1 Fig. 1 shows the speed-time graph of a runner during part of his training.

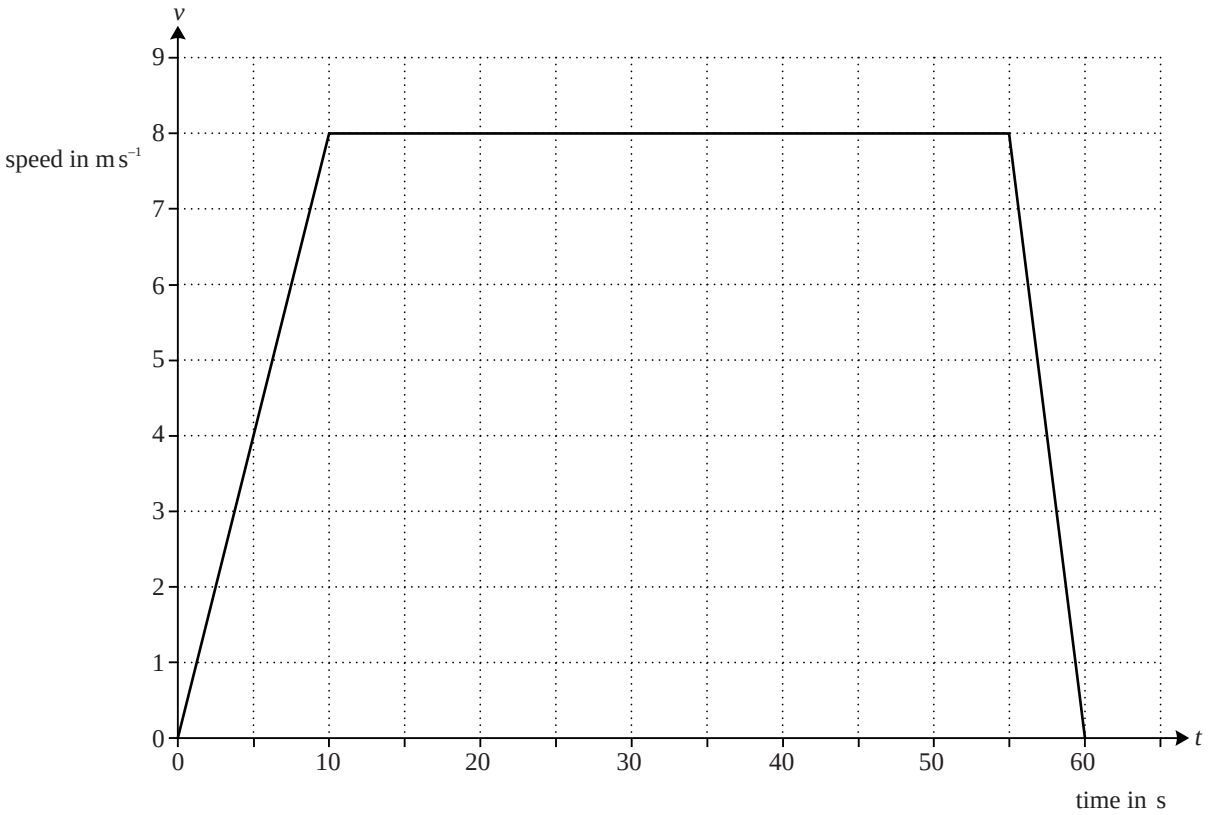

Fig. 1

For each of the following statements, say whether it is true or false. If it is false give a brief explanation.

(*A*) The graph shows that the runner finishes where he started.

(*B*) The runner's maximum speed is $8\,\mathrm{m\,s^{-1}}$.

(*C*) At time 58 seconds, the runner is slowing down at a rate of $1.6\,\mathrm{m\,s^{-2}}$.

(*D*) The runner travels 400 m altogether. **[6]**

2 A train consists of a locomotive pulling 17 identical trucks.

The mass of the locomotive is 120 tonnes and the mass of each truck is 40 tonnes. The locomotive gives a driving force of 121 000 N.

The resistance to motion on each truck is R N and the resistance on the locomotive is $5R$ N.

Initially the train is travelling on a straight horizontal track and its acceleration is $0.11\,\text{m}\,\text{s}^{-2}$.

(i) Show that $R = 1500$. **[4]**

(ii) Find the tensions in the couplings between

(*A*) the last two trucks, **[4]**

(*B*) the locomotive and the first truck. **[3]**

The train now comes to a place where the track goes up a straight, uniform slope at an angle α with the horizontal, where $\sin\alpha = \frac{1}{80}$.

The driving force and the resistance forces remain the same as before.

(iii) Find the magnitude and direction of the acceleration of the train. **[4]**

The train then comes to a straight uniform downward slope at an angle β to the horizontal.

The driver of the train reduces the driving force to zero and the resistance forces remain the same as before.

The train then travels at a constant speed down the slope.

(iv) Find the value of β. **[3]**

3 A point P on a piece of machinery is moving in a vertical straight line. The displacement of P above ground level at time t seconds is y metres. The displacement-time graph for the motion during the time interval $0 \leqslant t \leqslant 4$ is shown in Fig. 7.

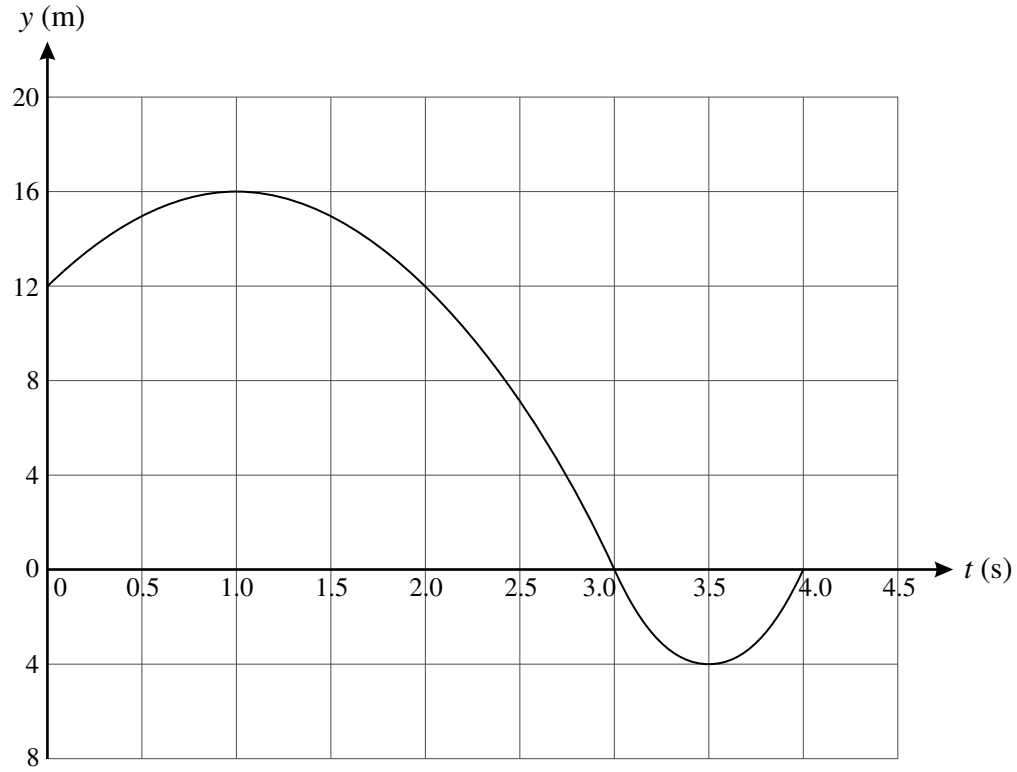

Fig. 7

(i) Using the graph, determine for the time interval $0 \leqslant t \leqslant 4$

(A) the greatest displacement of P above its position when $t = 0$,

(B) the greatest distance of P from its position when $t = 0$,

(C) the time interval in which P is moving downwards,

(D) the times when P is instantaneously at rest. **[6]**

The displacement of P in the time interval $0 \leqslant t \leqslant 3$ is given by $y = -4t^2 + 8t + 12$.

(ii) Use calculus to find expressions in terms of t for the velocity and for the acceleration of P in the interval $0 \leqslant t \leqslant 3$. **[3]**

(iii) At what times does P have a speed of $4\ \text{m s}^{-1}$ in the interval $0 \leqslant t \leqslant 3$? **[2]**

In the time interval $3 \leqslant t \leqslant 4$, P has a constant acceleration of $32\ \text{m s}^{-2}$. There is no sudden change in velocity when $t = 3$.

(iv) Find an expression in terms of t for the displacement of P in the interval $3 \leqslant t \leqslant 4$. **[5]**

4 The velocity-time graph shown in Fig. 1 represents the straight line motion of a toy car. All the lines on the graph are straight.

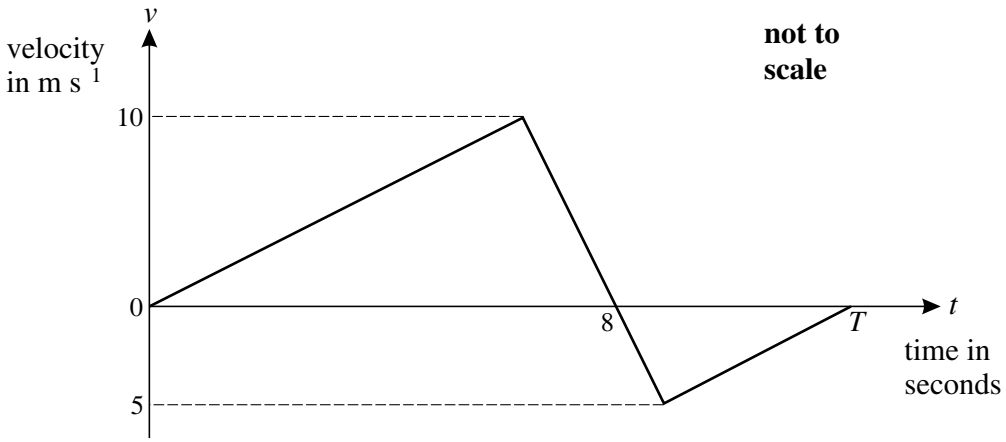

Fig. 1

The car starts at the point A at $t = 0$ and in the next 8 seconds moves to a point B.

(i) Find the distance from A to B. **[2]**

T seconds after leaving A, the car is at a point C which is a distance of 10 m from B.

(ii) Find the value of T. **[3]**

(iii) Find the displacement from A to C. **[1]**

5 Fig. 3 is a sketch of the velocity-time graph modelling the velocity of a sprinter at the start of a race.

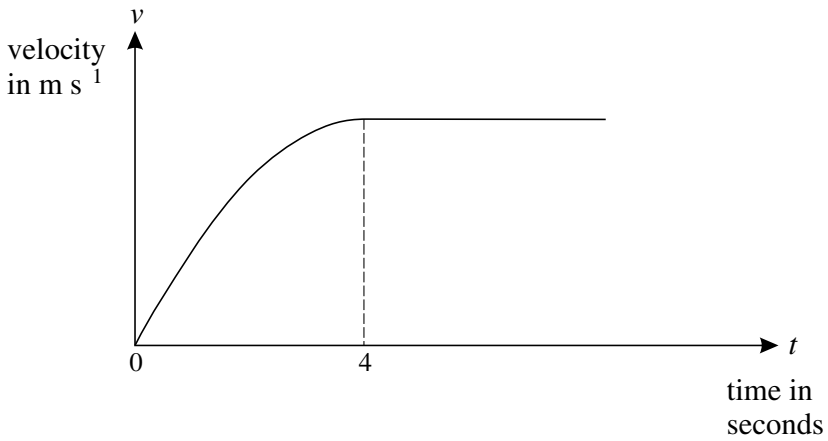

Fig. 3

(i) How can you tell from the sketch that the acceleration is not modelled as being constant for $0 \leqslant t \leqslant 4$? **[1]**

The velocity of the sprinter, v m s^{-1}, for the time interval $0 \leqslant t \leqslant 4$ is modelled by the expression

$$v = 3t - \tfrac{3}{8}t^2.$$

(ii) Find the acceleration that the model predicts for $t = 4$ and comment on what this suggests about the running of the sprinter. **[3]**

(iii) Calculate the distance run by the sprinter from $t = 1$ to $t = 4$. **[4]**

6 A car passes a point A travelling at $10\ \text{m s}^{-1}$. Its motion over the next 45 seconds is modelled as follows.

- The car's speed increases uniformly from $10\ \text{m s}^{-1}$ to $30\ \text{m s}^{-1}$ over the first 10 s.
- Its speed then increases uniformly to $40\ \text{m s}^{-1}$ over the next 15 s.
- The car then maintains this speed for a further 20 s at which time it reaches the point B.

(i) Sketch a speed-time graph to represent this motion. [3]

(ii) Calculate the distance from A to B. [3]

(iii) When it reaches the point B, the car is brought uniformly to rest in T seconds. The total distance from A is now 1700 m. Calculate the value of T. [2]