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

1. A golf ball and a table tennis ball are dropped together from the top of a building. The golf ball hits the ground after 1·7 seconds.

   (a) Calculate the height of the top of the building above the ground. **(3 marks)**

   According to a simple model, the two balls hit the ground at the same time.

   (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)**

2. A plank of wood XY has length $5a$ m and mass 5 kg. It rests on a support at Q, where $XQ = 3a$ m. When a kitten of mass 8 kg sits on the plank at P, where $PY = a$ m, the plank just remains horizontal.

   By modelling the plank as a non-uniform rod and the kitten as a particle, find

   (a) the magnitude of the reaction at the support, **(2 marks)**

   (b) the distance from X to the centre of mass of the plank, in terms of a. **(3 marks)**

3. A particle is in equilibrium under the action of three forces **P**, **Q** and **R** acting in the same horizontal plane. **P** has magnitude 9 N and acts on a bearing of 030°. **Q** has magnitude 12 N. and acts on a bearing of 225°.

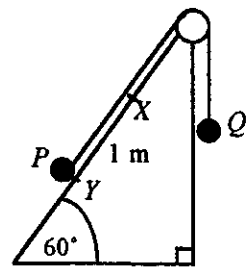
   (a) Find the values of a and b such that $\mathbf{R} = (a\mathbf{i} + b\mathbf{j})$ N, where **i** and **j** are unit vectors in the directions due East and due North respectively. **(5 marks)**

   (b) Calculate the magnitude and direction of **R**. **(4 marks)**

4. X and Y are two points 1 m apart on a line of greatest slope of a smooth plane inclined at 60° to the horizontal. A particle P of mass 1 kg is released from rest at X.

   (a) Find the speed with which P reaches Y. **(4 marks)**

   P is now connected to another particle Q, of mass M kg, by a light inextensible string. The system is placed with P at Y on the plane and Q hanging vertically at the other end of the string, which passes over a fixed pulley at the top of the plane.

   The system is released from rest and P moves up the plane with acceleration $\frac{g}{5}$.

   (b) Show that $M = \frac{5\sqrt{3}+2}{8}$. **(7 marks)**

   (c) State a modelling assumption that you have made about the pulley. Briefly state what would be implied if this assumption were not made. **(2 marks)**

5. Two model cars A and B have masses 200 grams and k grams respectively. They move towards each other in a straight line and collide directly when their speeds are 5 ms^{-1} and 4 ms^{-1} respectively. As a result the speed of A is reduced to 2 ms^{-1}, in the same direction as before. The direction of B's motion is reversed and its speed immediately after the impact is 5 ms^{-1}.

(a) Find the magnitude of the impulse exerted by A on B in the impact. State the units of your answer. **(3 marks)**

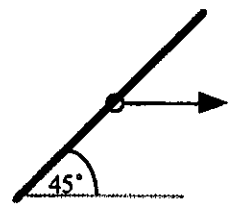
(b) Find the value of k. **(3 marks)**

The surface on which the cars move is rough, and B comes to rest 3 seconds after the impact. The coefficient of friction between both cars and the surface is μ.

(c) Find the value of μ. **(4 marks)**

(d) Find the distance travelled by A after the impact before it comes to rest. **(3 marks)**

6. A small ring, of mass m kg, can slide along a straight wire which is fixed at an angle of 45° to the horizontal as shown. The coefficient of friction between the ring and the wire is $\frac{2}{7}$.



The ring rests in equilibrium on the wire and is just prevented from sliding down the wire when a horizontal string is attached to it, as shown

(a) Show that the tension in the string has magnitude $\frac{5mg}{9}$ N. **(8 marks)**

The string is now removed and the ring starts to slide down the wire.

(b) Find the time that elapses before the ring has moved 10 cm along the wire. **(7 marks)**

7. Two cyclists, Alice and Bobbie, travel from P to Q along a straight path. Alice starts from rest at P just as Bobbie passes her at 3·5 ms^{-1}. Bobbie continues at this speed while Alice accelerates at 0·2 ms^{-2} for T seconds until she attains her maximum speed. At this moment both cyclists immediately start to slow down, with constant but different decelerations, and they come to rest at Q 80 seconds after Alice started moving.

(a) Sketch, on the same diagram, the velocity-time graphs for the two cyclists. **(6 marks)**

By using the fact that both cyclists cover the same distance, find

(b) the value of T, **(5 marks)**

(c) the distance between P and Q, **(2 marks)**

(d) the magnitude of Bobbie's deceleration. **(2 marks)**

