



Answer **all** the questions.

1 A car of mass 1200 kg is driven on a long straight horizontal road. There is a constant force of 250 N resisting the motion of the car. The engine of the car is working at a constant power of 10 kW.

(a) The car can travel at constant speed  $v \text{ m s}^{-1}$  along the road. Find  $v$ . [2]

(b) Find the acceleration of the car at an instant when its speed is  $30 \text{ m s}^{-1}$ . [3]

2 A particle  $P$  of mass 4.5 kg is moving in a straight line on a smooth horizontal surface at a speed of  $2.4 \text{ m s}^{-1}$  when it strikes a vertical wall directly. It rebounds at a speed of  $1.6 \text{ m s}^{-1}$ .

(a) Find the coefficient of restitution between  $P$  and the wall. [1]

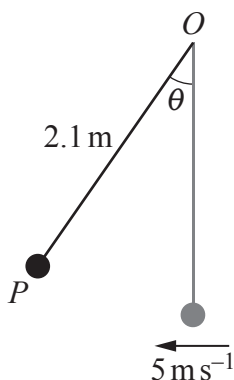
(b) Determine the impulse applied to  $P$  by the wall, stating its direction. [3]

(c) Find the loss of kinetic energy of  $P$  as a result of the collision. [2]

(d) State, with a reason, whether the collision is perfectly elastic. [1]

3 A particle  $P$  of mass 5.6 kg is attached to one end of a light rod of length 2.1 m. The other end of the rod is freely hinged to a fixed point  $O$ .

The particle is initially at rest directly below  $O$ . It is then projected horizontally with speed  $5 \text{ m s}^{-1}$ . In the subsequent motion, the angle between the rod and the downward vertical at  $O$  is denoted by  $\theta$  radians, as shown in the diagram.



(a) Find the speed of  $P$  when  $\theta = \frac{1}{4}\pi$ . [4]

(b) Find the value of  $\theta$  when  $P$  first comes to instantaneous rest. [2]

- 4 A particle  $P$  of mass  $2.4\text{ kg}$  is moving in a straight line  $OA$  on a horizontal plane.  $P$  is acted on by a force of magnitude  $30\text{ N}$  in the direction of motion. The distance  $OA$  is  $10\text{ m}$ .

(a) Find the work done by this force as  $P$  moves from  $O$  to  $A$ . [2]

The motion of  $P$  is resisted by a constant force of magnitude  $R\text{ N}$ . The velocity of  $P$  increases from  $12\text{ ms}^{-1}$  at  $O$  to  $18\text{ ms}^{-1}$  at  $A$ .

(b) Find the value of  $R$ . [3]

(c) Find the average power used in overcoming the resistance force on  $P$  as it moves from  $O$  to  $A$ . [3]

When  $P$  reaches  $A$  it collides directly with a particle  $Q$  of mass  $1.6\text{ kg}$  which was at rest at  $A$  before the collision. The impulse exerted on  $Q$  by  $P$  as a result of the collision is  $17.28\text{ N s}$ .

(d) (i) Find the speed of  $Q$  after the collision. [2]

(ii) Hence show that the collision is inelastic. [2]

- 5 A particle of mass  $m$  moves in a straight line with constant acceleration  $a$ . Its initial and final velocities are  $u$  and  $v$  respectively and its final displacement from its starting position is  $s$ . In order to model the motion of the particle it is suggested that the velocity is given by the equation

$$v^2 = pu^\alpha + qa^\beta s^\gamma$$

where  $p$  and  $q$  are dimensionless constants.

(a) Explain why  $\alpha$  must equal 2 for the equation to be dimensionally consistent. [2]

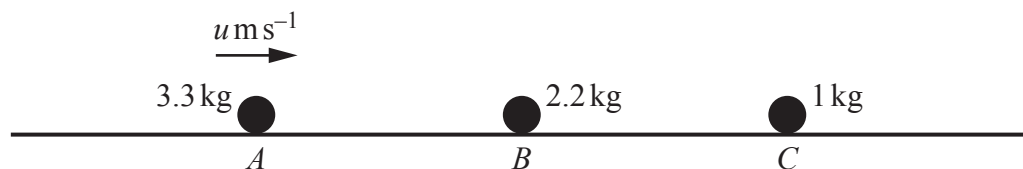
(b) By using dimensional analysis, determine the values of  $\beta$  and  $\gamma$ . [4]

(c) By considering the case where  $s = 0$ , determine the value of  $p$ . [1]

(d) By multiplying both sides of the equation by  $\frac{1}{2}m$ , and using the numerical values of  $\alpha$ ,  $\beta$  and  $\gamma$ , determine the value of  $q$ . [2]

- 6 Three particles  $A$ ,  $B$  and  $C$  are free to move in the same straight line on a large smooth horizontal surface. Their masses are 3.3 kg, 2.2 kg and 1 kg respectively. The coefficient of restitution in collisions between any two of them is  $e$ .

Initially,  $B$  and  $C$  are at rest and  $A$  is moving towards  $B$  with speed  $u \text{ m s}^{-1}$  (see diagram).  $A$  collides directly with  $B$  and  $B$  then goes on to collide directly with  $C$ .

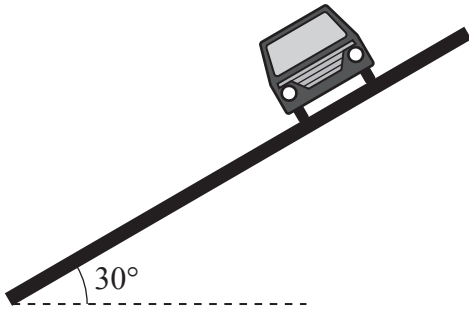


- (a) The velocities of  $A$  and  $B$  immediately after the first collision are denoted by  $v_A \text{ m s}^{-1}$  and  $v_B \text{ m s}^{-1}$  respectively.
- Show that  $v_A = \frac{u(3-2e)}{5}$ .
  - Find an expression for  $v_B$  in terms of  $u$  and  $e$ . [4]
- (b) Find an expression in terms of  $u$  and  $e$  for the velocity of  $B$  immediately after its collision with  $C$ . [4]

After the collision between  $B$  and  $C$  there is a further collision between  $A$  and  $B$ .

- (c) Determine the range of possible values of  $e$ . [4]

- 7 It is required to model the motion of a car of mass  $m$  kg travelling at a constant speed  $v$   $\text{m s}^{-1}$  around a circular portion of banked track. The track is banked at  $30^\circ$  (see diagram).



In a model, the following modelling assumptions are made.

- The track is smooth.
- The car is a particle.
- The car follows a horizontal circular path with radius  $r$  m.

(a) Show that, according to the model,  $\sqrt{3}v^2 = gr$ . [4]

For a particular portion of banked track,  $r = 24$ .

(b) Find the value of  $v$  as predicted by the model. [2]

A car is being driven on this portion of the track at the constant speed calculated in part (b). The driver finds that in fact he can drive a little slower or a little faster than this while still moving in the same horizontal circle.

(c) Explain

- how this contrasts with what the model predicts,
- how to improve the model to account for this.

[3]

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