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INTERNATIONAL A LEVEL MATHEMATICS • MECHANICS 2

Mechanics 2

Chapter 6: Statics of Rigid Bodies

Exam Questions by Topic

Pearson Edexcel International Advanced Level (WME02/01) • Calculator allowed • Take $g = 9.8\,\text{m}\,\text{s}^{-2}$

Multi-step exam questions at the difficulty of the real WME02 paper, with a full mark scheme

Chapters (tap a chapter to jump to it)		Qs	Marks	Page	My score
1	**Projectiles** Horizontal projection, projection at any angle, the equation of the path	10	84	separate file	
2	**Variable Acceleration** Calculus for motion in a line and in $\mathbf{i}, \mathbf{j}$ form	10	85	separate file	
3	**Centres of Mass** Particles, laminas, frameworks, suspended and tilting bodies	10	81	separate file	
4	**Work and Energy** Work done, kinetic and potential energy, the work–energy principle, power	10	82	separate file	
5	**Impulses and Collisions** Impulse as a vector, Newton's law of restitution, loss of kinetic energy	10	82	separate file	
6	**Statics of Rigid Bodies** Rods and ladders in equilibrium, friction, hinge forces	10	81	2	

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CHAPTER 6 • KEY SKILLS

6 Statics of Rigid Bodies

Specification M2: Statics of rigid bodies • 10 questions • 81 marks • about 97 minutes

1 Three equations

Resolve in two perpendicular directions and take moments about one point. Each equation must be dimensionally correct.

2 Moments of angled forces

Moment = force $\times$ perpendicular distance. A force T at θ to a rod at distance d from A: moment $Td\sin\theta$

3 Choosing the point

Take moments about a point where unknown forces act (a hinge or a contact) so they do not appear.

4 Hinges

Give the hinge force components X and Y. Magnitude $\sqrt{X^2+Y^2}$; direction from $\tan^{-1}\frac{Y}{X}$, then the angle asked for.

5 Smooth contacts

A smooth wall gives a horizontal reaction; a smooth peg gives a reaction perpendicular to the rod.

6 Rough contacts

Friction acts along the surface, opposing the motion that would happen. Limiting: $F = \mu R$

7 Ladders

Foot on rough ground: friction towards the wall. A rough wall adds an upward friction at the top when the ladder is about to slip down.

8 Inequalities

In equilibrium $F \leqslant \mu R$, so $\mu \geqslant \frac{F}{R}$. The limiting case gives the end of a range.

9 Accuracy

Keep exact values until the end: premature rounding gives answers such as 0.131 for 0.13

Skills map every skill above is tested at least once; interleaved skills come from GCSE or other chapters

Skill	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Marks	6	6	6	6	6	10	10	10	10	11
1 Three equations	●	●	●	●	●	●	●	●	●	●
2 Moments of angled forces	●	●	●	●	●	●	●	●	●	●
3 Choosing the point	●	●	●	●		●	●	●	●	●
4 Hinges	●						●	●		
5 Smooth contacts			●		●					●
6 Rough contacts			●	●	●	●			●	●
7 Ladders					●	●				●
8 Inequalities				●		●		●	●	●
9 Accuracy		●	●				●	●	●	
Interleaved: moments, friction and statics of a particle (M1)	●	●	●	●	●	●	●	●	●	●
Interleaved: centres of mass (Chapter 3)		●								
Interleaved: trigonometry, exact values and surds (P1, P2)	●	●			●	●	●	●	●	

Exam difficulty. Questions 1 to 5 check each skill on its own. Questions 6 to 10 are multi-step questions built like the last questions on a real WME02 paper, where one part leads into the next and skills from different topics are combined.

Must learn. Draw every force on the diagram, including both components at a hinge and friction at each rough contact. State what you are taking moments about. Read whether an angle is to be measured from the horizontal, the vertical or the rod.

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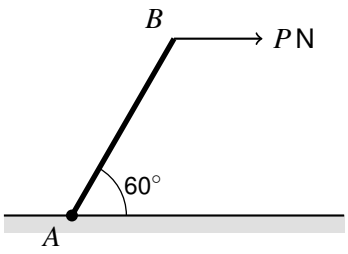


Figure 1

A uniform rod AB, of length 2 m and weight 50 N, is freely hinged at A to a point on horizontal ground. The rod is held in equilibrium at an angle of 60° to the horizontal by a horizontal force of magnitude P newtons applied at B, as shown in Figure 1. The force acts in the vertical plane containing the rod.

(a) Find the value of P.

(3)

(b) Find the magnitude of the force exerted on the rod by the hinge.

(2)

(c) Explain why the force exerted by the hinge does not act along the rod.

(1)

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Question 1 continued

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(Total for Question 1 is 6 marks)

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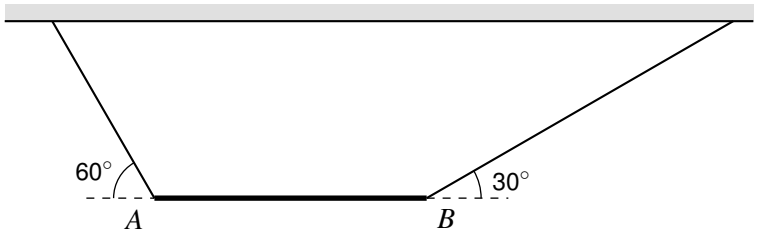


Figure 2

A non-uniform rod AB, of length 4 m and weight 60 N, hangs in equilibrium in a horizontal position, supported by two light strings attached at A and B. The string at A makes an angle of 60° with the rod and the string at B makes an angle of 30° with the rod, as shown in Figure 2. The strings and the rod lie in a vertical plane.

(a) Find the tension in each string.

(4)

(b) Find the distance of the centre of mass of the rod from A.

(2)

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Question 2 continued

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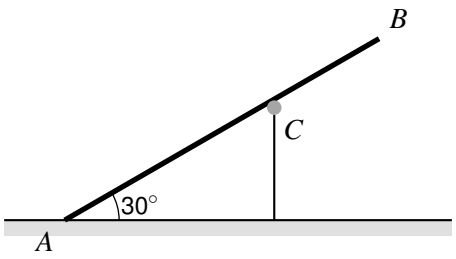


Figure 3

A uniform rod AB, of length 6 m and weight 100 N, rests with the end A on rough horizontal ground and with the rod in contact with a small smooth peg C, where $AC = 4$ m. The rod is inclined at 30° to the horizontal, as shown in Figure 3, and is in limiting equilibrium.

(a) Find the magnitude of the force exerted on the rod by the peg.

(3)

(b) Find the coefficient of friction between the rod and the ground.

(3)

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Question 3 continued

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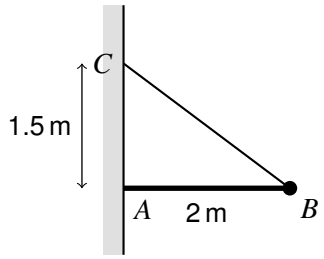


Figure 4

A uniform rod AB, of length 2 m and weight 30 N, rests in a horizontal position with the end A against a rough vertical wall. A particle of weight 10 N is attached to the rod at B. The rod is held in equilibrium by a light string attached at B and to the point C on the wall, 1.5 m vertically above A, as shown in Figure 4. The rod and the string lie in a vertical plane perpendicular to the wall.

(a) Find the tension in the string.

(3)

(b) Find the least possible value of the coefficient of friction between the rod and the wall.

(3)

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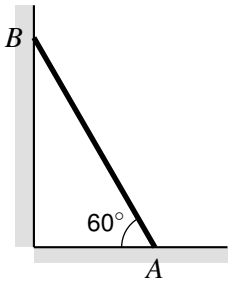


Figure 5

A uniform ladder AB, of length 4 m and mass 20 kg, rests with the end A on rough horizontal ground and the end B against a smooth vertical wall. The ladder makes an angle of 60° with the ground, as shown in Figure 5, and lies in a vertical plane perpendicular to the wall.

(a) Find the magnitude of the reaction exerted on the ladder by the wall.

(3)

(b) Find the least possible value of the coefficient of friction between the ladder and the ground.

(3)

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Question 5 continued

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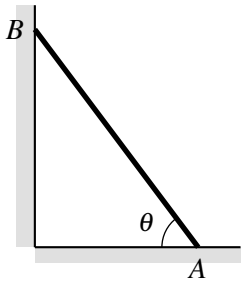


Figure 6

A uniform ladder AB, of length $2a$ and weight W, rests with its end A on rough horizontal ground and its end B against a rough vertical wall. The ladder makes an angle θ with the ground, as shown in Figure 6, and lies in a vertical plane perpendicular to the wall. The coefficient of friction between the ladder and the ground and between the ladder and the wall is μ. The ladder is about to slip.

(a) Show that $\tan\theta = \dfrac{1-\mu^2}{2\mu}$

(6)

(b) Given that $\mu = \frac{1}{3}$, find the value of θ.

(2)

(c) With $\mu = \frac{1}{3}$, explain why the ladder cannot rest in equilibrium at 45° to the ground.

(2)

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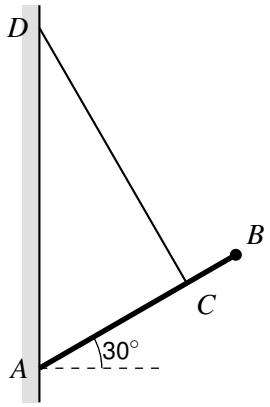


Figure 7

A uniform rod AB, of length $4a$ and weight W, is freely hinged at A to a vertical wall. A particle of weight $2W$ is attached to the rod at B. The rod is held in equilibrium at 30° above the horizontal by a light string attached to the rod at C, where $AC = 3a$, and to the point D on the wall vertically above A. The string is perpendicular to the rod, as shown in Figure 7, and the rod and string lie in a vertical plane perpendicular to the wall.

(a) Show that the tension in the string is $\frac{5\sqrt{3}}{3}W$

(4)

(b) Find, in terms of W, the magnitude of the force exerted on the rod by the hinge.

(4)

(c) Find the angle between the force exerted by the hinge and the rod, giving your answer to the nearest 0.1°

(2)

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Question 7 continued

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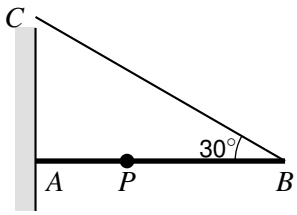


Figure 8

A uniform rod AB, of length $2a$ and weight W, is freely hinged at A to a vertical wall. The rod is held in a horizontal position by a light string attached at B and to the point C on the wall vertically above A, with angle $ABC = 30^\circ$. A particle of weight W is attached to the rod at the point P, where $AP = x$ and $0 \leqslant x \leqslant 2a$, as shown in Figure 8.

(a) Show that the tension in the string is $\dfrac{W(a+x)}{a}$

(3)

(b) Find, in terms of W, a and x, the horizontal and vertical components of the force exerted on the rod by the hinge.

(4)

(c) Explain why the force exerted by the hinge can never act along the rod.

(1)

(d) Find the exact value of x for which the force exerted by the hinge acts at 45° to the rod.

(2)

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Question 8 continued

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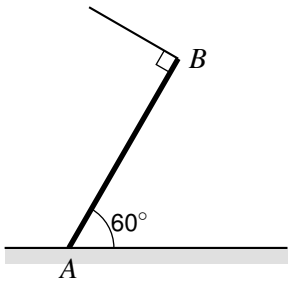


Figure 9

A uniform rod AB, of length $2a$ and weight W, rests with the end A on rough horizontal ground. The rod is held in equilibrium at 60° to the horizontal by a light string attached at B. The string is perpendicular to the rod, as shown in Figure 9, and the rod and string lie in a vertical plane. The rod is on the point of slipping.

(a) Find, in terms of W, the tension in the string.

(3)

(b) Show that the coefficient of friction between the rod and the ground is $\frac{\sqrt{3}}{7}$

(4)

A particle of weight W is now attached to the rod at B. The string is adjusted so that it remains perpendicular to the rod and the rod remains at 60° to the horizontal.

(c) Determine whether the rod can remain in equilibrium.

(3)

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Question 9 continued

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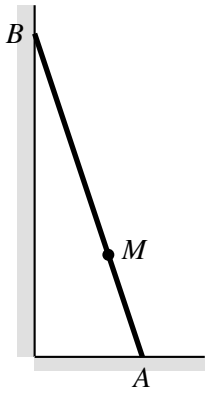


Figure 10

A uniform ladder AB, of length 6 m and mass 20 kg, rests with the end A on rough horizontal ground and the end B against a smooth vertical wall. The ladder makes an angle α with the ground, where $\tan\alpha = 3$, and lies in a vertical plane perpendicular to the wall. The coefficient of friction between the ladder and the ground is 0.25. A man of mass 80 kg climbs up the ladder, as shown in Figure 10. The man is modelled as a particle M.

(a) Find the greatest distance from A that the man can climb before the ladder slips.

(5)

To allow the man to reach the top of the ladder, a horizontal force of magnitude P newtons, towards the wall, is applied to the ladder at A.

(b) Find the least value of P.

(5)

(c) State one way in which modelling the man as a particle affects your answers.

(1)

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TOTAL FOR CHAPTER 6 IS 81 MARKS

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