

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

1. Particles of mass  $2m$ ,  $3m$  and  $5m$  are placed at the points in the  $x$ - $y$  plane with coordinates  $(-1, 5)$ ,  $(0, 6)$  and  $(3, -2)$  respectively.

Find the coordinates of the centre of mass of this system of particles. **(4 marks)**

2. A lorry of mass  $3800 \text{ kg}$  is pulling a trailer of mass  $1200 \text{ kg}$  along a straight horizontal road. At a particular moment, the lorry and trailer are moving at a speed of  $10 \text{ ms}^{-1}$  and accelerating at  $0.8 \text{ ms}^{-2}$ . The resistances to the motion of the lorry and the trailer are constant and of magnitude  $1600 \text{ N}$  and  $600 \text{ N}$  respectively.

Find the rate, in kW, at which the engine of the lorry is working. **(4 marks)**

3. A bullet of mass  $0.05 \text{ kg}$  is fired with speed  $u \text{ ms}^{-1}$  from a gun, which recoils at a speed of  $0.008u \text{ ms}^{-1}$  in the opposite direction to that in which the bullet is fired.

(a) Find the mass of the gun. **(2 marks)**

(b) Find, in terms of  $u$ , the kinetic energy given to the bullet and to the gun at the instant of firing. **(4 marks)**

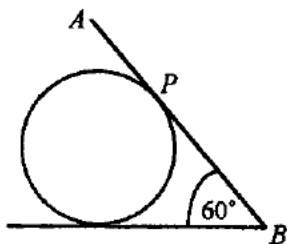
(c) If the total kinetic energy created in firing the gun is  $5100 \text{ J}$ , find the value of  $u$ . **(2 marks)**

4. The acceleration of a particle  $P$  at time  $t \text{ s}$  is  $a \text{ ms}^{-2}$ , where  $a = 4e^t i - e^t j$ . When  $t = 0$ ,  $P$  has velocity  $4i \text{ ms}^{-1}$ .

(a) Find the speed of  $P$  when  $t = 2$ . **(5 marks)**

(b) Find the time at which the direction of motion of  $P$  is parallel to the vector  $5i - j$ . **(5 marks)**

5.



A uniform plank  $AB$ , of mass  $3 \text{ kg}$  and length  $2 \text{ m}$ , rests in equilibrium with the point  $P$  in contact with a smooth cylinder. The end  $B$  rests on a rough horizontal surface and the coefficient of friction between the plank and the surface is  $\frac{1}{3}$ .  $AB$  makes an angle of  $60^\circ$  with the horizontal.

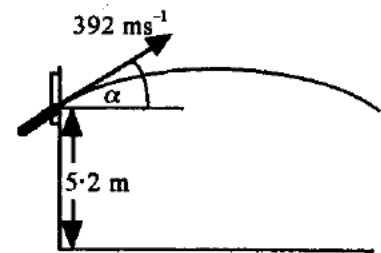
If the plank is in limiting equilibrium in this position, find

(a) the magnitude of the force exerted by the cylinder on the plank at  $P$ , **(7 marks)**

(b) the distance  $AP$ . **(3 marks)**

6. Two smooth spheres  $A$  and  $B$  have equal radii and masses  $0.4$  kg and  $0.8$  kg respectively. They are moving in opposite directions along the same straight line, with speeds  $3$   $\text{ms}^{-1}$  and  $2$   $\text{ms}^{-1}$  respectively, and collide directly. The coefficient of restitution between  $A$  and  $B$  is  $0.8$ .
- (a) Calculate the speeds of  $A$  and  $B$  after the impact, stating in each case whether the direction of motion has been reversed. (8 marks)
- (b) Find the kinetic energy, in J, lost in the impact. (3 marks)
7. A point of light,  $P$ , is moving along a straight line in such a way that,  $t$  seconds after passing through a fixed point  $O$  on the line, its velocity is  $v$   $\text{ms}^{-1}$ , where  $v = \frac{1}{2}t^2 - 4t + 10$ . Calculate
- (a) the velocity of  $P$  6 seconds after it passes  $O$ , (1 mark)
- (b) the magnitude of the acceleration of  $P$  when  $t = 1$ , (3 marks)
- (c) the minimum speed of  $P$ , (3 marks)
- (d) the distance travelled by  $P$  in the fourth second after it passes  $O$ . (5 marks)

8. A bullet is fired out of a window at a height of  $5.2$  m above horizontal ground. The initial velocity of the bullet is  $392$   $\text{ms}^{-1}$  at an angle  $\alpha$  above the vertical, where  $\sin \alpha = \frac{1}{20}$ , as shown.



- (a) the range of times after firing during which the bullet is  $15$  m or more above ground level, (6 marks)
- (b) the greatest height above the ground reached by the bullet, (3 marks)
- (c) the horizontal distance travelled by the bullet before it reaches its highest point. (3 marks)

Certain modelling assumptions have been made about the bullet.

- (d) State these assumptions and suggest a way in which the model could be refined. (2 marks)
- (e) State, with a reason, whether you think this refinement would make a significant difference to the answers. (2 marks)