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 $v\,\mathrm{m\,s^{-1}}$ along the road. Find v. **[2]**

(b) Find the acceleration of the car at an instant when its speed is $30\,\mathrm{m\,s^{-1}}$. **[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 $2.4\,\mathrm{m\,s^{-1}}$ when it strikes a vertical wall directly. It rebounds at a speed of $1.6\,\mathrm{m\,s^{-1}}$.

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

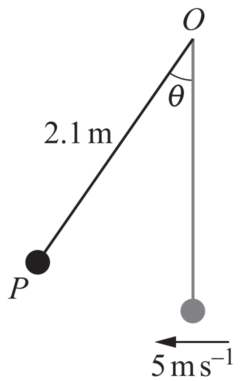
(b) Determine the impulse applied to P by the wall, stating its direction. **[3]**

(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 $5\,\mathrm{m\,s^{-1}}$. In the subsequent motion, the angle between the rod and the downward vertical at O is denoted by θ radians, as shown in the diagram.



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

(b) Find the value of θ when P first comes to instantaneous rest. **[2]**

4 A particle P of mass 2.4 kg is moving in a straight line OA on a horizontal plane. P is acted on by a force of magnitude 30 N in the direction of motion. The distance OA is 10 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 N. The velocity of P increases from $12\,\text{m s}^{-1}$ at O to $18\,\text{m s}^{-1}$ 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 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 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 α must equal 2 for the equation to be dimensionally consistent. **[2]**

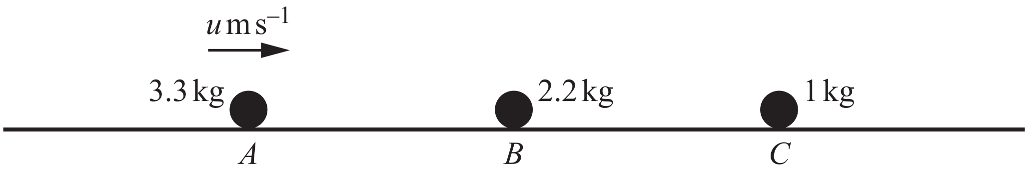
(b) By using dimensional analysis, determine the values of β and γ. **[4]**

(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 α, β and γ, 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 $u\,\mathrm{m\,s^{-1}}$ (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 $v_A\,\mathrm{m\,s^{-1}}$ and $v_B\,\mathrm{m\,s^{-1}}$ respectively.

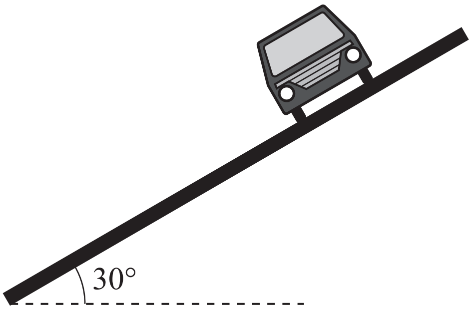
- Show that $v_A = \dfrac{u(3-2e)}{5}$.
- Find an expression for v_B in terms of u and e. **[4]**

(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 $v\,\mathrm{m\,s^{-1}}$ around a circular portion of banked track. The track is banked at 30° (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]**

END OF QUESTION PAPER

BLANK PAGE

BLANK PAGE