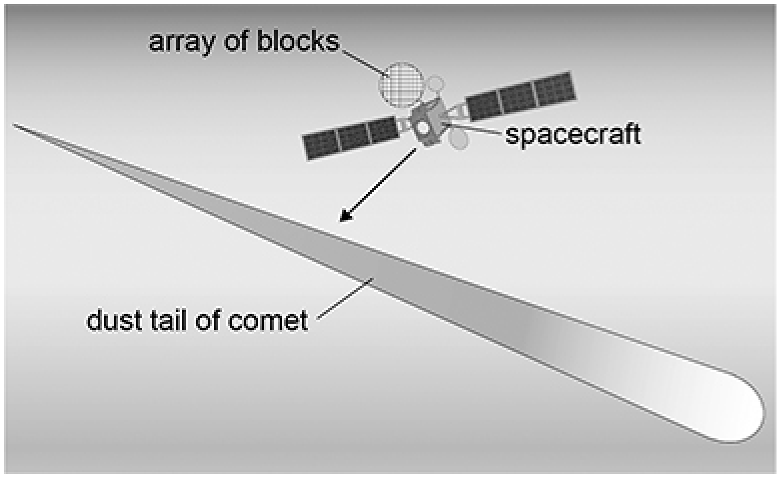
1. **Figure 1** shows a spacecraft travelling towards a comet.
The spacecraft has an array of blocks designed to capture small dust particles from the comet's tail.

Figure 1



To test the blocks before launch, a spherical dust particle **P** is fired at a right angle to the surface of a fixed, stationary block.

P has a mass of 1.1×10^{-9} kg. It has a speed of 5.9×10^{3} m s^{-1} when it hits the surface of the block.

P comes to rest inside the block.

(a) Calculate the work done in bringing **P** to rest.

work done = _______________ J

(1)

(b) **P** travels a distance of 2.9 cm in a straight line inside the block before coming to rest. The resultant force on **P** varies as it penetrates the block.

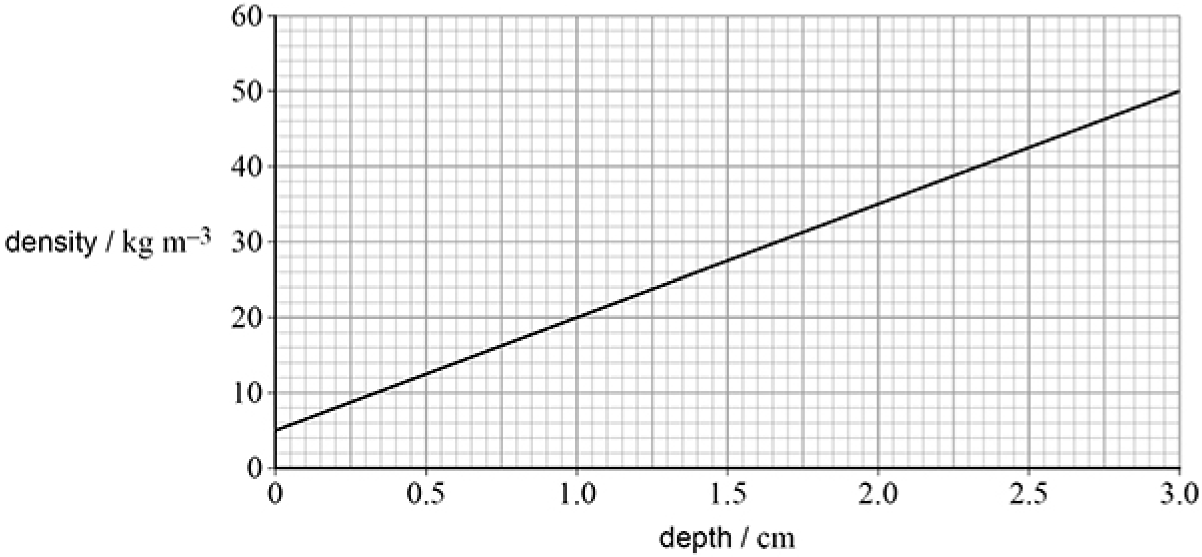
Calculate the average force acting on **P** as it is brought to rest.

average force = _______________ N

(2)

(c) The block is rectangular with an area of cross-section of 8.0 cm^2 and a thickness of 3.0 cm. **Figure 2** shows how the density of the block varies with depth up to its maximum thickness.

Figure 2



Calculate the mass of the block.

mass = ________________ kg

(4)

(d) In another test, a spherical particle **Q** is fired at a right angle to the surface of an identical block.

Q has the same mass as **P** and is travelling at the same speed as **P** when it strikes the surface of the block.
Q is made from a less dense material than **P**.

Compare the distance travelled by **Q** with that travelled by **P** as they are brought to rest.

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(3)
(Total 10 marks)

2. An electron has speed v. The electron's kinetic energy is doubled.

What is the new speed of the electron?

A $\frac{v}{\sqrt{2}}$ ⬭

B $\sqrt{2}v$ ⬭

C $2v$ ⬭

D $4v$ ⬭

(Total 1 mark)

3. An object of mass m is accelerated from rest to a velocity v by a constant resultant force F.

What is the work done on the object during this acceleration?

A $\frac{Fv}{2}$ ⬭

B Fv ⬭

C mv^2 ⬭

D $\frac{mv^2}{2}$ ⬭

(Total 1

4. What is true for an inelastic collision between two isolated objects?

A Both total momentum and total kinetic energy are conserved.

B Neither total momentum nor total kinetic energy is conserved.

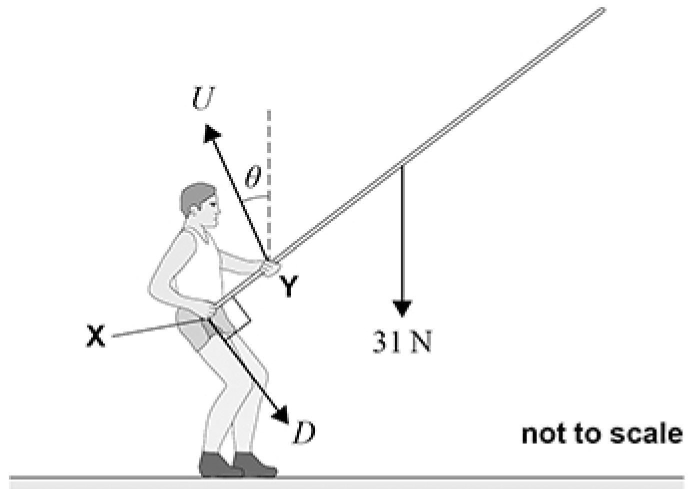
C Only total kinetic energy is conserved.

D Only total momentum is conserved.

(Total 1 mark)

5. **Figure 1** shows an athlete holding a vaulting pole at an angle of 40° to the horizontal.

Figure 1

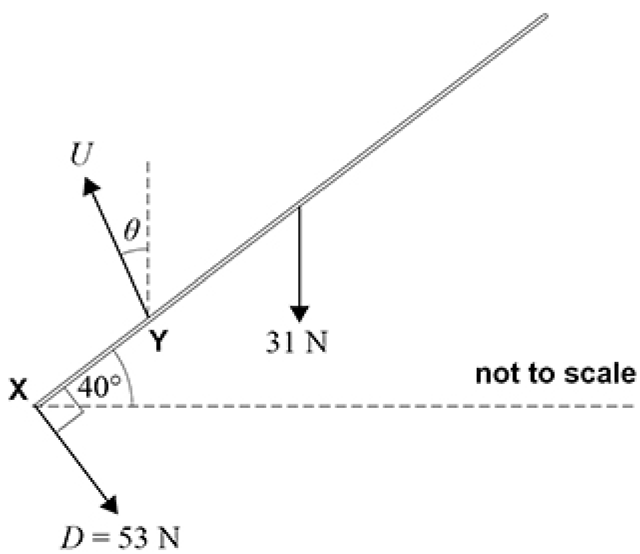


Forces D and U are exerted on the pole by the athlete's right and left hands respectively.
U is applied at point **Y** at an angle θ to the vertical.
The magnitude of D is 53 N and is applied at 90° to the pole at **X**.

The uniform pole is in equilibrium. It has a weight of 31 N.

Figure 2 shows the forces acting on the pole.

Figure 2



(a) Determine, using a scale Figure, θ and the magnitude of U.

θ = ________________ °

magnitude of U = ________________ N

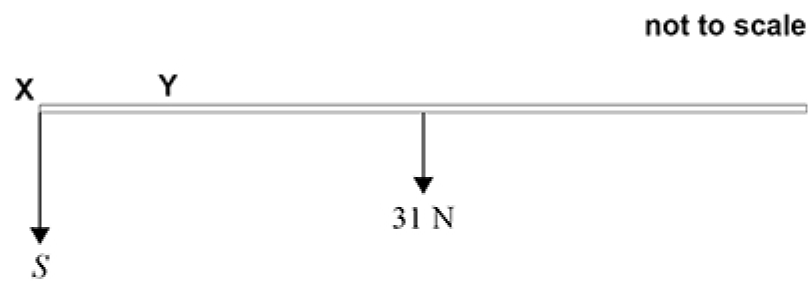
(4)

(b) The athlete now moves the pole to a horizontal position. The pole is held stationary in this position.

The athlete's right hand applies a force S vertically downwards at **X** as shown in **Figure 3**.

The athlete's left hand applies a force V at **Y**.

Figure 3



Discuss the differences between the magnitudes and directions of force U in **Figure 1** and force V applied at **Y** in **Figure 3**.

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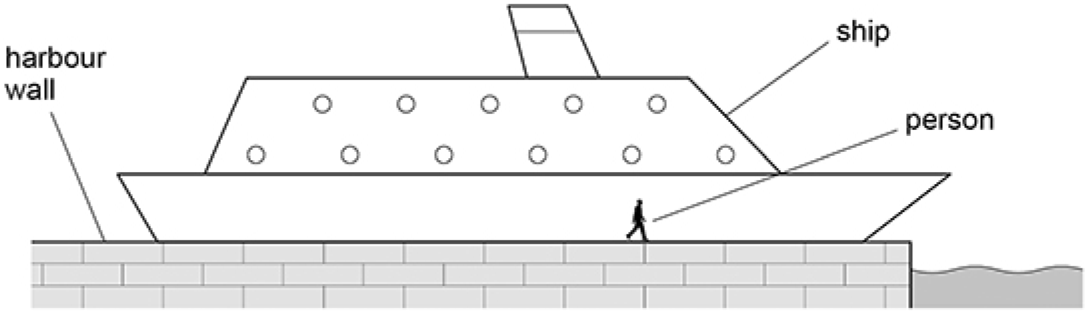
(3)

(Total 7 marks)

6. (a) **Figure 1** shows a ship leaving a harbour at a constant velocity.

The ship moves at the same velocity as a person walking on the harbour wall alongside the ship.

Figure 1



The momentum of the ship is approximately 1×10^7 N s.

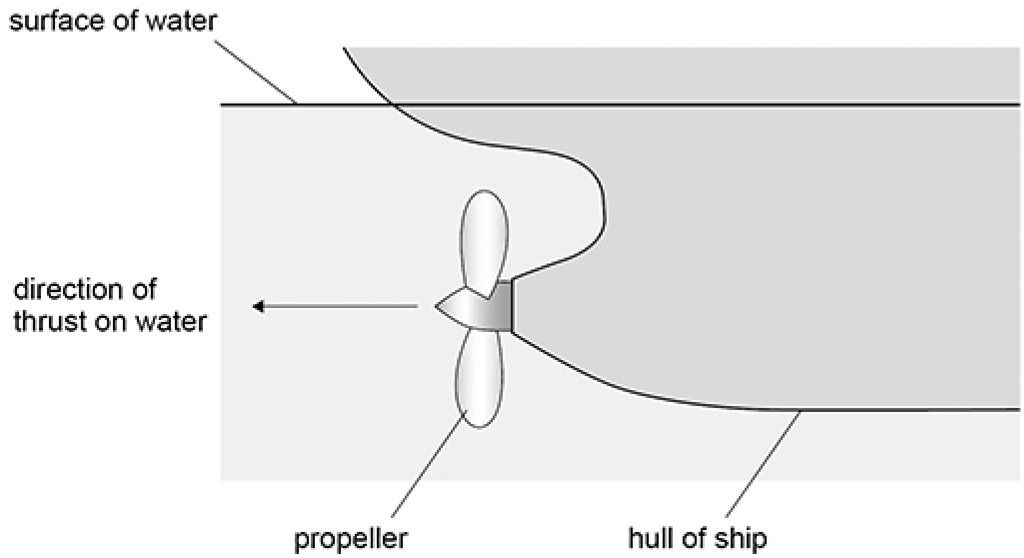
Estimate the mass of the ship.

mass of ship = _______________ kg

(2)

(b) **Figure 2** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 2



Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

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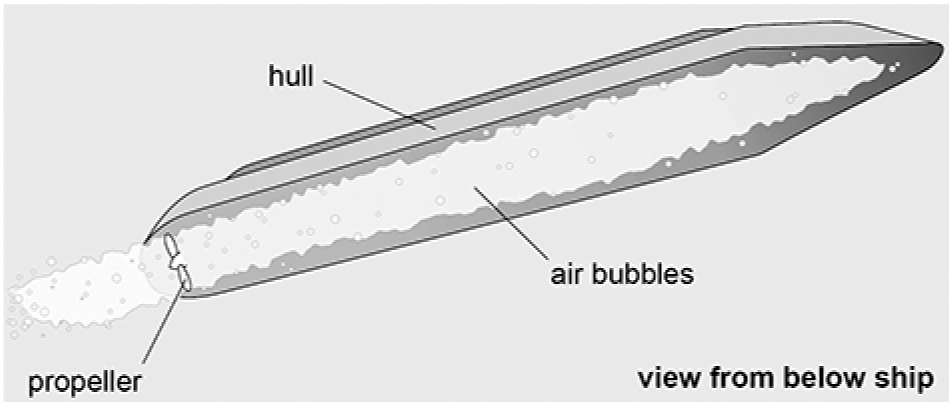
(4)

(c) **Figure 3** shows the bottom of the hull with a drag reduction system in operation. Air bubbles are introduced into the water below the hull. This reduces the work done per second against the drag on the hull at any given speed.

However, when the air bubbles reach the propeller they decrease the mass of water being accelerated by the propeller every second. This decreases the thrust produced by the propeller at a given speed of rotation.

Figure 3



The system enables the ship to save fuel while maintaining the same momentum.

Explain why the system delivers this fuel saving.
In your answer, consider the effects of the introduction of the system on

- the thrust
- the drag on the hull.

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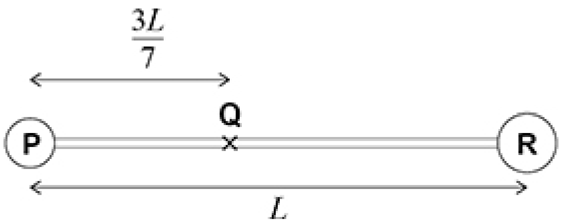
(3)

(Total 9 marks)

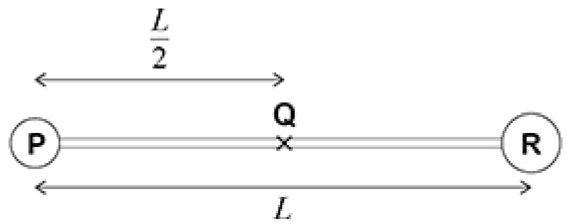
7. **P** and **R** are uniform spheres of mass 3 kg and 4 kg respectively.
P and **R** are joined by a rod of negligible mass.
The distance between their centres is L.
The centre of mass of this system is at **Q**.

Which diagram shows the position of the centre of mass?

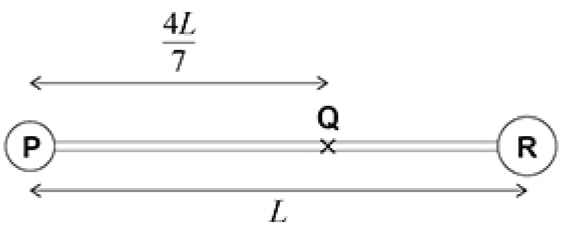
A



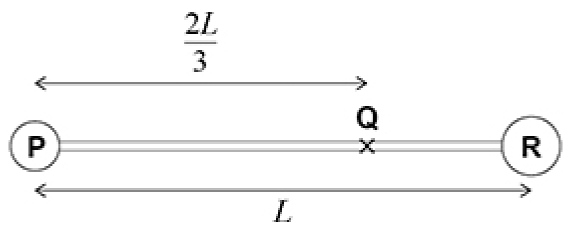
B



C



D



A ☐

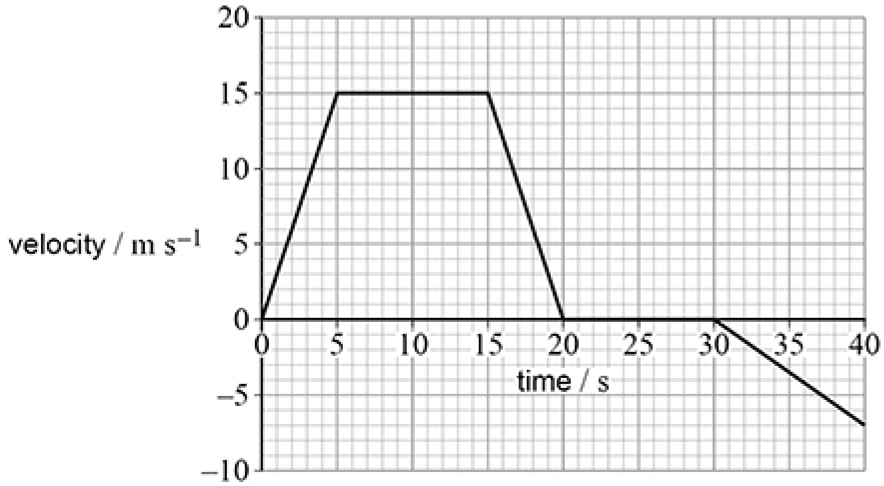
B ☐

C ☐

D ☐

(Total 1 mark)

8. A vehicle travels on a straight road, starting at time t = 0
The graph shows how its velocity varies with time.



What is the distance of the vehicle from its start position when t = 40 s?

A 115 m

B 190 m

C 260 m

D 370 m

(Total 1 mark)

9. **Figure 1** shows a conveyor used to raise concrete blocks on a building site. The blocks do not slip on the belt at any time.

Figure 1

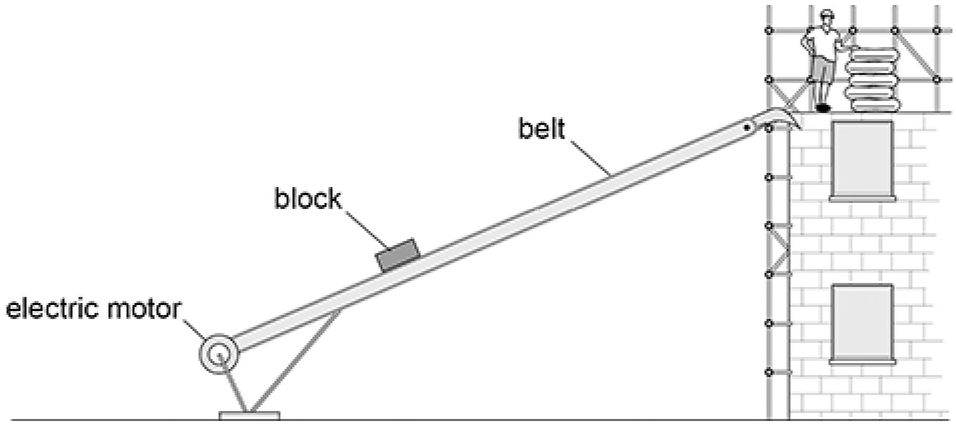
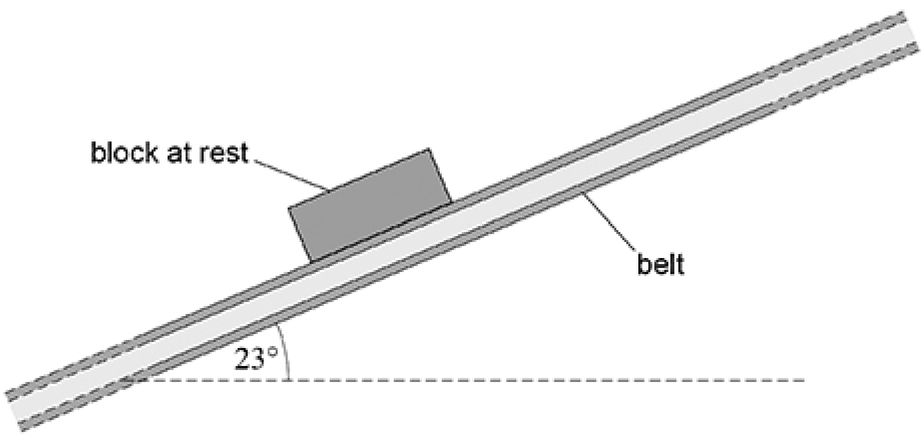


Figure 2 shows an enlarged view of one block on the belt. The belt is inclined at 23° to the horizontal. The mass of the block is 19 kg.

Figure 2



The belt exerts a frictional force F on the block when the block is at rest.

(a) Draw an arrow on **Figure 2** to show the line of action of F.

(1)

(b) Show that the magnitude of F is approximately 70 N.

(1)

(c) The belt is driven by an electric motor. When the motor is switched on, the belt and the block accelerate uniformly from rest to a speed of 0.32 m s^{-1} in a time of 0.50 s.

Calculate the magnitude of the frictional force of the belt on the block during this acceleration.

frictional force = ________________ N

(3)

(d) The motor is connected to a 110 V dc supply that has negligible internal resistance. The maximum operating current in the motor is 5.0 A.

The efficiency of the motor and drive system of the conveyor is 28%. The belt travels at 0.32 m s^{-1} and is 8.0 m long.

Deduce the maximum number of blocks that can be moved on the belt at one time.

maximum number of blocks = ________________

(4)

(Total 9 marks)

10. A suitcase weighing 200 N is placed on a weighing scale in a lift.
The scale reads 180 N when the lift is moving.

The lift is

A moving down at a constant velocity. ⬭

B moving down with a decreasing velocity. ⬭

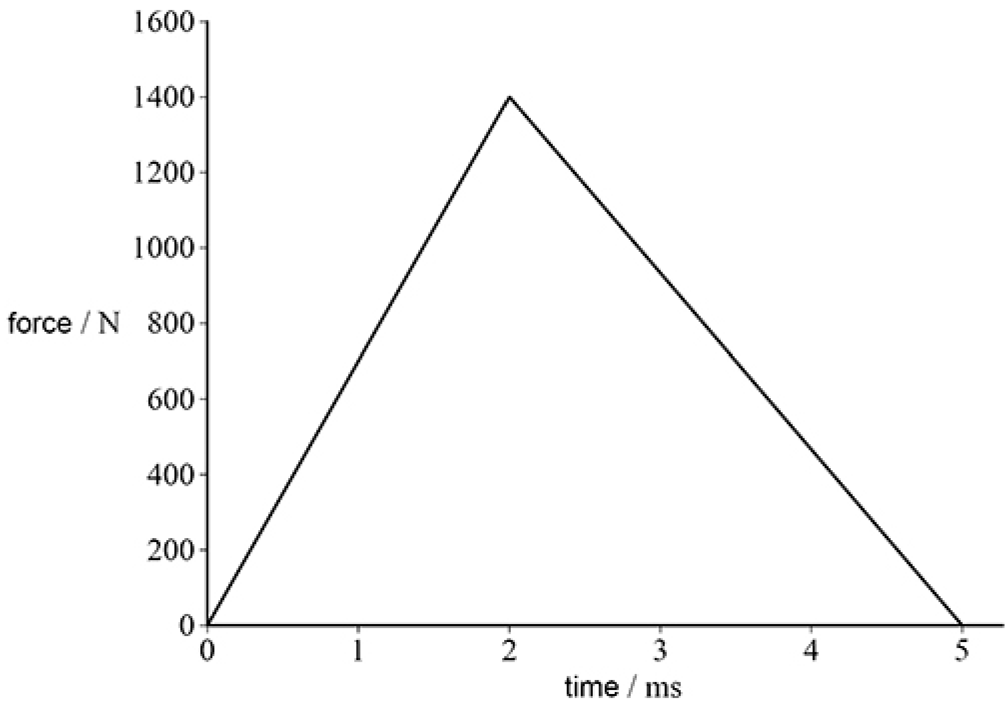
C moving up at a constant velocity. ⬭

D moving up with a decreasing velocity. ⬭

(Total 1 mark)

11. A stationary ball is free to move. The ball is hit with a bat.

The graph shows how the force of the bat on the ball changes with time.



The ball has a mass of 0.044 kg.

What is the speed of the ball immediately after being hit?

A 13 m s^{-1} ○

B 60 m s^{-1} ○

C 80 m s^{-1} ○

D 160 m s^{-1} ○

(Total 1 mark)

12. The question below is about three spheres **X**, **Y** and **Z**.

The relative mass and relative diameter of each sphere are given in the table.

	X	Y	Z
relative mass	1	5	1
relative diameter	1	1	5

Each sphere is dropped from rest and accelerates to its terminal speed.

What is true about the accelerations of the spheres at the instant they are released?

A The acceleration of **X** is less than that of **Y**. ○

B The acceleration of **X** is greater than that of **Z**. ○

C The acceleration of **X** is the same as that of **Y**. ○

D The acceleration of **Y** is less than that of **Z**. ○

(Total 1 mark)

13. The question below is about three spheres **X**, **Y** and **Z**.

The relative mass and relative diameter of each sphere are given in the table.

	X	Y	Z
relative mass	1	5	1
relative diameter	1	1	5

Each sphere is dropped from rest and accelerates to its terminal speed.

What is true about the terminal speeds?

A The terminal speed of **X** is greater than that of **Y**. ⬭

B The terminal speed of **X** is the same as that of **Y**. ⬭

C The terminal speed of **Y** is greater than that of **Z**. ⬭

D The terminal speed of **X** is less than that of **Z**. ⬭

(Total 1 mark)

14. **Figure 1** shows the H-shaped posts used in a game of rugby.

Figure 1

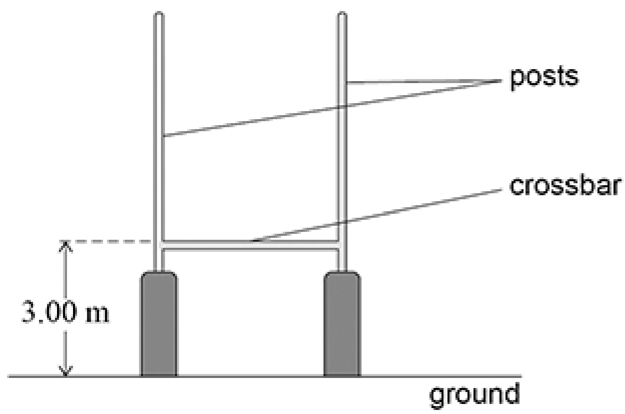
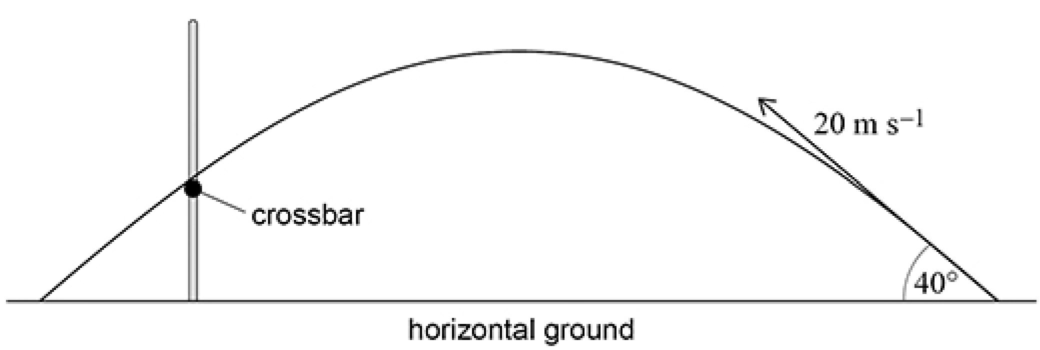


Figure 2 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is 20.0 m s^{-1} at an angle of 40.0° to the ground.

You should consider air resistance to be negligible and treat the ball as a simple projectile.

Figure 2



The top of the crossbar is 3.00 m above the horizontal ground.

(a) Show that the minimum speed of the ball in flight is about 15 m s^{-1}.

Explain your answer.

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(2)

(b) The ball just passes over the crossbar at a time t after it is kicked.

Show that t must satisfy the following equation:

$$4.91t^2 - 12.9t + 3.00 = 0$$

(2)

(c) There are two solutions to the equation

$$4.91t^2 - 12.9t + 3.00 = 0$$

Discuss which of the two solutions is the time taken for the ball to pass over the crossbar from when it is kicked.

In your answer you should

- state the value for t given by each solution
- explain the physical significance of the other solution.

solution 1 = _______________ s

solution 2 = _______________ s

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(4)

(d) Another attempt is made to kick the ball over the crossbar. The initial velocity of the ball is the same as in the first attempt.
This kick is made from a horizontal distance of 38 m from the posts.

Deduce whether the ball can pass over the crossbar.

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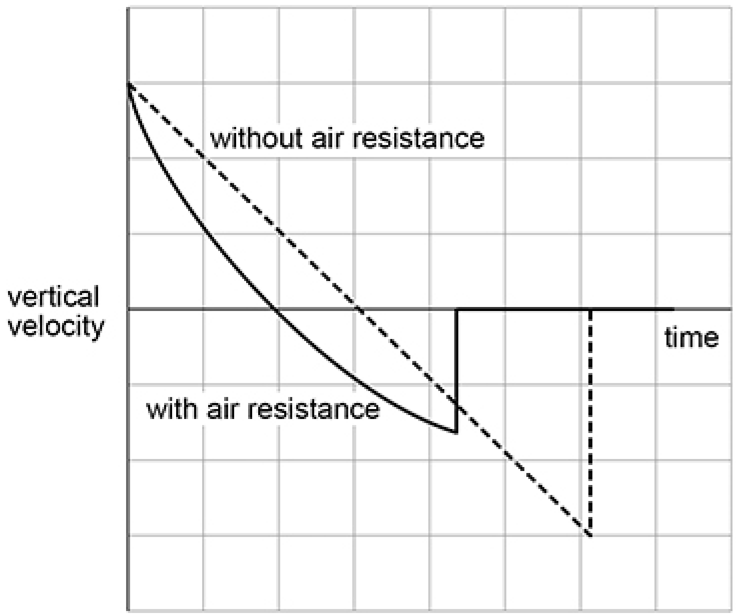
(1)

(e) **Figure 3** shows the variations with time of the vertical velocity of a ball with and without air resistance.

Figure 3



Discuss the features of the motion of the ball shown by the two graphs.

In your answer you should refer to

- the gradients of the graphs
- the area between each line and the time axis.

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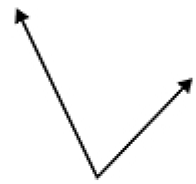
(5)

(Total 14

15. The diagram shows a vector diagram of two forces acting on an object.
The diagram is drawn to scale.
The magnitude of the smaller force is 5.0 N.



What is the magnitude of the resultant force on the object?

A 3.2 N ○

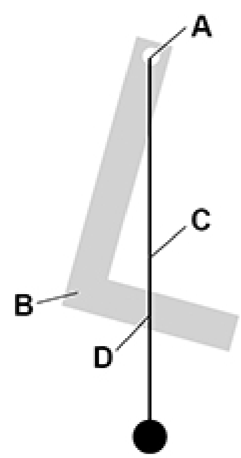
B 7.5 N ○

C 8.6 N ○

D 9.6 N ○

(Total 1 mark)

16. A uniform piece of card in the shape of the letter L is suspended freely from a horizontal pin.
A plumb line is also suspended from the pin.
The diagram shows the card in its equilibrium position.



What is the position of the centre of mass of the piece of card?

A ○

B ○

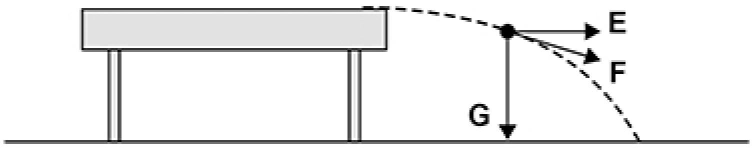
C ○

D ○

(Total 1 mark)

17. A coin is projected horizontally from the top of a desk.

The diagram shows the coin at one point in its path. The air resistance is negligible.



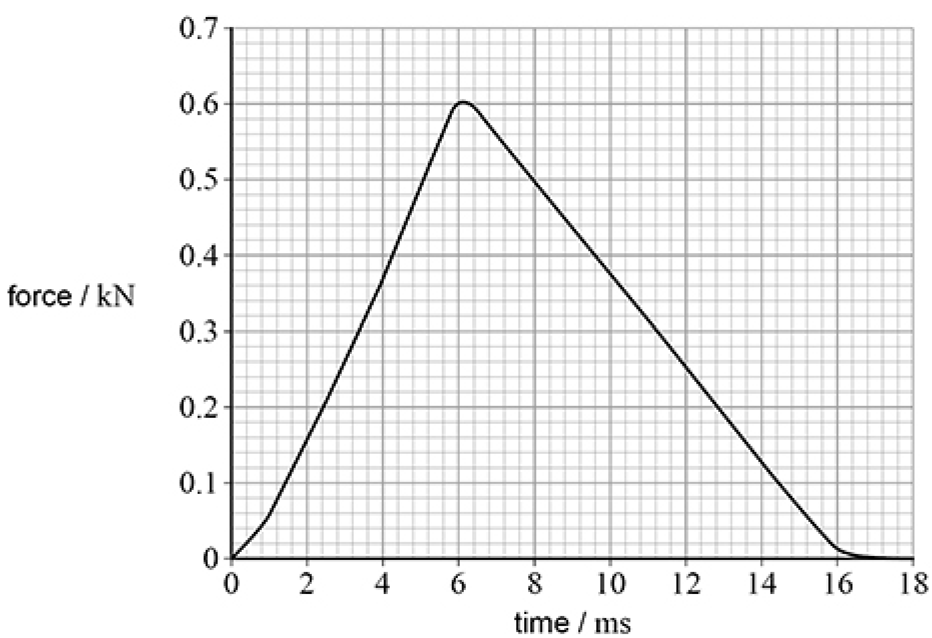
The arrows **E**, **F** and **G** represent different directions.

Which row gives the direction of the acceleration and the direction of the momentum of the coin at this point?

	Acceleration	Momentum	
A	**F**	**F**	⬭
B	**F**	**E**	⬭
C	**G**	**F**	⬭
D	**G**	**E**	⬭

(Total 1 mark)

18. A golf ball has a mass of 46 g and is initially stationary.
The diagram shows the variation with time of the force acting on the golf ball as it is hit with a golf club.



What is an estimate of the kinetic energy of the golf ball immediately after it is hit?

A 5 J ⬭

B 50 J ⬭

C 250 J ⬭

D 500 J ⬭

(Total 1 mark)

19. A Formula 1 racing car uses up its fuel during the race, causing its lap times to decrease.

The lap times decrease because

A the acceleration of the car increases. ⬭

B the drag forces on the car decrease. ⬭

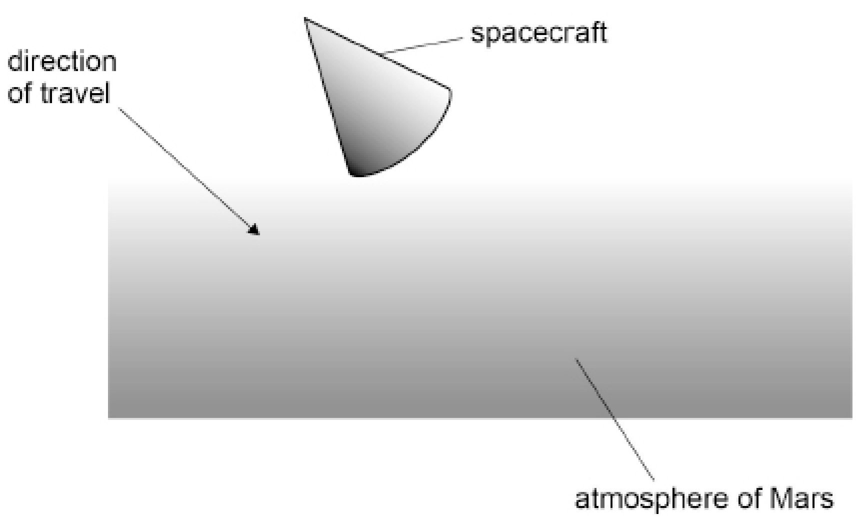
C the maximum speed of the car increases. ⬭

D the tyres become worn, reducing the friction with the road. ⬭

(Total 1 mark)

20. A spacecraft entering the atmosphere of Mars must decelerate to land undamaged on the surface.

Figure 1



(a) **Figure 1** shows the spacecraft of total mass 610 kg entering the atmosphere at a speed of 5.5 km s^{-1}.

Calculate the kinetic energy of the spacecraft as it enters the atmosphere. Give your answer to an appropriate number of significant figures.

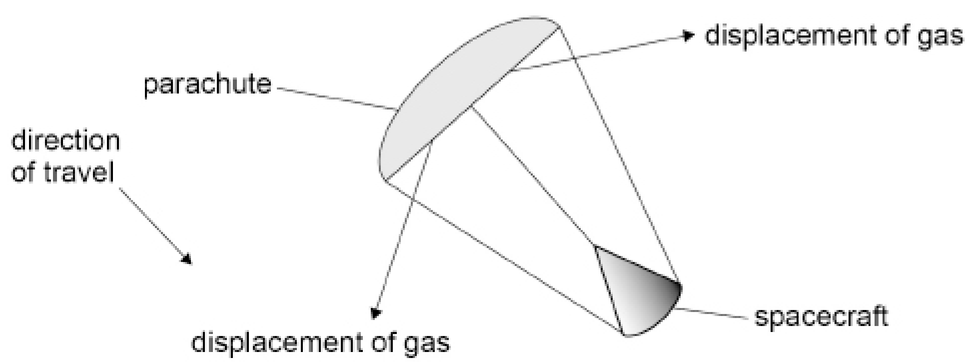
kinetic energy = ________________ J

(3)

(b) A parachute opens during the spacecraft's descent through the atmosphere.

Figure 2 shows the parachute–spacecraft system, with the open parachute displacing the atmospheric gas. This causes the system to decelerate.

Figure 2



Explain, with reference to Newton's laws of motion, why displacing the atmospheric gas causes a force on the system **and** why this force causes the system to decelerate.

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(4)

(c) As the parachute–spacecraft system decelerates, it falls through a vertical distance of 49 m and loses 2.2×10^5 J of kinetic energy.
During this time, 3.3×10^5 J of energy is transferred from the system to the atmosphere.
The total mass of the system is 610 kg.

Calculate the acceleration due to gravity as it falls through this distance.

acceleration due to gravity = ________________ m s^{-2}

(3)

(d) Dust from the surface of Mars can enter the atmosphere. This increases the density of the atmosphere significantly.

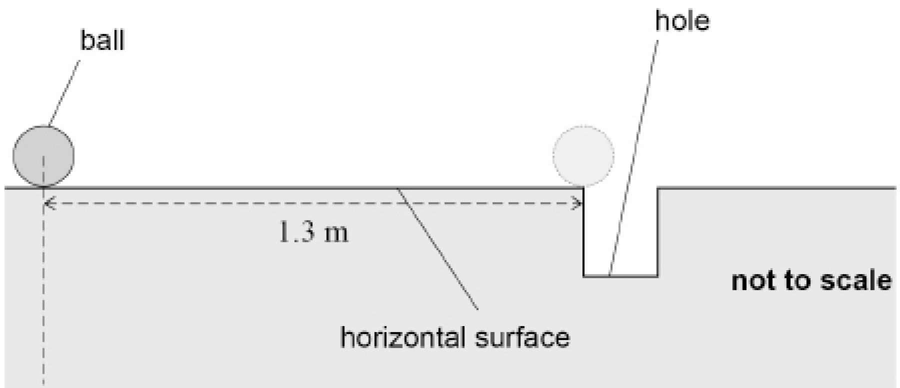
Deduce how an increase in dust content will affect the deceleration of the system.

(3)

(Total 13 marks)

21. (a) **Figure 1** shows a golf ball at rest on a horizontal surface 1.3 m from a hole.

Figure 1



A golfer hits the ball so that it moves horizontally with an initial velocity of 1.8 m s^{-1}. The ball experiences a constant deceleration of 1.2 m s^{-2} as it travels to the hole.

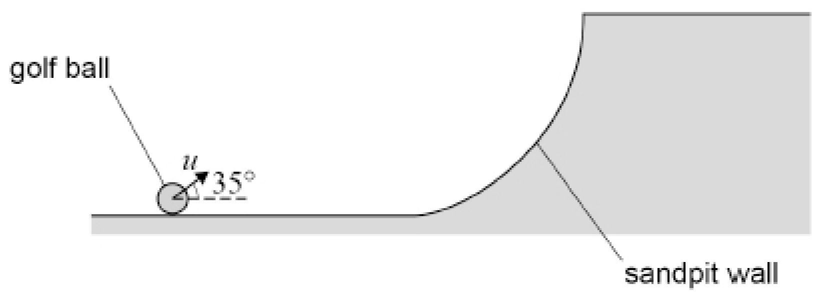
Calculate the velocity of the ball when it reaches the edge of the hole.

velocity = ________________ m s^{-1}

(2)

(b) Later, the golf ball lands in a sandpit. The golfer hits the ball, giving it an initial velocity u at 35° to the horizontal, as shown in **Figure 2**. The horizontal component of u is 8.8 m s^{-1}.

Figure 2



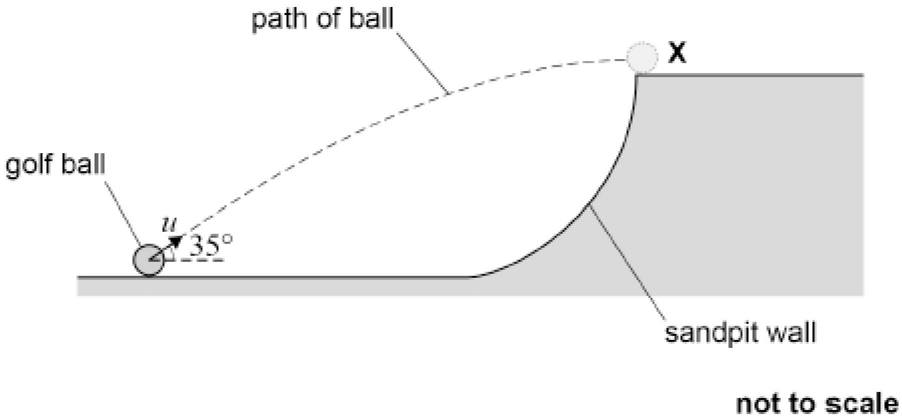
not to scale

Show that the vertical component of u is approximately 6 m s^{-1}.

(1)

(c) The ball is travelling horizontally as it reaches **X**, as shown in **Figure 3**.

Figure 3



Assume that weight is the only force acting on the ball when it is in the air.

Calculate the time for the ball to travel to **X**.

time = _______________ s

(2)

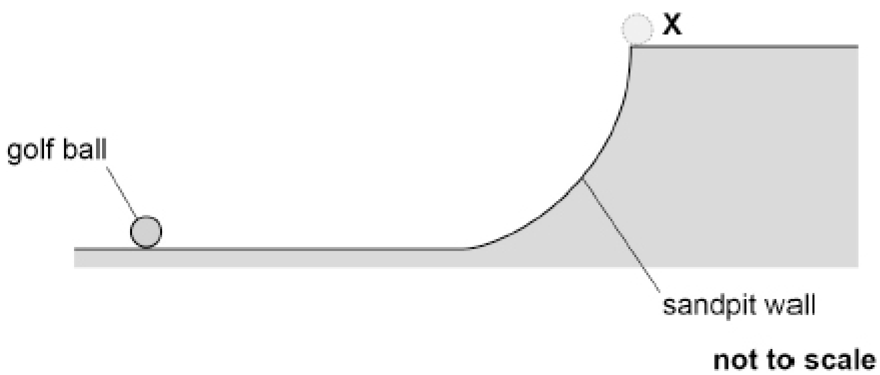
(d) Calculate the vertical distance of **X** above the initial position of the ball.

vertical distance = _______________ m

(2)

The golfer returns the ball to its original position in the sandpit. He wants the ball to land at **X** but this time with a **smaller** horizontal velocity than in **Figure 3**.

Figure 4



(e) Sketch on **Figure 4** a possible trajectory for the ball.

(1)

(f) Explain your reason for selecting this trajectory.

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(2)

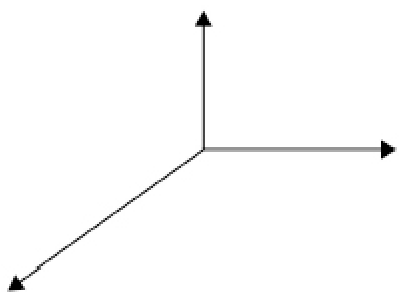
(Total 10 marks)

22. An object is in equilibrium when acted on by three coplanar forces.

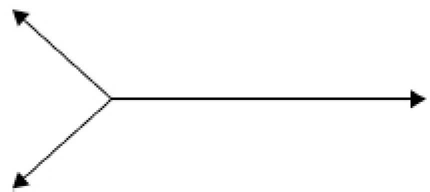
Which free-body diagram is correct?

Each diagram is drawn to scale.

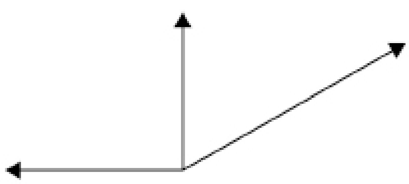
A



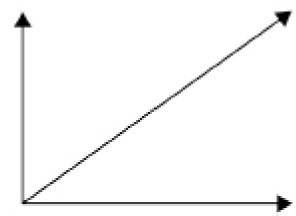
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

23. Which quantity is represented by the area under a force–time graph?

A average power ⬭

B elastic strain energy stored ⬭

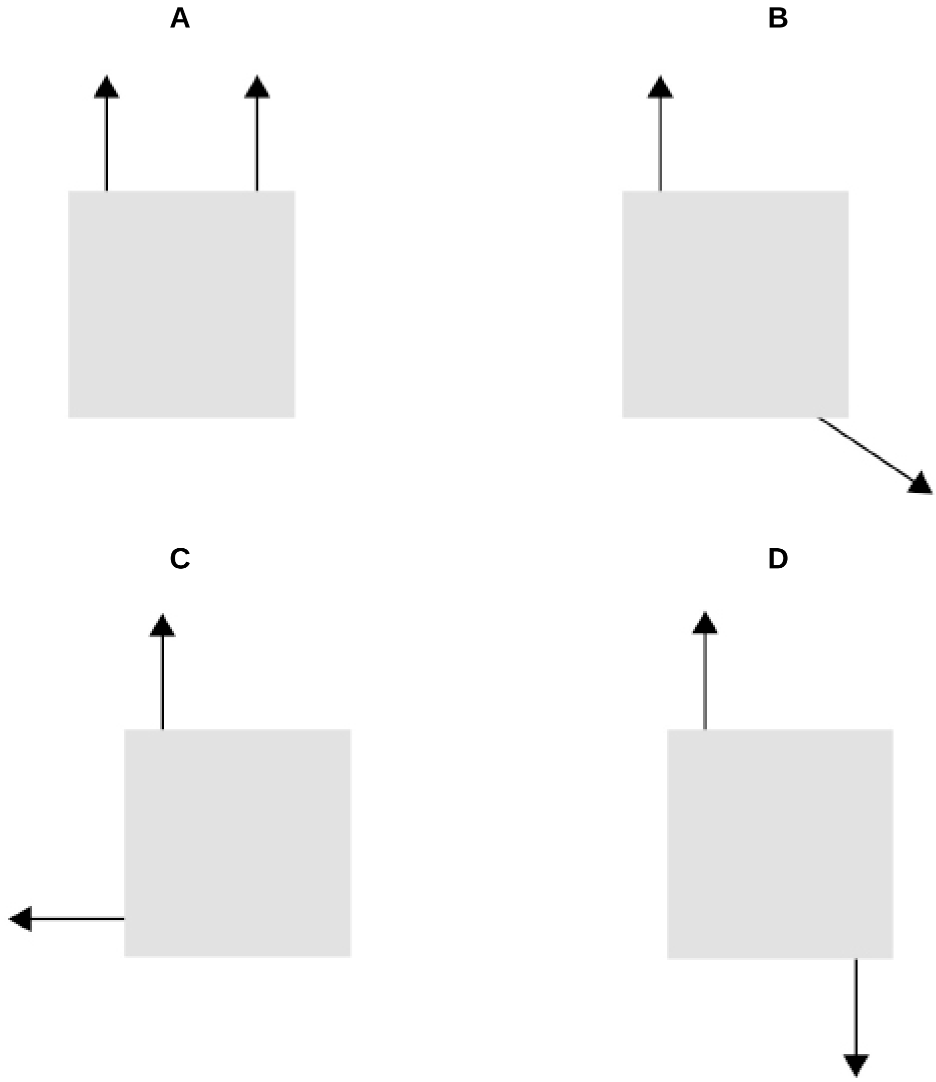
C momentum change ⬭

D work done ⬭

(Total 1 mark)

24. Each diagram shows two horizontal forces acting on a solid square object seen from above.

All the forces have the same magnitude.



Which system produces a couple about any point inside the object?

A ⬭

B ⬭

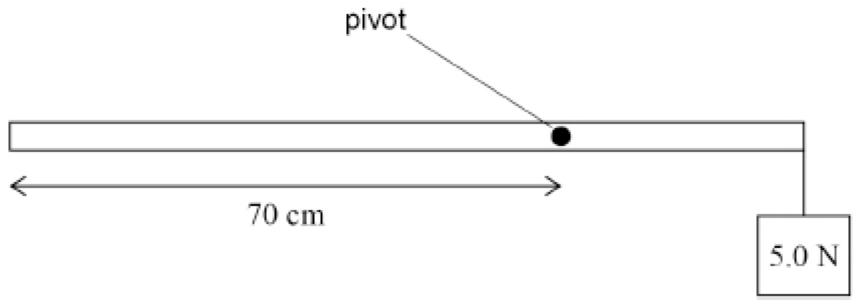
C ⬭

D ⬭

(Total 1 mark)

25. A uniform metre ruler of weight 2.0 N is freely pivoted at the 70 cm mark.

A student holds the ruler in a horizontal position and suspends a 5.0 N weight from the 100 cm end.

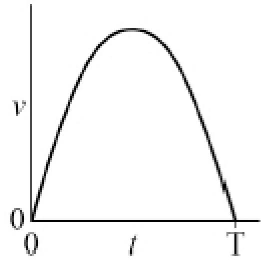


What is the magnitude of the resultant moment when the student releases the ruler?

A	0.15 N m	⬭
B	0.19 N m	⬭
C	1.1 N m	⬭
D	1.9 N m	⬭

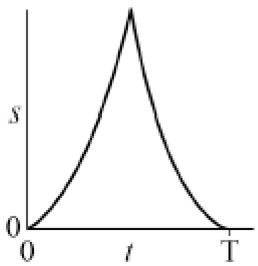
(Total 1 mark)

26. The diagram shows how the speed *v* of an object varies with time *t*.

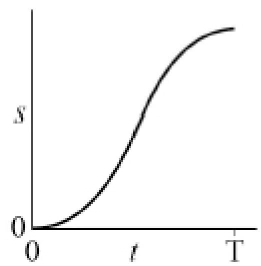


Which graph shows the variation of distance *s* with *t* for the object?

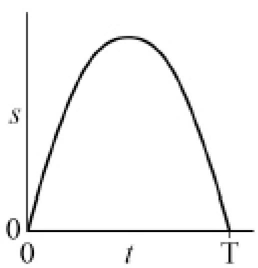
A



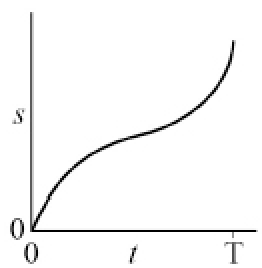
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

27. Two ball bearings **X** and **Y** are projected from horizontal ground at the same time.

X has mass $2m$ and is projected vertically upwards with speed u.

Y has mass m and is projected at 30° to the horizontal with speed $2u$.

Air resistance is negligible.

Which statement is correct?

A **X** and **Y** have the same initial momentum. ○

B **X** and **Y** reach their maximum heights at different times. ○

C The maximum height reached by **Y** is half that reached by **X**. ○

D **X** and **Y** reach the ground at the same time. ○

(Total 1 mark)

28. Which row is true for an elastic collision between two objects in an isolated system?

	Kinetic energy	**Momentum**	
A	conserved	conserved	○
B	not conserved	conserved	○
C	conserved	not conserved	○
D	not conserved	not conserved	○

(Total 1 mark)

29. The drag force on a boat is kv^2, where v is the speed and k = 64 kg m^{-1}.

The boat's engine has a useful power output of 8000 W.

What is the maximum speed of the boat?

A 0.2 m s^{-1} ○

B 5 m s^{-1} ○

C 11 m s^{-1} ○

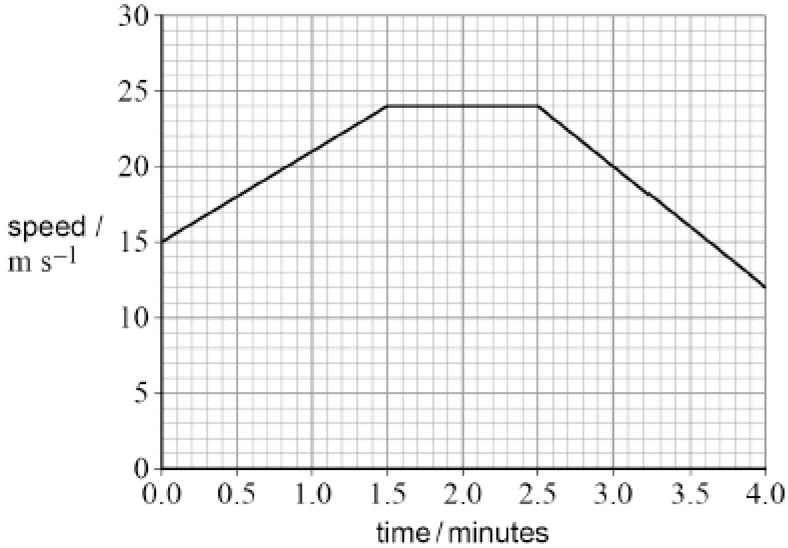
D 125 m s^{-1} ○

(Total 1 mark)

30. A pair of cameras is used on a motorway to help determine the average speed of vehicles travelling between the two cameras.

Figure 1 shows the speed–time graph for a car moving between the two cameras.

Figure 1



(a) The speed limit for the motorway between the two cameras is 22 m s^{-1}.

Determine whether the average speed of the car exceeded this speed limit.

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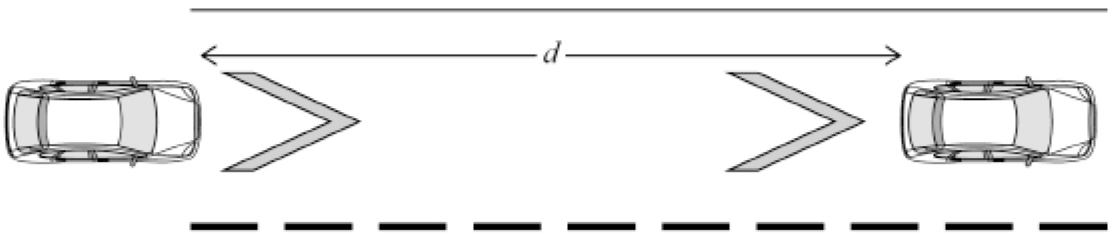
(3)

(b) Markings called chevrons are used on motorways.

The chevron separation is designed to give a driver time to respond to any change in speed of the car in front. The driver is advised to keep a minimum distance d behind the car in front, as shown in **Figure 2**.

Figure 2



not to scale

Government research suggests that the typical time for a driver to respond is between 1.6 s and 2.0 s.

Suggest a value for d where the speed limit is 31 m s^{-1}.

d = ____________________ m

(2)

(c) The chevron separation is based on the response time, not on the time taken for a car to stop.

The brakes of a car are applied when its speed is 31 m s^{-1} and the car comes to rest. The total mass of the car is 1200 kg.

The average braking force acting on the car is 6.8 kN.

Calculate the time taken for the braking force to stop the car **and** the distance travelled by the car in this time.

time = _______________ s

distance = _______________ m

(4)

(d) Suggest why the chevron separation on motorways does not take into account the distance travelled as a car comes to rest after the brakes are applied.

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(1)

(e) At bends on motorways the road is sloped so that a car is less likely to slide out of its lane when travelling at a high speed.

Figure 3 shows a car of mass 1200 kg travelling around a curve of radius 200 m. The motorway is sloped at an angle of 5.0°.

Figure 4 shows the weight W and reaction force N acting on the car. The advisory speed for the bend is chosen so that the friction force down the slope is zero.

Figure 3

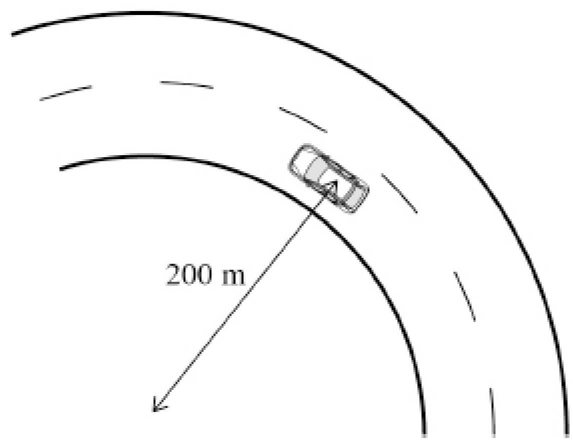
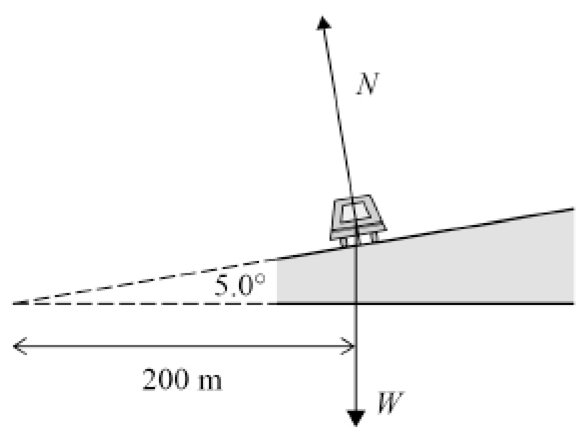


Figure 4



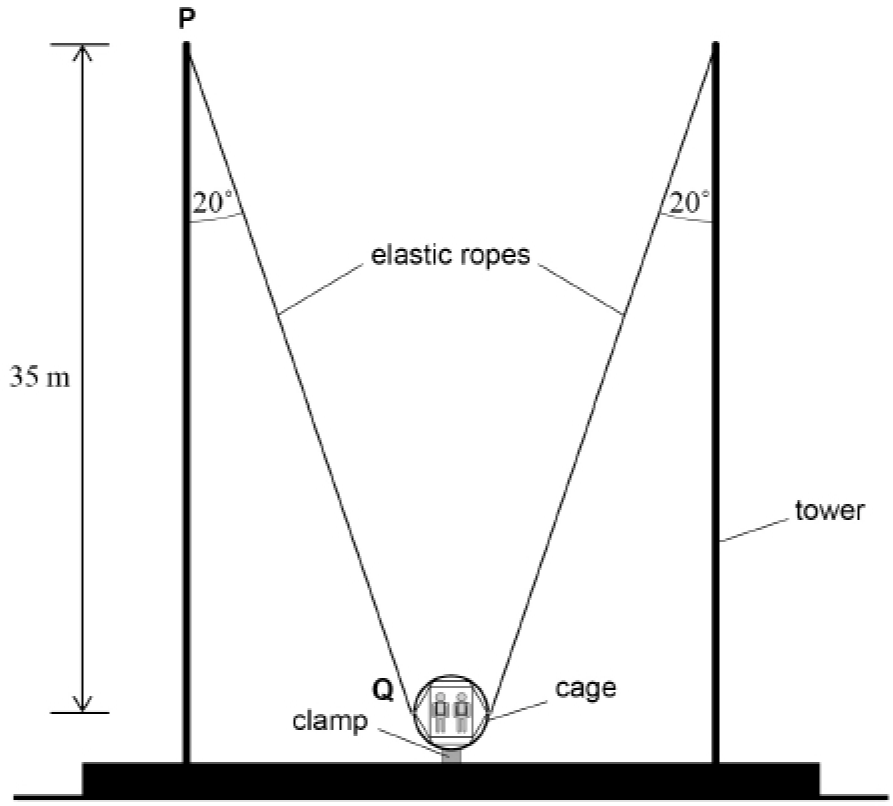
Suggest an appropriate advisory speed for this section of the motorway.

advisory speed = _______________ m s^{-1}

(4)

(Total 14 marks)

31. The diagram shows a fairground ride called a 'reverse bungee'.



Two identical stretched elastic ropes are fixed to a cage with passengers inside. The loaded cage is held in place by a clamp. When the clamp is released the elastic ropes accelerate the loaded cage vertically into the air.

P is the point where the rope attaches to the top of the vertical tower.
Q is the point where the rope attaches to the cage. **Q** is level with the centre of mass of the loaded cage.

Before release, the tension T in each elastic rope is 3.7×10^4 N and each rope makes an angle of 20° with the vertical tower.

The total mass M of the loaded cage is 1.2×10^3 kg and the mass of the elastic ropes is negligible.

(a) Show that the downward force F exerted by the clamp on the loaded cage is about 6×10^4 N.

(4)

(b) Calculate the initial acceleration of the loaded cage when the clamp is released.

acceleration = ____________________ m s^{-2}

(2)

(c) The unstretched length of each elastic rope is 24 m. The ropes obey Hooke's Law for all extensions used in the ride.
The **vertical** distance between points **P** and **Q** on the diagram above is 35 m.

Show that the total elastic potential energy stored in both ropes before the loaded cage is released is about 5×10^5 J.

(4)

(d) The designers of the ride claim that the loaded cage will reach a height of 50 m above **Q**.

Deduce whether this claim is justified.

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(3)

(e) The designers also claim that the loaded cage reaches a maximum speed of at least 90 km h^{-1}.

Calculate, in J, the kinetic energy of the loaded cage when it travels at 90 km h^{-1}.

kinetic energy = ____________________ J

(3)

(f) Deduce without further calculation whether the maximum speed claim is justified.

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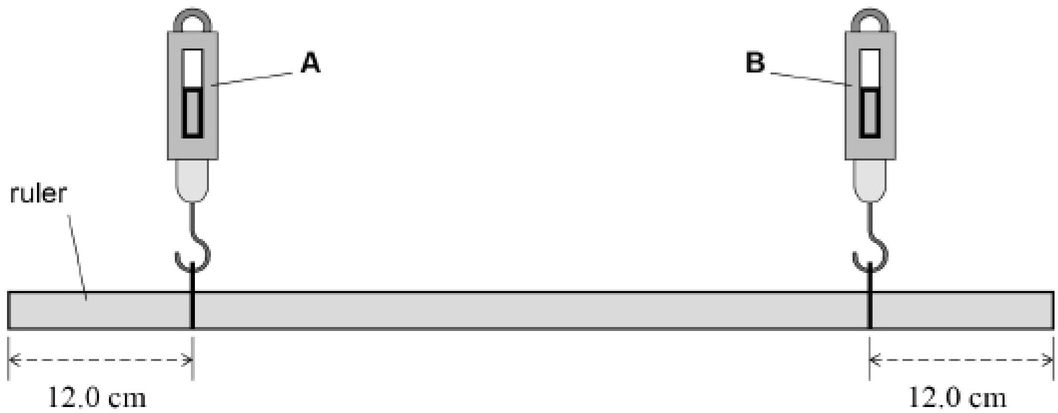
(1)

(Total 17 marks)

32. A student investigates moments by suspending a 100 cm ruler from two force meters, **A** and **B**. **A** and **B** are attached to the ruler 12.0 cm from each end. Their supports are adjusted to make **A** and **B** vertical and the ruler horizontal.

Figure 1 is a simplified diagram of the experiment.

Figure 1



(a) The ruler is uniform and weighs 1.12 N.

Determine the reading on **A**.

reading = ____________________ N

(1)

(b) The student suggests that the forces exerted on the ruler by **A** and **B** act as a couple.

Discuss whether his suggestion is correct.

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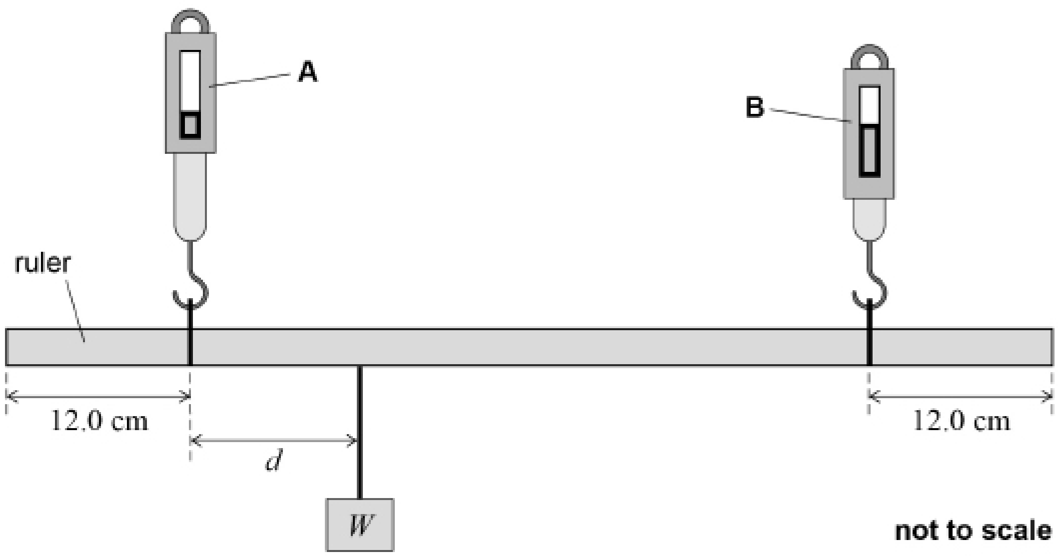
(2)

(c) The student hangs a mass of weight W on the ruler between **A** and **B**, as shown in **Figure 2**.

He adjusts the supports so that **A** and **B** are again vertical and the ruler is horizontal. The mass hangs at a distance d from **A**.

Figure 2



The reading on **A** is 0.82 N and the reading on **B** is 0.62 N.

Determine

- W
- d.

W = ______________________ N

d = ______________________ m

(4)

(d) A second student sets up the same apparatus as shown in **Figure 2**.
She suspends the mass in the same position on the ruler as in question (c).
She moves the supports to make **A** and **B** vertical but does not make the ruler horizontal.

Discuss whether the readings on **A** and **B** taken by this student are different to those in question (c).

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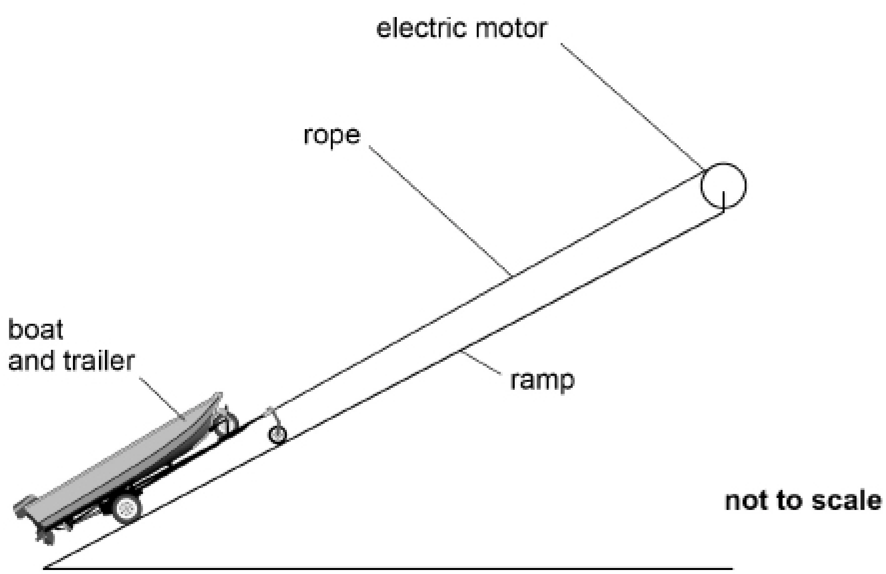
(2)
(Total 9 marks)

33. This question is about the initial motion of a boat and trailer when pulled up a ramp as shown in **Figure 1**.

Figure 1

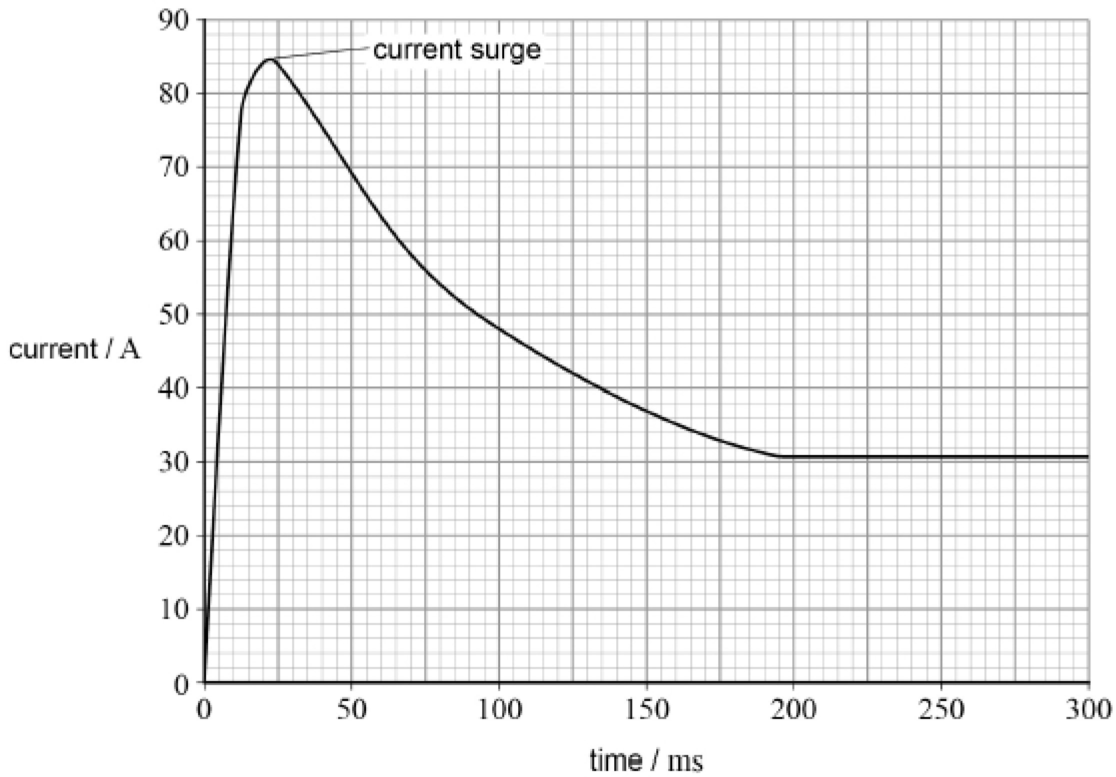


The boat and trailer are pulled by a motor which is connected to a 24 V battery of negligible internal resistance.

The motor is switched on at time t = 0

Figure 2 shows how the current in the motor's circuit varies with time.

Figure 2



(a) Determine the total energy input by the 24 V battery to the motor in the first 200 ms.

total energy input = ____________________ J

(3)

(b) The boat and trailer are initially at rest. In the first 200 ms the boat and trailer are raised through a vertical height of 3.3×10^{-2} m and the speed increases to 0.85 m s^{-1}.

Assume that all the useful energy output by the motor is transferred into kinetic energy and gravitational potential energy of the boat and trailer.
The boat and trailer have a total mass of 180 kg.

Determine the average efficiency of the motor during these first 200 ms.

average efficiency = ____________________

(3)

(c) Either of the circuits shown in **Figure 3a** and **Figure 3b** could be used to reduce the initial current surge.

Figure 3a

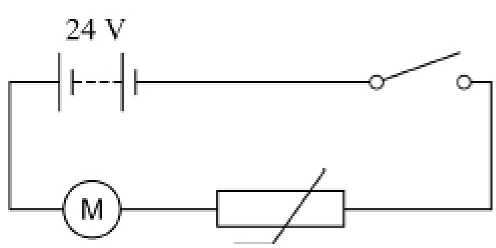
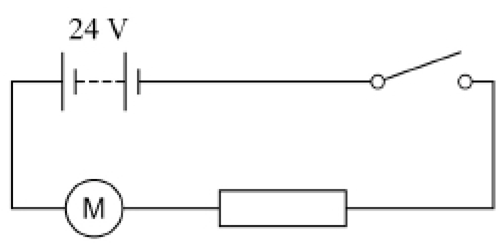


Figure 3b



The thermistor and the fixed resistor have the same resistance when they are at the temperature of the surroundings.

When the surge has ended, the boat and trailer continue to move at a constant speed to the top of the ramp.

Explain, with reference to the properties of the thermistor and the fixed resistor, why using the thermistor is preferable to using the fixed resistor.

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(3)

(Total 9 marks)

34. A railway truck of mass 2000 kg travelling horizontally at 1.5 m s^{-1} collides with a stationary truck of mass 3000 kg.
After the collision they move together.

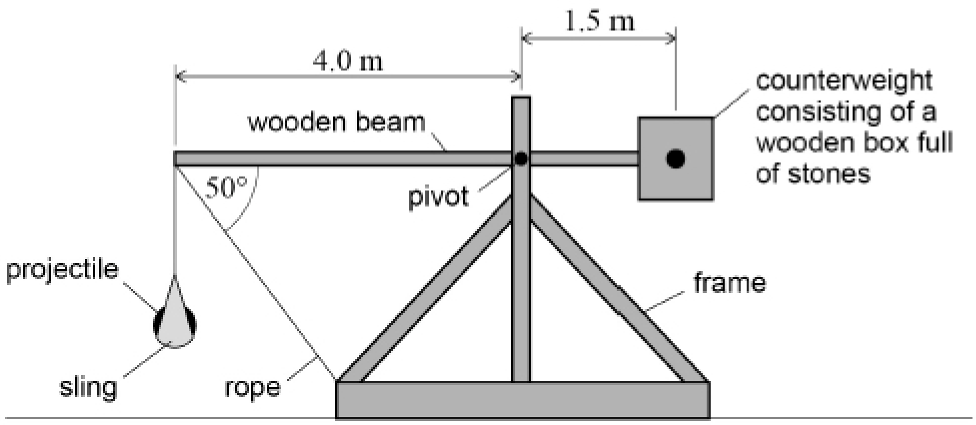
Which row is correct?

	Speed of the trucks immediately after collision / m s^{-1}	**Effect of collision on total kinetic energy**	
A	0.6	no change	⬭
B	0.6	decrease	⬭
C	1.0	no change	⬭
D	1.0	decrease	⬭

(Total 1 mark)

35. **Figure 1** shows a simplified catapult used to hurl projectiles a long way.

Figure 1



The counterweight is a wooden box full of stones attached to one end of the beam. The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.
The beam is held horizontal by a rope attached to the frame.

(a) The catapult is designed so that the weight of the beam and the weight of the **empty** wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

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(2)

(b) The stones in the counterweight have a total mass of 610 kg and the projectile weighs 250 N.

Calculate the tension in the rope.

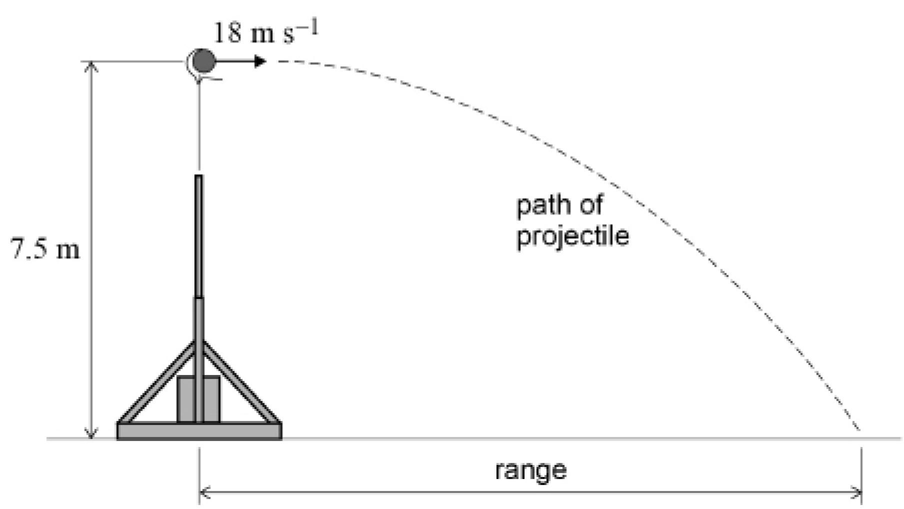
tension = ____________________ N

(5)

(c) When the rope is cut, the counterweight rotates clockwise. When the beam is vertical it is prevented from rotating further. The projectile is then released horizontally with a velocity of 18 m s^{-1}, as shown in **Figure 2**.

The projectile is released at a height of 7.5 m above ground level.

Figure 2



The range of the catapult is the horizontal distance between the point where the projectile is released to the point where it lands.

Calculate the range.
Ignore air resistance.

range = ______________________ m

(2)

(d) In another release, the sling is adjusted so that a projectile of the same mass is released just before the wooden beam is vertical. The projectile is not released horizontally.

Discuss the effect this change has on the range of the catapult.

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(3)

(Total 12 marks)

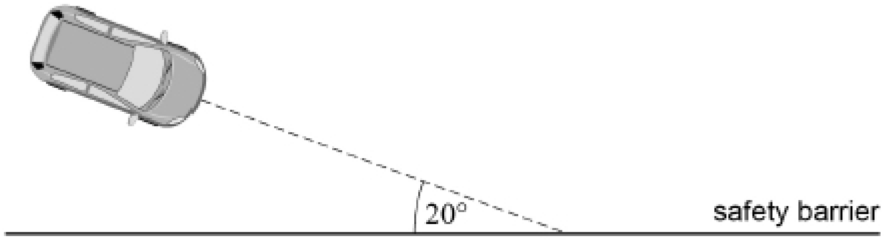
36. Safety barriers are used on UK motorways to prevent vehicles crossing from one carriageway to the other carriageway. The barriers also absorb some of the kinetic energy of a vehicle and deflect vehicles along the barrier.

The standard test of a safety barrier uses a vehicle that contains dummies. The total mass of the vehicle and its contents is 1.5×10^3 kg and its initial speed is 110 km h^{-1}.

(a) Show that the initial kinetic energy of the test vehicle is 700 kJ.

(2)

(b) The test vehicle hits a steel safety barrier at an angle of 20°, as shown in the diagram.



Calculate the component of the momentum of the test vehicle in a direction along the line of the safety barrier.
Give an appropriate unit for your answer.

momentum = ____________________ unit _________

(3)

(c) Immediately after the collision, the test vehicle moves along the safety barrier with no change in its momentum in this direction.

Show that the kinetic energy lost in the collision is about 80 kJ.

(3)

(d) The steel safety barrier deforms during the collision. For the barrier to pass the test, the test vehicle should not move more than 1.5 m towards the other carriageway.

The barrier can apply an average force of 60 kN at right angles to the carriageway.

Deduce whether the safety barrier will pass the test.

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(3)

(e) A different safety barrier uses a solid concrete wall which does not deform.
The same standard test is carried out on a concrete wall.

Discuss which type of barrier would cause less damage to the dummies in the test.

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(2)

(Total 13 marks)

37. A body of constant mass falls freely due to gravity.

The rate of change of momentum of the body is equal to its

A kinetic energy.

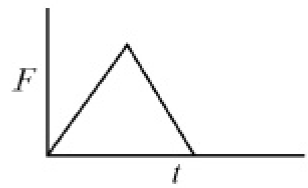
B mass.

C gravitational potential energy.

D weight.

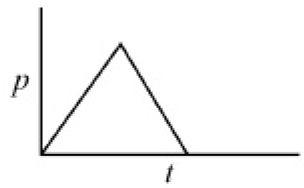
(Total 1 mark)

38. The graph shows how the resultant force F on a football, which is initially at rest, varies with time t.

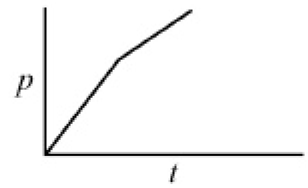


Which graph shows how the momentum p of the football varies with time t?

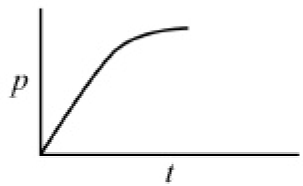
A



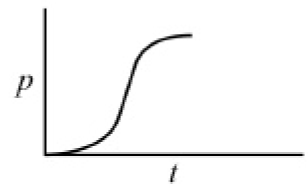
B



C



D



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

39. Objects **P** and **Q** are initially at rest at time $t = 0$

The same resultant force F is applied to **P** and **Q** for time T.

The mass of **P** is 10 times greater than the mass of **Q**.

What is the ratio $\dfrac{\textbf{kinetic energy of P}}{\textbf{kinetic energy of Q}}$?

A 0.1

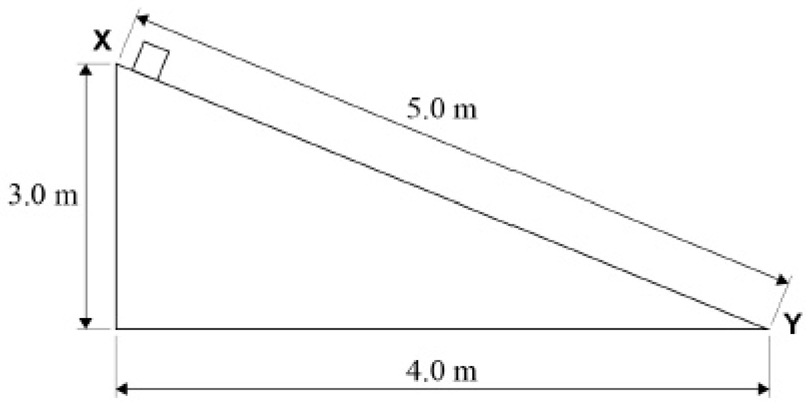
B 1

C 10

D 100

(Total 1 mark)

40. A mass of 2.5 kg is released from rest at **X** and slides down a ramp, of height 3.0 m, to point **Y** as shown.



When the mass reaches **Y** at the bottom of the ramp it has a velocity of 5.0 m s^{-1}.

What is the average frictional force between the mass and the ramp?

A 8.5 N

B 10.6 N

C 14.7 N

D 24.5 N

(Total 1 mark)