Exercise walk-through

Change in Momentum and Impulse ▪ 4.2

eXercise

You must be able to

- calculate **impulse** 冲量: $J = F\Delta t$
- use the impulse-momentum theorem: $J = \Delta p$
- explain why a longer contact time reduces the force for a given change in momentum
- find force, time, or change in momentum given the other two

Method — Impulse equals change in momentum

$$J = F\Delta t = \Delta p = m\Delta v.$$

A 50 N force acting for 0.2 s delivers $J = 50 \times 0.2 = 10$ kg m s^{-1}, changing the momentum by 10 kg m s^{-1}.

Method — Longer time, smaller force

For a fixed change in momentum, a longer contact time means a smaller force:

$$F = \frac{\Delta p}{\Delta t}.$$

This is why crumple zones and airbags help – they stretch Δt, cutting the force.

Method — Finding the change in velocity

A 2 kg ball receives an impulse of 12 kg m s^{-1}: $\Delta v = J/m = 12/2 = 6$ m s^{-1}.

Practice 2.1 ▪ 2 marks

A 20 N force acts for 3 s. Find the impulse.

Solution 2.1

Method: Impulse equals change in momentum

Worked steps

$J = F\Delta t = 20 \times 3 = 60$ kg m s^{-1} M1 A1.

Practice 2.2 ▪ 1 mark

State what impulse equals (the theorem).

Solution 2.2

Method: Impulse equals change in momentum

Worked steps

The change in momentum, Δp B1.

Practice 2.3 ▪ 2 marks

A 4 kg object receives an impulse of 16 kg m s^{-1}. Find its change in velocity.

Solution 2.3

Method: Finding the change in velocity

Worked steps

$\Delta v = J/m = 16/4 = 4$ m s^{-1} M1 A1.

Practice 2.4 ▪ 2 marks

Explain why a longer collision time reduces the force.

Solution 2.4

Method: Longer time, smaller force

Worked steps

For a fixed Δp, $F = \Delta p / \Delta t$; a larger Δt gives a smaller F M1 A1.

Exam-style 3.1 ▪ 1 mark

The impulse of a force equals the change in

A kinetic energy

B momentum

C mass

D acceleration

Solution 3.1

Method: Impulse equals change in momentum

A kinetic energy

B momentum ✓

C mass

D acceleration

Worked steps

B — impulse equals the change in momentum.

Exam-style 3.2 ▪ 1 mark

For a fixed change in momentum, increasing the contact time

A increases the force

B decreases the force

C leaves the force unchanged

D reverses the force

Solution 3.2

Method: Longer time, smaller force

A increases the force

B decreases the force ✓

C leaves the force unchanged

D reverses the force

Worked steps

B — a longer time reduces the force.

Exam-style 3.3 ▪ 2 marks

A 0.15 kg ball hits a wall at 10 m s^{-1} and bounces back at 8 m s^{-1} (opposite direction).

(a) Find the change in momentum.

(b) If the contact lasts 0.02 s, find the average force.

Solution 3.3

Worked steps

(a) Taking the incoming direction positive: $\Delta p = m(v_f - v_i) = 0.15(-8 - 10) = -2.7$ kg m s^{-1} (magnitude 2.7) M1 A1. (b) $F = \Delta p / \Delta t = 2.7/0.02 = 135$ N M1 A1.

Exam-style 3.4 ▪ 1 mark

A 60 kg person jumps down and lands, changing momentum by 300 kg m s^{-1}.
(a) Find the force if they stop in 0.1 s (stiff legs).
(b) Find the force if they stop in 0.5 s (bent knees).

Solution 3.4

Method: Impulse equals change in momentum

Worked steps

(a) $F = 300/0.1 = 3000$ N B1. (b) $F = 300/0.5 = 600$ N M1 A1.