1 Force $\mathbf{F}_1$ is $\begin{pmatrix} 6 \\ 13 \end{pmatrix}$N and force $\mathbf{F}_2$ is $\begin{pmatrix} 3 \\ 5 \end{pmatrix}$, where $\begin{pmatrix} \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are vectors east and north respectively.

(i) Calculate the magnitude of $\mathbf{F}_1$, correct to three significant figures. [2]

(ii) Calculate the direction of the force $\mathbf{F}_1 - \mathbf{F}_2$ as a bearing. [3]

Force $\mathbf{F}_2$ is the resultant of all the forces acting on an object of mass 5 kg.

(iii) Calculate the acceleration of the object and the change in its velocity after 10 seconds. [3]

2 The speed of a 100 metre runner in m s^{-1} is measured electronically every 4 seconds.

The measurements are plotted as points on the speed-time graph in Fig. 6. The vertical dotted line is drawn through the runner's finishing time.

Fig. 6 also illustrates Model P in which the points are joined by straight lines.

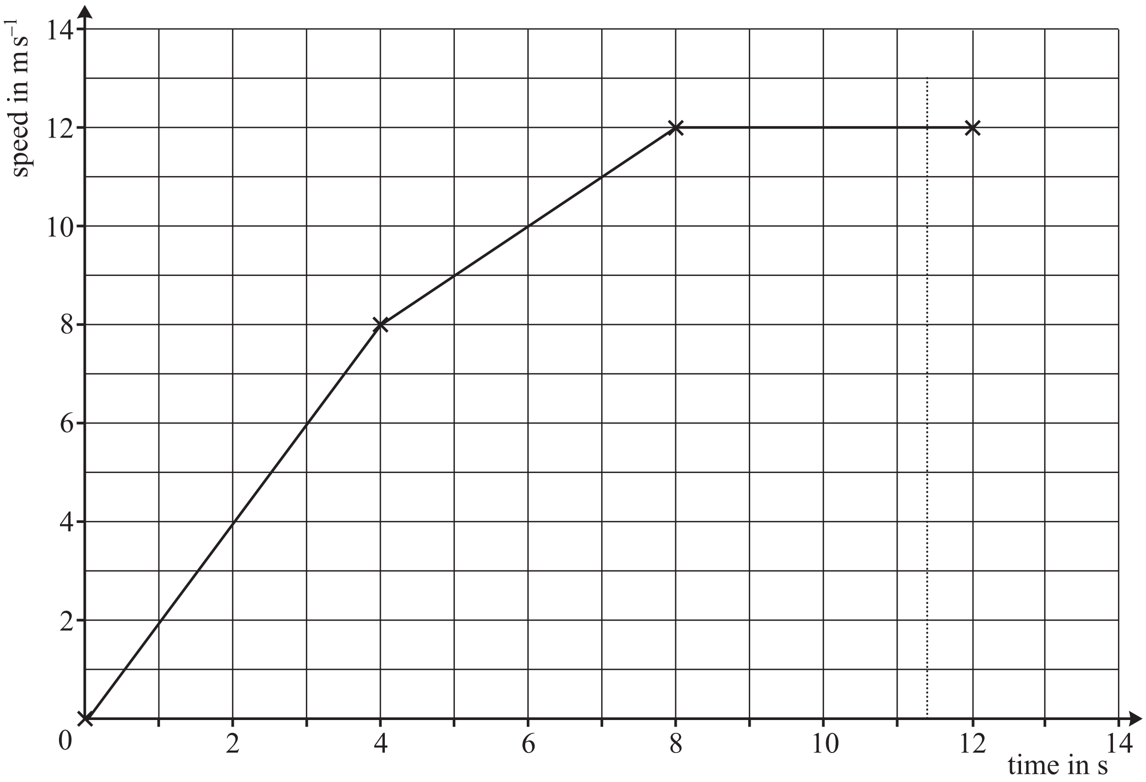

Fig. 6

(i) Use Model P to estimate

(*A*) the distance the runner has gone at the end of 12 seconds,

(*B*) how long the runner took to complete 100 m. **[6]**

A mathematician proposes Model Q in which the runner's speed, v m s^{-1} at time t s, is given by

$$v = \frac{5}{2}t - \frac{1}{8}t^2.$$

(ii) Verify that Model Q gives the correct speed for $t = 8$. **[1]**

(iii) Use Model Q to estimate the distance the runner has gone at the end of 12 seconds. **[4]**

(iv) The runner was timed at 11.35 seconds for the 100 m.

Which model places the runner closer to the finishing line at this time? **[3]**

(v) Find the greatest acceleration of the runner according to each model. **[4]**

3 **In this question take g as $10\,\text{m s}^{-2}$.**

A small ball is released from rest. It falls for 2 seconds and is then brought to rest over the next 5 seconds. This motion is modelled in the speed-time graph Fig. 6.

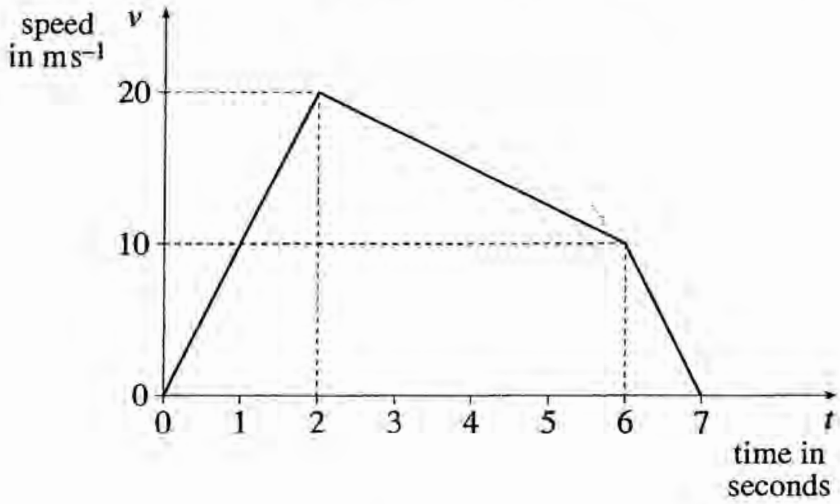

Fig. 6

For this model,

(i) calculate the distance fallen from $t = 0$ to $t = 7$, [3]

(ii) find the acceleration of the ball from $t = 2$ to $t = 6$, specifying the direction, [3]

(iii) obtain an expression in terms of t for the downward speed of the ball from $t = 2$ to $t = 6$, [3]

(iv) state the assumption that has been made about the resistance to motion from $t = 0$ to $t = 2$. [1]

The part of the motion from $t = 2$ to $t = 7$ is now modelled by $v = -\frac{3}{2}t^2 + \frac{19}{2}t + 7$.

(v) Verify that v agrees with the values given in Fig. 6 at $t = 2$, $t = 6$ and $t = 7$. [2]

(vi) Calculate the distance fallen from $t = 2$ to $t = 7$ according to this model. [7]