CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Unit 4: Moment of Force

Past Papers 2021 – 2025

QUESTION PAPER 16 Questions

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Question 1

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

....

....

.... [2]

(b) Fig. 3.1 shows a type of balance that is used for measuring mass.

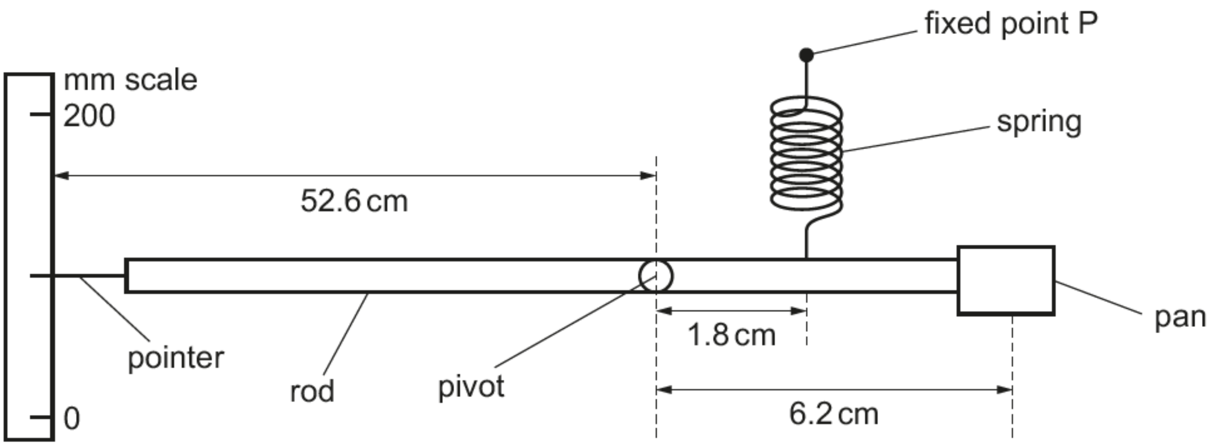

Fig. 3.1 (not to scale)

A rigid rod is pivoted about a point 6.2 cm from the centre of a pan which is attached to one end. The object being measured is placed on the centre of this pan.

A spring, attached to the rod 1.8 cm from the pivot, is attached at its other end to a fixed point P. The spring obeys Hooke's law over the full range of operation of the balance.

A pointer, on the other side of the pivot, is set against a millimetre scale which is a distance 52.6 cm from the pivot.

When the system is in equilibrium with no mass on the pan, the rod is horizontal and the pointer indicates a reading on the scale of 86 mm.

An object of mass 0.472 kg is now placed on the pan. As a result, the pointer moves to indicate a reading of 123 mm on the scale when the system is again in equilibrium.

(i) Show that the increase in the length of the spring is approximately 1.3 mm.

(ii) Calculate the magnitude of the moment about the pivot of the weight of the object.

moment = ... N m [2]

(iii) Use your answer in **(b)(ii)** to determine the increase in the tension in the spring due to the 0.472 kg mass.

increase in tension = ... N [2]

(iv) Use the information in **(b)(i)** and your answer in **(b)(iii)** to determine the spring constant *k* of the spring. Give a unit with your answer.

k = ... unit .... [2]

[Total: 10]

Question 2

(a) State what is meant by the centre of gravity of an object.

....

.... [1]

(b) A non-uniform rod XY is pivoted at point P, as shown in Fig. 2.1.

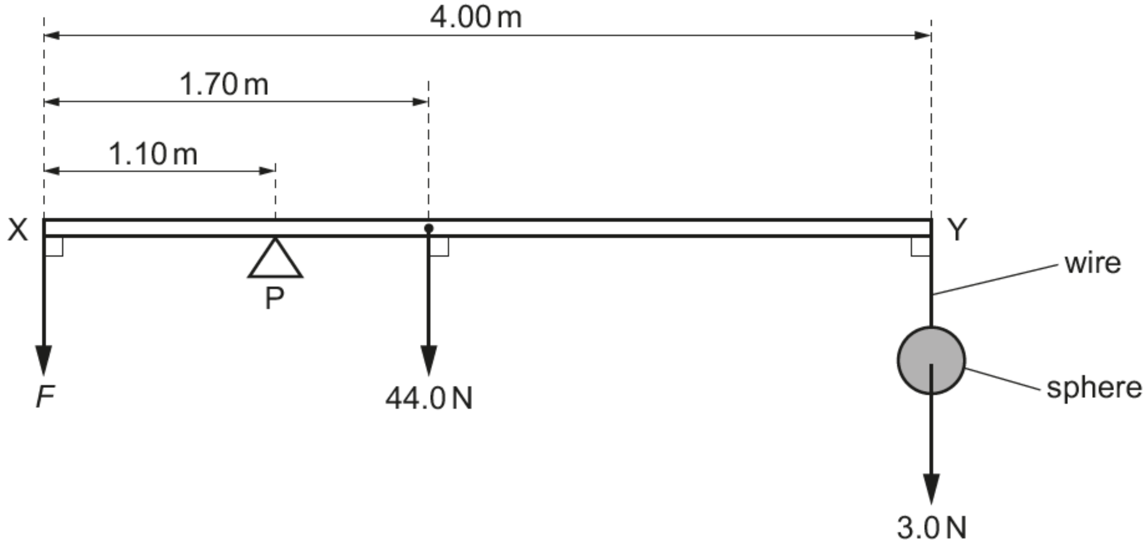

Fig. 2.1 (not to scale)

The rod has length 4.00 m and weight 44.0 N. The centre of gravity of the rod is 1.70 m from end X of the rod. Point P is 1.10 m from end X.

A sphere hangs by a wire from end Y of the rod. The weight of the sphere is 3.0 N. The weight of the wire is negligible.

A force *F* is applied vertically downwards at end X so that the horizontal rod is in equilibrium.

(i) By taking moments about P, calculate *F*.

F = ... N [3]

(ii) Calculate the force exerted on the rod by the pivot.

force = ... N [1]

(c) The sphere in **(b)** is now immersed in a liquid in a container, as shown in Fig. 2.2.

Fig. 2.2

The density of the liquid is 1100 kg m^{-3}. The upthrust acting on the sphere due to the liquid is 2.5 N. The magnitude of *F* is unchanged so that the horizontal rod is **not** in equilibrium.

(i) Use Archimedes' principle to determine the radius *r* of the sphere.

r = ... m [3]

(ii) Calculate the magnitude and direction of the resultant moment of the forces on the rod about P.

magnitude of resultant moment = ... N m

direction of resultant moment ....

[2]

[Total: 10]

Question 3

(a) State what is meant by the centre of gravity of an object.

....

.... [1]

(b) A uniform beam AB is attached by a frictionless hinge to a vertical wall at end A. The beam is held so that it is horizontal by a metal wire CD, as shown in Fig. 3.1.

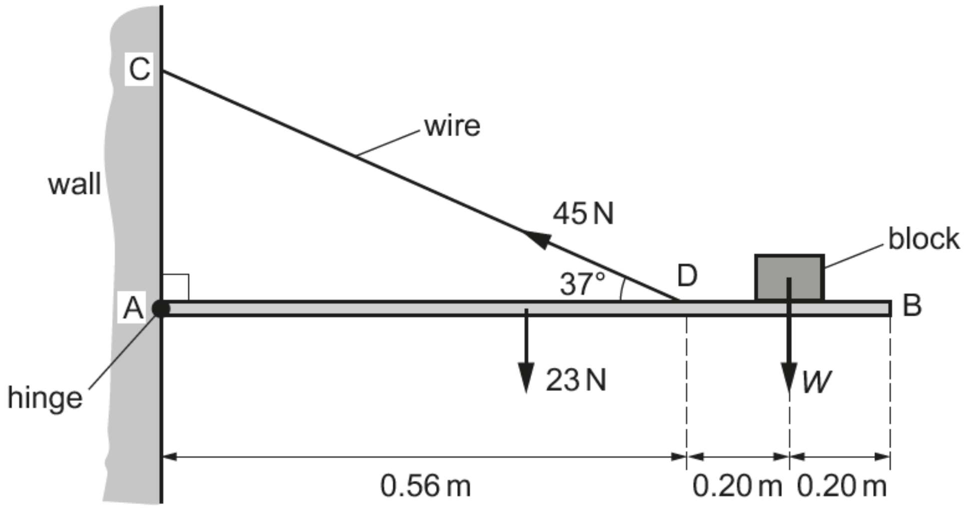

Fig. 3.1 (not to scale)

The beam is of length 0.96 m and weight 23 N. A block of weight W rests on the beam at a distance of 0.20 m from end B. The wire is attached to the beam at point D which is a distance of 0.40 m from end B. The wire exerts a force on the beam of 45 N at an angle of 37° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the wire on the beam.

vertical component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight W of the block.

W = ... N [3]

(iii) The hinge exerts a force on the beam at end A.

Calculate the horizontal component of this force.

horizontal component of force = ... N [1]

(iv) The block is now placed closer to point D on the beam.

State whether this change will increase, decrease or have no effect on the tension in the wire.

.... [1]

(v) The stress in the wire is 5.3×10^{7} Pa. The wire is now replaced by a second wire that has a radius which is three times greater than that of the original wire. The tension in the wire is unchanged.

Calculate the stress in the second wire.

stress = ... Pa [2]

[Total: 9]

Question 4

(a) State the principle of moments.

....

....

.... [2]

(b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

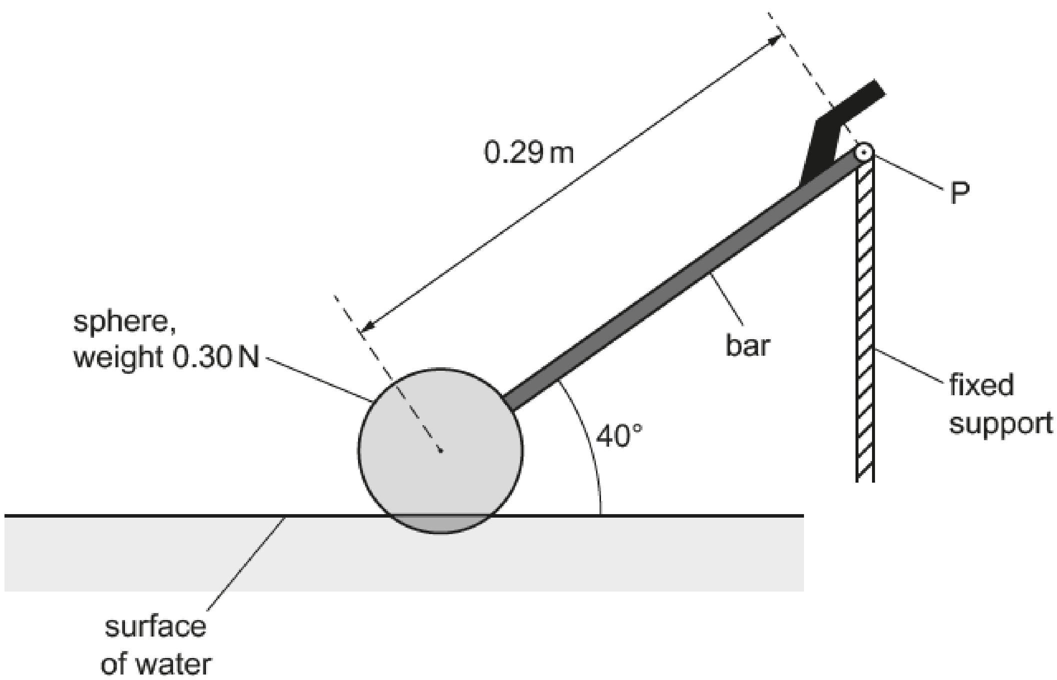

Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = ... N m [2]

(c) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

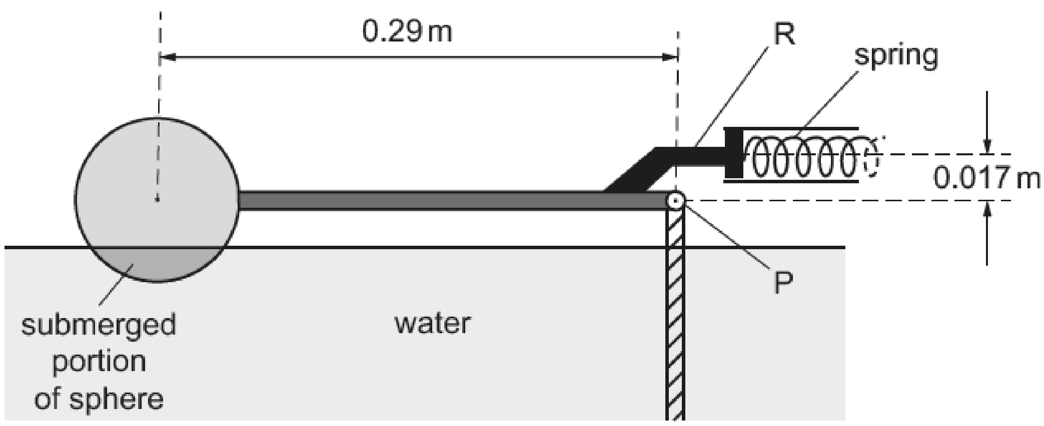

Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force F applied to the spring with compression x of the spring is shown in Fig. 3.3.

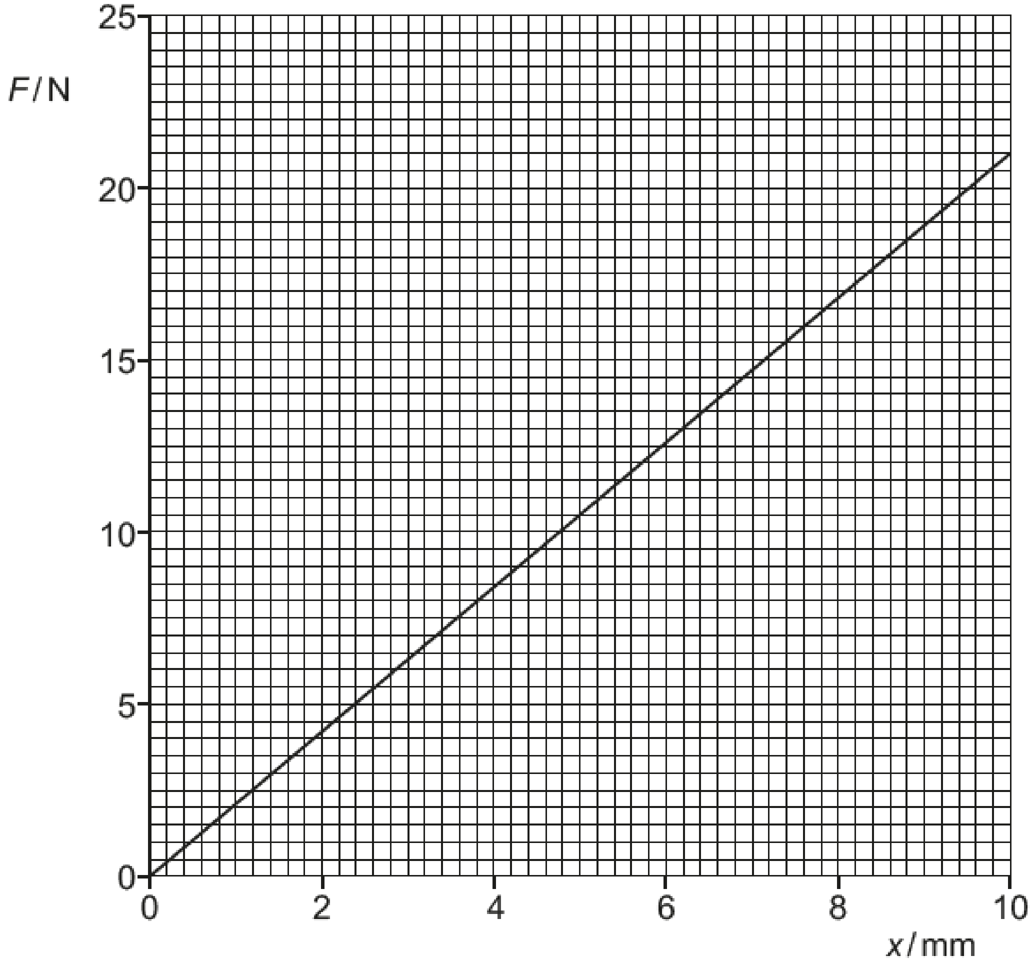

Fig. 3.3

(i) Use Fig. 3.3 to calculate the spring constant *k* of the spring.

k = ... $N\,m^{-1}$ [2]

(ii) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.
The density of water is $1.00 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

(iii) By taking moments about P, determine the force exerted on the spring by the rod R.

force = ... N [2]

(iv) Calculate the elastic potential energy E_P of the compressed spring.

E_P = ... J [2]

(d) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work.
Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

....

.... [1]

[Total: 13]

Question 5

A uniform beam AB is attached by a hinge to a wall at end A, as shown in Fig. 3.1.

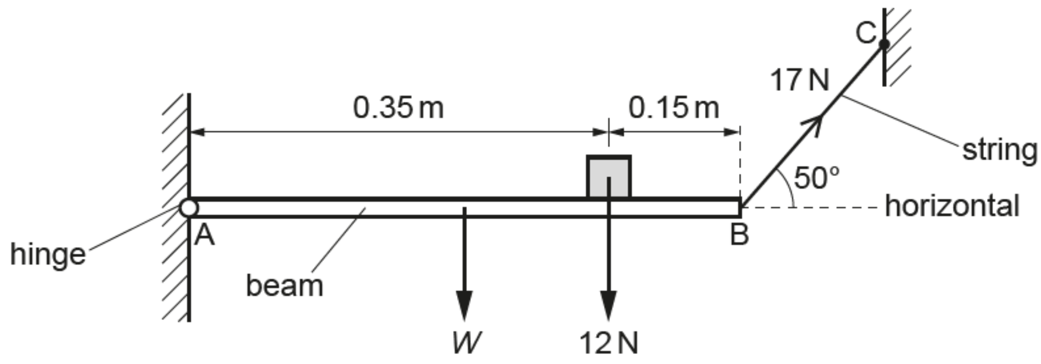

Fig. 3.1 (not to scale)

The beam has length 0.50 m and weight *W*. A block of weight 12 N rests on the beam at a distance of 0.15 m from end B.

The beam is held horizontal and in equilibrium by a string attached between end B and a fixed point C. The string has a tension of 17 N and is at an angle of 50° to the horizontal.

(a) State **two** conditions for an object to be in equilibrium.

1 ....

....

2 ....

....

[2]

(b) Show that the vertical component of the tension in the string is 13 N.

[1]

(c) By taking moments about end A, calculate the weight W of the beam.

W = ... N [2]

(d) Calculate the magnitude of the vertical component of the force exerted on the beam by the hinge.

force = ... N [1]

(e) The block is now moved closer to end A of the beam. Assume that the beam remains horizontal.

State whether this change will increase, decrease or have no effect on the horizontal component of the force exerted on the beam by the hinge.

.... [1]

[Total: 7]

Question 6

A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 2.1.

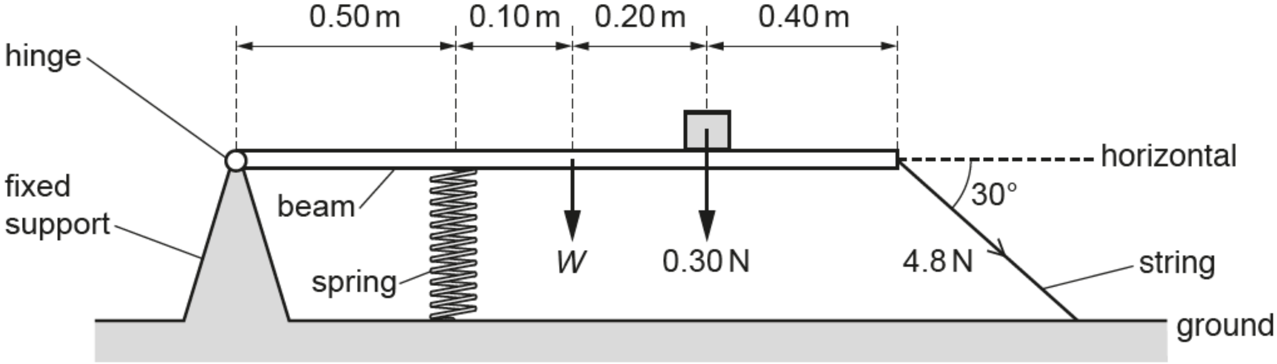

Fig. 2.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 2.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

(a) **(i)** Show that the vertical component of the tension in the string is 2.4 N.

[1]

(ii) By taking moments about the hinge, determine the weight W of the beam.

W = ... N [3]

(iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

force = ... N [1]

(b) The spring obeys Hooke's law and has an elastic potential energy of 0.32 J.

Calculate the compression of the spring.

compression = ... m [2]

Question 7

(a) State what is meant by the centre of gravity of an object.

....

.... [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

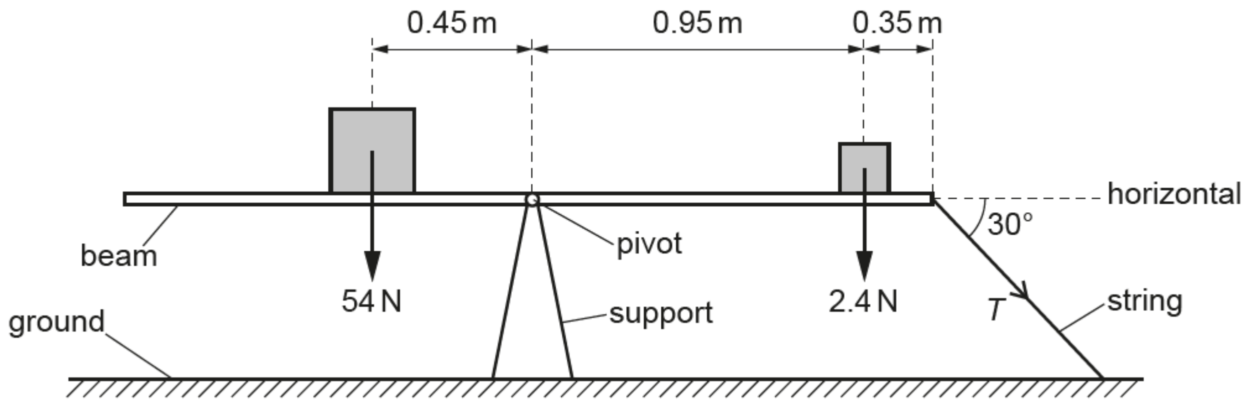

Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

(i) By taking moments about the pivot, calculate the tension *T* in the string.

T = ... N [3]

(ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = ... N m [1]

Question 8

(b) State the conditions necessary for an object to be in equilibrium.

....

....

.... [2]

(c) A wire is used to hold a uniform shelf AB horizontally in equilibrium as shown in Fig. 3.2.

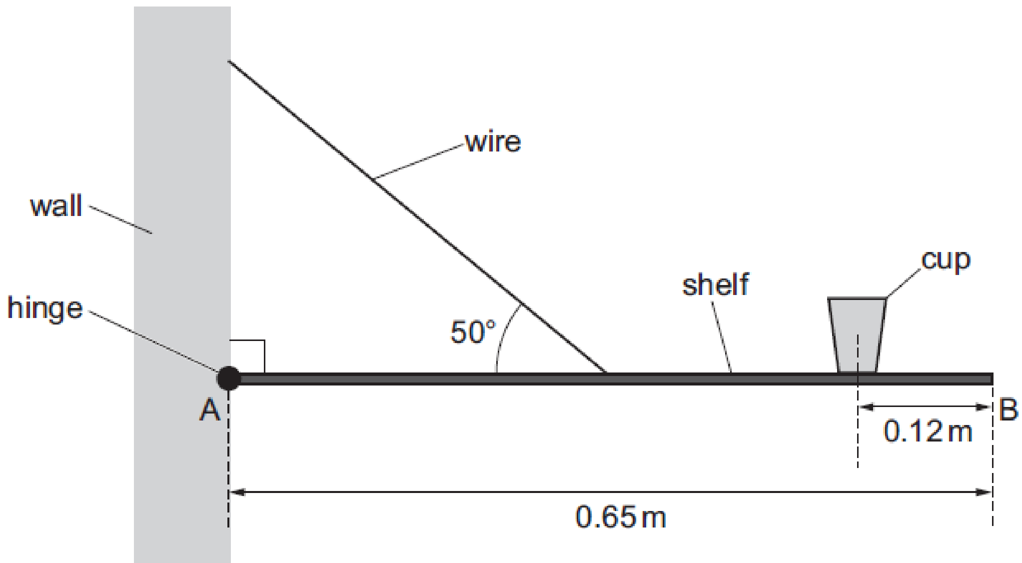

Fig. 3.2 (not to scale)

The wire is connected to the midpoint of shelf AB at an angle of 50° to the horizontal. The shelf is attached to a wall by a hinge at A. The length of shelf AB is 0.65 m and its weight is 33 N.
A cup of weight 1.5 N rests on the shelf with its centre of gravity at a horizontal distance of 0.12 m from B.

(i) By taking moments about A, determine the tension in the wire.

tension = ... N [3]

(ii) The stress in the wire is 1.5×10^7 Pa.

Determine the radius of the wire.

radius = ... m [2]

Question 9

(a) State the principle of moments.

....

....

.... [1]

(b) A rigid uniform beam rests on a pivot at its centre, as shown in Fig. 3.1.

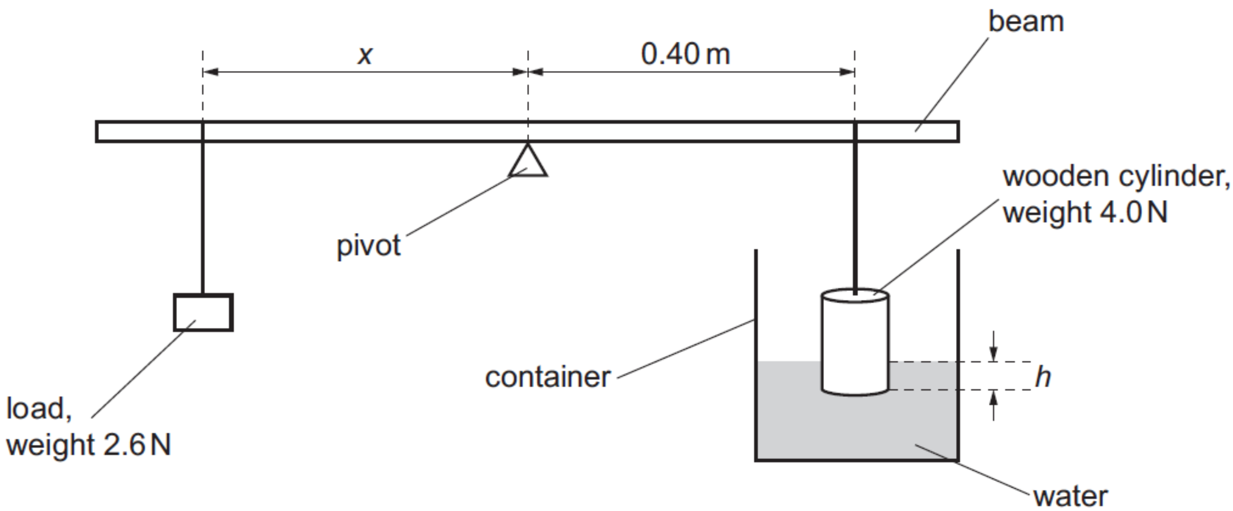

Fig. 3.1 (not to scale)

A load of weight 2.6 N is suspended from the beam at distance *x* from the pivot.

A wooden cylinder of weight 4.0 N is suspended from the beam at a distance of 0.40 m from the pivot on the opposite side of the pivot to the load. The cylinder rests in a container of water. The lower part of the cylinder is immersed in the water to depth *h*.

Initially, *h* is equal to 0.10 m and *x* is equal to 0.40 m. The system is in equilibrium.

(i) Use the principle of moments to show that the upthrust *U* exerted by the water on the cylinder is 1.4 N.

[2]

(ii) The density of the water is $1.0 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Calculate the area *A* of the circular cross-section of the cylinder.

A = ... m^2 [3]

(c) More water is gradually added to the container in **(b)**, so that depth *h* in Fig. 3.1 gradually increases. The length *x* is continuously adjusted so that the system remains in equilibrium.

On Fig. 3.2, sketch the variation of *x* with *h*. Use the space below for any working.

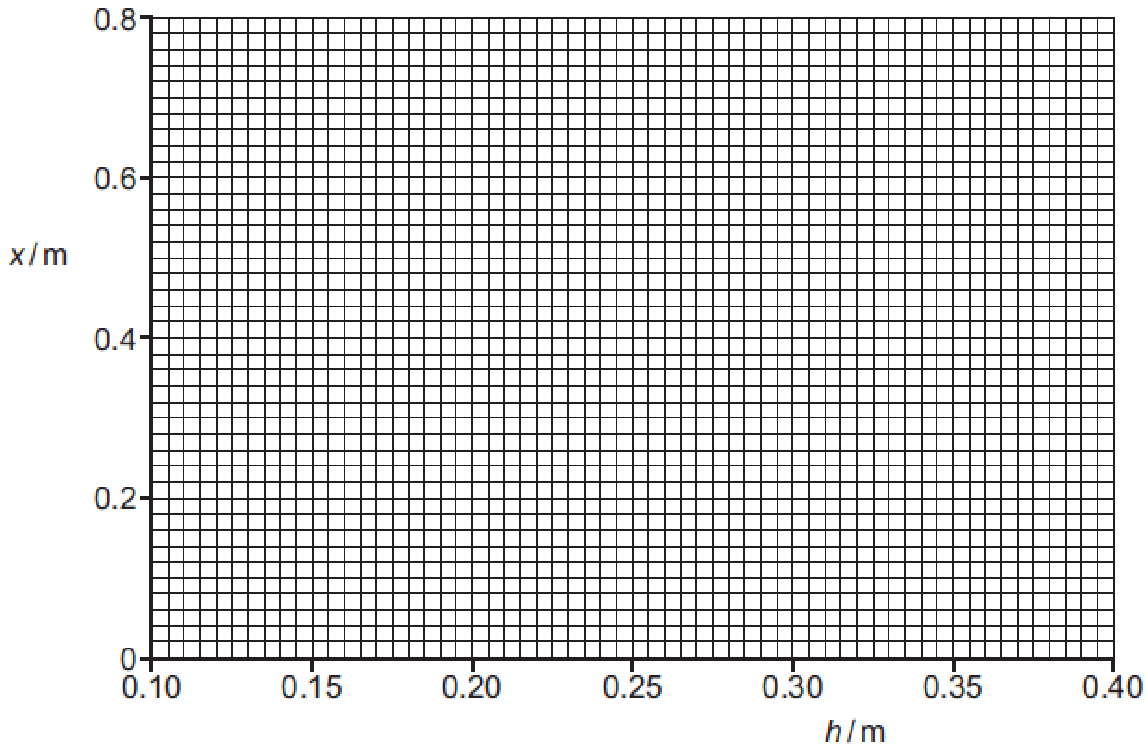

Fig. 3.2

[3]

[Total: 9]

Question 10

(a) State the principle of moments.

....

....

.... [2]

(b) A solid plastic cylinder floats in water. It is used to support one end of a horizontal uniform beam AB as shown in Fig. 2.1.

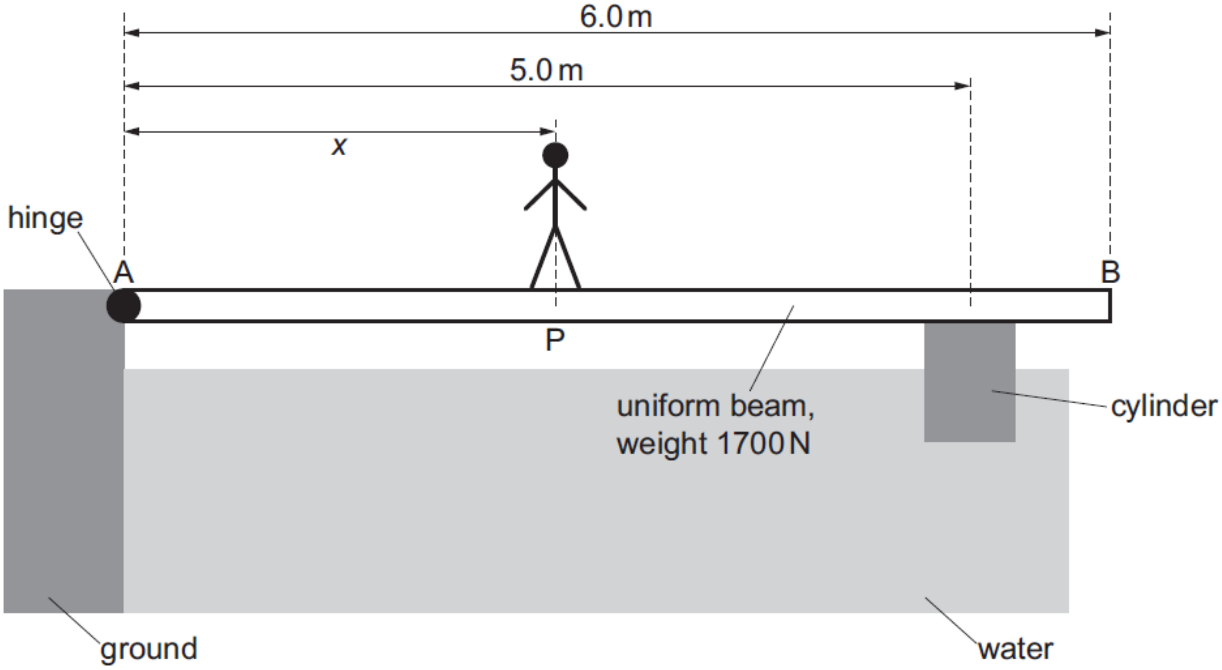

Fig. 2.1 (not to scale)

The beam has length 6.0 m and weight 1700 N. The beam is attached to solid ground with a hinge at end A.

The cylinder is floating vertically in the water. The top of the cylinder is attached at its centre to the beam at a horizontal distance of 5.0 m from end A. The cylinder applies a vertical force of 1300 N to the beam.

A person of weight 660 N stands on the beam at point P.

The beam AB is in equilibrium.

(i) By taking moments about end A, determine the distance *x* from A to P.

distance = ... m [3]

(ii) The bottom of the cylinder is submerged in the water to depth *y* as shown in Fig. 2.2. The beam is still attached to the cylinder but not shown.

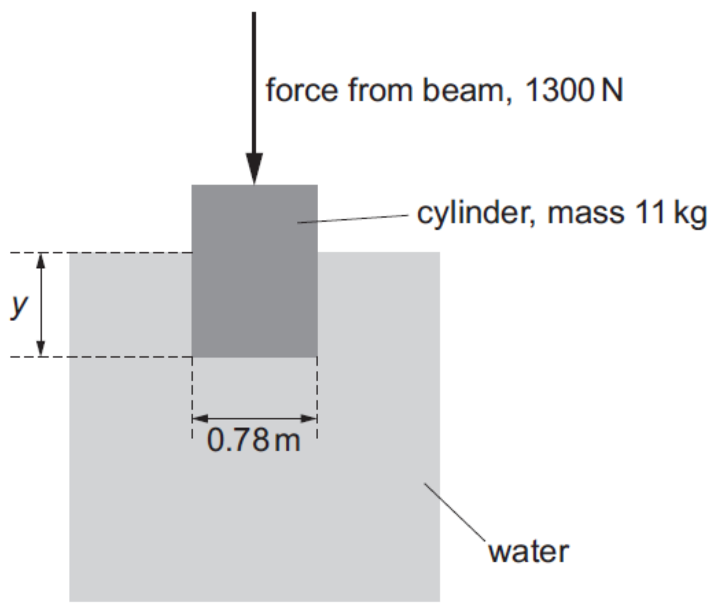

Fig. 2.2 (not to scale)

The cylinder has mass 11 kg and diameter 0.78 m. The beam exerts a vertical force of 1300 N on the cylinder. The cylinder is in equilibrium.

Show that the upthrust acting on the cylinder is 1400 N.

[1]

(iii) The water has density 990 kg m^{-3}.

Calculate the depth *y*.

y = ... m [2]

(iv) The person can stand anywhere between A and B.

On Fig. 2.3, sketch the variation of the depth of the bottom of the cylinder with the distance of the person from A, for distances between 0 and 6.0 m. Numerical values are not required.

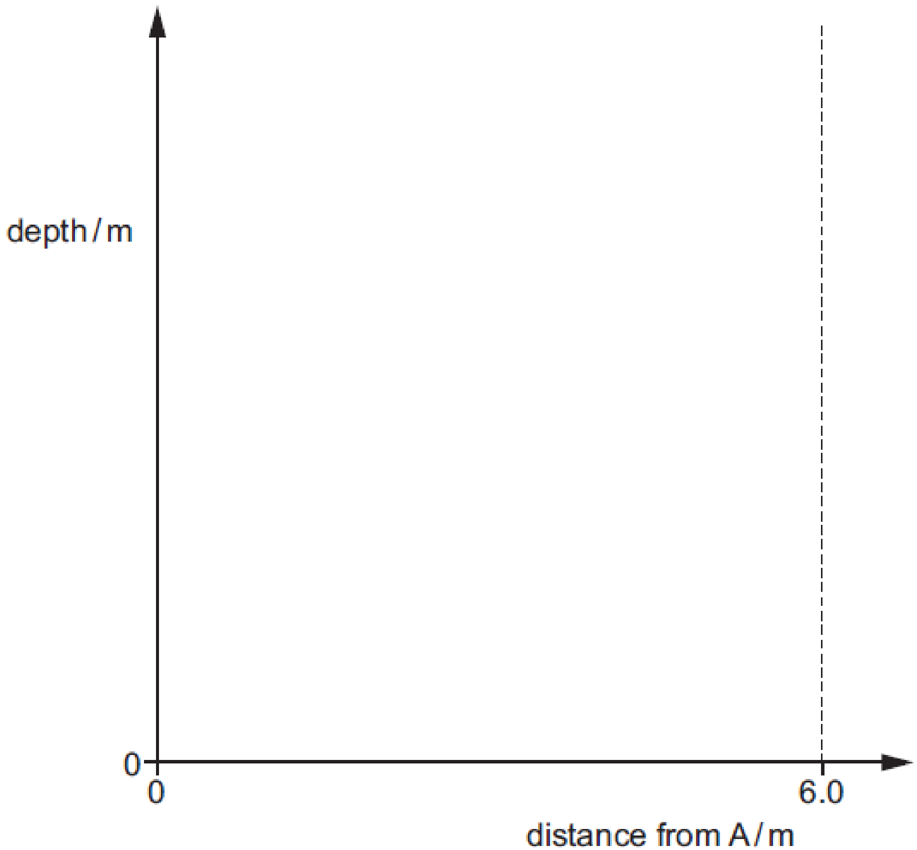

Fig. 2.3

[2]

[Total: 10]

Question 11

(a) State the principle of moments.

....

....

.... [2]

(b) Three objects A, B and C are placed on a horizontal beam. The beam is in equilibrium, as shown in Fig. 2.1.

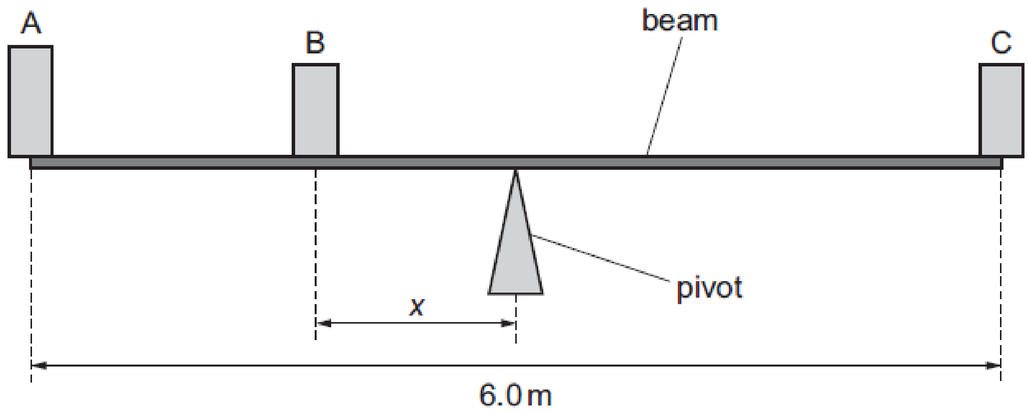

Fig. 2.1 (not to scale)

The beam is uniform and has length 6.0 m.
The pivot is at the midpoint of the beam.
Object A has mass 60 kg and is at one end of the beam.
Object B has mass 45 kg and is at a distance *x* from the pivot.
Object C has mass 80 kg and is at the other end of the beam.

Calculate *x*.

x = ... m [3]

(c) The beam is 0.80 m above horizontal ground.

Object A is removed and replaced by a spring connected to the ground and the beam, as shown in Fig. 2.2.

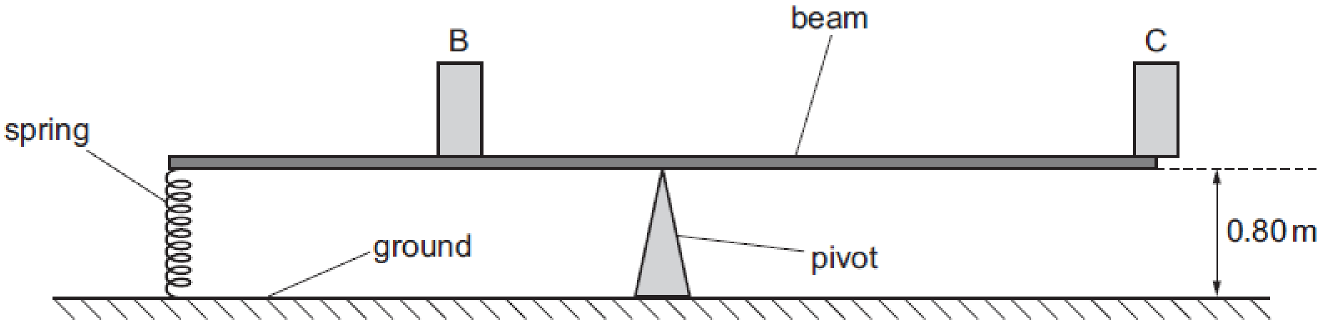

Fig. 2.2

After the change, the beam is again horizontal and in equilibrium. The positions of B and C are unchanged.

The spring has an unstretched length of 0.59 m and obeys Hooke's law.

(i) Calculate the spring constant of the spring.

spring constant = ... $N m^{-1}$ [3]

(ii) Calculate the elastic potential energy of the spring.

elastic potential energy = ... J [2]

[Total: 10]

Question 12

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

....

.... [1]

(b) A tree of mass 270 kg grows out of sloping ground and is supported by a post, as shown in Fig. 2.1.

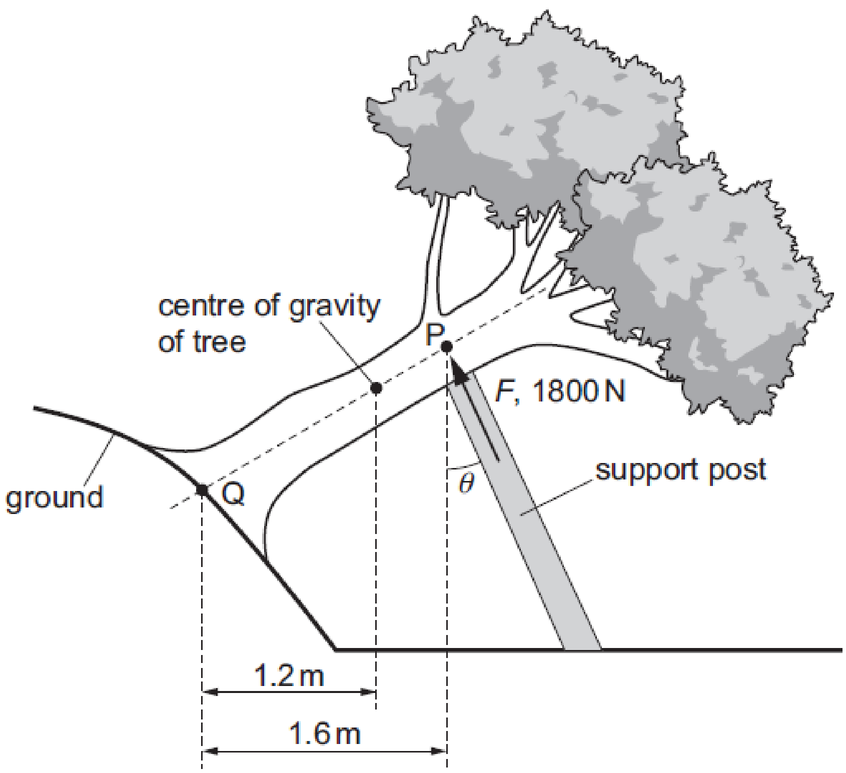

Fig. 2.1 (not to scale)

The ground applies a total force R on the tree at point Q.
The centre of gravity of the tree is a horizontal distance of 1.2 m from Q.
The post applies a force F of 1800 N perpendicular to the line PQ. The line of action of F passes through point P at an angle θ to the vertical. P is a horizontal distance of 1.6 m from Q.
The tree is in equilibrium and all forces act on the tree in the same plane.

(i) By taking moments about point Q, show that θ is 25°.

[3]

(ii) On Fig. 2.2, draw a labelled scale vector triangle to represent the forces acting on the tree. The weight of the tree has been drawn to scale.

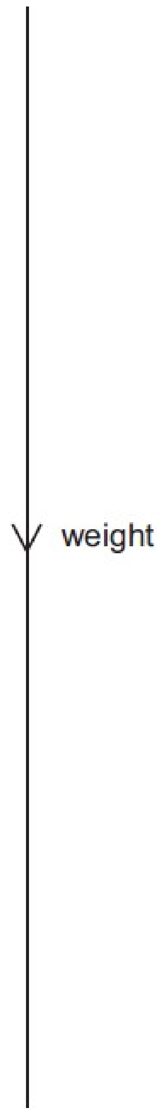

Fig. 2.2

[2]

(iii) The tree exerts a pressure of 150 kPa on the top of the post.

Determine the surface area of the tree in contact with the post.

area = ... m^2 [2]

[Total: 8]

Question 13

(a) Define the moment of a force about a pivot.

....

.... [1]

(b) Three objects A, B and C are placed on a horizontal beam. The beam is in equilibrium, as shown in Fig. 2.1.

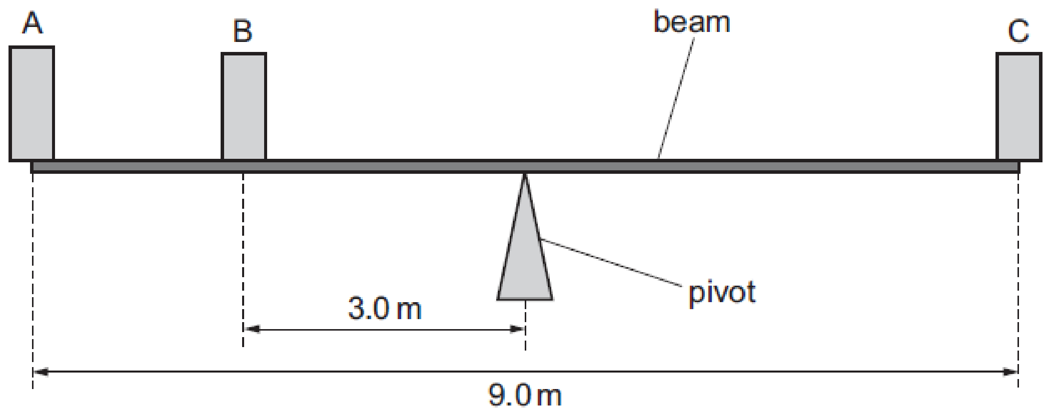

Fig. 2.1 (not to scale)

The beam is uniform and has length 9.0 m.
A pivot is at the midpoint of the beam.
Object A has mass 90 kg and is at one end of the beam.
Object B has mass m and is a distance of 3.0 m from the pivot.
Object C has mass 150 kg and is at the other end of the beam.

(i) Calculate m.

m = ... kg [3]

(ii) Object A is removed and replaced by a wire fixed to the end of the beam and to the ground, as shown in Fig. 2.2.

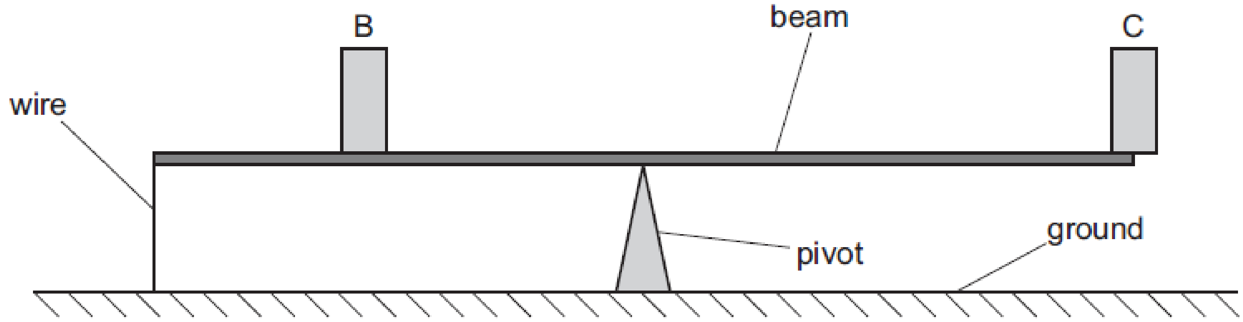

Fig. 2.2

After the change, the beam is again horizontal and in equilibrium. The positions of B and C are unchanged.

The wire has a diameter of 1.8×10^{-3} m and has a strain of 1.2×10^{-3}.
The wire is not extended beyond its limit of proportionality.

Calculate the Young modulus of the wire.

Young modulus = ... Pa [3]

(iii) Object B is now moved to a new position closer to the pivot without passing it. The beam is again horizontal and in equilibrium.

State and explain the effect, if any, that this has on the strain in the wire.

....

....

.... [2]

[Total: 9]

Question 14

(a) Define the moment of a force.

....

.... [1]

(b) A trapdoor has a hinge at end A, as shown in Fig. 1.1.

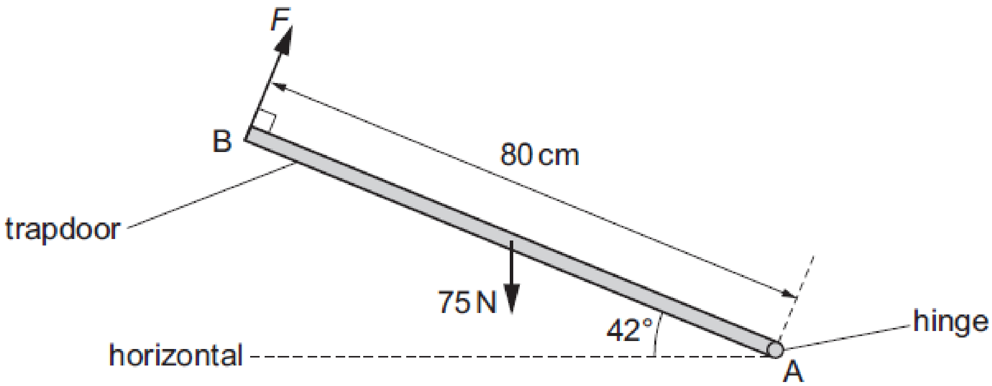

Fig. 1.1 (not to scale)

The trapdoor has length 80 cm and weight 75 N. The mass of the trapdoor is uniformly distributed along its length.

A force *F* acts at right angles to the trapdoor at end B so that the trapdoor is held in equilibrium at an angle of 42° to the horizontal.

(i) State the principle of moments.

....

....

.... [2]

(ii) Calculate the component of the weight that is perpendicular to the trapdoor.

component of weight = ... N [1]

(iii) Calculate the magnitude of the force *F*.

F = ... N [2]

[Total: 6]

Question 15

A spacecraft in deep space uses jets of hot gas from its thrusters to change its velocity. Fig. 2.1 shows a side view of the spacecraft and some of its thrusters.

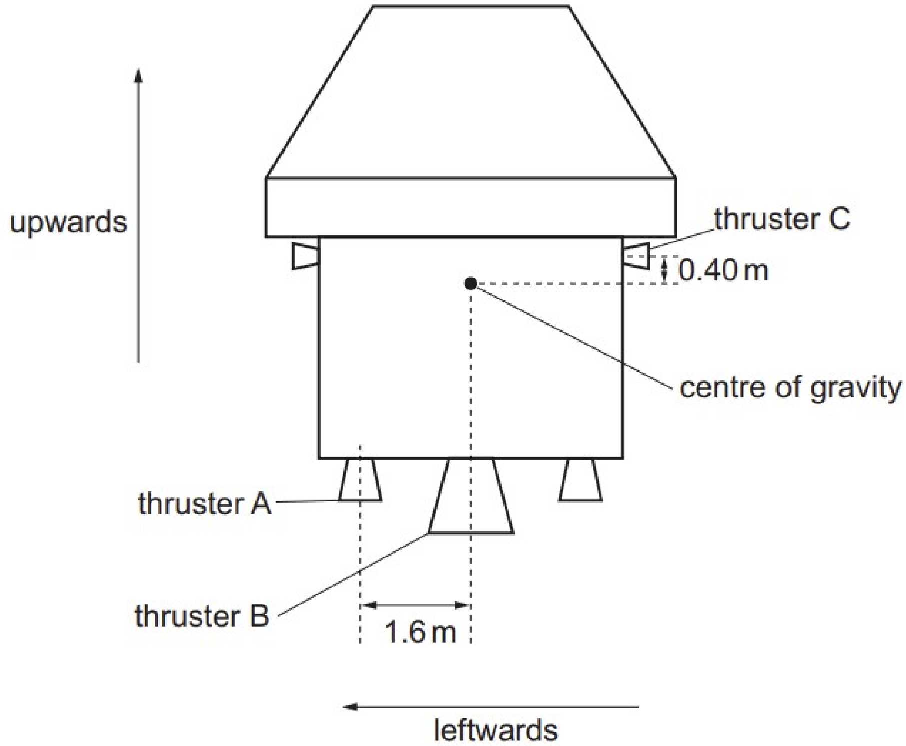

Fig. 2.1 (not to scale)

Thruster A is a distance of 1.6 m leftwards from the centre of gravity of the spacecraft. Thruster C is a distance of 0.40 m upwards from the centre of gravity of the spacecraft.

Thrusters A and B can produce forces on the spacecraft in the upwards direction only.
Thruster C can produce a force on the spacecraft in the leftwards direction only.
All the thrusters shown produce forces entirely in the same plane as the centre of gravity.

(a) **(i)** Thruster A is activated, producing a force of 60 N upwards on the spacecraft. Thruster C is also activated, producing a force of 220 N in the leftwards direction on the spacecraft.

Calculate the resultant moment due to these forces about the centre of gravity.

resultant moment = ... N m [2]

(ii) State and explain whether the forces from A and C are a couple.

....

....

.... [1]

(b) Thrusters A and C are now switched off and the spacecraft is stationary. Thruster B is activated at time t_1, producing a constant force on the spacecraft until the fuel runs out at time t_2. As the fuel is used, the total mass of the spacecraft decreases.

On Fig. 2.2, sketch the variation of speed of the spacecraft with time from t_1 to t_2.

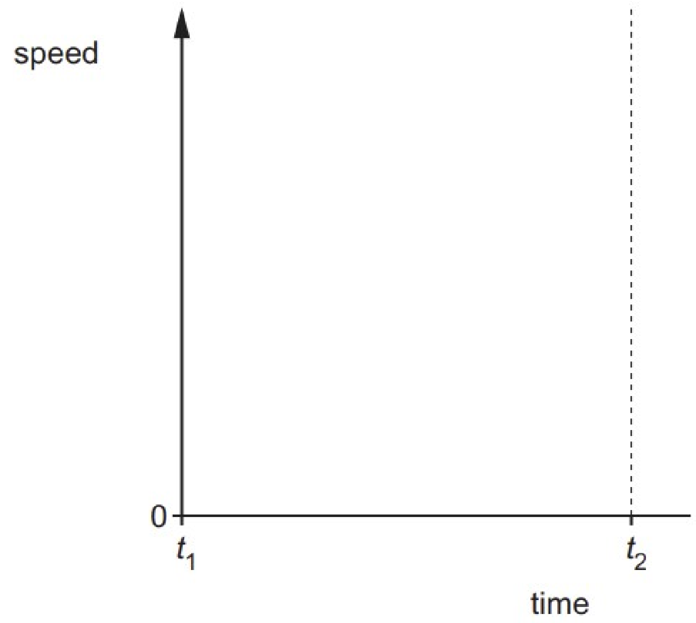

Fig. 2.2

[2]

(c) The spacecraft now splits apart into a carrier and a payload as shown in Fig. 2.3.

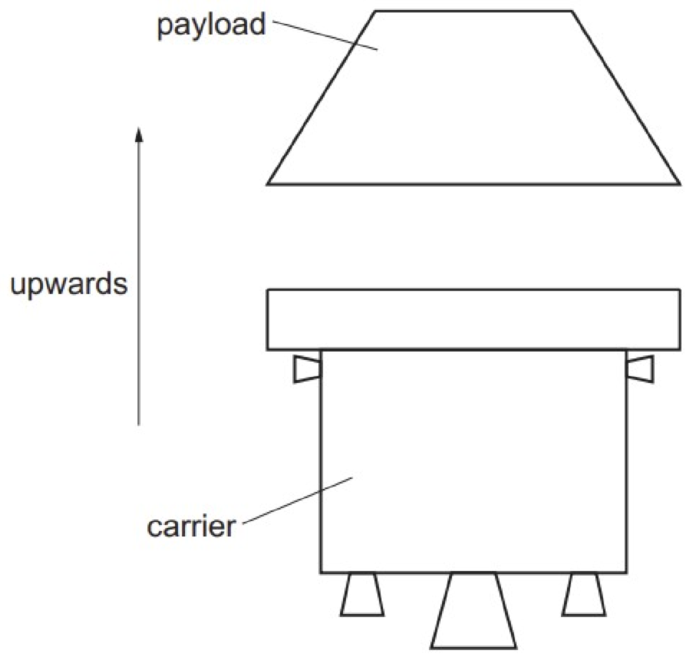

Fig. 2.3

During the split, an average force of 5500 N acts on the payload for a time of 0.36 s. The velocity of the payload increases by 8.5 m s^{-1} in the upwards direction.

The combined mass of the carrier and payload is 2.5×10^3 kg.

(i) State the principle of conservation of momentum.

....

....

.... [2]

(ii) Show that the mass of the payload is 230 kg.

[2]

(iii) Calculate the magnitude of the change in velocity of the carrier.

change in velocity = ... $m s^{-1}$ [3]

[Total: 12]

Question 16

Fig. 2.1 shows a square metal sheet of non-uniform density, with a thin wooden rod fixed at its centre. One of the corners of the sheet is labelled X.

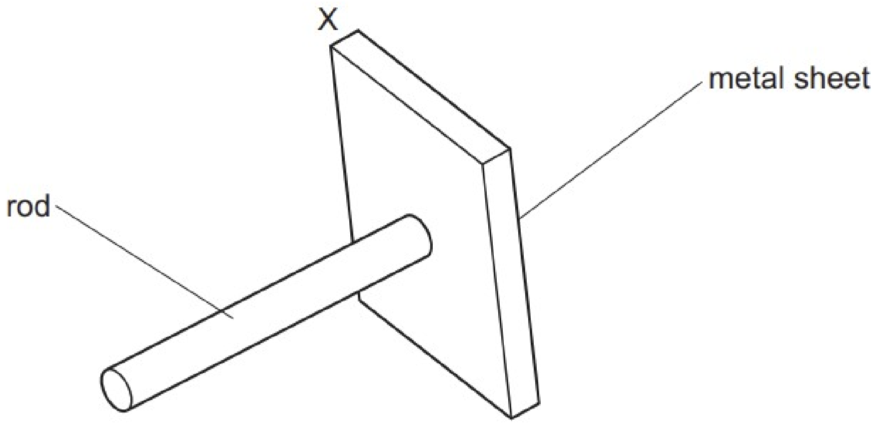

Fig. 2.1

The rod has negligible mass. The mass of the metal sheet is 2.8 kg.
The rod is supported so that the rod is horizontal and the metal sheet is vertical.

(a) Define the torque of a couple.

....

....

.... [2]

(b) When the rod is supported in such a way that it can rotate freely within its support, the sheet hangs in equilibrium with point X vertically above the rod, as shown in Fig. 2.2.

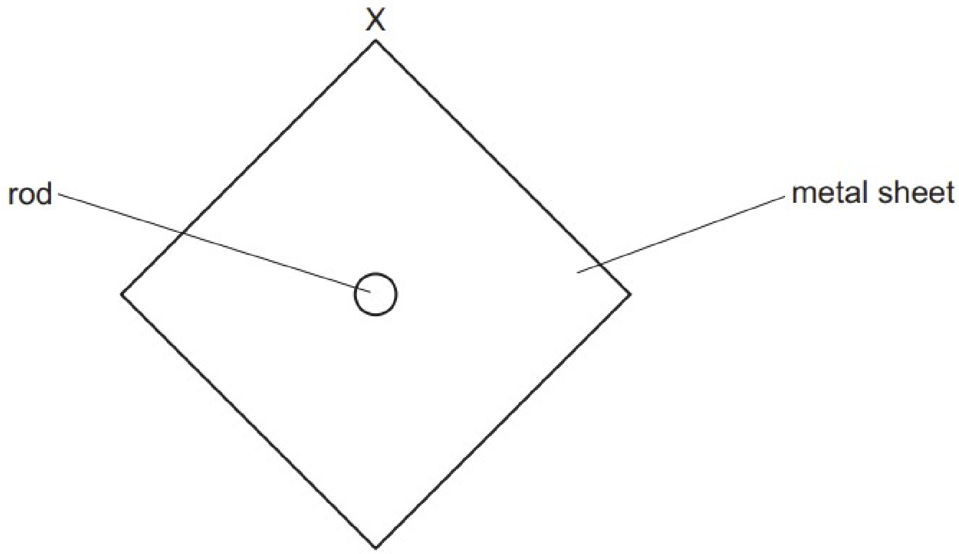

Fig. 2.2

On Fig. 2.2, draw a line to indicate the range of possible positions for the centre of gravity of the metal sheet. [1]

(c) When a torque of 3.3 N m is applied to the rod, the sheet is held in equilibrium with two of its edges horizontal, as shown in Fig. 2.3. Point X is at the top-left corner.

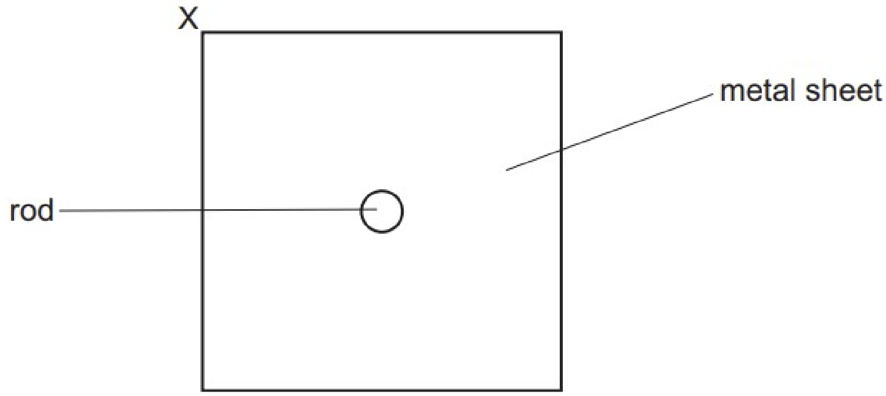

Fig. 2.3

(i) Explain whether the torque applied to the rod to hold the sheet in equilibrium is clockwise or anticlockwise.

....

.... [1]

(ii) Show that the centre of gravity of the sheet has a horizontal displacement of 0.12 m from the rod.

[1]

(d) The square metal sheet has an average density of 3000 kg m^{-3} and a uniform thickness of 4.0 mm.

Show that the side length of the sheet is 0.48 m.

[3]

(e) Use the answer in **(b)** and the information in **(c)** and **(d)** to determine the position of the centre of gravity of the sheet. Indicate this position on Fig. 2.3 with a point labelled Y. [2]

[Total: 10]

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