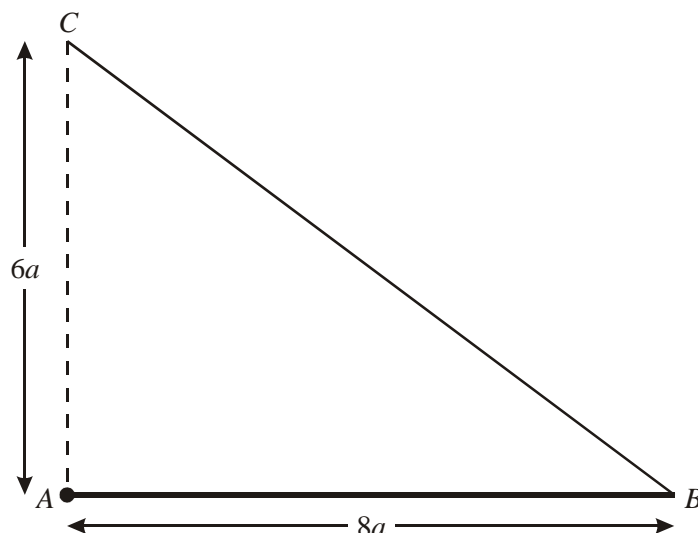


1.



A uniform rod AB , of length $8a$ and weight W , is free to rotate in a vertical plane about a smooth pivot at A . One end of a light inextensible string is attached to B . The other end is attached to point C which is vertically above A , with $AC = 6a$. The rod is in equilibrium with AB horizontal, as shown in the diagram.

- (a) By taking moments about A , or otherwise, show that the tension in the string is $\frac{5}{6}W$.

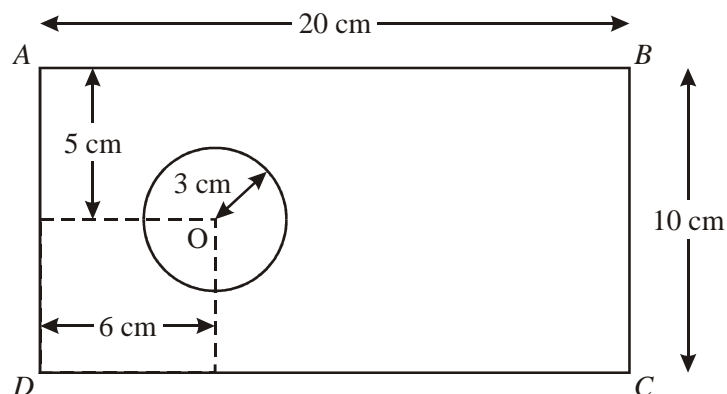
(4)

- (b) Calculate the magnitude of the horizontal component of the force exerted by the pivot on the rod.

(3)

(Total 7 marks)

2.



This diagram shows a metal plate that is made by removing a circle of centre O and radius 3 cm from a uniform rectangular lamina $ABCD$, where $AB = 20$ cm and $BC = 10$ cm. The point O is 5 cm from both AB and CD and is 6 cm from AD .

- (a) Calculate, to 3 significant figures, the distance of the centre of mass of the plate from AD .

(5)

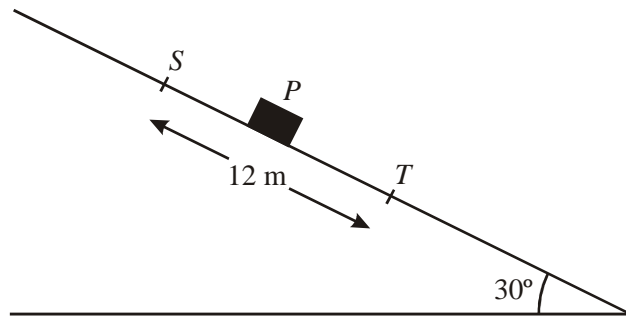
The plate is freely suspended from A and hangs in equilibrium.

- (b) Calculate, to the nearest degree, the angle between AB and the vertical.

(3)

(Total 8 marks)

3.



A small package P is modelled as a particle of mass 0.6 kg . The package slides down a rough plane from a point S to a point T , where $ST = 12\text{ m}$. The plane is inclined at an angle of 30° to the horizontal and ST is a line of greatest slope of the plane, as shown in the diagram. The speed of P at S is 10 m s^{-1} and the speed of P at T is 9 m s^{-1} . Calculate

- (a) the total loss of energy of P in moving from S to T ,

(4)

- (b) the coefficient of friction between P and the plane.

(5)

(Total 9 marks)

4. A particle P of mass 0.4 kg is moving under the action of a single force \mathbf{F} newtons. At time t seconds, the velocity of P , $\mathbf{v}\text{ m s}^{-1}$, is given by

$$\mathbf{v} = (6t + 4)\mathbf{i} + (t^2 + 3t)\mathbf{j}.$$

When $t = 0$, P is at the point with position vector $(-3\mathbf{i} + 4\mathbf{j})\text{ m}$. When $t = 4$, P is at the point S .

- (a) Calculate the magnitude of \mathbf{F} when $t = 4$.

(4)

- (b) Calculate the distance OS .

(5)

(Total 9 marks)

5. A car of mass 1000 kg is towing a trailer of mass 1500 kg along a straight horizontal road. The tow-bar joining the car to the trailer is modelled as a light rod parallel to the road. The total resistance to motion of the car is modelled as having constant magnitude 750 N. The total resistance to motion of the trailer is modelled as of magnitude R newtons, where R is a constant. When the engine of the car is working at a rate of 50 kW, the car and the trailer travel at a constant speed of 25 m s^{-1} .

(a) Show that $R = 1250$.

(3)

When travelling at 25 m s^{-1} the driver of the car disengages the engine and applies the brakes. The brakes provide a constant braking force of magnitude 1500 N to the car. The resisting forces of magnitude 750 N and 1250 N are assumed to remain unchanged. Calculate

(b) the deceleration of the car while braking,

(3)

(c) the thrust in the tow-bar while braking,

(2)

(d) the work done, in kJ, by the braking force in bringing the car and the trailer to rest.

(4)

(e) Suggest how the modelling assumption that the resistances to motion are constant could be refined to be more realistic.

(1)

(Total 13 marks)

6. A particle P of mass $3m$ is moving with speed $2u$ in a straight line on a smooth horizontal table. The particle P collides with a particle Q of mass $2m$ moving with speed u in the opposite direction to P . The coefficient of restitution between P and Q is e .

(a) Show that the speed of Q after the collision is $\frac{1}{5}u(9e + 4)$.

(5)

As a result of the collision, the direction of motion of P is reversed.

(b) Find the range of possible values of e .

(5)

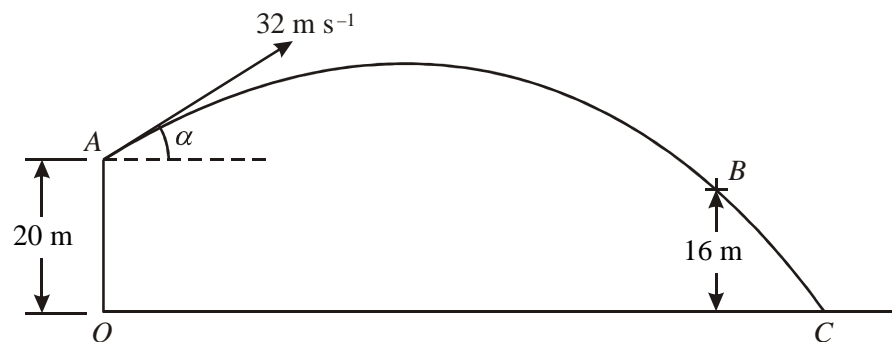
Given that the magnitude of the impulse of P on Q is $\frac{32}{5}mu$,

(c) find the value of e .

(4)

(Total 14 marks)

7.



A particle P is projected from a point A with speed 32 m s^{-1} at an angle of elevation α , where $\sin \alpha = \frac{3}{5}$. The point O is on horizontal ground, with O vertically below A and $OA = 20 \text{ m}$. The particle P moves freely under gravity and passes through a point B , which is 16 m above the ground, before reaching the ground at the point C , as shown in the diagram.

Calculate

- (a) the time of the flight from A to C , (5)
- (b) the distance OC , (3)
- (c) the speed of P at B , (4)
- (d) the angle that the velocity of P at B makes with the horizontal. (3)

(Total 15 marks)