

Impulse, momentum and force-time graphs

AP Physics 1 (algebra-based) · Test answers (mark scheme)

Model answers with the mark scheme. Award method marks where a signed momentum change is set up correctly even if the arithmetic is slightly wrong, and apply the unit mark in each calculation.

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

Question 1 Definitions (2 marks)

- a. Impulse is the product of the net force and the time for which it acts, $J = F\Delta t$ (or the area under a force-time graph).
- b. **Impulse equals the change in momentum**, $J = \Delta p$.

Marking: 1 mark for each statement; the first must include both force and time.

Question 2 Bullet and car (2 marks)

- a. Bullet: $p = 0.0040 \times 400 = 1.6 \text{ kg m/s}$. Car: $p = 1500 \times 1.0 = 1500 \text{ kg m/s}$.
- b. $1500 \div 1.6 = \mathbf{9.4 \times 10^2}$ times larger.

Marking: 1 mark for both momenta, 1 mark for the ratio.

Question 3 Goalkeeper's catch (3 marks)

- a. $\Delta p = 0.43 \times (0 - 20) = -8.6 \text{ kg m/s}$.
- b. Impulse = **-8.6 N s** (magnitude 8.6 N s against the motion).
- c. $F = -8.6 \div 0.040 = \mathbf{-2.2 \times 10^2 \text{ N}}$.

Marking: 1 mark each; allow the magnitude if the direction is stated.

Question 4 Skater and a graph (3 marks)

- a. Area = $\frac{1}{2} \times 2 \times 40 + 2 \times 40 + \frac{1}{2} \times 1 \times 40 = 40 + 80 + 20 = \mathbf{140 \text{ N s}}$.
- b. $v = J/m = 140 \div 70 = \mathbf{2.0 \text{ m/s}}$.

Marking: (a) 1 mark for method (splitting the area), 1 mark for the result; (b) 1 mark.

Question 5 Airbags (3 marks)

The driver's momentum must drop from its initial value to zero, so the impulse needed, Δp , is fixed. Since $F_{\text{avg}} = \Delta p / \Delta t$, an airbag that increases the stopping time gives a **smaller average force** on the driver than a rigid surface, reducing injury.

Marking: 1 mark for fixed change in momentum or impulse; 1 mark for the time of contact increasing; 1 mark for lower force as the consequence.

Question 6 Rebounding ball (3 marks)

a. $\Delta p = 0.25 \times (-6.0 - 8.0) = -3.5 \text{ kg m/s}$.

b. $F = -3.5 \div 0.020 = -1.8 \times 10^2 \text{ N}$ (175 N away from the wall).

Marking: (a) 1 mark for a correct subtraction with signs, 1 mark for the answer; (b) 1 mark.

Question 7 Car acceleration (2 marks)

a. $\Delta p = 1500 \times (20 - 8.0) = 1.8 \times 10^4 \text{ kg m/s}$.

b. $F = 18\,000 \div 5.0 = 3.6 \times 10^3 \text{ N}$.

Marking: 1 mark each.

Question 8 Sticking or bouncing (2 marks)

The **rubber ball** receives the larger impulse. The clay ball's velocity changes from v to 0, whereas the rubber ball's changes from v to $-v$, a change of $2v$, so Δp (and the impulse) is about twice as large.

Marking: 1 mark for naming rubber; 1 mark for comparing velocity changes.