

A-Level Physics – Mechanics

A-Level Physics (Edexcel/AQA/OCR style) · Total marks: 46 · Answers on the last page

Practice covering kinematics, projectiles, Newton's laws, momentum, work/energy, circular motion and simple harmonic motion. Calculator allowed; use $g = 9.81 \text{ m s}^{-2}$ throughout. Allow about 50 minutes.

Section A – Kinematics and forces (skills)

1. A car accelerates uniformly from 5.0 m s^{-1} to 25 m s^{-1} in 8.0 s .
 - (a) Calculate the acceleration of the car.
 - (b) Calculate the distance travelled during this time. [3]
2. A ball is dropped from rest from a height of 20 m above the ground (air resistance negligible).
 - (a) Calculate the speed of the ball when it lands.
 - (b) Calculate the speed of the ball after it has fallen 15 m . [3]
3. State Newton's second law of motion, and use it to explain why a resultant force is needed to keep an object moving in a circle at constant speed. [3]
4. A block of mass 5.0 kg rests on a frictionless plane inclined at 30° to the horizontal.
 - (a) Draw (describe in words) the forces acting on the block.
 - (b) Calculate the acceleration of the block down the slope. [3]

Section B – Exam-style: projectiles, momentum and energy

5. A ball is kicked with initial speed 20 m s^{-1} at 30° above the horizontal from level ground. Air resistance is negligible.
 - (a) Calculate the horizontal and vertical components of the initial velocity.
 - (b) Calculate the time of flight.
 - (c) Calculate the horizontal range and the maximum height reached. [6]
6. A trolley of mass 2.0 kg moving at 6.0 m s^{-1} collides with a stationary trolley of mass 4.0 kg . The trolleys stick together on impact.
 - (a) Calculate the common velocity immediately after the collision.
 - (b) Calculate the kinetic energy lost in the collision, and state what has happened to this energy. [4]
7. A block of mass 10 kg slides from rest down a rough slope of length 5.0 m , inclined at 20° to the horizontal. The coefficient of friction between block and slope is 0.20 .
 - (a) Calculate the normal reaction force and the friction force on the block.
 - (b) Calculate the speed of the block at the bottom of the slope. [5]
8. State the principle of conservation of momentum. A firework rocket of total mass 0.80 kg is moving at 30 m s^{-1} when it explodes into two fragments. One fragment of mass 0.50 kg continues forward at 50 m s^{-1} . Calculate the velocity of the other fragment immediately after the explosion. [4]

Section C – Challenge: circular motion and SHM

9. A car of mass 900 kg travels around a flat, unbanked circular bend of radius 50 m at constant speed 20 m s^{-1} .

- (a) Calculate the centripetal force required.
 - (b) Calculate the minimum coefficient of friction between the tyres and road needed for the car to complete the bend without skidding. [4]
10. A road is banked at angle θ so that a car can round a bend of radius 80 m at 25 m s^{-1} with no reliance on friction. Calculate θ . [3]
11. A mass of 0.50 kg is attached to a spring of spring constant 200 N m^{-1} and undergoes simple harmonic motion with amplitude 0.050 m on a frictionless horizontal surface.
- (a) Calculate the angular frequency ω and the period T of the oscillation.
 - (b) Calculate the maximum speed and maximum acceleration of the mass. [5]
12. For the mass–spring system in the previous question, explain, with reference to the defining equation of SHM ($a = -\omega^2 x$), how the acceleration and restoring force vary as the mass passes through the equilibrium position and through the extremes of its motion. [3]

Answers

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

- $a = \frac{25 - 5.0}{8.0} = 2.5 \text{ m s}^{-2}$.
 - $s = ut + \frac{1}{2}at^2 = 5.0(8.0) + 0.5(2.5)(8.0)^2 = 120 \text{ m}$.
- $v = \sqrt{2gh} = \sqrt{2(9.81)(20)} = 19.8 \text{ m s}^{-1}$.
 - $v = \sqrt{2(9.81)(15)} = 17.2 \text{ m s}^{-1}$.
- Newton's second law: the resultant force on an object is proportional to its rate of change of momentum, $F = ma$, in the direction of the resultant force. In circular motion at constant speed the velocity direction is continuously changing, so there is a centripetal acceleration directed toward the centre; by $F = ma$ this requires a resultant (centripetal) force directed toward the centre, even though speed is constant.
- Weight mg acting vertically downward; normal reaction N acting perpendicular to the incline surface (no friction as the plane is frictionless).
 - $a = g \sin 30^\circ = 9.81 \times 0.5 = 4.9 \text{ m s}^{-2}$ (down the slope).
- $v_x = 20 \cos 30^\circ = 17.3 \text{ m s}^{-1}$, $v_y = 20 \sin 30^\circ = 10.0 \text{ m s}^{-1}$.
 - $t = \frac{2v_y}{g} = \frac{2(10.0)}{9.81} = 2.04 \text{ s}$.
 - Range $= v_x t = 17.3 \times 2.04 = 35.3 \text{ m}$. Max height $= \frac{v_y^2}{2g} = \frac{100}{19.62} = 5.10 \text{ m}$.
- By conservation of momentum: $v = \frac{(2.0)(6.0) + 0}{2.0 + 4.0} = 2.0 \text{ m s}^{-1}$.
 - $E_{k,\text{before}} = \frac{1}{2}(2.0)(6.0)^2 = 36 \text{ J}$, $E_{k,\text{after}} = \frac{1}{2}(6.0)(2.0)^2 = 12 \text{ J}$. Energy lost $= 36 - 12 = 24 \text{ J}$; this energy is transferred to heat and sound (and to permanent deformation) during the (perfectly inelastic) collision.
- $N = mg \cos 20^\circ = 10(9.81) \cos 20^\circ = 92.2 \text{ N}$. Friction $= \mu N = 0.20 \times 92.2 = 18.4 \text{ N}$.
 - Resultant force down slope $= mg \sin 20^\circ - \mu N = 33.6 - 18.4 = 15.1 \text{ N}$, so $a = 1.51 \text{ m s}^{-2}$. Using $v^2 = u^2 + 2as = 2(1.51)(5.0) = 15.1$, $v = 3.9 \text{ m s}^{-1}$.
- Conservation of momentum: in an isolated system (no external resultant force) the total momentum before an event equals the total momentum after. Momentum before $= 0.80 \times 30 = 24 \text{ kg m s}^{-1}$. Mass of second fragment $= 0.80 - 0.50 = 0.30 \text{ kg}$. $24 = (0.50)(50) + (0.30)v \Rightarrow 24 - 25 = 0.30v \Rightarrow v = -3.3 \text{ m s}^{-1}$, i.e. 3.3 m s^{-1} in the direction opposite to the rocket's original motion.
- $F = \frac{mv^2}{r} = \frac{900(20)^2}{50} = 7200 \text{ N}$.
 - Friction provides the centripetal force, so $\mu mg \geq \frac{mv^2}{r} \Rightarrow \mu \geq \frac{v^2}{rg} = \frac{400}{50(9.81)} = 0.82$.
- For no friction needed, $\tan \theta = \frac{v^2}{rg} = \frac{625}{80(9.81)} = 0.796$, so $\theta = 38.5^\circ$.
- $\omega = \sqrt{k/m} = \sqrt{200/0.50} = 20 \text{ rad s}^{-1}$. $T = \frac{2\pi}{\omega} = 0.314 \text{ s}$.
 - $v_{\text{max}} = \omega A = 20 \times 0.050 = 1.0 \text{ m s}^{-1}$. $a_{\text{max}} = \omega^2 A = 400 \times 0.050 = 20 \text{ m s}^{-2}$.
- At the equilibrium position $x = 0$, so $a = -\omega^2 x = 0$: the restoring force and acceleration are zero and speed is maximum. At the extremes of the motion (displacement $= \pm A$), $|x|$ is maximum, so

the magnitude of the acceleration (and restoring force) is maximum ($\omega^2 A$), directed back toward the equilibrium position, while the speed is momentarily zero.

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