Write your name, centre number and candidate number in the boxes below.

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

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Kinematics

Time allowed: 2 hours

Subject code **0606**

Additional Mathematics

Questions from Paper 1 and Paper 2

You must have: a ruler marked in centimetres and millimetres, a protractor, compasses, a pen, an HB pencil and an eraser.
Questions 1-3, 7-9 (Paper 1): no calculator.
Questions 4-6, 10 (Paper 2): calculator allowed.

Total marks

/ 77

Instructions

- Answer every question in the space provided on this paper.
- Write in black or dark blue ink. Pencil may be used for diagrams and graphs.
- Fill in your name, centre number and candidate number above.
- Show your working: a correct method can earn marks even if the answer is wrong.
- Unless a question says otherwise, give answers that are not exact to 3 significant figures, and angles in degrees to 1 decimal place.

Information

- This paper has 10 questions worth 77 marks in total.
- The marks for each question or part are shown in brackets, for example [3].

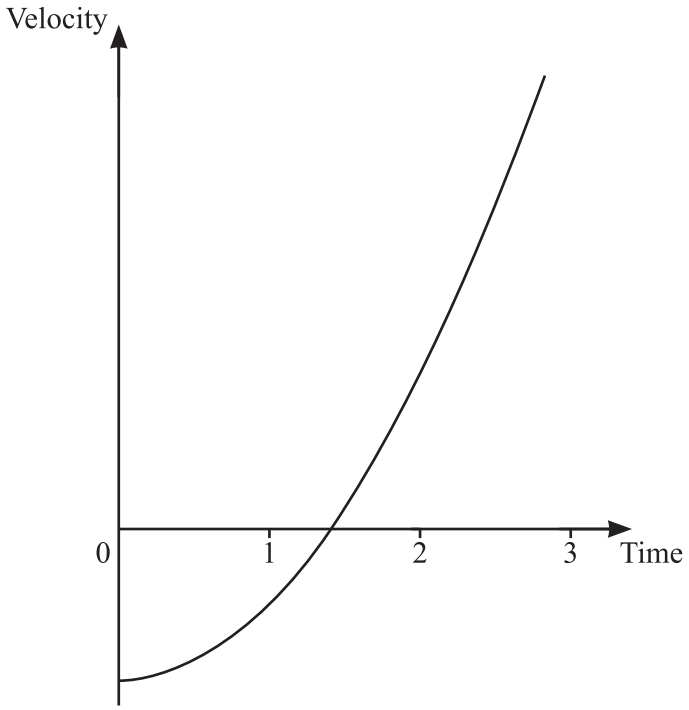
Advice

- Read every question through once before you write anything.
- Use the marks in brackets to judge how long to spend on each part.
- If you finish early, go back and check your working.

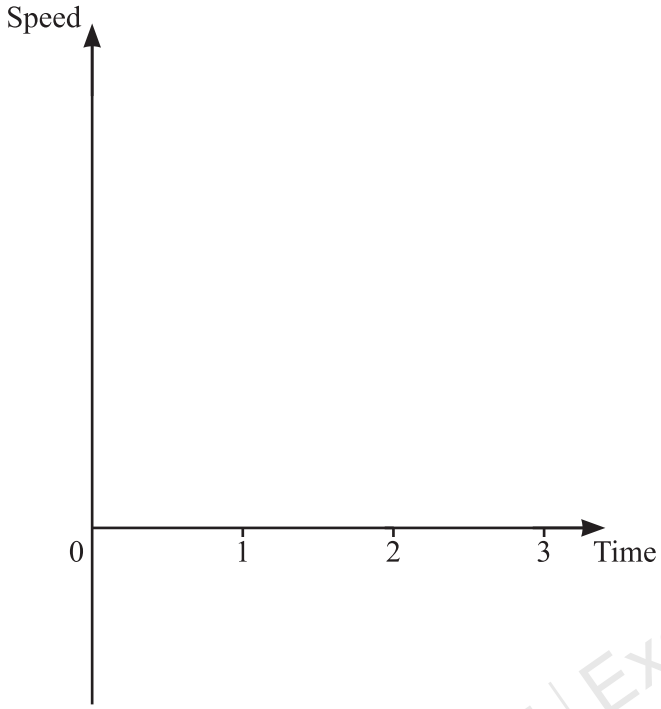
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Print at 100% (Actual size) so diagrams keep their real measurements.

1 The diagram shows the velocity–time graph for a particle moving in a straight line.



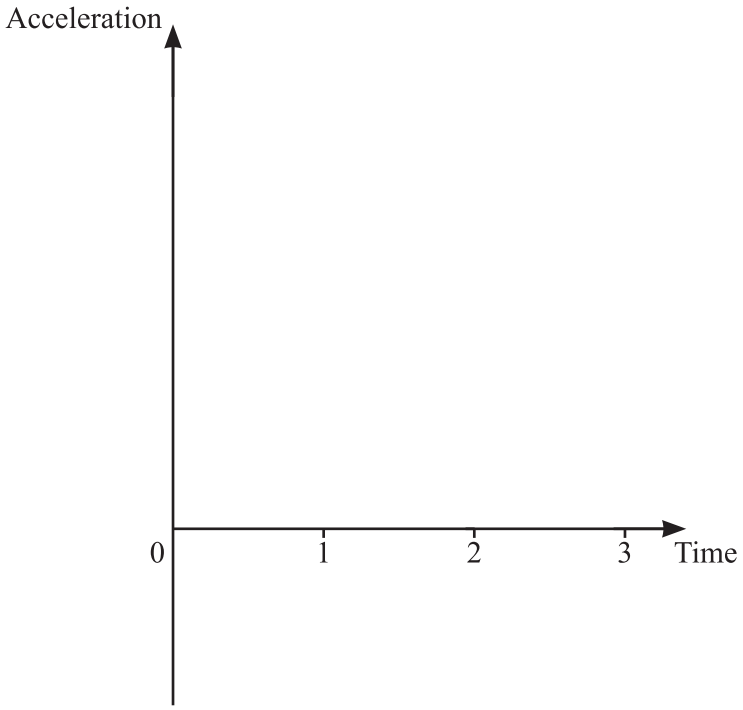
(a) On the diagram below, sketch the speed–time graph for the motion of this particle. [1]



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It is given that the velocity–time graph is part of a quadratic curve.
The curve has gradient 0 when time is 0.

(b) On the diagram below sketch a possible acceleration–time graph for the motion of the particle. [2]



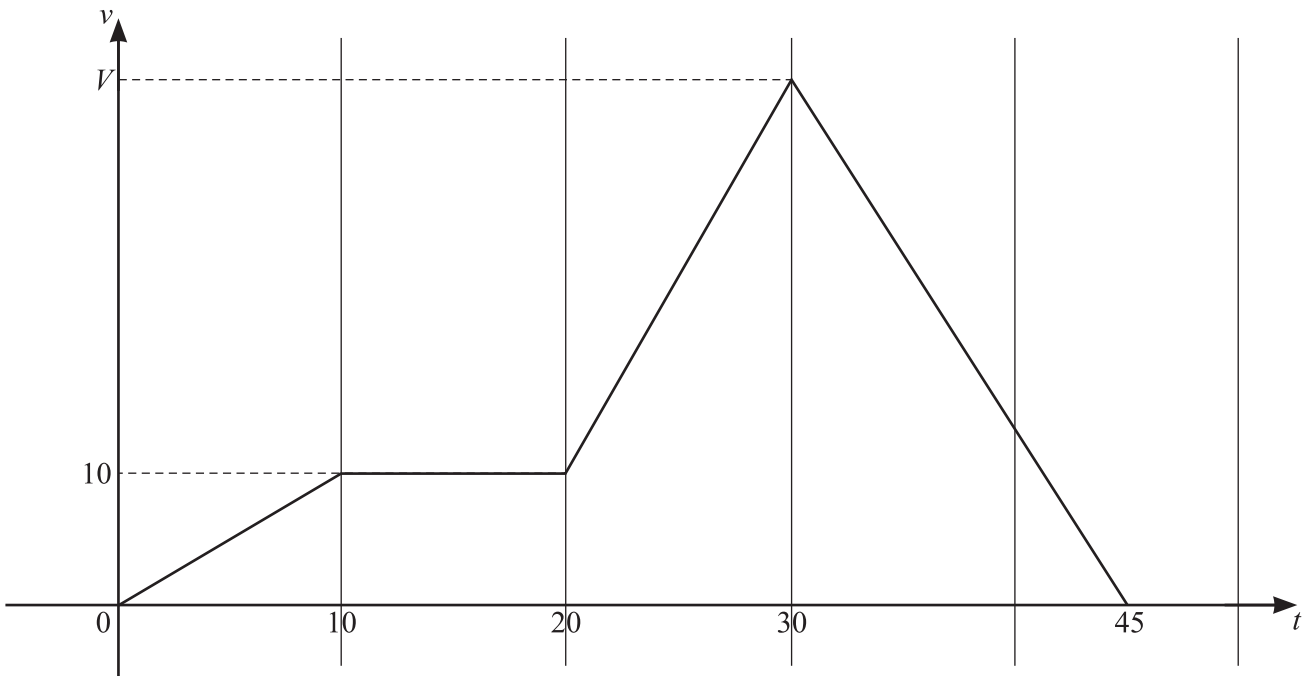
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1(a)	As v–t graph but negative portion reflected in x-axis	**B1**	
1(b)	Straight line with positive gradient	**B1**	
	Straight line starting at O	**B1**	

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2



The diagram shows the velocity–time graph for a particle travelling in a straight line with velocity, $v\,\text{ms}^{-1}$, at time t seconds. When $t = 30$ the velocity of the particle is $V\,\text{ms}^{-1}$. The particle travels 800 metres in 45 seconds.

(a) Find the value of V. [2]

(b) Find the acceleration of the particle when $t = 35$. [2]

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2(a)	Area under graph = 800 $\frac{1}{2}(10 \times 10) + (10 \times 10) + \frac{1}{2}(10(10 + V)) + \frac{15V}{2} = 800$	**M1**	For attempt to find the area, allow one error and one omission.
	$V = 48$	**A1**	

2(b)	$(-)\frac{their\ V}{15}$	**M1**	Allow omission of negative sign.
	$-\frac{16}{5}\text{ms}^{-2}$ oe	**A1**	**FT** on *their V* but must be negative.

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3 A particle moves in a straight line such that its displacement, s metres, from a fixed point, at time t seconds, $t \geqslant 0$, is given by $s = \left(1 + 3t\right)^{-\frac{1}{2}}$.

(a) Find the exact speed of the particle when $t = 1$. [3]

(b) Show that the acceleration of the particle will never be zero. [2]

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3(a)	$\frac{ds}{dt} = -\frac{3}{2}(1+3t)^{-\frac{3}{2}}$	**2**	**M1** for $a(1+3t)^{-\frac{3}{2}}$ **A1** all correct
	When t = 1, $\frac{ds}{dt} = -\frac{3}{16}$ Speed = $\frac{3}{16}$	**A1**	
3(b)	Acceleration = $\frac{27}{4}(1+3t)^{-\frac{5}{2}}$	**B1**	Allow unsimplified
	$(1+3t)^{-\frac{5}{2}}$ is always positive (so acceleration can never be zero.)	**B1**	Any valid explanation.

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4 A particle moves in a straight line so that, t seconds after passing through a fixed point O, its velocity, $v\,\text{ms}^{-1}$, is given by $v = 3t^2 - 30t + 72$.

(a) Find the distance between the particle's two positions of instantaneous rest. [6]

(b) Find the acceleration of the particle when $t = 2$. [2]

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4(a)	Factorises or solves $3t^2 - 30t + 72 = 0$ or $t^2 - 10t + 24 = 0$	**M1**	
	$t = 4$, $t = 6$	**A1**	
	Integrates v to find F(t): $\frac{3t^3}{3} - \frac{30t^2}{2} + 72t$	**M2**	**M1** for any two terms correct
	Correct substitution for F(6) – F(4) or F(4) – F(6)	**M1**	**dep** on at least **M1** for integration **FT** *their* 4 and *their* 6 provided they are **both positive**
	4 (m)	**A1**	**dep** on all previous marks being awarded
4(b)	$[a =]6t - 30$	**B1**	
	[When $t = 2$: $a = 6(2) - 30 =$] -18 (ms^{-2}) cao	**B1**	

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5 The acceleration, $a\,\text{ms}^{-2}$, of a particle at time t seconds is given by $a = -\dfrac{45}{(t+1)^2}$. When $t = 0$ the velocity of the particle is $50\,\text{ms}^{-1}$.

(a) Find an expression for the velocity of the particle in terms of t. [4]

(b) Find the distance travelled by the particle between $t = 1$ and $t = 10$. [4]

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5(a)	$\left[v=\int\frac{-45}{(t+1)^2}\,\mathrm{d}t=\right]\frac{-45(t+1)^{-1}}{-1}+C$ or better	**B2**	**B1** for $\left[v=\int\frac{-45}{(t+1)^2}\,\mathrm{d}t=\right]k(t+1)^{-1}$
	$50=\frac{their45}{0+1}+C$	**M1**	
	$\left[v=\right]\frac{45}{t+1}+5$	**A1**	
5(b)	$\left[\mathrm{F}(t)=\right]\quad\left[45\ln(t+1)+5t\right]_1^{10}$	**B2**	**B1** for (*their* 45)ln(t + 1)
	F(10) – F(1)	**M1**	**dep** on at least **B1**
	122 (m) or 121.7[13…] rot to 4 or more sf	**A1**	**dep** on all previous marks awarded

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6 A particle moves in a straight line such that its displacement, s metres, from a fixed point O at time t seconds, is given by $s = 2 + t - 2\cos t$, for $t \geqslant 0$.

(a) Find the displacement of the particle from O at the time when it first comes to instantaneous rest. [5]

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(b) Find the time when the particle next comes to rest. [1]

(c) Find the distance travelled by the particle for $0 \leqslant t \leqslant \frac{3\pi}{2}$. [2]

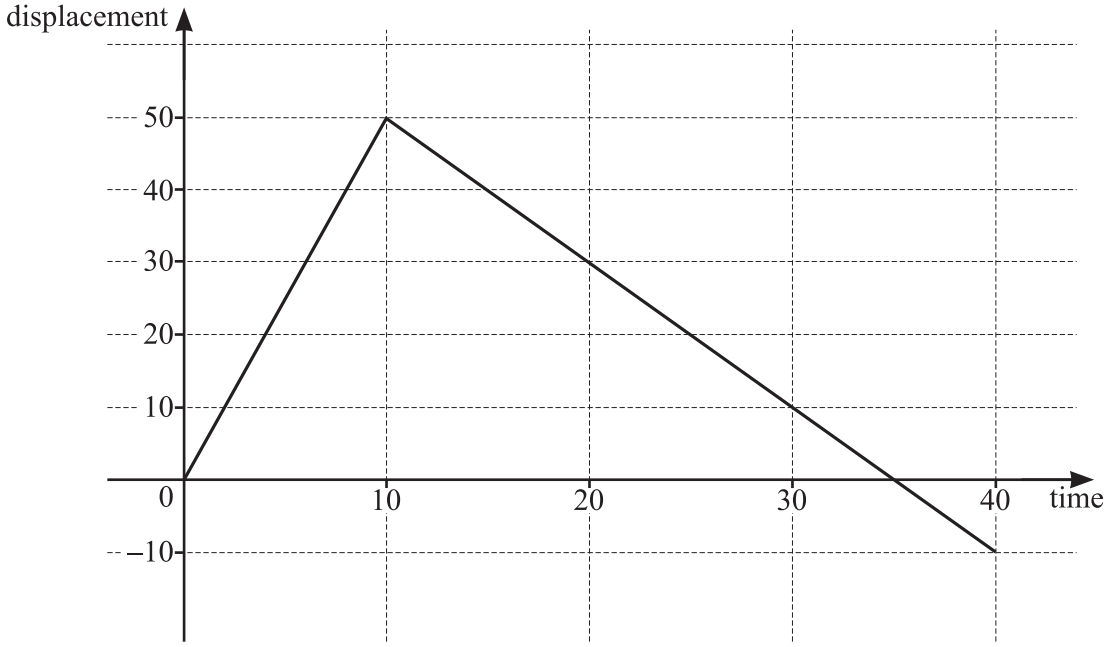
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6(a)	$\left[v = \frac{ds}{dt} = \right] 1 + 2\sin t$ soi	**B1**	
	Puts *their* $1 + 2\sin t = 0$ and solves for t	**M1**	**FT** $a + b\sin t$ where a and b are non-zero
	$t = \frac{7\pi}{6}$	**A1**	
	$s = \frac{7\pi}{6} + 2 - 2\cos\frac{7\pi}{6}$	**M1**	**FT** *their* $t \neq 0$; dep on previous **M1**
	7.4[0] or 7.397[24...] (metres) rot to 4 or more sig figs	**A1**	
6(b)	$t = \frac{11\pi}{6}$	**B1**	
6(c)	7.3972... + (7.3972... – 6.7123...)	**M1**	
	8.08[20...] (metres)	**A1**	

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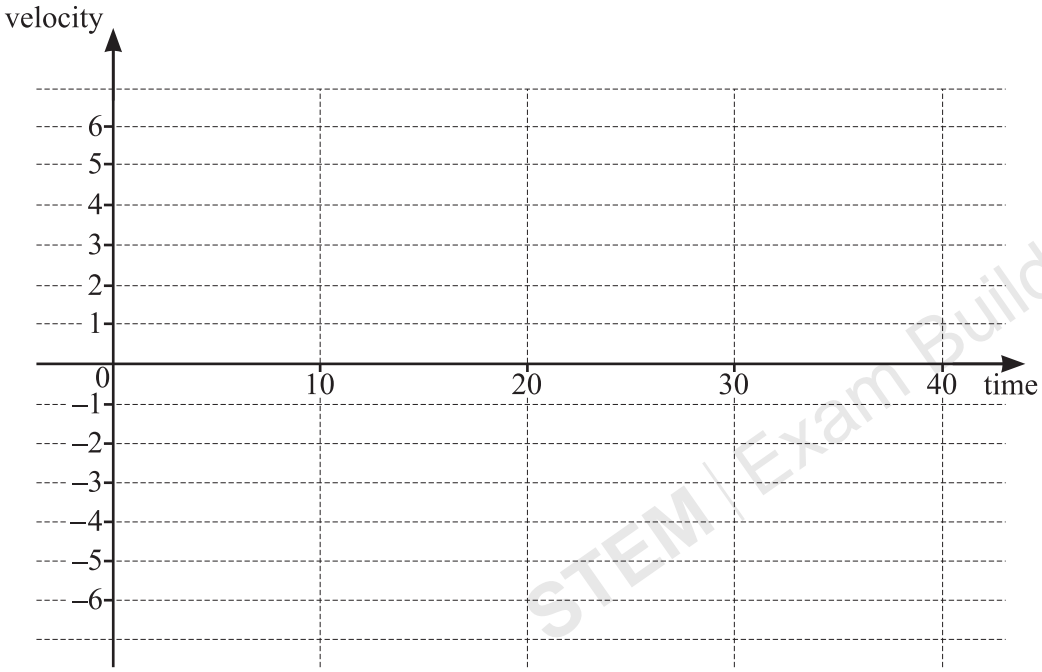
7 **(a)** In this question, all lengths are in metres and time, t, is in seconds.



The diagram shows the displacement–time graph for a runner, for $0 \leqslant t \leqslant 40$.

(i) Find the distance the runner has travelled when $t = 40$. [1]

(ii) On the axes, draw the corresponding velocity–time graph for the runner, for $0 \leqslant t \leqslant 40$. [2]



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(b) A particle, P, moves in a straight line such that its displacement from a fixed point at time t is s.

The acceleration of P is given by $(2t+4)^{-\frac{1}{2}}$, for $t > 0$.

(i) Given that P has a velocity of 9 when $t = 6$, find the velocity of P at time t. [3]

(ii) Given that $s = \frac{1}{3}$ when $t = 6$, find the displacement of P at time t. [3]

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7(a)(i)	110 (m)	**B1**	
7(a)(ii)		**B2**	**B1** for a line joining $(0,5)$ and $(10,5)$ **B1** for a line joining $(10,-2)$ and $(40,-2)$
7(b)(i)	$v=(2t+4)^{\frac{1}{2}}(+c)$	**M1**	For $k(2t+4)^{\frac{1}{2}}$
	$9=4+c$	**M1**	**Dep** for attempt to find c using $v=9$ and $t=6$ in *their* v
	$(2t+4)^{\frac{1}{2}}+5$	**A1**	
7(b)(ii)	$s=\frac{1}{3}(2t+4)^{\frac{3}{2}}\quad(+5t+d)$	**M1**	For $k(2t+4)^{\frac{3}{2}}$
	$\frac{1}{3}=\frac{64}{3}+30+d$	**M1**	**Dep** for attempt to find d using $s=\frac{1}{3}$ and $t=6$ in *their* s
	$\frac{1}{3}(2t+4)^{\frac{3}{2}}+5t-51$	**A1**	

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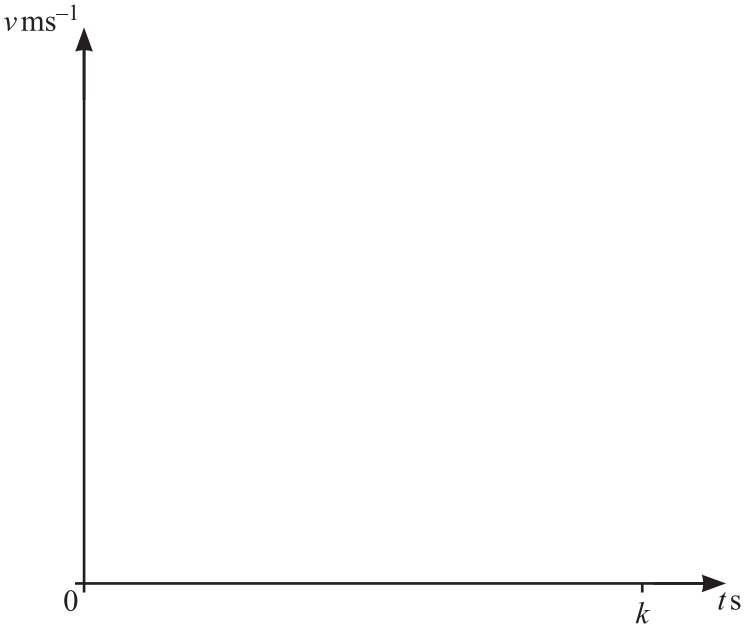
8 A particle P moves in a straight line and passes through a fixed point O.
At time t seconds, its displacement from O, s metres, is given by

$$s = t + 6t^2 - t^3 \qquad \text{for } 0 \leqslant t \leqslant 3$$

$$s = 12t - \frac{1}{3}t^2 - 3 \qquad \text{for } 3 \leqslant t \leqslant k \qquad \text{where } k \text{ is a constant.}$$

It is given that, for $3 \leqslant t \leqslant k$, the velocity of P is positive and its acceleration is negative.

(a) The maximum velocity of P occurs when $t = 2$.
On the axes below, sketch a velocity–time graph for the first k seconds of the motion of P. [4]



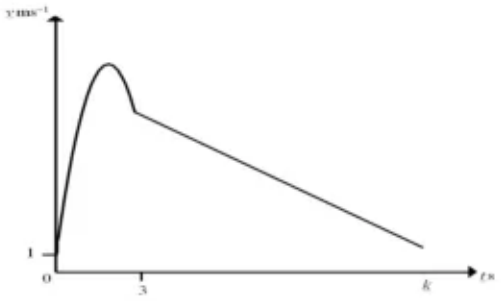
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(b) The total distance travelled by P for $0 \leqslant t \leqslant k$ is 57 metres.

Given that when $t = 3$ the distance and displacement of P from O are equal, find the value of k. [6]

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8(a)	$v = 1 + 12t - 3t^2$	**B1**	
	$v = 12 - \frac{2}{3}t$	**B1**	
		**2**	**B1** for correct shape for $0 \leqslant t \leqslant 3$, with v-intercept of 1 and end point (3, 10) soi and maximum point **B1** for a line with negative gradient for $3 \leqslant t \leqslant k$, start point (3, 10) soi and end point above the t-axis

8(b)	When $t = 3$, $s = 30$	**B1**	
	$\frac{1}{2}(10 + 12 - \frac{2}{3}k)(k - 3) = 57 - 30$ oe or $12k - \frac{k^2}{3} - 3\ [-30] = 57\ [-30]$ oe	**2**	**M1** for attempt at area using $t = k$
	$k = 6$ or $k = 30$	**2**	**A1** for $-\frac{1}{3}k^2 + 12k - 60[=0]$ or $k^2 - 36k + 180[=0]$ oe
	$k = 6$	**A1**	as v is negative when $k = 30$

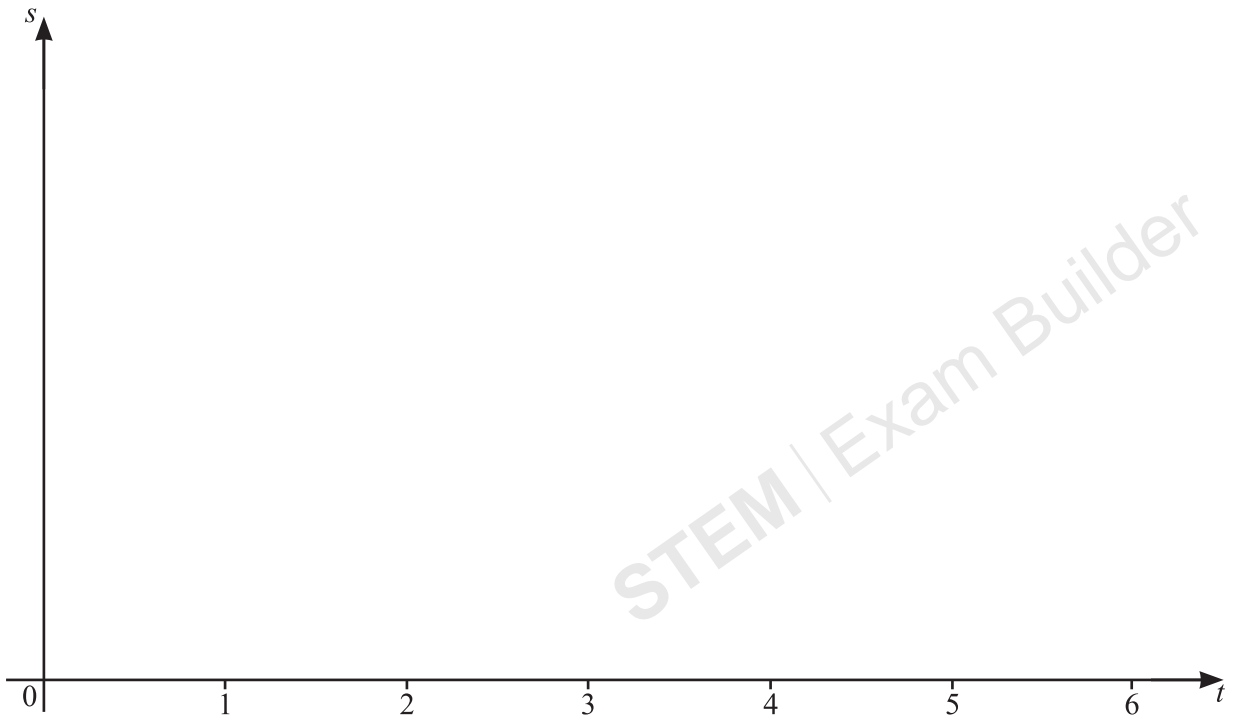
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9 In this question all lengths are in kilometres and time is in hours.

A particle P moves in a straight line such that its displacement, s, from a fixed point at time t is given by $s = (t+2)(t-5)^2$, for $t \geqslant 0$.

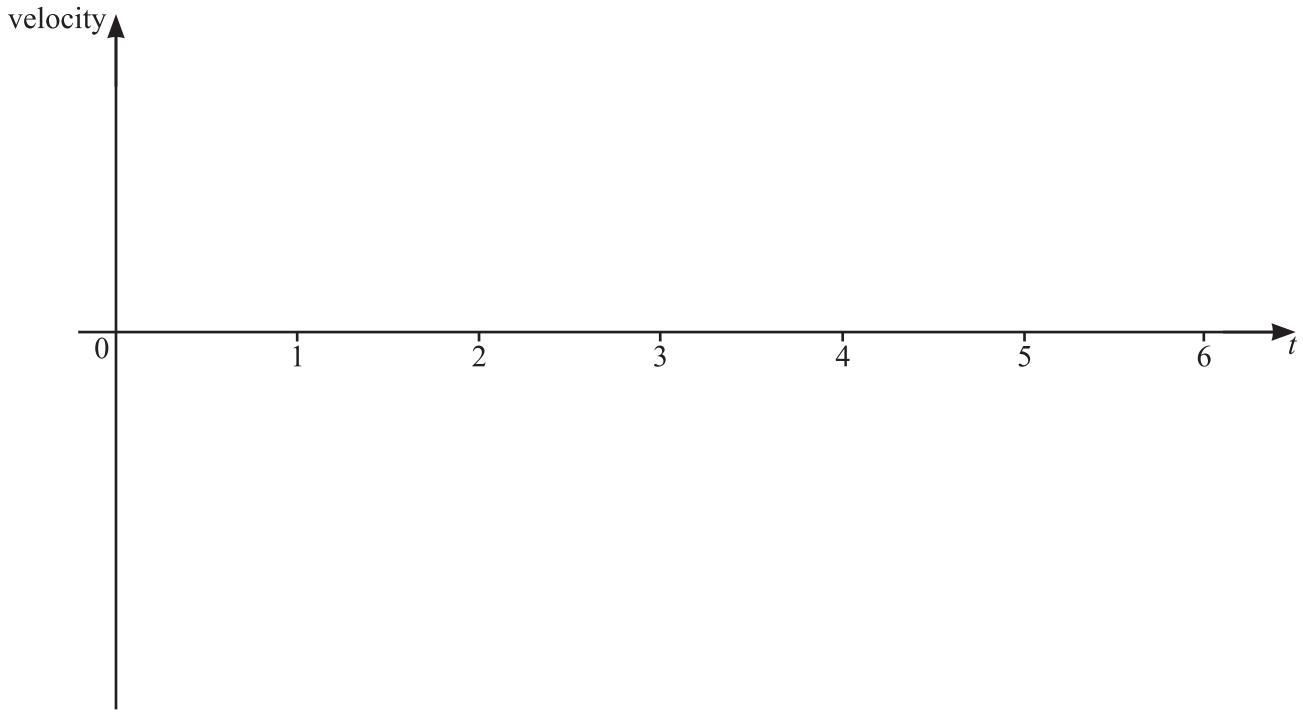
(a) Find the values of t for which the velocity of P is zero. [4]

(b) On the axes, draw the displacement–time graph for P for $0 \leqslant t \leqslant 6$, stating the coordinates of the points where the graph meets the coordinate axes. [2]



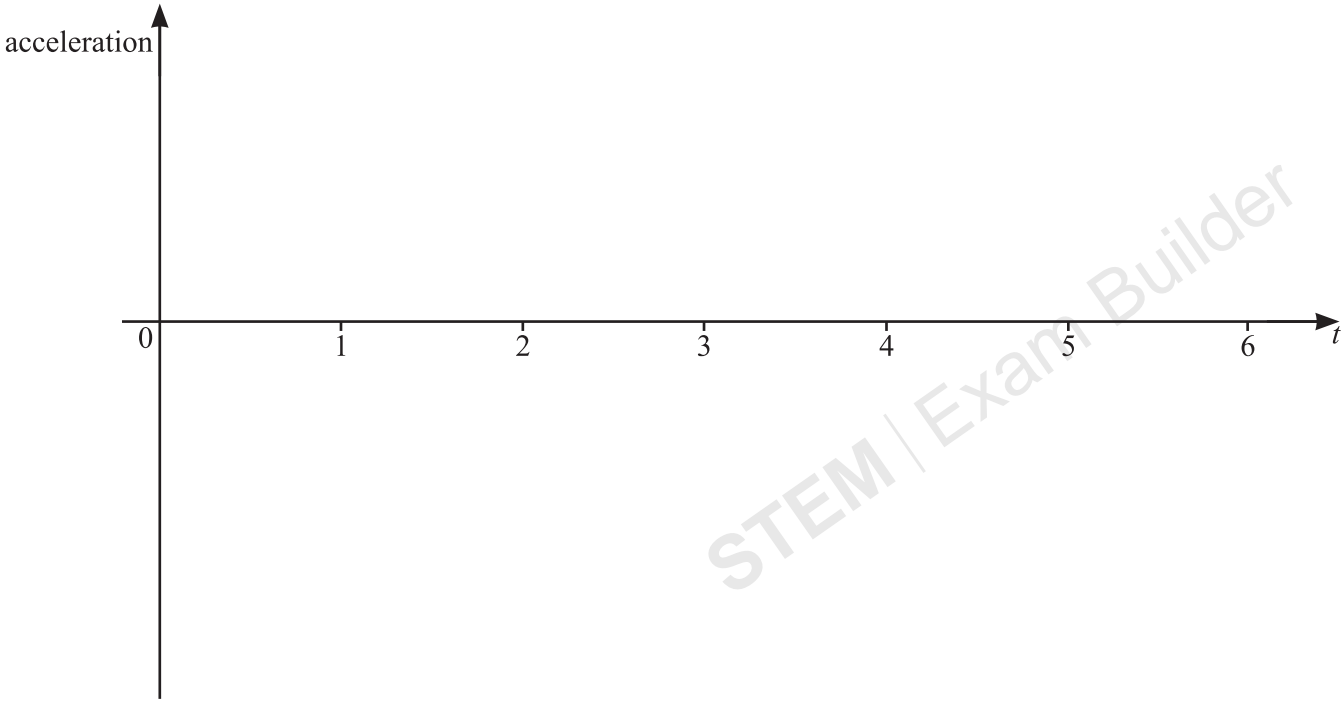
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(c) On the axes below, draw the velocity–time graph for P for $0 \leqslant t \leqslant 6$, stating the coordinates of the points where the graph meets the coordinate axes. [2]



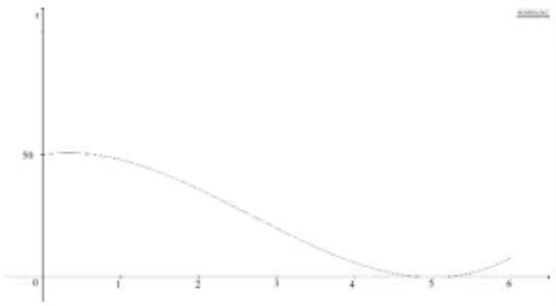
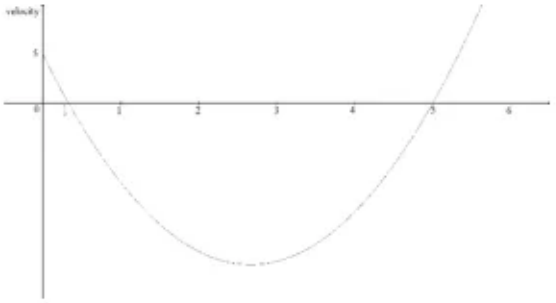
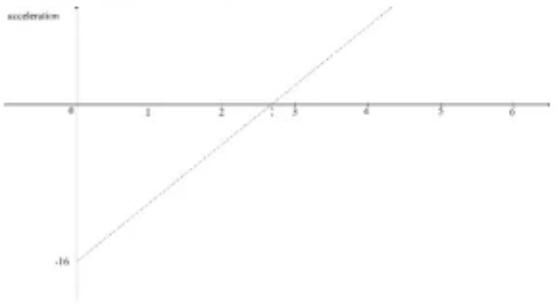
(d) **(i)** Write down an expression for the acceleration of P at time t. [1]

(ii) Hence, on the axes below, draw the acceleration–time graph for P for $0 \leqslant t \leqslant 6$, stating the coordinates of the points where the graph meets the coordinate axes. [2]



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9(a)	$\frac{ds}{dt} = 3t^2 - 16t + 5$ oe	**2**	**M1** for attempt at differentiation of a product or expansion and differentiation with at least two out of three terms of *their* expansion differentiated correctly **A1** all correct, allow factorised
	$t = \frac{1}{3},\ t = 5$	**2**	**Dep M1** for attempt to solve *their* $\frac{ds}{dt} = 0$, must be in quadratic form **A1** for both
9(b)		**2**	**B1** for a correct curve in the first quadrant only. There must be an indication of a max point in the correct position and a min point at $(5,\ 0)$ **B1** for $(0,\ 50)$ provided basic curve shape is correct
9(c)		**2**	**B1** for a quadratic curve in the first and fourth quadrants **B1** for $(0,\ 5)$, $\left(\frac{1}{3},\ 0\right)$ or $(0.333,\ 0)$ marked and passing through $(5,\ 0)$ on the x-axis
9(d)(i)	Acceleration = $6t - 16$	**B1**	
9(d)(ii)		**2**	**B1** for a straight line with a positive gradient in the first and fourth quadrants, meeting the vertical axis **Dep B1** for $\left(\frac{8}{3},\ 0\right)$ or $(2.67,\ 0)$ and $(0,-16)$

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10 In this question, all lengths are in metres and time is in seconds.

A particle, P, moves in a straight line such that t seconds after passing through a fixed point O its displacement, s, is given by $s = 5\ln(2t+1) - 5t$.

(a) Find the value of t for which P is instantaneously at rest. [4]

(b) Find the distance P travels between $t = 0$ and $t = 2$. [4]

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

(d) Find the acceleration when $t = 4.5$. [1]

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10(a)	$v = \frac{10}{2t+1} - 5$	**2**	**M1** for $v = \frac{A}{2t+1} - 5$
	When $v = 0$, $t = \frac{1}{2}$	**2**	**Dep M1** for attempt to solve *their* $v = 0$
10(b)	When $t = \frac{1}{2}$, $s = 0.9657$ or $5\ln 2 - 2.5$ **and** when $t = 2$ $s = -1.9528$ or $5\ln 5 - 10$	**2**	**FT** on *their t* from part **(a)** **B1FT** for when $t = \frac{1}{2}$, $s = 0.9657$ or $5\ln 2 - 2.5$
	3.88	**2**	**M1** for distance = $2(their 0.9657) + 1.9528$
10(c)	$-\frac{20}{(2t+1)^2}$ oe	**2**	**M1** for $\frac{B}{(2t+1)^2}$, where B is an integer
10(d)	–0.2	**B1**	Mark final answer, do not isw.

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