Take $g = 9{\cdot}8\ \text{ms}^{-2}$ and give all answers correct to 3 significant figures where necessary.

1. A heavy ball, of mass 2 kg, rolls along a horizontal surface. It strikes a vertical wall at a speed of $4\ \text{ms}^{-1}$ and rebounds. The coefficient of restitution between the ball and the wall is 0·4.
   Find the kinetic energy lost in the impact. **(5 marks)**

2. The velocity, $v\ \text{ms}^{-1}$, of a particle at time t s is given by $v = 4t^2 - 9$.
   (a) Find the acceleration of the particle when it is instantaneously at rest. **(3 marks)**
   (b) Find the distance travelled by the particle from time $t = 0$ until it comes to rest. **(4 marks)**

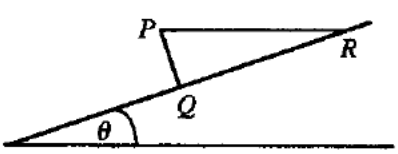
3. A particle P moves in a plane such that its position vector $\mathbf{r}$ metres at time t seconds, relative to a fixed origin O, is $\mathbf{r} = e^t\mathbf{i} - 2t\mathbf{j}$.
   (a) Find the velocity vector of P at time t seconds. **(2 marks)**
   (b) Show that the direction of the acceleration of P is constant. **(2 marks)**
   (c) Find the value of t when the acceleration of P has magnitude $12\ \text{ms}^{-2}$. **(3 marks)**

4. A uniform plank of wood XY, of mass 1·4 kg, rests with its upper end X against a rough vertical wall and its lower end Y on rough horizontal ground. The coefficient of friction between the plank and both the wall and the ground is μ. The plank is in limiting equilibrium at both ends and the vertical component of the force exerted on the plank by the ground has magnitude 12 N.
   Find the value of μ, to 2 decimal places. **(8 marks)**

5. A motor-cycle and its rider have a total mass of 460 kg. The maximum rate at which the cycle's engine can work is 25 920 W and the maximum speed of the cycle on a horizontal road is $36\ \text{ms}^{-1}$. A variable resisting force acts on the cycle and has magnitude kv^2, where v is the speed of the cycle in ms^{-1}.
   (a) Show that $k = \frac{5}{9}$. **(4 marks)**
   (b) Find the acceleration of the cycle when it is moving at $25\ \text{ms}^{-1}$ on the horizontal road, with its engine working at full power. **(5 marks)**

6. PQR is a triangular lamina with $PQ = 18$ cm, $QR = 24$ cm and $PR = 30$ cm.

(a) Verify that angle PQR is a right angle and find the distances of the centre of mass of the lamina from (i) PQ, (ii) QR. **(5 marks)**



The lamina is held in a vertical plane and placed on a line of greatest slope of a rough plane inclined at an angle θ to the horizontal, as shown.

(b) Find the largest value of θ for which equilibrium will not be broken by toppling. **(4 marks)**

7. Two smooth spheres A and B, of equal radius and masses $9m$ and $4m$ respectively, are moving towards each other along a straight line with speeds 4 ms^{-1} and 6 ms^{-1} respectively. They collide, after which the direction of motion of A remains unchanged.

(a) Show that the speed of B after the impact cannot be more than 3 ms^{-1}. **(5 marks)**

The coefficient of restitution between A and B is e.

(b) Show that $e < \frac{3}{10}$. **(5 marks)**

(c) Find the speeds of A and B after the impact in the case when $e = 0$. **(4 marks)**

8. An aeroplane, travelling horizontally at a speed of 55 ms^{-1} at a height of 600 metres above horizontal ground, drops a sealed packet of leaflets. Find

(a) the time taken by the packet to reach the ground, **(3 marks)**

(b) the horizontal distance moved by the packet during this time. **(2 marks)**

The packet will split open if it hits the ground at a speed in excess of 125 ms^{-1}.

(c) Determine, with explanation, whether the packet will split open. **(5 marks)**

(d) Find the lowest speed at which the aeroplane could be travelling, at the same height of 600 m, to ensure that the packet will split open when it hits the ground. **(3 marks)**

One of the leaflets is stuck to the front of the packet and becomes detached as it leaves the aeroplane.

(e) If the leaflet is modelled as a particle, state how long it takes to reach the ground. **(1 mark)**

(f) Comment on the model of the leaflet as a particle. **(2 marks)**

