## Momentum, energy and work

**1** In many sports events, an athlete tries to throw an object as far as possible.



(a) Sport scientists can use many words to describe the throwing of an object.
Four of these words are shown in the box.
Only one of these is a vector.

| energy | moment | wer | spe |
|---|---|---|---|

(i) Complete the sentence by putting a cross (☒) in the box next to your answer.

The vector is

**(1)**

- ☐ **A** energy
- ☐ **B** momentum
- ☐ **C** power
- ☐ **D** speed

(ii) Complete the sentence by using a word from the box above.

**(1)**

The rate of doing work is called .....

(b) A javelin has a mass of 0.8 kg. In one throw, the javelin left the athlete's hand at a velocity of 25 m/s.

(i) Calculate the kinetic energy of the javelin as it left the athlete's hand. State the unit.

**(3)**

kinetic energy = ..... unit .....

(ii) State the amount of work done by the athlete on the javelin to get it to a velocity of 25 m/s.

**(1)**

work done = .....

(iii) A good javelin thrower will try to extend their arm as much as possible before releasing the javelin.

Explain why this allows them to do more work on the javelin.

**(2)**

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**(Total for Question 2 = 8 marks)**

**2** (a) A father pushes his child in a cart. The cart starts to move.




Scientists can use many physical quantities to describe what is happening.

Four of these are shown in the box.

| | | | |
|---|---|---|---|
| energy | moment | wer | ork |

(i) Which one of these can be measured in joules per second?

Put a cross (☒) in the box next to your answer.

**(1)**

- ☐ **A** energy
- ☐ **B** momentum
- ☐ **C** power
- ☐ **D** work

(ii) Complete the sentence using words from the box.

**(1)**

The ..... transferred to the cart is equal to the ..... done on the cart.

(iii) The child and cart have a total mass of 50 kg. They travel at a velocity of 4 m/s.

Calculate the momentum of the child and cart.

**(2)**

momentum = ..... kg m/s

(iv) The father applies a steady force for a time of 1.5 s. The momentum of the child and cart increases by 450 kg m/s.

Calculate the force which the father applies.

**(2)**

force = ..... N

(v) Momentum is a vector quantity.

State what is meant by a vector quantity.

**(1)**

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(b) The photograph shows a mother and her daughter stationary on an ice rink.



The mother and daughter push each other away.
They move in opposite directions with different speeds.

Explain why they have different speeds.

**(3)**

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**(Total for Question 3 = 10 marks)**

## Force and acceleration

**3** (a) A car is travelling along a level road.



(i) Complete the sentence by putting a cross (☒) in the box next to your answer.

When the velocity of the car is constant, the force of friction on it is

**(1)**

☒ **A** zero

☒ **B** greater than the driving force

☒ **C** smaller than the driving force

☒ **D** the same size as the driving force

(ii) The car now accelerates in a straight line.
Its average acceleration is 12 $m/s^2$.

Calculate the increase in velocity of the car in 4.0 s.

**(3)**

speed = m/s

(b) This table shows data about two other cars.

| car | mass | time taken to reach 30 m/s from rest |
|---|---|---|
| family car | 1400 kg | 10 s |
| sports car | 600 kg | 5 s |

The owner of the family car claims that although the sports car has greater acceleration, it produces a smaller accelerating force than his family car.

Explain how these figures support his claim.

**(2)**

*(c) After going to the shops, a car driver places a bag of shopping on the passenger seat. During the journey home, the driver has to use the brakes to stop very suddenly. The driver is wearing a seat belt.

Explain what happens next to the car, the driver and the shopping bag.

**(6)**

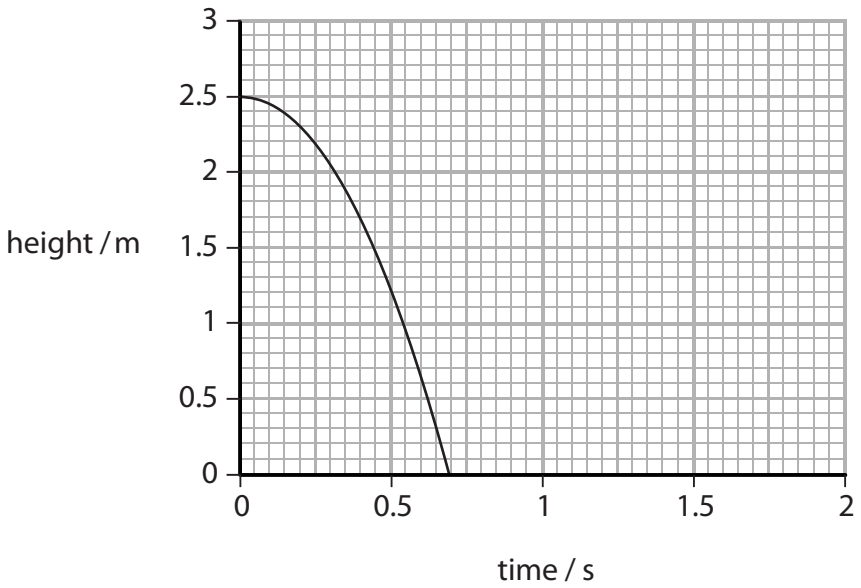
**(Total for Question 5 = 12 marks)**

**Collision**

**4** (a) The man in the photograph balances a ball above the ground.



He lets the ball fall.
He starts a timer at the same time.
The graph shows how the height of the ball above the ground changes with time.




(i) From the graph, state the height of the ball above the ground when the timer was started.

**(1)**

height above ground = ..... m

(ii) From the graph, state the time taken for the ball to reach the ground.

**(1)**

time = ..... s

(iii) The ball bounces back to a height of 1.9 m.
Continue the line on the graph to show this.

**(3)**

(iv) Explain why the ball does not bounce back to its original height.

**(2)**

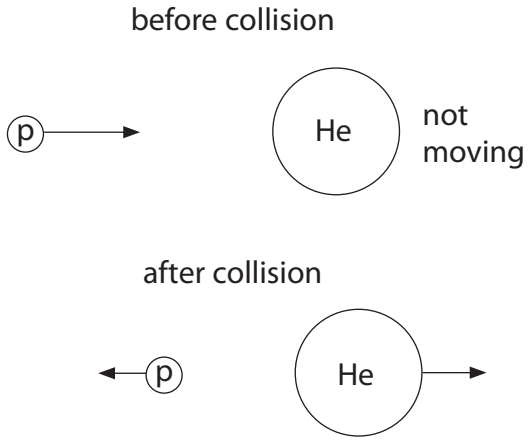
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(b) The diagram shows a collision between a proton (p) and a helium nucleus (He).




(i) The table gives some information about the collision.

| | | before collision | after collision |
|---|---|---|---|
| proton | kinetic energy (arbitrary units) | 12.5 | 4.5 |
| helium nucleus | kinetic energy (arbitrary units) | 0 | 8 |

Use information from the table to show that the collision is elastic.

**(2)**

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(ii) State the name of **one** device that can be used to accelerate protons to very high speeds.

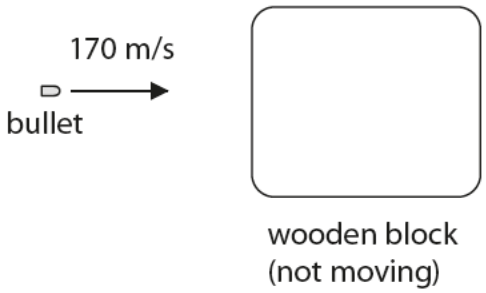
**(1)**

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**(Total for Question 4 = 10 marks)**

**5** (a) The diagram shows a bullet moving towards a wooden block.




(i) The bullet is moving with a velocity of 170 m/s.
The mass of the bullet is 0.030 kg.

Show that the momentum of the bullet is about 5.0 kg m/s.

**(1)**

(ii) The bullet collides with the wooden block and sticks in it.
The bullet and the wooden block move off together.
The mass of the wooden block is 0.80 kg.

Calculate the velocity of the wooden block and bullet immediately after the collision.

**(3)**

velocity = ..... m/s

(iii) The collision between the bullet and the wooden block is an inelastic collision.

State what is meant by an **inelastic collision**.

**(2)**

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(b) An electron and a positron collide and annihilate each other.
Two photons are produced.

(i) Explain why two photons must be produced, rather than just one.

**(2)**

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(ii) Calculate the minimum total energy of the photons produced when an electron and positron collide.

Use the equation

$$E = mc^2$$

mass of an electron = $9.1 \times 10^{-31}$ kg
speed of light = $3.0 \times 10^8$ m/s

**(2)**

energy = ..... J

**(Total for Question 4 = 10 marks)**