3.3 Mechanics: Moments: 2-hour Pack

EDEXCEL 9MA0 · Calculator allowed · about 120 minutes

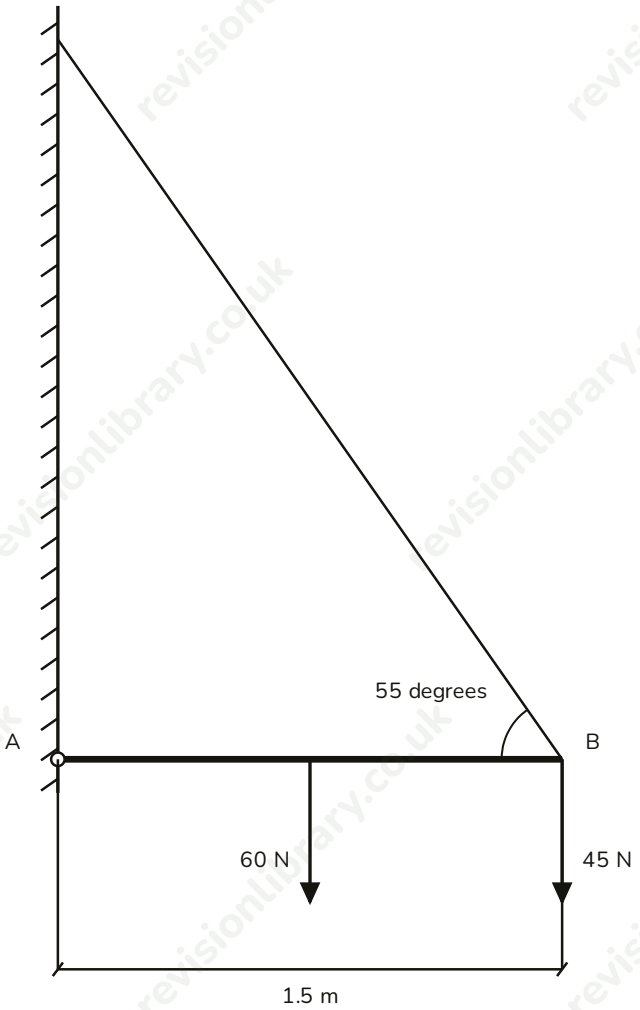
Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A uniform rod AB has length 1.5 m and weight 60 N. The rod is smoothly hinged to a vertical wall at A and held in a horizontal position by a light inextensible string attached to the rod at B, making an angle of 55 degrees with the rod. A shop sign of weight 45 N hangs from a hook at B.

Diagram NOT accurately drawn



(a) By taking moments about A, find the tension in the string, giving your answer to 3 significant figures. **(4)**

(b) Find the magnitude of the vertical component of the force exerted on the rod by the hinge at A. **(3)**

(c) Given additionally that the horizontal component of the hinge force has magnitude 52.5 N, find the angle that the resultant hinge force makes with the rod. **(3)**

(Total for Question 1 is 10 marks)

© Revision Library | revisionlibrary.co.uk

2 A uniform beam AB has length 2 m and weight 50 N. The beam rests horizontally on a pivot at a point M, 0.6 m from A (M is not the midpoint of the beam). A vertical force of magnitude P is applied downward at A, and a counterweight of weight 80 N hangs from B. The beam remains horizontal and in equilibrium.

(a) Explain why the weight of the beam does contribute a moment about M in this situation, unlike in a case where the pivot is at the beam's midpoint. **(1)**

(b) By taking moments about M, find P. **(4)**

(c) Find the reaction at the pivot M. **(2)**

(d) The counterweight is repositioned so that P can be reduced to 150 N, with the beam's weight and the pivot position unchanged. Find the new distance of the counterweight from the pivot M. **(3)**

(Total for Question 2 is 10 marks)

---

3 A non-uniform curtain pole AB has length 2.4 m. It is suspended horizontally by two vertical wires, one attached at A and the other attached at a point 1.6 m from A. The centre of mass of the pole is 1.0 m from A. The tension in the wire at A is 36 N; let T newtons be the tension in the other wire.

(a) By resolving vertically and taking moments about A, form two equations connecting the weight of the pole, W, and T, and hence find the values of W and T. **(5)**

(b) Verify your answer to part (a) by taking moments about the point where the second wire is attached. **(2)**

(c) State, giving a reason, whether the tension in the wire at A would be larger or smaller than 36 N if the pole were uniform instead of non-uniform (with the same length, weight and wire positions). **(2)**

(Total for Question 3 is 9 marks)

---

4 A mechanic applies a force of 70 N to the end of a wrench of length 0.3 m, at an angle of 55 degrees to the wrench, to loosen a bolt modelled as a fixed pivot at the other end of the wrench. Find the moment of the force about the pivot, giving your answer to 3 significant figures.

(Total for Question 4 is 3 marks)

© Revision Library | revisionlibrary.co.uk

5 A non-uniform beam AB has length 9 m and weight 240 N, acting at a point 4 m from A. The beam rests horizontally in equilibrium on two smooth supports, one at C, 1 m from A, and one at D, 7 m from A. By taking moments about C, find the reaction at D.

(Total for Question 5 is 3 marks)

---

6 A uniform ladder AB has length 5 m and weight 200 N. The ladder rests with end A on rough horizontal ground and end B against a smooth vertical wall, making an angle of 68 degrees with the horizontal ground. The ladder is on the point of slipping.

(a) State the four forces acting on the ladder, including the direction in which each acts. **(4)**

(b) By resolving vertically, find the normal reaction at A, N_A. **(2)**

(c) By taking moments about A, find the normal reaction at the wall, N_B, giving your answer to 3 significant figures. **(4)**

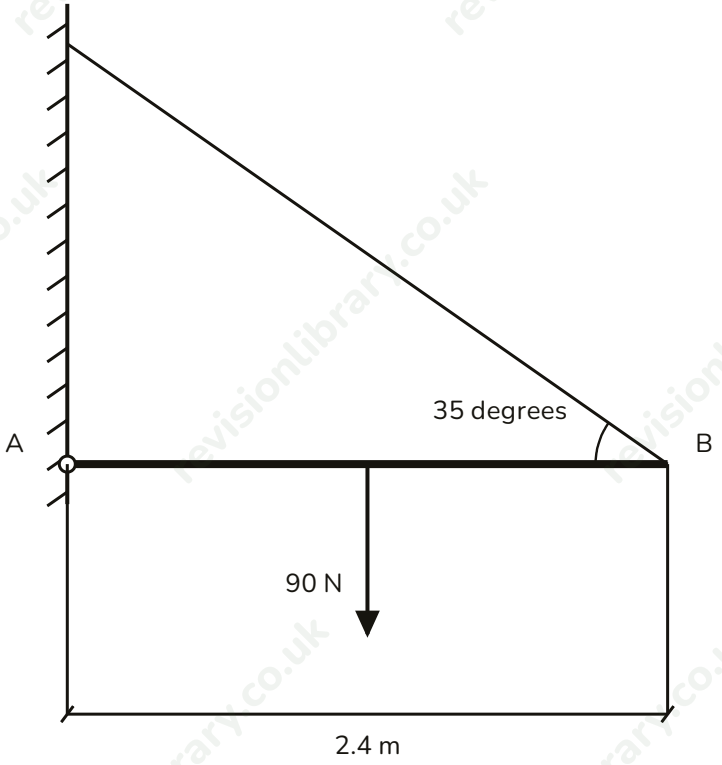
(d) Given that the ladder is on the point of slipping, find the coefficient of friction between the ladder and the ground, giving your answer to 3 significant figures. **(4)**

(Total for Question 6 is 14 marks)

© Revision Library | revisionlibrary.co.uk

7 A uniform rod AB has length 2.4 m and weight 90 N. The rod is smoothly hinged to a vertical wall at A and held in a horizontal position by a light inextensible string attached to the rod at B and to a point on the wall above A, the string making an angle of 35 degrees with the rod.

Diagram NOT accurately drawn



(a) By taking moments about A, find the tension in the string, giving your answer to 3 significant figures. **(4)**

(b) Find the magnitude of the horizontal and vertical components of the force exerted on the rod by the hinge at A, stating the direction in which each acts. **(5)**

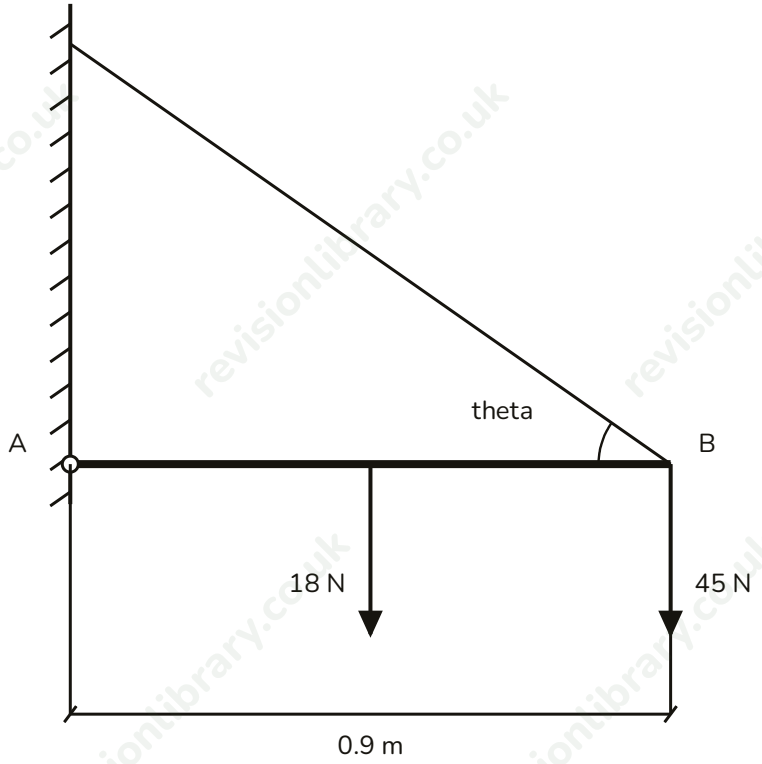
(c) Hence find the magnitude and direction of the resultant force exerted by the hinge on the rod. **(3)**

(Total for Question 7 is 12 marks)

© Revision Library | revisionlibrary.co.uk

8 A shop's hanging flower-basket bracket consists of a uniform rod AB of length 0.9 m and weight 18 N, smoothly hinged to the shop wall at A. The rod is held horizontal by a light string attached to the rod at B and to a point on the wall above A, the string making an angle θ with the rod. A basket of weight 45 N hangs from B. The string is rated to withstand a maximum tension of 150 N before it risks breaking.

Diagram NOT accurately drawn



(a) By taking moments about A, show that the tension in the string is given by $T = 54/\sin(\theta)$ (in newtons). **(4)**

(b) Given that the string must not exceed its rated maximum tension of 150 N, find the minimum angle θ, to 1 decimal place, at which the string may be attached. **(3)**

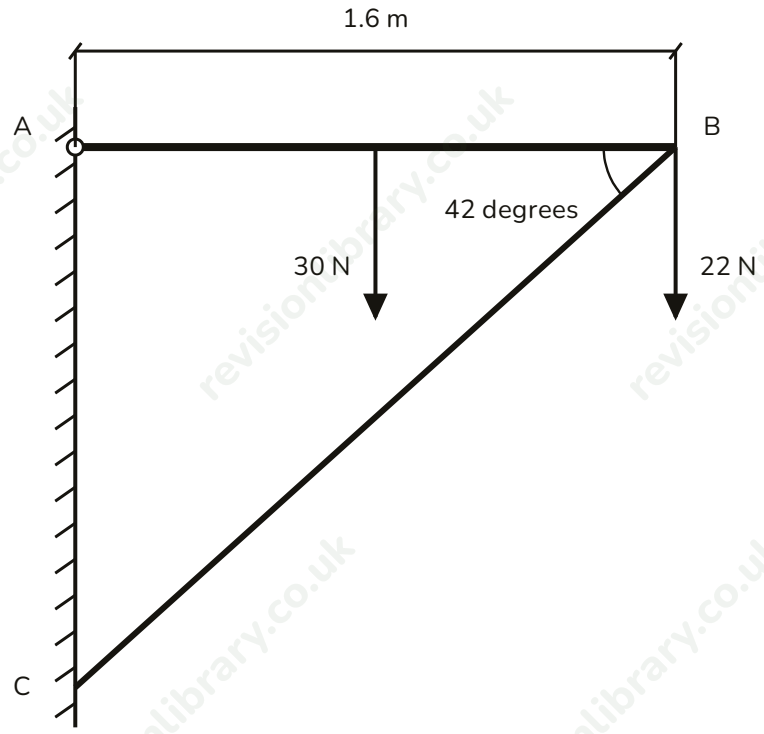
(c) The basket is replaced with a heavier one of weight 70 N (the rod's weight is unchanged). Find the new minimum safe angle θ, to 1 decimal place. **(3)**

(Total for Question 8 is 10 marks)

© Revision Library | revisionlibrary.co.uk

9 A shop awning arm AB has length 1.6 m and weight 30 N. It is smoothly hinged to the shop wall at A and held horizontal by a rigid strut CB, where C is a fixed point on the wall vertically below A, the strut making an angle of 42 degrees with the arm. The strut exerts a force of magnitude S on the arm at B, directed along CB. A hanging sign of weight 22 N is attached to the arm at B.

Diagram NOT accurately drawn



(a) By taking moments about A, find the force S in the strut, giving your answer to 3 significant figures. **(4)**

(b) Find the magnitude of the horizontal and vertical components of the force exerted on the arm by the hinge at A. **(4)**

(c) Hence find the magnitude of the resultant force exerted by the hinge on the arm, and the angle this resultant makes with the arm, both to 3 significant figures. **(3)**

(Total for Question 9 is 11 marks)

© Revision Library | revisionlibrary.co.uk

10 A garden centre displays a uniform wooden potting bench, modelled as a rigid plank AB of length 2.4 m and weight 180 N, resting on two smooth support posts, one at C, 0.3 m from A, and one at D, 1.8 m from A. A decorative stone urn of weight 40 N sits at end A. A sack of compost of weight w newtons is placed at end B. The bench remains horizontal and rests only on the two posts; it will tip about D (lifting off the post at C) if w becomes too large.

(a) Explain briefly why, as w increases, the bench would tip about D rather than about C. **(1)**

(b) By taking moments about C, show that $R_D = 100 + 1.4w$ (in newtons), where R_D is the reaction at post D. **(4)**

(c) Find, in terms of w, an expression for R_C. **(2)**

(d) Find the maximum value of w for which the bench remains in equilibrium without tipping. **(3)**

(Total for Question 10 is 10 marks)

---

11 A uniform rod AC of length 2L and weight W is smoothly hinged to a vertical wall at A. The rod is held horizontal by a light inextensible string attached to the rod at C and to a point on the wall above A, the string making an angle θ with the rod.

(a) By taking moments about A, show that the tension in the string is $T = W / (2 \sin(\theta))$. **(4)**

(b) Show that the magnitude of the force exerted on the rod by the hinge at A is also equal to T. **(5)**

(c) Given that θ = 40 degrees and W = 150 N, find the magnitude of the force exerted by the hinge on the rod, giving your answer to 3 significant figures. **(3)**

(Total for Question 11 is 12 marks)

© Revision Library | revisionlibrary.co.uk

Mark scheme · 3.3 Mechanics: Moments: 2-hour Pack

Question 1

(a) moments equation about A with all three terms: T sin(55 degrees) x 1.5 = 60 x 0.75 + 45 x 1.5 oe **M1**

(a) correct unsimplified equation **A1**

(a) rearranges to make T the subject **dM1**

(a) awrt 91.6 N **A1**

(a) Answer: 91.6 N (3 s.f.)

(b) vertical equilibrium: Y + T sin(55 degrees) = 60 + 45 oe **M1**

(b) substitutes T sin(55 degrees) = 75 (exact, from part a) **A1**

(b) Y = 30 N cao **A1**

(b) Answer: 30 N

(c) tan(angle) = Y / X, using their Y and the given 52.5 N **M1**

(c) tan(angle) = 30 / 52.5 oe **A1**

(c) awrt 29.7 degrees **A1**

(c) Answer: 29.7 degrees (3 s.f.)

Question 2

(a) because M is not the midpoint (centre of mass) of the beam, so the weight's line of action does not pass through M, giving a nonzero perpendicular distance and hence a nonzero moment about M **B1**

(a) Answer: The weight's line of action does not pass through M, since M is not the centre of mass, so it has a nonzero moment about M

(b) identifies the distance of each force from M (P at 0.6 m from M; the beam's weight at 0.4 m from M; the counterweight at 1.4 m from M) **M1**

(b) correct unsimplified equation: P x 0.6 = 50 x 0.4 + 80 x 1.4 oe **A1**

(b) rearranges to make P the subject **dM1**

(b) P = 220 N cao **A1**

(b) Answer: P = 220 N

(c) R = P + 50 + 80 (vertical equilibrium), ft their P **M1**

(c) R = 350 N cao **A1**

(c) Answer: 350 N

(d) new moments equation: 150 x 0.6 = 50 x 0.4 + 80 x d **M1**

(d) 90 = 20 + 80d oe **A1**

(d) d = 0.875 m cao **A1**

(d) Answer: 0.875 m from M

Question 3

(a) vertical equilibrium equation formed: 36 + T = W oe **M1**

(a) moments equation about A formed: T x 1.6 = W x 1.0 oe **M1**

(a) eliminates one variable (e.g. substitutes W = 36 + T) and solves **dM1**

(a) T = 60 N cao **A1**

(a) W = 96 N cao **A1**

(a) Answer: W = 96 N, T = 60 N

(b) alternative moments equation formed: 36 x 1.6 = W x (1.6 - 1.0), using their W **M1**

(b) both sides equal 57.6 (N m), confirming the values found in part (a) **A1**

(b) Answer: Consistent: both sides equal 57.6 N m

(c) correct statement: smaller **B1**

(c) valid reason: a uniform pole's centre of mass would be at its midpoint (1.2 m from A), further from A than the given 1.0 m, so more weight is supported by the wire nearer the centre of mass, leaving less tension needed at A **B1**

(c) Answer: Smaller than 36 N

Question 4

perpendicular distance = 0.3 sin55 **M1**

moment = 70 x (0.3 sin55) **M1**

awrt 17.2 N m **A1**

Answer: 17.2 N m (3 s.f.)

Question 5

identify distances from C: the weight acts 3 m from C; D is 6 m from C **M1**

take moments about C: R_D x 6 = 240 x 3 **M1**

120 N cao **A1**

Answer: 120 N

© Revision Library | revisionlibrary.co.uk

Question 6

(a) weight, 200 N, acting vertically downward at the midpoint of the ladder **B1**

(a) normal reaction at A, acting vertically upward **B1**

(a) friction at A, acting horizontally, directed toward the wall (to prevent the foot sliding away) **B1**

(a) normal reaction at B, acting horizontally, directed away from the wall **B1**

(a) Answer: Weight (down, midpoint); N_A (up, at A); friction (horizontal, toward wall, at A); N_B (horizontal, away from wall, at B)

(b) vertical equilibrium: $N_A = 200$ (no other vertical forces act) **M1**

(b) $N_A = 200$ N cao **A1**

(b) Answer: 200 N

(c) moments equation about A: $N_B \times 5 \sin(68 \text{ degrees}) = 200 \times 2.5 \cos(68 \text{ degrees})$ oe **M1**

(c) correct unsimplified equation **A1**

(c) rearranges to make N_B the subject, e.g. $N_B = 100 / \tan(68 \text{ degrees})$ **dM1**

(c) awrt 40.4 N **A1**

(c) Answer: 40.4 N (3 s.f.)

(d) horizontal equilibrium: $F = N_B$, ft their N_B **M1**

(d) F = awrt 40.4 N (ft) **A1**

(d) limiting friction: $\mu = F / N_A$, ft their F and N_A **M1**

(d) awrt 0.202 **A1**

(d) Answer: $\mu = 0.202$ (3 s.f.)

Question 7

(a) moments equation about A: $T \sin(35 \text{ degrees}) \times 2.4 = 90 \times 1.2$ oe **M1**

(a) correct unsimplified equation **A1**

(a) rearranges to make T the subject **dM1**

(a) awrt 78.5 N **A1**

(a) Answer: 78.5 N (3 s.f.)

(b) horizontal equilibrium: $X = T \cos(35 \text{ degrees})$, ft their T **M1**

(b) awrt 64.3 N, directed away from the wall **A1**

(b) vertical equilibrium: $Y = 90 - T \sin(35 \text{ degrees})$ oe, ft their T **M1**

(b) Y = 45 N cao, directed upward **A1**

(b) both directions correctly stated (away from wall / upward) **B1**

(b) Answer: Horizontal: 64.3 N (away from wall); Vertical: 45 N (upward)

(c) magnitude = $\sqrt{X^2 + Y^2}$, using their X and Y **M1**

(c) awrt 78.5 N (ft) **A1**

(c) direction: 35.0 degrees above the horizontal (ft), e.g. from tan(angle) = Y/X **A1**

(c) Answer: 78.5 N, at 35.0 degrees above the horizontal

Question 8

(a) moments equation about A: $T \sin(\theta) \times 0.9 = 18 \times 0.45 + 45 \times 0.9$ oe **M1**

(a) correct unsimplified equation **A1**

(a) divides by 0.9 and rearranges to make T the subject **dM1**

(a) $T = 54/\sin(\theta)$ cso **A1**

(a) Answer: $T = 54/\sin(\theta)$

(b) sets $T \leq 150$ and forms the inequality $54/\sin(\theta) \leq 150$ **M1**

(b) $\sin(\theta) \geq 0.36$ oe **A1**

(b) $\theta \geq 21.1$ degrees (1 d.p.) cao **A1**

(b) Answer: 21.1 degrees (1 d.p.)

(c) new constant found: $T \sin(\theta) \times 0.9 = 18 \times 0.45 + 70 \times 0.9$, i.e. $T \sin(\theta) = 79$ **M1**

(c) $\sin(\theta) \geq 79/150 = 0.5267$ oe **A1**

(c) $\theta \geq 31.8$ degrees (1 d.p.) cao **A1**

(c) Answer: 31.8 degrees (1 d.p.)

Question 9

(a) moments equation about A with all three terms: $S \sin(42 \text{ degrees}) \times 1.6 = 30 \times 0.8 + 22 \times 1.6$ oe **M1**

(a) correct unsimplified equation **A1**

(a) rearranges to make S the subject **dM1**

(a) awrt 55.3 N **A1**

(a) Answer: 55.3 N (3 s.f.)

(b) vertical equilibrium: $Y + S \sin(42 \text{ degrees}) = 30 + 22$ oe **M1**

(b) substitutes $S \sin(42 \text{ degrees}) = 37$ (exact, from part a) to get Y = 15 N cao **A1**

(b) horizontal equilibrium: $X = S \cos(42 \text{ degrees})$, ft their S **M1**

(b) awrt 41.1 N **A1**

(b) Answer: Vertical: 15 N; Horizontal: 41.1 N (3 s.f.)

(c) magnitude = $\sqrt{X^2 + Y^2}$, using their X and Y **M1**

(c) awrt 43.7 N (ft) **A1**

(c) angle: awrt 20.1 degrees (ft), e.g. from tan(angle) = Y/X **A1**

(c) Answer: 43.7 N, at 20.1 degrees to the arm

Question 10

(a) because the sack (at B) and part of the plank's own weight act beyond D, so increasing w increases the tendency to rotate the bench about D, lifting end A (and the reaction at C) off post C **B1**

(a) Answer: The bench would tip about D, lifting off at C

(b) moments equation about C attempted, with all four terms present **M1**

(b) correct unsimplified equation: $R_D \times 1.5 = 180 \times 0.9 + w \times 2.1 - 40 \times 0.3$ oe **A1**

(b) rearranges to make R_D the subject **dM1**

(b) $R_D = 100 + 1.4w$ cso **A1**

(b) Answer: $R_D = 100 + 1.4w$

(c) $R_C + R_D = 180 + 40 + w$ (vertical equilibrium), ft their R_D **M1**

(c) $R_C = 120 - 0.4w$ cao **A1**

(c) Answer: $R_C = 120 - 0.4w$

(d) sets $R_C \geq 0$ and solves: $120 - 0.4w \geq 0$ **M1**

(d) $w \leq 300$ **A1**

(d) maximum value of w is 300 N, ft their inequality **B1**

(d) Answer: 300 N

© Revision Library | revisionlibrary.co.uk

Question 11

(a) moments equation about A: T sin(θ) x 2L = W x L oe	**M1**
(a) correct unsimplified equation	**A1**
(a) divides both sides by 2L and rearranges	**dM1**
(a) T = W / (2 sin(θ)) cso	**A1**

(a) Answer: T = W / (2 sin(θ))

(b) horizontal equilibrium: X = T cos(θ)	**M1**
(b) correct expression for X	**A1**
(b) vertical equilibrium: Y = W - T sin(θ)	**M1**
(b) uses T sin(θ) = W/2 from part (a) to get Y = W/2 = T sin(θ)	**A1**
(b) magnitude = $\sqrt{X^2 + Y^2}$ = $\sqrt{(T \cos(\&\theta;))^2 + (T \sin(\&\theta;))^2}$ = T cso	**A1**

(b) Answer: Hinge force magnitude = T

(c) substitutes into T = W / (2 sin(θ)): T = 150 / (2 sin(40 degrees))	**M1**
(c) awrt 117 N	**A1**
(c) correctly states the hinge force equals this value of T, using the result of part (b)	**B1**

(c) Answer: 117 N (3 s.f.)

© Revision Library | revisionlibrary.co.uk