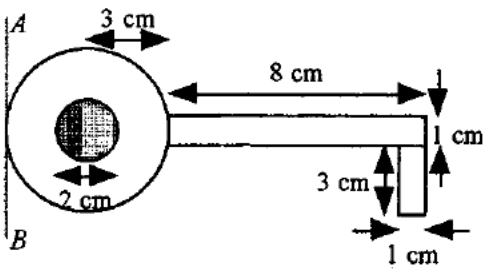
Take $g = 9{\cdot}8\ \text{ms}^{-2}$ and give all answers correct to 3 significant figures where necessary.

1. A particle P moves in a straight line so that its velocity $v\ \text{ms}^{-1}$ at time t seconds is given, for $t > 1$, by the formula $v = 2t + \frac{8}{t^2}$. Find the time when the acceleration of P is zero. **(5 marks)**

2. 

A key is modelled as a lamina which consists of a circle of radius 3 cm, with a circle of radius 1 cm removed from its centre, attached to a rectangle of length 8 cm and width 1 cm, with a rectangle measuring 3 cm by 1 cm fixed to its end as shown.
Calculate the distance of the centre of mass of the key from the line marked AB. **(7 marks)**

3. A van of mass 1600 kg is moving with constant speed **down** a straight road inclined at 7° to the horizontal. The non-gravitational resistance to the van's motion has a constant magnitude of 2000 N and the engine of the van is working at a rate of 1·5 kW. Find
   (a) the constant speed of the van, **(5 marks)**
   (b) the acceleration of the van if the resistance is suddenly reduced to 1900 N. **(2 marks)**

4. **i** and **j** are perpendicular unit vectors in a horizontal plane. A body of mass 1 kg moves under the action of a constant force $(4\mathbf{i} + 5\mathbf{j})$ N. The body moves from the point P with position vector $(-3\mathbf{i} - 15\mathbf{j})$ m to the point Q with position vector $9\mathbf{i}$ m.
   (a) Find the work done by the force in moving the body from P to Q. **(5 marks)**
   (b) Given that the body started from rest at P, find its speed when it is at Q. **(5 marks)**

5. Two railway trucks A and B, whose masses are $6m$ and $5m$ respectively, are moving in the same direction along a straight track with speeds $5u$ and $3u$ respectively, and collide directly. Immediately after this impact the speeds of A and B are v and kv respectively, in the same direction as before. The coefficient of restitution between A and B is e.
   Modelling the trucks as particles,
   (a) show that (i) $v = \frac{45u}{5k+6}$, (ii) $v = \frac{2eu}{k-1}$. **(8 marks)**
   (b) Use the fact that $0 \le e \le 1$ to deduce the range of possible values of k. **(5 marks)**

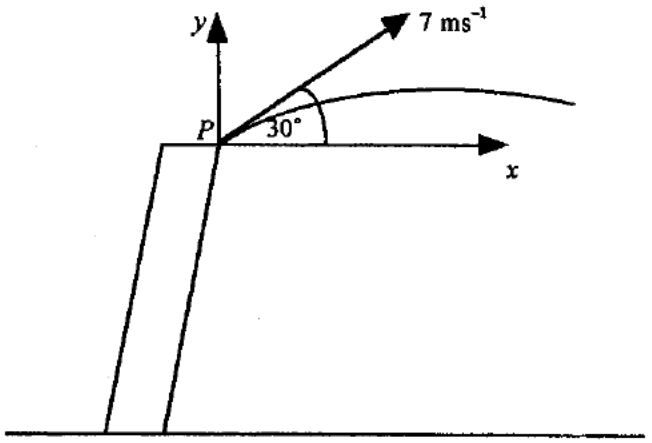
6. A piece of lead and a table tennis ball are dropped together from a point P near the top of the Leaning Tower of Pisa. The lead hits the ground after 3·3 seconds.

(a) Calculate the height above ground from which the lead was dropped. **(2 marks)**

According to a simple model, the ball hits the ground at the same time as the lead.

(b) State why this may not be true in practice and describe a refinement to the model which could lead to a more realistic solution. **(2 marks)**

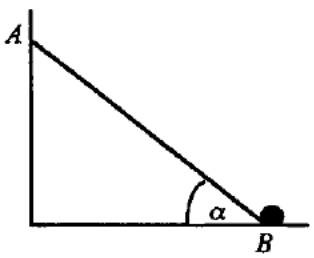
The piece of lead is now thrown again from P, with speed 7 ms^{-1} at an angle of 30° to the horizontal, as shown.



(c) Find expressions in terms of t for x and y, the horizontal and vertical displacements respectively of the piece of lead from P at time t seconds after it is thrown. **(4 marks)**

(d) Deduce that $y = \frac{\sqrt{3}}{3}x - \frac{2}{15}x^2$. **(3 marks)**

(e) Find the speed of the piece of lead when it has travelled 10 m horizontally from P. **(5 marks)**

7. 

A uniform ladder AB, of mass m kg and length $2a$ m, rests with its upper end A in contact with a smooth vertical wall and its lower end B in contact with a fixed peg on horizontal ground. The ladder makes an angle α with the ground, where $\tan\alpha = \frac{3}{4}$.

(a) Show that the magnitude of the resultant force acting on the ladder at B is $\frac{\sqrt{13}}{3}mg$. **(7 marks)**

(b) Find, to the nearest degree, the direction of this resultant force at B. **(3 marks)**

The peg will break when the horizontal force acting on it exceeds $2mg$ N.

A painter of mass $6m$ kg starts to climb the ladder from B.

(c) Find, in terms of a, the greatest distance up the ladder that the painter can safely climb. **(7 marks)**

