Past-paper walk-through

Equilibrium of forces ▪ 4.2

eXercise

Questions in this set

- 9702/11 N25 Q13 ▪ 1 mark
- 9702/12 N25 Q14 ▪ 1 mark
- 9702/14 N25 Q13 ▪ 1 mark
- 9702/14 N25 Q15 ▪ 1 mark
- 9702/22 N25 Q3 ▪ 9 marks
- 9702/11 J25 Q15 ▪ 1 mark
- 9702/13 J25 Q10 ▪ 1 mark
- 9702/13 J25 Q14 ▪ 1 mark
- 9702/14 J25 Q11 ▪ 1 mark
- 9702/12 M25 Q9 ▪ 1 mark

Questions in this set

- 9702/12 M25 Q11 ▪ 1 mark
- 9702/22 M25 Q2 ▪ 10 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 13

9702/11 N25 ▪ Q13 ▪ 1 mark

A uniform rod of weight 28 N is supported at one end by force F.
The rod is in equilibrium and attached to a frictionless hinge at end X.
What is the magnitude of F? **[1]**

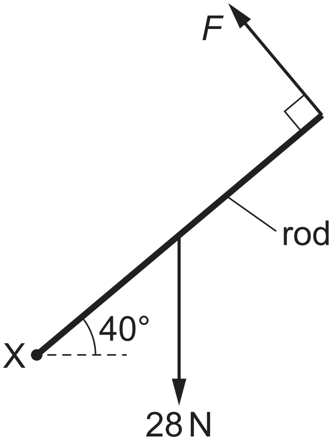
A 9.0 N

B 11 N

C 18 N

D 21 N

Question 13



Solution 13

A 9.0 N

B 11 N ✓

C 18 N

D 21 N

Why

- F is drawn perpendicular to the rod, so its moment arm about X is the full length L.
- The weight is vertical and acts at the midpoint, so its arm is the *horizontal* distance $\frac{L}{2}\cos 40^\circ$.
- $FL = 28 \times \frac{L}{2}\cos 40^\circ$, giving $F = 14\cos 40^\circ = 11$ N.

Question 14

9702/12 N25 ▪ Q14 ▪ 1 mark

The diagram shows a uniform bar of mass M and length L resting on a pivot at a distance x from end X.

An object of mass m is placed on the bar at distance y from the pivot so that the bar is in equilibrium.

What is an expression for y? **[1]**

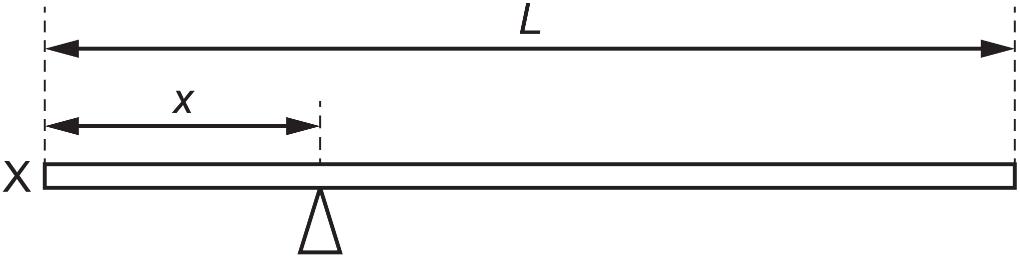
A $\frac{xM}{m}$

B $\frac{M}{m}(L - x)$

C $\frac{M}{2m}(L - 2x)$

D $\frac{1}{m}(Lm - xM)$

Question 14



Solution 14

A $\frac{xM}{m}$

B $\frac{M}{m}(L - x)$

C $\frac{M}{2m}(L - 2x)$ ✓

D $\frac{1}{m}(Lm - xM)$

Why

- The bar is uniform, so its weight acts at $L/2$ from end X.
- That point is $(L/2 - x)$ from the pivot, and the object at distance y balances it on the other side.
- $M(L/2 - x) = my$, so $y = M(L - 2x)/2m$.

Question 13

9702/14 N25 ▪ Q13 ▪ 1 mark

A uniform rod is attached by a hinge at one end to a wall. The other end of the rod is supported by a wire so that the rod is horizontal and in equilibrium.

Which arrow shows the direction of the force on the rod from the hinge? **[1]**

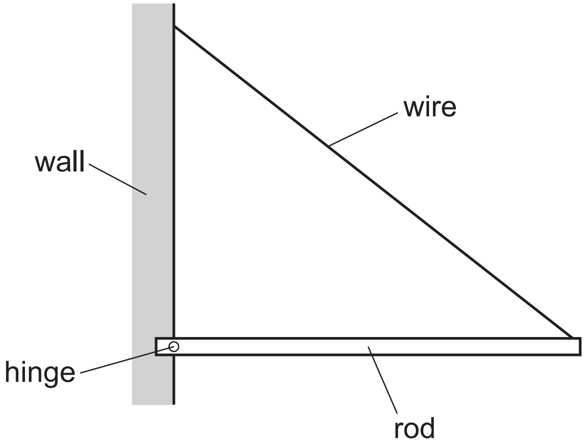
A an arrow pointing vertically upwards

B an arrow pointing vertically downwards

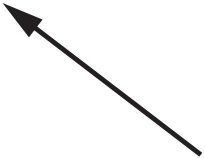
C an arrow pointing diagonally downwards and to the left

D an arrow pointing diagonally upwards and to the right

Question 13



Question 13



Solution 13

A an arrow pointing vertically upwards

B an arrow pointing vertically downwards

C an arrow pointing diagonally downwards and to the left

D an arrow pointing diagonally upwards and to the right ✓

Why

- Taking moments about the hinge, the wire's vertical pull carries half the rod's weight.
- So the hinge must supply the other half upwards, plus an outward push to balance the wire pulling the rod towards the wall.
- The hinge force therefore points upwards and away from the wall, not along the rod.

Question 15

9702/14 N25 ▪ Q15 ▪ 1 mark

A uniform beam rests on two supports, X and Y, as shown.
The beam has length 20.0 m and weight 200 N.
A man of weight 700 N stands on the beam at a distance of 6.0 m from support X.
The beam is in equilibrium.
What is the contact force of support X on the beam? **[1]**

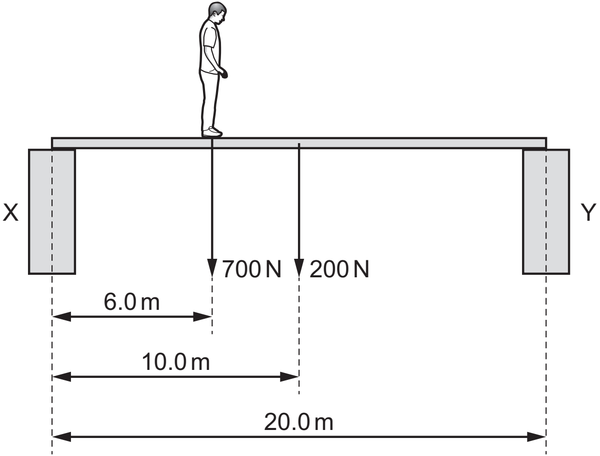
A 310 N

B 450 N

C 590 N

D 900 N

Question 15



Solution 15

A 310 N

B 450 N

C 590 N ✓

D 900 N

Why

- Take moments about Y, at the far end of the 20.0 m beam.
- The man is 14.0 m from Y, and the beam's own weight acts at its centre, 10.0 m from Y.
- $R_X \times 20.0 = 700 \times 14.0 + 200 \times 10.0 = 11800$, so $R_X = 590$ N.

Question 3

9702/22 N25 ▪ Q3 ▪ 9 marks

A spring is fixed at one end and attached to the frame of a pulley at the other end. A cable is passed around the wheel of the pulley. The spring is stretched to a fixed length using the cable and pulley.

Fig. 3.1 shows the view from above of the spring, cable and pulley.

The spring obeys Hooke's law and has a spring constant k of $250\ \mathrm{N\,m^{-1}}$. A force F acts on the spring. The tension in the cable is T. The pulley is in equilibrium.

(a) On Fig. 3.2, draw labelled arrows to show the directions of the forces acting on the pulley. **[2]**

(b)(i) Determine T. **[1]**

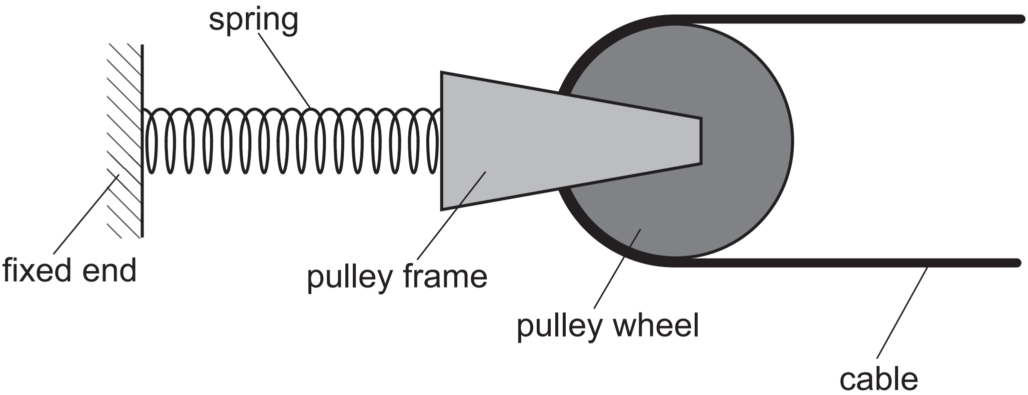
(b)(ii) Calculate the extension of the spring. **[2]**

(c)(i) The tension in the cable is kept the same. The pulley is again in equilibrium. Determine the extension of the springs. **[2]**

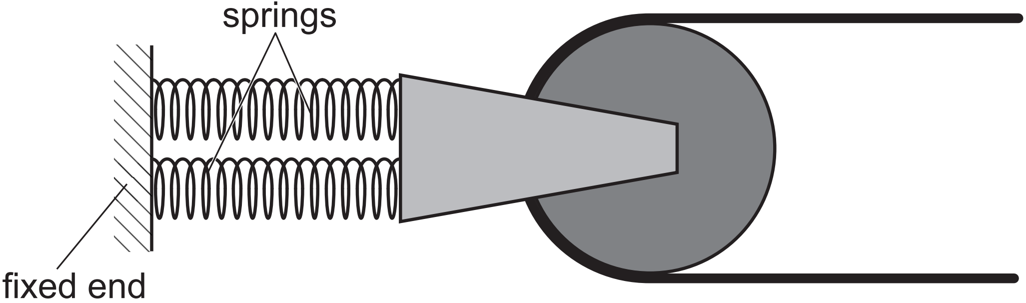
Question 3

(c)(ii) The elastic potential energy stored in the spring in Fig. 3.1 is E_1. The total elastic potential energy stored in the two springs in Fig. 3.3 is E_2.
Calculate the ratio $\frac{E_1}{E_2}$. **[2]**

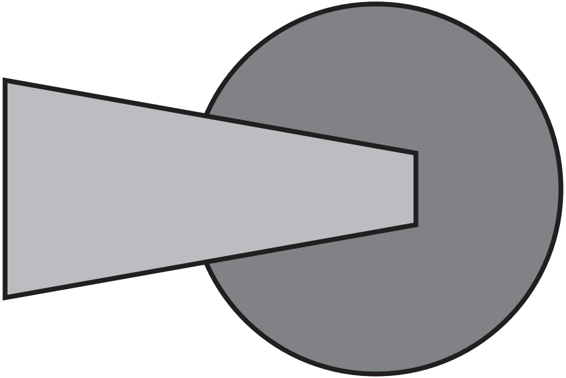
Question 3



Question 3



Question 3



Solution 3

(a)

Worked steps

The pulley is in equilibrium, so the forces on it must cancel.

- Draw one arrow to the **left**, labelled F: the pull of the spring on the pulley frame.
- Draw **two** arrows to the **right**, each labelled T: the cable passes round the wheel, so both sides of it pull the pulley the same way.

Mark scheme

- an arrow horizontally on the page to the left labelled F **B1**
- two arrows horizontally on the page to the right each labelled T **B1**

Solution 3

(b)(i)

Worked steps

Both sides of the cable pull with the same tension, and together they balance F.

- $2T = F$, so $T = \dfrac{110}{2}$
- $T = 55$ N

Mark scheme

- T $=$ 110 / 2
- $=$ 55 N **A1**

Solution 3

(b)(ii) Worked steps

- Hooke's law: $F = kx$, so $x = \dfrac{F}{k}$.
- The whole 110 N acts on this single spring.
- $x = \dfrac{110}{250} = 0.44$ m

Solution 3

Mark scheme

- $x = F / k$ **C1**
- $= 110 / 250$
- $= 0.44$ m **A1**

Solution 3

(c)(i) Worked steps

With two springs side by side the load shares between them, so each carries half.

- Force per spring $= \dfrac{110}{2} = 55$ N
- $x = \dfrac{55}{250}$
- $x = 0.22$ m

Solution 3

Mark scheme

- extension $= 55\ /\ 250$ or $110\ /\ (2 \times 250)$ **C1**
- extension $= 0.22$ m **A1**

Solution 3

(c)(ii) Worked steps

Compare the elastic potential energies, $E = \frac{1}{2}Fx$.

- One spring: $E_1 = \frac{1}{2} \times 110 \times 0.44 = 24.2$ J
- Two springs: $E_2 = 2 \times \left(\frac{1}{2} \times 55 \times 0.22\right) = 12.1$ J
- $\dfrac{E_1}{E_2} = 2.0$

Halving both the force and the extension quarters each spring's energy; two of them give back a half, which is why the ratio is exactly 2. **Mark scheme**

- E = 1

Solution 3

- 2 Fx or E = 1
- 2 kx2 or E = 1
- 2 F2 / k C1
- E1 / E2 = (1
- 2 × 110 × 0.44) / (2 × (1
- 2 × 55 × 10.22)) or
- E1 / E2 = (1
- 2 k × 0.442) / (2 × (1
- 2 k × 0.222)) or
- E1 / E2 = (1

Solution 3

- 2×1102 / k) / (2 $\times$ (1
- 2×552 / k))
- E1 / E2 $=$ 2.0 (no ECF from 3(b)(ii) and 3(c)(i)) **A1**

Question 15

9702/11 J25 ▪ Q15 ▪ 1 mark

A student balances a 30 cm ruler on a fulcrum set at the 15 cm mark. She then places a 50 g mass on the 23 cm mark and a 20 g mass on the 11 cm mark, as shown.

Which mass should she place on the 7 cm mark to restore the balance? **[1]**

A 30 g

B 40 g

C 47 g

D 133 g

Solution 15

A 30 g

B 40 g ✓

C 47 g

D 133 g

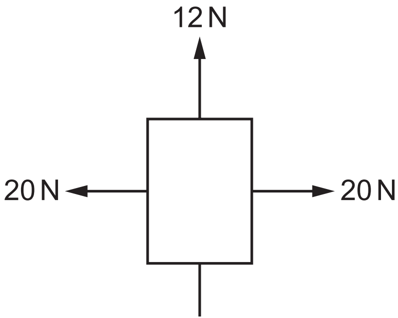
Why

- The ruler's own weight acts at the 15 cm mark, which is the fulcrum, so it has no moment.
- Clockwise: $50 \times 8 = 400$ g cm; the 20 g mass gives $20 \times 4 = 80$ g cm anticlockwise.
- The new mass sits 8 cm from the fulcrum, so $8m = 400 - 80$ and $m = 40$ g.

Question 10

9702/13 J25 ▪ Q10 ▪ 1 mark

10 Four forces, all in the same plane, act on an object.



Question 10

What could describe the motion of the object?

A It is accelerating.

B It is moving in a straight line.

C It is moving with decreasing speed.

D It is moving with increasing momentum.

Solution 10

Answer: **B**

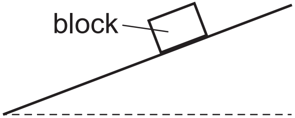
Why

- The four forces balance in pairs, so the resultant force on the object is zero.
- Zero resultant means zero acceleration, so the velocity cannot change.
- The object therefore keeps moving in a straight line at constant speed (or stays at rest).

Question 14

9702/13 J25 ▪ Q14 ▪ 1 mark

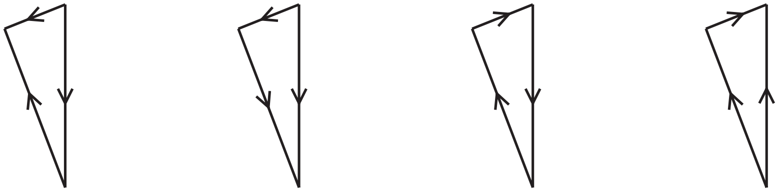
14 A block is in equilibrium on a slope.



Which vector triangle represents the three forces acting on the block?

A **B** **C** **D**

Question 14



Solution 14

Answer: **C**

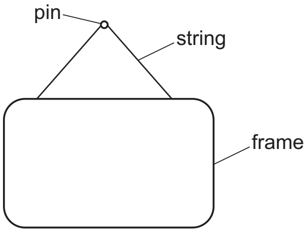
Why

- Three forces act: the weight vertically down, the normal force perpendicular to the slope, and friction along it.
- In equilibrium they must form a closed triangle when drawn nose to tail.
- So look for the triangle whose sides are vertical, perpendicular to the slope, and parallel to the slope.

Question 11

9702/14 J25 ▪ Q11 ▪ 1 mark

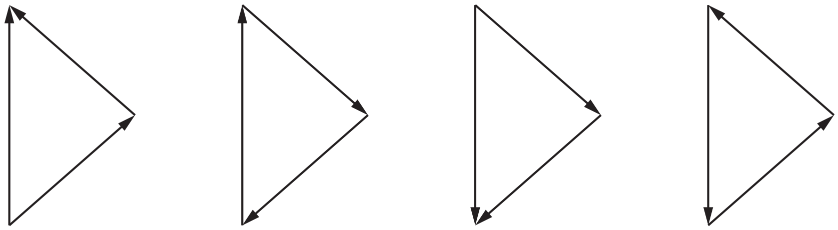
11 A picture frame hangs from a string. The string is supported by a pin. The frame is in equilibrium.



Which diagram shows the vector triangle of forces acting on the picture frame?

A **B** **C** **D**

Question 11



Solution 11

Answer: **D**

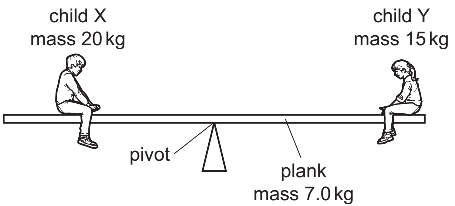
Why

- Three forces act on the frame: its weight straight down and a tension along each half of the string.
- In equilibrium they form a closed triangle drawn nose to tail.
- The weight side is vertical and the two tension sides slope symmetrically, since the pin is central.

Question 9

9702/12 M25 ▪ Q9 ▪ 1 mark

9 The diagram shows a child X of mass 20 kg and a child Y of mass 15 kg seated on a uniform plank.



The plank has a mass of 7.0 kg and has a pivot at its midpoint. The plank is horizontal and in equilibrium.

Which statement about the weight of the plank is correct?

Question 9

A The weight of the plank can be considered to be acting at its midpoint.

B The weight of the plank is causing an anticlockwise moment.

C The weight of the plank is causing a clockwise moment.

D The weight of the plank equals the force on the plank from the pivot.

Solution 9

Answer: **A**

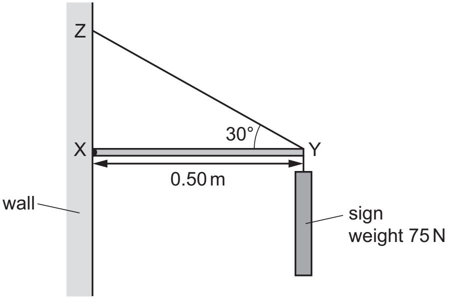
Why

- The plank is uniform, so its weight acts at its centre of gravity – the midpoint.
- The pivot is at that same midpoint, so the weight's moment arm is zero.
- It therefore produces no moment at all, neither clockwise nor anticlockwise.

Question 11

9702/12 M25 ▪ Q11 ▪ 1 mark

11 A shop sign weighing 75 N hangs from a frame attached to a vertical wall.



The frame consists of a horizontal rod XY and a rod YZ that is at an angle of 30° to the horizontal.

Question 11

Rod XY is attached to the wall by a hinge at X and has length 0.50 m. Assume that the weights of the rods are negligible.

What is the horizontal force exerted by the wall on rod XY?

A 0 N **B** 43 N **C** 130 N **D** 150 N

Solution 11

Answer: **C**

Why

- The sign's 75 N hangs at Y, held up by the tension along YZ at $30°$ to the horizontal.
- Vertically, $T \sin 30° = 75$, so $T = 150$ N.
- Horizontally the hinge must balance $T \cos 30° = 150 \times 0.866 = 130$ N.

Question 2

9702/22 M25 ▪ Q2 ▪ 10 marks

2 (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. A B P cylinder hinge ground water uniform beam, weight 1700 N 6.0 m 5.0 m x 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.

Question 2

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. 0.78 m y force from beam, 1300 N cylinder, mass 11 kg water 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.

Question 2

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. distance from A / m depth / m 0 0 6.0 Fig. 2.3
[2]

, ,
(a) (a) State the principle of moments. 2

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....

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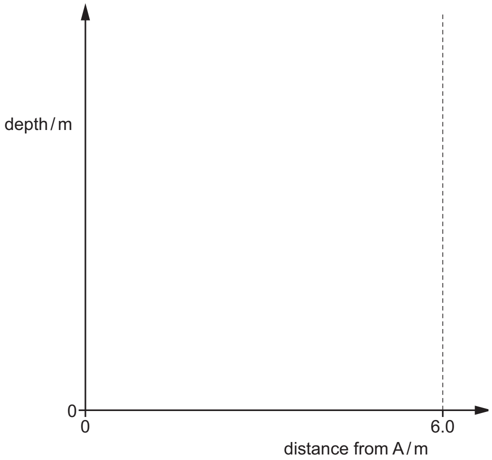
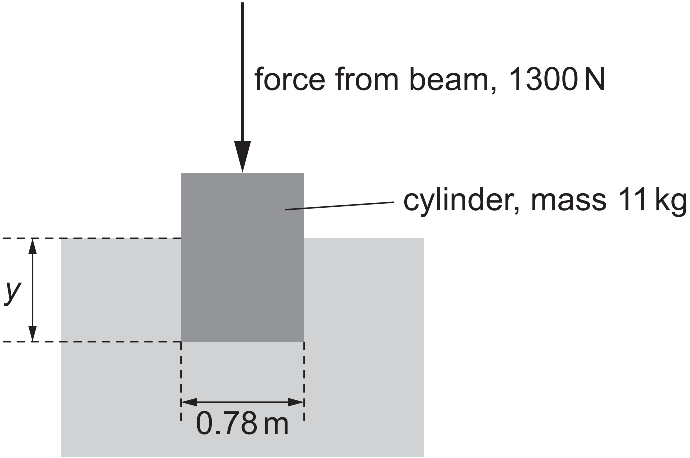
[2] **[2]**

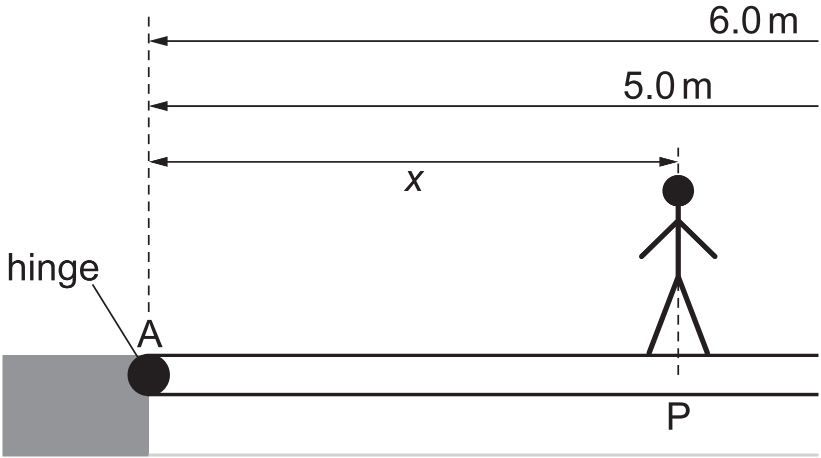
Question 2



Question 2



Question 2



Question 2

9702/22 M25 ▪ Q2 ▪ 10 marks

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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] , ,

Question 2

(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. 0.78 m y force from beam, 1300 N cylinder, mass 11 kg water 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.

distance from A / m depth / m 0 0 6.0 Fig. 2.3

Question 2

[2]

, ,

(b)(i) The cylinder applies a vertical force of 1300 N to the beam at a horizontal distance of 5.0 m from end A. A person of weight 660 N stands on the beam a distance *x* from A. Calculate *x*. **[3]**

(b)(ii) The cylinder has mass 11 kg and diameter 0.78 m, and the beam exerts a vertical force of 1300 N on it. The cylinder is in equilibrium. Show that the upthrust acting on the cylinder is 1400 N. **[1]**

(b)(iii) The water has density 990 kg m^{-3}. Calculate the depth *y* to which the cylinder is submerged. **[2]**

(b)(iv) The person can stand anywhere between A and B. 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. **[2]**

Solution 2

(a)

Mark scheme

- in (rotational) equilibrium
- sum / total of CW moments about a point = sum / total of ACW moments about the (same) point.

Solution 2

(b)(i) Worked steps

Take moments about A: the hinge force acts there, so it contributes nothing.

- The beam is uniform, so its weight acts at its midpoint, 3.0 m from A.
- Clockwise (loads pressing down): 1700×3.0 from the beam, $660 \times x$ from the person.
- Anticlockwise (the cylinder pushing up at 5.0 m): 1300×5.0.
- $(1700 \times 3.0) + 660x = 1300 \times 5.0$
- $660x = 6500 - 5100 = 1400$, so $x = 2.1$ m

Mark scheme

Solution 2

- The magnitudes of the moments about A are:
- (1700×3.0) $(660\ x)$ (1300×5)
- Correct magnitude of any one moment about A.
- Correct magnitudes of a second moment about A.
- $(1700 \times 3.0) + (660\ x) = (1300 \times 5)$
- $x = 2.1\,m$
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Solution 2

(b)(ii)

Worked steps

Now treat the **cylinder** as the body in equilibrium. Three vertical forces act on it.

- Up: the upthrust U. Down: its own weight $11 \times 9.81 = 108$ N, and the beam pressing on it with 1300 N.
- $U = 108 + 1300$
- $U = 1400$ N, as required.

Mark scheme

- (Upthrust =) 11 $\times$ 9.81 + 1300 = 1400 (N)

Solution 2

(b)(iii) Worked steps

Upthrust equals the weight of water displaced, and the submerged part is a cylinder of depth y.

- $U = \rho g V = \rho g A y$, with $A = \pi\left(\frac{0.78}{2}\right)^2 = 0.478\ \text{m}^2$.
- $y = \frac{U}{\rho g A} = \frac{1400}{990 \times 9.81 \times 0.478}$
- $y = 0.30\ \text{m}$

Mark scheme

Solution 2

- y = Upthrust / ρgA
- = 1400 / (990 × 9.81 × π × (0.78 / 2)2)
- = 0.30 m
- OR

)2 = 2930

- y = P / ρg
- = 2930 / (990 × 9.81)
- (C1)
- = 0.30 m
- (A1)

Solution 2

(b)(iv) Worked steps

Think about what moving the person does to the cylinder's share of the load.

- At $x = 0$ the person stands over the hinge and adds no moment, but the beam's own weight still loads the cylinder — so the depth starts at a **non-zero** value.
- Moving the person towards B increases their moment about A, so the cylinder must push harder, so the upthrust and hence the depth **increase**.
- Draw a line starting above the origin and rising all the way to 6.0 m — positive gradient throughout.

Solution 2

Mark scheme

- line with a non-zero value of depth at distance $= 0$
- A line from distance $= 0$ to distance $= 6.0\,\mathrm{m}$ with a gradient that is always positive
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