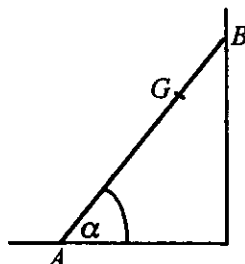


Take $g = 9.8 \text{ ms}^{-2}$ and give all answers correct to 3 significant figures where necessary.

1. A ball, of mass m kg, is moving with velocity $(5\mathbf{i} - 3\mathbf{j}) \text{ ms}^{-1}$ when it receives an impulse of $(-2\mathbf{i} - 4\mathbf{j}) \text{ Ns}$. Immediately after the impulse is applied, the ball has velocity $(3\mathbf{i} + k\mathbf{j}) \text{ ms}^{-1}$. Find the values of the constants k and m . (6 marks)

2. A particle P , initially at rest at the point O , moves in a straight line such that at time t seconds after leaving O its acceleration is $(12t - 15) \text{ ms}^{-2}$. Find
 - (a) the velocity of P at time t seconds after it leaves O , (3 marks)
 - (b) the value of t when the speed of P is 36 ms^{-1} . (3 marks)

3. A non-uniform ladder AB , of length $3a$, has its centre of mass at G , where $AG = 2a$. The ladder rests in limiting equilibrium with the end B against a smooth vertical wall and the end A resting on rough horizontal ground. The angle between AB and the horizontal in this position is α , where $\tan \alpha = \frac{14}{9}$. Calculate the coefficient of friction between the ladder and the ground. (7 marks)


4. A particle P starts from the point O and moves such that its position vector \mathbf{r} m relative to O after t seconds is given by $\mathbf{r} = at^2\mathbf{i} + bt\mathbf{j}$. 60 seconds after P leaves O it is at the point Q with position vector $(90\mathbf{i} + 30\mathbf{j}) \text{ m}$.
 - (a) Find the values of the constants a and b . (3 marks)
 - (b) Find the speed of P when it is at Q . (4 marks)
 - (c) Sketch the path followed by P for $0 \leq t \leq 60$. (2 marks)

5. A lorry of mass 4200 kg can develop a maximum power of 84 kW. On any road the lorry experiences a non-gravitational resisting force which is directly proportional to its speed. When the lorry is travelling at 20 ms^{-1} the resisting force has magnitude 2400 N. Find the maximum speed of the lorry when it is
 - (a) travelling on a horizontal road, (4 marks)
 - (b) climbing a hill inclined at an angle α to the horizontal, where $\sin \alpha = \frac{1}{7}$. (6 marks)

6. Two railway trucks, P and Q , of equal mass, are moving towards each other with speeds $4u$ and $5u$ respectively along a straight stretch of rail which may be modelled as being smooth. They collide and move apart. The coefficient of restitution between P and Q is e .

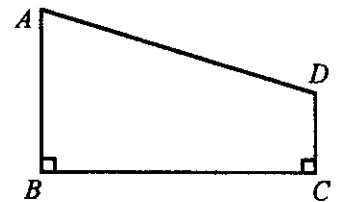
(a) Find, in terms of u and e , the speed of Q after the collision. **(6 marks)**

(b) Show that $e > \frac{1}{9}$. **(2 marks)**

Q now hits a fixed buffer and rebounds along the track. P continues to move with the speed that it had immediately after it collided with Q .

(c) Prove that it is impossible for a further collision between P and Q to occur. **(3 marks)**

7. A uniform lamina is in the form of a trapezium $ABCD$, as shown. AB and DC are perpendicular to BC . $AB = 17$ cm, $BC = 21$ cm and $CD = 8$ cm.



(a) Find the distances of the centre of mass of the lamina from
(i) AB , (ii) BC .

(8 marks)

The lamina is freely suspended from C and rests in equilibrium.

(b) Find the angle between CD and the vertical.

(3 marks)

8. A stone, of mass 1.5 kg, is projected horizontally with speed 4 ms^{-1} from a height of 7 m above horizontal ground.

(a) Show that the stone travels about 4.78 m horizontally before it hits the ground.

(4 marks)

(b) Find the height of the stone above the ground when it has travelled half of this horizontal distance.

(4 marks)

(c) Calculate the potential energy lost by the stone as it moves from its point of projection to the ground.

(2 marks)

(d) Showing your method clearly, use your answer to part (c) to find the speed with which the stone hits the ground.

(3 marks)

(e) State two modelling assumptions that you have made in answering this question.

(2 marks)