

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

- 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)**

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

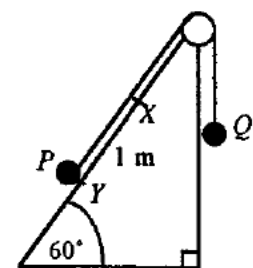
(a) Find the values of a and b such that $\mathbf{R} = (ai + bj)$ N, where \mathbf{i} and \mathbf{j} are unit vectors in the directions due East and due North respectively. **(5 marks)**

(b) Calculate the magnitude and direction of \mathbf{R} . **(4 marks)**

- 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)**

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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)

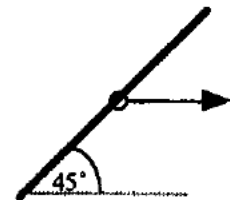
The surface on which the cars move is rough, and B comes to rest 3 seconds after the impact.

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)