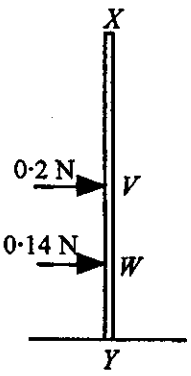
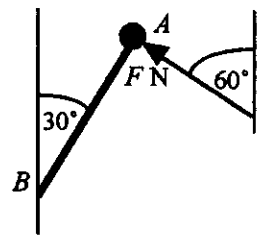
Take $g = 9{\cdot}8$ ms^{-2} and give all answers correct to 3 significant figures where necessary.

1. 

A vertical pole XY, of length 2·5 m and mass 0·5 kg, has its lower end Y free to move in a smooth horizontal groove. Forces of magnitude 0·2 N and 0·14 N are applied to the pole horizontally at the points V and W respectively, where $XV = 1{\cdot}5$ m and $VW = 0{\cdot}5$ m.
Find, to the nearest cm, the distance from X at which an opposing horizontal force must be applied to keep the pole at rest in equilibrium, and state the magnitude of this force. **(6 marks)**

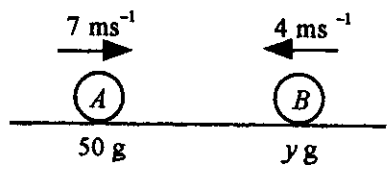
2. A particle passes through a point O with speed 9 ms^{-1} and moves in a straight line with constant acceleration 3·6 ms^{-2} for t seconds until it reaches the point P. The acceleration is then reduced to 2 ms^{-2} and this is maintained for another t seconds until the particle passes the point Q with speed 16 ms^{-1}. Calculate
   (a) the time taken by the particle to travel from O to Q, **(4 marks)**
   (b) the distance OQ. **(3 marks)**

3. A lump of clay, of mass 0·8 kg, is attached to the end A of a light rod AB, which is pivoted at its other end B so that it can rotate smoothly in a vertical plane. A force is applied to A at an angle of 60° to the vertical, as shown, the magnitude F N of this force being just enough to hold the lump of clay in equilibrium with AB inclined at an angle of 30° to the upward vertical.

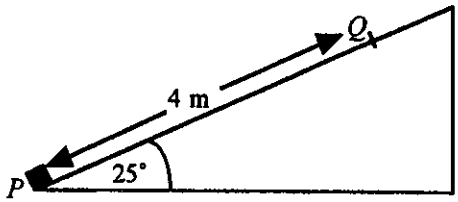


   (a) Find the value of F, **(6 marks)**
   (b) Find the magnitude of the force in the rod AB. **(2 marks)**
   (c) State the modelling assumption that you have made about the lump of clay. **(1 mark)**

4. Two particles A and B, of masses 50 grams and y grams, are moving in the same straight line, in opposite directions, with speeds 7 ms^{-1} and 4 ms^{-1} respectively, and collide.



In each of the following separate cases, find the value of y and the magnitude of the impulse exerted by each particle on the other:
   (a) after impact the particles move together with speed 2·25 ms^{-1}; **(5 marks)**
   (b) after impact the particles move in opposite directions with speed 5 ms^{-1}. **(5 marks)**

5. 

A small stone is projected with speed 7 ms^{-1} from P, the bottom of a rough plane inclined at 25° to the horizontal, and moves up a line of greatest slope of the plane until it comes to instantaneous rest at Q, where $PQ = 4$ m.

(a) Show that the deceleration of the stone as it moves up the plane has magnitude $\frac{49}{8}$ ms^{-2}. **(2 marks)**

(b) Find the coefficient of friction between the stone and the plane, **(4 marks)**

(c) Find the speed with which the stone returns to P. **(4 marks)**

(d) Name one force which you have ignored in your mathematical model, and state whether the answer to part (c) would be larger or smaller if that force were taken into account. **(2 marks)**

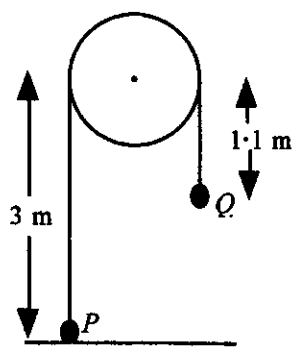
6. The points A and B have position vectors $(30\mathbf{i} - 60\mathbf{j})$ m and $(-20\mathbf{i} + 60\mathbf{j})$ m respectively relative to an origin O, where $\mathbf{i}$ and $\mathbf{j}$ are perpendicular unit vectors. A cyclist, Chris, starts at A and cycles towards B with constant speed 2·6 ms^{-1}. Another cyclist, Doug, starts at O and cycles towards B with constant speed $k\sqrt{10}$ ms^{-1}.

(a) Show that Chris's velocity vector is $(-\mathbf{i} + 2{\cdot}4\mathbf{j})$ ms^{-1}. **(4 marks)**

(b) Find Doug's velocity vector in the form $k(a\mathbf{i} + b\mathbf{j})$ ms^{-1}. **(4 marks)**

Given that Chris and Doug arrive at B at the same time,

(c) find the value of k. **(6 marks)**

7. 

A particle P, of mass 4 kg, rests on horizontal ground and is attached by a light, inextensible string to another particle Q of mass 4·5 kg. The string passes over a smooth pulley whose centre is 3 m above the ground. Initially Q is 1·1 m below the level of the centre of the pulley. The system is released from rest in this position.

(a) Find the acceleration of the two particles. **(5 marks)**

(b) Find the speed with which Q hits the ground. **(3 marks)**

Assuming that Q does not rebound from the ground while the string is slack,

(c) show that P does not reach the pulley before Q starts to move again. **(6 marks)**

(d) Find the speed with which Q leaves the ground when the string again becomes taut. **(3 marks)**

