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International Examinations Papers

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Forces-vectors and moments: 4

TOPIC- combining forces (add), components, turning effects-moment of force, torque

For Examiner's Use

Answer **all** the questions in the spaces provided.

1 (a) Derive the SI base unit of force.

SI base unit of force = ... [1]

(b) A spherical ball of radius r experiences a resistive force F due to the air as it moves through the air at speed v. The resistive force F is given by the expression

$$F = crv,$$

where c is a constant.

Derive the SI base unit of the constant c.

SI base unit of c = ... [1]

(c) The ball is dropped from rest through a height of 4.5 m.

(i) Assuming air resistance to be negligible, calculate the final speed of the ball.

speed = ... $m\,s^{-1}$ [2]

(ii) The ball has mass 15 g and radius 1.2 cm.

The numerical value of the constant *c* in the equation in **(b)** is equal to 3.2×10^{-4} when measured using the SI system of units.

Show quantitatively whether the assumption made in **(i)** is justified.

[3]

2 A rod AB is hinged to a wall at A. The rod is held horizontally by means of a cord BD, attached to the rod at end B and to the wall at D, as shown in Fig. 2.1.

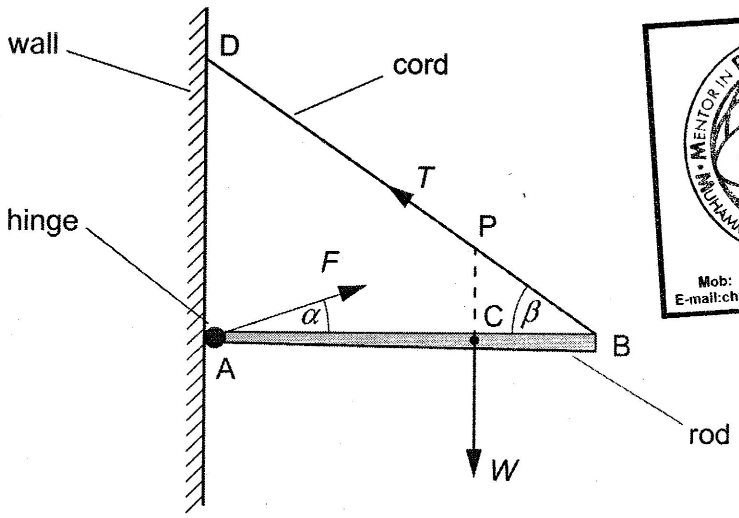

Fig. 2.1

The rod has weight W and the centre of gravity of the rod is at C. The rod is held in equilibrium by a force T in the cord and a force F produced at the hinge.

(a) Explain what is meant by

(i) the *centre of gravity* of a body,

....

....

.... [2]

(ii) the *equilibrium* of a body.

....

....

....

.... [2]

For Examiner's Use

(b) The line of action of the weight *W* of the rod passes through the cord at point P.

Explain why, for the rod to be in equilibrium, the force *F* produced at the hinge must also pass through point P.

....

....

....

.... [2]

(c) The forces *F* and *T* make angles α and β respectively with the rod and AC = $\frac{2}{3}$AB, as shown in Fig. 2.1.

Write down equations, in terms of *F*, *W*, *T*, α and β, to represent

(i) the resolution of forces horizontally,

.... [1]

(ii) the resolution of forces vertically,

.... [1]

(iii) the taking of moments about A.

.... [1]

3 A stone on a string is made to travel along a horizontal circular path, as shown in Fig. 3.1.

For Examiner's Use

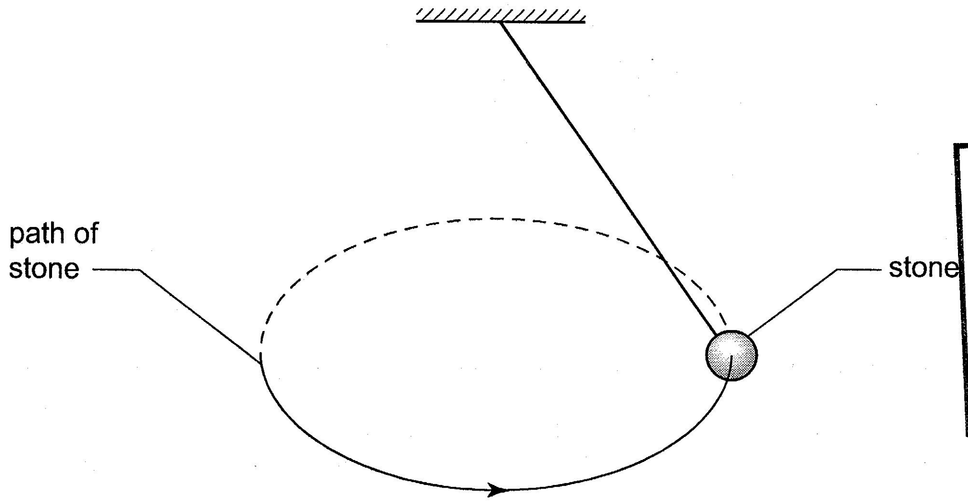

Fig. 3.1

The stone has a constant speed.

(a) Define *acceleration*.

....

.... [1]

(b) Use your definition to explain whether the stone is accelerating.

....

....

.... [2]

For Examiner's Use

(c) The stone has a weight of 5.0 N. When the string makes an angle of 35° to the vertical, the tension in the string is 6.1 N, as illustrated in Fig. 3.2.

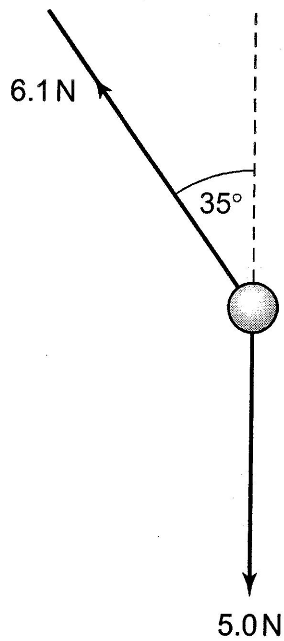

Fig. 3.2

Determine the resultant force acting on the stone in the position shown.

magnitude of force = ... N

direction of force.. [4]

4 **(a)** Define *moment of a force.*

....

....[1]

(b) An arrangement for lifting heavy loads is shown in Fig. 4.1.

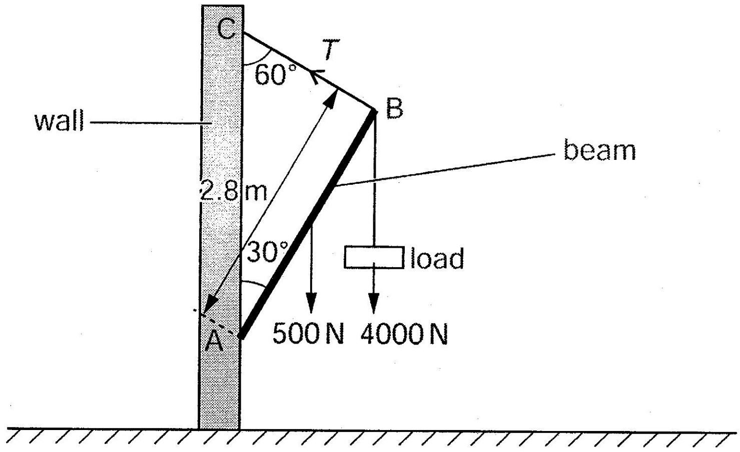

Fig. 4.1

A uniform metal beam AB is pivoted on a vertical wall at A. The beam is supported by a wire joining end B to the wall at C. The beam makes an angle of 30° with the wall and the wire makes an angle of 60° with the wall.

The beam has length 2.8 m and weight of 500 N. A load of 4000 N is supported from B. The tension in the wire is *T*. The beam is in equilibrium.

(i) By taking moments about A, show that *T* is 2.1 kN.

[2]

(ii) Calculate the vertical component T_v of the tension *T*.

T_v = ... N [1]

(iii) State and explain why T_v does not equal the sum of the load and the weight of the beam although the beam is in equilibrium.

....

....[2]

Answer **all** the questions in the spaces provided.

05 **(a)** The Young modulus of the metal of a wire is 1.8×10^{11} Pa. The wire is extended and the strain produced is 8.2×10^{-4}.
Calculate the stress in GPa.

stress = ... GPa [2]

(b) An electromagnetic wave has frequency 12 THz.

(i) Calculate the wavelength in μm.

wavelength = ... μm [2]

(ii) State the name of the region of the electromagnetic spectrum for this frequency.

.... [1]

(c) An object B is on a horizontal surface. Two forces act on B in this horizontal plane. A vector diagram for these forces is shown to scale in Fig. 1.1.

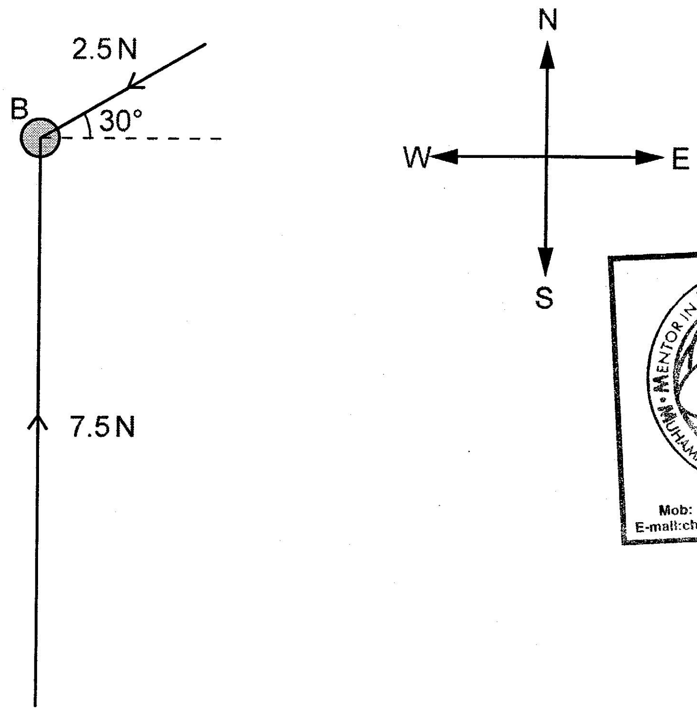

Fig. 1.1

A force of 7.5 N towards north and a force of 2.5 N from 30° north of east act on B. The mass of B is 750 g.

(i) On Fig. 1.1, draw an arrow to show the approximate direction of the resultant of these two forces. [1]

(ii) **1.** Show that the magnitude of the resultant force on B is 6.6 N.

[1]

2. Calculate the magnitude of the acceleration of B produced by this resultant force.

magnitude = ... $m\,s^{-2}$ [2]

(iii) Determine the angle between the direction of the acceleration and the direction of the 7.5 N force.

angle = ... ° [1]

For Examiner's Use

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

1. ....

....

2. ....

.... [2]

(b) Three co-planar forces act on a body that is in equilibrium.

(i) Describe how to draw a vector triangle to represent these forces.

....

....

....

....

....

....

.... [3]

(ii) State how the triangle confirms that the forces are in equilibrium.

....

.... [1]

(c) A weight of 7.0 N hangs vertically by two strings AB and AC, as shown in Fig. 2.1.

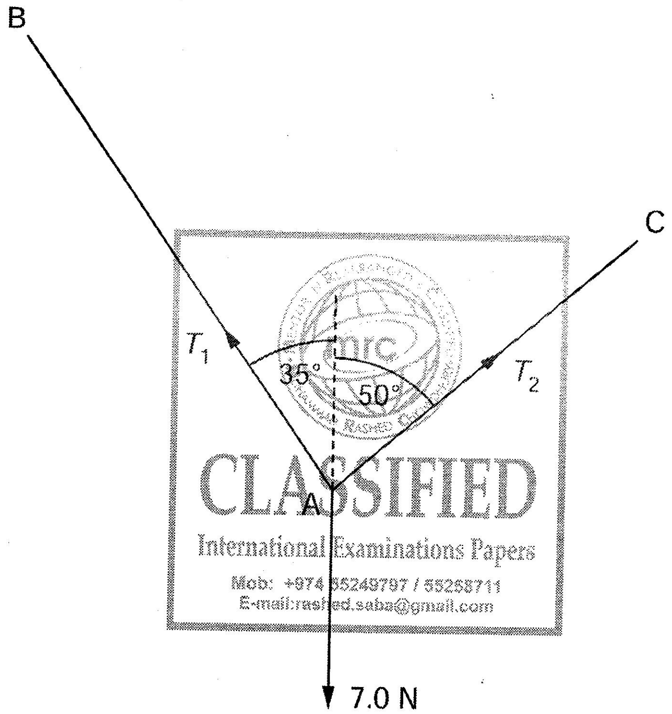

Fig. 2.1

For the weight to be in equilibrium, the tension in string AB is T_1 and in string AC it is T_2.

On Fig. 2.1, draw a vector triangle to determine the magnitudes of T_1 and T_2.

T_1 = ... N

T_2 = ... N

[3]

(d) By reference to Fig. 2.1, suggest why the weight could not be supported with the strings AB and AC both horizontal.

....

....[2]

7 (a) Distinguish between *mass and weight.*

For Examiner's Use

mass: ....

....

weight: ....

....

[2]

(b) An object O of mass 4.9 kg is suspended by a rope A that is fixed at point P. The object is pulled to one side and held in equilibrium by a second rope B, as shown in Fig. 2.1.

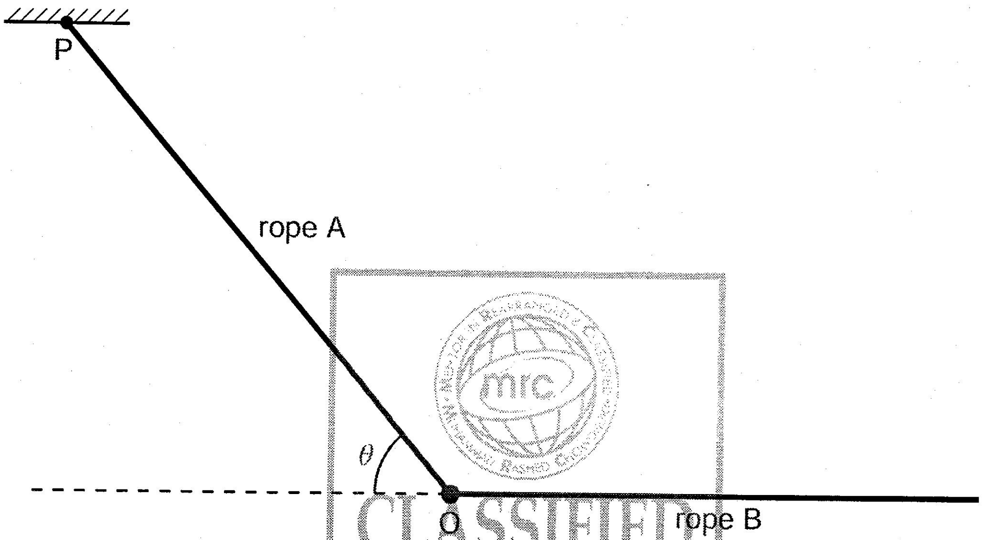

Fig. 2.1

Rope A is at an angle θ to the horizontal and rope B is horizontal. The tension in rope A is 69 N and the tension in rope B is T.

(i) On Fig. 2.1, draw arrows to represent the directions of all the forces acting on object O. [2]

(ii) Calculate

For Examiner's Use

1. the angle θ,

θ = ...° [3]

2. the tension T.

T = ... N [2]

08 A climber is supported by a rope on a vertical wall, as shown in Fig. 2.1.

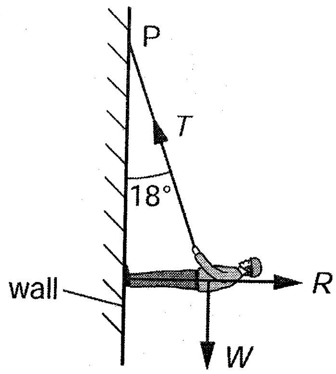

Fig. 2.1

The weight W of the climber is 520 N. The rope, of negligible weight, is attached to the climber and to a fixed point P where it makes an angle of 18° to the vertical. The reaction force R acts at right-angles to the wall.
The climber is in equilibrium.

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

....

....

.... [2]

(b) Complete Fig. 2.2 by drawing a labelled vector triangle to represent the forces acting on the climber.

Fig. 2.2

[2]

(c) Resolve forces or use your vector triangle to calculate

For Examiner's Use

(i) the tension T in the rope,

T = ... N [2]

(ii) the reaction force R.

R = ... N [1]

(d) The climber moves up the wall and the angle the rope makes with the vertical increases. Explain why the magnitude of the tension in the rope increases.

....

....

....[1]

09

(a) State Newton's first law.

....

.... [1]

(b) A log of mass 450 kg is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

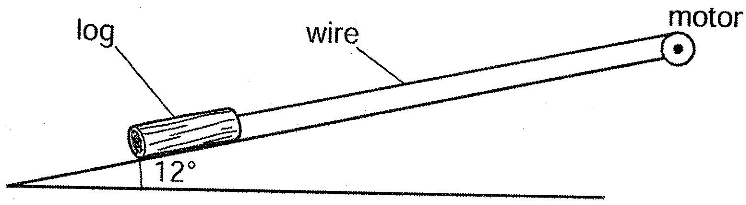

Fig. 3.1

The angle that the slope makes with the horizontal is 12°. The frictional force acting on the log is 650 N. The log travels with constant velocity.

(i) With reference to the motion of the log, discuss whether the log is in equilibrium.

....

....

....

.... [2]

(ii) Calculate the tension in the wire.

tension = ... N [3]

(iii) State and explain whether the gain in the potential energy per unit time of the log is equal to the output power of the motor.

....

....

....

.... [2]

For Examiner's Use

10 A motor drags a log of mass 452 kg up a slope by means of a cable, as shown in Fig. 2.1.

For Examiner's Use

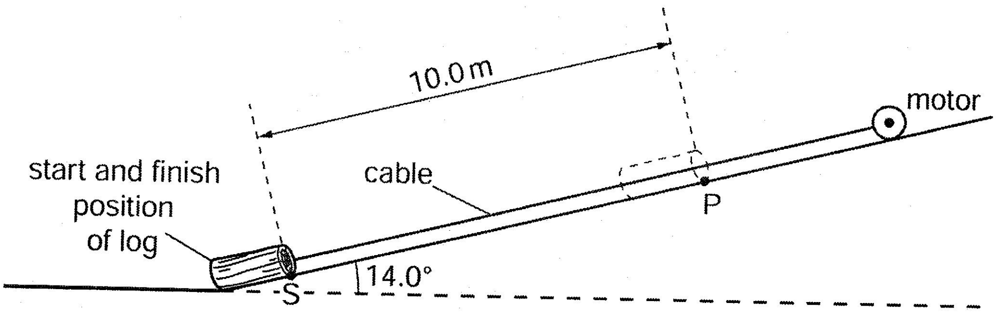

Fig. 2.1

The slope is inclined at 14.0° to the horizontal.

(a) Show that the component of the weight of the log acting down the slope is 1070 N.

[1]

(b) The log starts from rest. A constant frictional force of 525 N acts on the log. The log accelerates up the slope at $0.130\,m\,s^{-2}$.

(i) Calculate the tension in the cable.

tension = ... N [3]

For Examiner's Use

(ii) The log is initially at rest at point S. It is pulled through a distance of 10.0 m to point P.

Calculate, for the log,

1. the time taken to move from S to P,

time = ... s [2]

2. the magnitude of the velocity at P.

velocity = ... m s^{-1} [1]

(c) The cable breaks when the log reaches point P. On Fig. 2.2, sketch the variation with time *t* of the velocity *v* of the log. The graph should show *v* from the start at S until the log returns to S. [4]

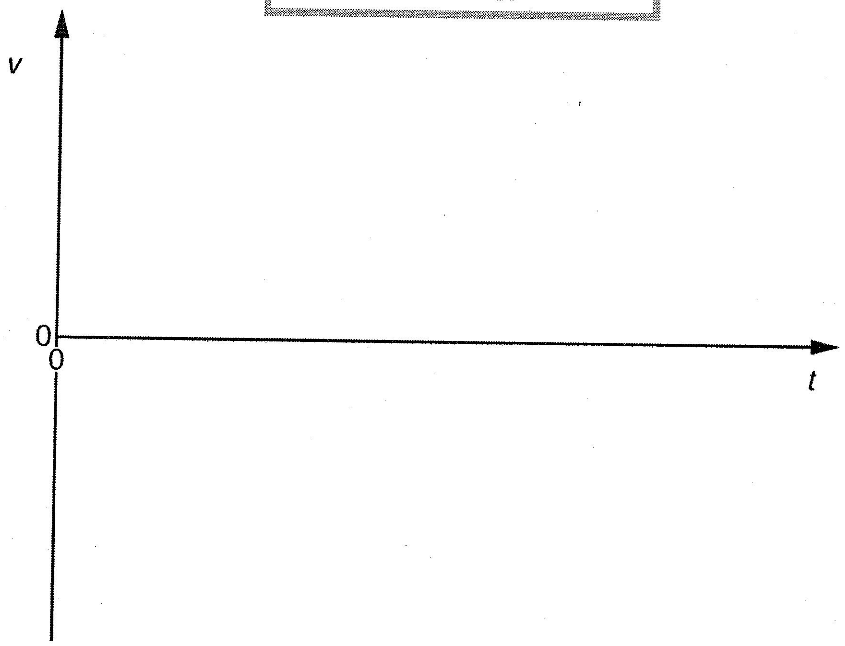

Fig. 2.2

Answer **all** the questions in the spaces provided.

1 **(a)** Two forces, with magnitudes 5.0 N and 12 N, act from the same point on an object. Calculate the magnitude of the resultant force R for the forces acting

(i) in opposite directions,

R = ... N [1]

(ii) at right angles to each other.

R = ... N [1]

(b) An object X rests on a smooth horizontal surface. Two horizontal forces act on X as shown in Fig. 1.1.

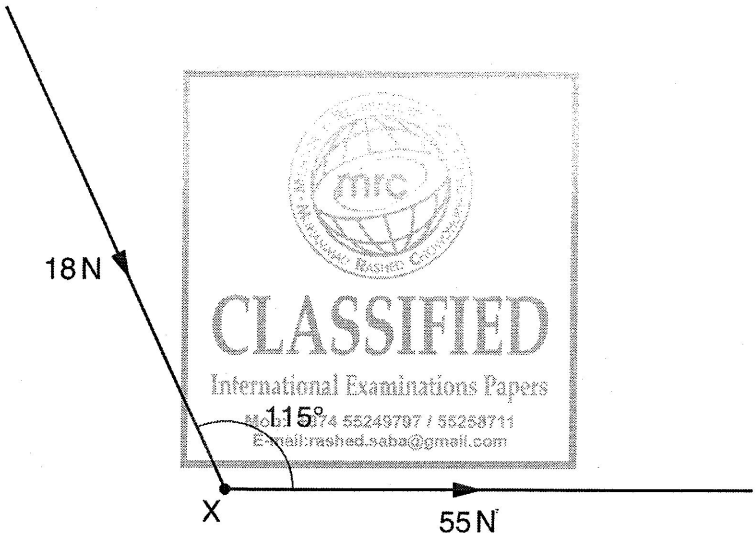

Fig. 1.1 (not to scale)

A force of 55 N is applied to the right. A force of 18 N is applied at an angle of 115° to the direction of the 55 N force.

(i) Use the resolution of forces or a scale diagram to show that the magnitude of the resultant force acting on X is 65 N.

[2]

(ii) Determine the angle between the resultant force and the 55 N force.

angle = ... ° [2]

(c) A third force of 80 N is now applied to X in the opposite direction to the resultant force in **(b)**.

The mass of X is 2.7 kg.

Calculate the magnitude of the acceleration of X.

acceleration = ... m s^{-2} [3]

[Total: 9]

Answer **all** the questions in the spaces provided.

1 **(a)** The frequency of an X-ray wave is 4.6×10^{20} Hz.

Calculate the wavelength in pm.

wavelength = ... pm [3]

(b) The distance from Earth to a star is 8.5×10^{16} m. Calculate the time for light to travel from the star to Earth in Gs.

time = ... Gs [2]

(c) The following list contains scalar and vector quantities.

Underline **all** the scalar quantities.

acceleration   force   mass   power   temperature   weight   [1]

(d) A boat is travelling in a flowing river. Fig. 1.1 shows the velocity vectors for the boat and the river water.

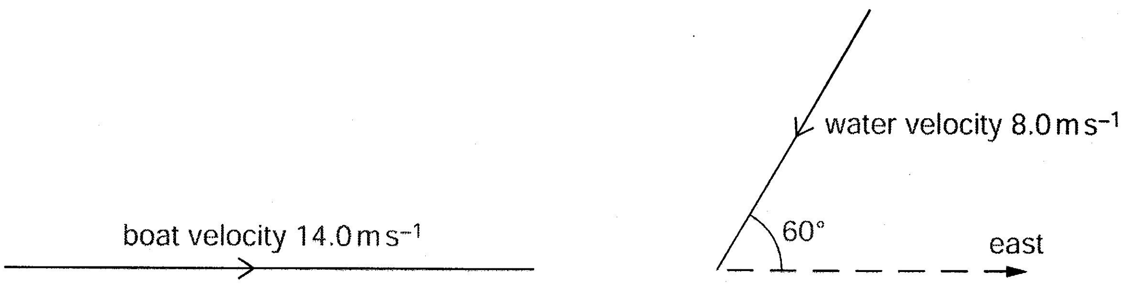

Fig. 1.1

The velocity of the boat in still water is $14.0\,\mathrm{m\,s^{-1}}$ to the east. The velocity of the water is $8.0\,\mathrm{m\,s^{-1}}$ from 60° north of east.

(i) On Fig. 1.1, draw an arrow to show the direction of the resultant velocity of the boat. [1]

(ii) Determine the magnitude of the resultant velocity of the boat.

magnitude of velocity = ... $m s^{-1}$ [2]

13 **(a)** State Newton's first law of motion.

....

.... [1]

(b) A box slides down a slope, as shown in Fig. 3.1.

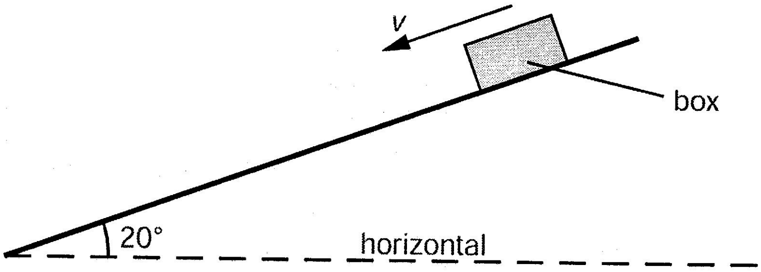

Fig. 3.1

The angle of the slope to the horizontal is 20°. The box has a mass of 65 kg. The total resistive force R acting on the box is constant as it slides down the slope.

(i) State the names and directions of the other two forces acting on the box.

1. ....

2. ....
[2]

(ii) The variation with time t of the velocity v of the box as it moves down the slope is shown in Fig. 3.2.

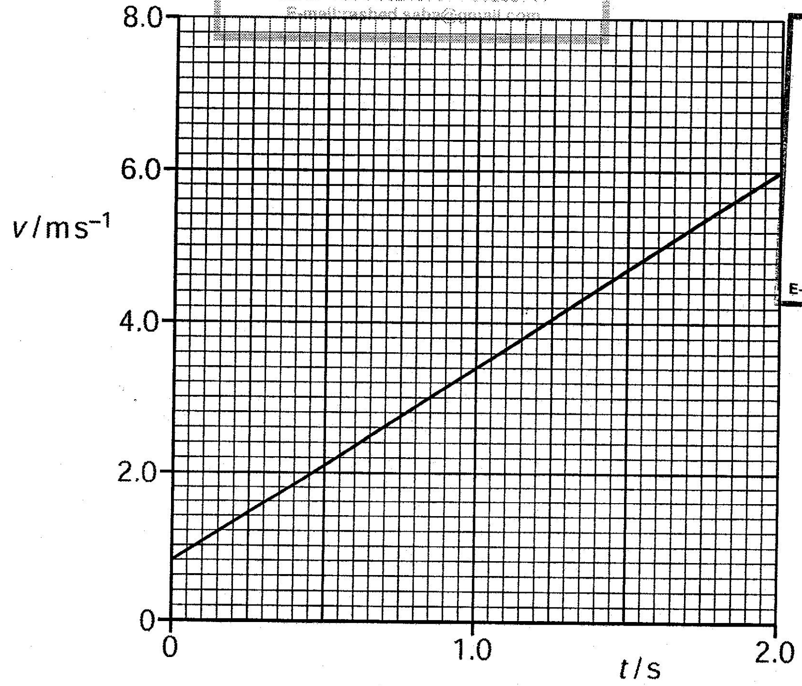

Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 $m\,s^{-2}$.

[2]

2. Calculate the resultant force on the box.

resultant force = ... N [1]

3. Determine the resistive force R on the box.

R = ... N [3]

Answer **all** the questions in the spaces provided.

For Examiner's Use

14 **(a)** Explain the differences between the quantities *distance* and *displacement*.

....

....

.... [2]

(b) State Newton's first law.

....

....

.... [1]

(c) Two tugs pull a tanker at constant velocity in the direction XY, as represented in Fig. 1.1.

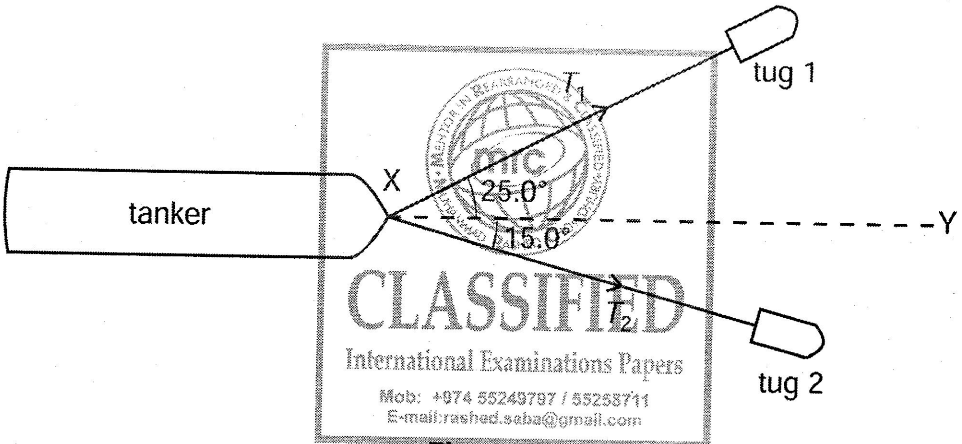

Fig. 1.1

Tug 1 pulls the tanker with a force T_1 at 25.0° to XY. Tug 2 pulls the tanker with a force of T_2 at 15.0° to XY. The resultant force R due to the two tugs is 25.0×10^3 N in the direction XY.

(i) By reference to the forces acting on the tanker, explain how the tanker may be described as being in equilibrium.

....

....

....

.... [2]

(ii) **1.** Complete Fig. 1.2 to draw a vector triangle for the forces R, T_1 and T_2. [2]

For Examiner's Use

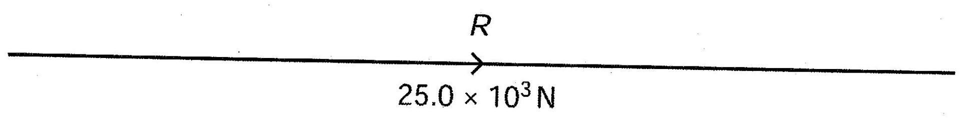

Fig. 1.2

2. Use your vector triangle in Fig. 1.2 to determine the magnitude of T_1 and of T_2.

T_1 = ... N

T_2 = ... N
[2]

Answer **all** the questions in the spaces provided.

1 5 **(a)** State the difference between a scalar quantity and a vector quantity.

scalar: ....

....

vector: ....

.... [2]

(b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40°.
Fig. 1.1 shows two lines at an angle of 40° to one another.

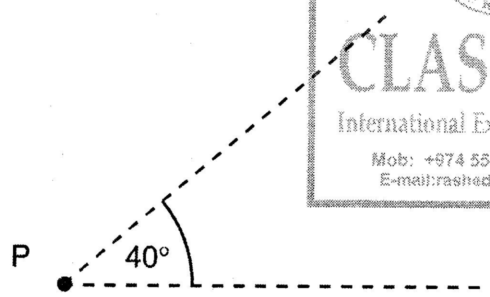

Fig. 1.1

On Fig. 1.1, draw a vector diagram to determine the magnitude of the resultant of the two forces.

magnitude of resultant = ... N [4]

Answer **all** the questions in the spaces provided.

For Examiner's Use

16 **(a)** **(i)** Distinguish between vector quantities and scalar quantities.

....

....

.... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.... [1]

2. acceleration of free fall

.... [1]

3. electrical resistance

.... [1]

(b) A block of wood of weight 25 N is held stationary on a slope by means of a string, as shown in Fig. 1.1.

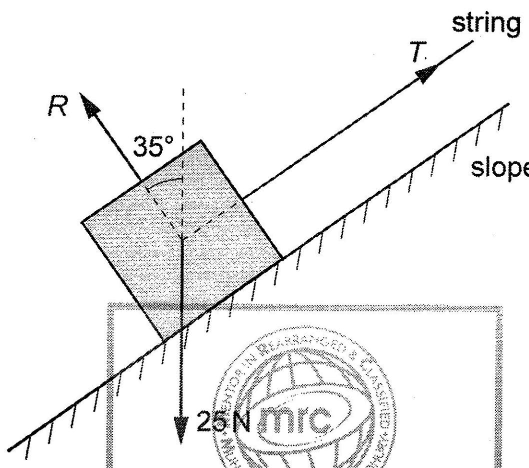

Fig. 1.1

The tension in the string is T and the slope pushes on the block with a force R that is normal to the slope.

Either by scale drawing on Fig. 1.1 or by calculation, determine the tension T in the string.

T = ... N [3]

17 **(a)** State the two conditions for a system to be in equilibrium.

1. ....

....

2. ....

....
[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

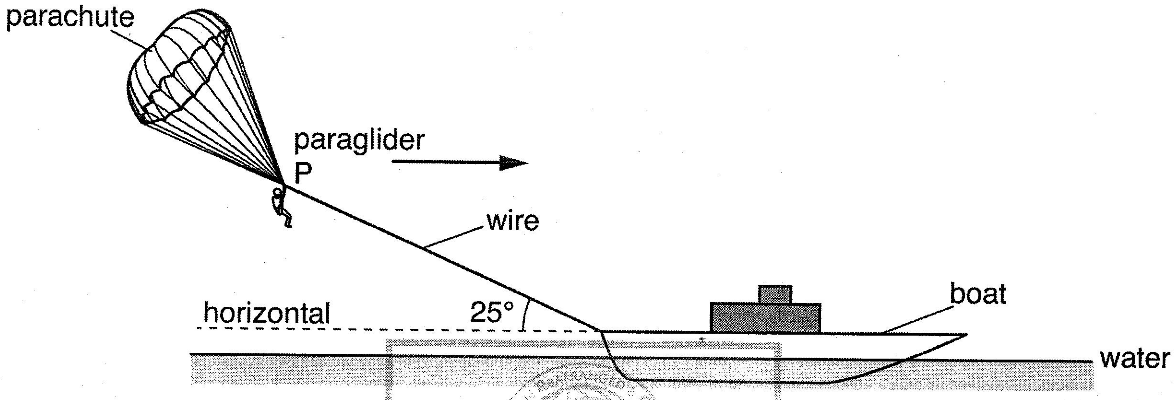

Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

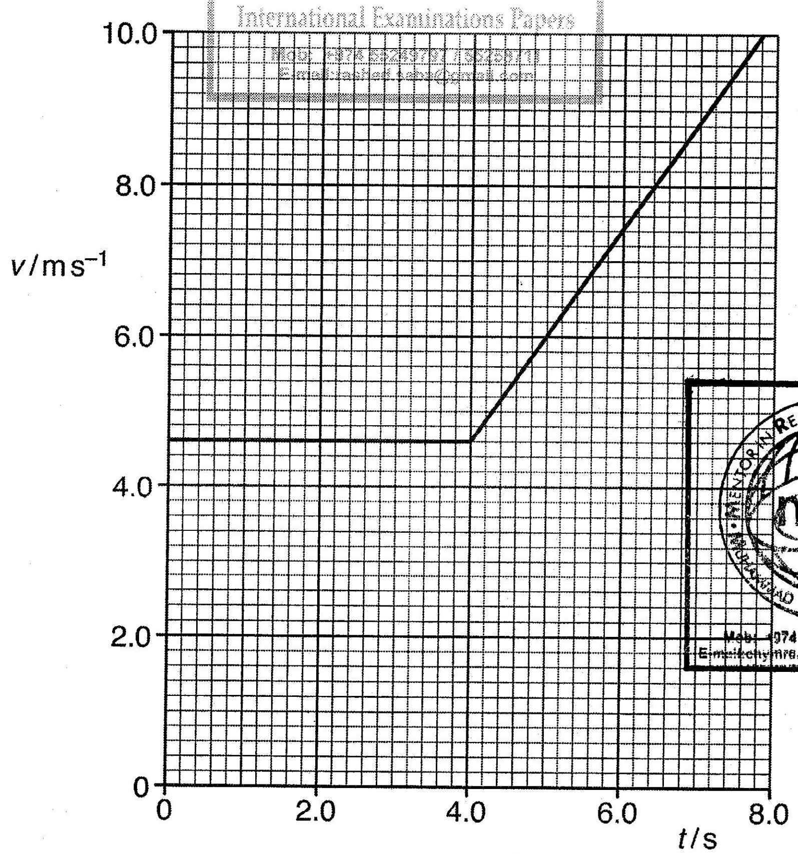

Fig. 2.2

(i) Show that the acceleration of P is 1.4 m s^{-2} at time t = 5.0 s.

[2]

(ii) Calculate the total distance moved by P from time t = 0 to t = 7.0 s.

distance = ... m [2]

(iii) Calculate the change in kinetic energy of P from time t = 0 to t = 7.0 s.

change in kinetic energy = ... J [2]

(iv) The tension in the wire at time t = 5.0 s is 280 N.

Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]

[Total: 14]

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Forces-vectors and moments: 4

TOPIC- combining forces (add), components, turning effects-moment of force, torque

3 **(a)** Define *centre of gravity.*

....

....[2]

(b) A uniform rod AB is attached to a vertical wall at A. The rod is held horizontally by a string attached at B and to point C, as shown in Fig. 3.1.

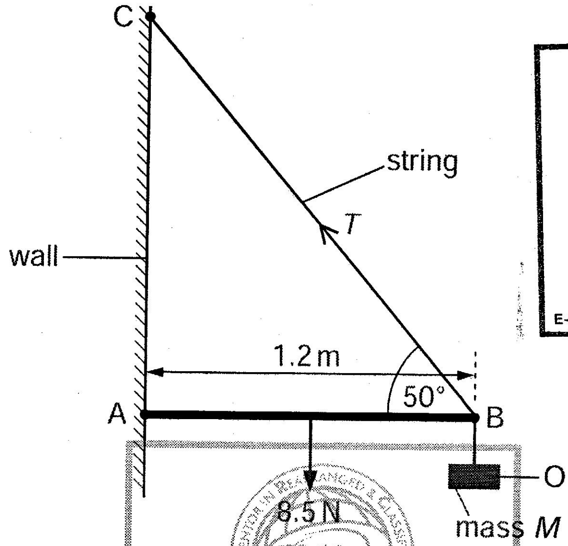

Fig. 3.1

The angle between the rod and the string at B is 50°. The rod has length 1.2 m and weight 8.5 N. An object O of mass *M* is hung from the rod at B. The tension *T* in the string is 30 N.

(i) Use the resolution of forces to calculate the vertical component of *T*.

vertical component of *T* = ... N [1]

(ii) State the *principle of moments.*

....

....[1]

For Examiner's Use

(iii) Use the principle of moments and take moments about A to show that the weight of the object O is 19 N.

[3]

(iv) Hence determine the mass M of the object O.

M = ... kg [1]

(c) Use the concept of equilibrium to explain why a force must act on the rod at A.

....

....

....[2]

19 A rod PQ is attached at P to a vertical wall, as shown in Fig. 3.1.

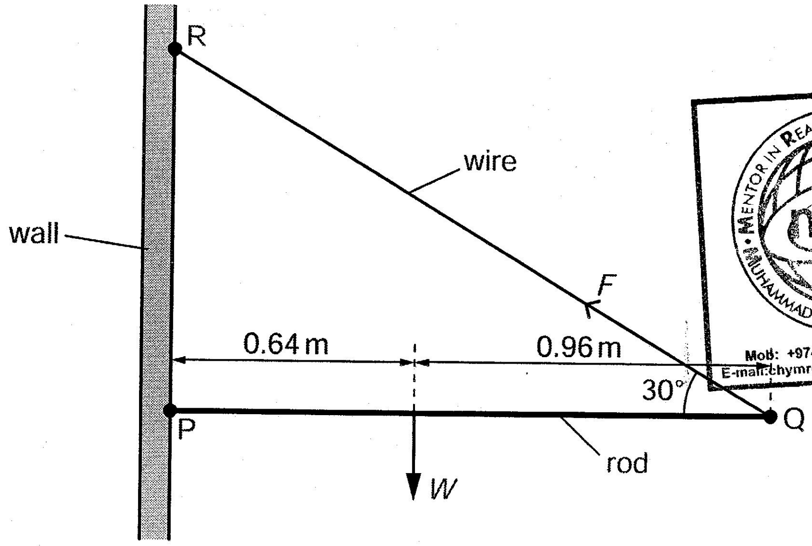

Fig. 3.1

The length of the rod is 1.60 m. The weight W of the rod acts 0.64 m from P. The rod is kept horizontal and in equilibrium by a wire attached to Q and to the wall at R. The wire provides a force F on the rod of 44 N at 30° to the horizontal.

(a) Determine

(i) the vertical component of F,

vertical component = ... N [1]

(ii) the horizontal component of F.

horizontal component = ... N [1]

(b) By taking moments about P, determine the weight W of the rod.

W = ... N [2]

(c) Explain why the wall must exert a force on the rod at P.

....

....

.... [1]

(d) On Fig. 3.1, draw an arrow to represent the force acting on the rod at P. Label your arrow with the letter S. [1]

2 0 **(a)** State the two conditions for an object to be in equilibrium.

1. ....

....

2. ....

....
[2]

(b) A uniform beam AC is attached to a vertical wall at end A. The beam is held horizontal by a rigid bar BD, as shown in Fig. 3.1.

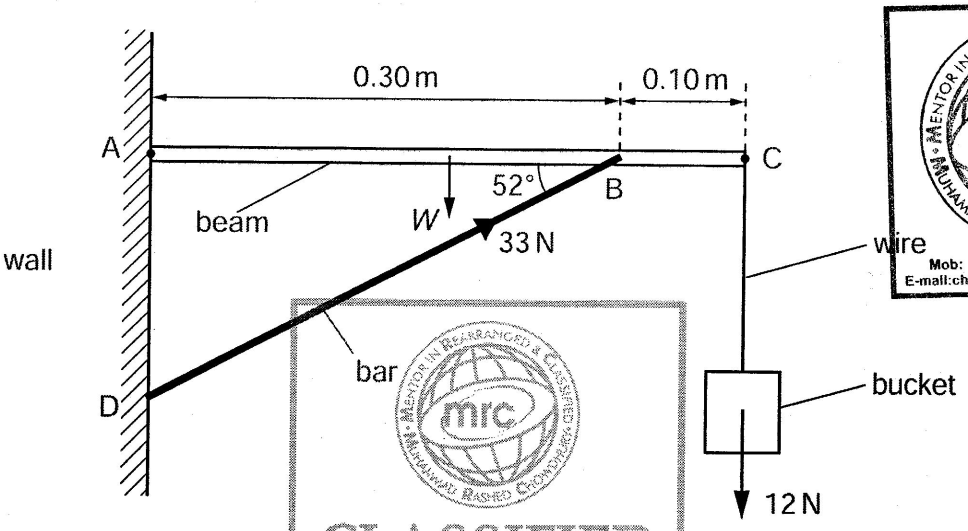

Fig. 3.1 (not to scale)

The beam is of length 0.40 m and weight W. An empty bucket of weight 12 N is suspended by a light metal wire from end C. The bar exerts a force on the beam of 33 N at 52° to the horizontal. The beam is in equilibrium.

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

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

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

W = ... N [3]

(c) The metal of the wire in **(b)** has a Young modulus of 2.0×10^{11} Pa.
Initially the bucket is empty. When the bucket is filled with paint of weight 78 N, the strain of the wire increases by 7.5×10^{-4}. The wire obeys Hooke's law.

Calculate, for the wire,

(i) the increase in stress due to the addition of the paint,

increase in stress = ... Pa [2]

(ii) its diameter.

diameter = ... m [3]

[Total: 11]

For Examiner's Use

1 **(a)** Define the *torque* of a couple.

....

.... [2]

(b) A uniform rod of length 1.5 m and weight 2.4 N is shown in Fig. 2.1.

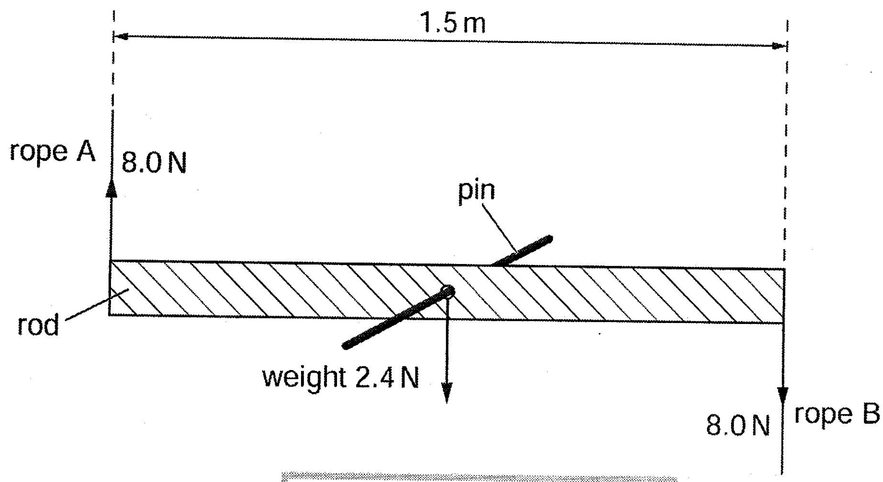

Fig. 2.1

The rod is supported on a pin passing through a hole in its centre. Ropes A and B provide equal and opposite forces of 8.0 N.

(i) Calculate the torque on the rod produced by ropes A and B.

torque = ... N m [1]

(ii) Discuss, briefly, whether the rod is in equilibrium.

....

....

....

.... [2]

(c) The rod in **(b)** is removed from the pin and supported by ropes A and B, as shown in Fig. 2.2.

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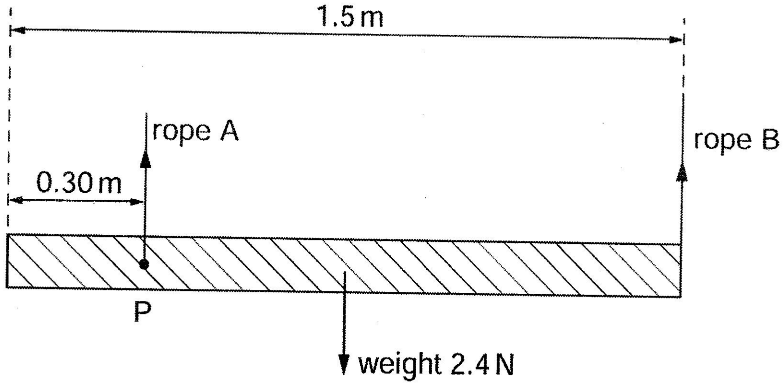

Fig. 2.2

Rope A is now at point P 0.30 m from one end of the rod and rope B is at the other end.

(i) Calculate the tension in rope B.

tension in B = ... N [2]

(ii) Calculate the tension in rope A.

tension in A = ... N [1]

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

....

.... [2]

(b) Define *moment* of a force.

....

.... [1]

(c) A student is being weighed. The student, of weight *W*, stands 0.30 m from end A of a uniform plank AB, as shown in Fig. 3.1.

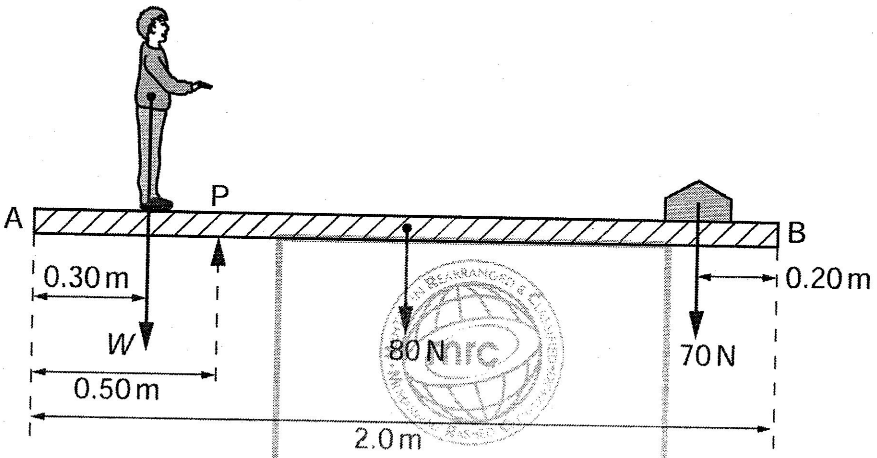

Fig. 3.1 (not to scale)

The plank has weight 80 N and length 2.0 m. A pivot P supports the plank and is 0.50 m from end A.
A weight of 70 N is moved to balance the weight of the student. The plank is in equilibrium when the weight is 0.20 m from end B.

(i) State the two conditions necessary for the plank to be in equilibrium.

1. ....

....

2. ....

....
[2]

(ii) Determine the weight *W* of the student.

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W = ... N [3]

(iii) If only the 70 N weight is moved, there is a maximum weight of student that can be determined using the arrangement shown in Fig. 3.1. State and explain **one** change that can be made to increase this maximum weight.

....

....

.... [2]

3 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 3.1.

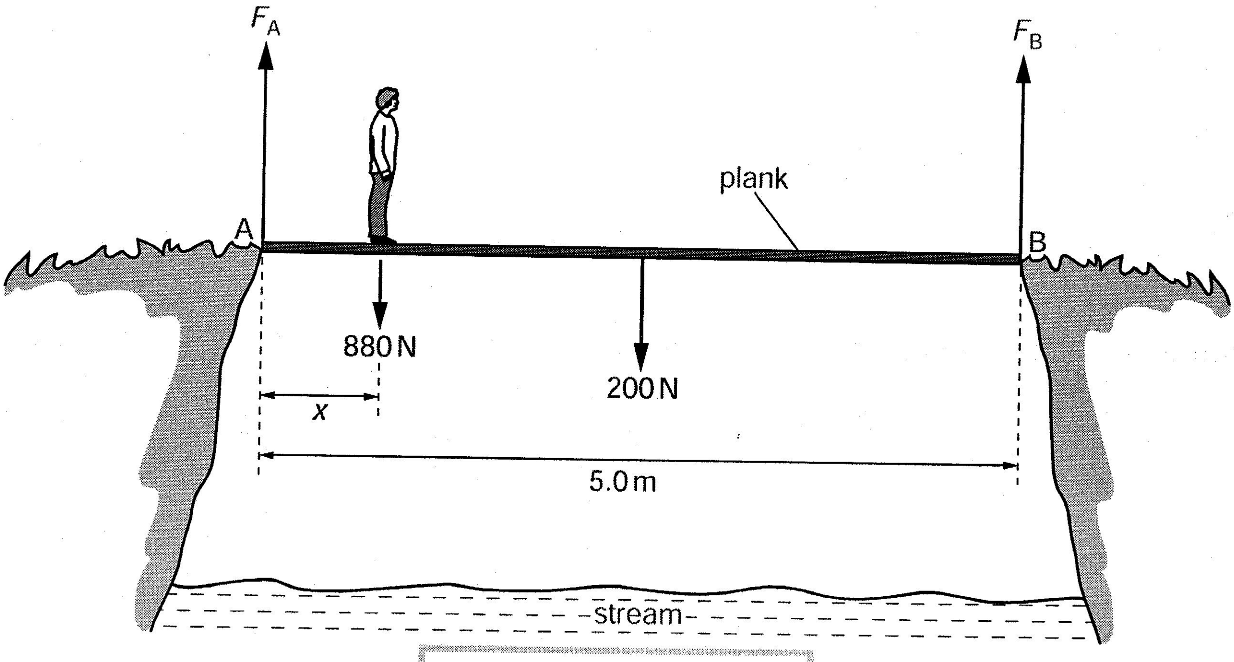

Fig. 3.1

A man of weight 880 N stands a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B.
As the man moves along the plank, the plank is always in equilibrium.

(a) **(i)** Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

....

....

.... [2]

(ii) The man stands a distance x = 0.50 m from end A. Use the principle of moments to calculate the magnitude of F_B.

F_B = ... N [4]

(b) The variation with distance x of force F_A is shown in Fig. 3.2.

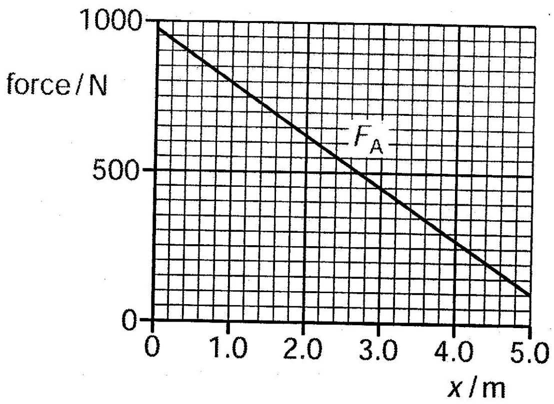

Fig. 3.2

On the axes of Fig. 3.2, sketch a graph to show the variation with x of force F_B. [3]

2 4 **(a)** A cylinder is made from a material of density 2.7 g cm^{-3}. The cylinder has diameter 2.4 cm and length 5.0 cm.

Show that the cylinder has weight 0.60 N.

[3]

(b) The cylinder in **(a)** is hung from the end A of a non-uniform bar AB, as shown in Fig. 3.1.

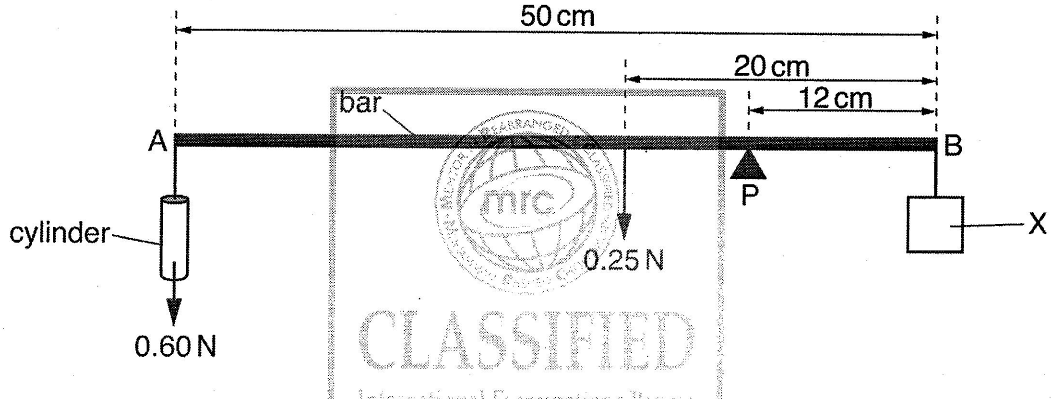

Fig. 3.1

The bar has length 50 cm and has weight 0.25 N. The centre of gravity of the bar is 20 cm from B. The bar is pivoted at P. The pivot is 12 cm from B.

An object X is hung from end B. The weight of X is adjusted until the bar is horizontal and in equilibrium.

(i) Explain what is meant by *centre of gravity*.

....

....[1]

(ii) Calculate the weight of X.

weight of X = ... N [3]

(c) The cylinder is now immersed in water, as illustrated in Fig. 3.2.

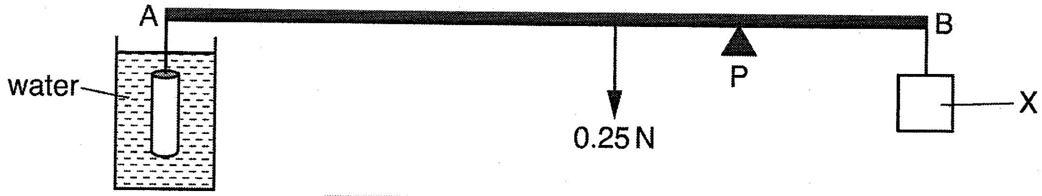

Fig. 3.2

An upthrust acts on the cylinder and the bar is not in equilibrium.

(i) Explain the origin of the upthrust.

....

....

....

....[2]

(ii) Explain why the weight of X must be reduced in order to obtain equilibrium for AB.

....

....

....[1]

[Total: 10]

25 **(a)** Distinguish between the moment of a force and the torque of a couple.

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moment of a force ....

....

....

torque of a couple ....

....

.... [4]

(b) One type of weighing machine, known as a steelyard, is illustrated in Fig. 3.1.

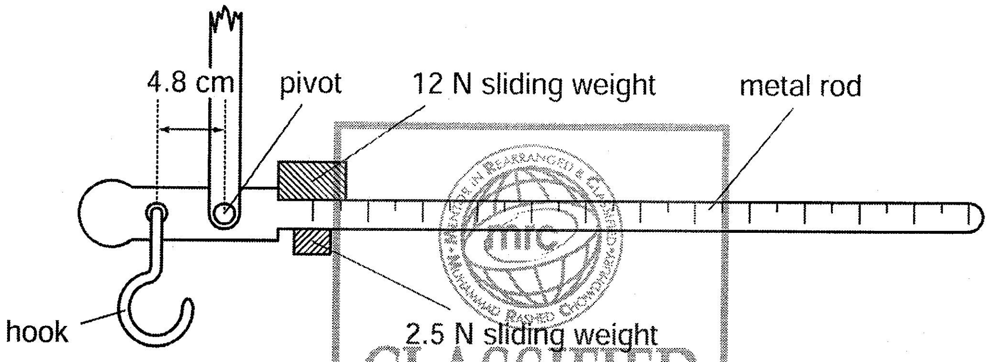

Fig. 3.1

The two sliding weights can be moved independently along the rod.

With no load on the hook and the sliding weights at the zero mark on the metal rod, the metal rod is horizontal. The hook is 4.8 cm from the pivot.

A sack of flour is suspended from the hook. In order to return the metal rod to the horizontal position, the 12 N sliding weight is moved 84 cm along the rod and the 2.5 N weight is moved 72 cm.

(i) Calculate the weight of the sack of flour.

weight = ...N [2]

(ii) Suggest why this steelyard would be imprecise when weighing objects with a weight of about 25 N.

....

....[1]

2 6 **(a)** Define the *torque* of a couple.

For Examiner's Use

....

....

.... [2]

(b) A torque wrench is a type of spanner for tightening a nut and bolt to a particular torque, as illustrated in Fig. 3.1.

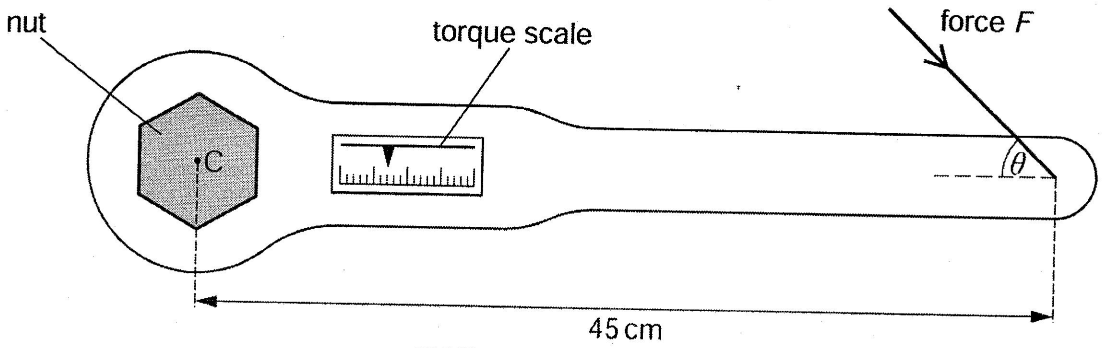

Fig. 3.1

The wrench is put on the nut and a force is applied to the handle. A scale indicates the torque applied.

The wheel nuts on a particular car must be tightened to a torque of 130 N m. This is achieved by applying a force *F* to the wrench at a distance of 45 cm from its centre of rotation C. This force *F* may be applied at any angle θ to the axis of the handle, as shown in Fig. 3.1.

For the minimum value of *F* to achieve this torque,

(i) state the magnitude of the angle θ that should be used,

θ = ... ° [1]

(ii) calculate the magnitude of *F*.

F = ... N [2]

21 **(a)** Define the *moment* of a force.

....

.... [2]

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

1. ....

....

2. ....

.... [2]

(c) Two parallel strings S_1 and S_2 are attached to a disc of diameter 12 cm, as shown in Fig. 3.1.

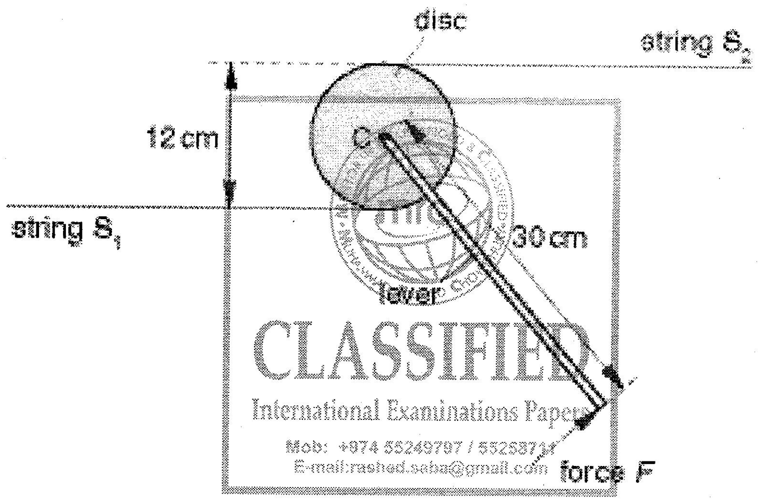

Fig. 3.1

The disc is free to rotate about an axis normal to its plane. The axis passes through the centre C of the disc.

A lever of length 30 cm is attached to the disc. When a force F is applied at right angles to the lever at its end, equal forces are produced in S_1 and S_2. The disc remains in equilibrium.

(i) On Fig. 3.1, show the direction of the force in each string that acts on the disc. [1]

(ii) For a force *F* of magnitude 150 N, determine

1. the moment of force *F* about the centre of the disc,

moment = ... N m

2. the torque of the couple produced by the forces in the strings,

torque = ... N m

3. the force in S_1.

force = ... N
[4]

28 **(a)** Define the *torque* of a couple.

....

.... [2]

For Examiner's Use

(b) A wheel is supported by a pin P at its centre of gravity, as shown in Fig. 4.1.

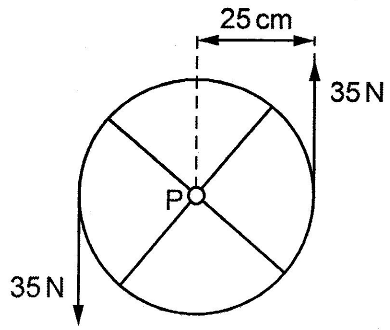

Fig. 4.1

The plane of the wheel is vertical. The wheel has radius 25 cm.
Two parallel forces each of 35 N act on the edge of the wheel in the vertical directions shown in Fig. 4.1. Friction between the pin and the wheel is negligible.

(i) List two other forces that act on the wheel. State the direction of these forces and where they act.

1. ....

2. .... [2]

(ii) Calculate the torque of the couple acting on the wheel.

torque = ... N m [2]

(iii) The resultant force on the wheel is zero. Explain, by reference to the four forces acting on the wheel, how it is possible that the resultant force is zero.

....

.... [1]

(iv) State and explain whether the wheel is in equilibrium.

.... [1]

2 9 **(a)** State the relation between force and momentum.

.... [1]

For Examiner's Use

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 3.1.

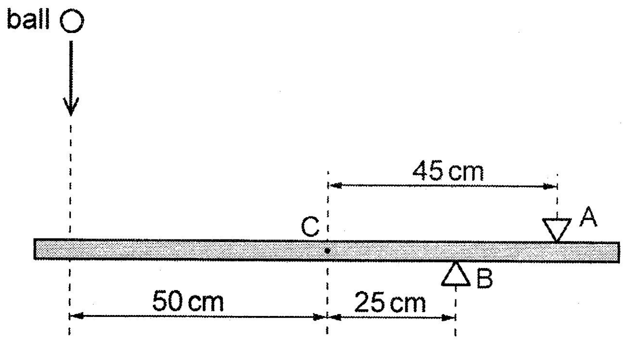

Fig. 3.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 3.1.
The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 3.2.

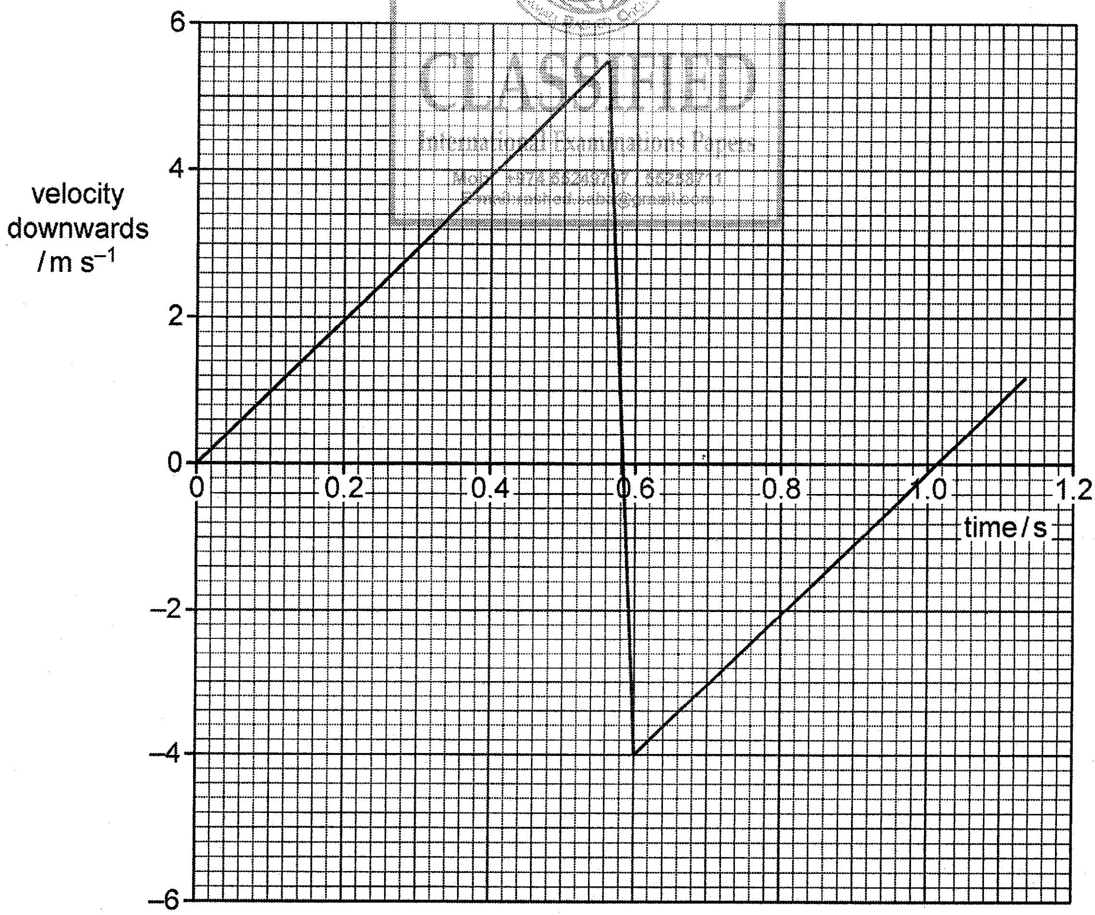

Fig. 3.2

For the time that the ball is in contact with the bar, use Fig. 3.2

For Examiner's Use

(i) to determine the change in momentum of the ball,

change = ... $kg\,m\,s^{-1}$ [2]

(ii) to show that the force exerted by the ball on the bar is 33 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 3.1 and **(b)(ii)** to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B.

force = ... N [2]