For Examiner's Use

1 **(a)** Explain what is meant by the *centre of gravity* of an object.

....

....

....[2]

(b) A non-uniform plank of wood XY is 2.50 m long and weighs 950 N. Force-meters (spring balances) A and B are attached to the plank at a distance of 0.40 m from each end, as illustrated in Fig. 3.1.

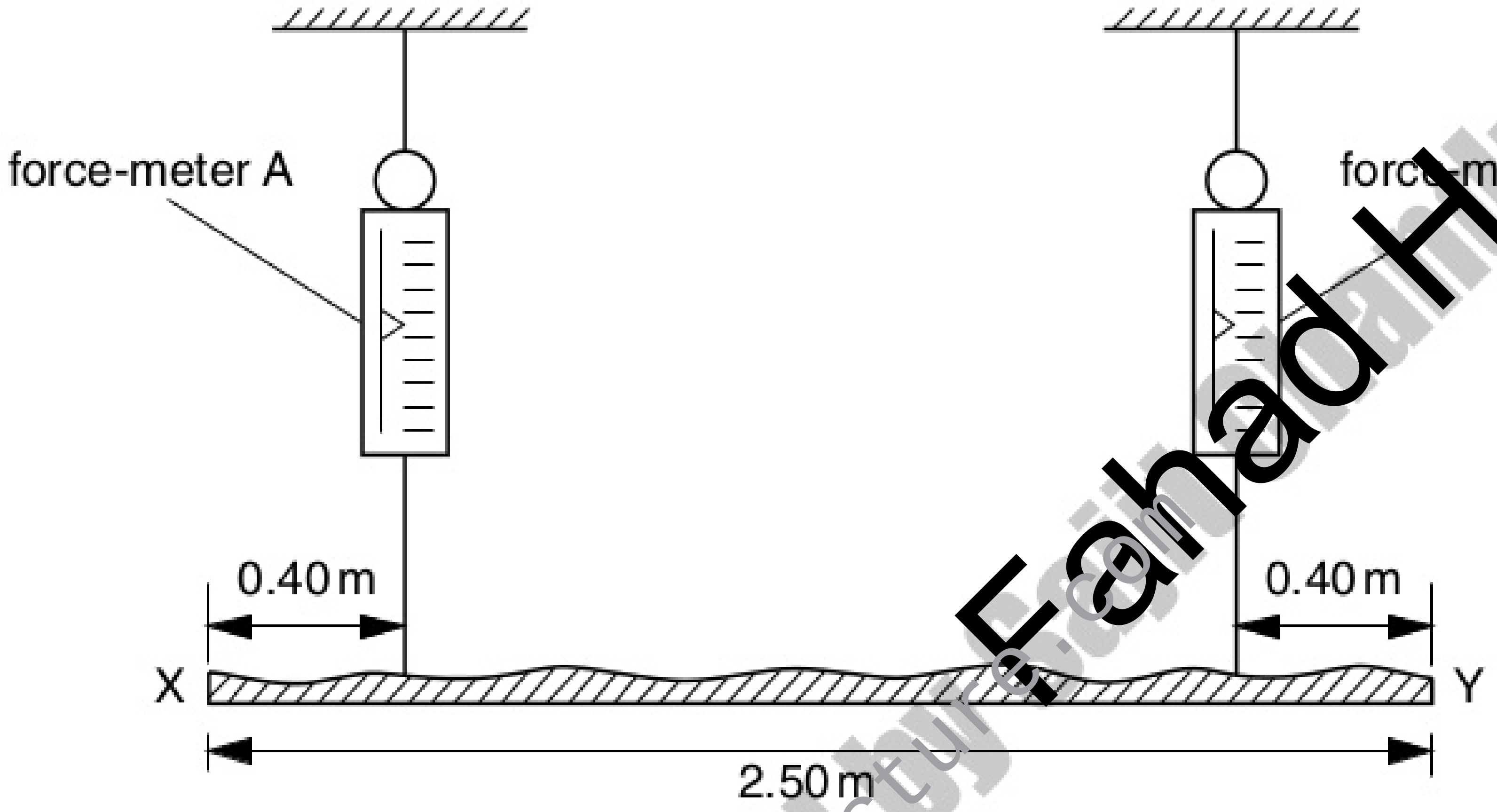


Fig. 3.1

When the plank is horizontal, force-meter A records 570 N.

(i) Calculate the reading on force-meter B.

reading = ... N

(ii) On Fig. 3.1, mark a likely position for the centre of gravity of the plank.

(iii) Determine the distance of the centre of gravity from the end X of the plank.

distance = ... m

[6]

2 Two forces, each of magnitude F, form a couple acting on the edge of a disc of radius r, as shown in Fig. 5.1.

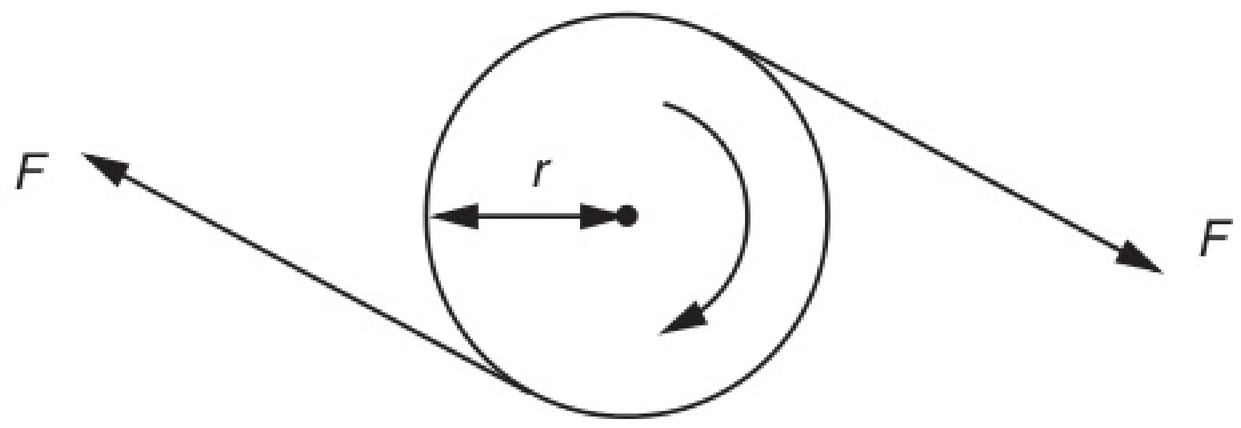


Fig. 5.1

(a) The disc is made to complete n revolutions about an axis through its centre, normal to the plane of the disc. Write down an expression for

(i) the distance moved by a point on the circumference of the disc,

distance = ...

(ii) the work done by one of the two forces.

work done = ...
[2]

(b) Using your answer to **(a)**, show that the work W done by a couple producing a torque T when it turns through n revolutions is given by

$$W = 2\pi nT.$$
[2]

For Examiner's Use

(c) A car engine produces a torque of 470 N m at 2400 revolutions per minute. Calculate the output power of the engine.

power = ... W [2]

3 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.

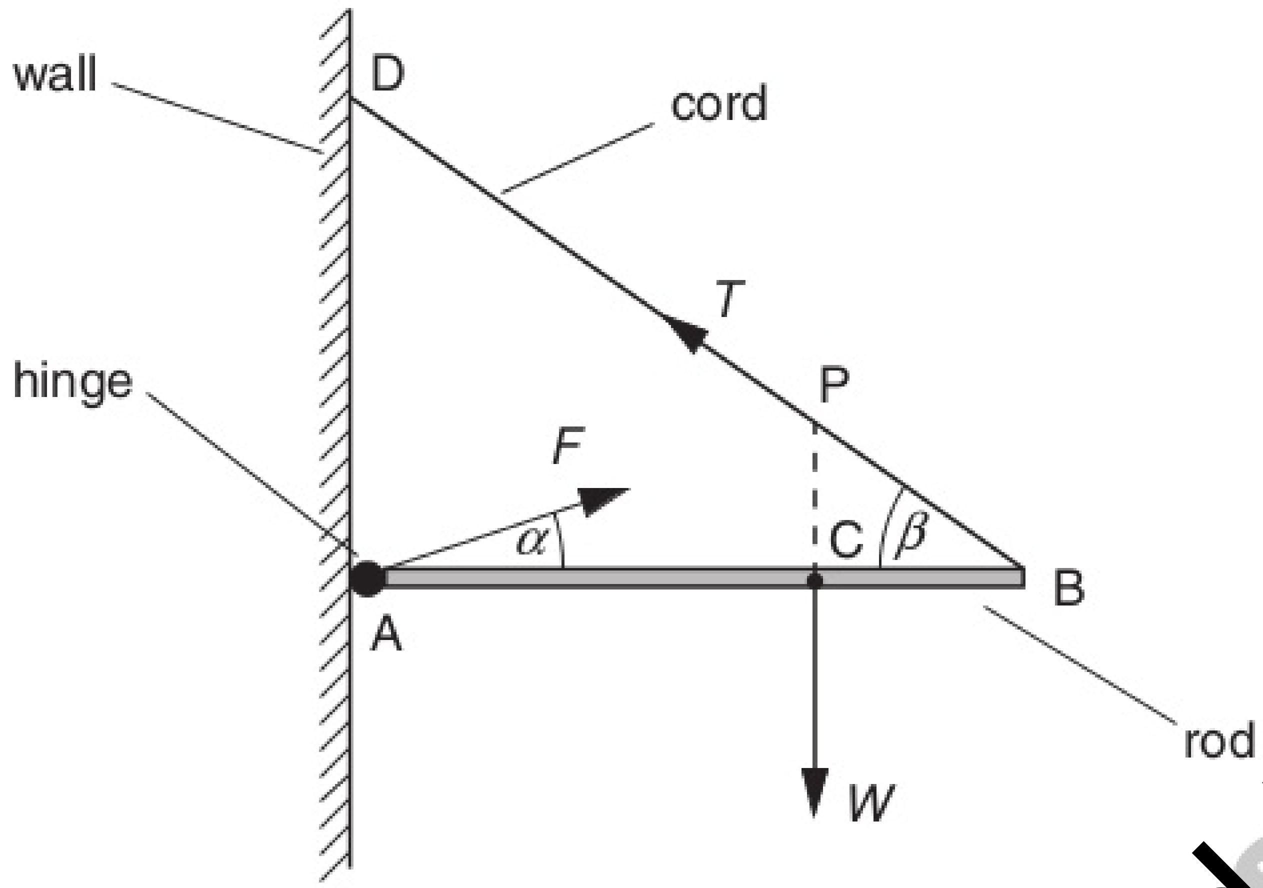


Fig. 2.1

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]

(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 = 2AB, 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]

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

....

....

.... [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.

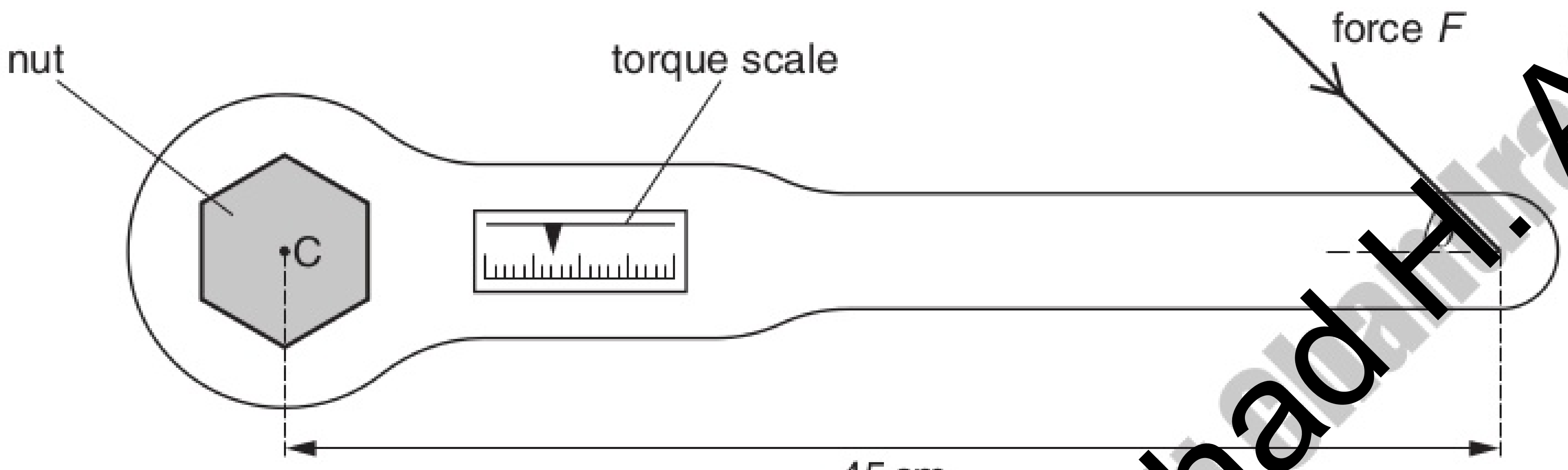


Fig. 3.1

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]

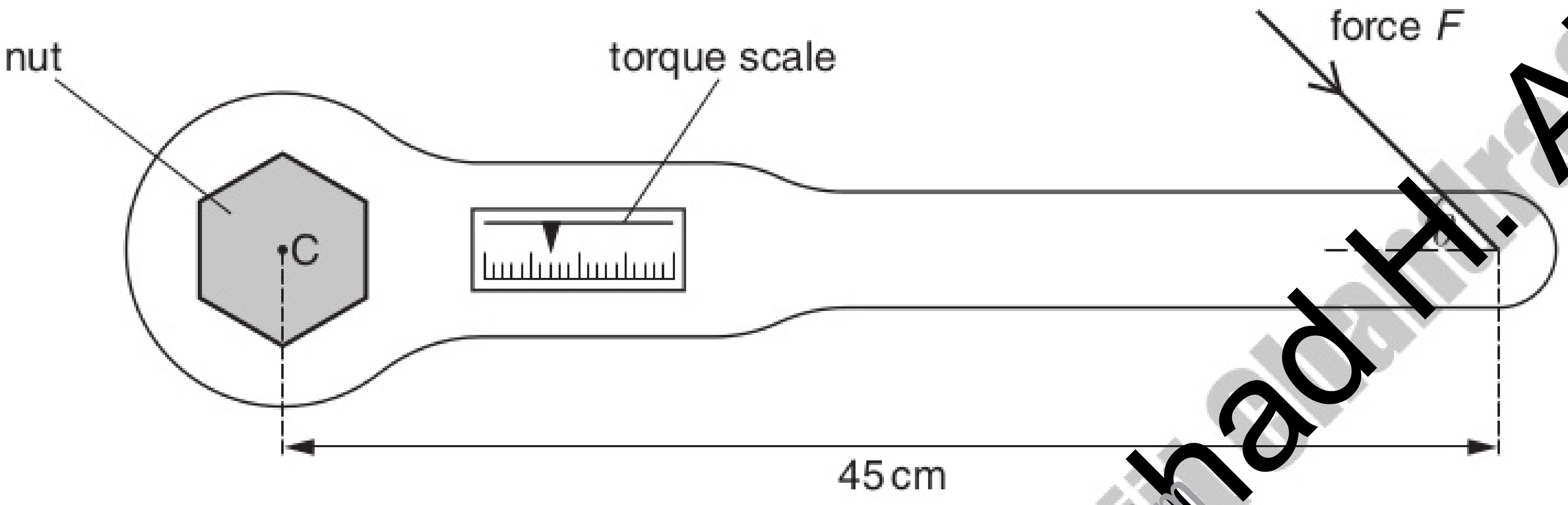
5 **(a)** Define the *torque* of a couple.

....

....

.... [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.



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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]

6 **(a)** State the two conditions necessary for the equilibrium of a body which is acted upon by a number of forces.

1. ....

....

2. ....

....[2]

(b) Three identical springs S_1, S_2 and S_3 are attached to a point A such that the angle between any two of the springs is 120°, as shown in Fig. 3.1.

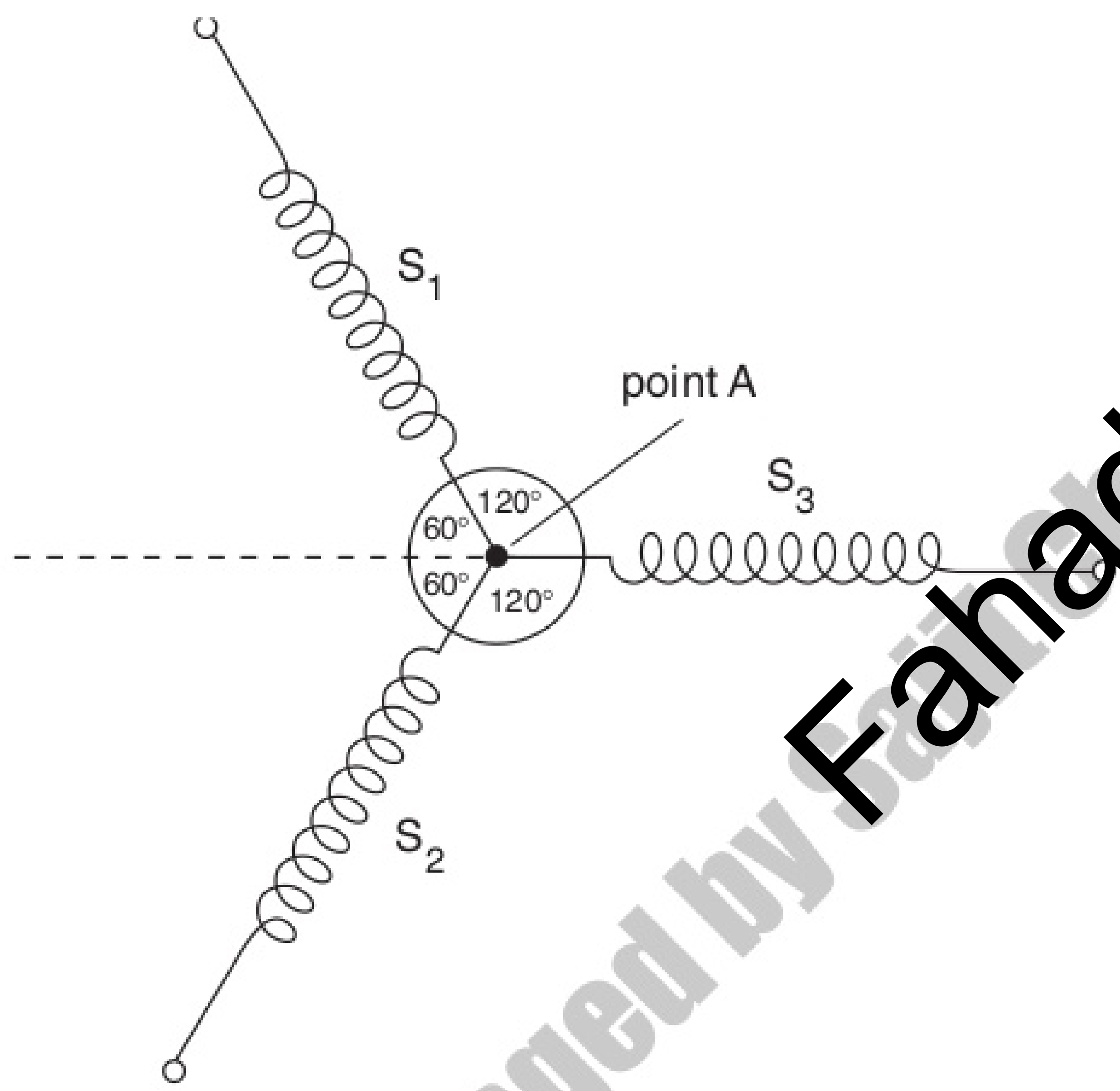

Fig. 3.1

The springs have extended elastically and the extensions of S_1 and S_2 are x. Determine, in terms of x, the extension of S_3 such that the system of springs is in equilibrium. Explain your working.

extension of S_3 = ... [3]

(c) The lid of a box is hinged along one edge E, as shown in Fig. 3.2.

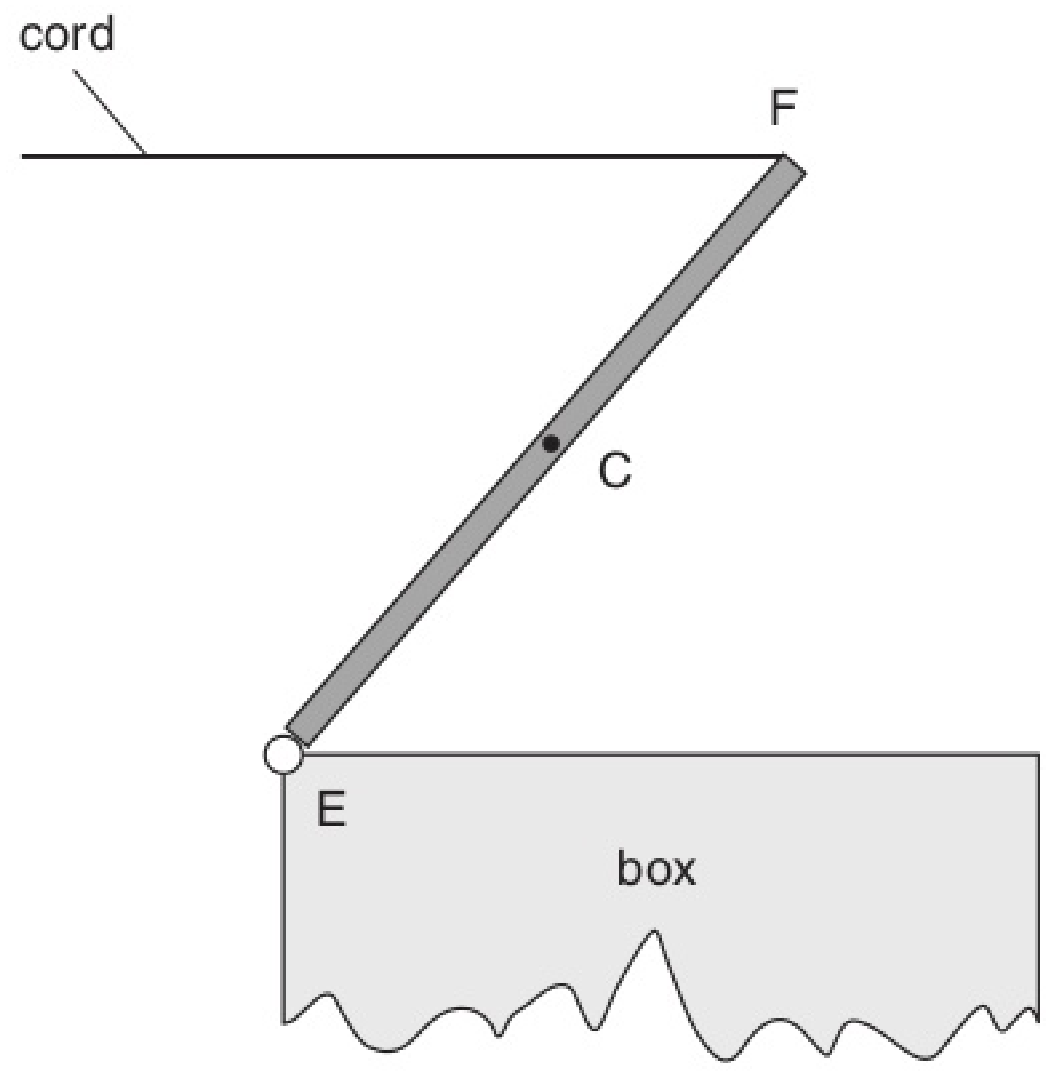

Fig. 3.2

The lid is held open by means of a horizontal cord attached to the edge F of the lid. The centre of gravity of the lid is at point C.

On Fig. 3.2 draw

(i) an arrow, labelled W, to represent the weight of the lid,

(ii) an arrow, labelled T, to represent the tension in the cord acting on the lid,

(iii) an arrow, labelled R, to represent the force of the hinge on the lid.

[3]

7 **(a)** Explain what is meant by the *centre of gravity* of a body.

....

....

.... [2]

(b) An irregularly-shaped piece of cardboard is hung freely from one point near its edge, as shown in Fig. 2.1.

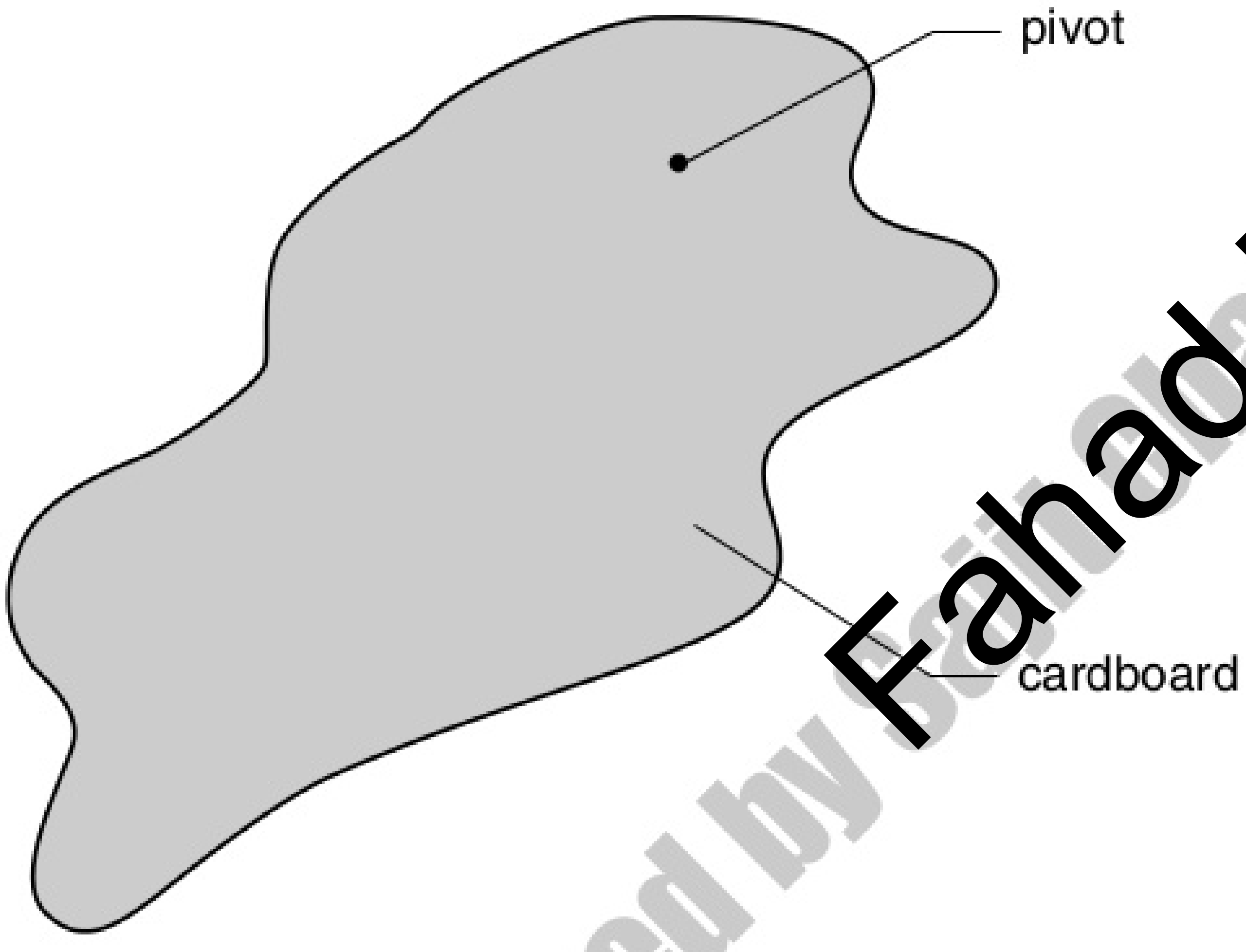

Fig. 2.1

Explain why the cardboard will come to rest with its centre of gravity vertically below the pivot. You may draw on Fig. 2.1 if you wish.

....

....

.... [2]

For Examiner's Use

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

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.

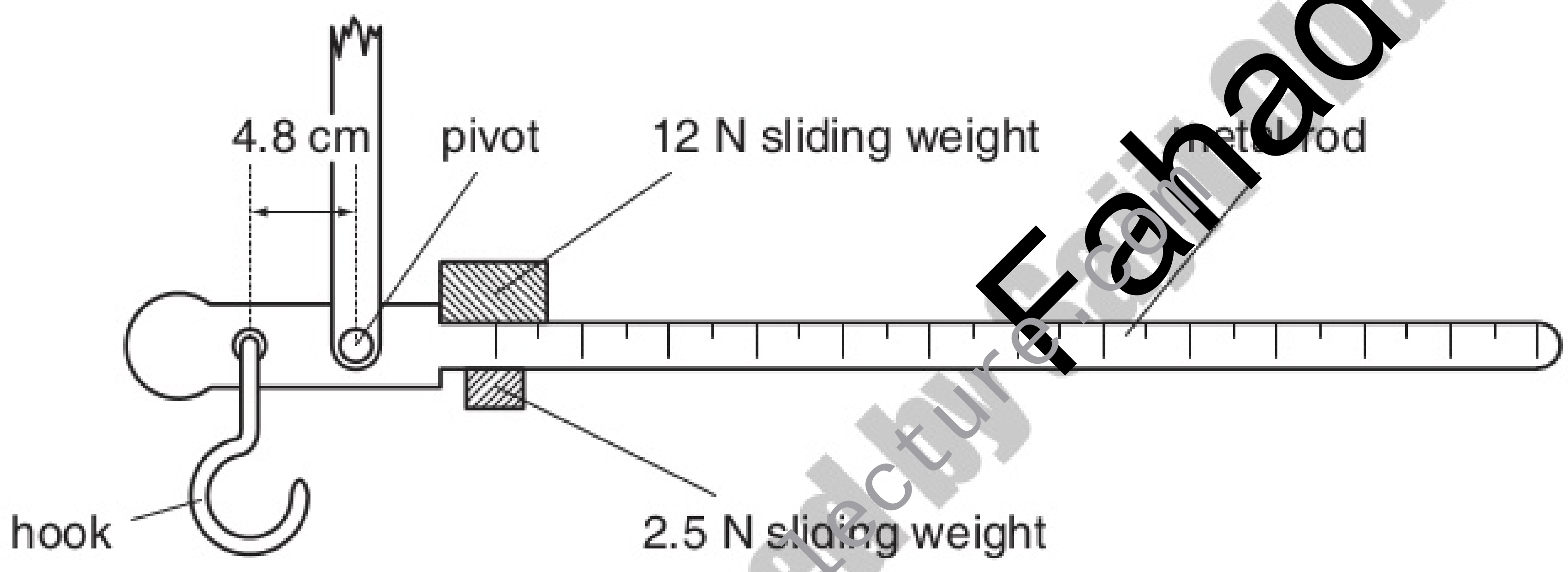

Fig. 3.1

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]

3 **(a)** **(i)** Define *force*.

....

....[1]

(ii) State Newton's third law of motion.

....

....

....

....[3]

(b) Two spheres approach one another along a line joining their centres, as illustrated in Fig. 3.1.

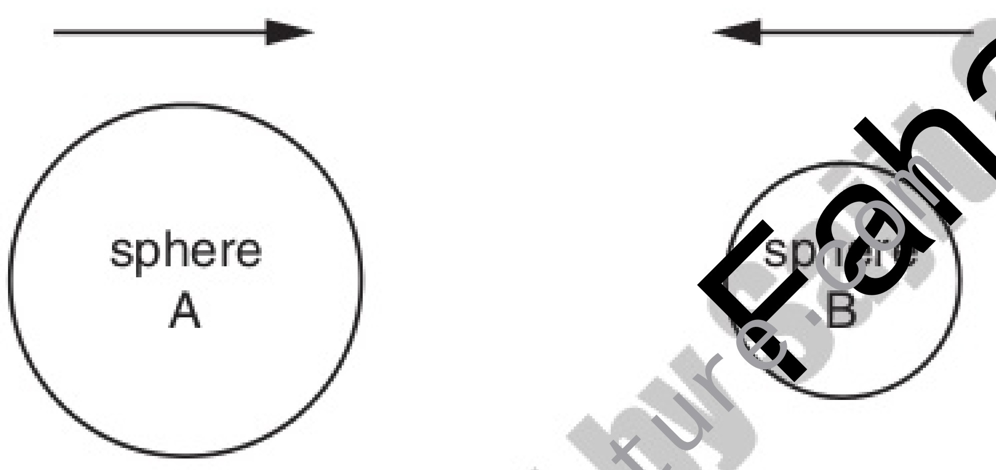

Fig. 3.1

When they collide, the average force acting on sphere A is F_A and the average force acting on sphere B is F_B.

The forces act for time t_A on sphere A and time t_B on sphere B.

(i) State the relationship between

1. F_A and F_B,

....[1]

2. t_A and t_B.

....[1]

(ii) Use your answers in **(i)** to show that the change in momentum of sphere A is equal in magnitude and opposite in direction to the change in momentum of sphere B.

....

....[1]

(c) For the spheres in **(b)**, the variation with time of the momentum of sphere A before, during and after the collision with sphere B is shown in Fig. 3.2.

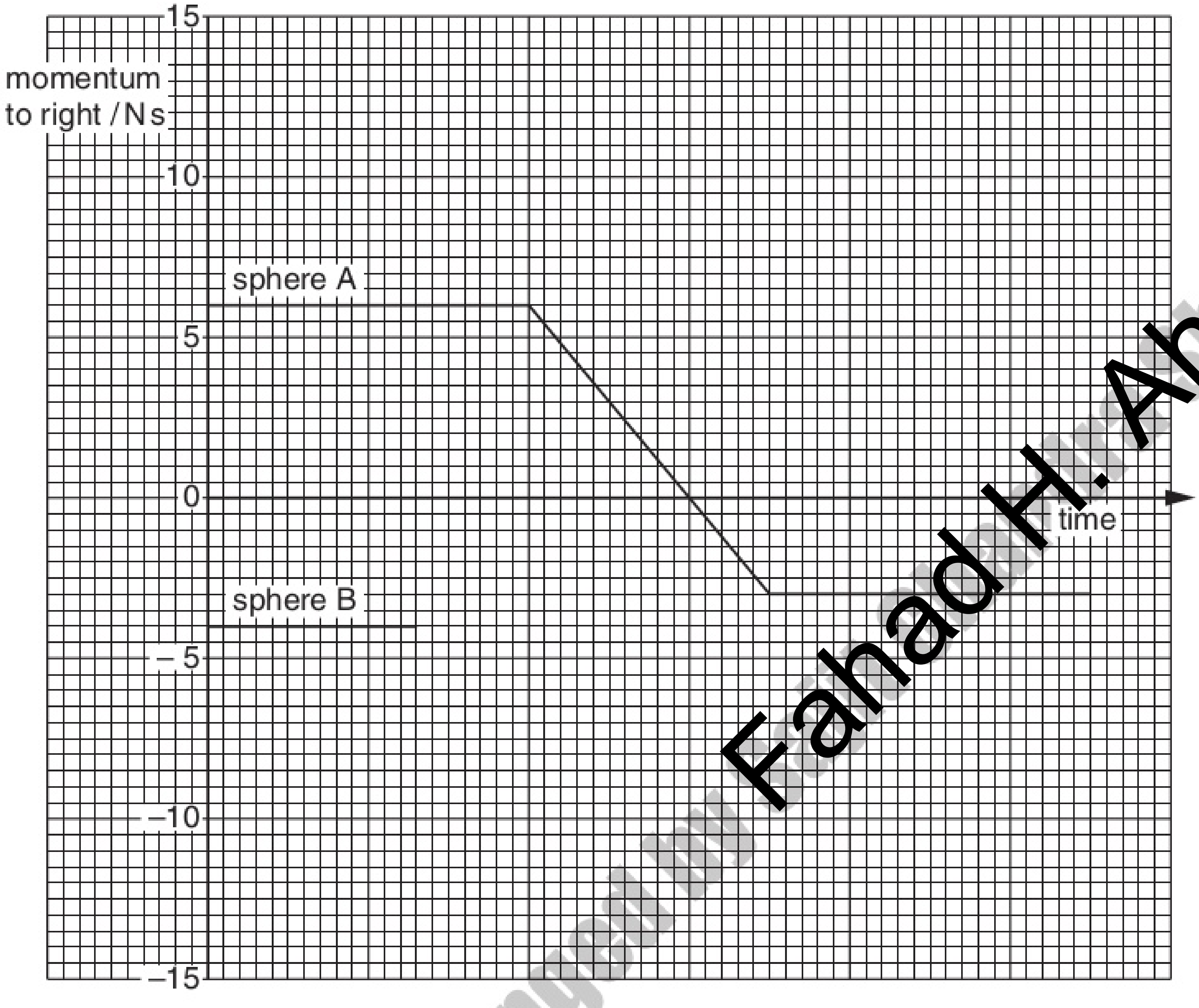

Fig. 3.2

The momentum of sphere B before the collision is also shown on Fig. 3.2.

Complete Fig. 3.2 to show the variation with time of the momentum of sphere B during and after the collision with sphere A. [3]

2 (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.

For Examiner's Use

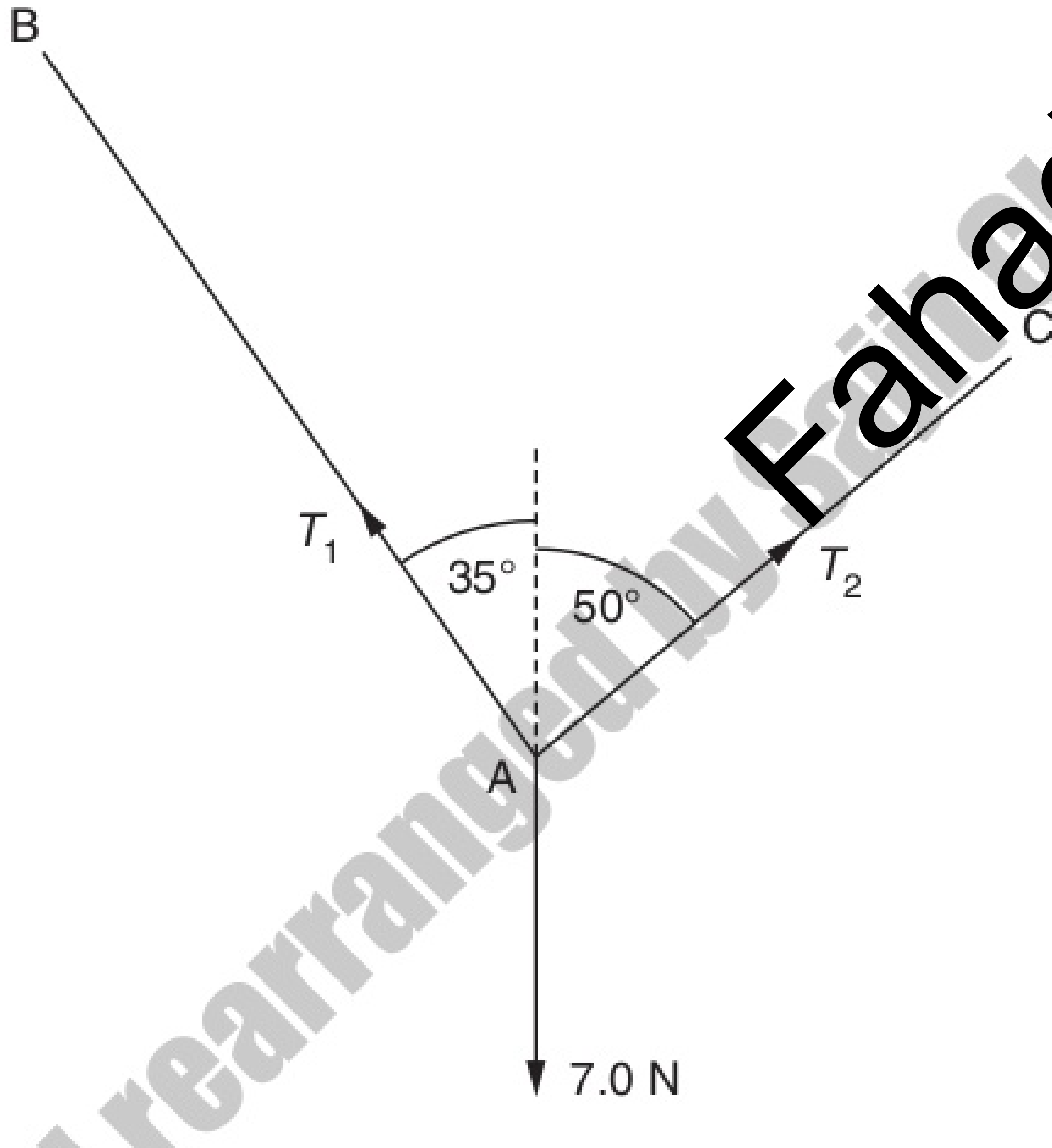

Fig. 2.1

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]

[Turn over

For Examiner's Use

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

.... [1]

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

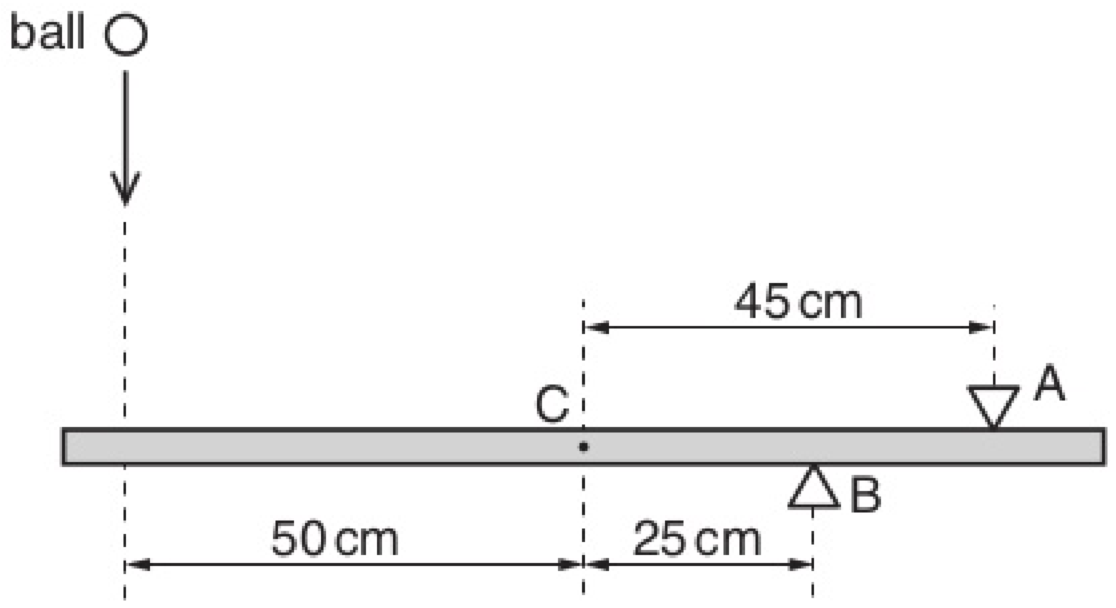

Fig. 3.1

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.

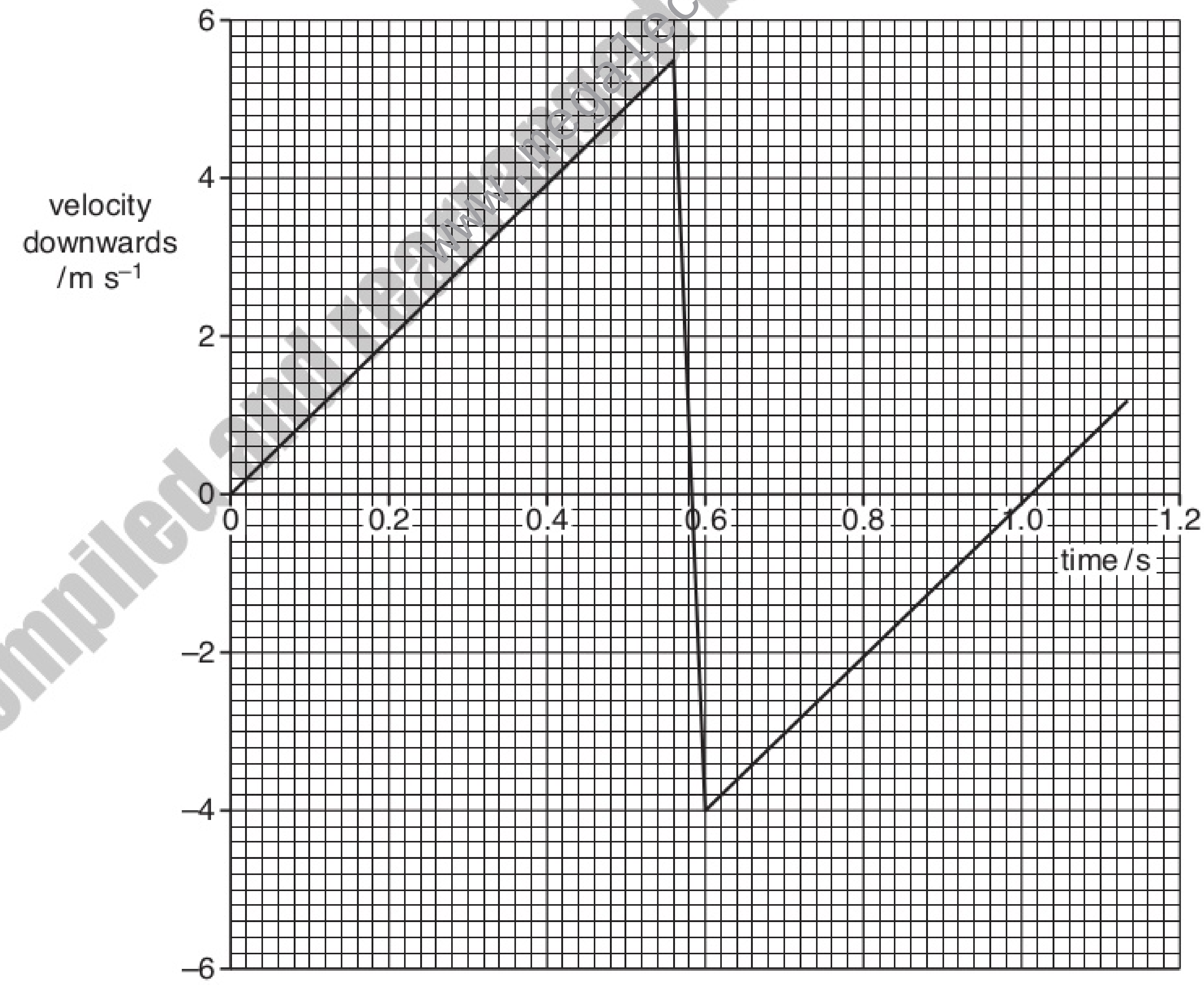

Fig. 3.2

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

(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]

3 **(a)** State what is meant by the *centre of gravity* of a body.

....

....

....[2]

(b) A uniform rectangular sheet of card of weight *W* is suspended from a wooden rod. The card is held to one side, as shown in Fig. 3.1.

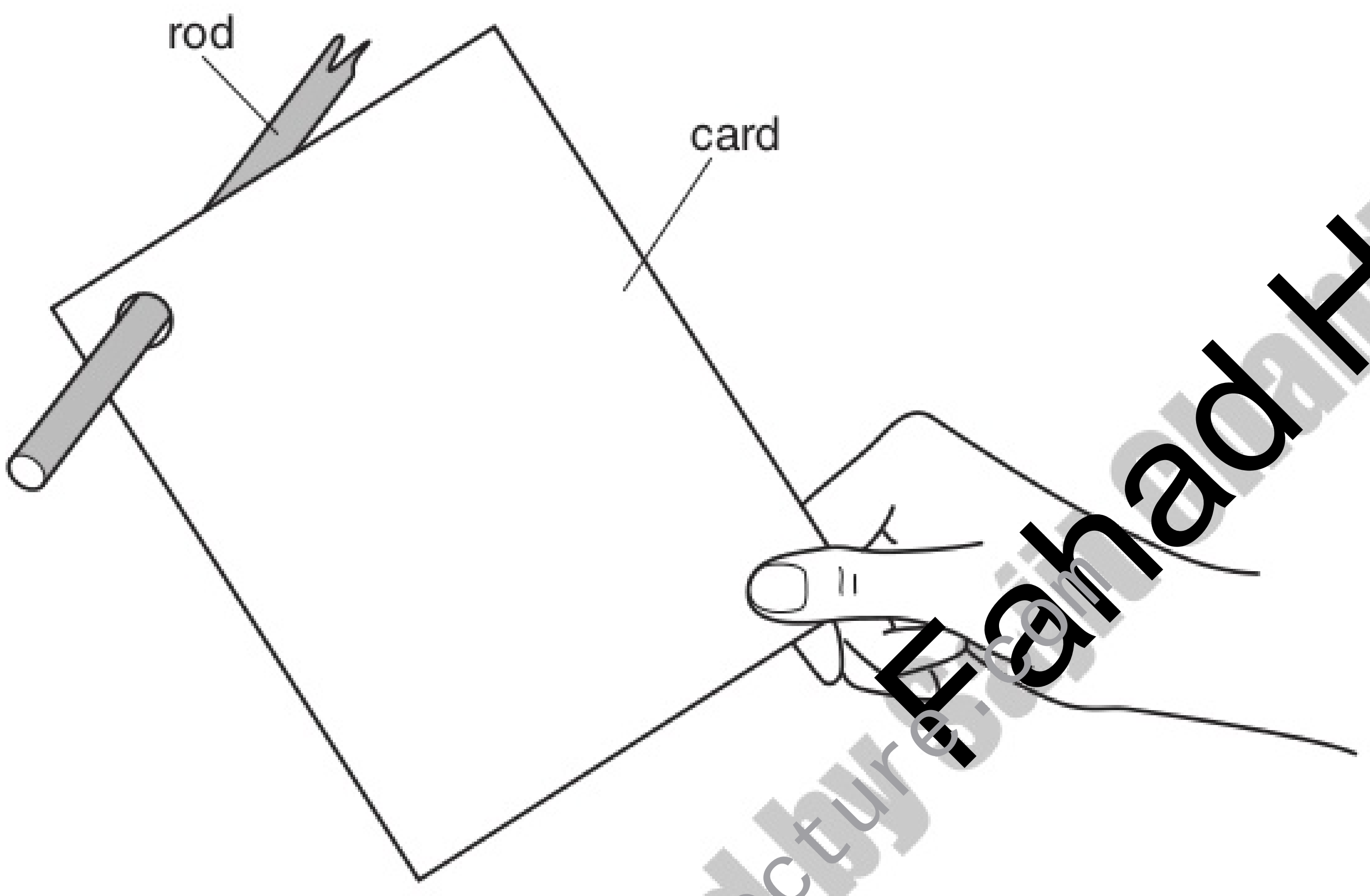

Fig. 3.1

On Fig. 3.1,

(i) mark, and label with the letter C, the position of the centre of gravity of the card, [1]

(ii) mark with an arrow labelled *W* the weight of the card. [1]

(c) The card in **(b)** is released. The card swings on the rod and eventually comes to rest.

(i) List the two forces, other than its weight and air resistance, that act on the card during the time that it is swinging. State where the forces act.

1. ....

....

2. ....

.... [3]

(ii) By reference to the completed diagram of Fig. 3.1, state the position in which the card comes to rest.
Explain why the card comes to rest in this position.

....

....

.... [2]

3 **(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.

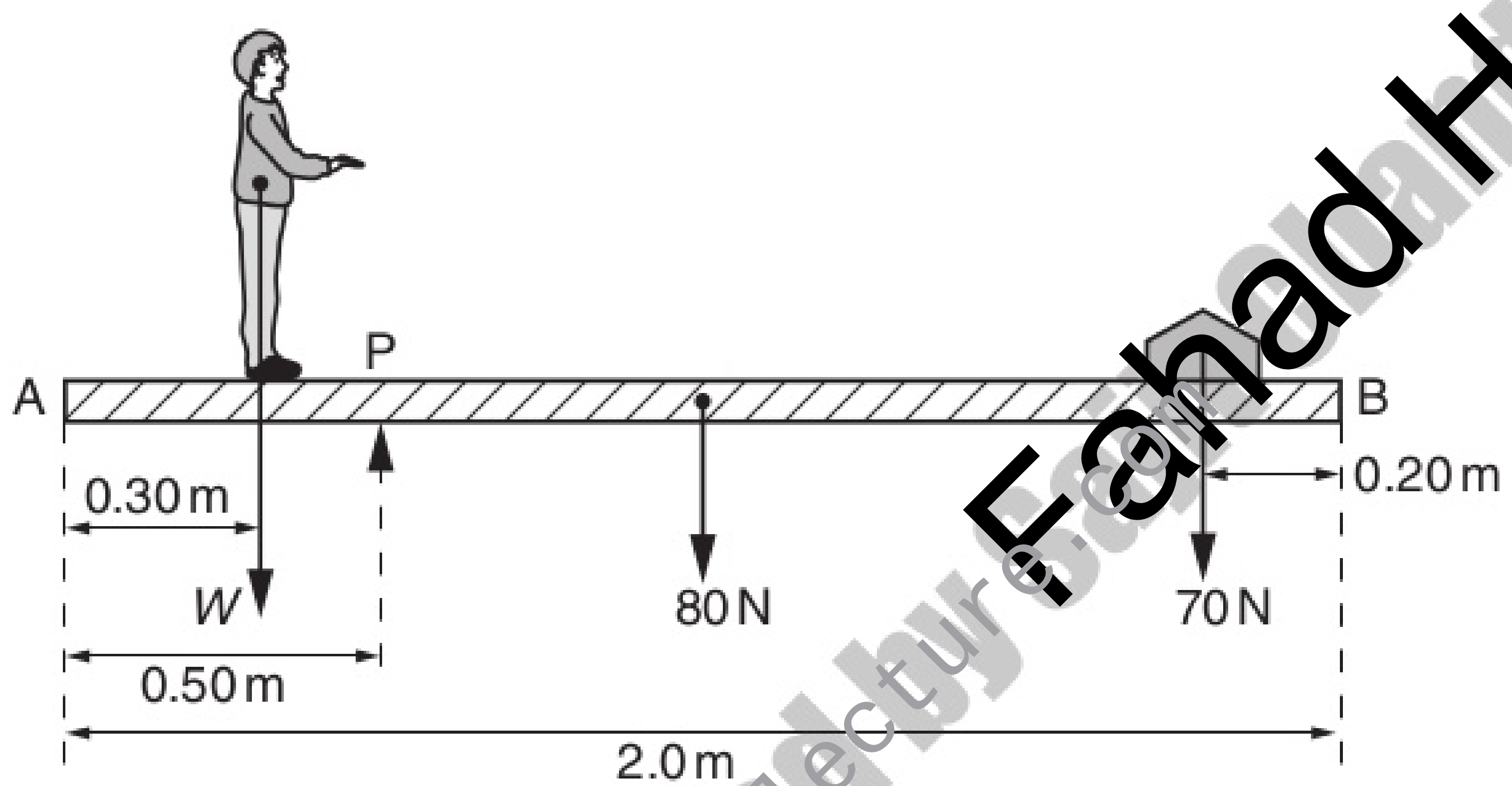

Fig. 3.1 (not to scale)

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]

For Examiner's Use

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

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]

For Examiner's Use

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

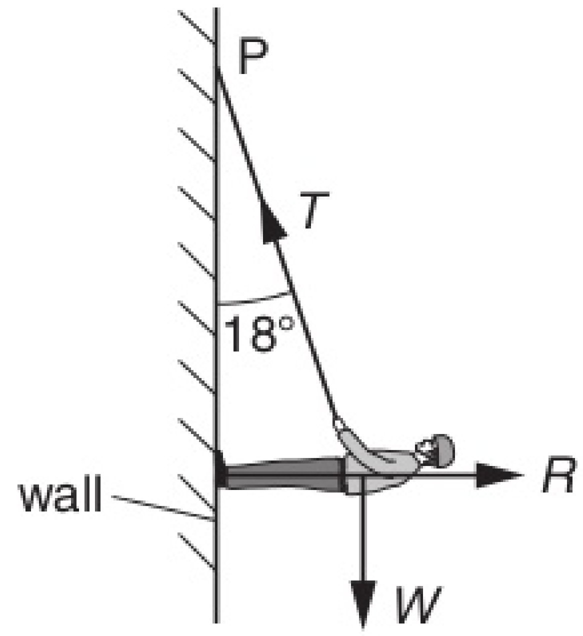

Fig. 2.1

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]

For Examiner's Use

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

(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]

For Examiner's Use

2 **(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.

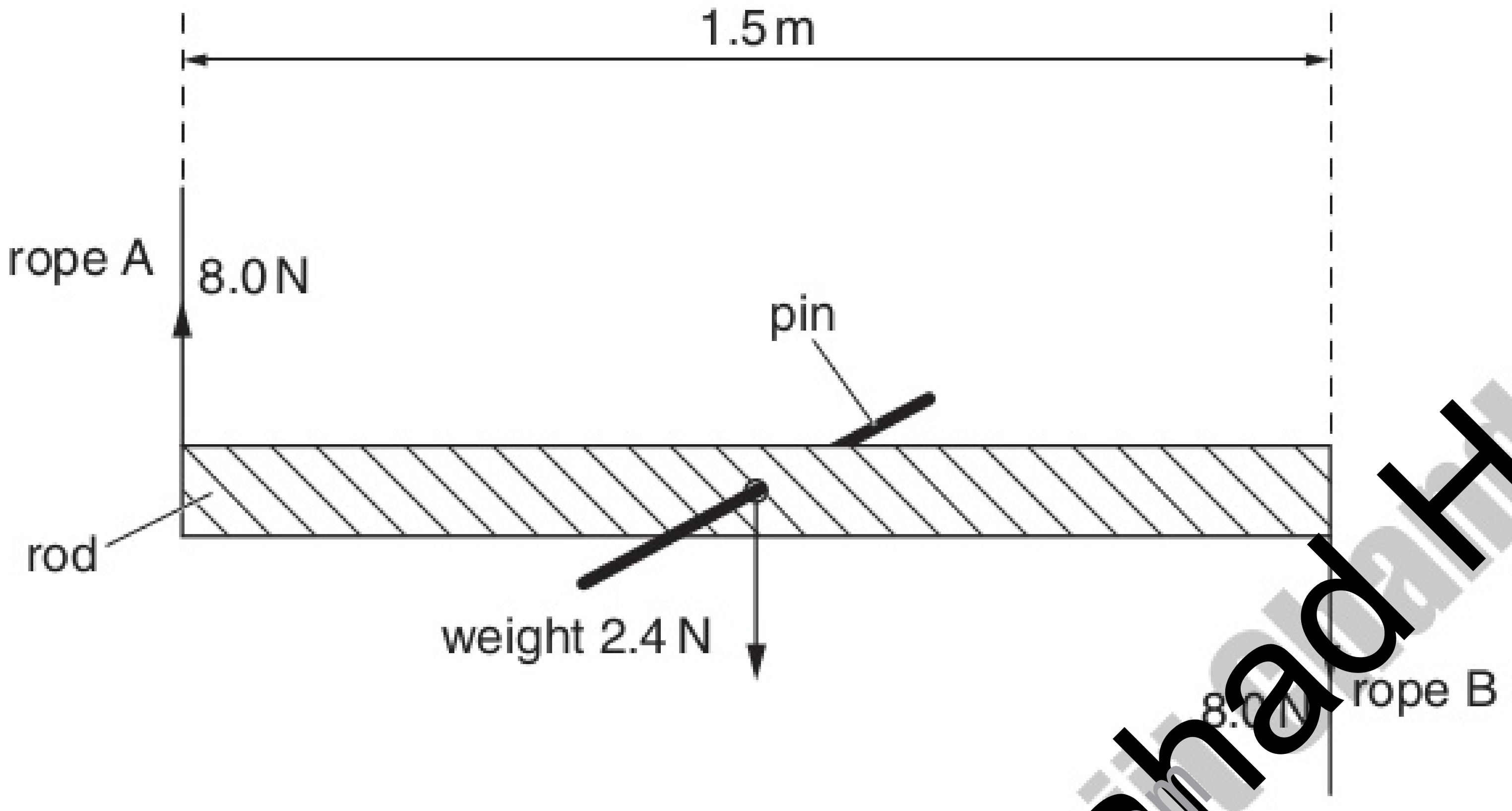

Fig. 2.1

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.

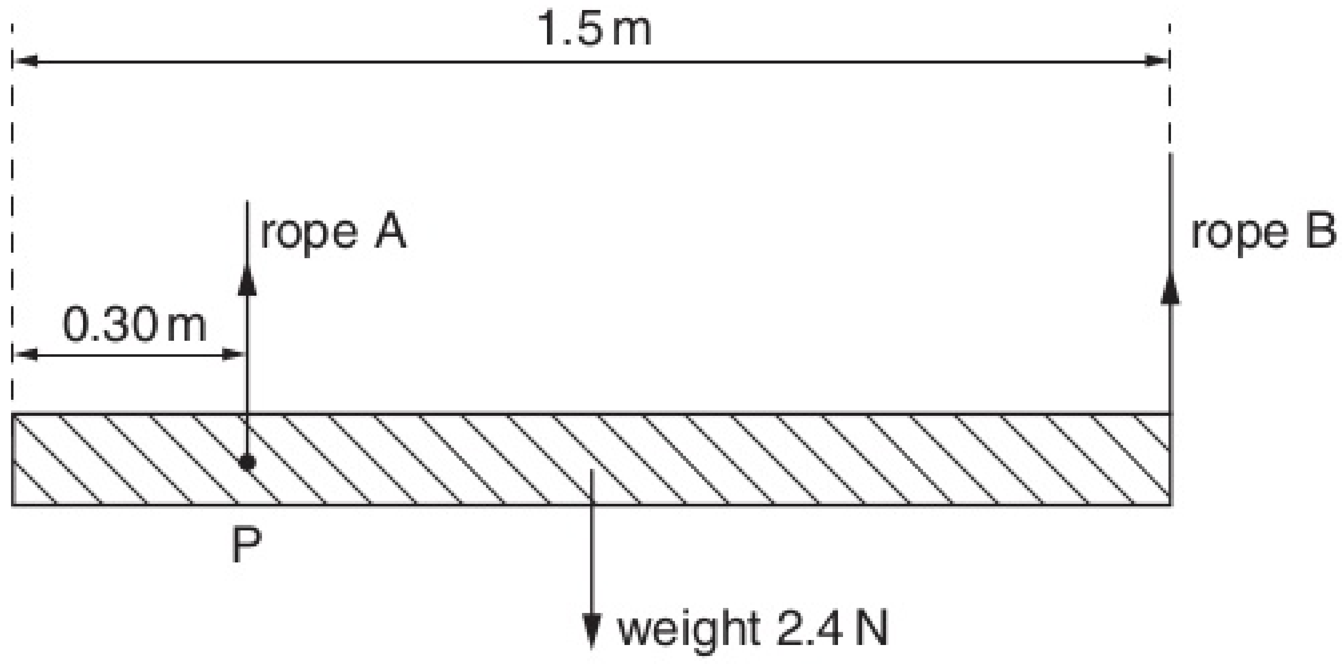

Fig. 2.2

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]

For Examiner's Use

2 **(a)** Define

(i) *force*,

....

....[1]

(ii) *work done*.

....

....[1]

(b) A force F acts on a mass m along a straight line for a distance s. The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v.

(i) State the work W done by F.

[1]

(ii) Use your answer in **(i)** and an equation of motion to show that kinetic energy of a mass can be given by the expression

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

[3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of $15\,\text{m}\,\text{s}^{-1}$ to a final speed of $30\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the distance moved by the car during this acceleration.

distance = ... m [2]

(ii) The same force is used to change the speed of the car from $30\,\text{m}\,\text{s}^{-1}$ to $45\,\text{m}\,\text{s}^{-1}$. Explain why the distance moved is not the same as that calculated in **(i)**.

....

....

....[1]

For Examiner's Use

3 **(a)** Define the terms

(i) *power*,

.... [1]

(ii) the *Young modulus*.

....

....

.... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

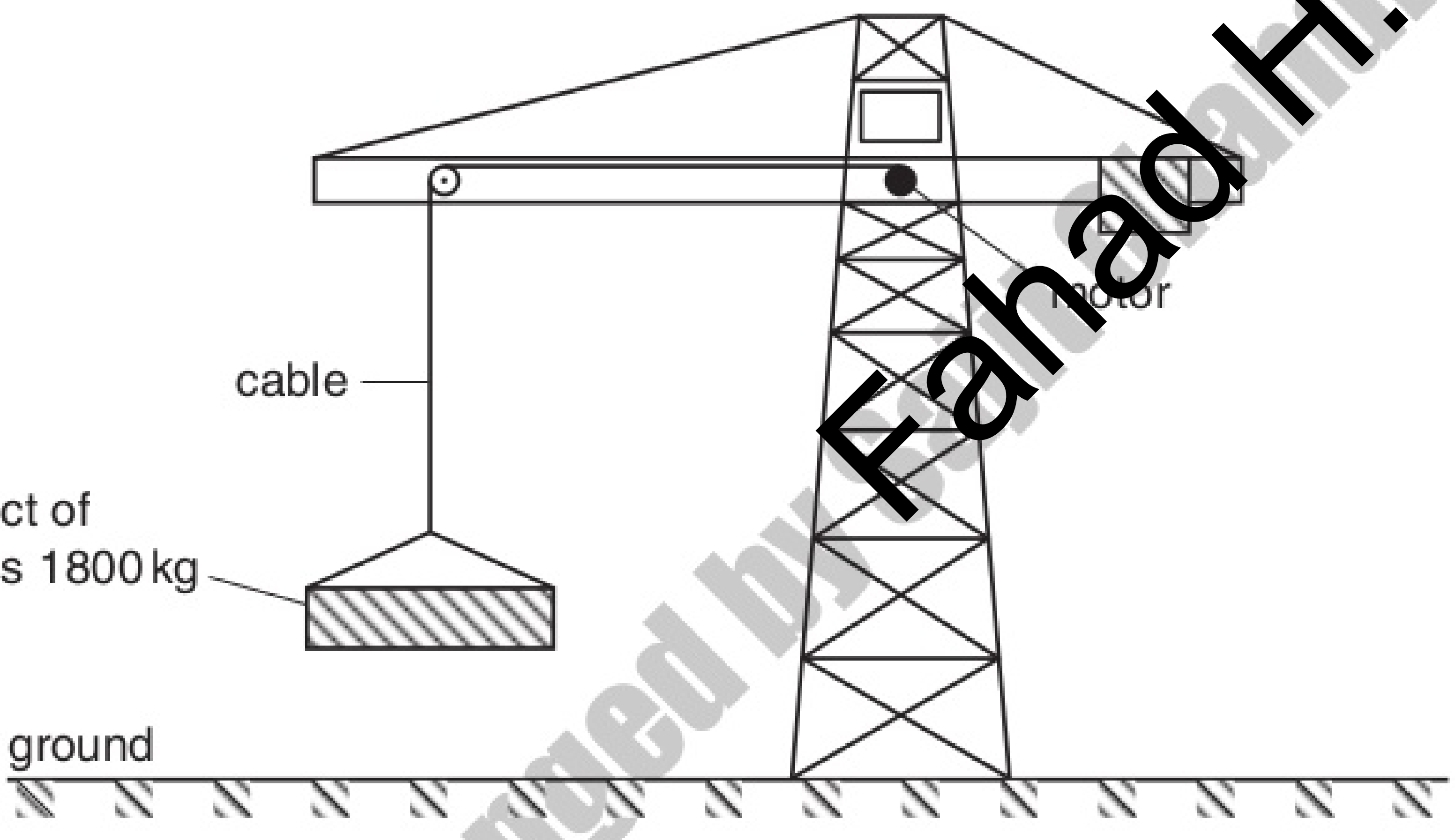

Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is $1.3 \times 10^{-4}\,m^2$. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) **1.** Use the Young Modulus of the steel to show that the tension in the cable is 3.1×10^4 N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

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

For Examiner's Use

(ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ... J [2]

(iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of $0.5\,\text{m s}^{-1}$.

input power = ... W [3]

For Examiner's Use

2 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,m\,s^{-1}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,m\,s^{-1}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,m\,s^{-1}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force ....

[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

....

....

.... [1]

3 **(a)** State Newton's first law.

....

....[1]

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

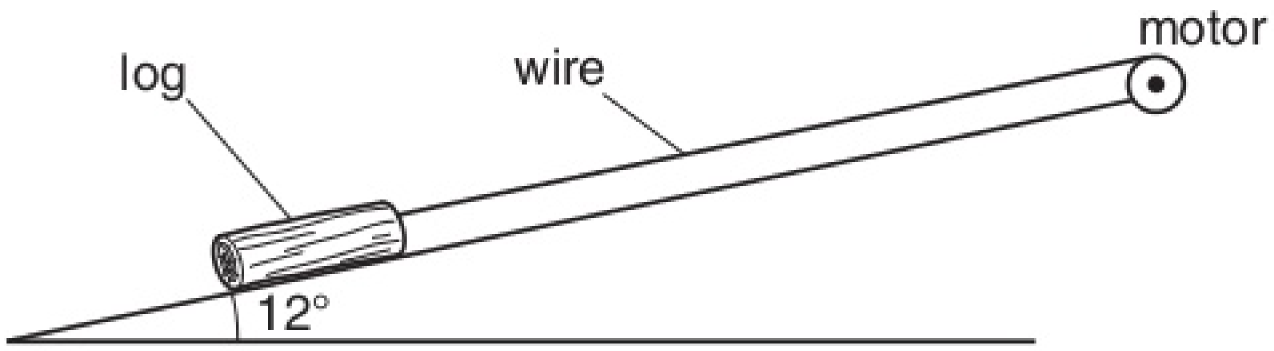

Fig. 3.1

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

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

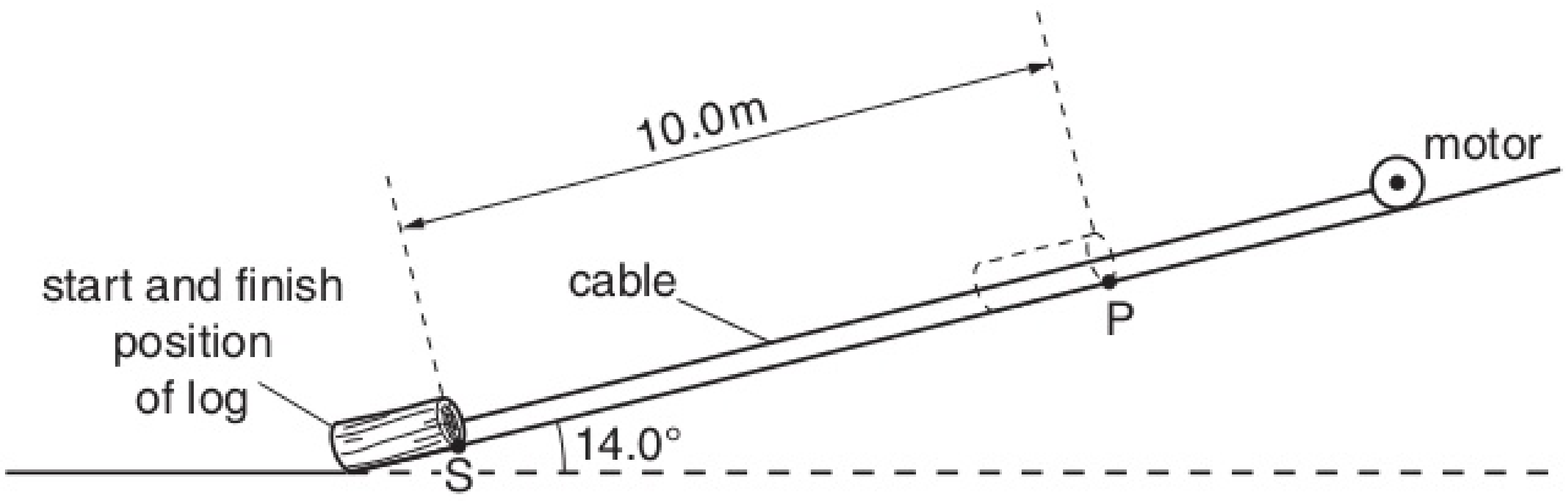

Fig. 2.1

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 $0.130\,\mathrm{m\,s^{-2}}$.

(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

2 **(a)** State Newton's second law.

....

....[1]

(b) A ball of mass 65 g hits a wall with a velocity of 5.2 m s^{-1} perpendicular to the wall. The ball rebounds perpendicularly from the wall with a speed of 3.7 m s^{-1}. The contact time of the ball with the wall is 7.5 ms.

Calculate, for the ball hitting the wall,

(i) the change in momentum,

change in momentum = ... N s [2]

(ii) the magnitude of the average force.

force = ... N [1]

(c) **(i)** For the collision in **(b)** between the ball and the wall, state how the following apply:

1. Newton's third law,

....

....

....

....[2]

2. the law of conservation of momentum.

....

....[1]

(ii) State, with a reason, whether the collision is elastic or inelastic.

....

....[1]

For Examiner's Use

1 (a) The drag force D on an object of cross-sectional area A, moving with a speed v through a fluid of density ρ, is given by

$$D = \frac{1}{2} C \rho A v^2$$

where C is a constant.

Show that C has no unit.

[2]

(b) A raindrop falls vertically from rest. Assume that air resistance is negligible.

(i) On Fig. 1.1, sketch a graph to show the variation with time t of the velocity v of the raindrop for the first 1.0 s of the motion.

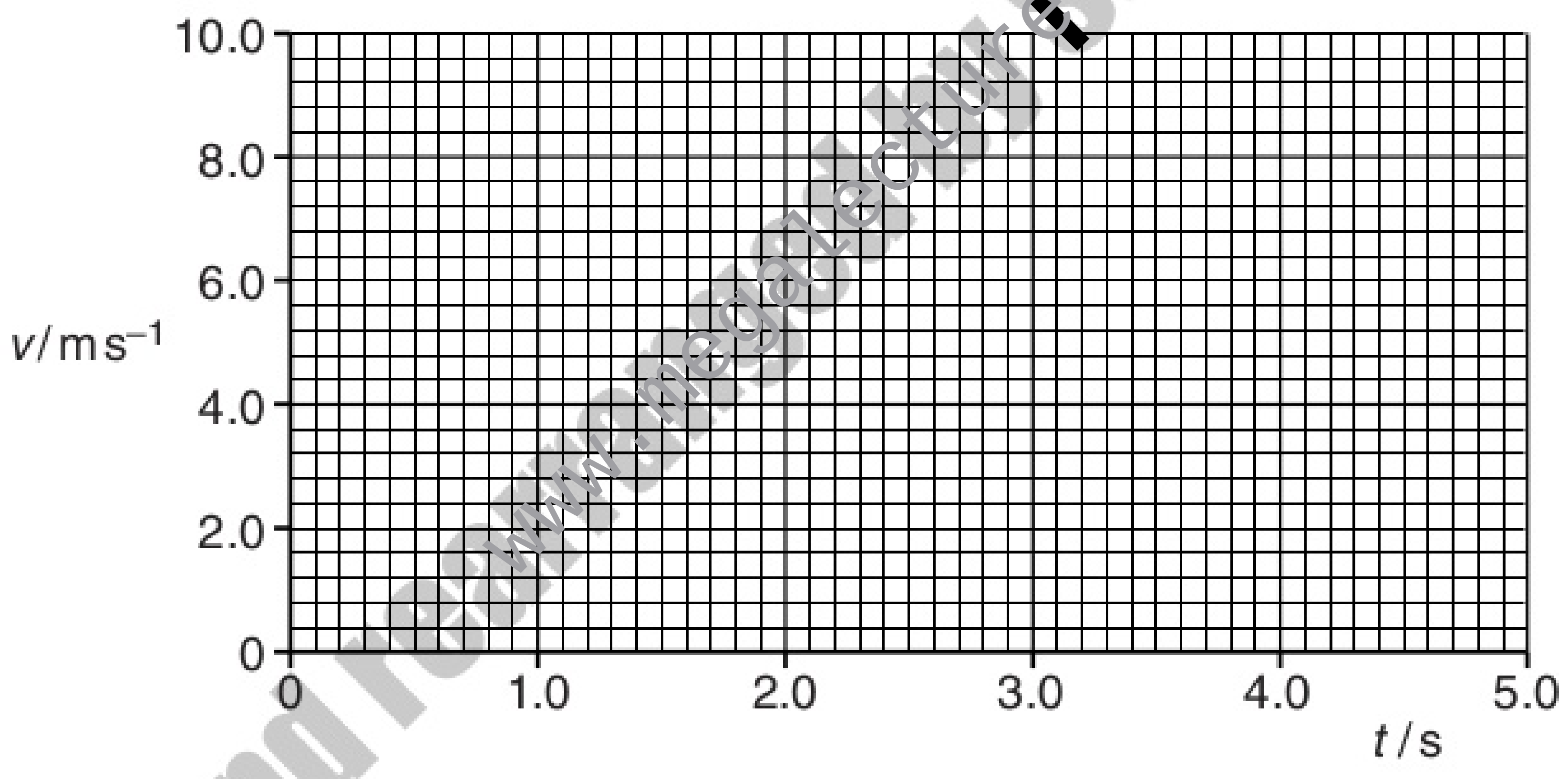

Fig. 1.1

[1]

(ii) Calculate the velocity of the raindrop after falling 1000 m.

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

For Examiner's Use

(c) In practice, air resistance on raindrops is not negligible because there is a drag force. This drag force is given by the expression in **(a)**.

(i) State an equation relating the forces acting on the raindrop when it is falling at terminal velocity.

[1]

(ii) The raindrop has mass 1.4×10^{-5} kg and cross-sectional area 7.1×10^{-6} m^2. The density of the air is 1.2 kg m^{-3} and the initial velocity of the raindrop is zero. The value of C is 0.60.

1. Show that the terminal velocity of the raindrop is about 7 m s^{-1}.

[2]

2. The raindrop reaches terminal velocity after falling approximately 10 m. On Fig. 1.1, sketch the variation with time t of velocity v for the raindrop. The sketch should include the first 5 s of the motion.

[2]