InkMaths

ANSWER BOOK

Moments

Mechanics · Year 12-13

6 questions · 23 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The moment is the force multiplied by the perpendicular distance from the point to the force's line of action, measured in newton metres. Each moment turns either clockwise or anticlockwise about the point, and the two senses oppose one another, so equilibrium of moments means the two totals are equal. B1 for force times perpendicular distance, B1 for newton metres, B1 for the role of sense. Perpendicular is the word that earns the mark; a distance measured along the force does no turning at all. [3]

A2 Take moments about the pivot. Clockwise $300 \times 2 = 600$ N m, anticlockwise $200 \times x$, so $200x = 600$ and $x = 3$ m. M1 for taking moments about the pivot, A1 for $200x = 600$, A1 for 3 m. Less weight needs more distance in exact proportion. Taking moments about the pivot also removes the reaction there from the equation, since its perpendicular distance is zero. [3]

SECTION B · Standard

B1 Uniform means the beam's weight acts at its midpoint, which here is the support itself, so its perpendicular distance from the pivot is zero and it contributes no moment. Balancing the rest, $450 \times 1 = 300 \times x$ gives $x = 1.5$ m from the centre. B1 for the beam's weight giving no moment, M1 for the moments equation, A1 for 1.5 m. The 90 N is not irrelevant to the reaction at the support, but it is irrelevant to this moments equation, and saying why is worth a mark. [3]

B2 The beam is uniform, so its weight acts at the 4 m mark. Take moments about the support at 1 m, which removes R_1 from the equation: $200 \times 3 = R_2 \times 5$, so $R_2 = 120$ N. Vertical equilibrium then gives $R_1 = 200 - 120 = 80$ N. B1 for the weight acting at the 4 m mark, M1 for taking moments about a support, A1 for the second reaction, M1 for resolving vertically, A1 for the first reaction. Check by taking moments about the end instead: $80 \times 1 + 120 \times 6 = 800 = 200 \times 4$. Choosing a pivot that sits under an unknown force is the labour-saving move of the whole topic, and full marks need both a moments equation and a resolving equation. [5]

B3 Take moments about the 300 N end, which removes that reaction: $500 \times x = 200 \times 10$, so $x = 4$ m. M1 for taking moments about the 300 N end, A1 for $500x = 2000$, A1 for 4 m. The reactions already sum to 500 N, so vertical equilibrium is satisfied and carries no new information. The centre of mass sits nearer the end carrying more, which is the sense check. For a non-uniform beam you must never assume the weight acts at the midpoint. [3]

SECTION C · Stretch

C1 [6]

The rod is uniform, so its weight 12g acts at the midpoint, 2 m from A and therefore 0.5 m from C on the A side. The particle at B is 1.5 m from C on the other side. As m grows the rod threatens to tip about C, so the condition at the point of tipping is $R_A = 0$. Taking moments about C with $R_A = 0$: $12g \times 0.5 = mg \times 1.5$, so $m = 6/1.5 = 4$ kg. With A carrying nothing, C supports everything: $R_C = (12 + 4)g = 156.8$ N. B1 for the weight acting at the midpoint, M1 for setting the reaction at A to zero at the point of tipping, M1 for taking moments about C, A1 for m = 4 kg, M1 for resolving vertically, A1 for 156.8 N. Setting the far reaction to zero is how every on-the-point-of-tipping question is solved, and g cancels from the moments equation, so working in masses is fine as long as you restore g for the reaction.