Past-paper walk-through

Turning effects of forces ▪ 4.1

eXercise

Questions in this set

- 9702/11 N25 Q14 ▪ 1 mark
- 9702/12 N25 Q13 ▪ 1 mark
- 9702/14 N25 Q14 ▪ 1 mark
- 9702/24 N25 Q2 ▪ 10 marks
- 9702/11 J25 Q13 ▪ 1 mark
- 9702/12 J25 Q15 ▪ 1 mark
- 9702/12 J25 Q17 ▪ 1 mark
- 9702/13 J25 Q12 ▪ 1 mark
- 9702/14 J25 Q10 ▪ 1 mark
- 9702/22 J25 Q2 ▪ 8 marks

Questions in this set

- 9702/23 J25 Q2 ▪ 9 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 14

9702/11 N25 ▪ Q14 ▪ 1 mark

Two forces, each of magnitude F, act in opposite directions on a rod.
Each force acts on the rod at a distance d from the pivot P.
What is the torque of this couple about P? **[1]**

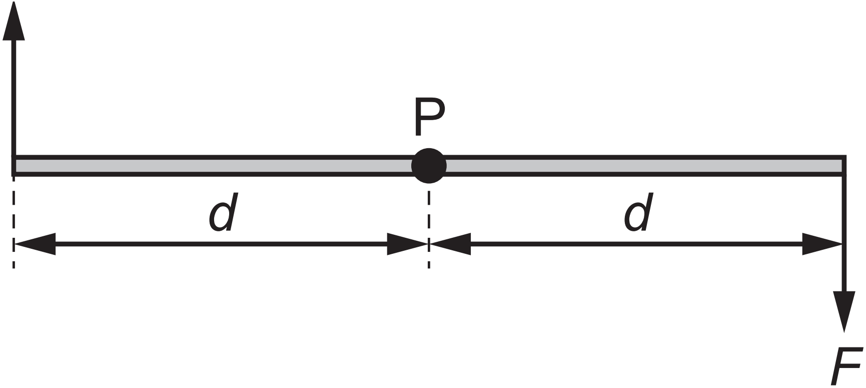
A 0

B $F \times d$

C $2F \times d$

D $2F \times 2d$

Question 14



Solution 14

A 0

B $F \times d$

C $2F \times d$ ✓

D $2F \times 2d$

Why

- Each force produces a moment Fd about P, and both turn the rod the same way.
- So they add rather than cancel: torque $= Fd + Fd = 2Fd$.
- Equivalently, it is one force times the $2d$ separation between their lines of action.

Question 13

9702/12 N25 ▪ Q13 ▪ 1 mark

Which diagram shows a couple? **[1]**

A Diagram A

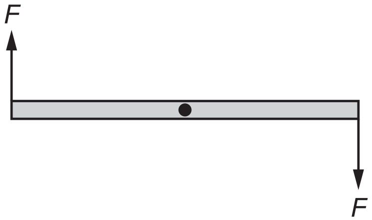
B Diagram B

C Diagram C

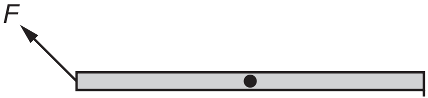
D Diagram D

Question 13

A



C



Solution 13

- **A** Diagram A ✓
- **B** Diagram B
- **C** Diagram C
- **D** Diagram D

Why

- A couple needs two forces equal in magnitude, opposite in direction, and on different lines of action.
- Equal and opposite gives zero resultant force; separate lines of action give a turning effect.
- Two opposite forces along the *same* line would simply cancel with no rotation.

Question 14

9702/14 N25 ▪ Q14 ▪ 1 mark

A couple is applied to a tap, as shown.

What is the torque of the couple? **[1]**

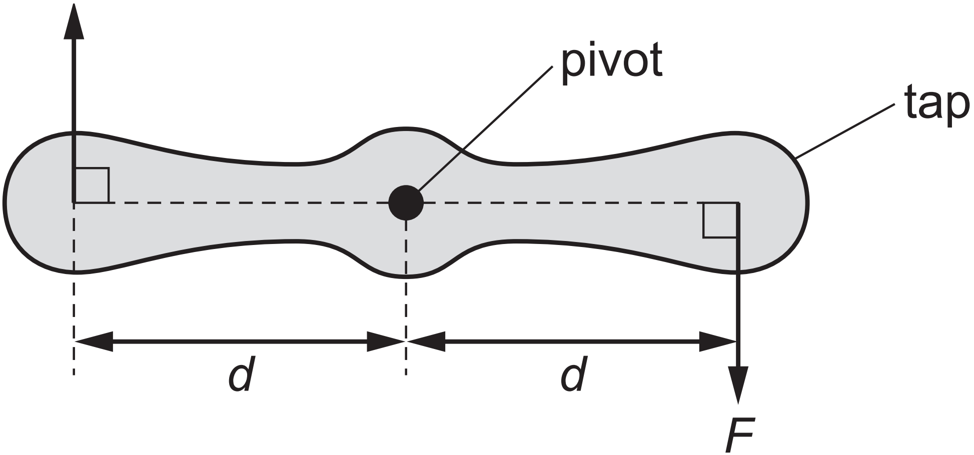
A $\frac{Fd}{2}$

B Fd

C $2Fd$

D $4Fd$

Question 14



Solution 14

- **A** $\frac{Fd}{2}$
- **B** Fd
- **C** $2Fd$ ✓
- **D** $4Fd$

Why

- Each force acts a distance d from the pivot, so each gives a moment Fd.
- Both turn the tap the same way, so the torque is $Fd + Fd = 2Fd$.
- Equivalently, one force times the $2d$ separation between them.

Question 2

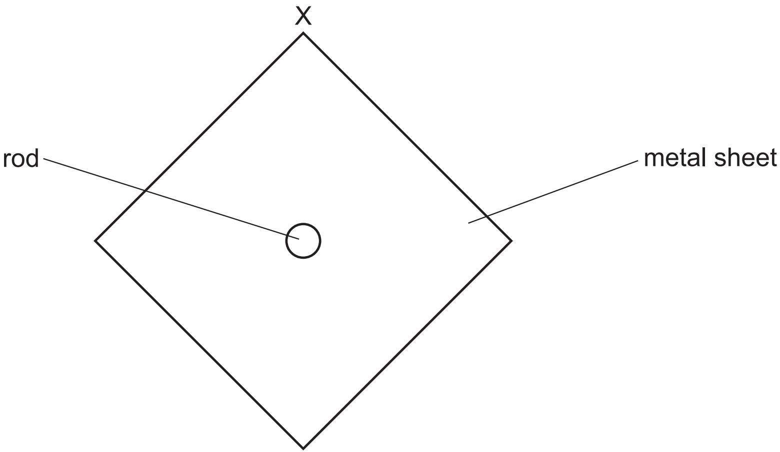
9702/24 N25 ▪ Q2 ▪ 10 marks

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.

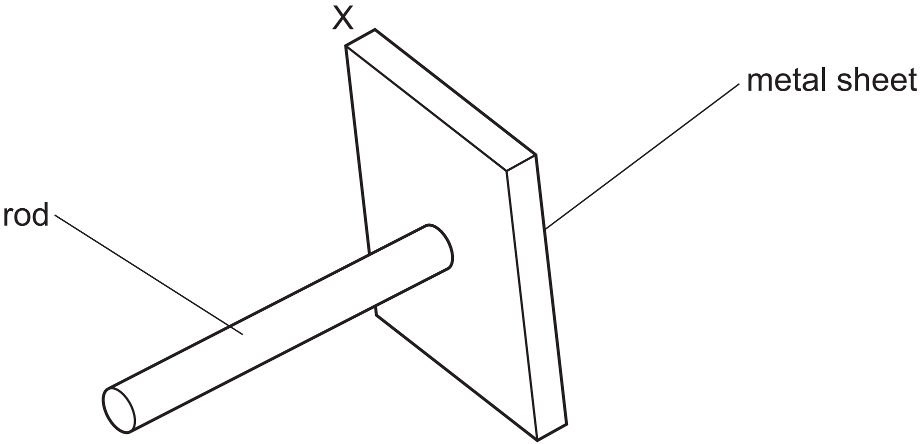
The rod has negligible mass. The mass of the metal sheet is 2.8 kg. The rod is supported so that the rod is horizontal and the metal sheet is vertical.

(a) Define the torque of a couple. **[2]**

Question 2



Question 2



Question 2

9702/24 N25 ▪ Q2 ▪ 10 marks

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.

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.

(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.

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

Question 2

9702/24 N25 ▪ Q2 ▪ 10 marks

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.

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.

(c)(i) Explain whether the torque applied to the rod to hold the sheet in equilibrium is clockwise or anticlockwise. **[1]**

(c)(ii) Show that the centre of gravity of the sheet has a horizontal displacement of 0.12 m from the rod. **[1]**

Question 2

9702/24 N25 ▪ Q2 ▪ 10 marks

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.

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.

(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]**

Question 2

9702/24 N25 ▪ Q2 ▪ 10 marks

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.

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.

(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]**

Solution 2

(a)

Mark scheme

- product of force and distance **M1**
- perpendicular distance between the (line of action of the two) forces **A1**

Solution 2

(b)

Worked steps

A freely hanging body settles with its centre of gravity **directly below** the pivot.

- Corner X is vertically above the rod, so the centre of gravity lies somewhere on the vertical line running down from the rod.
- Draw that vertical line, from the centre of the sheet down to the bottom corner — every point on it is a possible position.

Mark scheme

- straight vertical line drawn from centre to bottom corner B1

Solution 2

(c)(i)

Mark scheme

- centre of gravity is to the right of the rod so torque is anticlockwise or moment of weight of sheet about rod is clockwise so torque is anticlockwise **B1**

Solution 2

(c)(ii) Worked steps

The torque you apply balances the moment of the sheet's weight about the rod.

- Moment of weight $= W \times x = mgx$, and this equals the applied torque.
- $x = \dfrac{\tau}{mg} = \dfrac{3.3}{2.8 \times 9.81}$
- $x = 0.12$ m, as required.

Solution 2

Mark scheme

- (horizontal displacement) $= 3.3 \ / \ (2.8 \times 9.81) = 0.12$ (m) **A1**

Solution 2

(d) Worked steps

Turn the density into the side length through the volume.

- $\rho = \dfrac{m}{V}$, so $V = \dfrac{m}{\rho} = \dfrac{2.8}{3000} = 9.33 \times 10^{-4}$ m^3.
- The sheet is a square slab: $V = L^2 t$, with $t = 4.0$ mm $= 4.0 \times 10^{-3}$ m.
- $L = \sqrt{\dfrac{V}{t}} = \sqrt{\dfrac{9.33 \times 10^{-4}}{4.0 \times 10^{-3}}}$
- $L = 0.48$ m, as required.

Mark scheme

Solution 2

- $\rho = \text{m} / \text{V}$ C1
- $\text{V} = 4.0 \times 10–3 \times$ (side length)2 C1
- side length $=$
- (
-)
- 2.8 / 3000
- 0.0040
- 0.48m
-
- $\times$

Solution 2

- $=$
- **A1**

Solution 2

(e) Worked steps

Combine the two facts you have proved: the direction from part (b) and the distance from part (c)(ii).

- The sheet hangs with X above the rod, so the diagonal through X is vertical: the line of possible positions runs at 45° to the sides of the square.
- The centre of gravity sits 0.12 m horizontally from the rod, and the half-width of the sheet is $0.48/2 = 0.24$ m — so it is **half-way** between the rod and the right-hand edge.
- Mark Y at that point on the diagonal and label it.

Solution 2

Mark scheme

- point lies on a straight line at $45°$ to the horizontal from the bottom-right corner to the edge of the rod **B1**
- point lies on a vertical line half-way between rod and right-hand edge **B1**

Question 13

9702/11 J25 ▪ Q13 ▪ 1 mark

13 Which row describes a pair of forces that forms a couple?

	direction of the forces	magnitude of the forces
A	opposite	different
B	opposite	equal
C	same	different
D	same	equal

Question 13

D	same	equal

Solution 13

Answer: **B**

Why

- A couple is two forces equal in magnitude, opposite in direction, and not along the same line.
- Equal and opposite means the resultant force is zero, so there is no acceleration.
- Because they are not in line, they still produce a turning effect.

Question 15

9702/12 J25 ▪ Q15 ▪ 1 mark

A square shop sign of uniform density has mass 2.4 kg and sides of length 0.86 m.
The sign is supported by a hinge along its top edge.
There is friction in the hinge so that the sign hangs from it in equilibrium at an angle of $15°$ to the vertical, as shown.
What is the moment about the hinge of the weight of the sign? **[1]**

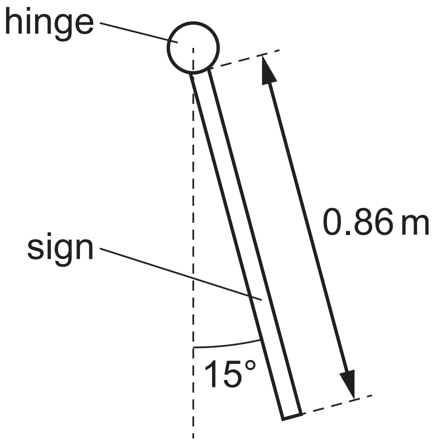
A 2.6 N m

B 4.0 N m

C 5.2 N m

D 9.8 N m

Question 15



Solution 15

- **A** 2.6 N m ✓
- **B** 4.0 N m
- **C** 5.2 N m
- **D** 9.8 N m

Why

- The sign is uniform, so its weight acts at the centre, $0.86/2 = 0.43$ m from the hinge.
- A moment needs the *horizontal* offset of that point: $0.43 \sin 15^\circ = 0.111$ m.
- $M = (2.4 \times 9.81) \times 0.111 = 2.6$ N m; C uses the whole side and D uses $\cos$.

Question 17

9702/12 J25 ▪ Q17 ▪ 1 mark

The diagram shows a couple.

How is the torque of the couple calculated? **[1]**

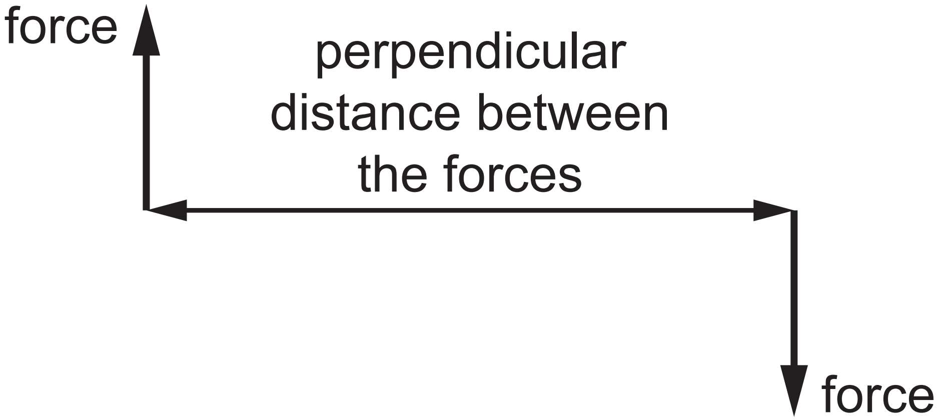
A $\frac{1}{2}$ $\times$ perpendicular distance between the forces $\times$ magnitude of one of the forces

B perpendicular distance between the forces $\times$ magnitude of one of the forces

C perpendicular distance between the forces $\times$ magnitude of the sum of the forces

D 2 $\times$ perpendicular distance between the forces $\times$ magnitude of one of the forces

Question 17



Solution 17

A $\frac{1}{2} \times$ perpendicular distance between the forces $\times$ magnitude of one of the forces

B perpendicular distance between the forces $\times$ magnitude of one of the forces ✓

C perpendicular distance between the forces $\times$ magnitude of the sum of the forces

D $2 \times$ perpendicular distance between the forces $\times$ magnitude of one of the forces

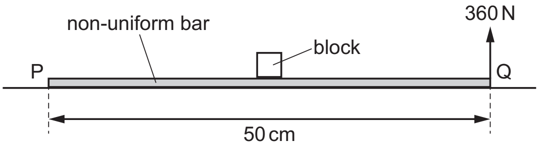
Why

- The torque of a couple is one force multiplied by the perpendicular distance between them.
- Each force contributes $F \times d/2$ about the centre, and the two add to Fd.
- So there is no extra factor of 2 (D) and no halving (A).

Question 12

9702/13 J25 ▪ Q12 ▪ 1 mark

12 A non-uniform bar PQ has length 50 cm and weight 200 N.



A block of weight 400 N is attached to the top of the bar at its centre. The bar rests on horizontal ground.

A vertical force of 360 N is now exerted upwards on the bar at end Q and is just sufficient to lift end Q from the ground.

What is the distance from the centre of gravity of the bar to end P?

Question 12

A 0.050 m **B** 0.10 m **C** 0.25 m **D** 0.40 m

Solution 12

Answer: **D**

Why

- Take moments about P, the end still touching the ground.
- $360 \times 0.50 = 200 \times d + 400 \times 0.25$, so $180 = 200d + 100$.
- $d = 80/200 = 0.40$ m from P.

Question 10

9702/14 J25 ▪ Q10 ▪ 1 mark

10 Which statement about a couple is correct?

A It acts to produce both translational motion and rotation.

B It acts to produce rotation only.

C It acts to produce translational motion only.

D It acts to produce neither rotation nor translational motion.

Solution 10

Answer: **B**

Why

- The two forces of a couple are equal and opposite, so the resultant force is zero.
- With no resultant force the centre of mass does not accelerate – there is no translation.
- They act along different lines, so they do turn the object: rotation only.

Question 2

9702/22 J25 ▪ Q2 ▪ 8 marks

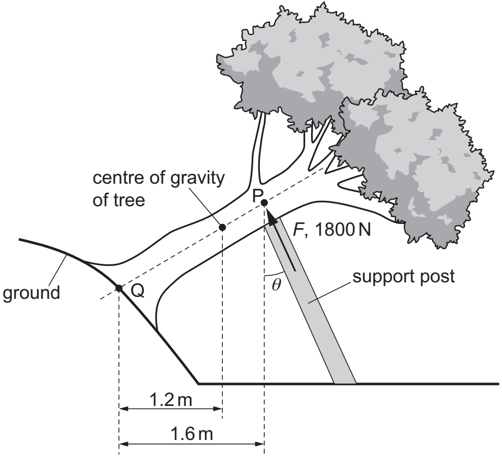
(a) Define the moment of a force about a point. **[1]**

(b)(i) By taking moments about point Q, show that θ is 25°. **[3]**

(b)(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. **[2]**

(b)(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. **[2]**

Question 2



centre of gravity
of tree
P
F, 1800 N
support post
ground
Q
θ
1.2 m
1.6 m

Solution 2

(a)

Mark scheme

- force $\times$ perpendicular distance (of line of action of force to / from the point) **B1**

Solution 2

(b)(i) Worked steps

"Show that" a whole angle: take moments about Q, where the unknown reaction acts and so contributes nothing.

- Moment of the tree's weight $= 1.2 \times 270 \times 9.81 = 3180$ N m (clockwise).
- The post pushes with 1800 N; its perpendicular distance from Q along the leaning trunk is $\dfrac{1.6}{\cos\theta}$, so its moment is $1800 \times \dfrac{1.6}{\cos\theta}$.
- In equilibrium the two are equal: $1.2 \times 270 \times 9.81 = \dfrac{1800 \times 1.6}{\cos\theta}$
- $\cos\theta = \dfrac{2880}{3180} = 0.906$, so $\theta = 25^\circ$, as required.

Solution 2

Mark scheme

- (moment due to weight =) $1.2 \times 270 \times 9.81$ **B1**
- (moment due to post =) $1800 \times (1.6 / \cos\theta)$ **B1**
- $1.2 \times 270 \times 9.81 = 1800 \times (1.6 / \cos\theta)$ so $\theta = 25(°)$ or
- $1.2 \times 270 \times 9.81 - 1800 \times (1.6 / \cos\theta) = 0$ so $\theta = 25(°)$ **B1**

Solution 2

(b)(ii) Worked steps

Three forces in equilibrium close into a triangle, drawn tip to tail.

- Start from the weight vector already drawn to scale.
- Add *F* (the post's push) at 25° anticlockwise from the vertical, label it.
- Close the triangle with *R* (the ground's reaction), which comes out about 37° clockwise from the vertical. Label it.
- A **closed** triangle is the point: it is what "resultant force is zero" looks like.

Solution 2

Mark scheme

- A closed tip-to-tail vector triangle **M1**
- vector labelled F at an angle of $25° \pm 3°$ anticlockwise from vertical and vector labelled R at an angle of $37° \pm 3°$ clockwise from vertical **A1**

Solution 2

(b)(iii) Worked steps

- Pressure is force per unit area: $p = \dfrac{F}{A}$, so $A = \dfrac{F}{p}$.
- Use the force the tree exerts on the post, 1800 N, and convert the pressure: 150 kPa $= 150 \times 10^3$ Pa.
- $A = \dfrac{1800}{150 \times 10^3}$
- $A = 0.012$ m^2

Solution 2

Mark scheme

- A = F / p
- = 1800 / (150 × 103) **C1**
- = 0.012 m2 **A1**

Question 2

9702/23 J25 ▪ Q2 ▪ 9 marks

2 (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. C beam pivot 9.0 m 3.0 m B A 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] , ,

Question 2

(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. C beam wire pivot B ground 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 $1.8 \times 10{-}3$ m and has a strain of $1.2 \times 10{-}3$.
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]

, ,

(a) Define the moment of a force about a pivot. **[1]**

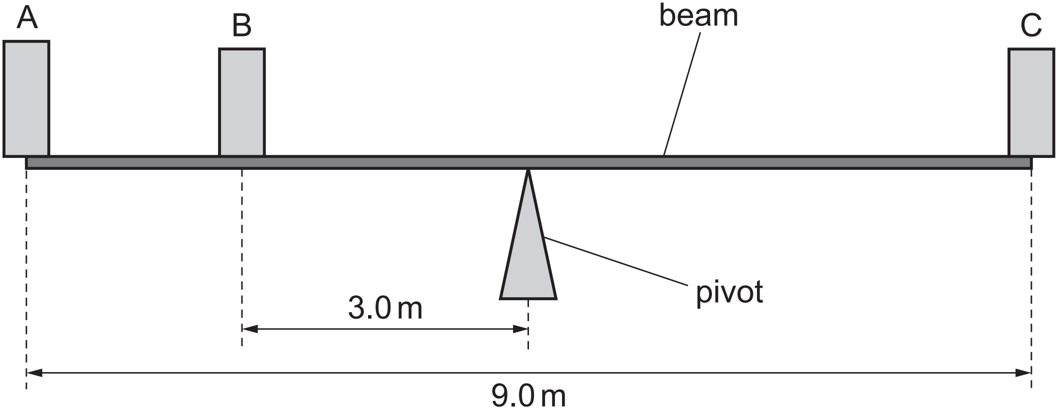
Question 2

(b)(i) The beam is uniform, of length 9.0 m and mass 150 kg, with the pivot at its midpoint. Object A has mass 90 kg and is at one end of the beam; object B has mass *m* and is 3.0 m from the pivot on the other side. Calculate the mass *m*. **[3]**

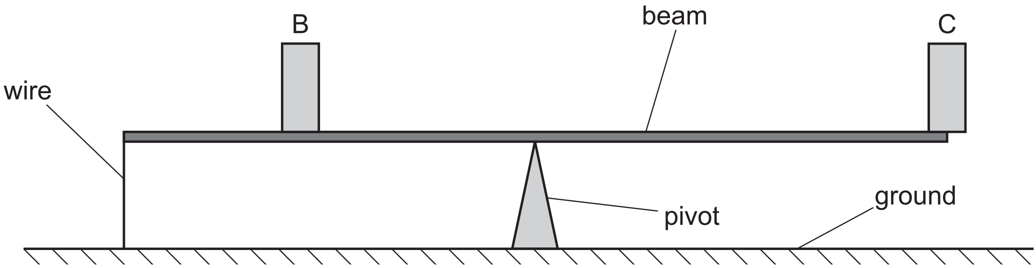
(b)(ii) Object C hangs from a steel wire of diameter 1.8 mm, which extends by 1.2×10^{-3} of its length. Calculate the Young modulus of the steel. **[3]**

(b)(iii) State and explain the effect on the strain in the wire if object B is moved closer to the pivot. **[2]**

Question 2



Question 2



Solution 2

(a)

Mark scheme

- force $\times$ perpendicular distance (of line of action of force to / from the point)

Solution 2

(b)(i) Worked steps

Take moments about the pivot. The beam is uniform and the pivot is at its midpoint, so the beam's own weight has no moment about it.

- Clockwise moment (from the beam's loaded side): $150 \times 9.81 \times 4.5$
- Anticlockwise moments: $90 \times 9.81 \times 4.5$ from A, plus $m \times 9.81 \times 3.0$ from B.
- $150 \times 9.81 \times 4.5 = (90 \times 9.81 \times 4.5) + (3.0 \times 9.81 \times m)$
- $m = 90$ kg

Solution 2

Mark scheme

- $150 \times 9.81 \times 4.5$ or $90 \times 9.81 \times 4.5$ or $3.0 \times 9.81 \times m$
- $(150 \times 9.81 \times 4.5) = (90 \times 9.81 \times 4.5) + (3.0 \times 9.81 \times m)$
- $m = 90\,\text{kg}$

Solution 2

(b)(ii) Worked steps

- Young modulus $E = \dfrac{\sigma}{\varepsilon} = \dfrac{F/A}{\varepsilon}$.
- Cross-sectional area from the **diameter**: $A = \pi \left(\dfrac{1.8 \times 10^{-3}}{2} \right)^2 = 2.5 \times 10^{-6}\ \mathrm{m}^2$.
- Force is the weight it carries: $F = 90 \times 9.81 = 883$ N.
- $E = \dfrac{883/2.5 \times 10^{-6}}{1.2 \times 10^{-3}}$
- $E = 2.9 \times 10^{11}$ Pa

Solution 2

Mark scheme

- Young modulus $= \sigma / \varepsilon$ or F / Aε or FL / Ax
- Area of wire $= \pi \times (1.8 \times 10–3 / 2)2$
- $= 2.5 \times 10–6$
- So Young modulus $= ((90 \times 9.81) / \pi \times (9.0\times10–4)2\ ) / 1.2\times10–3$
- $= 2.9 \times1011$ Pa

Solution 2

(b)(iii)

Worked steps

- Moving B towards the pivot shortens its distance, so **its moment falls**.
- To keep the beam in equilibrium the wire must supply more moment, so the **force in the wire rises**.
- E and A are unchanged, and $\varepsilon = \dfrac{F}{AE}$, so the **strain increases**.

Mark scheme

- Moment provided by B will decrease / moment due to wire will increase
- So force acting on wire will increase (Young's modulus and area remain constant) and the strain will increase