AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 2

SCORE	PERCENTAGE
/203	%

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1. 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)

2. 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 ⬭

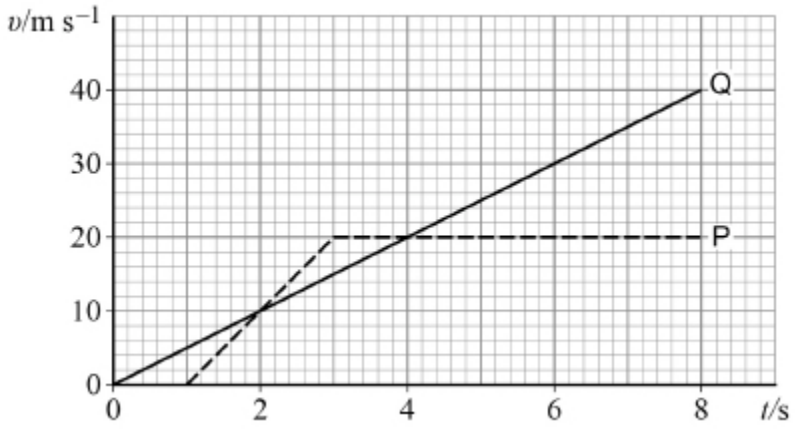
C mv^2 ⬭

D $\frac{mv^2}{2}$ ⬭

(Total 1 mark)

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3. Two cars **P** and **Q** leave from the same point and travel in the same direction.
Q leaves at time $t = 0$ and **P** leaves one second later.
The figure shows the velocity–time graph for **P** and **Q**.



What is the distance between **Q** and **P** when $t = 8$ s?

A 40 m ⬭

B 80 m ⬭

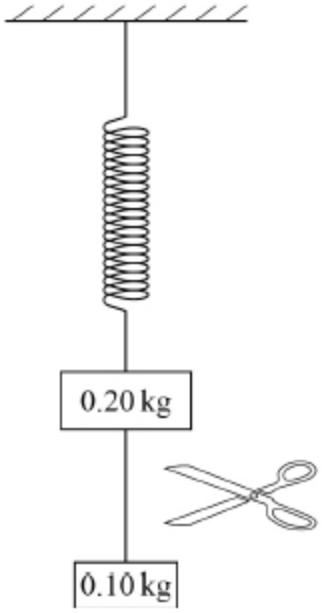
C 160 m ⬭

D 180 m ⬭

(Total 1 mark)

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4. A 0.20 kg mass is suspended from a spring. A 0.10 kg mass is suspended from the 0.20 kg mass using a thread of negligible mass.
The system is in equilibrium and the thread is then cut.



What is the upward acceleration of the 0.20 kg mass at the instant that the thread is cut?

A 3.3 m s^{-2} ⬭

B 4.9 m s^{-2} ⬭

C 6.5 m s^{-2} ⬭

D 9.8 m s^{-2} ⬭

(Total 1 mark)

5. A lift of mass M is suspended from a cable. The lift descends with a downward acceleration, a. A frictional force F acts on the lift.

What is the tension T in the cable?

A $T = Ma + F$ ⬭

B $T = Ma - F$ ⬭

C $T = M(g + a) - F$ ⬭

D $T = M(g - a) - F$ ⬭

(Total 1 mark)

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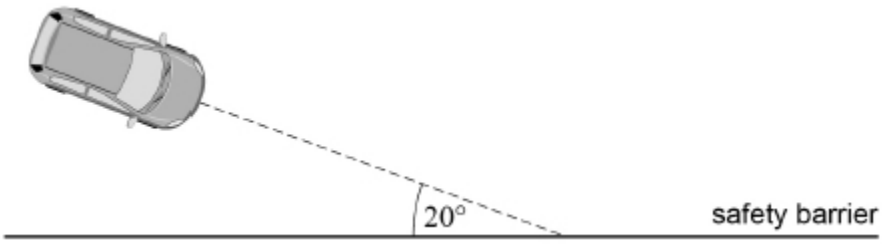
6. Safety barriers are used on UK motorways to prevent vehicles crossing from one carriageway to the other carriageway. The barriers also absorb some of the kinetic energy of a vehicle and deflect vehicles along the barrier.

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)

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(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.

_____

_____

(3)

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(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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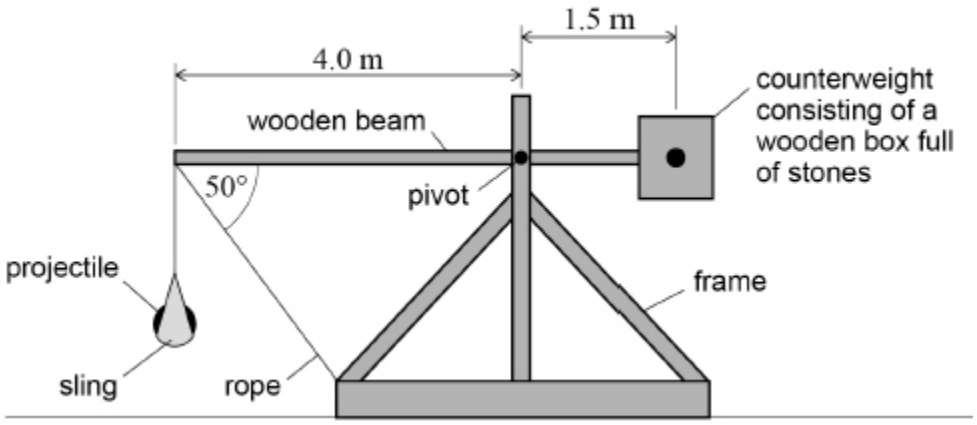
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(2)

(Total 13 marks)

7. **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.

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(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

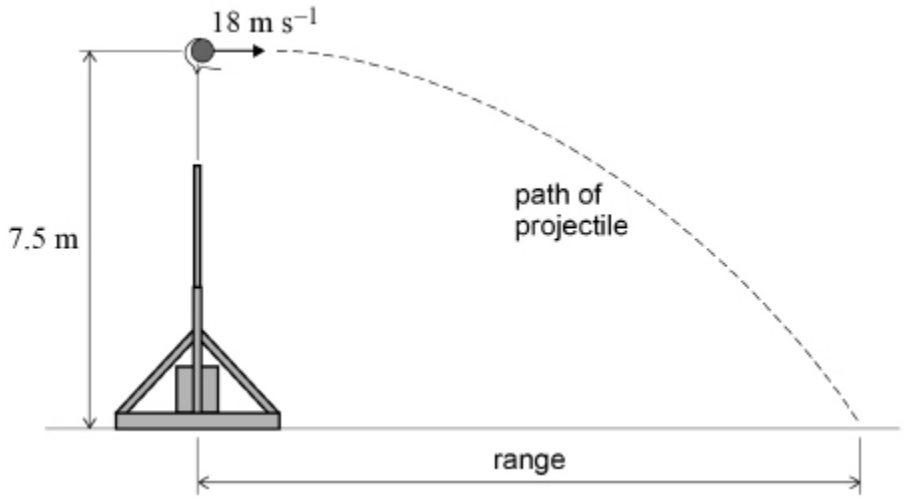
(5)

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(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)

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(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)

8. Which quantities can be written in the fundamental units kg m^{-1} s^{-2}?

A Tensile stress and kinetic energy ⬭

B The moment of a force and kinetic energy ⬭

C Young modulus and the moment of a force ⬭

D Young modulus and tensile stress ⬭

(Total 1 mark)

9. A car of mass 1000 kg accelerates uniformly from rest to a speed of 25.0 m s^{-1} in 50.0 s. The car is travelling along a horizontal road.

What is the average useful power output of the car over this period?

A 0.50 kW ⬭

B 2.00 kW ⬭

C 6.25 kW ⬭

D 12.5 kW ⬭

(Total 1 mark)

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10. 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?

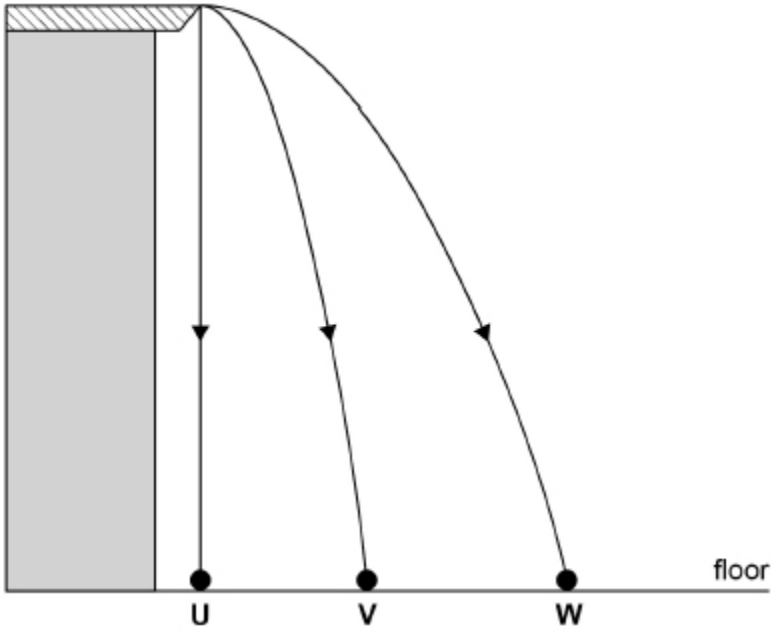
	Speed of the trucks immediately after collision / m s^{-1}	Effect of collision on total kinetic energy	
A	0.6	no change	⬭
B	0.6	decrease	⬭
C	1.0	no change	⬭
D	1.0	decrease	⬭

(Total 1 mark)

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11. Three objects **U**, **V** and **W** leave the edge of a bench at the same time.
The objects fall in the same vertical plane with negligible air resistance.
U is released from rest so that it falls vertically.
V and **W** are projected horizontally.

The paths of the three objects are shown.



Which statement is correct?

A **U** hits the floor before **V** and **W**. ⬭

B **W** hits the floor before **V**. ⬭

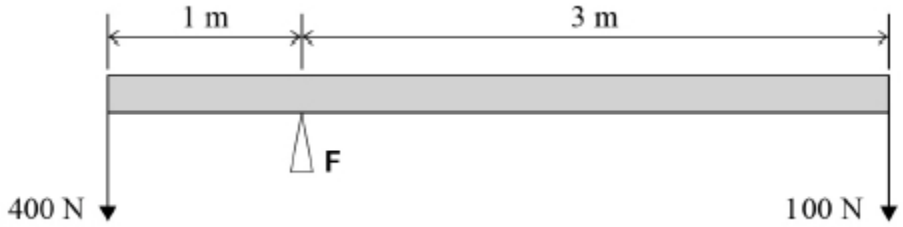
C **W** hits the floor with the greatest speed. ⬭

D **U** hits the floor with the greatest speed. ⬭

(Total 1 mark)

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12. A uniform rod is balanced horizontally about a support **F**. Forces of 400 N and 100 N act at the ends of the rod, as shown.



What is the reaction force acting on the rod at support **F**?

A 100 N ⬭

B 500 N ⬭

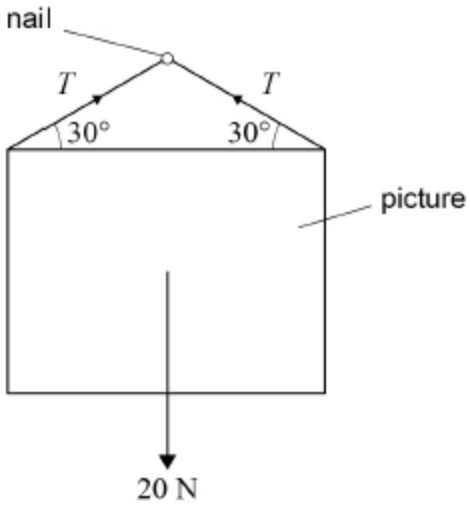
C 550 N ⬭

D 600 N ⬭

(Total 1 mark)

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13. A uniform picture is suspended from a string which passes over a smooth nail. The tension in the string is T and the weight of the picture is 20 N.



What is T?

A 10 N ⬭

B 12 N ⬭

C 20 N ⬭

D 40 N ⬭

(Total 1 mark)

14. Which row contains vector quantities only?

A	acceleration	mass	⬭
B	displacement	momentum	⬭
C	energy	force	⬭
D	distance	speed	⬭

(Total 1 mark)

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15. What is the approximate average kinetic energy of a cyclist in a race?

A 10 J ⬭

B 10 kJ ⬭

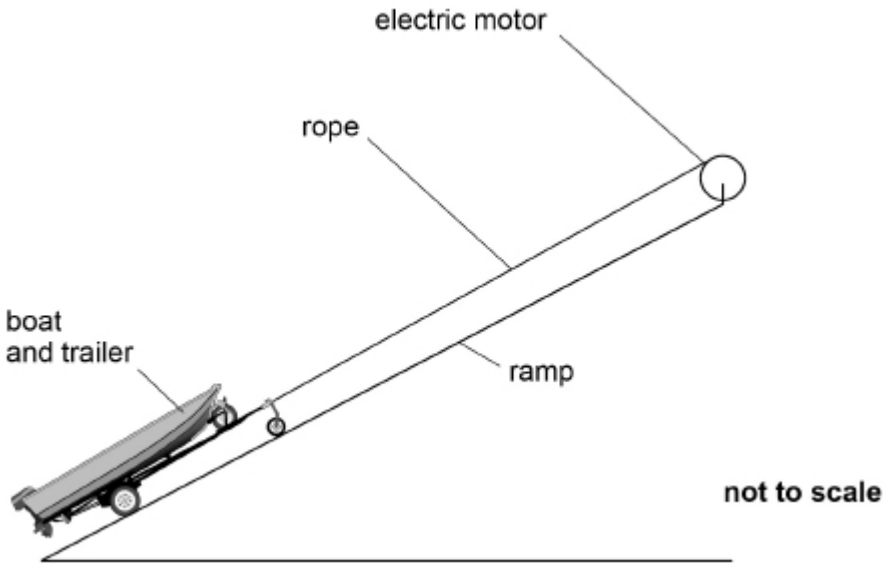
C 10 MJ ⬭

D 10 TJ ⬭

(Total 1 mark)

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

Figure 1



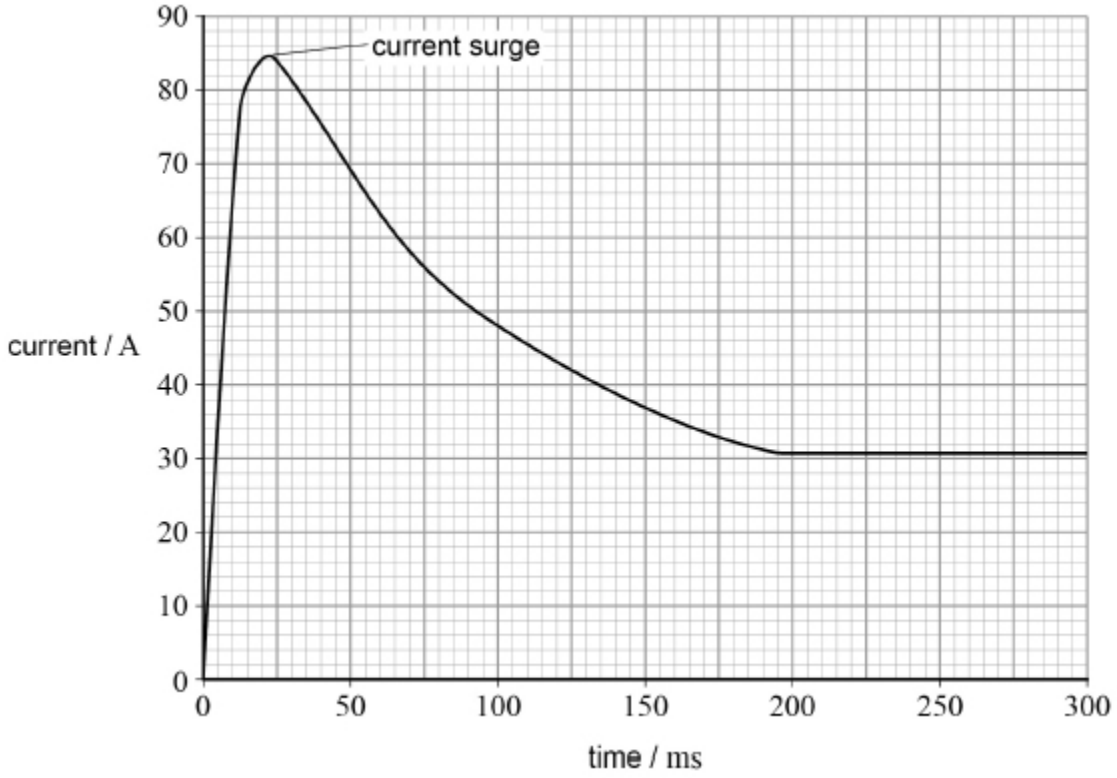
The boat and trailer are pulled by a motor which is connected to a 24 V battery of negligible internal resistance.

The motor is switched on at time $t = 0$

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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)

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(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

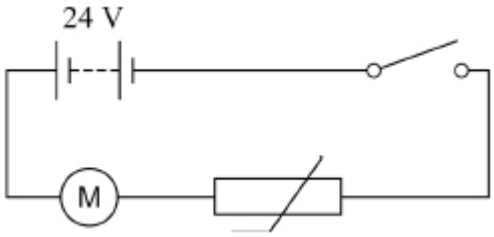
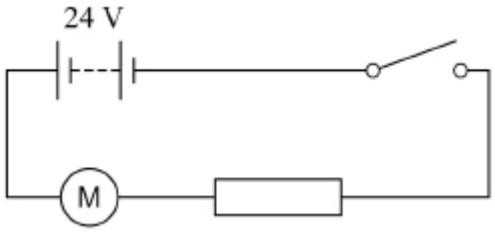


Figure 3b



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.

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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)

17. An electric motor lifts a load of weight W through a vertical height h in time t. The potential difference across the motor is V and the current in it is I.

What is the efficiency of the motor?

A $\frac{Wh}{VIt}$ ⬭

B $\frac{VI}{Wht}$ ⬭

C $\frac{Wht}{VI}$ ⬭

D $\frac{VIt}{Wh}$ ⬭

(Total 1 mark)

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18. This question is about two applications of photon energy and momentum: positron emission tomography (PET) and a solar sail.

$$\text{The momentum of a photon is } \frac{\text{photon energy}}{\text{speed of light in a vacuum}}$$

(a) In preparing for a PET scan of a patient's brain, a small sample of a substance containing unstable nuclei is injected into the patient.
A positron is emitted when one of the unstable nuclei undergoes β^+decay.

Explain how the change in quark character in β^+decay affects the number of neutrons and the number of protons in the unstable nucleus.

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(2)

(b) The positron interacts with an electron, resulting in annihilation. As a result, gamma photons are produced.
The energy of each gamma photon is 0.52 MeV.

Calculate the momentum, in N s, of one of the gamma photons produced in this annihilation.

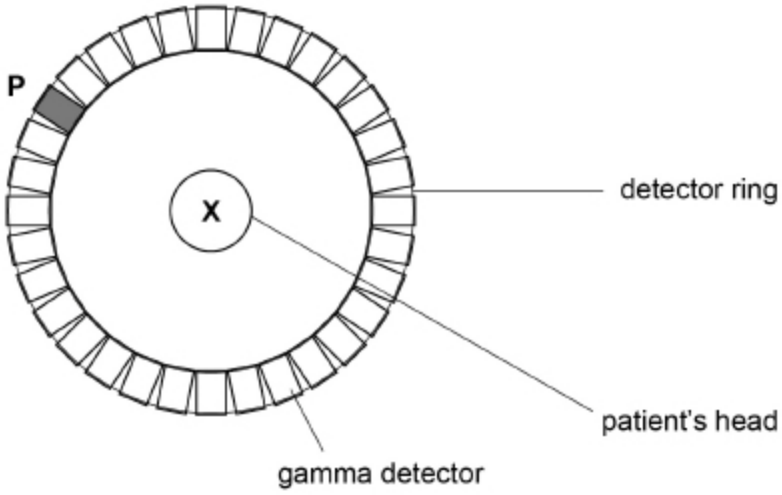
momentum = _____ N s

(2)

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(c) **Figure 1** shows a cross-sectional view of the patient's head inside a ring of gamma detectors during the PET scan.

Figure 1



A positron and an electron meet and annihilate at position **X** shown in **Figure 1**. Assume they have negligible kinetic energy when they meet.

Gamma photons are produced in this annihilation and are detected. The arrival of one gamma photon at detector **P** triggers a signal. Detector **P** has been shaded in **Figure 1**.

Identify by shading any other detectors that will be triggered by this annihilation.

(1)

(d) Explain your answer to question **(c)**.

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(2)

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(e) **Figure 2** shows a stream of photons of light, emitted from the Sun, incident on a solar sail. A solar sail is an experimental spacecraft that uses photons of light to accelerate it.

Figure 2

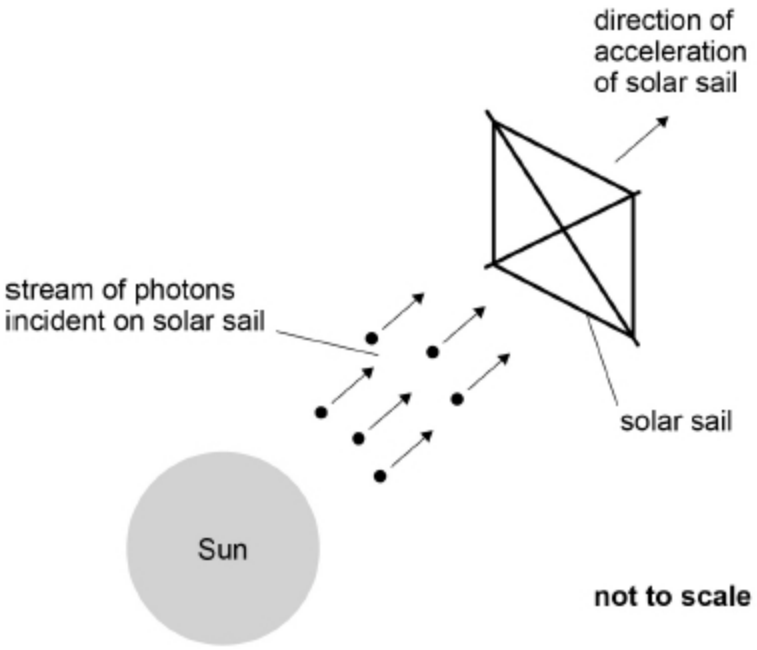
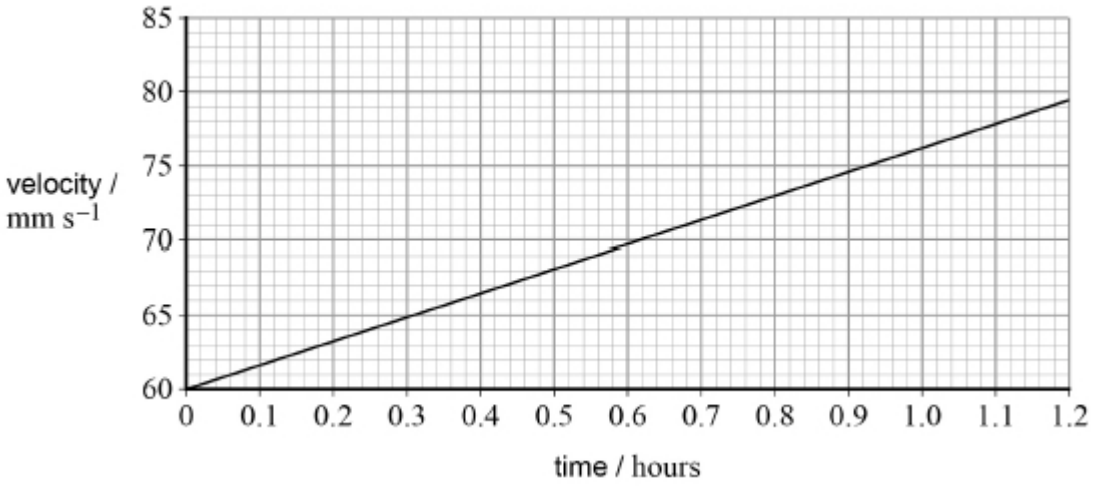


Figure 3 shows the velocity–time graph for the solar sail.

Figure 3



Calculate the acceleration, in m s^{-2}, of the solar sail.

acceleration = _____ m s^{-2}

(2)

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(f) The reflectance of a surface is proportional to the percentage of incident photons that are reflected off the surface.

Explain the effect of increasing the reflectance of the solar sail on the acceleration. Assume gravity has negligible effect on the solar sail.

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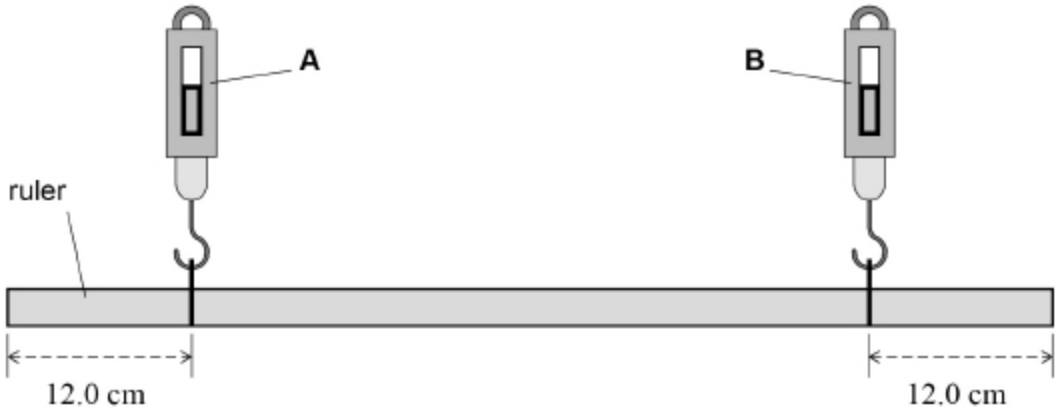
(2)

(Total 11 marks)

19. 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



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(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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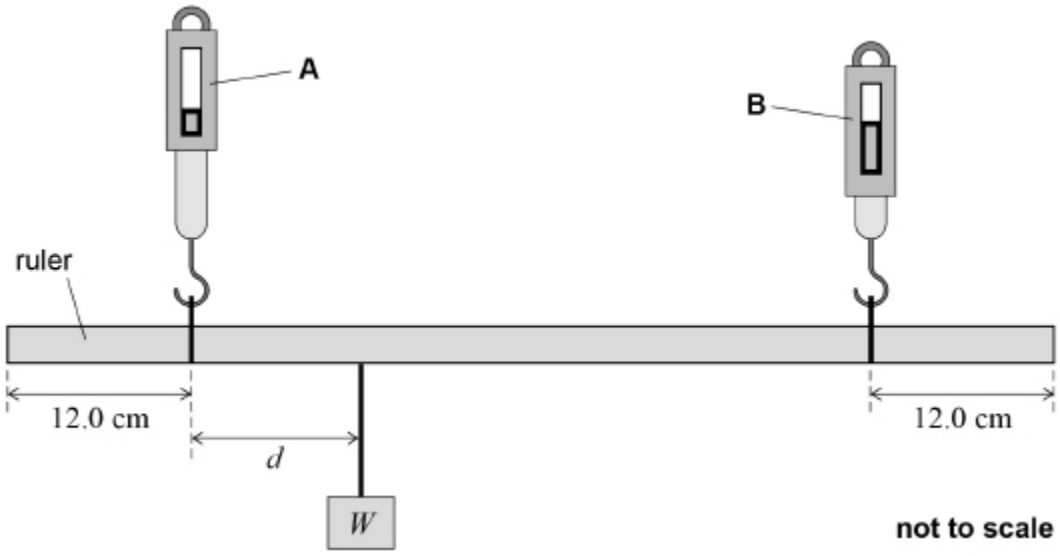
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(2)

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(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)

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(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)

20. A particle of mass m undergoes simple harmonic motion with amplitude A and frequency f.

What is the total energy of the particle?

A $2\pi mfA^2$ ⬭

B $2\pi^2 mf^2A^2$ ⬭

C $4\pi^2 m^2 f^2 A$ ⬭

D $4\pi^2 mf^2A^2$ ⬭

(Total 1 mark)

21. The period of a simple pendulum is doubled when the pendulum length is increased by 1.8 m.

What is the original length of the pendulum?

A 0.45 m ⬭

B 0.60 m ⬭

C 0.90 m ⬭

D 3.6 m ⬭

(Total 1 mark)

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22. A mass of 0.90 kg is suspended from the lower end of a light spring of stiffness 80 N m^{-1}.

When the mass is displaced vertically and released, it undergoes vertical oscillations of small amplitude.

What is the frequency of the oscillations?

A 0.071 Hz ⬭

B 0.67 Hz ⬭

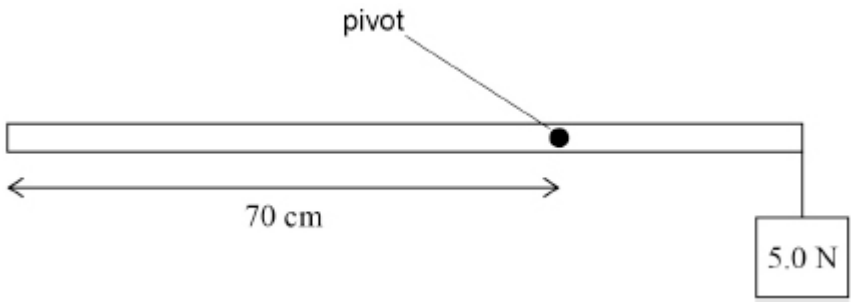
C 1.50 Hz ⬭

D 14 Hz ⬭

(Total 1 mark)

23. 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)

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24. A pellet with velocity 200 m s^{-1} and mass 5.0 g is fired vertically upwards into a stationary block of mass 95.0 g. The pellet remains in the block. The impact causes the block to move vertically upwards.

What is the maximum vertical displacement of the block?

A 5.1 m ⬭

B 10 m ⬭

C 51 m ⬭

D 100 m ⬭

(Total 1 mark)

25. Small water drops leave a tap with zero velocity at intervals of 0.20 s. They then fall freely 0.80 m to reach a horizontal surface.

How far has a drop fallen when the previous drop hits the surface?

A 0.16 m ⬭

B 0.20 m ⬭

C 0.40 m ⬭

D 0.60 m ⬭

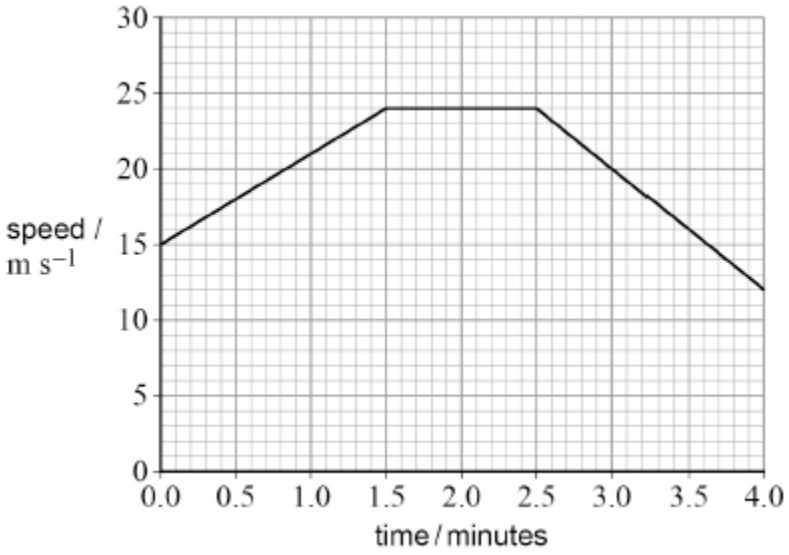
(Total 1 mark)

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26. 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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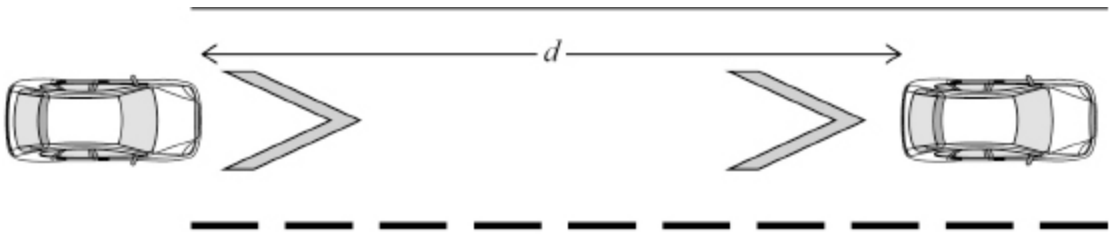
(3)

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(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)

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(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)

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(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

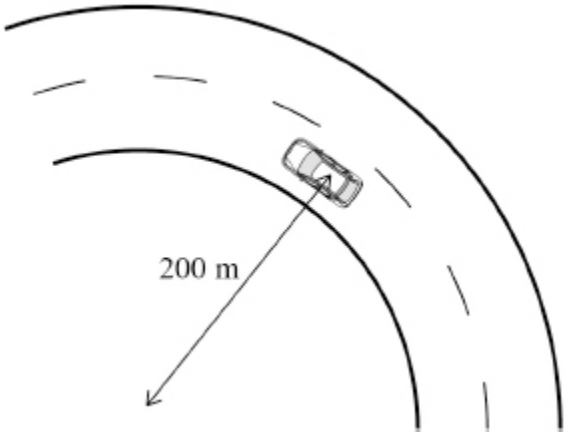
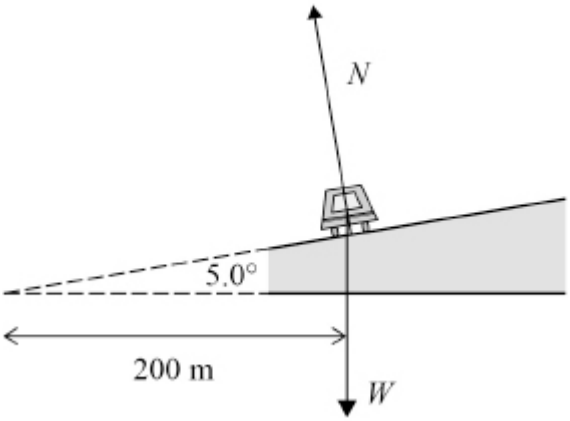


Figure 4



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

advisory speed = _____ m s^{-1}

(4)

(Total 14 marks)

27. Mechanical power

A is a vector quantity. ⬭

B is measured in J. ⬭

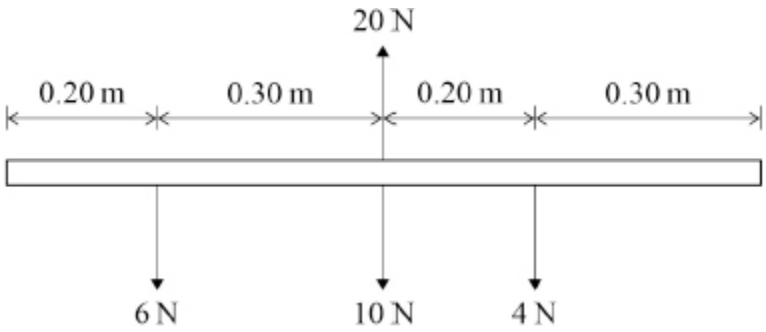
C has base units of kg m^2 s^{-3}. ⬭

D can be calculated from force × distance moved. ⬭

(Total 1 mark)

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28. The diagram shows the forces acting on a uniform rod.



Which statement is correct?

A The rod is in equilibrium. ⬭

B For equilibrium, an anticlockwise moment of 1.0 N m is needed. ⬭

C For equilibrium, a clockwise moment of 1.0 N m is needed. ⬭

D For equilibrium, the 10 N force should be increased to 20 N. ⬭

(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} ⬭

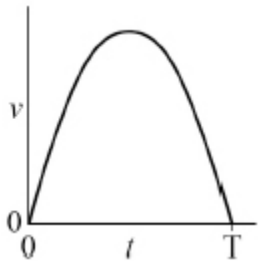
C 11 m s^{-1} ⬭

D 125 m s^{-1} ⬭

(Total 1 mark)

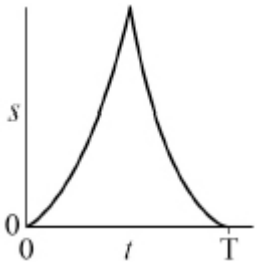
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30. The diagram shows how the speed v of an object varies with time t.

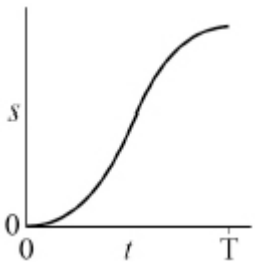


Which graph shows the variation of distance s with t for the object?

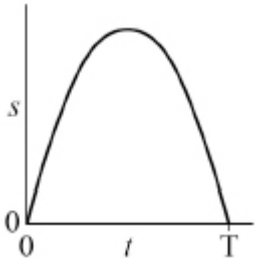
A



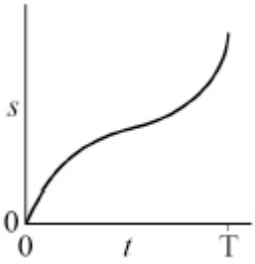
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

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31. 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)

32. 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. ⬭

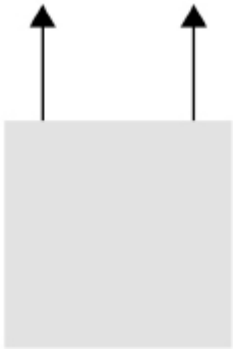
(Total 1 mark)

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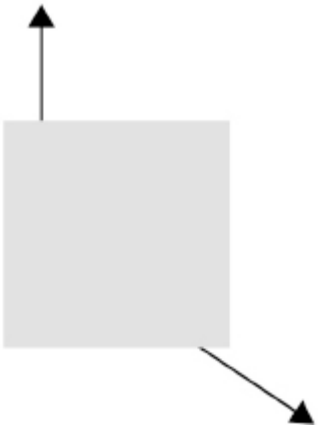
33. Each diagram shows two horizontal forces acting on a solid square object seen from above.

All the forces have the same magnitude.

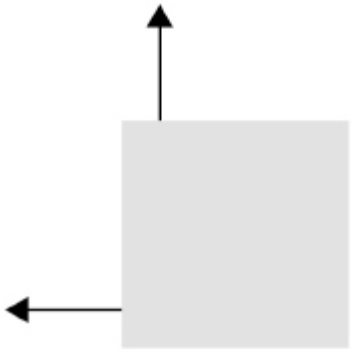
A



B



C



D



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

A ⬭

B ⬭

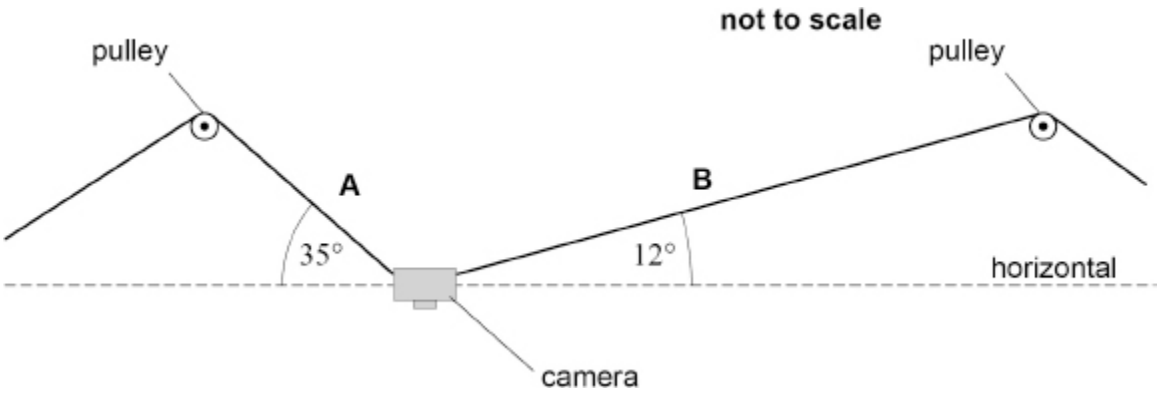
C ⬭

D ⬭

(Total 1 mark)

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34. The diagram shows a camera filming a sports event from above. The position of the camera is controlled by two steel cables, **A** and **B**, that pass over fixed, smooth pulleys.



(a) In the diagram above the camera is stationary. The tension in **A** is 430 N and **A** makes an angle of 35° to the horizontal. **B** makes an angle of 12° to the horizontal.

Calculate the tension in **B**.

tension in **B** = _____ N

(2)

(b) The cross-sectional area of **A** is 7.0×10^{-6} m^2. The unstretched length of **A** is 150 m.

Calculate the extension of **A** when the tension in it is 430 N.

Young modulus of steel = 210 GPa

extension = _____ m

(2)

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(c) The camera is moved horizontally to the right to a new stationary position. The tension in **A** is now different from that in the diagram above.

Deduce whether the tension in **A** has increased or decreased.

(3)

(d) The camera's signal is transmitted as a series of pulses through an optical fibre. The table shows data for two optical fibres **X** and **Y**. Both optical fibres are identical except for their core diameter.

Optical fibre	Core diameter / μm
X	8
Y	50

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Deduce which fibre allows a greater pulse transmission rate.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

35. Which row describes charge and impulse?

	Charge	Impulse	
A	scalar	scalar	⬭
B	scalar	vector	⬭
C	vector	scalar	⬭
D	vector	vector	⬭

(Total 1 mark)

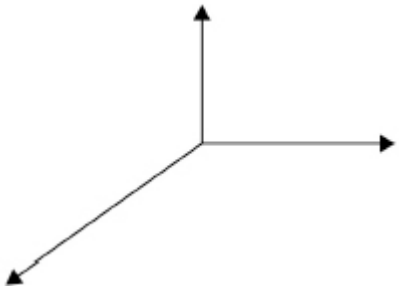
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36. An object is in equilibrium when acted on by three coplanar forces.

Which free-body diagram is correct?

Each diagram is drawn to scale.

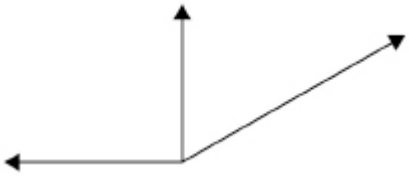
A



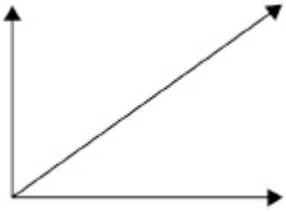
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

37. 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)

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38. 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. ⬭

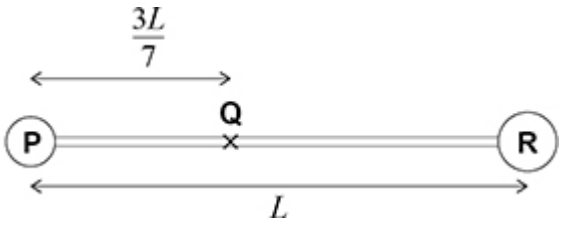
D Only total momentum is conserved. ⬭

(Total 1 mark)

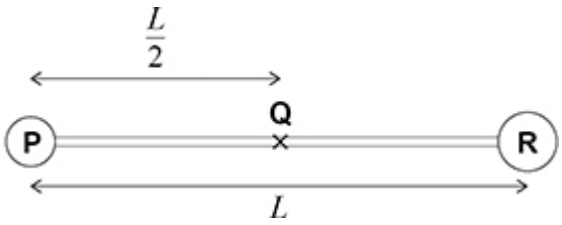
39. **P** and **R** are uniform spheres of mass 3 kg and 4 kg respectively.
P and **R** are joined by a rod of negligible mass.
The distance between their centres is L.
The centre of mass of this system is at **Q**.

Which diagram shows the position of the centre of mass?

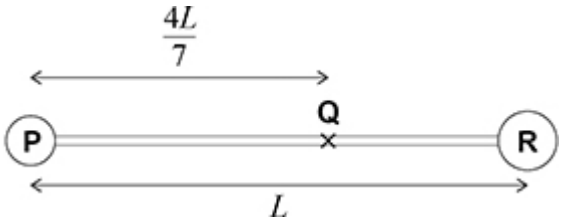
A



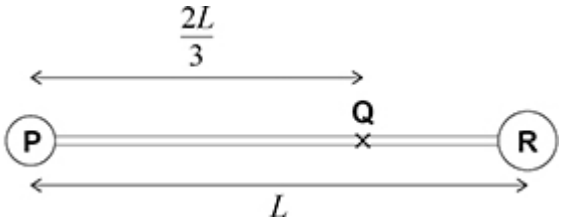
B



C



D



A ⬭

B ⬭

C ⬭

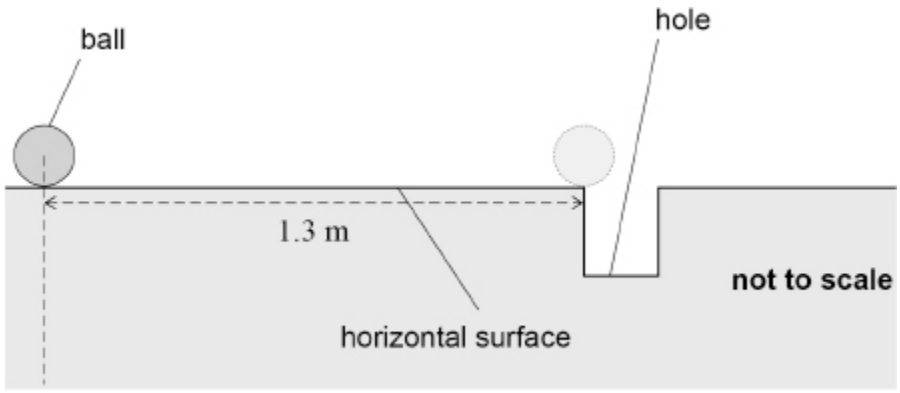
D ⬭

(Total 1 mark)

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40. (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.

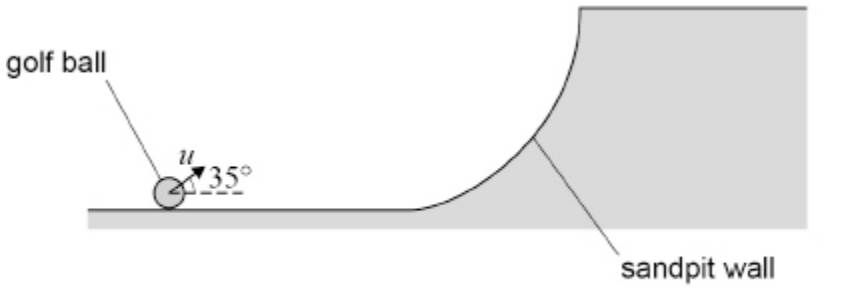
velocity = _____ m s^{-1}

(2)

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(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

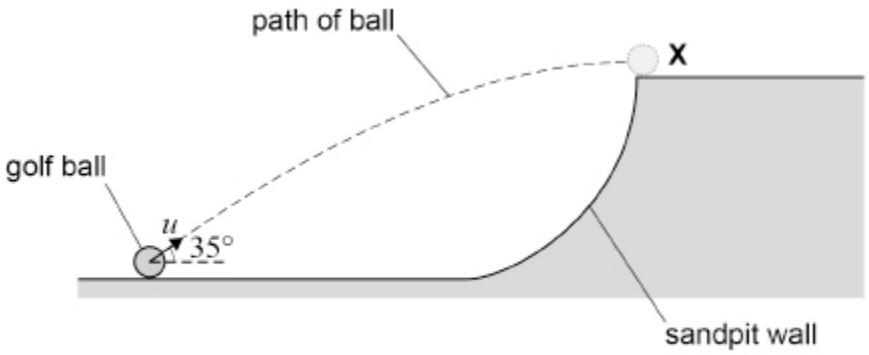
Show that the vertical component of u is approximately 6 m s^{-1}.

(1)

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

Figure 3



not to scale

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.

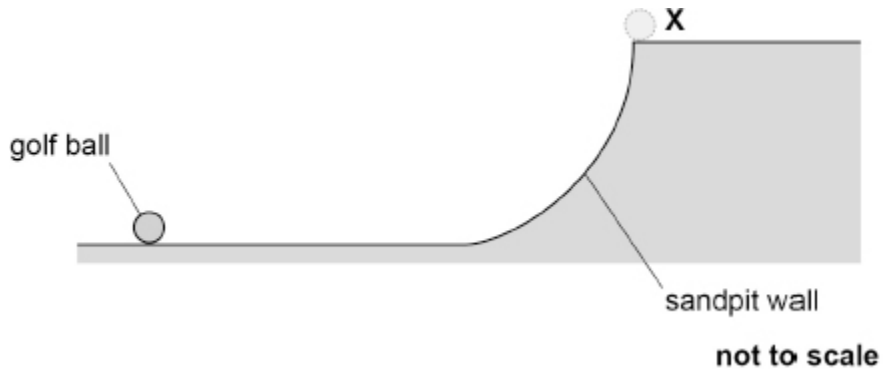
vertical distance = _____ m

(2)

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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.

_____

_____

_____

_____

_____

_____

_____

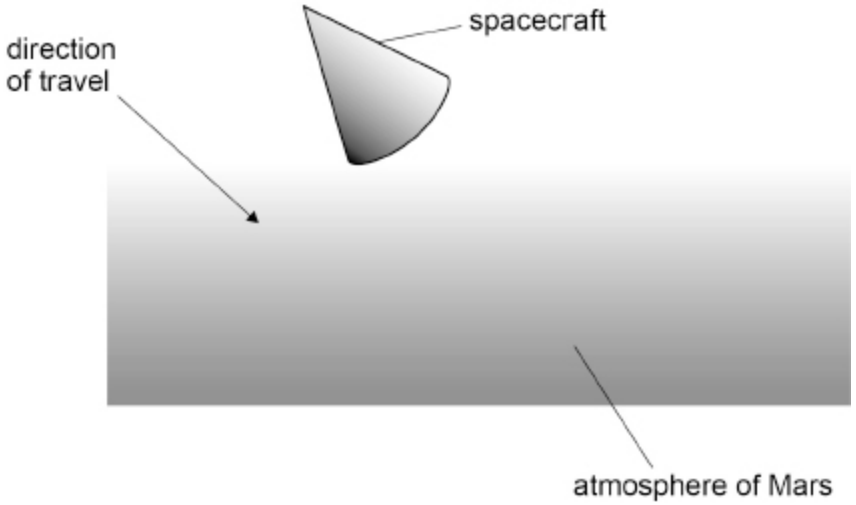
(2)

(Total 10 marks)

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41. 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

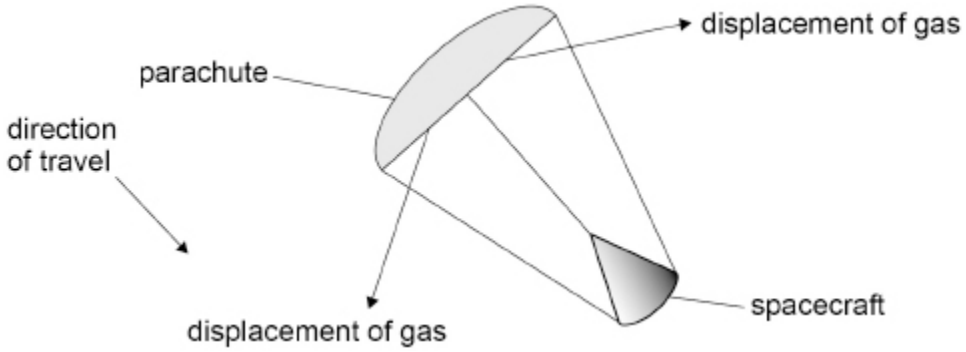
(3)

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(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.

(4)

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(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)

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42. A particle of mass m is oscillating with simple harmonic motion.
The period of the oscillation is T and the amplitude is A.

What is the maximum kinetic energy of the particle?

A $\frac{mA^2}{2T^2}$ ⬭

B $\frac{\pi^2 mA^2}{2T^2}$ ⬭

C $\frac{2mA^2}{T^2}$ ⬭

D $\frac{2\pi^2 mA^2}{T^2}$ ⬭

(Total 1 mark)

43. A simple pendulum and a mass–spring system each have a time period T on the Earth.

They are taken to the surface of a planet where the acceleration due to gravity is $\frac{g}{4}$.

What are the time periods of the pendulum and the mass–spring system on this planet?

	Simple pendulum	Mass–spring system	
A	$\frac{T}{2}$	T	⬭
B	$2T$	T	⬭
C	$\frac{T}{2}$	$2T$	⬭
D	$2T$	$2T$	⬭

(Total 1 mark)

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44. 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. ⬭

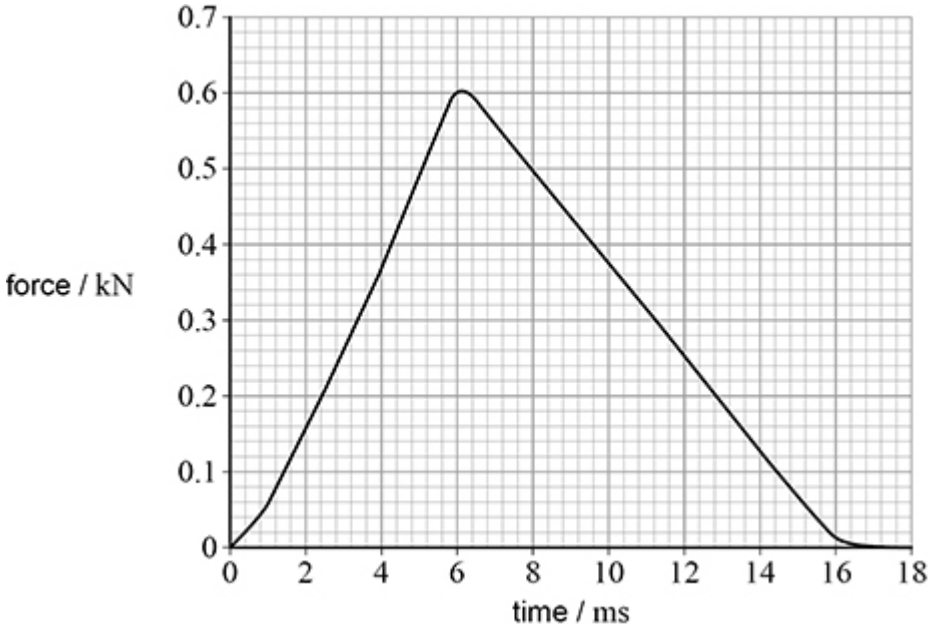
B moving down with a decreasing velocity. ⬭

C moving up at a constant velocity. ⬭

D moving up with a decreasing velocity. ⬭

(Total 1 mark)

45. 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 ⬭

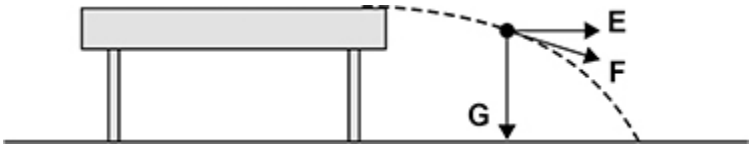
D 500 J ⬭

(Total 1 mark)

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46. 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.



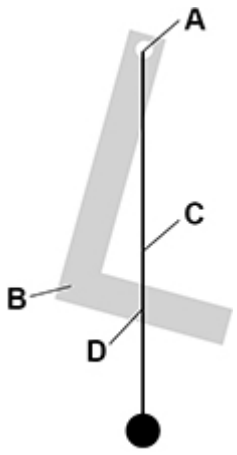
The arrows **E**, **F** and **G** represent different directions.

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)

47. 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.



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

A ⬭

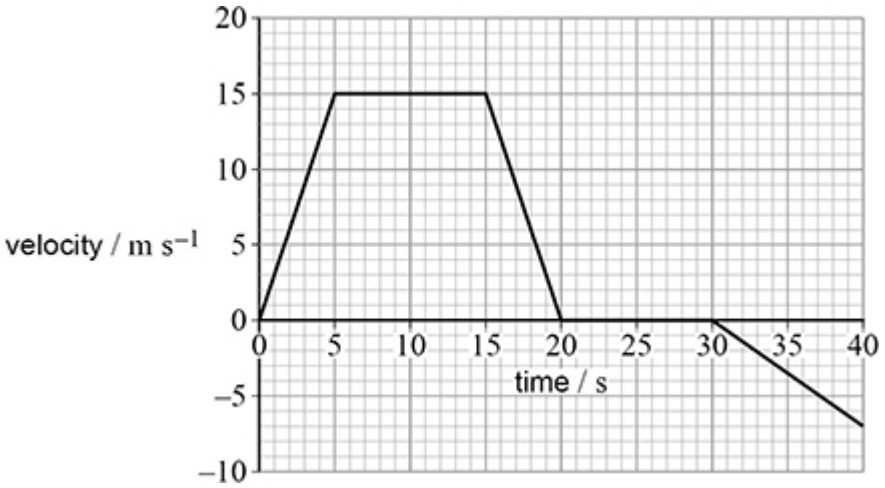
B ⬭

C ⬭

D ⬭

(Total 1 mark)

48. 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)

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49. Which is the shortest distance?

A 10^{-19} Gm ⬭

B 10^{-14} km ⬭

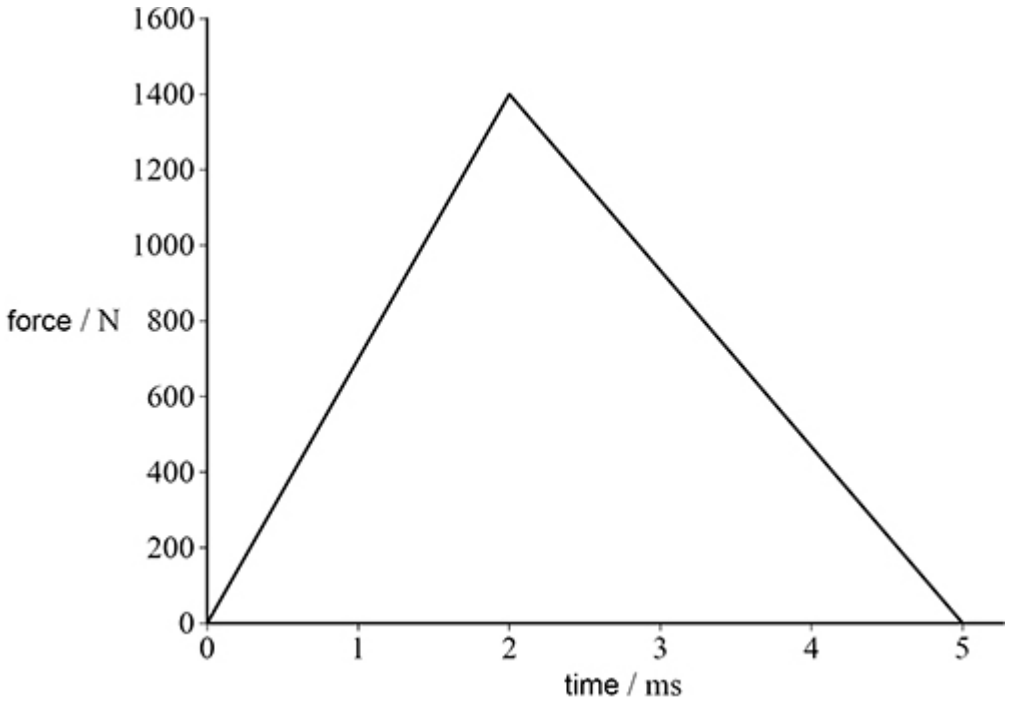
C 10^{-4} μm ⬭

D 10^{7} fm ⬭

(Total 1 mark)

50. 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)

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51. A mass m is added to a vertical spring that is initially unextended, as shown in **Diagram 1**.

The mass is then lowered until it hangs stationary on the spring, as shown in **Diagram 2**.

The extension of the spring is now ΔL.

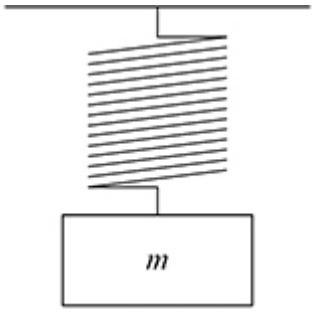


Diagram 1

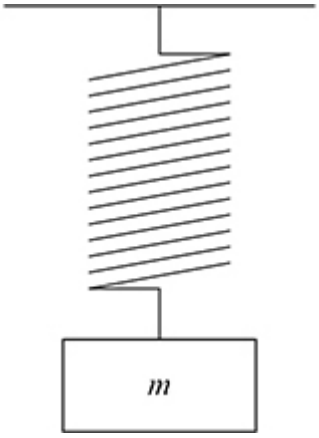


Diagram 2

How much energy is transferred from the mass–spring system?

A $\frac{mg\Delta L}{2}$ ⬭

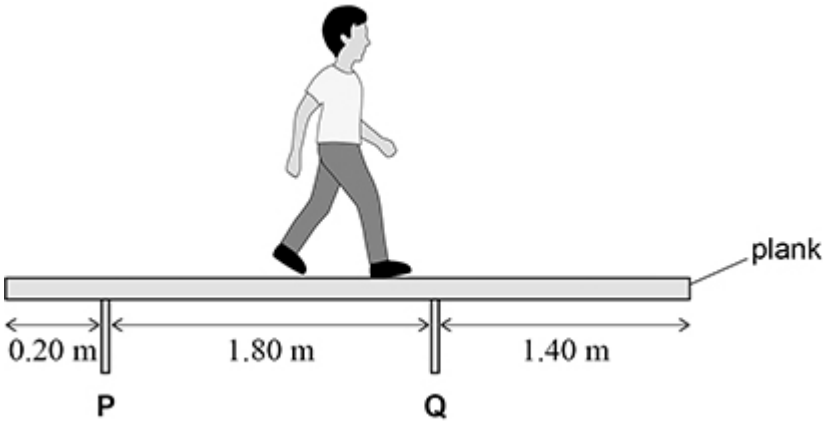
B $mg\Delta L$ ⬭

C $\frac{3mg\Delta L}{2}$ ⬭

D $2mg\Delta L$ ⬭

(Total 1 mark)

52. A uniform plank weighs 1200 N and rests on two pillars **P** and **Q**.
P and **Q** are 1.80 m apart.
P is 0.20 m from one end of the plank. **Q** is 1.40 m from the other end of the plank.
A man weighs 800 N and walks along the plank away from pillar **P**.



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What is the horizontal distance between pillar **P** and the centre of mass of the man when the plank starts to tip?

A 0.45 m ⬭

B 2.25 m ⬭

C 2.45 m ⬭

D 3.15 m ⬭

(Total 1 mark)

53. 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)

54. 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

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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**. ⬭

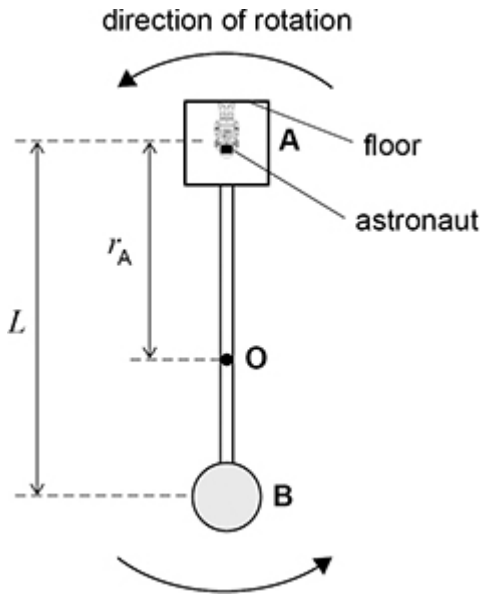
C The terminal speed of **Y** is greater than that of **Z**. ⬭

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

(Total 1 mark)

55. **Figure 1** shows a rotating spacecraft that is proposed to carry astronauts to Mars.

Figure 1



The spacecraft consists of two parts **A** and **B** connected by a rigid cylindrical rod. When the spacecraft is travelling, **A** and **B** rotate at a constant angular speed about their common centre of mass **O**.

L is the distance between the centre of mass of **A** and the centre of mass of **B**. r_A is the distance from **O** to the centre of mass of **A**.

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(a) As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why.

_____

_____

_____

_____

_____

_____

(2)

(b) The forces exerted on **A** and **B** by the connecting rod have the same magnitude.

m_A is the mass of **A**
m_B is the mass of **B**

Show, by considering the centripetal forces acting on **A** and **B**, that r_A is given by

$$r_A = \frac{m_B L}{m_A + m_B}$$

(2)

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(c) In this spacecraft $m_A < m_B$.

Deduce whether the centre of mass of **A** or the centre of mass of **B** rotates with a greater linear speed.

_____

_____

_____

_____

_____

_____

(2)

The astronauts live in **A** and the cargo is stored in **B**.

When loaded,

$m_A = 1.32 \times 10^6$ kg

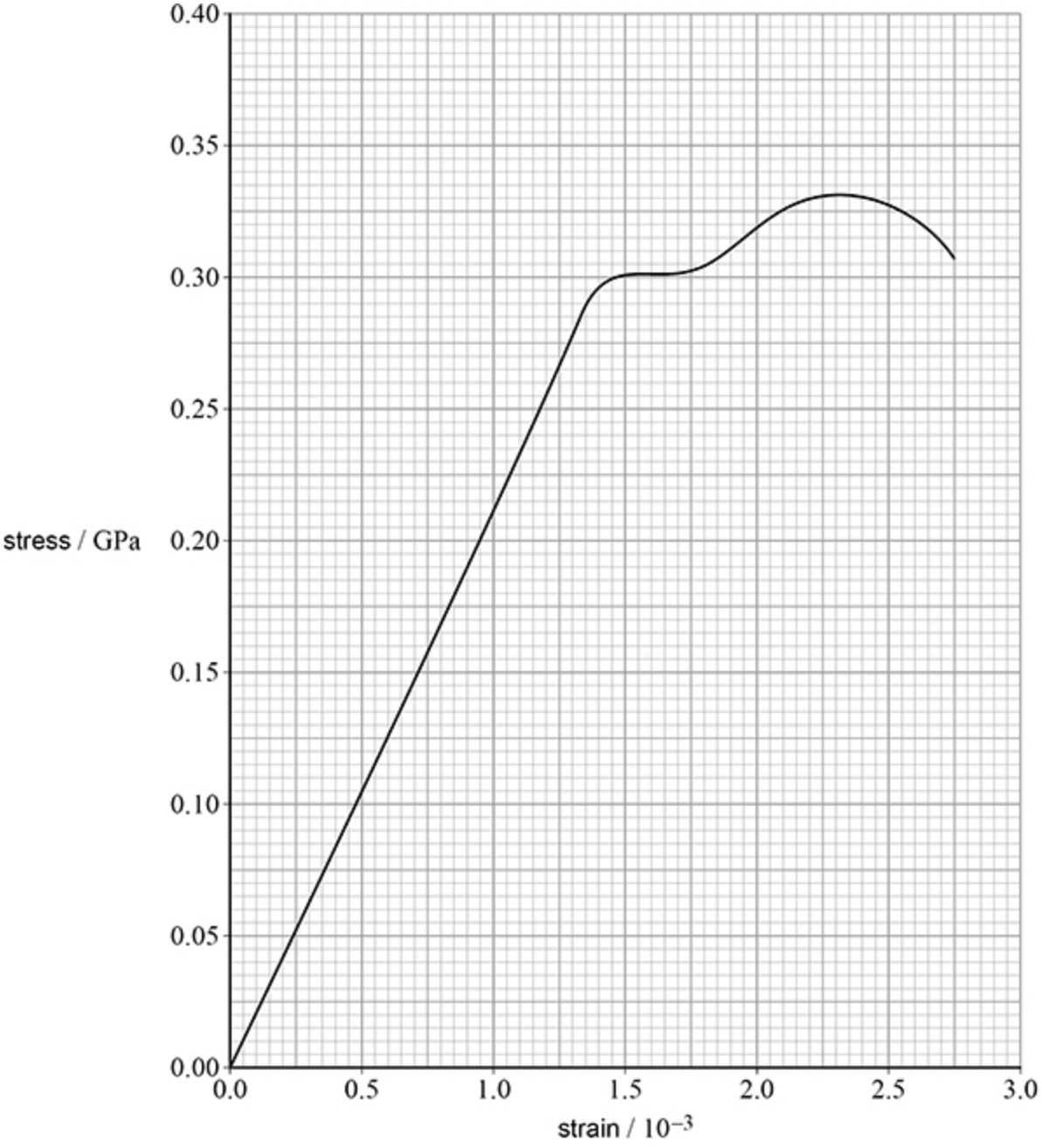
$m_B = 3.30 \times 10^6$ kg.

The spacecraft imitates the gravity of Mars where $g = 3.7$ m s^{-2}.

Figure 2 shows a stress–strain curve for the metal used for the rigid rod.

Figure 2

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stress / GPa
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
strain / 10^{-3}

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(d) Suggest a suitable diameter for the rod.
Justify your answer.

diameter = _____ m

_____

_____

_____

_____

_____

_____

(5)

(Total 11 marks)

56. 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.



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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)

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

Figure 1

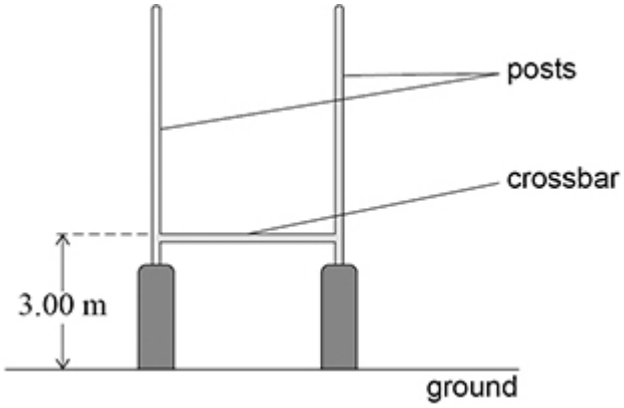
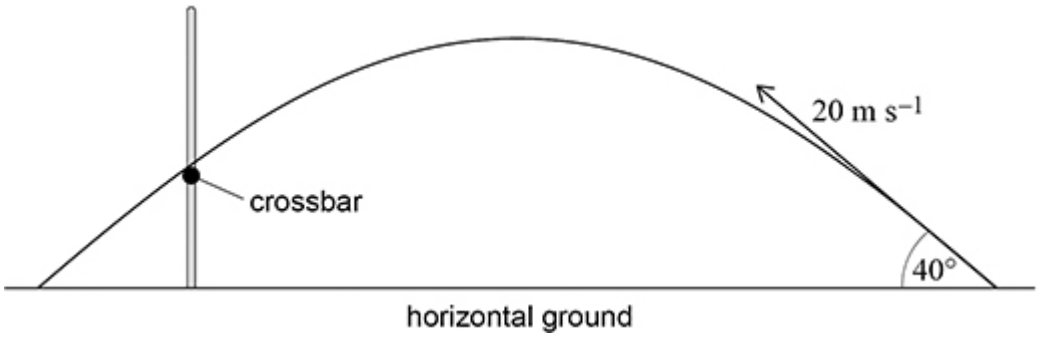


Figure 2 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is 20.0 m s^{-1} at an angle of 40.0° to the ground.

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.

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

Explain your answer.

_____

_____

_____

(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)

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(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

_____

_____

_____

_____

_____

_____

(4)

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(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.

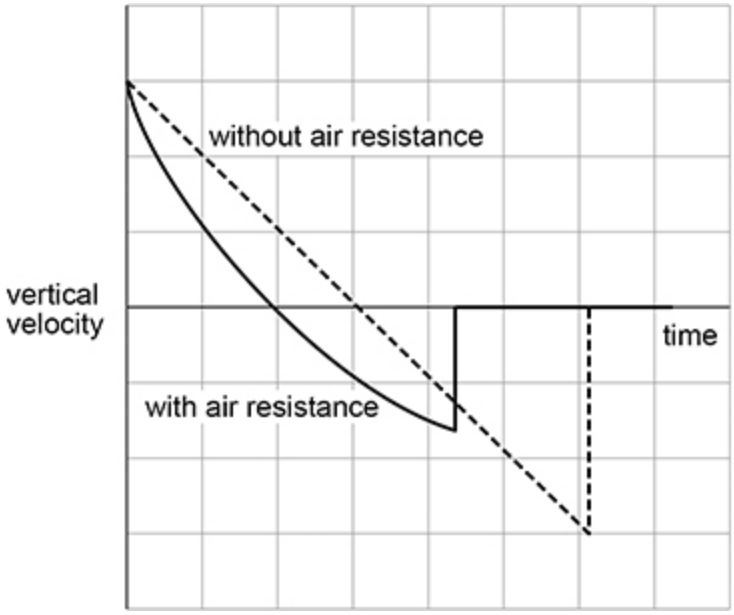
_____

(1)

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(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.

(5)

(Total 14 marks)

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58. 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. ⬭

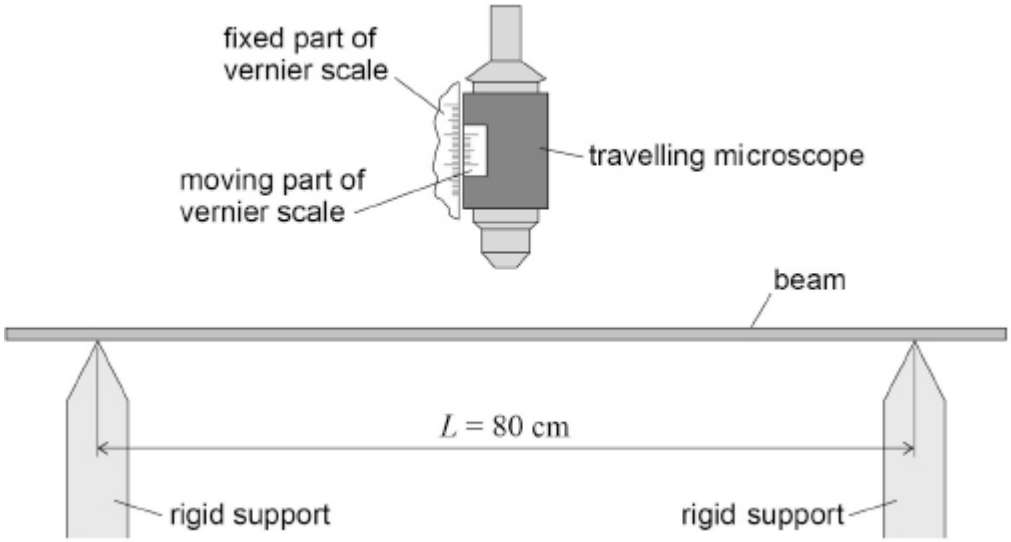
C the maximum speed of the car increases. ⬭

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

(Total 1 mark)

59. **Figure 1** shows apparatus used to investigate the bending of a beam.

Figure 1

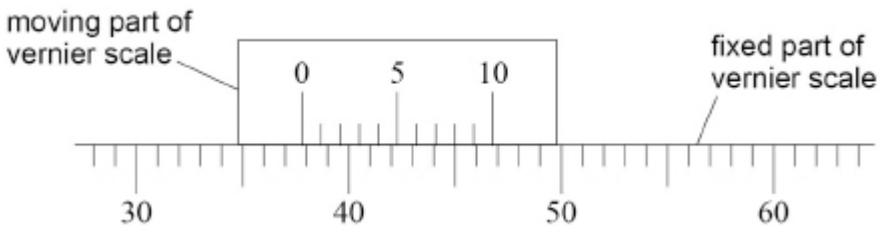


The beam is placed horizontally on rigid supports.
The distance L between the supports is 80 cm.

A travelling microscope is positioned above the midpoint of the beam and focused on the upper surface.

(a) **Figure 2** shows an enlarged view of both parts of the vernier scale.

Figure 2



The smallest division on the fixed part of the scale is 1 mm.

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What is the value of the vernier reading R_0 in mm?
Tick (✓) **one** box.

34.8 ☐

37.8 ☐

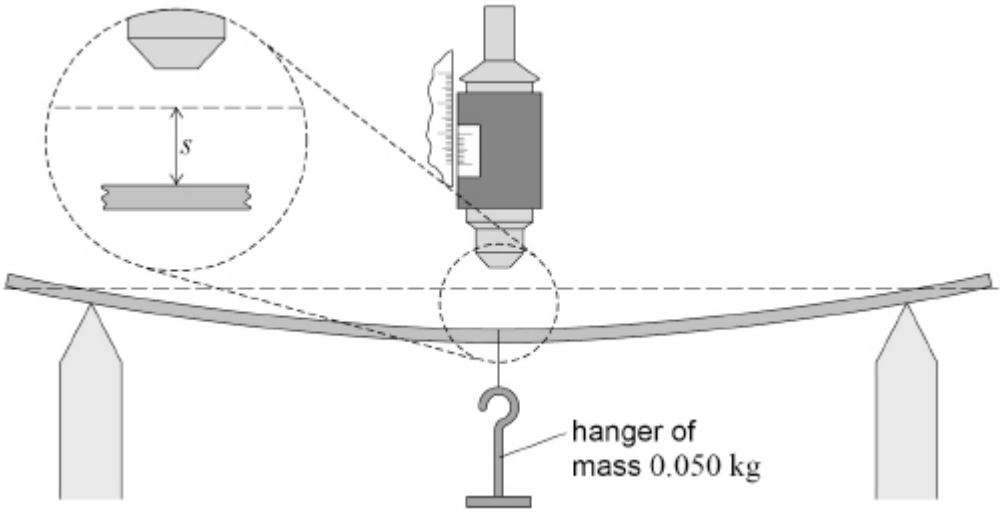
45.8 ☐

49.8 ☐

(1)

(b) **Figure 3** shows the beam bending when a hanger of mass 0.050 kg is suspended from the midpoint.

Figure 3



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The microscope is refocused on the upper surface and the new vernier reading R is recorded.
The vertical deflection s of the beam is equal to $(R - R_0)$.

The total mass m suspended from the beam is increased in steps of 0.050 kg.
A value of s is recorded for each m up to a value of m = 0.450 kg.
Further values of s are then recorded as m is decreased in 0.050 kg steps until m is zero.

Student **A** performs the experiment and observes that values of s during unloading are **sometimes** different from the corresponding values for loading.

State the type of error that causes the differences student **A** observes.

_____

(1)

(c) Student **B** performs the experiment using a thinner beam but with the same width and made from the same material as before.

Discuss **one** possible advantage and **one** possible disadvantage of using the thinner beam.

Advantage _____

_____

_____

_____

_____

Disadvantage _____

_____

_____

_____

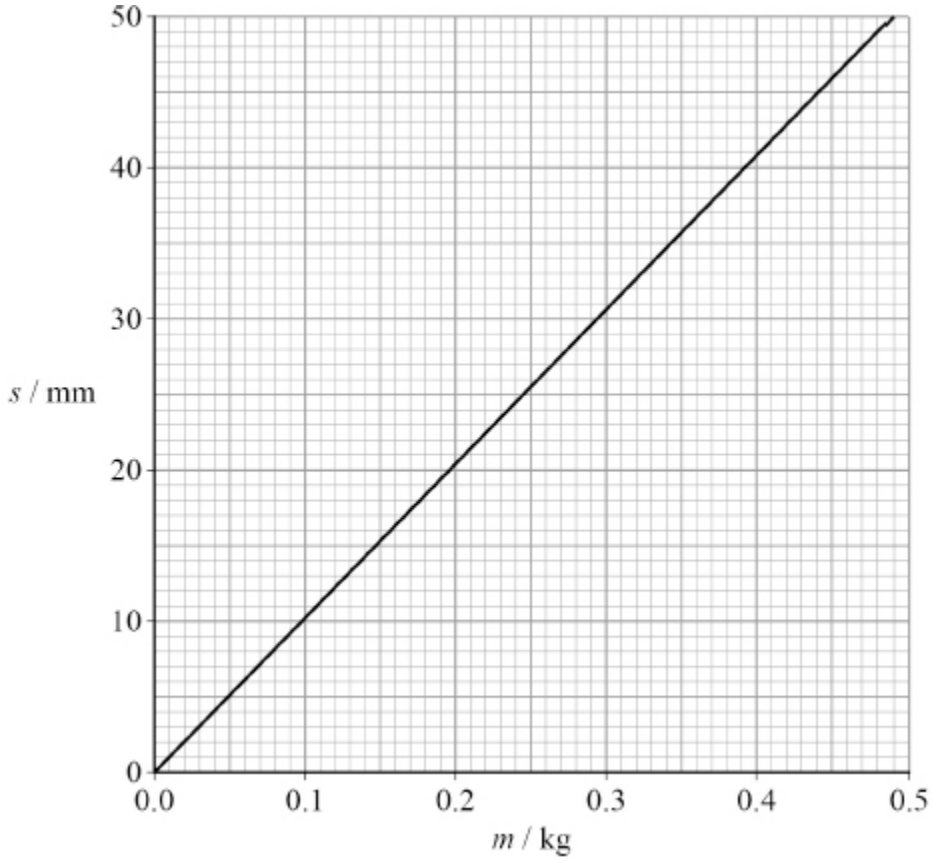
_____

(3)

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(d) **Figure 4** shows the best-fit line produced using the data collected by student **A**.

Figure 4



It can be shown that $s = \frac{\eta m}{E}$

where E is the Young modulus of the material of the beam and η is a constant.

Deduce in s^{-2} the order of magnitude of η.

E = 1.14 GPa

order of magnitude of η = _____ s^{-2}

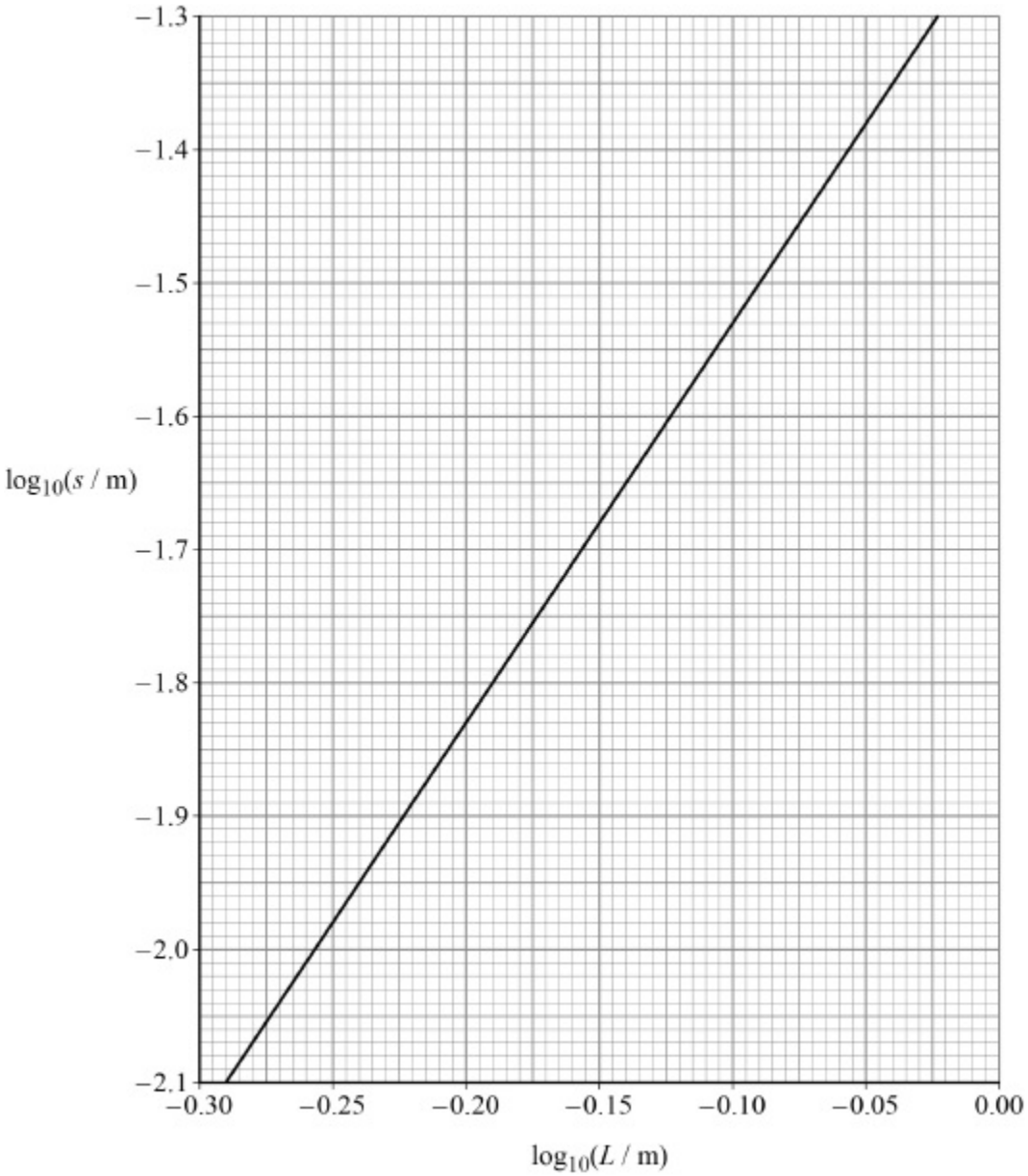
(4)

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(e) Student **C** performs a different experiment using the same apparatus shown in **Figure 1**.
A mass M is suspended from the midpoint of the beam.
The vertical deflection s of the beam is measured for different values of L.

Figure 5 shows a graph of the results for this experiment.

Figure 5



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Figure 5 shows that log10(s / m) varies linearly with log10(L / m).

State what this shows about the mathematical relationship between s and L. You do **not** need to do a calculation.

_____

_____

_____

(1)

(f) Deduce, using **Figure 5**, the value of s when L = 80 cm.

s = _____ m

(2)

(g) Determine M using **Figure 4**.

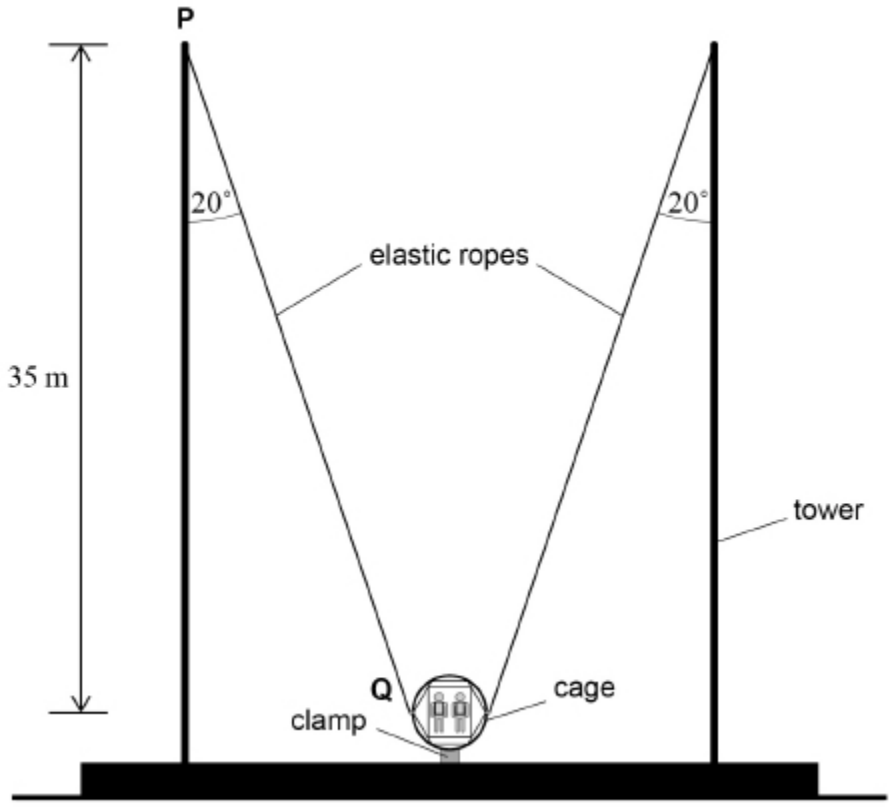
M = _____ kg

(1)

(Total 13 marks)

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60. 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.

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(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)

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(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.

_____

_____

(3)

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(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.

_____

_____

_____

_____

_____

_____

(1)

(Total 17 marks)

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