1. The speed of a 100 metre runner in ms^{-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.

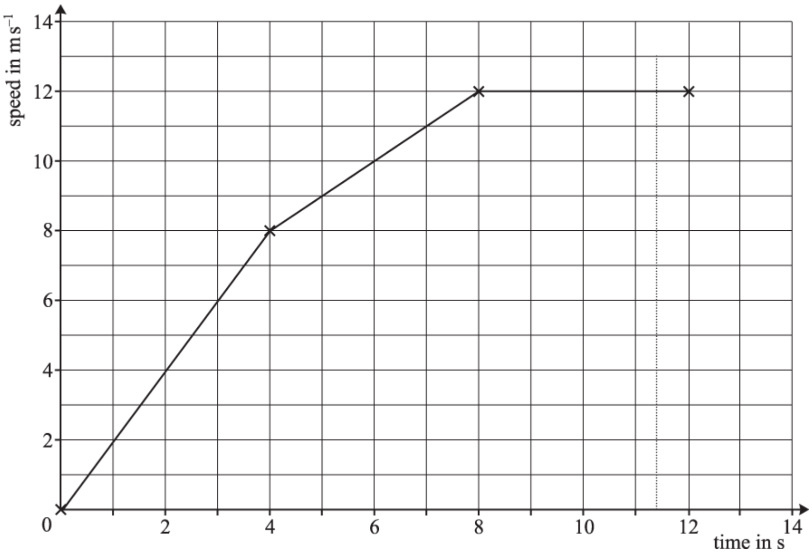


Fig. 6

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 ms^{-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]

2. A particle is travelling along a straight line with constant acceleration. P, O and Q are points on the line, as illustrated in Fig. 4. The distance from P to O is 5 m and the distance from O to Q is 30 m.

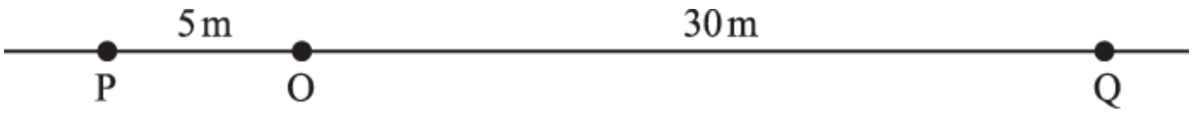


Fig. 4

Initially the particle is at O. After 10 s, it is at Q and its velocity is 9 ms^{-1} in the direction $\overrightarrow{OQ}$.

i. Find the initial velocity and the acceleration of the particle.

[4]

ii. Prove that the particle is never at P.

[3]

3. Fig. 1 shows the velocity-time graph of a cyclist travelling along a straight horizontal road between two sets of traffic lights. The velocity, v, is measured in metres per second and the time, t, in seconds. The distance travelled, s metres, is measured from when $t = 0$.

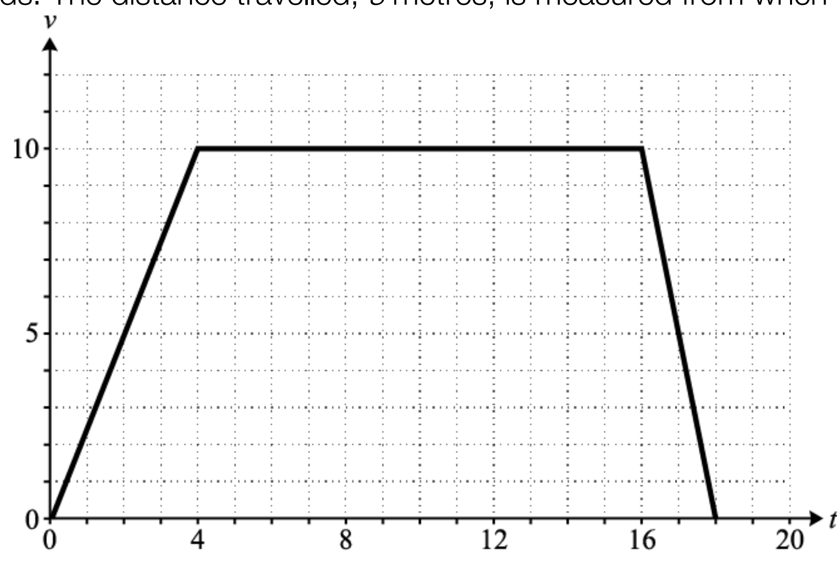


Fig. 1

i. Find the values of s when $t = 4$ and when $t = 18$.

[3]

ii. Sketch the graph of s against t for $0 \leqslant t \leqslant 18$.

[3]

4. A car is usually driven along the whole of a 5 km stretch of road at a constant speed of 25 m s^{-1}. On one occasion, during a period of 50 seconds the speed of the car is as shown by the speed-time graph in Fig. 7; the rest of the 5 km is travelled at 25 m s^{-1}.

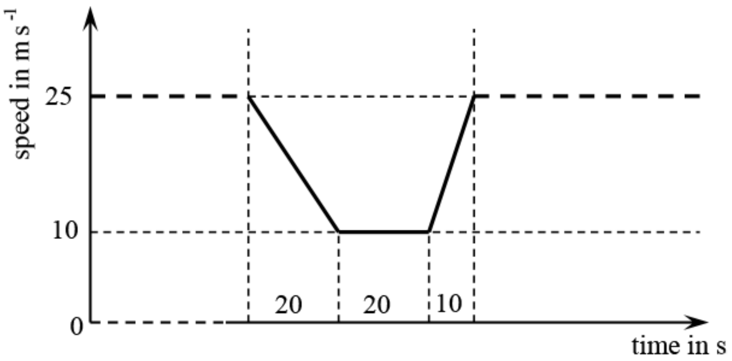


Fig. 7

How much more time than usual did the journey take on this occasion? Show your working clearly. [4]

5. Two cars, A and B, are travelling in different lanes in the same direction along a straight road. The initial situation is illustrated in Fig. 5.

- At this time, A is stationary at traffic lights at O. The lights have just turned green and A is on the point of moving off.
- B is travelling towards O with speed 20 m s^{-1}. B is 75 m behind A.

Fig. 5

During the subsequent motion,

- A has constant acceleration 2 m s^{-2},
- the traffic lights remain green and B maintains a constant speed 20 m s^{-1}.

In order to model the subsequent motion you should make two assumptions.

- The cars can overtake each other with no interference from other traffic.
- The position of a car is defined by a point at its front and so the length of the car need not be considered.

(i) Find the times at which the two cars are side by side. [4]

(ii) Find the distance A travels while it is behind B. [2]

(iii) There is a speed camera 400 m from O.

How fast is A travelling when it passes the speed camera? [2]

6. A train is travelling along a straight test track. It starts from rest and reaches its maximum speed after a time of
2 minutes and 21 seconds. During that time it travels 5 km.

Two models, A and B, are considered for its motion.

In Model A, it is assumed that the train has constant acceleration.

(i) Find the acceleration of the train and its maximum speed according to Model A. [5]

In Model B, it is assumed that the acceleration, a m s^{-2} at time t seconds after starting, is given by

$$a = 0.6 - 3 \times 10^{-5} \times t^2.$$

(ii) Show that, according to Model B, the time taken for the train to reach its maximum speed is 2 minutes 21.42 seconds (to the nearest 0.01 s). [2]

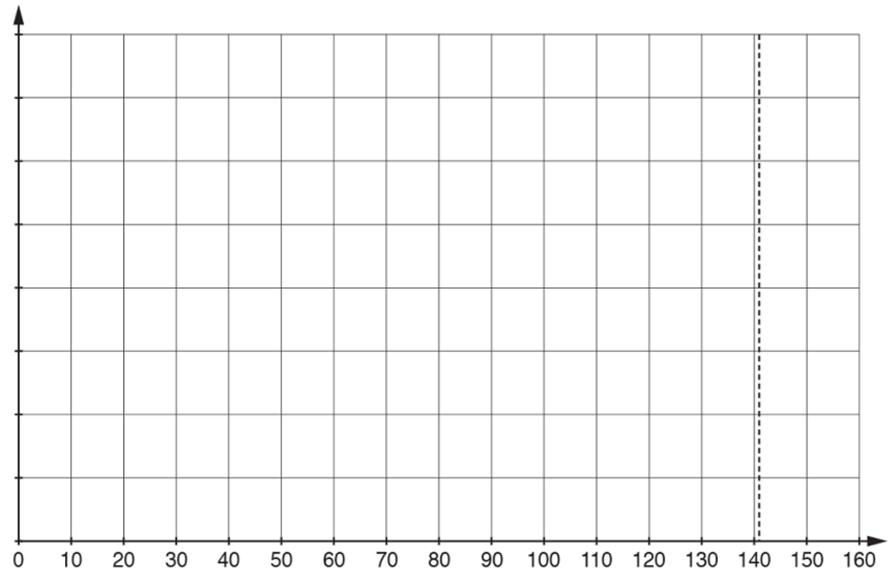
(iii) Find expressions for the speed of the train and the distance that it has travelled at time t, according to Model B. [4]

(iv) Hence show that Model B is consistent with the train travelling a distance of 5 km to attain maximum speed.

Find the maximum speed of the train according to this model. [3]

(v) When the train reaches its maximum speed it continues at that speed.

Draw the speed-time graphs for both models on the grid provided, labelling them A and B. [4]



7. A truck is travelling along a straight road ABC, and is slowing down at a constant rate. The truck takes 4 s to travel the 64 m from A to B and it takes another 4 s to travel the 32 m from B to C.

(a) Find

- the speed of the truck at A,
- the acceleration of the truck. [6]

(b) Find how far beyond C the truck travels before coming to rest. [2]

8. Rory runs a distance of 45 m in 12.5 s. He starts from rest and accelerates to a speed of 4 m s^{-1}. He runs the remaining distance at 4 m s^{-1}.

Rory proposes a model in which the acceleration is constant until time T seconds.

(a) Sketch the velocity-time graph for Rory's run using this model. [2]

(b) Calculate T. [2]

(c) Find an expression for Rory's displacement at time t s for $0 \le t \le T$. [2]

(d) Use this model to find the time taken for Rory to run the first 4 m. [1]

Rory proposes a refined model in which the velocity during the acceleration phase is a quadratic function of t. The graph of Rory's quadratic goes through (0, 0) and has its maximum point at (S, 4). In this model the acceleration phase lasts until time S seconds, after which the velocity is constant.

(e) Sketch a velocity-time graph that represents Rory's run using this refined model. [1]

(f) State with a reason whether S is greater than T or less than T. (You are not required to calculate the value of S.) [1]

9. A bus travelling on a straight road accelerates uniformly from 2.5 m s^{-1} to 7.5 m s^{-1} in 12 s. It then travels at 7.5m s^{-1} for 20 s before slowing uniformly to rest in 8 s.

(a) Sketch a velocity-time graph for the bus. [3]

(b) Calculate the average speed of the bus. [4]

10. A cyclist is travelling in a straight line. She has a velocity of $3 ms^{-1}$ when passing O. After 4 s she reaches A which is 24 m from O. After a further 6 s she reaches B which is 80 m beyond A.

Determine whether modelling the motion as having constant acceleration is consistent with these values. [5]

END OF QUESTION paper

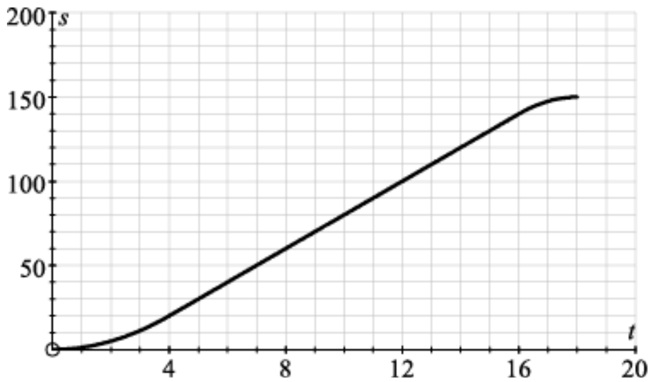
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	*(A)* Distance travelled = Area under the graph	M1	Attempt to find area
		i	$\frac{1}{2}\times 4\times 8+\frac{1}{2}\times 4\times(8+12)+4\times 12$	M1	Splitting into suitable parts
		i	104 m	A1	Cao Allow all 3 marks for 104 without any working
		i	*(B)* Either Working backwards from distance when $t = 12$	M1	
		i	$12-\frac{(104-100)}{12}$	M1	Allow this mark for 0.33… Follow through from their total distance
		i	11.67 s	A1	Cao
		i	Or		
		i	Working forwards from when $t = 8$	M1	
		i	$8+\frac{(100-56)}{12}$	M1	Allow this mark for 3.67… Follow through from their distance at time 8s
		i	11.67 s	A1	Coa
		ii	Substituting $t=8$ gives $v=\frac{5}{2}\times 8-\frac{1}{8}\times 8^2=12$	B1	
		iii	Distance $=\int_0^{12}\left(\frac{5t}{2}-\frac{t^2}{8}\right)\mathrm{d}t$	M1	Integrating v. Condone no limits.

		iii	$\left[\frac{5t^2}{4}-\frac{t^3}{24}\right]_0^{12}$	A1	Condone no limits
		iii	[180–72] (–[0])	M1	Substituting $t = 12$
		iii	108 m	A1	
		iv	Model P: distance at $t = 11.35$ is 96.2	B1	Cao
		iv	Model Q: distance at $t = 11.35$ is		
		iv	$\left[\frac{5t^2}{4}-\frac{t^3}{24}\right]_0^{11.35} = 100.1$	M1	Substituting 11.35 in their expression from part (**iii**)
		iv	Model Q places the runner closer	E1	Cao from correct previous working for both models
		v	Model P: Greatest acceleration $\frac{8}{4} = 2 \text{ m s}^{-2}$	B1	
		v	Model Q: $a = \frac{dv}{dt} = \frac{5}{2} - \frac{t}{4}$	M1	Differentiating v
		v		A1	
		v	Model Q: Greatest acceleration is 2.5 ms^{-2}	B1	Award if correct answer seen **Examiner's Comments** This was the first of the two Section B questions. It involved two models for the speed of a runner covering 100 metres. It was well answered. In part (i) candidates worked from a given speed-time graph and most were successful in doing so; however some did not realise that the second request needed some calculation and could not be obtained just from reading off the graph. The question then presented the second model as an equation for v in terms of t; most candidates realised that the questions on this involved the use of calculus and answered them correctly. The last two parts of the question involved comparing results from the two

					models and there were many correct answers, well presented with clear statements as to which model was being considered.
			Total	18	
2		i	Either $s = \frac{1}{2}(u+v)t$ Take O as the origin.	M1	Use of one relevant equation, including substitution
		i	$30 = \frac{1}{2} \times (u+9) \times 10$		Enter text here.
		i	$u = -3$	A1	
		i	$v = u + at$	M1	Use of a second relevant equation including substitution
		i	$9 = -3 + 10a$		
		i	$a = 1.2$	A1	
		i	or $v = u + at \Rightarrow u + 10a = 9$	M1	Use of one relevant equation, including substitution
		i	$s = ut + \frac{1}{2}at^2 \;\Rightarrow\; u + 5a = 3$	M1	Use of a second relevant equation including substitution
		i	Solving simultaneously: $a = 1.2$	A1	
		i	$u = -3$	A1	
		i	or $s = vt - \frac{1}{2}at^2$	M1	Use of one relevant equation, including substitution
		i	$\Rightarrow a = 1.2$	A1	
		i	$v = u + at$	M1	Use of a second relevant equation including substitution
		i	$\Rightarrow u = -3$	A1	<u>Examiner's Comments</u> This question involved a particle travelling under constant acceleration along a straight line, two constant acceleration formulae were required and most candidates obtained the right answers but there were some careless mistakes, and some mistakes in quoting the standard results.

		ii	Either $s = ut + \frac{1}{2}at^2$	3	
		ii	Solving for P: $-5 = -3t + \frac{1}{2} \times 1.2t^2$	M1	Quadratic equation with s=−5
		ii	$0.6t^2 - 3t + 5 = 0$		
		ii	Discriminant = $3^2 - 4 \times 0.6 \times 5 = -3$	M1	Considering the discriminant or equivalent
		ii	No real roots for t (⇒ Particle is never at P)	E1	Cao without wrong working in the whole question.
		ii	Or Find when $v = 0$	M1	
		ii	$v = u + at$, $v = 0 \Rightarrow t = 2.5$		
		ii	$s = ut + \frac{1}{2}at^2$ and $t = 2.5$	M1	Or use $v^2 = u^2 + 2as$
		ii		E1	Cao without wrong working in the whole question. Comparison necessary
		ii	$\Rightarrow s = -3.75 > -5$		
		ii	Special cases when their $u > 0$ and their $a > 0$	SC1	"It is always going to the right"
		ii		SC1	Demonstration that it is at −5 for two negative times. **Examiner's Comments** This question involved a particle travelling under constant acceleration along a straight line. In part (i) two constant acceleration formulae were required and most candidates obtained the right answers but there were some careless mistakes, and some mistakes in quoting the standard results. In part (ii) candidates were asked to **prove** that the particle was never at a certain point and it was a pleasure to see how well this was answered, usually either by setting up a quadratic equation and showing it had a negative discriminant, or by finding the turning point in the motion. A handful of candidates just tested some particular cases and no credit was given for this.
			Total	7	

Question			Answer	Marks	Guidance
3		i	When $t=4$, $s=\frac{1}{2}\times 4\times 10$		Finding the area of the triangle or equivalent.
		i	$s=20$	B1	
		i	When $t=18$, $s=\frac{1}{2}\times(18+12)\times 10$	M1	A complete method of finding the area of the trapezium or equivalent.
		i	$s=150$	A1	CAO
		ii			
		ii	Graph joining (0,0), (4,20) and (18, 150)	B1	Allow FT for their (4,20) and (18, 150) Condone extension to (20, 150) with a horizontal line.
		ii	The graph goes through (16, 140)	B1	Allow SC1 for the first two marks if there is a consistent displacement from a correct scale, eg plotting (18,150) at (19, 150)
		ii	Curves at both ends	B1	The sections from $t = 0$ to $t = 4$ and from $t = 16$ to $t = 18$ are both curves **Examiner's Comments** This question, about interpreting a velocity-time graph, was well answered. It ended with a request to draw the equivalent distance-time graph, parts of which were curves; many candidates did not realise this and so lost the final mark.

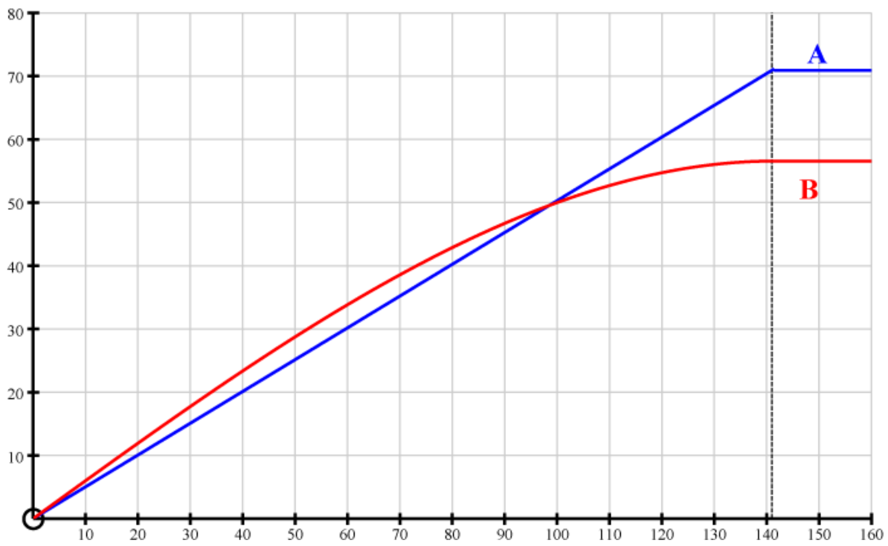
			Total	6		
4			Find how much less distance travelled in the 50 s Distance is the area (of trapezium and is) $\frac{(25-10)\times(50+20)}{2}=525\text{ m}$ This distance is made up at 25 m s^{-1} to give extra time Extra time is $\frac{525}{25}=21$	M1(AO3.1b) A1(AO1.1) M1(AO3.4) A1(AO3.2a)	Sensible attempt at method including finding distance as an area cao. Need not be evaluated. Many correct routes. FT their area	
			Alternative method Find the distance travelled in the 50 s Find the time for the rest of the journey + 50 and subtract $\frac{5000}{25}=200$ Distance travelled in the 50 s is 725 m Extra time is $\frac{(5000-725)}{25}+50-200=21$	M1(AO3.1b) M1(AO3.4) A1(AO1.1) A1(AO3.2a) [4]	Sensible attempt at method including finding distance as an area May be scored later. oe cao. Many correct routes to find area FT their area. Many correct routes here.	Award full marks for 21 seen www
			Total	4		

Question			Answer	Marks	Guidance
5		i	A: $x = t^2$ B: $x = -75 + 20t$ When the cars are side by side, $t^2 = -75 + 20t$ $t^2 = -20t + 75 = 0$ $(t - 5)(t - 15) = 0$ The times are 5 seconds and 15 seconds	B1 B1 M1 A1 [4]	Or displacements from B's start point: $x = t^2 + 75$ and $x = 20t$ Must be consistent For equating two distances even if inconsistent **Examiner's Comments** This question involved the motion of two cars in parallel lanes on a road. One had constant acceleration and the other travelled at constant speed. One car was initially behind the other. In part (i) candidates were asked to find the times when the cars were side by side. While there were many fully correct answers to this, there were also plenty of sign errors involving the 75 m difference in starting position. A few candidates did not realise that answering this question involved setting up an equation for the time t.
		ii	For A, $s = 225$ when $t = 15$ $s = 25$ when $t = 5$ So A is behind B for 200 m **Alternative Using motion of B** Speed of B is (constant at) 20 m s^{-1} So between $t = 5$ and $t = 15$, B travels $20 \times (15 - 5)$ (= 200 m)	M1 A1 [2] M1	FT for two positive times from part (i) for the M mark only Both values of s attempted CAO Or equivalent, eg using $s = ut + \frac{1}{2}at^2$ with $a = 0$

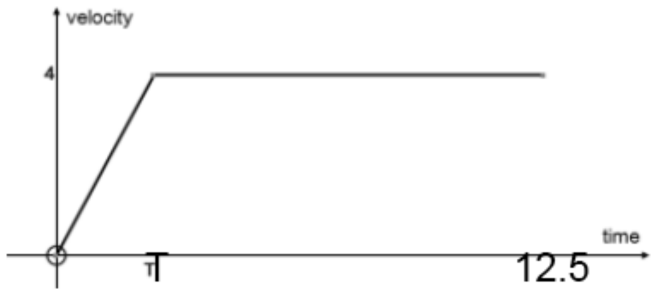
			So A is behind B for 200 m **Alternative Using motion of A with the clock re-set** When the cars are first level, the motion of A is defined by $u = 10$ and $a = 2$. If the clock is re-set at this moment, $t = 0$ In this case, when they are next level, $t = 10$ $s = ut + \frac{1}{2}at^2 \Rightarrow s = 10\times10 + \frac{1}{2}\times2\times10^2$ $\Rightarrow s = 200$	A1 M1 A1	Or $v = u = at \Rightarrow v = 10+2\times10 = 30$ followed by use of $v^2 - u^2 = 2as$ **Examiner's Comments** In part (ii) the question for the distance for which one particular car was ahead of the other. This was lower scoring than the other parts of the question.
		iii	For A: $v^2 - u^2 = 2as$ $v^2 = 2\times2\times400$ $v = 40$, (so speed 40 ms^{-1}). **Alternative finding the time first** For A: $s = 400 \Rightarrow t = 20$ $v = u + at$ $\Rightarrow v = 40$ so 40 m s^{-1}	M1 A1 [2] M1 A1	There must be an attempt to use the formula There must be evidence of a complete method that can lead to the value of v **Examiner's Comments**

					In part (iii) they were asked to find the speed of one of the cars after it had travelled 400 m and this was very well answered, even by those who had made mistakes on earlier parts.
			Total	8	
6		i	2 minutes 21 seconds is 141 seconds $s = ut + \frac{1}{2}at^2$ $5000 = 0 + 0.5 \times a \times 141^2$ $a = 0.503$ (ms^{-2}) $v = u + at$ $v = 0.503 \times 141 = 70.9$ so 70.9 ms^{-1} **Alternative using** $s = \frac{1}{2}(u+v)t$ $5000 = \frac{1}{2} \times (0 + v) \times 141$ $v = \frac{10000}{141} = 70.9\ldots$ so 70.9 $m\,s^{-1}$	B1 M1 A1 M1 A1 [5] M1 A1	Allow 0.50 but not 0.5 Or equivalent, eg $v^2 - u^2 = 2as$ CAO (including 70.5 m s^{-1}) CAO **Examiner's Comments** This was the first of the two long questions. It was based on two different models for the motion of a train from rest to maximum speed. It involved both constant and variable acceleration. On the whole this question was well answered with many high marks. Part (i) was based on a constant acceleration model. It was very well answered with most candidates obtaining all the five available marks. However, many candidates lost one mark by giving the acceleration to only one significant figure.

		ii	At maximum speed the acceleration is zero $t=\sqrt{\dfrac{0.6}{3\times10^{-5}}}\ \left(=\sqrt{20\,000}\right)\ =141.421...$ So 2 minutes 21.42 seconds	M1 A1 [2]	Setting $a = 0$ in the given equation for a. Accept answer in seconds **Examiner's Comments** The question then moved on to a model with variable acceleration. Part (ii) required candidates to recognise that when the train reached maximum speed its acceleration is zero and so obtain a given value for the time taken. While most candidates were successful in this, a substantial number did not recognise the significance of zero acceleration and tried other unsuccessful approaches, often involving a lot of fruitless work.
		iii	Integrating $v = 0.6t - 0.000\,01t^3\ (+c)$, $(t = 0,\ v = 0 \Rightarrow c = 0)$ $s = 0.3t^2 - 0.000\,0025t^4\ (+k)$ $t = 0,\ s = 0 \Rightarrow k = 0$	M1 A1 A1 A1 [4]	Attempt at integration. Or equivalent, eg $v = 0.6t - 10^{-5}\times t^3\ (+c)$ Coefficients do not need to be simplified in either integral. FT from v. Integration must be attempted. Or equivalent, eg $s = 0.3t^2 - 2.5\times10^{-6}\times t^4\ (+k)$ Use of mechanics and not assertion to show $k = 0$ **Examiner's Comments** Part (iii) required candidates to integrate the acceleration to find the speed and then to integrate again to find the distance travelled by the train. Many candidates did not consider the constants of integration, or just declared them to be zero without any reason, and this was penalised.
		iv	Substituting $t = 141.42...$ in $s = 0.3t^2 - 0.000\,0025t^4$ $s = 5000$ so consistent with 5 km Substituting $t = 141.42...$ in $v = 0.6t - 0.000\,01t^3$ $v = 56.57\ \text{ms}^{-1}$	M1 A1	Allow substituting $s = 5000$ to show that $t = 141.42...$ Notice that $141.42.... = \sqrt{20\ 000}$ and so the answer of 5000 is exact

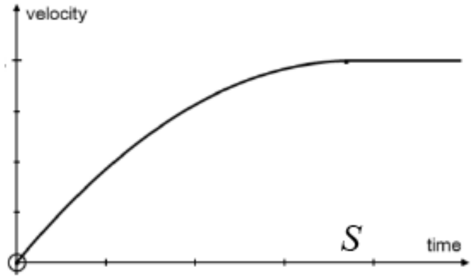
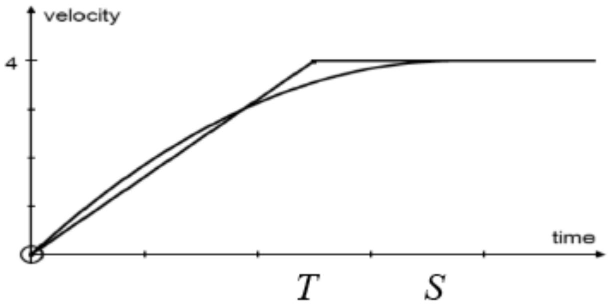
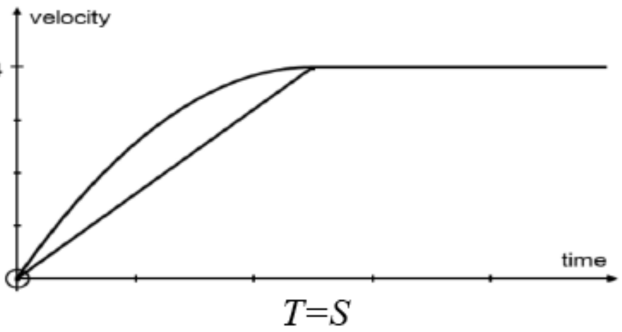
				B1 [3]	**Examiner's Comments** In part (iv) candidates were expected to use the time given in part (ii) and their expression for the distance travelled from part (iii) to verify the distance the train had travelled in attaining maximum speed. Many knew just what to do and were successful. Some tried to do the question in reverse, substituting the distance and forming a quartic equation for the time; this was a viable approach and a few candidates realised that their equation could be written as a quadratic in *t*2 and went on to solve it. The question continued to ask for the maximum speed and this was well answered, even by those who had not been successful with the distance.
		v		B1 B1 B1 B1 [4]	Vertical scale from 0 that ensures that at least half the height is used. For the remaining marks do not allow FT from earlier parts. A: A straight line from (0, 0) to (141, 70.9) B: A curve from (0, 0) to (141, 56.6); the curvature must be in the right sense. Both A from (141, 70.9) to (160, 70.9) and B from (141, 56.6) to (160, 56.6). CAO. **Examiner's Comments** The final part (v) required the two models to be shown on a speed-time graph. This produced a wide spread of marks. Most candidates knew what they were trying to do but made errors. Some lost a mark by not showing the motion after the train had reached maximum speed and many others drew a straight line rather than a curve for the variable acceleration model.
			Total	18	
7		a	For AB: use of $s = ut + \frac{1}{2}at^2$ with $s = 64$, $t = 4$ gives	M1(AO3.3) A1(AO1.1b)	Allow use of a different sign convention (egnegative *a)* provided it is used consistently throughout and is explained

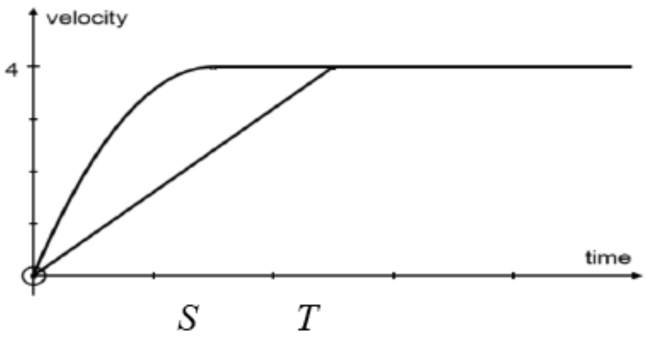
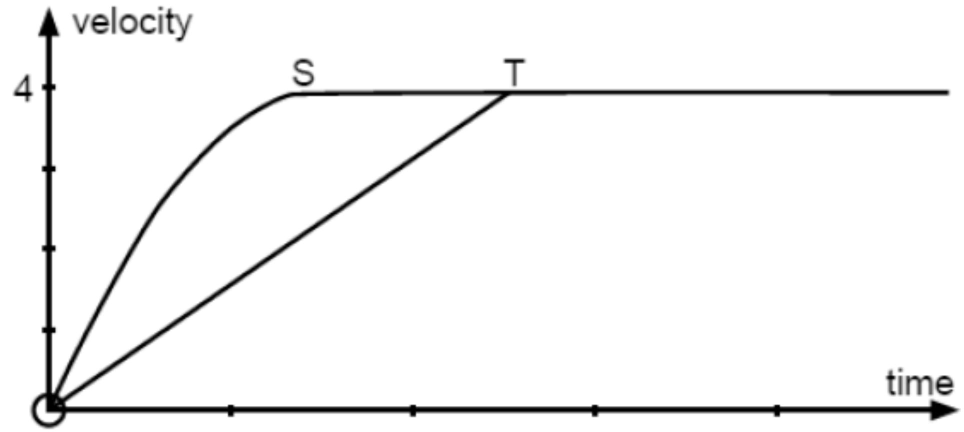
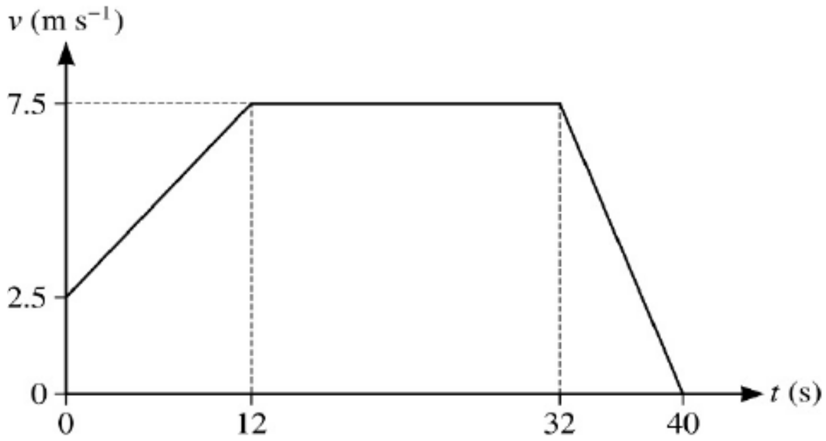
$64 = 4u + \frac{1}{2}a \times 4^2$	B1(AO3.1b)	Correct (unsimplified) equation	
For AC: $s = 96$ and $t = 8$	M1(AO3.4)	For both 96 and 8 seen	
$96 = 8u + \frac{1}{2}a \times 8^2$	M1(AO1.1a)	Forming second equation in u and a	
Solve simultaneously (16 = u + 2a, 12 = u + 4a)	M1	May be implied if calculator used	
u = 20 and a = −2	A1(AO1.1b)	Both correct; allow deceleration = 2	Allow use of a different sign convention (eg negative *a)* provided it is used consistently throughout and is explained
Alternative solution			
For AB: use of $s = ut + \frac{1}{2}at^2$ with $s = 64$, $t = 4$ gives $64 = 4u + \frac{1}{2}a \times 4^2$	B1	Correct (unsimplified) equation	
For BC: speed at B is u + 4a	M1	Use of v = u + *at* for AB	
$32 = 4(u + 4a) + \frac{1}{2}a \times 4^2$	M1	Forming second equation in u and a	
Solve simultaneously (16 = u + 2a, 8 = u + 6a)	M1	oe BC	
u = 20 and a = − 2	A1	Both correct; allow deceleration = 2	
	[6]		

Question			Answer	Marks	Guidance
		b	$u = 20$, $v = 0$, $a = -2$ gives $0 = 20^2 - 2 \times 2 \times s$ $s = 100$ so truck comes to rest 4 m beyond C	M1(AO3.4) A1(AO1.1b) [2]	Allow for any *suvat* equation(s) leading to a value for *s*
			Total	8	
8		a		B1 (AO1.1a) B1 (AO1.1a) [2]	Two line segments with one horizontal (*T*, 4) and (12.5, 4) labelled or indicated on scales. Allow their 2.5 marked instead of *T*. On axes labelled v and t oe **Examiner's Comments** Most candidates gave a graph with two straight line segments but marks were often lost for graphs that were not fully labelled. Make sure you label the axes and show the values of *v* and *t* at the significant points.
		b	$\frac{1}{2} \times 4 \times \left(12.5 + \left(12.5 - T\right)\right) = 45$	M1 (AO3.1a)	Attempt to find area of trapezium or both the the triangle $\left(\frac{1}{2}T \times 4\right)$ *Suvat* equations can be used for two phases of motion.

			$T = 2.5$	A1 (AO1.1b) [2]	and the rectangle $(12.5 - T) \times 4$. cao **Examiner's Comments** Candidates who used the area under the graph were usually successful. Candidates using the *suvat* equations often incorrectly combined values from the two separate phases of motion into a single equation.
		c	EITHER $$a = \frac{4}{2.5} = 1.6 \text{ m s}^{-2}$$ $$s = \frac{1}{2} \times 1.6t^2 = 0.8t^2$$ OR $$a = \frac{4}{2.5} = 1.6 \text{ m s}^{-2}$$ $v = \int a\,\mathrm{d}t = 1.6t + c$ When $t = 0$, $v = 0$ so $c = 0$ $s = \int v\,\mathrm{d}t = 0.8t^2 + c$	M1 (AO1.1a) A1 (AO3.3) [2] M1	Soi FT their T Soi FT their T

			When $t = 0$, $s = 0$ so $c = 0$ Giving $s = 0.8t^2$	A1 [2]	Must be complete solution – do not award without consideration of + c at least once **Examiner's Comments** This was not well answered, as many candidates did not realise that the value of the acceleration was the key to this question. Many incorrectly used $s = \frac{1}{2}(u+v)t$ with $u = 0$ and $v = 4$, and the resulting linear expression did not qualify for follow-through marks in part (d).
		d	$0.8t^2 = 4$ $t = \sqrt{5} = 2.24$ s	B1FT (AO3.4) [1]	FT their quadratic model in **(c)** **Examiner's Comments** This was usually credited to candidates who had had a quadratic expression for s in part (iii) as follow-through was allowed.

		e		B1 (AO1.1a) [1]	Must have curved section of the graph decreasing gradient. *S* must be labelled. **Examiner's Comments** Most candidates who attempted this question got it right. The mark was only credited where the curved part of the graph had a decreasing gradient.
		f	Total distance (area under the graph) can only be equal if $S > T$ If $S > T$  If $S = T$  If $S < T$	E1 (AO3.5c) [1]	Needs to give reason relating to the refinement of the model. Graphs not required | "It takes longer to reach 4 ms^{-1}" is not sufficient reason **Examiner's Comments** Very few candidates were credited this mark. Many argued that the decreasing gradient implied it would take longer to reach maximum speed – the incorrect underlying assumption here was that the gradient at the origin would be the same, so these arguments were not credited the mark. This model gives the same total distance in 12.5 s and only answers which compared distances or areas were eligible for the mark. The easiest way to decide was to sketch the graphs with $S > T$ and to realise that this meant the total distance would be larger and so to argue that $S > T$.

			 		
			Total	9	
9		a	 	B1 (AO 3.3) B1 (AO 1.1) B1 (AO 1.1) [3]	Graph with three straight lines with positive, zero and negative gradients Vertical axis labelled with 2.5 and 7.5 marked Horizontal axis labelled with 12, 32 and 40 marked (oe, e.g.separate time intervals indicated)
		b	Total distance = area under graph $=\frac{1}{2}\times(2.5+7.5)\times12+(20\times7.5)+\frac{1}{2}\times8\times7.5$ = 240 m	M1 (AO 3.1b) A1 (AO 1.1)	Any complete method

			Average speed is $\frac{240}{40}$ $= 6 \text{ m s}^{-1}$	M1 (AO 1.1a) A1 (AO 1.1) [4]	Dividing their distance by their total time FT	
			Total	7		
10			Use of $s = ut + \frac{1}{2}at^2$ to compare two accelerations For OA: $24 = 3 \times 4 + \frac{1}{2} a \times 4^2$ $a = 1.5$ For OB: $104 = 3 \times 10 + \frac{1}{2} a \times 10^2$ $a = 1.48$ Similar values, so constant acceleration is a good model **Alternative solution** Predicting a value and comparing with given figure	M1 (AO 3.3) A1 (AO 1.1b) M1 (AO 3.3) A1 (AO 1.1b) A1 (AO 3.5a)	Use formula with $u = 3$, $s = 24$, $t = 4$ Use formula with $u = 3$, $s = 104$, $t = 10$ or (for AB) with $u = 9$, $s = 80$, $t = 6$ (or a = 1.44 using data for AB) Clear comparison and conclusion. Allow alternative conclusion, i.e. that the model is not [exactly] consistent with the data	If AB considered do not allow $u = 3$; there must be an attempt to find the speed at A, e.g. via *suvat* for OA

			Answer	Marks	Guidance	
			For OA: $24 = 3 \times 4 + \frac{1}{2} a \times 4^2$	M1	Find a for OA using $u = 3$, $s = 24$, $t = 4$	Allow credit for any complete method
			$a = 1.5$	A1		
			For OB: $s = 3 \times 10 + \frac{1}{2} \times 1.5 \times 10^2$	M1	Use of $a = 1.5$ for OB, oe	
			OB = 105 m	A1		
			Actual distance is 104 m, which is very close, so constant acceleration is a good model	A1	Clear comparison and conclusion Allow alternative conclusion, i.e. that the model is not [exactly] consistent with the data	Do not allow $u = 3$ as initial speed for AB
				[5]		
			Total	5		