{1.8 \times 10^4 \text{ kg m/s}}$.
- $p = 0.058 \times 50 = \mathbf{2.9 \text{ kg m/s}}$.
- The car has the larger momentum: $18\,000 \div 2.9 \approx \mathbf{6.2 \times 10^3 \text{ times}}$ larger.

Problem 2 Impulse from a force

- $J = F\Delta t = 250 \times 0.040 = \mathbf{10 \text{ N s}}$.
- It points in the direction of the force. $1 \text{ N s} = 1 (\text{kg m/s}^2) \times \text{s} = \mathbf{1 \text{ kg m/s}}$.

Problem 3 Change in momentum

- $\Delta p = 2.0 \times (7.0 - 3.0) = \mathbf{8.0 \text{ kg m/s}}$.
- Impulse equals the change in momentum: $\mathbf{8.0 \text{ N s}}$ in the direction of motion.
- $F = \Delta p / \Delta t = 8.0 \div 0.50 = \mathbf{16 \text{ N}}$.

Problem 4 Matching units

- $1 \text{ N s} = 1 (\text{kg m/s}^2) \text{ s} = \mathbf{1 \text{ kg m/s}}$.
- Both N s and kg m/s; N/s is the unit of a rate of change of force, not impulse. $\mathbf{N s}$ and $\mathbf{kg m/s}$.

Problem 5 Speed from impulse

- $v = J/m = 9.0 \div 0.45 = \mathbf{20 \text{ m/s}}$.
- $v = 9.0 \div 0.90 = \mathbf{10 \text{ m/s}}$, half as fast for double the mass.

Problem 6 Stopping a cricket ball

- $\Delta p = 0.16 \times (0 - 30) = \mathbf{-4.8 \text{ kg m/s}}$.
- $F = \Delta p / \Delta t = -4.8 \div 0.020 = \mathbf{-2.4 \times 10^2 \text{ N}}$, a force of 240 N against the ball's motion.

Problem 7 Bouncing off a wall

1. $\Delta p = 0.15 \times (-12 - 20) = -4.8 \text{ kg m/s}$.
2. $F = -4.8 \div 0.010 = -4.8 \times 10^2 \text{ N}$: 480 N directed away from the wall (opposite to the initial motion).

Problem 8 Area under a graph

1. Area of the triangle = $\frac{1}{2} \times 2.0 \times 60 = 60 \text{ N s}$.
2. Triangle 60 + rectangle ($3.0 \times 60 = 180$) + triangle ($\frac{1}{2} \times 1.0 \times 60 = 30$) = **270 N s**.
3. $v = J/m = 270 \div 30 = 9.0 \text{ m/s}$.

Problem 9 Airbag in a crash

- $\Delta p = 70 \times (0 - 14) = -980 \text{ kg m/s}$.
1. $F = -980 \div 0.10 = -9.8 \times 10^3 \text{ N}$.
 2. $F = -980 \div 0.020 = -4.9 \times 10^4 \text{ N}$.
 3. $49\,000 \div 9800 = 5$ times larger.

Problem 10 Impulse of gravity

1. $J = mg\Delta t = 0.20 \times 9.81 \times 1.5 = 2.9 \text{ N s}$ (2.94 N s).
2. $v = J/m = 2.943 \div 0.20 = 15 \text{ m/s}$ (14.7 m/s), which matches $gt = 9.81 \times 1.5 = 14.7 \text{ m/s}$.

Problem 11 Force that reverses

1. Area = $40 \times 3.0 = +120 \text{ N s}$.
2. Area = $-20 \times 4.0 = -80 \text{ N s}$.
3. Total = $+40 \text{ N s}$. $\Delta v = J/m = 40 \div 10 = 4.0 \text{ m/s}$, so $v_f = 2.0 + 4.0 = +6.0 \text{ m/s}$.

Problem 12 Clay and rubber

1. Clay: $\Delta p = 0.30 \times (0 - 6.0) = -1.8 \text{ kg m/s}$. Rubber: $\Delta p = 0.30 \times (-6.0 - 6.0) = -3.6 \text{ kg m/s}$.
2. The rubber ball receives twice the impulse, because its velocity changes by 12 m/s while the clay ball's changes by only 6.0 m/s. The wall must reverse the rubber ball, not just stop it.

Problem 13 Volleyball bump

1. $\Delta p = 0.27 \times (0 - 12) = -3.2 \text{ kg m/s}$ (-3.24).
2. $F = -3.24 \div 0.050 = -65 \text{ N}$.
3. $F = -3.24 \div 0.15 = -22 \text{ N}$, one third of the first force.

Problem 14 Accelerating car

1. $\Delta p = 1200 \times (25 - 10) = \mathbf{1.8 \times 10^4 \text{ kg m/s}}$.
2. $\Delta t = \Delta p / F = 18\,000 \div 3000 = \mathbf{6.0 \text{ s}}$.

Problem 15 Bouncing tennis ball

1. Before: $v = \sqrt{2 \times 9.81 \times 1.8} = 5.94 \text{ m/s}$ downward. After: $v = \sqrt{2 \times 9.81 \times 1.0} = 4.43 \text{ m/s}$ upward. **5.9 m/s and 4.4 m/s**.
2. Take up as positive: $J = 0.060 \times (4.43 - (-5.94)) = 0.060 \times 10.37 = \mathbf{0.62 \text{ N s}}$ upward.
3. Net force = $0.622 \div 0.012 = 51.9 \text{ N}$, and the floor also supports the weight of 0.59 N , so the floor force is about **52 N**.

Problem 16 Hose against a wall

1. In one second 3.0 kg changes velocity from 8.0 m/s to 0 : $|\Delta p| = 3.0 \times 8.0 = 24 \text{ kg m/s}$, so $F = 24 \div 1.0 = \mathbf{24 \text{ N}}$.
2. Now $\Delta v = 16 \text{ m/s}$, so $|\Delta p| = 3.0 \times 16 = 48 \text{ kg m/s}$ and $F = \mathbf{48 \text{ N}}$.
3. A bounce reverses the velocity, so the change in momentum per second is twice as great, requiring twice the force.

Problem 17 Jumping from the floor

1. $J = \Delta p = 60 \times 2.8 = \mathbf{1.7 \times 10^2 \text{ N s}}$ (168 N s).
2. $F_{\text{net}} = 168 \div 0.30 = \mathbf{5.6 \times 10^2 \text{ N}}$.
3. The floor must also support the weight: $N = F_{\text{net}} + mg = 560 + 589 = \mathbf{1.1 \times 10^3 \text{ N}}$.
4. $h = v^2 / 2g = 2.8^2 \div 19.62 = \mathbf{0.40 \text{ m}}$.

Problem 18 Trolley data table

1. Area by trapezoids = $0.1 \times (0/2 + 2 + 6 + 8 + 6 + 2 + 0/2) = 0.1 \times 24 = \mathbf{2.4 \text{ N s}}$.
2. $\Delta v = J/m = 2.4 \div 0.80 = 3.0 \text{ m/s}$, so $v_f = 0.50 + 3.0 = \mathbf{3.5 \text{ m/s}}$.
3. Where the real curve is convex (a rounded peak), straight segments between points cut off part of the area under the curve, so the estimate is slightly too small.

Problem 19 Spot the error

1. Momentum is a vector. The ball reverses direction, so p changes from $+0.80$ to -0.80 kg m/s ; only the speed is unchanged.
2. $J = 0.20 \times (-4.0 - 4.0) = \mathbf{-1.6 \text{ N s}}$.
3. $F = -1.6 \div 0.025 = \mathbf{-64 \text{ N}}$, directed away from the wall.

Problem 20 Comparing two ways to find impulse

1. $\Delta p = 0.50 \times (-0.40 - 0.60) = -0.50 \text{ N s}$, magnitude 0.50 N s.
2. Difference = $(0.50 - 0.48) \div 0.50 = 4 \%$.
3. Friction or a small tilt in the track changes the velocity, and the sensor may miss the first and last part of the contact. Using a level track, a higher sampling rate and several repeats reduce the difference.