

A-Level Maths – Mechanics

A-Level (Edexcel/AQA/OCR) · Total marks: 71 · Answers on the last page

Covers constant-acceleration (suvat) equations, forces and Newton's laws, connected particles, moments, projectiles and friction. Take $g = 9.8 \text{ m s}^{-2}$ throughout and give answers to 3 significant figures unless exact. Calculator allowed; allow about 80 minutes.

Section A – Skills (Short questions.)

1. A particle moves in a straight line with constant acceleration 2.5 m s^{-2} . Its initial velocity is 4 m s^{-1} .
 - (a) Find its velocity after 6 s.
 - (b) Find the distance travelled in the first 6 s. [4]
2. A ball is projected vertically upwards from ground level with speed 14 m s^{-1} .
 - (a) Find the maximum height reached.
 - (b) Find the time taken for the ball to return to the ground.
 - (c) State one modelling assumption you have made. [5]
3. A car travelling at 30 m s^{-1} brakes with constant deceleration and comes to rest in 75 m.
 - (a) Find the deceleration.
 - (b) Find the time taken to stop. [4]
4. A lift of mass 400 kg carries a person of mass 60 kg.
 - (a) The lift accelerates upwards at 1.5 m s^{-2} . Find the normal reaction force exerted by the floor on the person.
 - (b) The lift then decelerates at 2 m s^{-2} while still moving upwards. Find the new normal reaction. [5]

Section B – Exam-style (Show full method, including a clear force diagram description.)

5. Two particles P and Q , of masses 3 kg and 5 kg respectively, are connected by a light inextensible string passing over a smooth fixed pulley. The system is released from rest with the string taut.
 - (a) Find the acceleration of the system.
 - (b) Find the tension in the string.
 - (c) State how you have used the fact that the pulley is smooth. [6]
6. A block A of mass 4 kg rests on a rough horizontal table. It is connected by a light inextensible string over a smooth pulley at the edge of the table to a block B of mass 2 kg hanging freely. The coefficient of friction between A and the table is 0.3. The system is released from rest.
 - (a) Find the acceleration of the system.
 - (b) Find the tension in the string.
 - (c) Find the speed of B after it has fallen 0.5 m. [7]
7. A uniform beam AB of length 4 m and mass 20 kg rests horizontally on two supports, one at A and the other at C where $AC = 3 \text{ m}$. A child of mass 30 kg stands on the beam at a point 3.5 m from A .
 - (a) Find the magnitude of the reaction at C .
 - (b) Find the magnitude of the reaction at A .
 - (c) Find the greatest distance from A at which the child can stand without the beam tipping. [7]

8. A particle is projected from a point on horizontal ground with speed 25 m s^{-1} at an angle of 40° above the horizontal.
- (a) Find the time of flight.
 - (b) Find the horizontal range.
 - (c) Find the maximum height reached. [7]
9. A box of mass 5 kg is placed on a rough plane inclined at 25° to the horizontal. The coefficient of friction between the box and the plane is 0.4 .
- (a) Find the component of the weight acting down the plane.
 - (b) Find the maximum possible frictional force.
 - (c) Show that the box slides down the plane, and find its acceleration. [7]

Section C – Extended (Longer structured questions.)

10. A stone is thrown from the top of a vertical cliff 40 m high with speed 20 m s^{-1} at an angle of 30° above the horizontal. It lands in the sea at the foot of the cliff.
- (a) Show that the time taken to reach the sea satisfies $4.9t^2 - 10t - 40 = 0$.
 - (b) Find the time taken to reach the sea.
 - (c) Find the horizontal distance from the foot of the cliff to the point where the stone lands.
 - (d) Find the speed of the stone as it hits the sea, and the angle its velocity makes with the horizontal. [10]
11. A car of mass 1000 kg tows a trailer of mass 400 kg along a straight horizontal road using a light rigid tow-bar. The engine produces a driving force of 2500 N . The resistances to motion on the car and trailer are 300 N and 200 N respectively.
- (a) Find the acceleration of the car and trailer.
 - (b) Find the tension in the tow-bar.
 - (c) The driver now applies the brakes, producing a braking force of 1800 N on the car only. The resistances are unchanged. Find the deceleration of the car and trailer.
 - (d) Find the magnitude of the force in the tow-bar during braking, and state whether it is a tension or a thrust. [9]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- $v = 4 + 2.5(6) = 19 \text{ m s}^{-1}$
 - $s = 4(6) + \frac{1}{2}(2.5)(36) = 69 \text{ m}$
- $0 = 14^2 - 2(9.8)h \Rightarrow h = 10 \text{ m}$
 - $0 = 14t - 4.9t^2 \Rightarrow t = 2.86 \text{ s (20/7)}$
 - Air resistance negligible / ball is a particle / g constant
- $0 = 900 - 2a(75) \Rightarrow a = 6 \text{ m s}^{-2}$ (deceleration)
 - $t = 30/6 = 5 \text{ s}$
- $R - 60g = 60(1.5) \Rightarrow R = 678 \text{ N}$
 - $60g - R = 60(2) \Rightarrow R = 468 \text{ N}$
- $5g - 3g = 8a \Rightarrow a = \frac{g}{4} = 2.45 \text{ m s}^{-2}$
 - $T - 3g = 3a \Rightarrow T = 36.75 \approx 36.8 \text{ N}$
 - Tension is the same on both sides of the pulley
- $B: 2g - T = 2a; A: T - 0.3(4g) = 4a$; adding: $2g - 1.2g = 6a, a = 1.31 \text{ m s}^{-2}$ ($0.8g/6$)
 - $T = 2(g - a) = 17.0 \text{ N}$
 - $v^2 = 2(1.307)(0.5), v = 1.14 \text{ m s}^{-1}$
- Moments about $A: 3R_C = 20g(2) + 30g(3.5) = 145g, R_C = 474 \text{ N}$
 - $R_A = 50g - R_C = 16.3 \text{ N}$
 - Tipping: $R_A = 0$; moments about $C: 30g(d - 3) = 20g(1) \Rightarrow d = 3\frac{2}{3} = 3.67 \text{ m}$
- $0 = 25 \sin 40^\circ t - 4.9t^2 \Rightarrow t = 3.28 \text{ s}$
 - $25 \cos 40^\circ \times 3.280 = 62.8 \text{ m}$
 - $\frac{(25 \sin 40^\circ)^2}{2g} = 13.2 \text{ m}$
- $5g \sin 25^\circ = 20.7 \text{ N}$
 - $F_{\max} = 0.4 \times 5g \cos 25^\circ = 17.8 \text{ N}$
 - $20.7 > 17.8$ so it slides; $5a = 20.71 - 17.76, a = 0.589 \text{ m s}^{-2}$
- $u_y = 20 \sin 30^\circ = 10; -40 = 10t - 4.9t^2$
 - $t = 4.05 \text{ s}$
 - $20 \cos 30^\circ \times 4.054 = 70.2 \text{ m}$
 - $v_x = 17.32, v_y = 10 - 9.8(4.054) = -29.7$; speed = 34.4 m s^{-1} at 59.8° below the horizontal
- $2500 - 500 = 1400a \Rightarrow a = 1.43 \text{ m s}^{-2}$
 - Trailer: $T - 200 = 400(1.4286), T = 771 \text{ N}$
 - $1800 + 500 = 1400a \Rightarrow a = 1.64 \text{ m s}^{-2}$
 - Trailer: $200 + F = 400(1.6429), F = 457 \text{ N}$; thrust (tow-bar in compression)

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