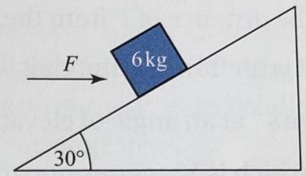
In questions that tell you to show your working, you shouldn't depend solely on a calculator. For these questions, solutions based entirely on graphical or numerical methods are not acceptable.

1 A particle moves with an initial velocity of $(14\mathbf{i} - 4\mathbf{j})\ \text{m s}^{-1}$ and a constant acceleration of $(-\mathbf{i} + 7\mathbf{j})\ \text{m s}^{-2}$

a Work out its velocity at time $t = 4$ **[3 marks]**

b Work out its speed at this time. **[2]**

2 A box of mass 6 kg moves up a smooth plane, at constant velocity, under action of a horizontal force of magnitude F Newtons. The plane is inclined at an angle of 30° to the horizontal. Work out the value of F **[5]**



3 An object moving with constant acceleration has an initial velocity of $(-2\mathbf{i} + 5\mathbf{j})\ \text{m s}^{-1}$. Six seconds later it has a velocity of $(4\mathbf{i} - 7\mathbf{j})\ \text{m s}^{-1}$. Work out

a Its acceleration, **[3]**

b The distance of the object from its starting position after these six seconds. **[4]**

4 A particle is projected with a velocity of $58.8\ \text{m s}^{-1}$ at an angle of 30° to the horizontal from a point, X, on horizontal ground. Taking $g = 9.81\ \text{m s}^{-2}$, work out

a The highest point above the ground of the path of the particle, **[4]**

b The distance from X to the point where the particle lands, giving your answer correct to the nearest metre. **[5]**

5 A stone is thrown horizontally with a velocity of $20\ \text{m s}^{-1}$ from the top of a vertical cliff. Five seconds later the stone reaches the sea. Work out

a The height of the cliff, **[3]**

b The horizontal distance from the base of the cliff to the point where the stone lands, **[2]**

c The direction in which the stone is travelling at the instant before it hits the sea. **[4]**

6 Referred to a fixed origin, the position vector, **r** metres, of a particle, P, at a time t seconds is given by $\mathbf{r} = (\sin 2t)\mathbf{i} + (\cos 4t)\mathbf{j}$, where $t \geq 0$. At the instant when $t = \frac{\pi}{6}$, work out

a The velocity of P, showing your working, **[4]**

b The acceleration of P, showing your working. **[4]**

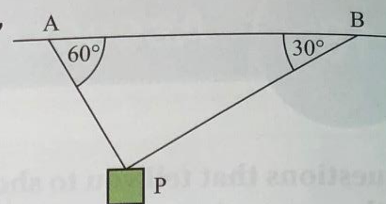
7 A particle moves through the origin with constant acceleration. It has an initial velocity of $(2\mathbf{i} - 3\mathbf{j})\ \text{m s}^{-1}$. After six seconds it is moving through the point with position vector $(-6\mathbf{i} + 18\mathbf{j})$ m. Work out

a Its velocity at $t = 6$ **[3]**

b Its acceleration, **[2]**

c The time at which the particle is moving parallel to the x-axis. **[2]**

8 A parcel, P, of mass 5 kg, hangs from the horizontal roof of a lift, supported by two light inextensible strings, AP and BP. The lift is accelerating upwards at $\frac{1}{5}g$ m s^{-2}. Work out



a The tension in BP, showing all your working, [7]

b The tension in AP [1]

9 A particle, P, of mass 0.4 kg moves under the action of a single force, **F** Newtons. At time t, the velocity, $\mathbf{v}$ m s^{-1} of P is given by $\mathbf{v} = \begin{pmatrix} 3t^2+5 \\ 14t-2 \end{pmatrix}$ m s^{-1}

At time $t = 0$, P is at the origin. Work out

a **F** when $t = 2$. Show all your working. [5]

b The distance of P from the origin when $t = 2$ [7]

10 A ball is hit from a point that is one metre above horizontal ground, with a velocity of 20 m s^{-1} at an angle of elevation of α where $\tan\alpha = \frac{4}{3}$. The ball just clears a vertical wall, which is 12 metres horizontally from the point where the ball was hit.

Work out (to 3 sf)

a The height of the wall, [7]

b The speed of the ball at the instant when it passes over the wall, [4]

c The direction in which the ball is travelling at the instant when it passes over the wall. [2]

11 At time $t = 0$, a particle, P, is at rest at the point (2, 0). At time t seconds, its acceleration, $\mathbf{a}$ m s^{-2} is given by $\mathbf{a} = \begin{pmatrix} 16\cos 4t \\ \sin t - 2\sin 2t \end{pmatrix}$. Work out

a The acceleration of P when $t = \frac{\pi}{2}$ [2]

b The velocity of P when $t = \frac{\pi}{4}$ [7]

c The position of P when $t = \pi$ [7]

12 Two boats, P and Q, are travelling with constant velocities $(3\mathbf{i} - 8\mathbf{j})$ km h^{-1} and $(-7\mathbf{i} + 12\mathbf{j})$ km h^{-1} respectively, relative to a fixed origin O. At noon, the position vectors of P and Q are $(4\mathbf{i} + 11\mathbf{j})$ km and $(9\mathbf{i} + 3.5\mathbf{j})$ km respectively. At time t hours after noon, the position vectors of P and Q, relative to O, are $\mathbf{S}_P$ and $\mathbf{S}_Q$. Write

a An expression in terms of t for $\mathbf{S}_P$ [2]

b An expression in terms of t for $\mathbf{S}_Q$ [2]

At a time, t hours after noon, the distance between the boats is given by d km

c Prove that $d^2 = (-5 + 10t)^2 + (7.5 - 20t)^2$ [4]

d Work out the time at which the boats are closest together. Show all your working. [5]

e Work out the distance between the boats at the time when they are closest together. [2]

13 A particle is projected from a point O, with an initial velocity of u m s^{-1}, at an angle of α to the horizontal. In the vertical plane of projection, taking x and y as the horizontal and vertical axes respectively

a Show that $y = x\tan\alpha - \frac{gx^2}{2u^2}\sec^2\alpha$ [5]

Given that $u = 42$ and that the particle passes through the point (60, 70)

b Find the two possible angles of projection. Take $g = 9.8$ m s^{-2} and show all your working. [6]