3.3 Mechanics: Moments: Test Pack

EDEXCEL 9MA0 · Calculator allowed · about 95 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 State the formula for the moment of a force about a point, in terms of the force and the perpendicular distance from the point to the line of action of the force.

(Total for Question 1 is 1 mark)

2 A rod is described as "uniform". State what this tells you about the position of its centre of mass.

(Total for Question 2 is 1 mark)

3 A force of 25 N acts at right angles to a rod at a point 1.6 m from a pivot. Find the moment of the force about the pivot.

(Total for Question 3 is 1 mark)

4 A force of 32 N acts at right angles to a crowbar at a point 0.75 m from the pivot. Find the moment of the force about the pivot.

(Total for Question 4 is 1 mark)

5 Explain, in terms of the formula for a moment, why the unit of a moment is written as N m and not N/m.

(Total for Question 5 is 1 mark)

6 A force of 15 N acting at right angles to a door produces a moment of 12 N m about the hinge. Find the distance from the hinge to the point where the force acts.

(Total for Question 6 is 2 marks)

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7 A mechanic applies a force of 60 N to the end of a spanner of length 0.24 m, at an angle of 70 degrees to the spanner, in order to loosen a nut. The nut is modelled as a fixed pivot at the other end of the spanner.

(a) Calculate the perpendicular distance from the pivot to the line of action of the force, giving your answer to 3 significant figures. **(2)**

(b) Hence calculate the moment of the force about the pivot, stating the appropriate units, giving your answer to 3 significant figures. **(2)**

(c) State, with a reason, whether the moment calculated in part (b) would increase or decrease if the angle between the force and the spanner were reduced to 40 degrees, with the magnitude of the force unchanged. **(2)**

(Total for Question 7 is 6 marks)

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8 A market stallholder's uniform wooden display plank AB has length 3 m and weight 120 N. The plank rests horizontally in equilibrium on two smooth trestle supports, one at C, 0.5 m from A, and one at D, 0.5 m from B. Two display boxes rest on the plank; the table below gives each box's weight and its distance from A.

Item	Weight (N)	Distance from A (m)
Box P	50	1.0
Box Q	30	2.0

(a) By taking moments about C, show that the reaction at D, R_D, is 95 N. **(4)**

(b) Find the reaction at C, R_C. **(2)**

(c) Box Q is now repositioned along the plank (its weight is unchanged) so that the reactions at C and D become equal. Find the new distance of Box Q from A, giving your answer to 3 significant figures. **(3)**

(Total for Question 8 is 9 marks)

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9 A uniform plank is pivoted at its centre. A force of 72 N acts vertically downward at a point 1.05 m from the pivot on one side. Find the distance from the pivot at which a force of 84 N must act vertically downward on the other side, for the plank to remain in equilibrium.

(Total for Question 9 is 2 marks)

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10 A uniform beam AB has length 8 m and weight 260 N. The beam is held horizontally in equilibrium by two vertical cables attached to the beam at points C and D, where AC = 1.5 m and AD = 6.5 m. A load of weight 140 N is attached to the beam at point E, where AE = 3 m.

(a) By taking moments about C, show that the tension in the cable at D, T_D, is 172 N. **(4)**

(b) Find the tension in the cable at C, T_C. **(2)**

(c) The load is now moved to the midpoint of the beam, with everything else unchanged. Find the new tensions in the two cables. **(5)**

(Total for Question 10 is 11 marks)

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11 A uniform beam AB has length 5 m and weight 200 N. The beam rests horizontally in equilibrium on two smooth supports, one at C, 1 m from A, and one at D, 1 m from B. By taking moments about C, find the reaction at D.

(Total for Question 11 is 3 marks)

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12 A student is asked to find the reaction at support B for a uniform beam AB of length 6 m and weight 150 N, resting horizontally in equilibrium on smooth supports at A and at B. The student takes moments about A and writes: $R_B \times 6 = 150 \times 6$. Identify the error in the student's equation, and write down the correct equation and the resulting value of R_B.

(Total for Question 12 is 3 marks)

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13 A uniform plank AB has length 6 m and weight 200 N. The plank rests horizontally on two smooth supports, one at C, 1 m from A, and one at D, 1 m from B. A person of weight 800 N walks slowly along the plank from A to B. Let x metres be the distance of the person from A, where $0 \leq x \leq 6$. The plank remains in equilibrium as long as both support reactions are greater than or equal to zero; it tips about a support if that support's reaction would otherwise need to be negative.

(a) By taking moments about C, show that, while the person is between A and B, the reaction at D is given by $R_D = 200x - 100$ (in newtons). **(4)**

(b) Find, in terms of x, an expression for R_C, the reaction at support C. **(2)**

(c) Find the range of values of x for which the plank remains in equilibrium without tipping. **(4)**

(d) Hence state the length of plank over which the person can walk while the plank remains in equilibrium. **(1)**

(Total for Question 13 is 11 marks)

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14 A uniform rod AB has length 1.8 m and weight 40 N. The rod rests horizontally on a smooth pivot at its midpoint M. A mass hanging from a string attached at B exerts a force of 25 N vertically downward on the rod. A force of magnitude P is applied to the rod at B, at an angle of 50 degrees above the horizontal, directed so that its vertical component acts upward, such that the rod remains horizontal and in equilibrium.

(a) Explain why the weight of the rod produces no moment about M. **(1)**

(b) By taking moments about M, find the value of P, giving your answer to 3 significant figures. **(4)**

(c) Find the magnitude of the force exerted on the rod by the pivot at M, giving your answer to 3 significant figures. **(5)**

(Total for Question 14 is 10 marks)

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15 A uniform ladder AB has length 5 m and weight 220 N. It rests with end A on rough horizontal ground, where the coefficient of friction is 0.3, and end B against a smooth vertical wall, making an angle of 65 degrees with the ground. A steady horizontal wind force of magnitude P acts at the midpoint of the ladder, blowing in the direction from the wall towards A (tending to push the ladder away from the wall). The ladder remains in equilibrium and is on the point of slipping at A.

(a) By resolving vertically, find the normal reaction at A, N_A. (The wind force is horizontal, so does not affect this.) **(2)**

(b) Hence write down the friction force at A, given that the ladder is on the point of slipping there. **(2)**

(c) By taking moments about A, show that $N_B = 110/\tan(65 \text{ degrees}) - 0.5P$, where N_B is the normal reaction at the wall (both terms in newtons). **(4)**

(d) By resolving horizontally, find the value of P, giving your answer to 3 significant figures. **(3)**

(Total for Question 15 is 11 marks)

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16 A uniform footbridge deck AB has length 10 m and weight 400 N. The deck is held horizontally in equilibrium by two vertical cables attached to the deck at C and D, where AC = 2 m and AD = 8 m. Two maintenance workers stand on the deck: one of combined weight (with equipment) 150 N at a point 3 m from A, and another of weight 90 N at a point 7 m from A.

(a) By taking moments about C, find the tension in the cable at D. **(2)**

(b) Hence find the tension in the cable at C. **(2)**

(Total for Question 16 is 4 marks)

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Mark scheme · 3.3 Mechanics: Moments: Test Pack

Question 1

moment = force x perpendicular distance **B1**

Answer: Moment = Force x perpendicular distance

Question 2

the centre of mass acts at the midpoint of the rod **B1**

Answer: The centre of mass is at the midpoint of the rod.

Question 3

40 cao **B1**

Answer: 40 N m

Question 4

24 cao **B1**

Answer: 24 N m

Question 5

moment = force x perpendicular distance, so the units are multiplied together (newtons x metres = N m), not divided (oe) **B1**

Answer: Moment = force x distance, so the units multiply: N x m = N m (not N/m, which would apply if the quantities were divided).

Question 6

d = moment / force = 12 / 15 **M1**

0.8 m cao **A1**

Answer: 0.8 m

Question 7

(a) d = 0.24 x sin(70 degrees) oe **M1**

(a) awrt 0.226 (m) **A1**

(a) Answer: 0.226 m (3 s.f.)

(b) moment = 60 x their (a), or 60 x 0.24 x sin(70 degrees) **M1**

(b) awrt 13.5 N m (units required), ft their (a) **A1**

(b) Answer: 13.5 N m (3 s.f.)

(c) correct statement: the moment would decrease **B1**

(c) valid reason: sin(40 degrees) < sin(70 degrees), so the perpendicular distance 0.24 sin(θ) is smaller, or equivalently the perpendicular force component F sin(θ) is smaller, oe **B1**

(c) Answer: The moment decreases

Question 8

(a) moments equation about C attempted, with all four terms present (plank weight, Box P, Box Q, R_D) **M1**

(a) correct unsimplified equation: R_D x 2.0 = 120 x 1.0 + 50 x 0.5 + 30 x 1.5 oe **A1**

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

(a) R_D = 95 N cso **A1**

(a) Answer: R_D = 95 N

(b) R_C = (120 + 50 + 30) - 95 (vertical equilibrium), ft their (a) **M1**

(b) R_C = 105 N cao **A1**

(b) Answer: R_C = 105 N

(c) recognises that equal reactions require $R_C = R_D$ = 100 N (half the total weight of 200 N) **M1**

(c) forms a moments equation about C with Box Q's distance d as the unknown: 100 x 2.0 = 120 x 1.0 + 50 x 0.5 + 30 x (d - 0.5) oe **M1**

(c) d = awrt 2.33 m cao **A1**

(c) Answer: 2.33 m from A (3 s.f.)

Question 9

take moments about the pivot: 72 x 1.05 = 84 x d **M1**

0.9 m cao **A1**

Answer: 0.9 m

Question 10

(a) moments equation about C attempted, with all three terms present **M1**

(a) correct unsimplified equation: T_D x 5 = 260 x 2.5 + 140 x 1.5 oe **A1**

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

(a) T_D = 172 N cso **A1**

(a) Answer: T_D = 172 N

(b) T_C = 260 + 140 - 172 (vertical equilibrium), ft their (a) **M1**

(b) T_C = 228 N cao **A1**

(b) Answer: 228 N

(c) moments equation about C with the load now at the midpoint (4 m from A, 2.5 m from C) **M1**

(c) correct unsimplified equation: T_D x 5 = 260 x 2.5 + 140 x 2.5 oe **A1**

(c) rearranges to make T_D the subject **dM1**

(c) T_D = 200 N cao **A1**

(c) T_C = 200 N (using vertical equilibrium or the symmetry of equal distances from C and D) **B1**

(c) Answer: $T_C = T_D$ = 200 N

Question 11

identify distances from C: weight (midpoint, 2.5 m from A) is 1.5 m from C; D (4 m from A) is 3 m from C **M1**

take moments about C: R_D x 3 = 200 x 1.5 **M1**

100 N cao **A1**

Answer: 100 N

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Question 12

identifies the error: the weight of the beam acts at its midpoint (3 m from A), not at the position of B (6 m from A) oe **B1**

correct equation: $R_B \times 6 = 150 \times 3$ **M1**

75 N cao **A1**

Answer: The student used the wrong distance for the weight's moment arm (6 m, the position of B, instead of 3 m, the midpoint where the weight acts). Correct equation: $R_B \times 6 = 150 \times 3$, giving $R_B = 75$ N.

Question 13

(a) moments equation about C with all three terms present: $R_D \times 4 = 200 \times 2 + 800 \times (x - 1)$ oe **M1**

(a) correct unsimplified equation: $4R_D = 400 + 800(x - 1)$ oe **A1**

(a) expands and rearranges to make R_D the subject **dM1**

(a) $R_D = 200x - 100$ cso **A1**

(a) Answer: $R_D = 200x - 100$

(b) $R_C + R_D = 200 + 800$ (vertical equilibrium), ft their R_D **M1**

(b) $R_C = 1100 - 200x$ oe cao **A1**

(b) Answer: $R_C = 1100 - 200x$

(c) sets $R_D \geq 0$ and solves: $200x - 100 \geq 0$ **M1**

(c) $x \geq 0.5$ **A1**

(c) sets $R_C \geq 0$ and solves: $1100 - 200x \geq 0$ **M1**

(c) $0.5 \leq x \leq 5.5$ stated as the combined range **A1**

(c) Answer: $0.5 \leq x \leq 5.5$

(d) 5 m, ft from their range in part (c) as (upper bound - lower bound) **B1**

(d) Answer: 5 m

Question 14

(a) the rod is uniform and M is its midpoint (centre of mass), so the weight acts through M and has zero perpendicular distance from M **B1**

(a) Answer: Weight acts through the pivot M, so its moment about M is zero

(b) moments equation about M: $25 \times 0.9 = P \sin(50 \text{ degrees}) \times 0.9$ oe **M1**

(b) simplifies to $25 = P \sin(50 \text{ degrees})$ **A1**

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

(b) awrt 32.6 N **A1**

(b) Answer: 32.6 N (3 s.f.)

(c) horizontal equilibrium: $X = P \cos(50 \text{ degrees})$, ft their P **M1**

(c) awrt 21.0 N **A1**

(c) vertical equilibrium gives $Y = 40$, using $Y + P \sin(50 \text{ degrees}) = 40 + 25$ and $P \sin(50 \text{ degrees}) = 25$ (exact, from part b) **B1**

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

(c) awrt 45.2 N (ft) **A1**

(c) Answer: 45.2 N (3 s.f.)

Question 15

(a) vertical equilibrium: $N_A = 220$ (the wall's reaction and the wind force are both horizontal) **M1**

(a) $N_A = 220$ N cao **A1**

(a) Answer: 220 N

(b) limiting friction: $F_A = 0.3 \times N_A$, using their N_A **M1**

(b) $F_A = 66$ N cao **A1**

(b) Answer: 66 N

(c) moments equation about A with all three terms: $N_B \times 5 \sin(65 \text{ degrees}) + P \times 2.5 \sin(65 \text{ degrees}) = 220 \times 2.5 \cos(65 \text{ degrees})$ oe **M1**

(c) correct unsimplified equation **A1**

(c) divides by 5 sin(65 degrees) and rearranges to isolate N_B **dM1**

(c) $N_B = 110/\tan(65 \text{ degrees}) - 0.5P$ cso **A1**

(c) Answer: $N_B = 110/\tan(65 \text{ degrees}) - 0.5P$

(d) horizontal equilibrium: $F_A = N_B + P$, using their F_A and their expression for N_B **M1**

(d) substitutes and rearranges: $66 = 110/\tan(65 \text{ degrees}) - 0.5P + P$ **M1**

(d) awrt 29.4 (N) **A1**

(d) Answer: 29.4 N (3 s.f.)

Question 16

(a) take moments about C: $T_D \times 6 = 400 \times 3 + 150 \times 1 + 90 \times 5$ (the deck's weight is 3 m from C, the first worker is 1 m from C, the second worker is 5 m from C, and D is 6 m from C) **M1**

(a) 300 N cao **A1**

(a) Answer: 300 N

(b) resolve vertically: $T_C + T_D = 400 + 150 + 90$ **M1**

(b) 340 N cao **A1**

(b) Answer: 340 N

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