3.7 Mechanics: Moments and Statics Depth: 2-hour Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 120 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A particle of weight 60 N hangs in equilibrium, attached to two light inextensible strings whose other ends are fixed to a horizontal ceiling, on opposite sides of the vertical through the particle. String 1 makes an angle of 55 degrees with the ceiling, and string 2 makes an angle of 40 degrees with the ceiling. Find the tension in each string, giving your answers to 3 significant figures.

(Total for Question 1 is 4 marks)

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2 A uniform beam AB has length 7 m and weight 230 N. It rests horizontally on two supports at C and D, where AC = 3 m and AD = 4 m. A particle of weight 45 N is placed on the beam at the point E, where AE = 4 m.

(a) Find the magnitudes of the reactions at C and D. **(5)**

(b) The particle is now moved along the beam towards B. Find the greatest distance from A at which it can be placed so that the beam remains in equilibrium, resting on both supports. **(3)**

(Total for Question 2 is 8 marks)

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3 A uniform plank AB has length 3 m and weight 40 N. It rests horizontally on a single support at the point C, where AC = 3/2 m. A load of weight w N is hung from A so that the plank is in equilibrium and about to tilt about C.

(a) Find the value of w. **(3)**

(b) Find the magnitude of the reaction of the support on the plank. **(2)**

(Total for Question 3 is 5 marks)

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4 A uniform ladder of length 6 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 $\tan \alpha = 5/12$. A man of weight 150 N stands on the ladder at a distance 3 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 uniform beam AB has length 5 m and weight 210 N. It rests horizontally on two supports at C and D, where AC = 2 m and AD = 3 m. A particle of weight 95 N is placed on the beam at the point E, where AE = 2 m.

(a) Find the magnitudes of the reactions at C and D. **(5)**

(b) The particle is now moved along the beam towards B. Find the greatest distance from A at which it can be placed so that the beam remains in equilibrium, resting on both supports. **(3)**

(Total for Question 5 is 8 marks)

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6 A uniform plank AB has length 3 m and weight 60 N. It rests horizontally on a single support at the point C, where AC = 1 m. A load of weight w N is hung from A so that the plank is in equilibrium and about to tilt about C.

(a) Find the value of w. **(3)**

(b) Find the magnitude of the reaction of the support on the plank. **(2)**

(Total for Question 6 is 5 marks)

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7 A uniform beam AB has length 12 m and weight 110 N. It rests horizontally on two supports at C and D, where AC = 4 m and AD = 8 m. A particle of weight 60 N is placed on the beam at the point E, where AE = 2 m.

(a) Find the magnitudes of the reactions at C and D. **(5)**

(b) The particle is now moved along the beam towards B. Find the greatest distance from A at which it can be placed so that the beam remains in equilibrium, resting on both supports. **(3)**

(Total for Question 7 is 8 marks)

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8 A uniform ladder of length 4 m and weight 200 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 $\tan \alpha = 5/12$. A man of weight 100 N stands on the ladder at a distance 4/3 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 8 is 9 marks)

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9 A uniform beam AB has length 7 m and weight 100 N. It rests horizontally on two supports at C and D, where AC = 3 m and AD = 4 m. A particle of weight 30 N is placed on the beam at the point E, where AE = 5 m.

(a) Find the magnitudes of the reactions at C and D. **(5)**

(b) The particle is now moved along the beam towards B. Find the greatest distance from A at which it can be placed so that the beam remains in equilibrium, resting on both supports. **(3)**

(Total for Question 9 is 8 marks)

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10 A uniform plank AB has length 6 m and weight 120 N. It rests horizontally on a single support at the point C, where AC = 2 m. A load of weight w N is hung from A so that the plank is in equilibrium and about to tilt about C.

(a) Find the value of w. **(3)**

(b) Find the magnitude of the reaction of the support on the plank. **(2)**

(Total for Question 10 is 5 marks)

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11 A uniform beam AB has length 7 m and weight 220 N. It rests horizontally on two supports at C and D, where AC = 1 m and AD = 4 m. A particle of weight 70 N is placed on the beam at the point E, where AE = 2 m.

(a) Find the magnitudes of the reactions at C and D. **(5)**

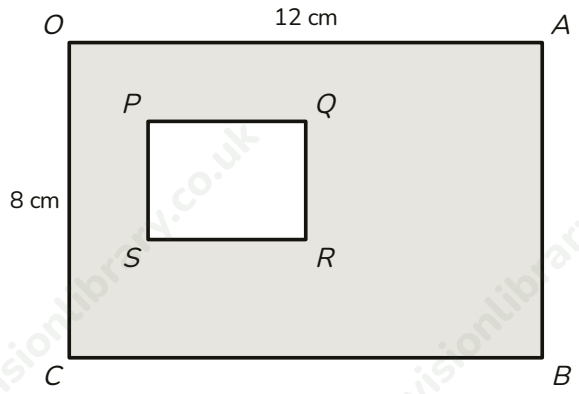
(b) The particle is now moved along the beam towards B. Find the greatest distance from A at which it can be placed so that the beam remains in equilibrium, resting on both supports. **(3)**

(Total for Question 11 is 8 marks)

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12 A uniform lamina occupies the region of a rectangle OABC, where O is the origin, OA lies along the x-axis with OA = 12 cm, and OC lies along the y-axis with OC = 8 cm. A rectangular hole PQRS is removed from the lamina, where P = (2, 2), Q = (6, 2), R = (6, 5) and S = (2, 5), all coordinates in cm.

Diagram NOT accurately drawn



(a) Find the coordinates of the centre of mass of the remaining lamina. **(6)**

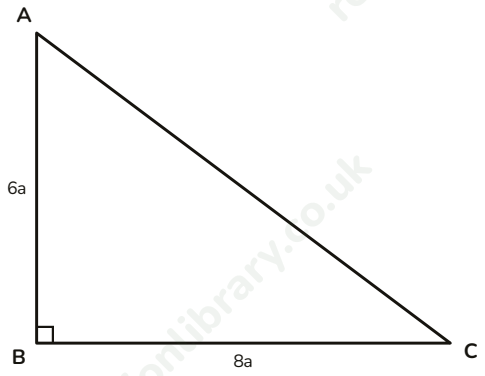
(b) The lamina is freely suspended from the point A and hangs in equilibrium. Find the angle that AB makes with the vertical, giving your answer to 3 significant figures. **(3)**

(Total for Question 12 is 9 marks)

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13 A framework is formed from three uniform rods AB, BC and CA, rigidly joined at their ends to form a triangle with a right angle at B. The rods are made of the same material, with the same mass per unit length, and AB = 6a, BC = 8a.

Diagram NOT accurately drawn



(a) Show that CA = 10a. **(1)**

(b) Taking B as the origin, with BC along the x-axis and BA along the y-axis, find the coordinates of the centre of mass of the framework, giving your answer in terms of a. **(7)**

(c) The framework is freely suspended from A and hangs in equilibrium. Find, to 3 significant figures, the angle that AB makes with the vertical. **(4)**

(Total for Question 13 is 12 marks)

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Mark scheme · 3.7 Mechanics: Moments and Statics Depth: 2-hour Pack

Question 1

resolve horizontally: T1 cos55 = T2 cos40	**M1**
resolve vertically: T1 sin55 + T2 sin40 = 60, and eliminate T1 (or T2) using the horizontal equation	**M1**
awrt T1 = 46.1 N	**A1**
awrt T2 = 34.5 N	**A1**

Answer: T1 = 46.1 N, T2 = 34.5 N (both 3 s.f.)

Question 2

(a) takes moments about C	**M1**
(a) $R_D(1) = 230(1/2) + 45(1)$	**A1**
(a) $R_D = 160$ N	**A1**
(a) resolves vertically: $R_C + R_D = W + w$	**M1**
(a) $R_C = 115$ N	**A1**

(a) Answer: $R_C = 115$ N, $R_D = 160$ N

(b) when the beam is about to tilt about D, $R_C = 0$, so takes moments about D	**M1**
(b) $230(4 - 7/2) = 45(y - 4)$ where y is the distance of the particle from A	**M1**
(b) y = 59/9 m	**A1**

(b) Answer: 59/9 m from A

Question 3

(a) takes moments about C	**M1**
(a) w(3/2) = 40(0)	**A1**
(a) w = 0	**A1**

(a) Answer: w = 0

(b) resolves vertically	**M1**
(b) R = 40 + 0 = 40 N	**A1**

(b) Answer: 40 N

Question 4

(a) takes moments about the foot of the ladder	**M1**
(a) $N(6) \sin\alpha = 100(3) \cos\alpha + 150(3) \cos\alpha$	**A1**
(a) N = 300 N	**A1**

(a) Answer: 300 N

(b) resolves horizontally: F = N	**M1**
(b) F = 300 N	**A1**
(b) resolves vertically: R = weights	**M1**
(b) R = 250 N	**A1**

(b) Answer: F = 300 N, R = 250 N

(c) uses $F = \mu R$ in limiting equilibrium	**M1**
(c) $\mu = 300/250 = 6/5$	**A1**

(c) Answer: 6/5

Question 5

(a) takes moments about C	**M1**
(a) $R_D(1) = 210(1/2) + 95(0)$	**A1**
(a) $R_D = 105$ N	**A1**
(a) resolves vertically: $R_C + R_D = W + w$	**M1**
(a) $R_C = 200$ N	**A1**

(a) Answer: $R_C = 200$ N, $R_D = 105$ N

(b) when the beam is about to tilt about D, $R_C = 0$, so takes moments about D	**M1**
(b) $210(3 - 5/2) = 95(y - 3)$ where y is the distance of the particle from A	**M1**
(b) y = 78/19 m	**A1**

(b) Answer: 78/19 m from A

Question 6

(a) takes moments about C	**M1**
(a) w(1) = 60(1/2)	**A1**
(a) w = 30	**A1**

(a) Answer: w = 30

(b) resolves vertically	**M1**
(b) R = 60 + 30 = 90 N	**A1**

(b) Answer: 90 N

Question 7

(a) takes moments about C	**M1**
(a) $R_D(4) = 110(2) + 60(-2)$	**A1**
(a) $R_D = 25$ N	**A1**
(a) resolves vertically: $R_C + R_D = W + w$	**M1**
(a) $R_C = 145$ N	**A1**

(a) Answer: $R_C = 145$ N, $R_D = 25$ N

(b) when the beam is about to tilt about D, $R_C = 0$, so takes moments about D	**M1**
(b) $110(8 - 6) = 60(y - 8)$ where y is the distance of the particle from A	**M1**
(b) y = 35/3 m	**A1**

(b) Answer: 35/3 m from A

Question 8

(a) takes moments about the foot of the ladder	**M1**
(a) $N(4) \sin\alpha = 200(2) \cos\alpha + 100(4/3) \cos\alpha$	**A1**
(a) N = 320 N	**A1**

(a) Answer: 320 N

(b) resolves horizontally: F = N	**M1**
(b) F = 320 N	**A1**
(b) resolves vertically: R = weights	**M1**
(b) R = 300 N	**A1**

(b) Answer: F = 320 N, R = 300 N

(c) uses $F = \mu R$ in limiting equilibrium	**M1**
(c) $\mu = 320/300 = 16/15$	**A1**

(c) Answer: 16/15

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Question 9

(a) takes moments about C **M1**

(a) $R_D(1) = 100(1/2) + 30(2)$ **A1**

(a) $R_D = 110$ N **A1**

(a) resolves vertically: $R_C + R_D = W + w$ **M1**

(a) $R_C = 20$ N **A1**

(a) Answer: $R_C = 20$ N, $R_D = 110$ N

(b) when the beam is about to tilt about D, $R_C = 0$, so takes moments about D **M1**

(b) $100(4 - 7/2) = 30(y - 4)$ where y is the distance of the particle from A **M1**

(b) y = 17/3 m **A1**

(b) Answer: 17/3 m from A

Question 10

(a) takes moments about C **M1**

(a) $w(2) = 120(1)$ **A1**

(a) w = 60 **A1**

(a) Answer: w = 60

(b) resolves vertically **M1**

(b) R = 120 + 60 = 180 N **A1**

(b) Answer: 180 N

Question 11

(a) takes moments about C **M1**

(a) $R_D(3) = 220(5/2) + 70(1)$ **A1**

(a) $R_D = 620/3$ N **A1**

(a) resolves vertically: $R_C + R_D = W + w$ **M1**

(a) $R_C = 250/3$ N **A1**

(a) Answer: $R_C = 250/3$ N, $R_D = 620/3$ N

(b) when the beam is about to tilt about D, $R_C = 0$, so takes moments about D **M1**

(b) $220(4 - 7/2) = 70(y - 4)$ where y is the distance of the particle from A **M1**

(b) y = 39/7 m **A1**

(b) Answer: 39/7 m from A

Question 12

(a) area of the hole = 12 cm^2, with its centroid at (4, 3.5) **B1**

(a) remaining area = 96 - 12 = 84 cm^2 **B1**

(a) xbar = (96*6 - 12*4)/84 **M1**

(a) xbar = 44/7 (awrt 6.29) **A1**

(a) ybar = (96*4 - 12*3.5)/84 **M1**

(a) ybar = 57/14 (awrt 4.07) **A1**

(a) Answer: (44/7, 57/14) cm, i.e. awrt (6.29, 4.07) cm

(b) finds the horizontal and vertical displacement of the centre of mass from A: 40/7 cm and 57/14 cm (or equivalent decimals) **B1**

(b) tan(angle) = (40/7) / (57/14), using AB as the local vertical direction **M1**

(b) angle = awrt 54.5 (degrees) cao **A1**

(b) Answer: awrt 54.5 degrees

Question 13

(a) CA = $\sqrt{(6a)^2+(8a)^2} = \sqrt{100a^2} = 10a$, using Pythagoras' theorem, cso **B1**

(a) Answer: CA = 10a (shown)

(b) masses (lengths) of the three rods are proportional to 6a, 8a, 10a, with total 24a **B1**

(b) identifies the midpoint of each rod: AB -> (0,3a), BC -> (4a,0), CA -> (4a,3a) **M1**

(b) all three midpoints correct **A1**

(b) xbar = (6a*0 + 8a*4a + 10a*4a)/24a **M1**

(b) xbar = 3a **A1**

(b) ybar = (6a*3a + 8a*0 + 10a*3a)/24a **M1**

(b) ybar = 2a **A1**

(b) Answer: (3a, 2a)

(c) identifies the horizontal and vertical displacement of G from A: 3a horizontally and 6a-2a=4a vertically **B1**

(c) sets up tan(angle) = horizontal/vertical = 3a/4a **M1**

(c) = 3/4 (oe) **A1**

(c) angle = awrt 36.9 (degrees) cao **A1**

(c) Answer: awrt 36.9 degrees

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