AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 5

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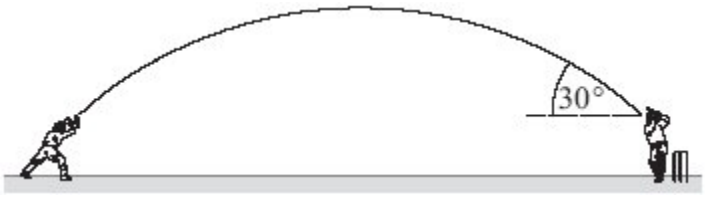
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1. **Figure 1** shows the flight of a cricket ball hit by a batsman at 30° to the horizontal at a speed of 22 m s^{-1}. The ball reached a fielder without bouncing and was caught at the same height as it was hit. The effect of air resistance on the cricket ball is negligible.

Figure 1



(a) (i) Calculate the vertical speed of the ball at the instant it left the bat.

vertical speed _____ m s^{-1}

(1)

(ii) Show that the ball was in the air for about 2.2 s.

(3)

(iii) How far did the ball travel horizontally before it was caught?

distance _____ m

(1)

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(b) (i) A tennis ball is about the same size as a cricket ball but has a lower mass.
By considering the energy changes that take place, explain why a tennis ball hit at the same speed and angle as the cricket ball would be unlikely to reach the fielder without bouncing.

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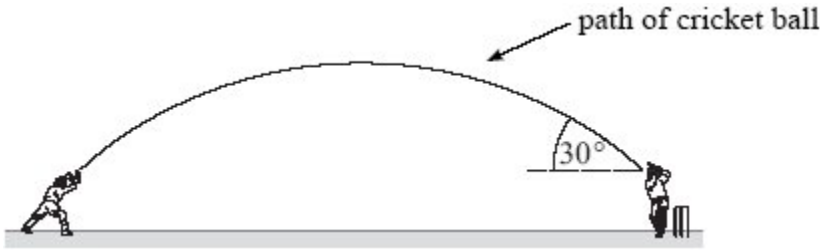
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(3)

(ii) Draw on **Figure 2** the path you would expect a tennis ball to follow when hit at the same speed and angle as the cricket ball.

Figure 2



(2)

(Total 10 marks)

2. (a) Define *gravitational field strength* at a point in a gravitational field.

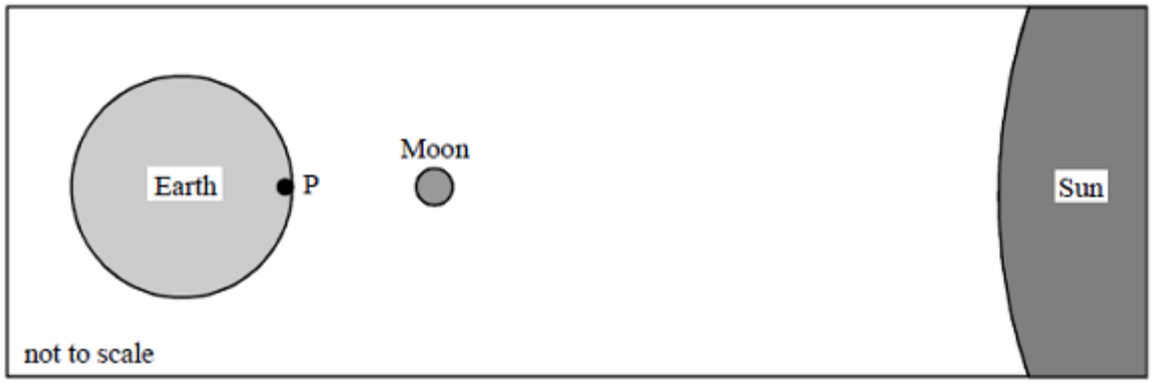
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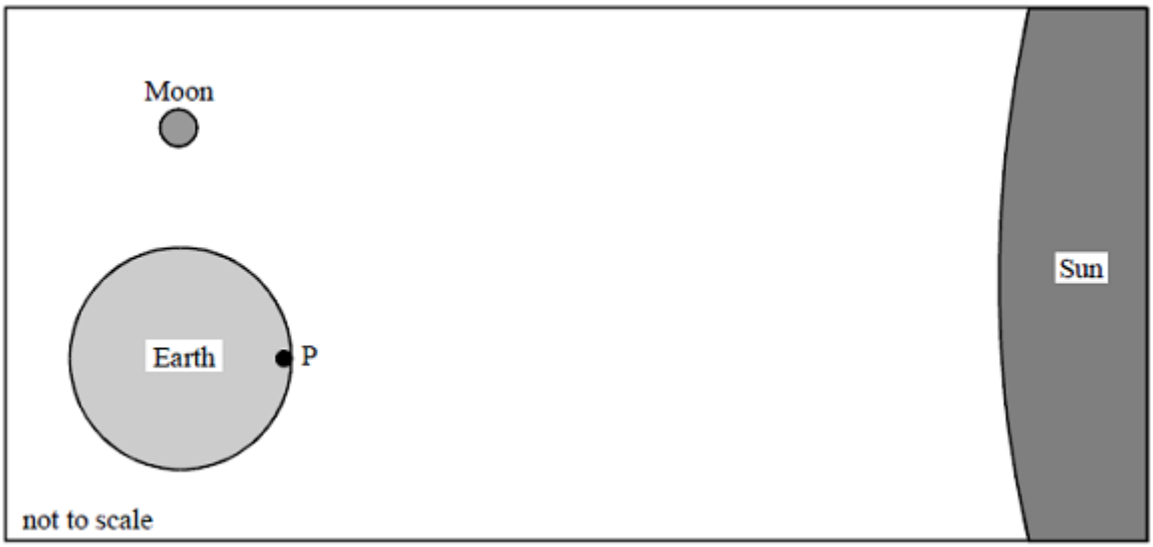
(1)

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(b) Tides vary in height with the relative positions of the Earth, the Sun and the moon which change as the Earth and the Moon move in their orbits. Two possible configurations are shown in **Figure 1**.



Configuration A



Configuration B

Figure 1

Consider a 1 kg mass of sea water at position **P**. This mass experiences forces F_E, F_M and F_S due to its position in the gravitational fields of the Earth, the Moon and the Sun respectively.

(i) Draw labelled arrows on **both** diagrams in **Figure 1** to indicate the three forces experienced by the mass of sea water at **P**.

(3)

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(ii) State and explain which configuration, **A** or **B**, of the Sun, the Moon and the Earth will produce the higher tide at position **P**.

_____

_____

_____

(2)

(c) Calculate the magnitude of the gravitational force experienced by 1 kg of sea water on the Earth's surface at **P**, due to the **Sun**'s gravitational field.

radius of the Earth's orbit $= 1.5 \times 10^{11}$ m

mass of the Sun $= 2.0 \times 10^{30}$ kg

universal gravitational constant, G $= 6.7 \times 10^{-11}$ Nm^2 kg^{-2}

(3)

(Total 9 marks)

3. A 10 mF capacitor is charged to 10 V and then discharged completely through a small motor. During this process, the motor lifts a weight of mass 0.10 kg. If 10% of the energy stored in the capacitor is used to lift the weight, through what approximate height will the weight be lifted?

A 0.05 m

B 0.10 m

C 0.50 m

D 1.00 m

(Total 1 mark)

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4. (a) State the conditions necessary for a body to be in equilibrium.

_____

_____

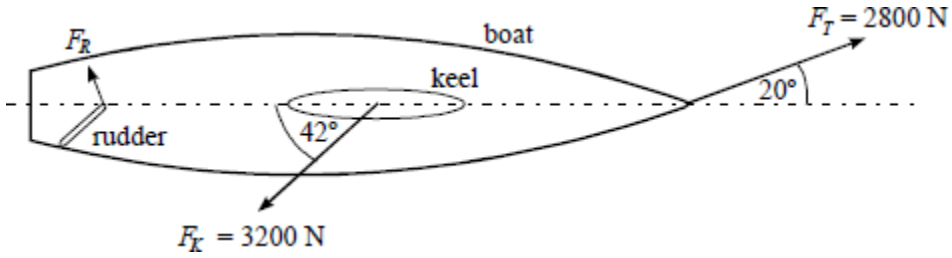
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(2)

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(b) The boat shown in the figure below is being towed at constant velocity. The tension force (F_T) in the towing rope is 2800 N. The forces resisting the motion can be assumed to be the force of the water on the keel (F_K) and the force of the water on the rudder (F_R).



By calculation or by scale drawing, find the size of the force, F_R, needed to keep the boat in equilibrium.

(6)

(Total 8 marks)

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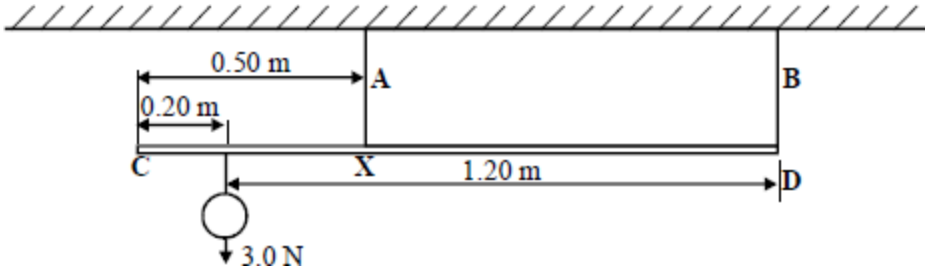
5. (a) Define the moment of a force about a point.

_____

_____

(2)

(b) The system shown in the diagram below is in equilibrium. The uniform rod, **CD**, has a weight of 15 N and is suspended by two lengths of string, **A** and **B**. A ball of weight 3.0 N is attached to the rod in the position shown.



(i) Accurately draw an arrow onto the diagram to represent the weight of the rod. You need not represent the magnitude of the weight.

(2)

(ii) **X** is the point at which string **A** is attached to the rod. By taking moments about point **X**, determine the tension in string **B**.

(2)

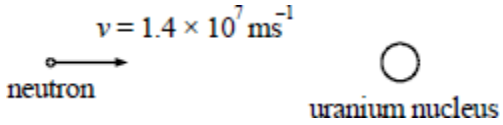
(iii) Determine the tension in string **A**.

(1)

(Total 7 marks)

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6. The figure below shows a neutron of mass 1.7×10^{-27} kg about to collide inelastically with a stationary uranium nucleus of mass 4.0×10^{-25} kg. During the collision, the neutron will be absorbed by the uranium nucleus.



(a) Calculate the velocity of the uranium nucleus immediately after the neutron has been absorbed.

(3)

(b) Collisions between neutrons and uranium nuclei can also be elastic. State, and explain briefly, how the speed of the uranium nucleus after impact would be different in the case of an elastic collision.
Do not perform any further calculations.

_____

_____

_____

_____

_____

_____

(3)

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(c) Using the data at the beginning of the question, calculate the kinetic energy of the neutron before it collides with the uranium nucleus.

(3)

(Total 9 marks)

7. (a) (i) A label on a capacitor shows it to have a capacitance of 0.020 F. Explain what this tells you about the capacitor.

_____

_____

(1)

(ii) Sketch on **Figure 1** the graph that shows how the charge on the 0.020 F capacitor varies with the potential difference across it over the voltage range given. Insert an appropriate scale on the charge axis.

(2)

(iii) Explain how your graph could be used to obtain the energy stored for a given potential difference.

_____

_____

_____

(2)

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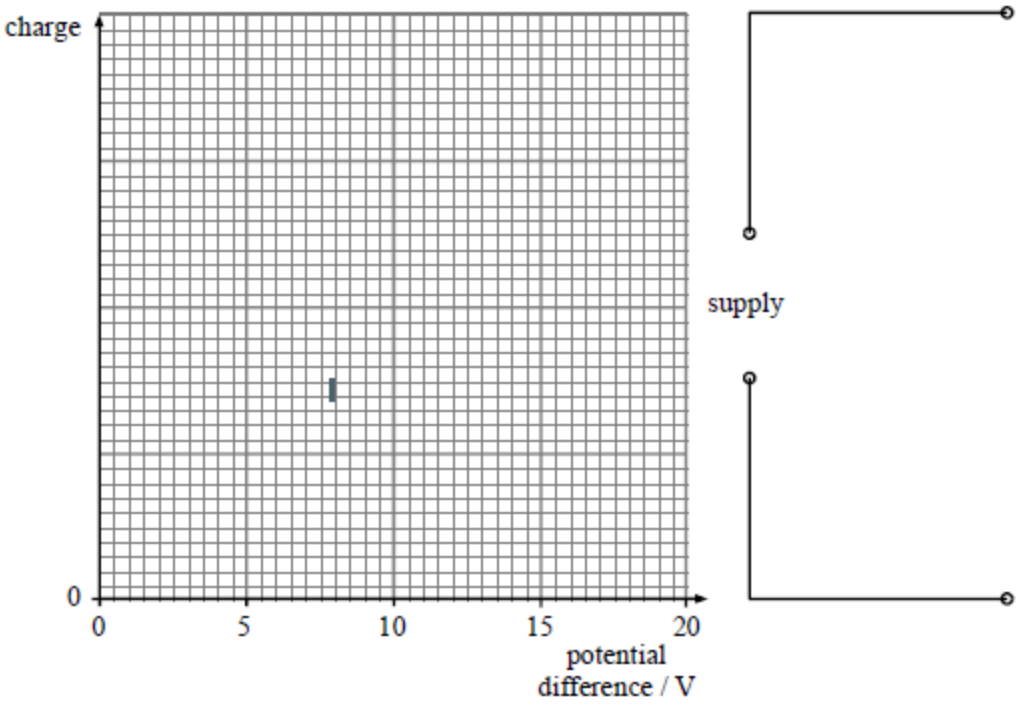


Figure 1 **Figure 2**

(iv) Show on **Figure 2** how **two** similar capacitors could be connected to a supply to store more energy for the same potential difference.

(1)

(b) **Figure 3** shows one 0.020 F capacitor connected to a 20 V supply. By means of the changeover switch **S**, the capacitor is disconnected from the supply and connected to a small motor. The motor lifts an object of mass 0.15 kg through a height of 0.80 m, after which the energy left in the capacitor is negligible.

acceleration of free fall, g = 9.8 m s^{-2}

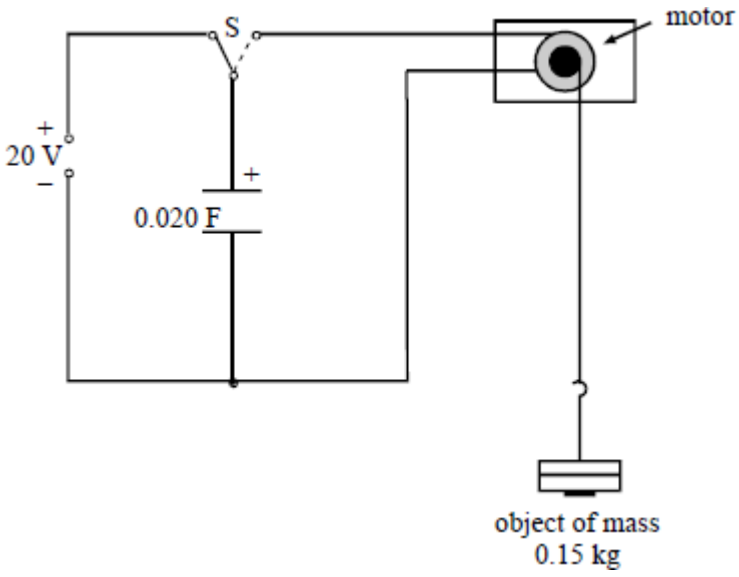


Figure 3

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Calculate:

(i) the initial energy stored by the capacitor;

(2)

(ii) the efficiency of the energy conversion.

(3)
(Total 11 marks)

8. **Figure 1** and **Figure 2** both show the side view of a steel bolt.

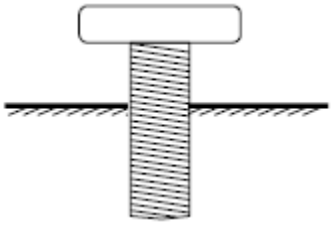


Figure 1

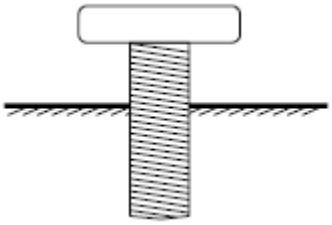


Figure 2

(a) Show on **Figure 1** forces acting on the bolt which would produce a tensile strain.

(1)

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(b) The ultimate tensile stress of steel is 5.0×10^8 Pa, the elastic limit is 2.5×10^8 Pa and the Young modulus of steel is 2.0×10^{11} Pa.

Defining any terms used, state what is meant by:

(i) *tensile stress;*

_____

_____

(1)

(ii) *tensile strain;*

_____

_____

(1)

(iii) *the elastic limit.*

_____

_____

(1)

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(c) When the main engines of a space shuttle are fired, they develop a total thrust of 4.5×10^6 N. In a test firing the shuttle is held to the launch pad by 8 steel bolts each of diameter 9.0×10^{-2} m. Using data given in (b):

(i) calculate the strain for each bolt during the test;

(4)

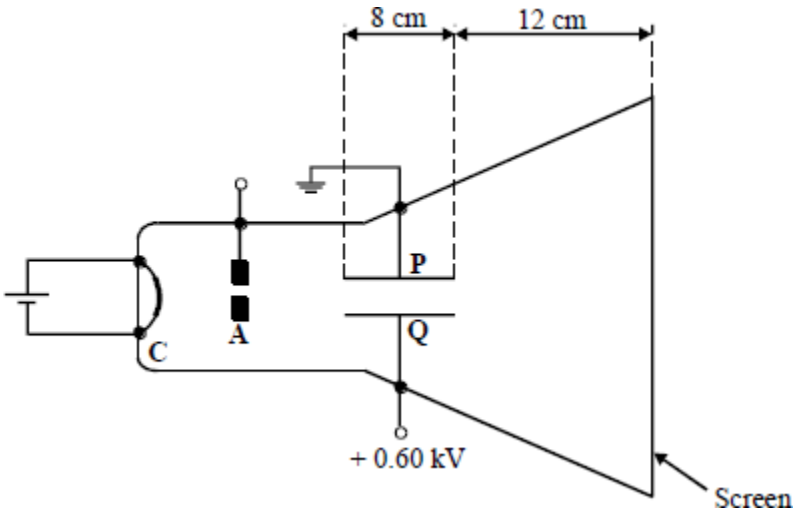
(ii) determine the minimum number of bolts that could have been used when carrying out the test.

(3)

(Total 11 marks)

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9. In the cathode ray tube illustrated below, electrons are accelerated by a potential difference of 1.8 kV between the cathode (**C**) and the anode (**A**).



(a) (i) Calculate the kinetic energy, in J, of the electrons after they have passed the anode.

charge on an electron, $e = -1.6 \times 10^{-19}$ C

(2)

(ii) Calculate the velocity of the electrons after they have passed the anode.

Mass of an electron = 9.1×10^{-31} kg

(2)

(b) The plates **P** and **Q** are 8.0 cm long and are separated by a gap of 4.0 cm.

(i) Define electric field strength.

_____

_____

(1)

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(ii) Calculate the force acting on an electron when it is between **P** and **Q** and state the direction of the force.

Direction _____

(3)

(iii) Calculate the time taken for an electron to pass between the plates.

(1)

(iv) Calculate the vertical component of velocity at the time the electron leaves the electric field between **P** and **Q**.

(2)

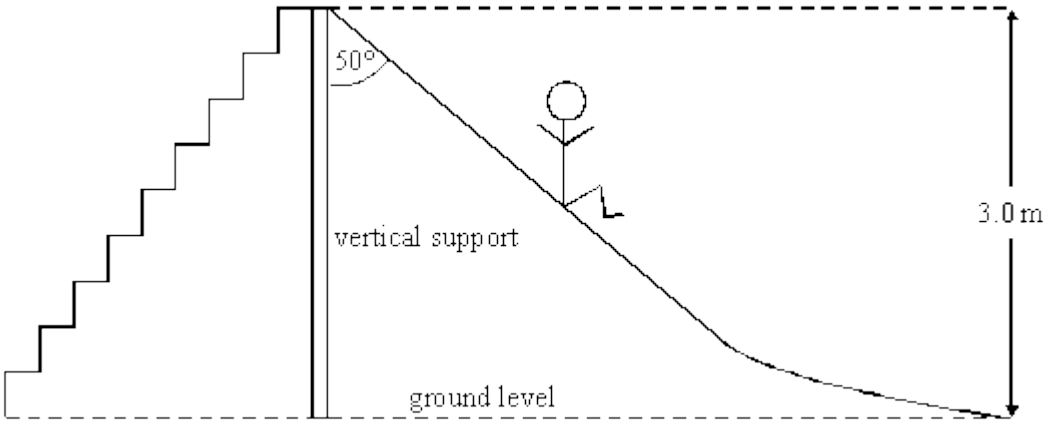
(v) Calculate the additional vertical displacement of the electron between the time it leaves the electric field between **P** and **Q** and when it reaches the screen.

(1)
(Total 12 marks)

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10. The diagram below shows a child coming down a slide in a playground. The vertical height of the slide is 3.0 m. The angle between the main slope of the slide and its vertical support is 50°.

acceleration of free fall $g = 9.8 \text{ m s}^{-2}$



(a) The child has a mass of 41 kg. Calculate the gain in gravitational potential energy as the child climbed to the top of the slide.

Gravitational potential energy gained _____

(2)

(b) Assume that the slide is frictionless.

(i) Use your answer to part (a) to calculate the speed of the child when reaching the bottom of the slide.

Speed _____

(2)

(ii) Calculate the resultant force acting on the child when in the position shown in the diagram above.

Resultant force _____

(2)

(Total 6 marks)

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11. (a) (i) State the principle of conservation of momentum.

_____

_____

(2)

(ii) Explain briefly how an elastic collision is different from an inelastic collision.

_____

_____

(1)

(b) Describe and explain what happens when a moving particle collides elastically with a stationary particle of equal mass.

_____

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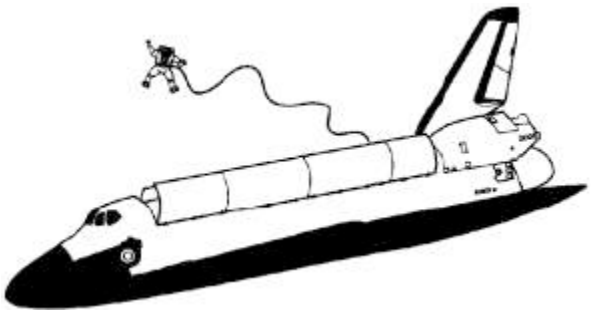
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(3)

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(c) The diagram below shows an astronaut undertaking a space-walk. The astronaut is tethered by a rope to a spacecraft of mass 4.0×10^4 kg. The spacecraft is moving at constant velocity.



The astronaut and spacesuit have a total mass of 130 kg. The change in velocity of the astronaut after pushing off is 1.80 m s^{-1}.

(i) Determine the velocity change of the spacecraft.

(2)

(ii) The astronaut pushes for 0.60 s in achieving this speed. Calculate the average power developed by the astronaut. Neglect the change in motion of the spacecraft.

(3)

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(iii) The rope eventually becomes taut. Suggest what would happen next.

_____

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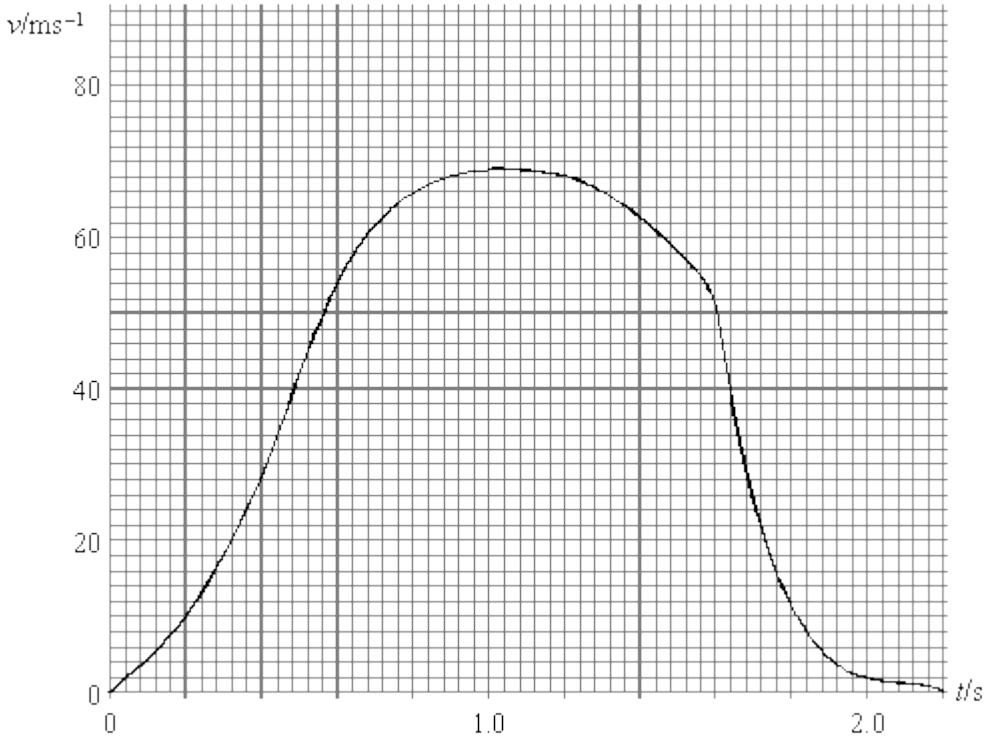
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(2)

(Total 13 marks)

12. The graph below shows how the vertical component, *v*, of the velocity of a rocket varies with time, *t*, from its take-off on level ground to the **highest point of its trajectory**.



(a) Take readings from the graph to calculate the average vertical acceleration of the rocket from time $t = 0$ to time $t = 0.60$ s.

Average acceleration _____

(3)

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(b) Use the graph to estimate the maximum height reached by the rocket.

Maximum height _____

(3)

(c) Assume that air resistance is negligible. Calculate the time taken for the rocket to fall from its maximum height back to the ground.

acceleration of free fall $g = 9.8$ m s^{-2}

Time to fall to the ground _____

(2)

(Total 8 marks)

13. (a) State the difference between vector and scalar quantities.

_____

_____

(1)

(b) State **one** example of a vector quantity (other than force) and **one** example of a scalar quantity.

vector quantity _____

scalar quantity _____

(2)

(c) A 12.0 N force and a 8.0 N force act on a body of mass 6.5 kg at the same time. For this body, calculate

(i) the maximum resultant acceleration that it could experience,

_____

_____

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(ii) the minimum resultant acceleration that it could experience.

_____

_____

(4)

(Total 7 marks)

14. (a) State the principle of conservation of momentum.

_____

_____

_____

(2)

(b) Two carts **A** and **B**, with a compressed spring between them, are pushed together and held at rest, as shown in **Figure 1**. The spring is not attached to either cart. The carts are then released. **Figure 2** shows how the force, *F*, exerted by the spring on the carts varies with time, *t*, after release.

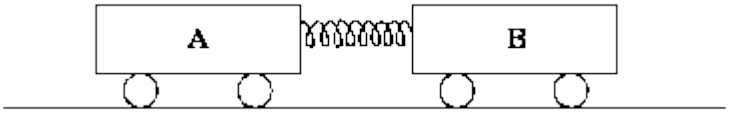


Figure 1

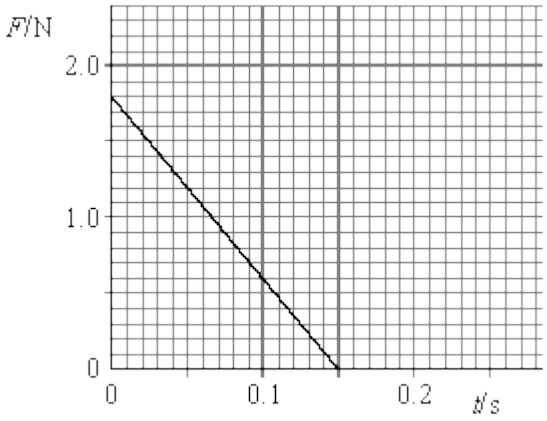


Figure 2

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When the spring returns to its unstretched length and drops away, cart **A** is moving at 0.60 m s^{-1}.

(i) Calculate the impulse given to each cart by the spring as it expands.

(2)

(ii) Calculate the mass of cart **A**.

(2)

(iii) State the final total momentum of the system at the instant the spring drops away.

(1)

(Total 7 marks)

15. (a) Explain why an engineer needs to consider *the yield stress* of a metal such as steel when deciding on its suitability for use in the construction of a building or a bridge.

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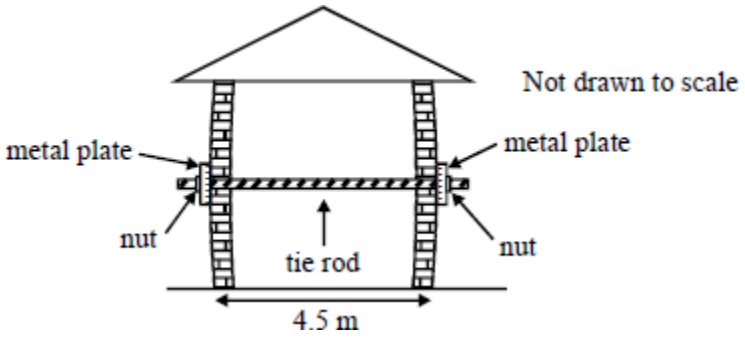
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(2)

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(b) In order to prevent the collapse of walls of old buildings a metal rod is often used to tie opposite walls together, as shown below.



In one case a steel tie rod of diameter 19 mm is used as shown above. When the nuts are tightened, the rod extends by 1.5 mm. The Young modulus of steel is 2.1×10^{11} Pa.

Calculate:

(i) the force exerted on the walls by the rod;

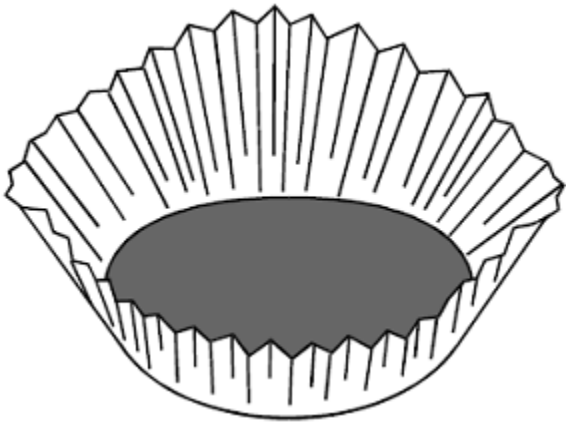
(3)

(ii) the elastic strain energy in the rod when it is extended by 1.5 mm.

(2)
(Total 7 marks)

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16. When a paper cake-case falls, right way up, through the air, it quickly reaches terminal velocity.



The drag force, D, acting on the paper cake-case, is given by

$$D = f\rho Av^2,$$

where ρ is the density of air (known to be 1.2 kg m^{-3}), v is the terminal velocity and A is the cross-sectional area of the base of the cake-case; f is a number (having no units) called the **shape factor**. Regardless of their size, paper cake-cases always have the same shape factor, even when several are stacked together.

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Design an experiment to determine the shape factor for empty paper cake-cases. You shouldassume that the normal laboratory apparatus used in schools and colleges is available to you.
No diagram will be required for this question.

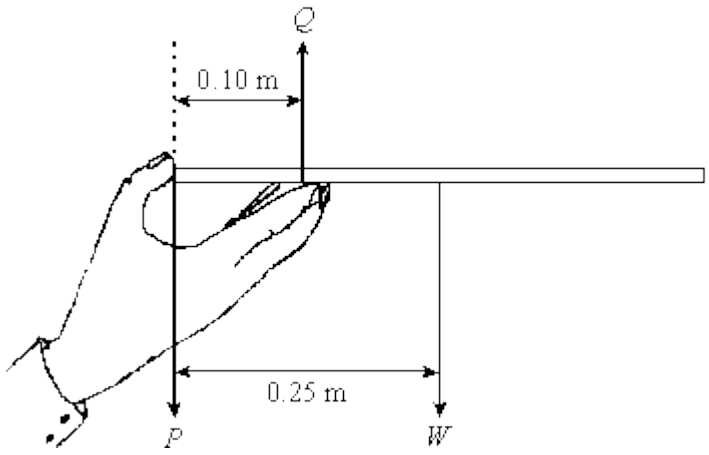
You should also include the following in your answer:

- The quantities you intend to measure and how you will measure them.
- How you propose to use your measurements to determine a reliable result for the shape factor.
- The factors you will need to control and how you will do this.
- How you could overcome any difficulties in obtaining reliable results.

(Total 8 marks)

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17. A waiter holds a tray horizontally in one hand between fingers and thumb as shown in the diagram.



P, *Q* and *W* are the three forces acting on the tray.

(a) (i) State **two** relationships between the forces that must be satisfied if the tray is to remain horizontal and in equilibrium.

_____

_____

_____

(ii) If the mass of the tray is 0.12 kg, calculate the magnitude of the force *W*.

_____

_____

_____

(iii) Calculate the magnitudes of forces *P* and *Q*.

_____

_____

_____

_____

(6)

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(b) The waiter places a glass on the tray. State and explain where the glass should be positioned on the tray if the force, *P*, is to have the same value as in part (a).

_____

_____

_____

(2)

(Total 8 marks)

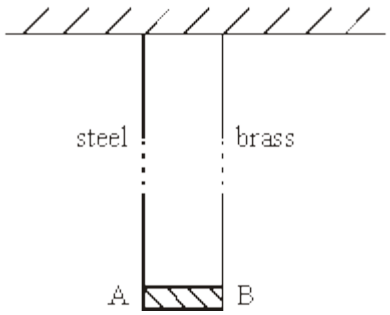
18. (a) State *Hooke's law* for a material in the form of a wire.

_____

_____

(2)

(b) A rigid bar AB of negligible mass, is suspended horizontally from two long, vertical wires as shown in the diagram. One wire is made of steel and the other of brass. The wires are fixed at their upper end to a rigid horizontal surface. Each wire is 2.5 m long but they have different cross-sectional areas.



When a mass of 16 kg is suspended from the centre of AB, the bar remains horizontal.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) What is the tension in each wire?

_____

(ii) If the cross-sectional area of the steel wire is 2.8×10^{-7} m^2, calculate the extension of the steel wire.

_____

_____

_____

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(iii) Calculate the cross-sectional area of the brass wire.

_____

_____

_____

(iv) Calculate the energy stored in the steel wire.

_____

_____

(7)

(c) The brass wire is replaced by a steel wire of the same dimensions as the brass wire. The same mass is suspended from the midpoint of AB.

(i) Which end of the bar is lower?

_____

(ii) Calculate the vertical distance between the ends of the bar.

_____

_____

(2)

(Total 11 marks)

19. A skydiver of mass 70 kg, jumps from a stationary balloon and reaches a speed of 45 m s^{-1} after falling a distance of 150 m.

(a) Calculate the skydiver's

(i) loss of gravitational potential energy,

_____

_____

(ii) gain in kinetic energy.

_____

_____

(4)

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(b) The difference between the loss of gravitational potential energy and the gain in kinetic energy is equal to the work done against air resistance. Use this fact to calculate

(i) the work done against air resistance,

_____

_____

(ii) the average force due to air resistance acting on the skydiver.

_____

_____

_____

(3)

(Total 7 marks)

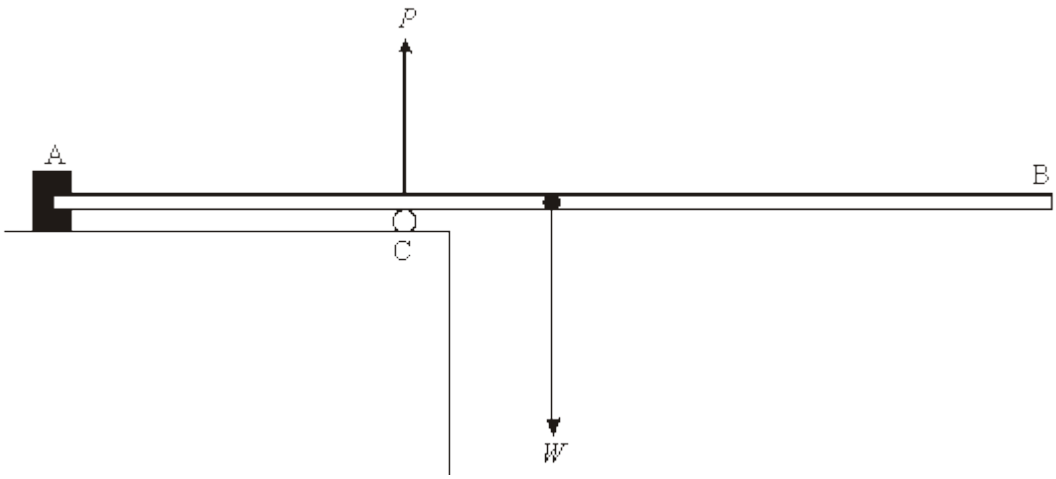
20. (a) Define the moment of a force.

_____

_____

(2)

(b) The diagram shows a uniform diving board of weight, *W*, that is fixed at A. The diving board is supported by a cylinder at C, that exerts an upward force, *P*, on the board.



(i) By considering moments about A, explain why the force *P* must be greater than the weight of the board, *W*.

_____

_____

_____

_____

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(ii) State and explain what would be the effect on the force *P* of a girl walking along the board from A to B.

_____

_____

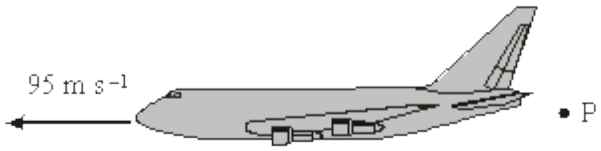
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(4)

(Total 6 marks)

21. The aeroplane shown in the diagram below is travelling horizontally at 95 m s^{-1}.
It has to drop a crate of emergency supplies.
The air resistance acting on the crate may be neglected.





(a) (i) The crate is released from the aircraft at point **P** and lands at point **Q**. Sketch the path followed by the crate between **P** and **Q** as seen from the ground.

(ii) Explain why the horizontal component of the crate's velocity remains constant while it is moving through the air.

_____

_____

_____

(3)

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(b) (i) To avoid damage to the crate, the maximum vertical component of the crate's velocity on landing should be 32 m s^{-1}. Show that the maximum height from which the crate can be dropped is approximately 52 m.

_____

_____

_____

(ii) Calculate the time taken for the crate to reach the ground if the crate is dropped from a height of 52 m.

_____

_____

(iii) If **R** is a point on the ground directly below **P**, calculate the horizontal distance **QR**.

_____

_____

(6)

(c) In practice air resistance is **not** negligible. State and explain the effect this has on the maximum height from which the crate can be dropped.

_____

_____

(2)

(Total 11 marks)

22. In a football match, a player kicks a stationary football of mass 0.44 kg and gives it a speed of 32 m s^{-1}.

(a) (i) Calculate the change of momentum of the football.

_____

(ii) The contact time between the football and the footballer's boot was 9.2 m s. Calculate the average force of impact on the football.

_____

_____

_____

(3)

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(b) A video recording showed that the toe of the boot was moving on a circular arc of radius 0.62 m centred on the knee joint when the football was struck. The force of the impact slowed the boot down from a speed of 24 m s^{-1} to a speed of 15 m s^{-1}.



Figure 1

(i) Calculate the deceleration of the boot along the line of the impact force when it struck the football.

_____

_____

_____

(ii) Calculate the centripetal acceleration of the boot just before impact.

_____

_____

_____

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(iii) Discuss briefly the radial force on the knee joint before impact and during the impact.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 7 marks)

23. (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

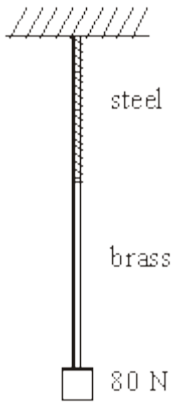
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(2)

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(b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in the figure below.



Each wire has a cross-sectional area of 2.4×10^{-6} m^2.

length of the steel wire = 0.80 m
length of the brass wire = 1.40 m
the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) Calculate the total extension produced when the force of 80 N is applied.

_____

_____

_____

_____

_____

_____

(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = 7.9×10^3 kg m^{-3}
density of brass = 8.5×10^3 kg m^{-3}

_____

_____

_____

_____

_____

(7)

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(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

_____

_____

_____

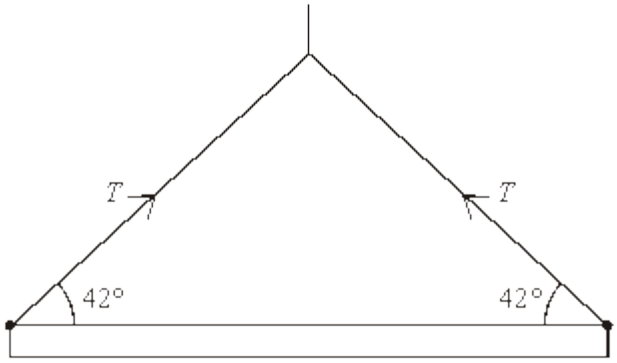
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(2)

(Total 11 marks)

24. The figure below shows a uniform steel girder being held horizontally by a crane. Two cables are attached to the ends of the girder and the tension in each of these cables is *T*.



(a) If the tension, *T*, in each cable is 850 N, calculate

(i) the horizontal component of the tension in each cable,

_____

_____

(ii) the vertical component of the tension in each cable,

_____

_____

(iii) the weight of the girder.

_____

_____

(4)

(b) On the figure draw an arrow to show the line of action of the weight of the girder.

(1)

(Total 5 marks)

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25. (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* is measured.

(i) State the meaning of

tensile stress _____

_____

tensile strain _____

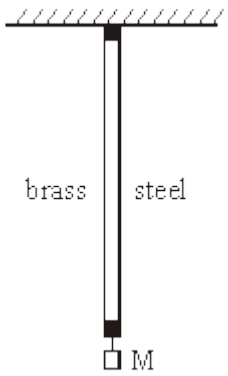
_____

(ii) Define the Young modulus _____

_____

(3)

(b) The diagram below shows two wires, one made of steel and the other of brass, firmly clamped together at their ends. The wires have the same unstretched length and the same cross-sectional area.
One of the clamped ends is fixed to a horizontal support and a mass M is suspended from the other end, so that the wires hang vertically.



(i) Since the wires are clamped together the extension of each wire will be the same.
If E_S is the Young modulus for steel and E_B the Young modulus for brass, show that

$$\frac{E_S}{E_B} = \frac{F_S}{F_B}$$

where F_S and F_B are the respective forces in the steel and brass wire.

_____

_____

_____

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(ii) The mass M produces a total force of 15 N. Show that the magnitude of the force $F_S = 10$ N.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

_____

_____

_____

_____

(iii) The cross-sectional area of each wire is 1.4×10^{-6} m^2 and the unstretched length is 1.5 m. Determine the extension produced in either wire.

_____

_____

_____

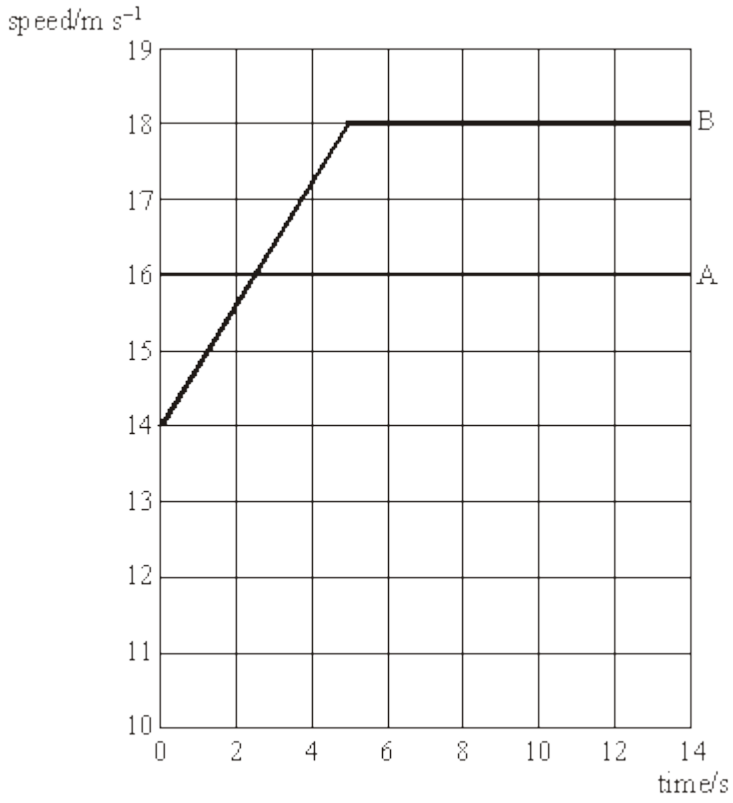
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(6)

(Total 9 marks)

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26. The graph represents the motion of two cars, A and B, as they move along a straight, horizontal road.



(a) Describe the motion of each car as shown on the graph.

(i) car A: _____

_____

(ii) car B: _____

_____

(3)

(b) Calculate the distance travelled by each car during the first 5.0 s.

(i) car A: _____

_____

_____

(ii) car B: _____

_____

_____

(4)

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(c) At time t = 0, the two cars are level. Explain why car A is at its maximum distance ahead of B at t = 2.5 s

_____

_____

_____

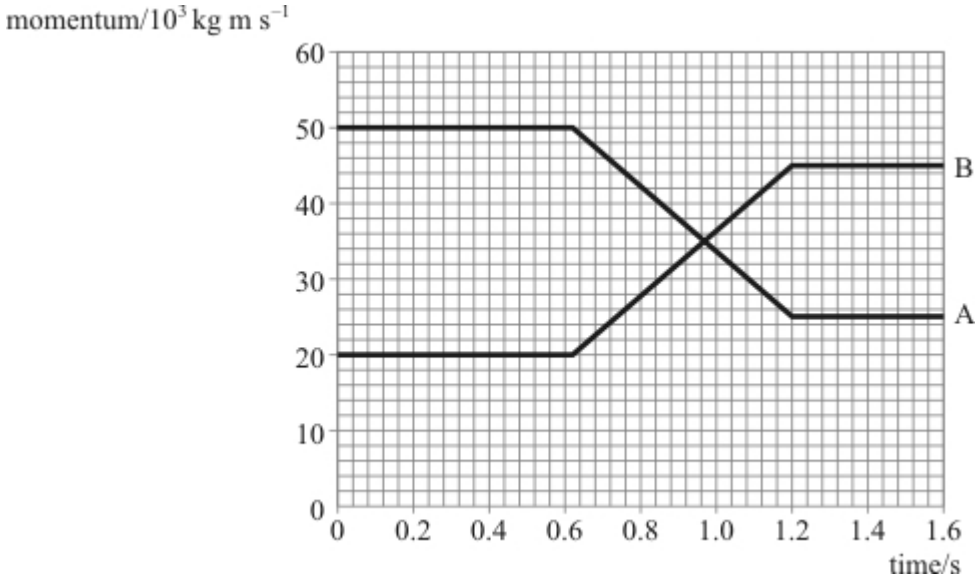
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(3)

(Total 10 marks)

27. The graph shows how the momentum of two colliding railway trucks varies with time. Truck **A** has a mass of 2.0×10^4 kg and truck **B** has a mass of 3.0×10^4 kg. The trucks are travelling in the same direction.



(a) Calculate the change in momentum of

(i) truck **A**,

_____

(ii) truck **B.**

_____

(4)

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(b) Complete the following table.

	Initial velocity/m s^{-1}	Final velocity/m s^{-1}	Initial kinetic energy/J	Final kinetic energy/J
truck **A**				
truck **B**				

(4)

(c) State and explain whether the collision of the two trucks is an example of an elastic collision.

_____

_____

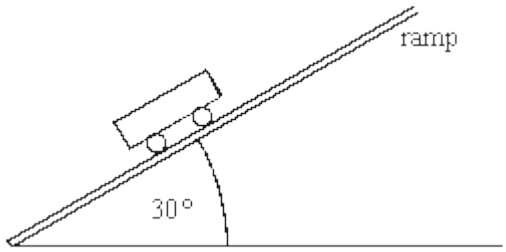
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_____

(3)

(Total 11 marks)

28. A fairground ride ends with the car moving up a ramp at a slope of 30° to the horizontal as shown in the figure below.



(a) The car and its passengers have a total weight of 7.2×10^3 N. Show that the component of the weight parallel to the ramp is 3.6×10^3 N.

_____

_____

(1)

(b) Calculate the deceleration of the car assuming the only force causing the car to decelerate is that calculated in part (a).

_____

_____

(2)

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(c) The car enters at the bottom of the ramp at 18 m s^{-1}. Calculate the minimum length of the ramp for the car to stop before it reaches the end. The length of the car should be neglected.

_____

_____

_____

_____

(2)

(d) Explain why the stopping distance is, in practice, shorter than the value calculated in part (c).

_____

_____

_____

_____

(2)

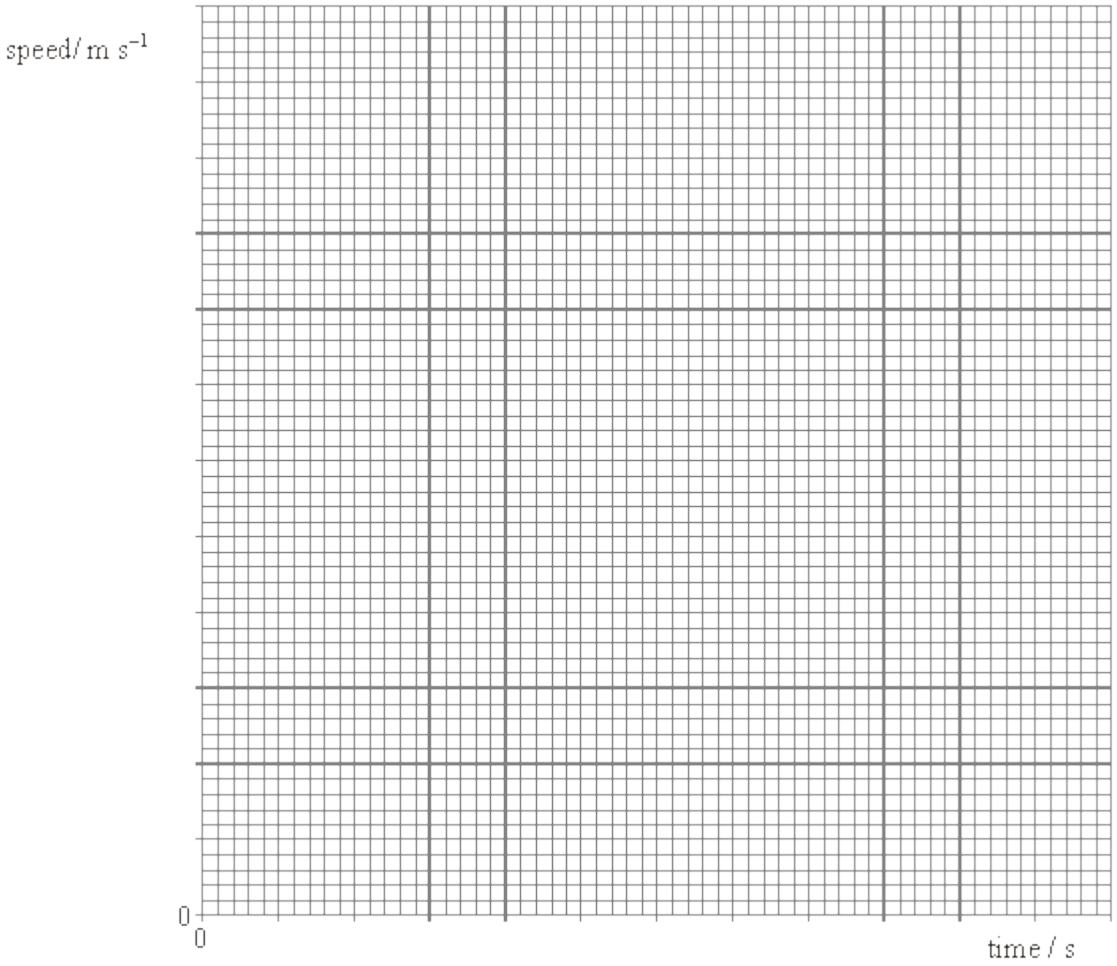
(Total 7 marks)

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29. A car accelerates from rest to a speed of 26 m s^{-1}. The table shows how the speed of the car varies over the first 30 seconds of motion.

time/ s	0	5.0	10.0	15.0	20.0	25.0	30.0
speed/ m s^{-1}	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid provided.



(3)

(b) Calculate the average acceleration of the car over the first 25 s.

_____

_____

(2)

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(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

_____

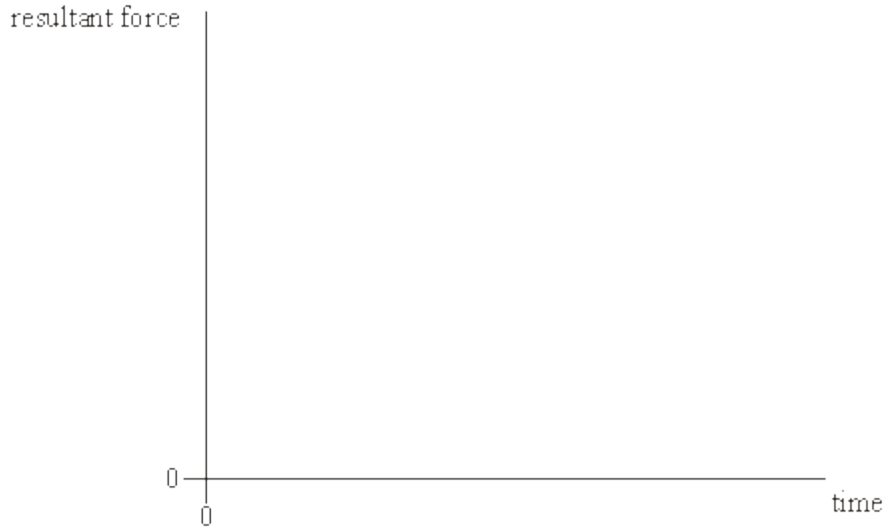
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_____

_____

(2)

(d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(2)

(e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

_____

_____

_____

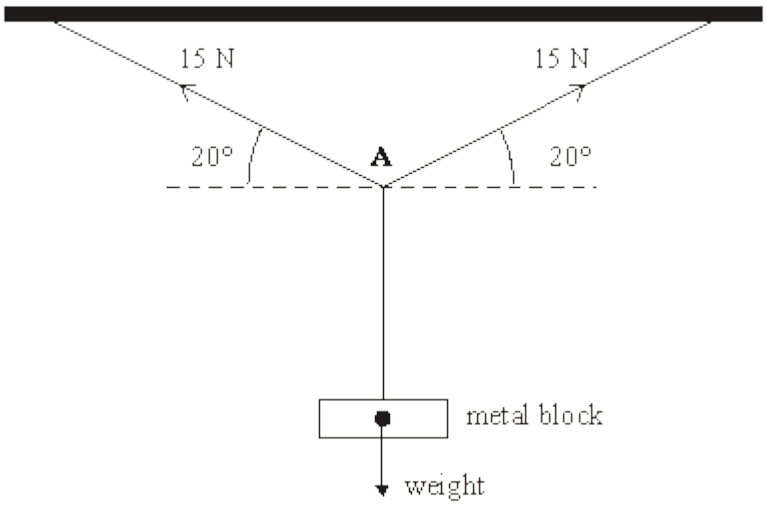
_____

(2)

(Total 11 marks)

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30. The figure below shows a stationary metal block hanging from the middle of a stretched wire which is suspended from a horizontal beam. The tension in each half of the wire is 15 N.



(a) Calculate for the wire at **A**,

(i) the resultant horizontal component of the tension forces,

_____

_____

(ii) the resultant vertical component of the tension forces.

_____

_____

(3)

(b) (i) State the weight of the metal block.

_____

(ii) Explain how you arrived at your answer, with reference to an appropriate law of motion.

_____

_____

_____

_____

_____

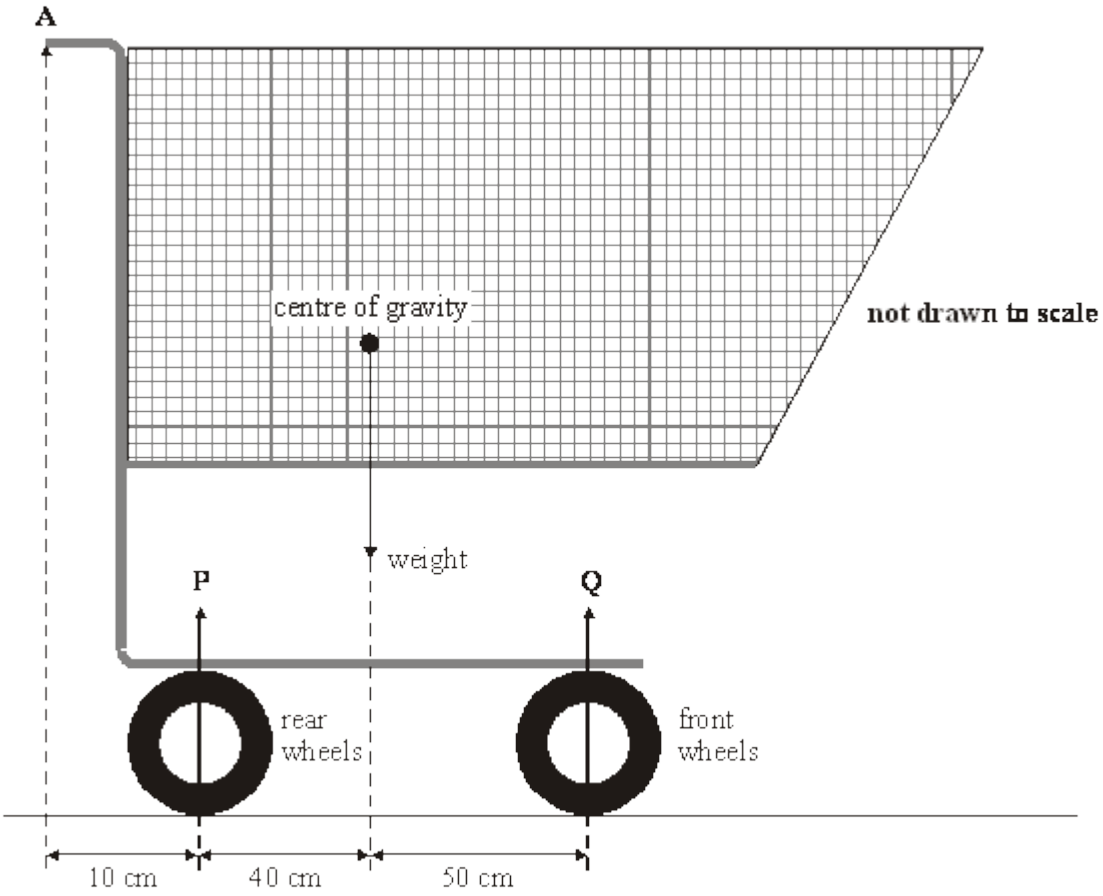
_____

(3)

(Total 6 marks)

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31. The figure below shows a supermarket trolley.



The weight of the trolley and its contents is 160 N.

(a) Explain what is meant by centre of gravity.

_____

_____

(2)

(b) **P** and **Q** are the resultant forces that the ground exerts on the rear wheels and front wheels respectively. Calculate the magnitude of

(i) force **P**,

_____

_____

_____

(ii) force **Q**.

_____

_____

(3)

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(c) Calculate the minimum force that needs to be applied vertically at **A** to lift the front wheels off the ground.

_____

_____

_____

(2)

(d) State and explain, without calculation, how the minimum force that needs to be applied vertically at **A** to lift the rear wheels off the ground compares to the force you calculated in part (c).

You may be awarded marks for the quality of written communication in your answer.

_____

_____

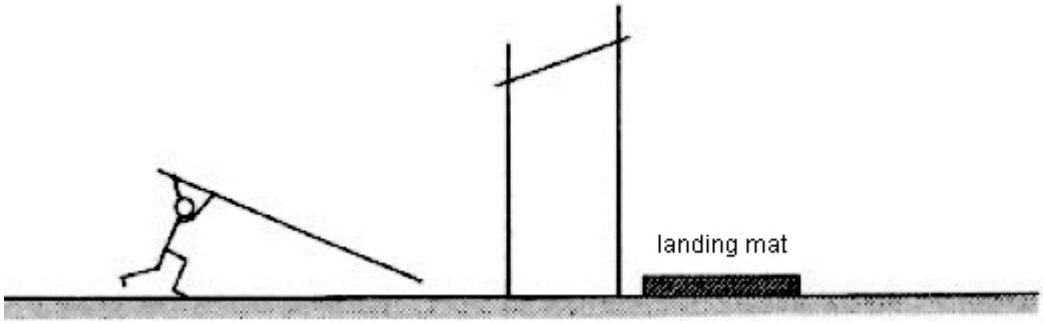
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_____

(3)

(Total 10 marks)

32. The following figure shows an athlete of mass 65 kg about to perform a pole vault.



The centre of mass of the athlete rises 4.2 m during the vault.

(a) Calculate the change in potential energy of the athlete between take off and reaching the highest point.

change in potential energy _____ J

(2)

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(b) Assuming that the centre of mass falls the same distance when falling. Calculate the vertical speed, in m s^{-1}, of the athlete when he lands.

vertical speed _____ m s^{-1}

(2)

(c) Explain how the landing mat reduces the force experienced by the athlete to an acceptable level when landing.

_____

_____

_____

_____

(2)

(Total 6 marks)

33. In the leisure pursuit called parascending a person attached to a parachute is towed by a towrope attached to a motor boat as shown in **Figure 1**.

Figure 1

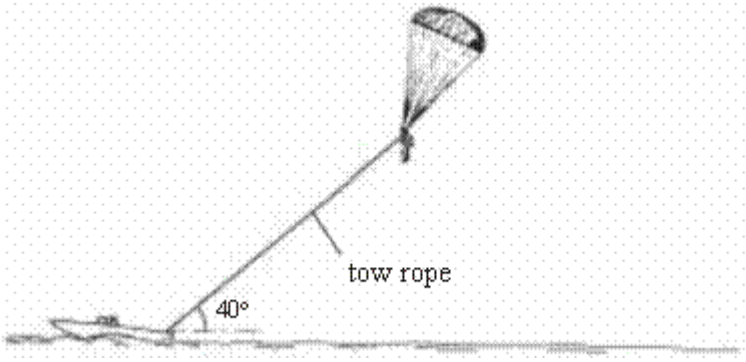


Figure 2

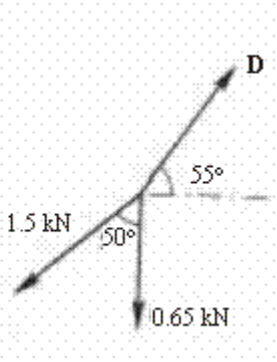


Figure 2 shows the directions of the forces acting on a person of weight 0.65 kN when being towed horizontally at a constant speed of 8.5 m s^{-1}.

The tension in the tow rope is 1.5 kN and *D* is resultant force exerted by the parachute on the parascender.

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(a) (i) State why the resultant force on the parascender must be zero.

_____

_____

(2)

(ii) Calculate the magnitude of *D*.

magnitude of _____ kN

(2)

(b) (i) Calculate the horizontal resistance to motion of the boat produced by the tow rope.

resistance _____ kN

(1)

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(ii) The horizontal resistance to the motion of the boat produced by the water is 1200 N. Calculate the total power developed by the boat.

power _____

(4)

(c) State and explain the initial effect on the boat if the tow rope were to break.

_____

_____

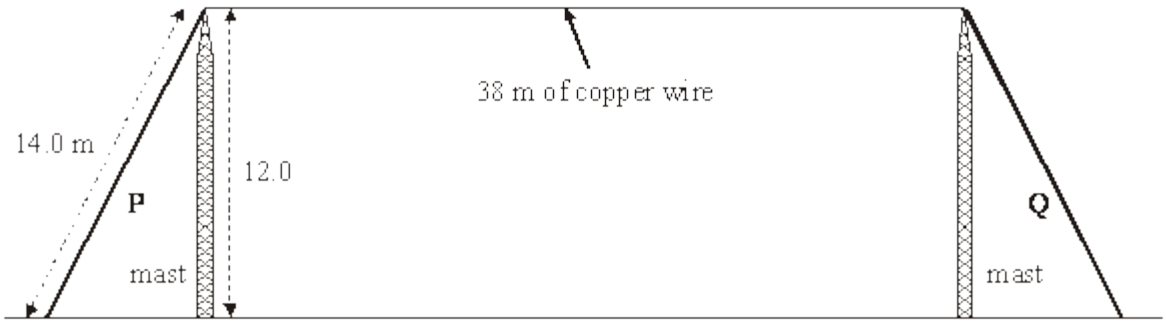
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(2)

(Total 11 marks)

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34. An aerial system consists of a horizontal copper wire of length 38 m supported between two masts, as shown in the figure below. The wire transmits electromagnetic waves when an alternating potential is applied to it at one end.



(a) The wavelength of the radiation transmitted from the wire is twice the length of the copper wire. Calculate the frequency of the transmitted radiation.

_____

_____

_____

_____

(1)

(b) The ends of the copper wire are fixed to masts of height 12.0 m. The masts are held in a vertical position by cables, labelled **P** and **Q**, as shown in the figure above.

(i) **P** has a length of 14.0 m and the tension in it is 110 N. Calculate the tension in the copper wire.

_____

_____

_____

_____

_____

(ii) The copper wire has a diameter of 4.0 mm. Calculate the stress in the copper wire.

_____

_____

_____

_____

_____

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(iii) Discuss whether the wire is in danger of breaking if it is stretched further due to movement of the top of the masts in strong winds.

breaking stress of copper = 3.0×10^8 Pa

_____

_____

_____

_____

_____

_____

_____

_____

(7)

(Total 8 marks)

35. **Figure 1** shows the speed-time graph for a swimmer performing one complete cycle of the breast stroke.

Figure 1

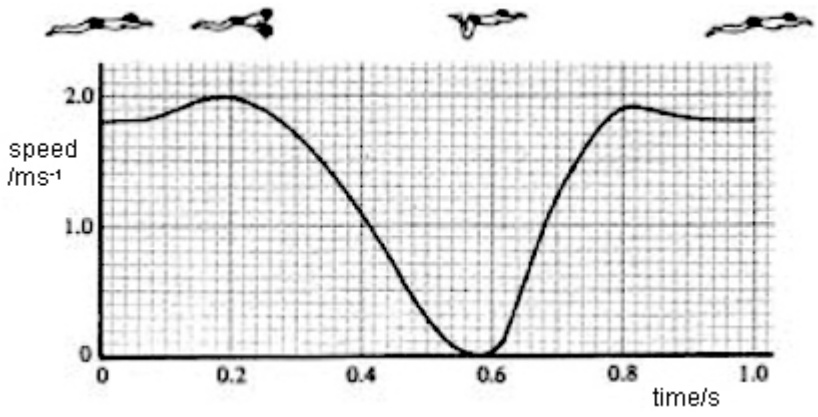
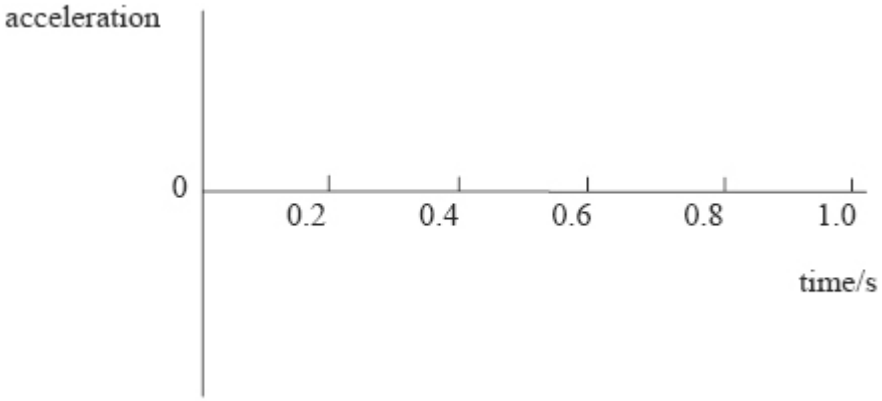


Figure 2



STEMUP.CO.UK

(a) (i) Find the acceleration of the swimmer at time 0.65 s.

acceleration _____

(2)

(ii) Sketch, on the axes in **Figure 2**, a graph to show how the acceleration of the swimmer varies with time for the same time interval. You are not required to make any further calculations but your graph should show relative values.

(2)

(b) Use the graph in **Figure 1** to estimate the distance travelled by the swimmer in one complete cycle of the stroke. Show your working clearly.

distance travelled _____ m

(4)

(Total 8 marks)

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36. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

_____

_____

(ii) Explain what is meant by the elastic limit of the wire.

_____

_____

(iii) Define the Young modulus of a material and state the unit in which it is measured.

_____

_____

(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

_____

_____

(ii) Explain how the student may obtain a value of the Young modulus.

_____

_____

_____

_____

_____

_____

(iii) How would a value for the elastic energy stored in the wire be found from the results?

_____

_____

(6)

(Total 11 marks)

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37. (a) Give **two** examples of the techniques used by geologists to obtain values of the strength of the local gravitational field of the Earth.
In each of your quoted examples, describe the information that the geologists can derive from their measurements.

_____

_____

_____

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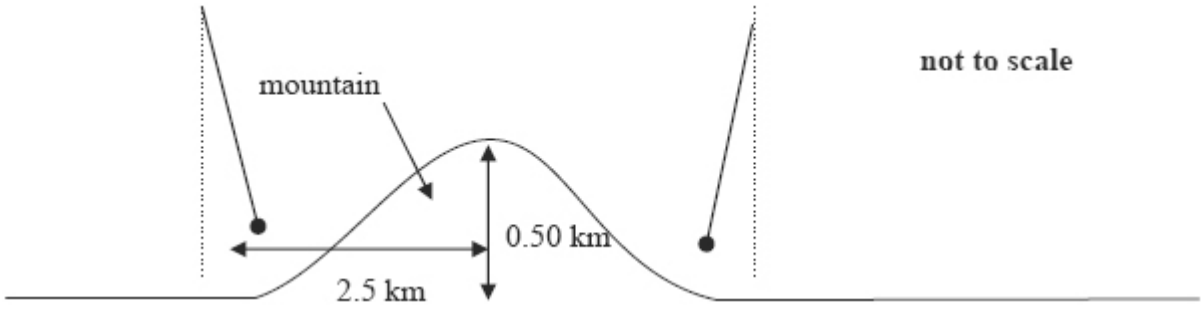
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(4)

In 1774, Nevil Maskelyne carried out an experiment near the mountain of Schiehallion in Scotland to determine the density of the Earth.

Figure 1 shows two positions of a pendulum hung near to, but on opposite sides of, the mountain. The centre of mass of the mountain is at the same height as the pendulum.

Figure 1



(b) (i) Explain why the pendulums do not point towards the centre of the Earth.

_____

_____

_____

_____

(2)

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(ii) Suggest why Maskelyne carried out the experiment on both sides of the mountain.

_____

_____

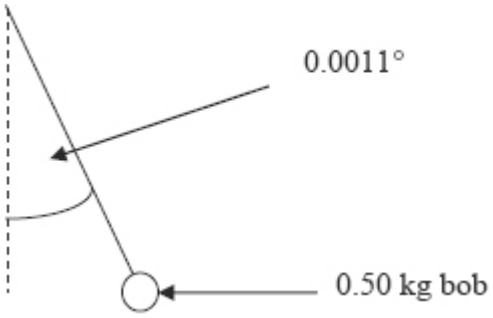
_____

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(1)

(c) **Figure 2** shows measurements made with the left-hand pendulum in **Figure 1**.

Figure 2



(i) The mountain is in the appropriate shape of a cone 0.50 km high and 1.3 km base radius; it rises from a locally flat plain.
Show that the mass of the mountain is about 2×10^{12} kg.

volume of a cone $= \frac{1}{3} \pi r^2 h$

density of rock = 2.5×10^3 kg m^{-3}

(3)

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(ii) **Figure 2** shows the left-hand pendulum bob lying on a horizontal line that also passes through the centre of mass of the mountain. The bob is 1.4 km from the centre of the mountain and it hangs at an angle of 0.0011° to the vertical.

Calculate the mass of the Earth.

(3)

(iii) The answer Maskelyne obtained for the mass of the Earth was lower than today's accepted value even though he had an accurate value for the Earth's radius.

Suggest **one** reason why this should be so.

_____

_____

_____

_____

(1)

(Total 14 marks)

38. A supertanker of mass 4.0×10^8 kg, cruising at an initial speed of 4.5 m s^{-1}, takes one hour to come to rest.

(a) Assuming that the force slowing the tanker down is constant, calculate

(i) the deceleration of the tanker,

_____

_____

(ii) the distance travelled by the tanker while slowing to a stop.

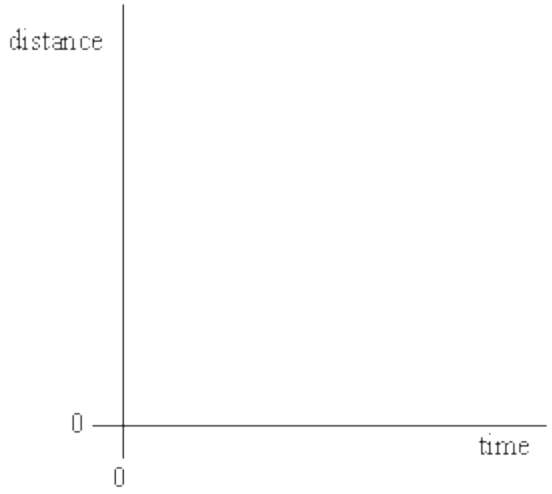
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_____

(4)

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(b) Sketch, using the axes below, a distance-time graph representing the motion of the tanker until it stops.



(2)

(c) Explain the shape of the graph you have sketched in part (b).

_____

_____

_____

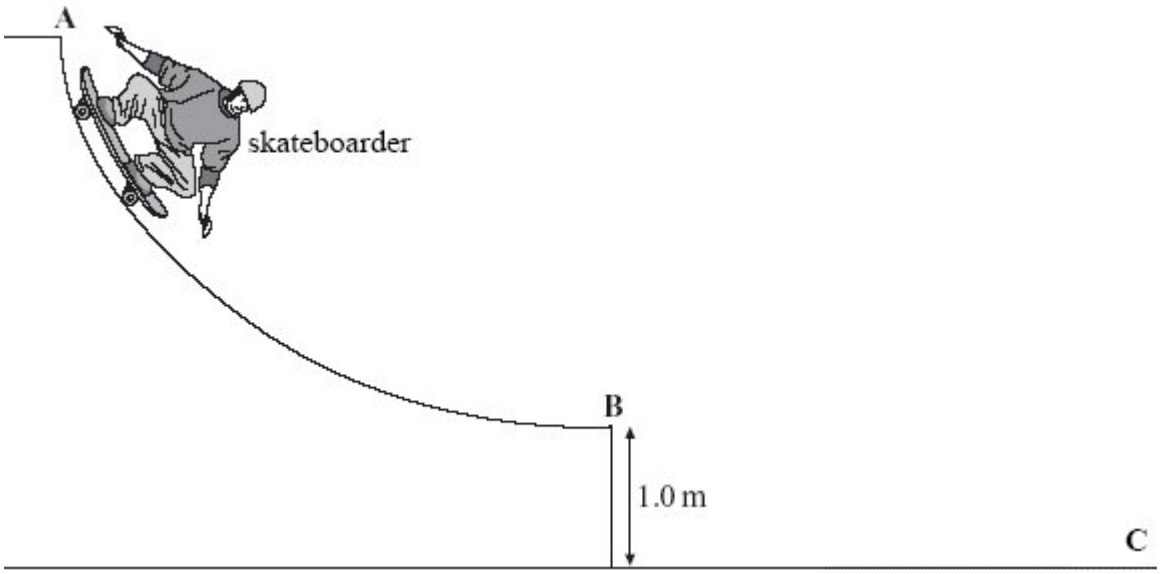
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(2)

(Total 8 marks)

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39. The figure below shows a skateboarder descending a ramp.



The skateboarder starts from rest at the top of the ramp at **A** and leaves the ramp at **B** horizontally with a velocity *v*.

(a) State the energy changes that take place as the skateboarder moves from **A** to **B**.

_____

_____

(2)

(b) In going from **A** to **B** the skateboarder's centre of gravity descends a vertical height of 1.5 m. Calculate the horizontal velocity, *v*, stating an assumption that you make.

_____

_____

_____

_____

_____

_____

(3)

(c) Explain why the acceleration decreases as the skateboarder moves from **A** to **B**.

_____

_____

_____

_____

(2)

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(d) After leaving the ramp at **B** the skateboarder lands on the ground at **C** 0.42 s later.

Calculate for the skateboarder

(i) the horizontal distance travelled between **B** and **C**,

_____

_____

(ii) the vertical component of the velocity immediately before impact at **C**,

_____

_____

_____

(iii) the magnitude of the resultant velocity immediately before impact at **C**.

_____

_____

_____

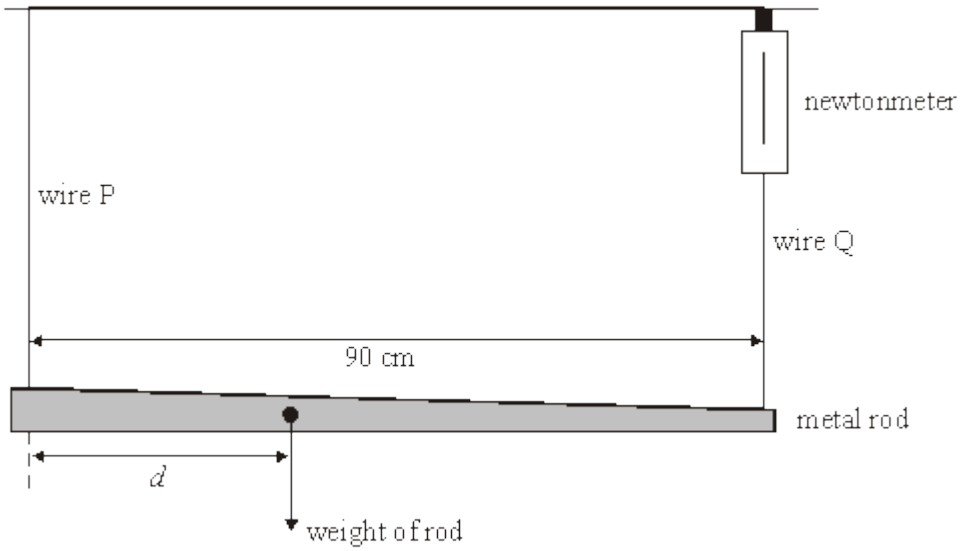
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(5)

(Total 12 marks)

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40. The figure below shows an apparatus used to locate the centre of gravity of a non-uniform metal rod.



The rod is supported horizontally by two wires, P and Q and is in equilibrium.

(a) State **two** conditions that must be satisfied for the rod to be in equilibrium.

_____

_____

_____

_____

(2)

(b) Wire Q is attached to a newtonmeter so that the force the wire exerts on the rod can be measured. The reading on the newtonmeter is 2.0 N and the weight of the rod is 5.0 N. Calculate

(i) the force that wire P exerts on the rod,

_____

(ii) the distance *d*.

_____

_____

_____

(3)

(Total 5 marks)

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