1 The displacement, x m, from the origin O of a particle on the x-axis is given by

$$x = 10 + 36t + 3t^2 - 2t^3,$$

where t is the time in seconds and $-4 \leqslant t \leqslant 6$.

(i) Write down the displacement of the particle when $t = 0$. [1]

(ii) Find an expression in terms of t for the velocity, v m s^{-1}, of the particle. [2]

(iii) Find an expression in terms of t for the acceleration of the particle. [2]

(iv) Find the maximum value of v in the interval $-4 \leqslant t \leqslant 6$. [3]

(v) Show that $v = 0$ only when $t = -2$ and when $t = 3$. Find the values of x at these times. [5]

(vi) Calculate the *distance* travelled by the particle from $t = 0$ to $t = 4$. [3]

(vii) Determine how many times the particle passes through O in the interval $-4 \leqslant t \leqslant 6$. [3]

2 A particle moves along the x-axis with velocity, v m s^{-1}, at time t given by

$$v = 24t - 6t^2.$$

The positive direction is in the sense of x increasing.

(i) Find an expression for the acceleration of the particle at time t. [2]

(ii) Find the times, t_1 and t_2, at which the particle has zero speed. [2]

(iii) Find the distance travelled between the times t_1 and t_2. [4]

3 Two girls, Marie and Nina, are members of an Olympic hockey team. They are doing fitness training.

Marie runs along a straight line at a constant speed of $6\,\text{m s}^{-1}$.

Nina is stationary at a point O on the line until Marie passes her. Nina immediately runs after Marie until she catches up with her.

The time, t s, is measured from the moment when Nina starts running. So when $t = 0$, both girls are at O.

Nina's acceleration, $a\ \text{m s}^{-2}$, is given by

$$a = 4 - t \qquad \text{for } 0 \leqslant t \leqslant 4,$$

$$a = 0 \qquad \text{for } t > 4.$$

(i) Show that Nina's speed, $v\,\text{m s}^{-1}$, is given by

$$v = 4t - \tfrac{1}{2}t^2 \qquad \text{for } 0 \leqslant t \leqslant 4,$$

$$v = 8 \qquad \text{for } t > 4. \qquad \textbf{[3]}$$

(ii) Find an expression for the distance Nina has run at time t, for $0 \leqslant t \leqslant 4$.

Find how far Nina has run when $t = 4$ and when $t = 5\tfrac{1}{3}$. **[4]**

(iii) Show that Nina catches up with Marie when $t = 5\tfrac{1}{3}$. **[1]**

4 Two cars, P and Q, are being crashed as part of a film 'stunt'.

At the start

- P is travelling directly towards Q with a speed of $8\,\text{m s}^{-1}$,
- Q is instantaneously at rest and has an acceleration of $4\,\text{m s}^{-2}$ directly towards P.

P continues with the same velocity and Q continues with the same acceleration. The cars collide T seconds after the start.

(i) Find expressions in terms of T for how far each of the cars has travelled since the start. **[2]**

At the start, P is 90 m from Q.

(ii) Show that $T^2 + 4T - 45 = 0$ and hence find T. **[5]**

5 The velocity, $v\,\mathrm{m\,s^{-1}}$, of a particle moving along a straight line is given by

$$v = 3t^2 - 12t + 14,$$

where t is the time in seconds.

(i) Find an expression for the acceleration of the particle at time t. **[2]**

(ii) Find the displacement of the particle from its position when $t = 1$ to its position when $t = 3$. **[4]**

(iii) You are *given* that v is always positive. Explain how this tells you that the distance travelled by the particle between $t = 1$ and $t = 3$ has the same value as the displacement between these times. **[2]**