1. A train travels along a straight horizontal track from station P to station Q.

In a model of the motion of the train, at time $t = 0$ the train starts from rest at P, and moves with constant acceleration until it reaches its maximum speed of $25\,\mathrm{m\,s^{-1}}$

The train then travels at this constant speed of $25\,\mathrm{m\,s^{-1}}$ before finally moving with constant deceleration until it comes to rest at Q.

The time spent decelerating is four times the time spent accelerating.

The journey from P to Q takes 700 s.

Using the model,

(a) sketch a speed-time graph for the motion of the train between the two stations P and Q.
(1)

The distance between the two stations is 15 km.

Using the model,

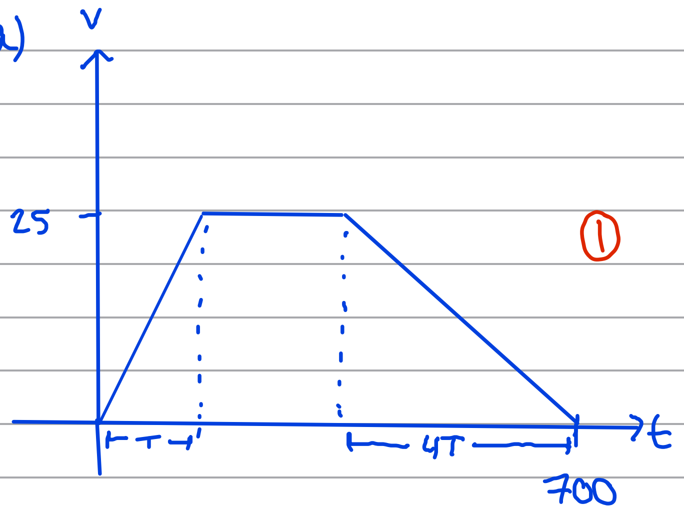
(b) show that the time spent accelerating by the train is 40 s,
(3)

(c) find the acceleration, in $\mathrm{m\,s^{-2}}$, of the train,
(1)

(d) find the speed of the train 572 s after leaving P.
(2)

(e) State one limitation of the model which could affect your answers to parts (b) and (c).
(1)

a)



b) Area = 15,000 m $\Rightarrow$ $\dfrac{700 + (700 - T - 4T)}{2} \times 25 = 15{,}000$ 2

$1400 - 5T = 15000 \times \dfrac{2}{25}$

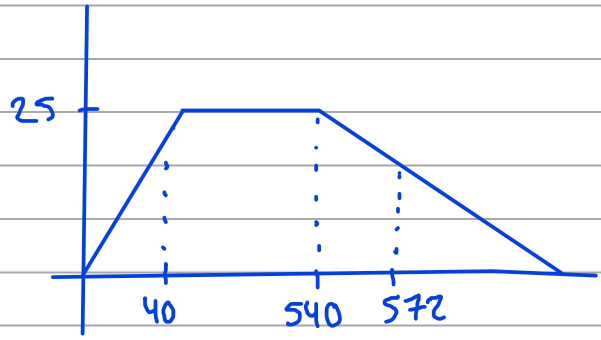
$5T = 200$

$T = 40$ 1

c) time taken = 40 seconds
velocity reached = $25 ms^{-1}$

$acc^n = \frac{25}{40} = 0.625 ms^{-2}$ (1)

d) rate of deceleration = $\frac{25}{40} \div 4 = \frac{5}{32} ms^{-2}$



$572 - 540 = 32$

Train decelerated from $25ms^{-1}$ at a rate of $\frac{5}{32} ms^{-2}$ for 32 seconds

$\therefore v = 25 - \frac{5}{32} \times 32$ (1)

$v = 20 ms^{-1}$ (1)

e) the train cannot instantaneously change acceleration (1)

2.

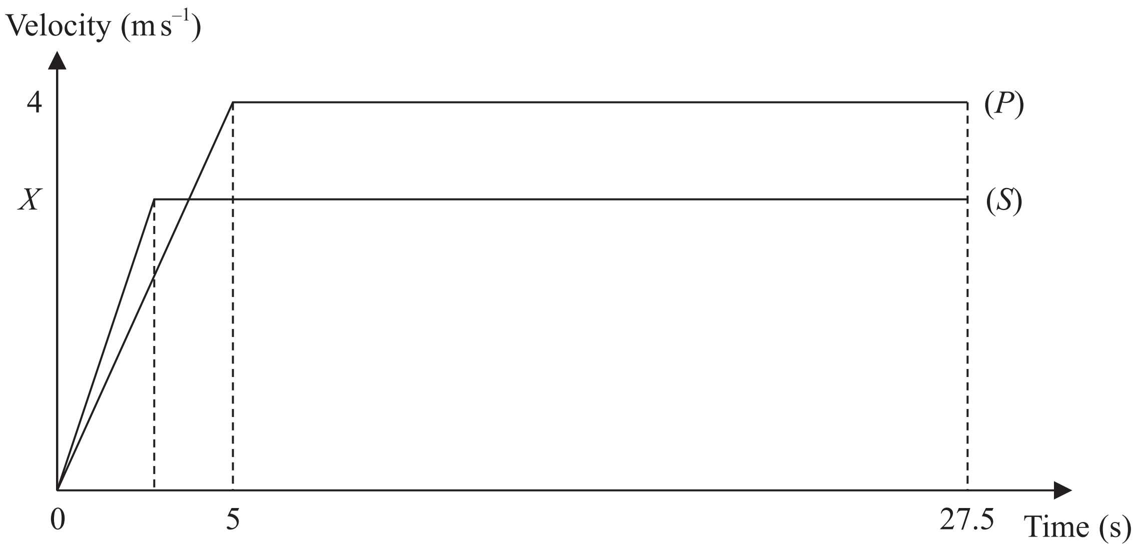


Figure 1

Two children, Pat (P) and Sam (S), run a race along a straight horizontal track.

Both children start from rest at the same time and cross the finish line at the same time.

In a model of the motion:

Pat accelerates at a constant rate from rest for 5 s until reaching a speed of 4 m s^{-1} and then maintains a constant speed of 4 m s^{-1} until crossing the finish line.

Sam accelerates at a constant rate of 1 m s^{-2} from rest until reaching a speed of X m s^{-1} and then maintains a constant speed of X m s^{-1} until crossing the finish line.

Both children take 27.5 s to complete the race.

The velocity-time graphs shown in Figure 1 describe the model of the motion of each child from the instant they start to the instant they cross the finish line together.

Using the model,

(a) explain why the areas under the two graphs are equal,
(1)

(b) find the acceleration of Pat during the first 5 seconds,
(1)

(c) find, in metres, the length of the race,
(2)

(d) find the value of X, giving your answer to 3 significant figures.
(4)

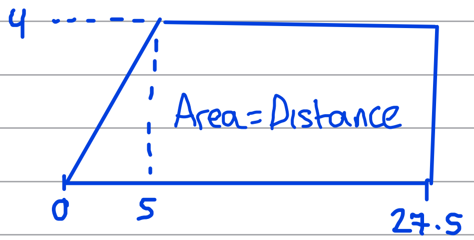
a) Pat and Sam ran the same race, so the distance they ran is equal. 1

Area under a velocity-time graph = distance travelled

b) $t = 5\,s$ $\quad$ acceleration $= \frac{v}{t} = \frac{4}{5}\,ms^{-2}$ (1)

$v = 4\,ms^{-1}$

c) considering Pat:

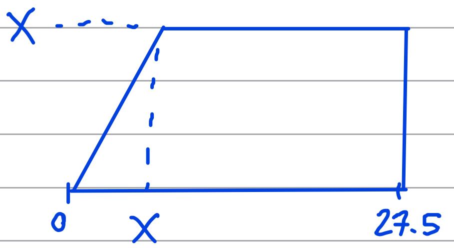


$$\text{Area} = \frac{(27.5-5)+27.5}{2} \times 4 \quad (1)$$

$$= 100 \quad (1)$$

distance is 100m

d) considering Sam:



find time when sam stops accelerating:

$V = X$

$a = 1 \qquad t = \frac{V}{a} = X$

$$\text{Area} = \left[\frac{(27.5-X)+27.5}{2}\right] X = 100$$

(1) (1)

distances for Sam and Pat are equal, so the areas are also equal

$$X(55-X) = 200$$

$$55X - X^2 = 200$$

$$X^2 - 55X + 200 = 0 \quad (1)$$

$$X = 51.08 \text{ or } X = 3.92$$

$$X < 27.5 \text{ so } X = 3.92 \quad (1)$$