3.7 Mechanics: Moments and Statics Depth: Test Pack

EDEXCEL 9MA0 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A light rod pivots about a point O. A force of 200 N acts perpendicular to the rod at a distance of 0.4 m from O. Find the moment of the force about O.

(Total for Question 1 is 1 mark)

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2 State the condition, in terms of moments, that a rigid body must satisfy (in addition to zero resultant force) to be in equilibrium under a system of coplanar forces.

(Total for Question 2 is 1 mark)

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3 A worker uses a crowbar to lift the edge of a heavy paving slab. The crowbar is modelled as a light rigid lever, pivoting on a fixed fulcrum stone at the point O.

(a) The worker applies a force of 180 N, perpendicular to the crowbar, at a point 0.9 m from O. Calculate the moment of this force about O. **(2)**

(b) The slab requires a moment of at least 126 N m about O to lift it. Find the minimum distance from O at which the worker would need to apply a force of 120 N, acting perpendicular to the crowbar, to lift the slab. **(2)**

(Total for Question 3 is 4 marks)

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4 A uniform ladder of length 3 m and weight 100 N rests with its upper end against a smooth vertical wall and its lower end on rough horizontal ground. The ladder makes an angle α with the ground, where $\tan \alpha = 12/5$. A man of weight 150 N stands on the ladder at a distance 1 m from its foot.

(a) Find the magnitude of the normal reaction of the wall on the ladder. **(3)**

(b) Find the magnitude of the friction force at the ground and the normal reaction at the ground. **(4)**

(c) Given that the ladder is in limiting equilibrium, find the coefficient of friction between the ladder and the ground. **(2)**

(Total for Question 4 is 9 marks)

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5 A non-uniform rod AB has length 4 m and weight 200 N. The rod is held in equilibrium in a horizontal position by two vertical strings, one attached at A and the other attached at B. The tension in the string at A is three times the tension in the string at B.

(a) Show that the tension in the string at B is 50 N. **(2)**

(b) By taking moments about A, find the distance of the centre of mass of the rod from A. **(3)**

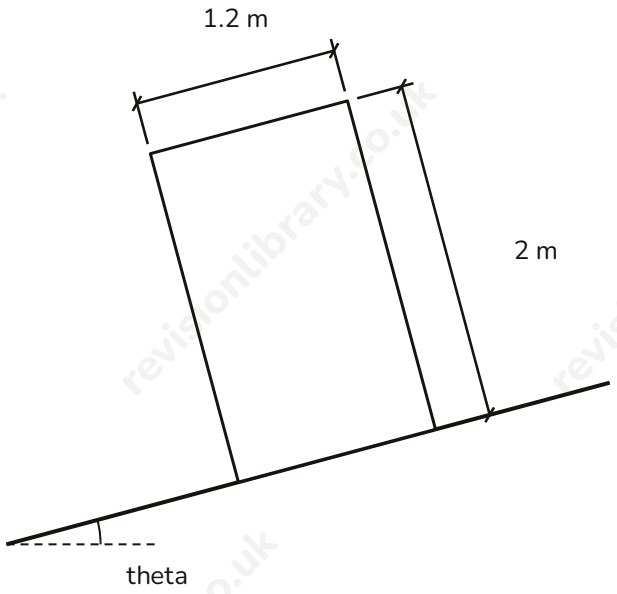
(c) A particle of weight 40 N is attached to the rod at B. Given that the rod remains in horizontal equilibrium, find the new tension in the string at A. **(2)**

(Total for Question 5 is 7 marks)

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6 A uniform solid cuboid rests in equilibrium on a rough plane inclined at an angle θ to the horizontal, with its longer edges horizontal and its rectangular cross-section, of width 1.2 m and height 2 m, lying in a vertical plane containing a line of greatest slope. The coefficient of friction between the cuboid and the plane is $\mu = 0.4$. The angle θ is slowly increased from 0. Take $g = 9.8$ m/s^2 where needed.

Diagram NOT accurately drawn



(a) Given that the cuboid does not slide, find the angle θ at which it is on the point of toppling about its lower edge, giving your answer to 3 significant figures. **(4)**

(b) Given instead that the cuboid does not topple, find the angle θ at which it is on the point of sliding, giving your answer to 3 significant figures. **(4)**

(c) Hence determine, with justification, whether the cuboid slides or topples first as θ increases from 0, and state the critical value of θ at which equilibrium first breaks down. **(2)**

(d) Given that the mass of the cuboid is 45 kg, find the normal reaction between the cuboid and the plane at this critical angle, giving your answer to 3 significant figures. **(3)**

(Total for Question 6 is 13 marks)

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7 A uniform ladder AB has length 6 m and weight 290 N. The ladder rests in limiting equilibrium, on the point of slipping at both ends, with end A on rough horizontal ground and end B against a rough vertical wall, inclined at angle θ to the horizontal. The coefficient of friction between the ladder and the ground equals the coefficient of friction between the ladder and the wall, both equal to $\mu = 0.4$. Let N_A and F_A denote the normal reaction and friction force at A, and N_B and F_B denote the normal reaction and friction force at B.

(a) By resolving horizontally and vertically, and using $F_A = \mu * N_A$ and $F_B = \mu * N_B$, show that $N_A = 250$ N and $N_B = 100$ N. **(5)**

(b) By taking moments about A, find the angle θ, giving your answer to 3 significant figures. **(5)**

(c) Find the magnitude of the resultant contact force exerted on the ladder by the ground at A. **(3)**

(Total for Question 7 is 13 marks)

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Mark scheme · 3.7 Mechanics: Moments and Statics Depth: Test Pack

Question 1

80 cao **B1**

Answer: 80 N m

Question 2

the sum of the moments about any point must be zero **B1**

Answer: The sum of the moments about any point must be zero.

Question 3

(a) moment = force * distance = 180 * 0.9 **M1**

(a) 162 N m cao (units required) **A1**

(a) Answer: 162 N m

(b) 126 = 120 * d **M1**

(b) d = 1.05 m cao **A1**

(b) Answer: 1.05 m

Question 4

(a) takes moments about the foot of the ladder **M1**

(a) N(3) sin α = 100(3/2) cos α + 150(1) cos α **A1**

(a) N = 125/3 N **A1**

(a) Answer: 125/3 N

(b) resolves horizontally: F = N **M1**

(b) F = 125/3 N **A1**

(b) resolves vertically: R = weights **M1**

(b) R = 250 N **A1**

(b) Answer: F = 125/3 N, R = 250 N

(c) uses F = μ R in limiting equilibrium **M1**

(c) μ = 125/3/250 = 1/6 **A1**

(c) Answer: 1/6

Question 5

(a) forms $3T_B + T_B = 200$, using $T_A = 3T_B$ and $T_A + T_B = 200$ **M1**

(a) $T_B = 50$ cso **A1**

(a) Answer: $T_B = 50$ N (shown)

(b) takes moments about A: $200x = T_B * 4$ **M1**

(b) $200x = 50 * 4 = 200$ **A1**

(b) x = 1 (m) cao **A1**

(b) Answer: 1 m from A

(c) takes moments about B: $T_A' * 4 = 200 * (4-1) + 40 * 0$ **M1**

(c) $T_A' = 150$ (N) cao **A1**

(c) Answer: 150 N

Question 6

(a) identifies the toppling condition: the vertical line through the centre of mass passes through the lower edge when tan(θ) = half-width/half-height **M1**

(a) tan(θ) = 0.6/1 = 0.6, using half-width 0.6 m and half-height 1 m **A1**

(a) θ = arctan(0.6) **M1**

(a) θ = awrt 31.0 (degrees) cao **A1**

(a) Answer: awrt 31.0 degrees (tan(θ) = 0.6 exactly)

(b) resolves perpendicular to the plane: R = Mg*cos(θ) **M1**

(b) resolves along the plane at limiting equilibrium: F = Mg*sin(θ) **A1**

(b) uses F = μ*R to get tan(θ) = μ = 0.4 **M1**

(b) θ = awrt 21.8 (degrees) cao **A1**

(b) Answer: awrt 21.8 degrees (tan(θ) = 0.4 exactly)

(c) compares the two critical angles, 21.8 and 31.0 degrees, noting θ increases continuously from 0 so equilibrium first breaks at the smaller of the two **M1**

(c) concludes the cuboid slides first, since 21.8 < 31.0, at θ = awrt 21.8 degrees **A1**

(c) Answer: the cuboid slides first, at θ = awrt 21.8 degrees

(d) weight = Mg = 45*9.8 = 441 N **M1**

(d) R = Mg*cos(θ) at θ = 21.8 degrees **M1**

(d) R = 441*cos(21.8) = awrt 409 (N) cao **A1**

(d) Answer: awrt 409 N

Question 7

(a) resolves vertically: $N_A + F_B = 290$ **M1**

(a) resolves horizontally: $N_B = F_A$ **M1**

(a) substitutes the limiting friction conditions $F_A = \mu * N_A$ and $F_B = \mu * N_B$ into both equations **B1**

(a) combines the two equations to eliminate a variable, e.g. $N_A*(1 + \mu^2) = 290$ **M1**

(a) $N_A = 290/1.16 = 250$ (N) and $N_B = \mu * N_A = 100$ (N), both values, cso **A1**

(a) Answer: $N_A = 250$ N; $N_B = 100$ N (shown)

(b) takes moments about A, identifying moment arms (L/2)cos(θ) for W, L*sin(θ) for N_B and L*cos(θ) for F_B, with L cancelling **M1**

(b) (W/2)*cos(θ) = N_B*sin(θ) + F_B*cos(θ) **A1**

(b) substitutes W = 290, $N_B = 100$, $F_B = 40$ and rearranges to isolate tan(θ) **M1**

(b) tan(θ) = 105/100 = 1.05 (oe, e.g. 21/20) **A1**

(b) θ = awrt 46.4 (degrees) **A1**

(b) Answer: θ = awrt 46.4 degrees (tan(θ) = 1.05)

(c) uses Pythagoras: magnitude = $\sqrt{N_A^2 + F_A^2}$ **M1**

(c) = $\sqrt{250^2 + 100^2} = \sqrt{72500}$ **A1**

(c) = awrt 269 (N) cao **A1**

(c) Answer: awrt 269 N (= $50*\sqrt{29}$ N exactly)

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