

Exercise walk-through

# 1.6

## Momentum

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IGCSE Physics

# Momentum

**Momentum**  $p = mv$  (a vector). Force is the change per unit time:

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

**Conservation** : total momentum before = after (no outside force).

2.0 kg at 3.0 m/s hits a still  
1.0 kg; they stick

$$v = \frac{2.0 \times 3.0}{3.0} = 2.0 \text{ m/s}$$

# Momentum, impulse and what is conserved

## Momentum

$p = mv$ : a vector, so direction matters and opposite directions carry opposite signs.

## Impulse

**Impulse** is  $F\Delta t$ , and it equals the change in momentum – which is why a longer collision time means a smaller force.

## Conservation of momentum

In any collision or explosion with no external force, the total momentum before equals the total after – the **conservation of momentum**.

## Energy too

The **principle of conservation of energy**: energy is never created or destroyed, only transferred between stores.

Total momentum is conserved when the resultant external force is negligible; kinetic energy may change. Crumple zones exist to lengthen  $\Delta t$ .

## Exercises 2.1·2.2

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**2.1** Find the momentum of a 0.40 kg ball moving at  $5.0 \frac{\text{m}}{\text{s}}$ . [2]

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**2.2** State the principle of conservation of momentum. [1]

## Exercises 2.1·2.2

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**2.1** Find the momentum of a 0.40 kg ball moving at  $5.0 \frac{\text{m}}{\text{s}}$ . [2]

**2.1**

- $p = mv$

$$p = mv = (0.40 \text{ kg})(5.0 \frac{\text{m}}{\text{s}}) = \mathbf{2.0 \text{ kg m/s}}$$

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**2.2** State the principle of conservation of momentum. [1]

**2.2**

- when no external force acts, the total momentum before a collision equals the total momentum after

## Exercise 3.1

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**3.1** The momentum of an object is its mass multiplied by its:

[1]

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**A** acceleration

**B** velocity

**C** weight

**D** density

## Exercise 3.1

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**3.1** The momentum of an object is its mass multiplied by its:

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**A** acceleration

**B** velocity

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**3.1 B**

- $\text{momentum} = \text{mass} \times \text{velocity}$

## Exercise 3.2 (a)

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**3.2** A 3.0 kg trolley moving at  $4.0 \frac{\text{m}}{\text{s}}$  collides with a stationary 1.0 kg trolley and they move off together.

(a) Find the total momentum before the collision.

[2]

## Exercise 3.2 (a)

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**3.2** A 3.0 kg trolley moving at  $4.0 \frac{\text{m}}{\text{s}}$  collides with a stationary 1.0 kg trolley and they move off together.

(a) Find the total momentum before the collision. [2]

(a) total momentum before

$$p = m_1 u_1 + m_2 u_2 = (3.0 \text{ kg})(4.0 \frac{\text{m}}{\text{s}}) + (1.0 \text{ kg})(0) = \mathbf{12 \text{ kg m/s}}$$

## Exercise 3.2 (b)

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**3.2** A 3.0 kg trolley moving at  $4.0 \frac{\text{m}}{\text{s}}$  collides with a stationary 1.0 kg trolley and they move off together.

(b) Find their common velocity after the collision.

[2]

## Exercise 3.2 (b)

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**3.2** A 3.0 kg trolley moving at  $4.0 \frac{\text{m}}{\text{s}}$  collides with a stationary 1.0 kg trolley and they move off together.

(b) Find their common velocity after the collision. [2]

(b) conservation of momentum,  $p = (m_1 + m_2)v$ :  $12 \text{ kg m/s} = (3.0 \text{ kg} + 1.0 \text{ kg})v$

$$v = \frac{p}{m_1 + m_2} = \frac{12 \text{ kg m/s}}{4.0 \text{ kg}} = \mathbf{3.0} \frac{\text{m}}{\text{s}}$$

## Exercises 3.3-3.4

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**3.3** A force acts on a 2.0 kg ball for 0.10 s and changes its velocity from 0 to  $6.0 \frac{\text{m}}{\text{s}}$ . Find the force. [3]

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**3.4** Take right as positive. A 3.0 kg trolley at  $+2.0 \text{ m s}^{-1}$  sticks to a 1.0 kg trolley at  $-2.0 \text{ m s}^{-1}$ . External impulse is negligible. Find the combined velocity and explain why the signs must be kept. [4]

## Exercises 3.3·3.4

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**3.3** A force acts on a 2.0 kg ball for 0.10 s and changes its velocity from 0 to  $6.0 \frac{\text{m}}{\text{s}}$ . Find the force. [3]

**3.3**

- $F = \Delta p / \Delta t$

$$\Delta p = m \Delta v = (2.0 \text{ kg})(6.0 \frac{\text{m}}{\text{s}}) = 12 \text{ kg m/s}$$

$$F = \frac{\Delta p}{t} = \frac{12 \text{ kg m/s}}{0.10 \text{ s}} = \mathbf{120 \text{ N}}$$

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**3.4** Take right as positive. A 3.0 kg trolley at  $+2.0 \text{ m s}^{-1}$  sticks to a 1.0 kg trolley at  $-2.0 \text{ m s}^{-1}$ . External impulse is negligible. Find the combined velocity and explain why the signs must be kept. [4]

**3.4**

$p = m_1 u_1 + m_2 u_2 = 3(2) + 1(-2) = 4.0 \text{ kg m s}^{-1}$ ;  $v = p / (m_1 + m_2) = 1.0 \text{ m s}^{-1}$ , right; opposite velocities have opposite momenta, so adding speed magnitudes loses direction.