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EDEXCEL INTERNATIONAL GCSE MATHS: QUESTIONS BY TOPIC

Calculus (C1)

International GCSE Mathematics A (4MA1) · Higher tier

31 questions · 166 marks · Mark schemes included

Past papers June 2018 - June 2025 · 2 sub-topics

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HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

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QUESTIONS

31 questions · 166 marks · 2 sub-topics

SUB-TOPIC C1a

DIFFERENTIATION

Sub-topic C1a · 10 questions · 53 marks · lowest tariff first



23 Curve **C** has equation $y = px^3 - mx$ where p and m are positive integers.

Find the range of values of x , in terms of p and m , for which the gradient of **C** is negative.

(Total for Question 23 is 4 marks)



16 A curve has equation $y = 4x^3 - 8x + 5$

Find the x coordinates of the two points on the curve where the gradient is $\frac{1}{3}$

(Total for Question 16 is 4 marks)



12 The curve C has equation $y = \frac{1}{3}x^3 - 9x + 1$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \quad (2)$$

(b) Find the range of values of x for which C has a negative gradient.

(3)

(Total for Question 12 is 5 marks)



- 23** G is the point on the curve with equation $y = 8x^2 - 14x - 6$ where the gradient is 10
The straight line **Q** passes through the point G and is perpendicular to the tangent at G

Find an equation for **Q**

Give your answer in the form $ax + by + c = 0$ where a , b and c are integers.

(Total for Question 23 is 5 marks)



18 A curve C has equation $y = x^3 - 40x + 1$

Find the coordinates of both the points on C at which the gradient is 8

(..... , ...)

(..... , ...)

(Total for Question 18 is 5 marks)



17

$$y = x^3 - 2x^2 - 15x + 5$$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \dots\dots\dots (2)$$

C is the curve with equation $y = x^3 - 2x^2 - 15x + 5$

(b) Work out the range of values of x for which C has a negative gradient.

.....
(4)

(Total for Question 17 is 6 marks)



13 The curve C has equation $y = 5x^3 - x^2 - 6x + 4$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \dots\dots\dots$$

(2)

There are two points on the curve C at which the gradient of the curve is 2

(b) Find the x coordinate of each of these two points.
Show clear algebraic working.

.....

(4)

(Total for Question 13 is 6 marks)



24 The curve **C** has equation $y = ax^3 + bx^2 - 12x + 6$ where a and b are constants.

The point A with coordinates $(2, -6)$ lies on **C**

The gradient of the curve at A is 16

Find the y coordinate of the point on the curve whose x coordinate is 3

Show clear algebraic working.

$y = \dots\dots\dots$

(Total for Question 24 is 6 marks)

TOTAL FOR PAPER IS 100 MARKS



11 The curve C has equation $y = 4x^3 + x^2 - 20x$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \dots\dots\dots$$

(2)

(b) Find the x coordinates of the points on C where the gradient is 4
Show clear algebraic working.

.....

(4)

(Total for Question 11 is 6 marks)



21 The curve **T** has equation $y = x^3 - 2x^2 - 9x + 15$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \dots\dots\dots$$

(2)

(b) Find the range of values of x for which **T** has a positive gradient.
Give your values correct to 3 significant figures.
Show your working clearly.

(4)

(Total for Question 21 is 6 marks)



SUB-TOPIC C1b

TURNING POINTS & KINEMATICS

Sub-topic C1b · 21 questions · 113 marks · lowest tariff first



- 24 A particle P is moving along a straight line that passes through the fixed point O .
The displacement, s metres, of P from O at time t seconds is given by

$$s = t^3 - 6t^2 + 5t - 4$$

Find the value of t for which the acceleration of P is 3 m/s^2

$t = \dots\dots\dots$

(Total for Question 24 is 4 marks)

TOTAL FOR PAPER IS 100 MARKS



- 18** A particle is moving along a straight line that passes through the fixed point O
The displacement, s metres, of the particle from O at time t seconds is given by

$$s = 2t^3 - 5t^2 + 6t - 5$$

Find the value of t when the acceleration of the particle is 5 m/s^2

$t = \dots\dots\dots$

(Total for Question 18 is 4 marks)



20 The curve with equation $y = 2x^4 - 64x$ has a minimum point.

Find an equation of the tangent to the curve at the minimum point.
Show clear algebraic working.

(Total for Question 20 is 4 marks)



- 16 A particle P is moving along a straight line.
The fixed point O lies on this line.

At time t seconds, the displacement, s metres, of P from O is given by

$$s = 4t^3 - 6t^2 + 5t$$

At time t seconds, the velocity of P is v m/s.

- (a) Find an expression for v in terms of t .

$$v = \dots\dots\dots (2)$$

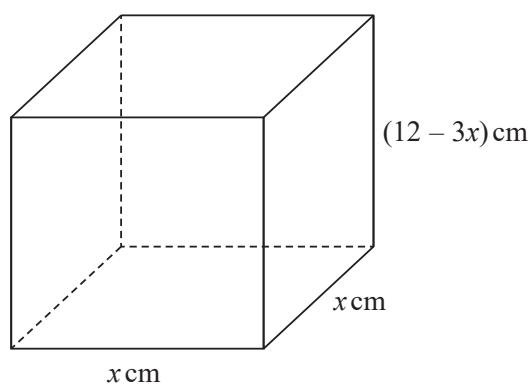
- (b) Find the time at which the acceleration of the particle is 6 m/s^2

$$\dots\dots\dots \text{ seconds} (3)$$

(Total for Question 16 is 5 marks)



18 The diagram shows a solid cuboid.



The total surface area of the cuboid is $A \text{ cm}^2$

Find the maximum value of A .

(Total for Question 18 is 5 marks)

- 20** A particle P is moving along a straight line.
The fixed point O lies on the line.

At time t seconds ($t \geq 0$), the displacement of P from O is s metres where

$$s = t^3 - 9t^2 + 33t - 6$$

Find the minimum speed of P .

..... m/s

(Total for Question 20 is 5 marks)



- 19 A particle P is moving along a straight line.
The fixed point O lies on this line.

At time t seconds where $t \geq 0$, the displacement, s metres, of P from O is given by

$$s = t^3 + 5t^2 - 8t + 10$$

Find the displacement of P from O when P is instantaneously at rest.

Give your answer in the form $\frac{a}{b}$ where a and b are integers.

..... metres

(Total for Question 19 is 5 marks)



- 21 The point A is the only stationary point on the curve with equation $y = kx^2 + \frac{16}{x}$ where k is a constant.

Given that the coordinates of A are $\left(\frac{2}{3}, a\right)$

find the value of a .

Show your working clearly.

$a = \dots\dots\dots$

(Total for Question 21 is 5 marks)



24 A particle P moves along a straight line that passes through the fixed point O

The displacement, x metres, of P from O at time t seconds, where $t \geq 0$, is given by

$$x = 4t^3 - 27t + 8$$

The direction of motion of P reverses when P is at the point A on the line.

The acceleration of P at the instant when P is at A is $a \text{ m/s}^2$

Find the value of a

$a = \dots\dots\dots$

(Total for Question 24 is 5 marks)



- 17 A particle P moves along a straight line.
The fixed point O lies on this line.

The displacement of P from O at time t seconds, $t \geq 1$, is s metres where

$$s = 4t^2 + \frac{125}{t}$$

The velocity of P at time t seconds, $t \geq 1$, is v m/s

Work out the distance of P from O at the instant when $v = 0$

..... m

(Total for Question 17 is 5 marks)



20 The radius of a right circular cylinder is x cm.

The height of the cylinder is $\left(\frac{800}{\pi x} - x\right)$ cm.

The volume of the cylinder is $V\text{cm}^3$

Find the maximum value of V

Give your answer correct to the nearest whole number.



.....

(Total for Question 20 is 5 marks)

Turn over for Question 21



19 A curve C has equation $y = x^3 - 8x^2 - 12x + 5$

Curve C has exactly two stationary points, one at point A and one at point B such that

x coordinate of point $A > x$ coordinate of point B

Find the coordinates of point A

Show clear algebraic working.

(....., ...)

(Total for Question 19 is 5 marks)



- 20 (a) Express $2x^2 - 11x + 9$ in the form $a(x - b)^2 - c$ where a , b and c are numbers to be found.

.....
(3)

The curve **C** has equation $y = 2(x - 3)^2 - 11(x - 3) + 9$

The point P is the minimum point on **C**

- (b) Find the coordinates of P

(..... , ...)
(2)

(Total for Question 20 is 5 marks)



22 The diagram shows a solid cuboid.

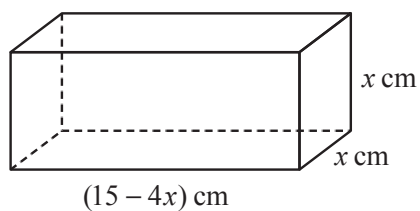


Diagram **NOT**
accurately drawn

The volume of the cuboid is $V \text{ cm}^3$

Find the maximum value of V

(Total for Question 22 is 5 marks)

19 The curve shown in the diagram has equation

$$y = x^3 - 27x + k \text{ where } k \text{ is a positive constant with } k < 54$$

The curve has a maximum point at $A(a, b)$

The curve has a minimum point at $B(c, d)$

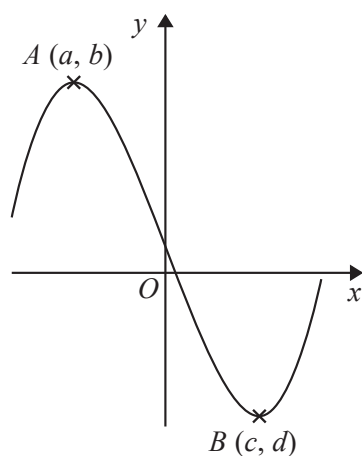


Diagram **NOT**
accurately drawn

Using differentiation, find the value of $b - d$
Show your working clearly.

(Total for Question 19 is 6 marks)



23 A particle moves along a straight line.

The fixed point O lies on this line.

The displacement of the particle from O at time t seconds, $t \geq 0$, is s metres where

$$s = t^3 + 4t^2 - 5t + 7$$

At time T seconds the velocity of P is V m/s where $V \geq -5$

Find an expression for T in terms of V .

Give your expression in the form $\frac{-4 + \sqrt{k + mV}}{3}$ where k and m are integers to be found.

$T = \dots\dots\dots$

(Total for Question 23 is 6 marks)

TOTAL FOR PAPER IS 100 MARKS



- 23 Two particles, P and Q , move along a straight line.
The fixed point O lies on this line.

The displacement of P from O at time t seconds is s metres, where

$$s = t^3 - 4t^2 + 5t \quad \text{for } t > 1$$

The displacement of Q from O at time t seconds is x metres, where

$$x = t^2 - 4t + 4 \quad \text{for } t > 1$$

Find the range of values of t where $t > 1$ for which both particles are moving in the same direction along the straight line.



.....

(Total for Question 23 is 6 marks)

Turn over for Question 24



17 $y = 4x^3 + 5x^2 + 2x$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \dots\dots\dots (2)$$

(b) Find the coordinates of the turning points on the graph with equation $y = 4x^3 + 5x^2 + 2x$
Show clear algebraic working.

.....
(4)

(Total for Question 17 is 6 marks)



13 A curve C has equation $y = x^3 - x^2 - 8x + 12$

(a) Find $\frac{dy}{dx}$

$$\frac{dy}{dx} = \quad (2)$$

The curve C has two turning points.

(b) Work out the x coordinates of the two turning points.
Show your working clearly.

(3)

(c) Show that the x -axis is a tangent to the curve C.

(2)

(Total for Question 13 is 7 marks)



- 22 The diagram shows a sketch of part of the curve with equation $y = x^2 - \frac{p}{x}$ where p is a positive constant.

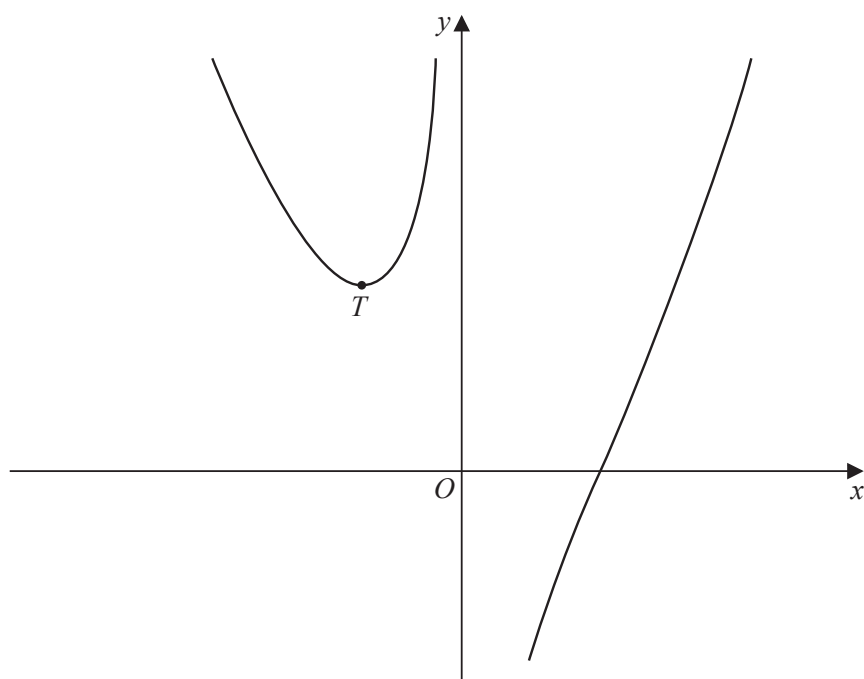


Diagram **NOT**
accurately drawn

For all values of p , the curve has exactly one turning point and this turning point is a minimum shown as the point T in the sketch.

For the curve where the x coordinate of T is -3

- (a) find the value of p

$p = \dots\dots\dots$
(4)



The line with equation $y = k$ is a tangent to the curve with equation $y = x^2 - \frac{16}{x}$

(b) Find the value of k

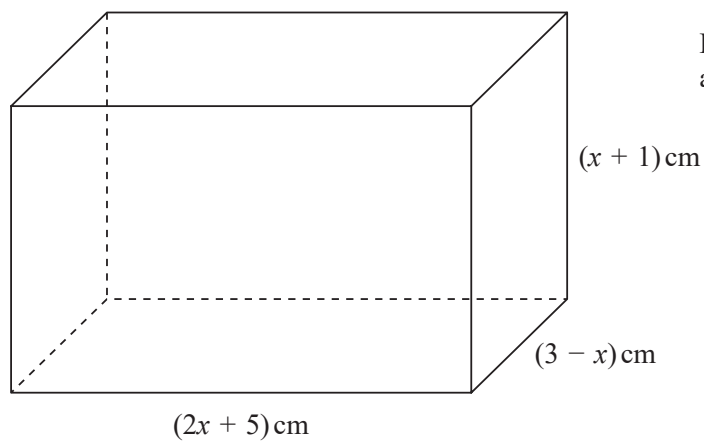
$$k = \dots\dots\dots (3)$$

(Total for Question 22 is 7 marks)

Turn over for Question 23



15

Diagram **NOT**
accurately drawn

The diagram shows a cuboid of volume $V\text{cm}^3$

(a) Show that $V = 15 + 16x - x^2 - 2x^3$

(3)



There is a value of x for which the volume of the cuboid is a maximum.

(b) Find this value of x .

Show your working clearly.

Give your answer correct to 3 significant figures.

$x = \dots\dots\dots$
(5)

(Total for Question 15 is 8 marks)



MARK SCHEMES

official mark schemes, in the same order as the questions



22	$y = -\frac{7}{2}x(+10)$ or (gradient $\Rightarrow -\frac{7}{2}$		4	B1 for correct gradient which may be seen in an equation. Condone $-\frac{7}{2}x$
	$-\frac{7}{2}, m = -1$ or $(m =) \frac{2}{7}$			M1 ft their gradient for use of $m_1 \times m_2 = -1$
	$-11 = \frac{2}{7} \times 6 + c$ or $y - -11 = \frac{2}{7}(x - 6)$ oe			M1 ft dep on M1
		$\left(0, -\frac{89}{7}\right)$		A1 accept $\left(0, -12\frac{5}{7}\right)$ must be exact values
				Total 4 marks

23	$\left(\frac{dy}{dx} = \right) 3px^2 - m$		4	M1 for $3px^2$ or $-m$
	$3px^2 - m < 0$ oe			M1 ft dep on M1 for setting up an inequality with their ' $3px^2$ ' or ' m ' must be a two-term expression in the form $apx^2 \pm m$
	$\pm \sqrt{\frac{m}{3p}}$			B1 for both critical values
		$-\sqrt{\frac{m}{3p}} < x < \sqrt{\frac{m}{3p}}$		A1 may be seen as two separate inequalities
				Total 4 marks

15	$3nx - 4x = 3p + n$		3	M1 for removing the denominator and expanding in a correct equation
	$3nx - n = 3p + 4x$ or $-4x - 3p = n - 3nx$			M1ft for gathering terms in n on one side and other terms the other side in an equation ft their equation dep on 2 terms in n and 2 other terms
	<i>Working not required, so correct answer scores full marks (unless from obvious incorrect working)</i>	$n = \frac{3p + 4x}{3x - 1}$		A1 oe $n = \frac{-3p - 4x}{1 - 3x}$ oe (must see " $n =$ "... on answer line or in working)
Total 3 marks				

16	$\left(\frac{dy}{dx} = \right) 3 \times 4x^2 - 8 (= 12x^2 - 8)$		4	B2 for $3 \times 4x^2 - 8$ or $12x^2 - 8$ (with no other terms) (B1 for one term, ie $3 \times 4x^2$ or $12x^2$ or -8)
	" $12x^2 - 8$ " = $\frac{1}{3}$			M1 for equating their initial derivative with the given gradient. Derivative must be a quadratic (dep on B1)
	<i>Working not required, so correct answer scores full marks (unless from obvious incorrect working)</i>	$\pm \frac{5}{6}$		A1oe Ignore y values Allow $\pm 0.83(333\dots)$ or $\pm \sqrt{\frac{25}{36}}$ oe
Total 4 marks				



Question	Working	Answer	Mark	Notes
12 (a)	$3 \times \frac{1}{3}x^2 - 9$			M1 for $3 \times \frac{1}{3}x^2$ oe or -9 oe
		$x^2 - 9$ oe	2	A1 or for $1x^2 - 9$ oe
(b)		$-3 < x < 3$ oe	3	B3 may be seen as two separate inequalities if not B3 then award B2 for $x < 3$ or $x > -3$ or $-3 \leq x \leq 3$ if not B2 then award B1 for $x^2 - 9 < 0$ or $x^2 < 9$ oe or for $(x-3)(x+3)$ or for $(x=)\pm 3$ (values maybe seen in incorrect inequalities) SC: If no marks awarded and M1 awarded in (a) then award B1 for "quadratic" < 0

23	$\left(\frac{dy}{dx} = \right) 16x - 14$		5	M1	Differentiation to obtain 2 terms with at least 1 correct
	$16x - 14 = 10$			M1	their $dy/dx = 10$ dep on M1
	$(1.5, -9)$ or $x = 1.5, y = -9$			A1	coordinates of point on curve at which gradient is 10 – allow given as coordinates or as x worked out and y worked out if meaning is clear
	eg $y - -9 = -\frac{1}{10}(x - \frac{3}{2})$ oe or eg $-9 = -\frac{1}{10} \times 1.5 + c$ oe			M1	A correct method to find the equation for line Q using $(1.5, -9)$
	<i>Correct answer scores full marks (unless from obvious incorrect working)</i>	$2x + 20y + 177 = 0$		A1	oe where a, b, c are integers eg $10x + 100y + 885 = 0$
					Total 5 marks

18	$3x^2$ or -40		5	M1 for differentiating one of the first two terms correctly
	$3x^2 - 40$			A1 for both terms correct and no additions
	$“3x^2 - 40” = 8$			M1ft dep on M1 for equating their quadratic derivative with 8 (Derivative must be in the form $ax^2 - 40$ or $3x^2 - b$ where $a \neq 0$ and $b \neq 0$)
	$(y =) “4”^3 - 40 \times “4” + 1 (= -95)$ or $y = (“-4”)^3 - 40 \times “-4” + 1 (= 97)$			M1ft dep on previous M1 for substituting at least one x value into y NB Following through from $ax^2 - 40 = 8$ or $3x^2 - b = 8$, their x values must be correct
	<i>Working not required, so correct answer scores full marks (unless from obvious incorrect working)</i>	$(4, -95), (-4, 97)$		A1 both coordinates must be paired correctly
				Total 5 marks



Question	Working	Answer	Mark	Notes
17 (a)		$3x^2 - 4x - 15$	2	B2 Award B1 for any 2 or 3 of the 4 terms differentiated correctly.
(b)	$3x^2 - 4x - 15 < 0$ (or $= 0$)		4	M1 ft from (a) ie "their (a)" $= 0$ (or < 0)
	$(3x + 5)(x - 3) < 0$ or $\frac{-(-4) \pm \sqrt{(-4)^2 - 4 \times 3 \times (-15)}}{2 \times 3}$			M1 ft from "their (a)" $(=0)$ for 3 term quadratic, for correct factorisation or correct use of quadratic formula to find the two critical values, allow 1 sign error. $[-(-4)]$ could be 4 and $(-4)^2$ could be 4^2 (condone missing brackets)
	$-\frac{5}{3}, 3$			M1 Both critical values correct Accept -1.66... rounded or truncated to 3SF.
		$-\frac{5}{3} < x < 3$		A1oe Inequality signs needed Allow $x > -\frac{5}{3}, x < 3$
				Total 6 marks



13	(a)		$15x^2 - 2x - 6$	2	B2 for correct differentiation
	(b)	e.g. " $15x^2 - 2x - 6$ " = 2 oe		4	(B1 for 2 of $15x^2$, $-2x$, -6 correct) M1 ft, for equating their dy/dx to 2
		$15x^2 - 2x - 8 (= 0)$			M1 (dep on M1) ft their three-term quadratic
		e.g. $(3x + 2)(5x - 4) (= 0)$ $x = \frac{2 \pm \sqrt{(-2)^2 - (4 \times 15 \times -8)}}{2 \times 15}$			M1 for solving their quadratic equation using any correct method - if factorising, allow brackets which expanded give 2 out of 3 terms correct (if using formula or completing the square allow one sign error and some simplification – allow as far as e.g. $\frac{2 \pm \sqrt{4 + 480}}{30}$ oe)
			$-\frac{2}{3}, \frac{4}{5}$		A1 oe, dep on M2 (allow -0.66 or better), Both values – isw any attempt to find y coordinates
Total 6 marks					

24	eg $-6 = 8a + 4b - 24 + 6$ or $8a + 4b = 12$ oe		6	M1	for substituting $x = 2$ and $y = -6$ into the equation for C
	$\left(\frac{dy}{dx}\right) 3ax^2 + 2bx - 12$ oe			M1	at least 2 terms correct
	eg $16 = 12a + 4b - 12$ or $12a + 4b = 28$ oe			M1ft	(dep on previous M1) follow through their $\frac{dy}{dx}$
	$a = 4$ and $b = -5$			M1	for $a = 4$ and $b = -5$
	eg “4” $\times 3^3 +$ “-5” $\times 3^2 - 12 \times 3 + 6$			M1ft	correctly substituting their a , their b and $x = 3$ into the equation for C
		33		A1	(dep on M3) allow (3, 33)
				Total 6 marks	

11	(a)		2	M1 for at least 2 of $12x^2$, $2x$, -20
		$12x^2 + 2x - 20$		A1
	(b)	$12x^2 + 2x - 20 = 4$ oe	4	M1 ft, for equating their dy/dx to 4
		$12x^2 + 2x - 24 (= 0)$ or $6x^2 + x - 12 (= 0)$		M1 (dep on M1) ft their dy/dx in the form $ax^2 + bx (+ c)$
		eg $(6x - 8)(2x + 3) (= 0)$ or $(3x - 4)(2x + 3) (= 0)$ or $x = \frac{-2 \pm \sqrt{(2)^2 - (4 \times 12 \times -24)}}{2 \times 12}$		M1 for solving their three-term quadratic equation using any correct method - if factorising, allow brackets which expanded give 2 out of 3 terms correct (if using formula or completing the square allow one sign error and some simplification – allow as far as eg $\frac{-2 \pm \sqrt{4 + 1152}}{24}$ oe)
		Working required	$\frac{4}{3}, -\frac{3}{2}$	A1 (dep on M2) oe, allow 1.33(3...) for $\frac{4}{3}$, both values – isw any attempt to find y coordinates
Total 6 marks				
12	(a)	28	1	B1 allow 27.5 – 28.5
	(b)	14	1	B1 cao
	(c)		2	M1 for a reading of 38 from vertical axis or 50 – (their reading from a height of 35)
		Correct answer scores full marks (unless from obvious incorrect working)		A1 cao
				Total 4 marks

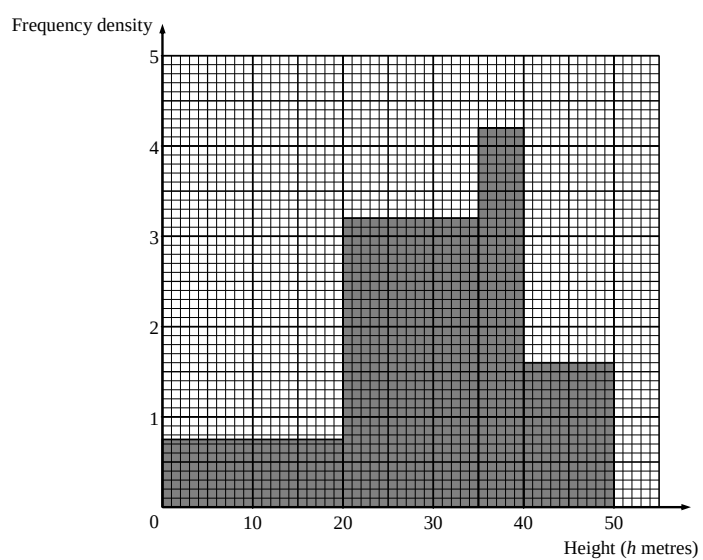
21	(a)	$3x^2$ or $-2 \times 2x$ or $-4x$ or -9 oe		2	M1 for differentiating one term correctly
			$3x^2 - 4x - 9$		A1 for a correct expression Allow $3x^2 - 2 \times 2x - 9$
	(b)	$(x =) \frac{4 \pm \sqrt{(-4)^2 - (4 \times 3 \times -9)}}{2 \times 3}$ or $3 \left[\left(x - \frac{2}{3} \right)^2 - \left(\frac{2}{3} \right)^2 \right] - 9 (= 0)$		4	M1 for finding the critical values for a 3-term quadratic using any correct method - if using formula or completing the square allow one sign error and some simplification – allow as far as eg $\frac{4 \pm \sqrt{16 + 108}}{6}$ oe or eg $3 \left(x - \frac{2}{3} \right)^2 - 10\frac{1}{3}$ oe)
			-1.19 and 2.52		A1 for critical values of -1.19 and 2.52 or better (for this A1 mark allow -1.2 or -1.18 and 2.5 or $\frac{2 \pm \sqrt{31}}{3}$ oe)
			$x < -1.19$		A1 awrt -1.19
			$x > 2.52$		A1 awrt 2.52
Total 6 marks					

23		$\left(\frac{10+2}{2}, \frac{7+19}{2}\right)$ or (6, 13)		5	M1
		$\frac{19-7}{10-2} \left(= \frac{12}{8}\right)$ oe or 1.5 oe			M1
		$m \times \frac{3}{2} = -1$ oe or $m = -\frac{2}{3}$			M1 for use of $m_1 m_2 = -1$
		"13" = $-\frac{2}{3} \times$ "6" + c or $c = 17$ oe or $y -$ "13" = $-\frac{2}{3}(x -$ "6")			M1 Or for $y = -\frac{2}{3}x + 17$ [NB: "13", "6" and $-\frac{2}{3}$ " must come from correct working]
			$3y + 2x = 51$		A1 for $3y + 2x = 51$ or $3y = -2x + 51$ etc but must be integer coefficients
					Total 5 marks

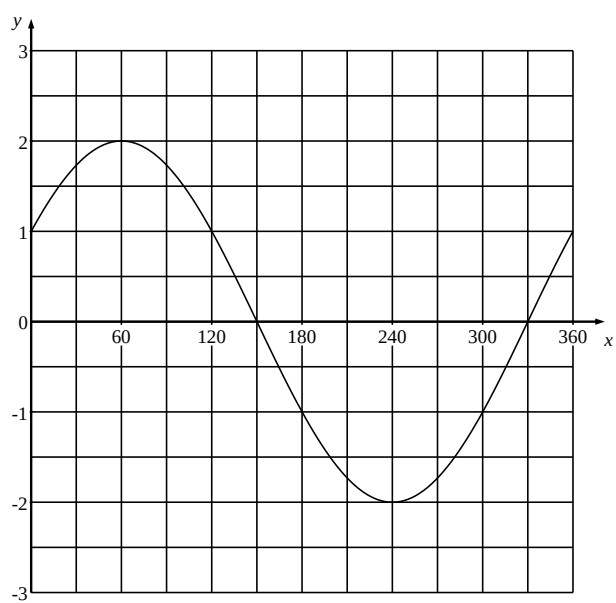
24		$(v \Rightarrow) 3t^2 - 6 \times 2t + 5 (+0)$		4	M1 for differentiating at least 2 terms correctly
		$(a \Rightarrow) 3 \times 2t - 12$			M1 dep ft
		$6t - 12 = 3$			M1 dep on at least M1 for equating their acceleration in terms of t to 3
			2.5 oe		A1
					Total 4 marks



Q19



q22



Question	Working	Answer	Mark	Notes
18	$(\frac{ds}{dt} =) 6t^2 - 10t + 6$		4	M1 at least 2 terms correct
	$(\frac{dv}{dt} =) 12t - 10$			M1 ft ft from a 3 term quadratic
	" $12t - 10 = 5$ "			M1 ft ft dep on previous M1 awarded
	<i>Working not required, so correct answer scores full marks (unless from obvious incorrect working)</i>	1.25		A1 oe
				Total 4 marks

20	$4 \times 2x^3$ or $8x^3$ or ± 64		4	M1 for differentiating one term correctly
	$8x^3 - 64 = 0$ oe			M1 dep on M1 The equation must be in the form $ax^3 - 64 = 0$ oe where $a \neq 0$ or $8x^3 + b = 0$ oe where $b \neq 0$ where a and b are constants
	$x = \sqrt[3]{\frac{64}{8}} (= 2)$			M1 dep on previous M1 for solving for x . The equation must be in the form $ax^3 - 64 = 0$ oe where $a \neq 0$ or $8x^3 + b = 0$ oe where $b \neq 0$ where a and b are constants
	Working required	$y = -96$		A1 oe eg $y + 96 = 0$ or $y = 0x - 96$ or $-y = 96$ dep on M3 must be an equation in terms of y Do not accept -96 or $(2, -96)$
				Total 4 marks



15	(Gradient of L_1) $6 \div 2 (=3)$		4	M1	could be seen as part of an equation. Ignore constant term if candidate rearranges L_1
	$m \times "3" = -1$ or $m = -\frac{1}{"3"}$			M1	for use of $m_1 m_2 = -1$ could be seen as part of an equation
	$-1 = -\frac{1}{3} \times 9 + c$ or $y - -1 = -\frac{1}{3}(x - 9)$ or $c = 2$			M1	
		$y + \frac{1}{3}x = 2$		A1	oe in required form eg $3y + x = 6$, $6y + 2x = 12$ etc
					Total 4 marks
16	(a)	$3 \times 4t^2 - 2 \times 6t + 5$	2	M1	For 2 terms correct
		$12t^2 - 12t + 5$		A1	Fully correct
	(b)	$24t - 12$	3	M1	Method to differentiate their v , ft a 3 term quadratic expression from (a)
		$"24t - 12" = 6$		M1	ft if previous M1 awarded
		0.75		A1	oe
					Total 5 marks

18		x^2 oe or $x(12 - 3x)$ oe			M1 for finding an expression for the area of one face
		$x^2 + x^2 + 48x - 12x^2 (= 48x - 10x^2)$			M1 for a complete expression for A (6 sides) with brackets expanded
		'48 - 20x' = 0	'-10'[(x - '2.4') ² - '2.4' ²] oe		M1 for differentiating a correct expression for A (allow 1 error) and equating to zero or completing the square
		(x = 2.4) 48 × '2.4' - 10 × '2.4' ²	'-10' × - '2.4' ² or '-10' × - '5.76'		M1 ft if previous M1 awarded for isolating x and substituting into A or finding max value of A from completing the square
			57.6	5	A1 accept 58 from correct working
					Total 5 marks

20	$(v \Rightarrow) 3t^2 - 9 \times 2t + 33$		5	M1	for differentiating at least 2 terms correctly
	$(a \Rightarrow) 3 \times 2t - '18'$ or $(t \Rightarrow) -\frac{-18}{2 \times 3} \left(= \frac{18}{6} \right)$	$(v \Rightarrow) 3 \left[(t-3)^2 - (3)^2 \right] (+33) \text{ or }$ $(v \Rightarrow) 3 \left[(t-3)^2 - (3)^2 (+11) \right]$		M1	dep ft must be a two term linear equation or for the use of $(t \Rightarrow) -\frac{b}{2a}$ or for a correct first step for completing the square on at least a two term quadratic
	$6t - 18 = 0 \text{ or } t = 3$	$(v \Rightarrow) 3 \left[(t-3)^2 - (3)^2 \right] + 33 \text{ or }$ $(v \Rightarrow) 3 \left[(t-3)^2 - (3)^2 + 11 \right]$		M1	dep on at least M2 for equating their acceleration to 0 or for a correct method for completing the square on at least a two term quadratic
	$3 \times '3'^2 - 18 \times '3' + 33$	$(v \Rightarrow) 3(t-3)^2 + 6 \text{ or }$ $(v \Rightarrow) 3 \left[(t-3)^2 + 2 \right]$		M1	dep on at least M2 for substituting their t into v or for a seeing a correct simplified expression after completing the square
			6	A1	
					Total 5 marks



19		$(v =) 3t^2 + 10t - 8$		5	M1 For at least 2 terms differentiated correctly
		$3t^2 + 10t - 8 = 0$			M1 Their $v = 0$ dep on M1 could be implied by correct values
		$(3t - 2)(t + 4) (= 0)$ $(t =) \frac{2}{3}$ or $(t =) -4$			M1 dep on M1 for correct values for t or for $t = \frac{2}{3}$ or correct method to solve their 3 term quadratic equation: If factorising, allow brackets which when expanded give 2 out of 3 terms correct (If using formula or completing the square allow one sign error and some simplification – allow as far as eg $\frac{-10 \pm \sqrt{100 + 96}}{6}$ oe $3(t + \frac{5}{3})^2 - \frac{48}{3} = 0$)
		$(s =) \left(\frac{2}{3}\right)^3 + 5 \times \left(\frac{2}{3}\right)^2 - 8 \times \frac{2}{3} + 10$			M1 For $\frac{2}{3}$ (only) substituted into formula for s or for selecting the value from this substitution or for an answer of 7.185...
			$\frac{194}{27}$		A1 oe but numerator and denominator must be integers.
					Total 5 marks

Question	Working	Answer	Mark	Notes
21	$\left[\frac{dy}{dx} = \right] 2 \times kx - 16x^{-2}$ or $2kx - \frac{16}{x^2}$ oe		5	M2 for both terms differentiated correctly (M1) for one term differentiated correctly
	" $2kx - 16x^{-2} = 0$ " oe			M1 ft dep on M1
	eg $\frac{8}{27}k = 8$ or $\frac{4}{3}k = 36$ or $k = 27$ oe			M1 (not ft) for substituting $x = \frac{2}{3}$ into their correct equation for k and getting as far as one step from the value of k or the correct value of k
	Working must be seen	36		A1 dep on M4
				Total 5 marks



24	$(v =) 12t^2 - 27 (= 0)$		5	M1 Correct differentiation
	$t^2 = \frac{27}{12} (= \frac{9}{4})$ oe or $(3)(2t + 3)(2t - 3) (= 0)$			M1 dep M1 first stage to solve $v = 0$ by rearranging, factorising, quadratic formula, or completing the square
	$\sqrt{\frac{9}{4}}$ oe $(= \frac{3}{2})$ or $\pm \sqrt{\frac{9}{4}}$ oe $(= \pm \frac{3}{2})$			A1 Correct value of t (allow $\pm$)
	$(a =) 24t$			M1 dep 1st M1 for differentiating v
		36		A1 correct answer
				Total 5 marks

17	$8t$ or $\pm 125t^{-2}$ oe		5	M1 for differentiating one term correctly
	$8t - 125t^{-2}$ oe or $8t - \frac{125}{t^2}$ oe			A1 for both terms correct
	$8t - 125t^{-2} = 0$ and $(t =) \sqrt[3]{\frac{125}{8}} (= 2.5)$			M1 for equating their $8t \pm at^{-2}$ oe or $bt \pm 125t^{-2}$ oe to zero and solving for t ie must have correct powers of t and at least one correct coefficient and correct isolation of t
	$4("2.5")^2 + \frac{125}{"2.5"}$			M1 dep on previous M mark for substituting into s
		75		A1
				Total 5 marks



20	$(V =) \pi x^2 \left(\frac{800}{\pi x} - x \right)$ or $800x - \pi x^3$ oe		5	M1 for volume of cylinder (in terms of one variable, e.g. x or r)
	$\left(\frac{dV}{dx} = \right) 800 - 3\pi x^2$			M1ft for differentiating an expression in one variable to find 800 or $\pm 3\pi x^2$ (must come from a cubic in the form $800x \pm \pi x^3$ or $800x \pm ax^3$ or $bx \pm \pi x^3$ where $a \neq 0$ and $b \neq 0$)
	" $800 - 3\pi x^2 = 0$ "			M1ft dep on previous M1 for equating their $\frac{dV}{dx}$ to zero (must be a quadratic in the form $800 \pm ax^2$ or $b \pm 3\pi x^2$ where $a \neq 0$ and $b \neq 0$)
	$(x =) \sqrt{\frac{800}{3\pi}} (= \sqrt{84.8(8263...)})$ or $\frac{\sqrt{9600\pi}}{6\pi}$ or $9.2(13177...)$			A1 for a correct value of x Allow use of quadratic formula
	Award marks within the range from correct working	4914		A1 accept 4910 – 4914
				Total 5 marks



19	$\left(\frac{dy}{dx} = \right) 3x^2 - 16x - 12$		5	M1 for differentiation with at least 2 terms correct
	" $3x^2 - 16x - 12 = 0$ "			M1ft (dep on previous M1) for their $\frac{dy}{dx} = 0$
	eg $(3x+2)(x-6) (= 0)$ or $(x =) \frac{-(-16) \pm \sqrt{(-16)^2 - 4 \times 3 \times (-12)}}{2 \times 3}$ or $3 \left[\left(x - \frac{8}{3} \right)^2 - \frac{64}{9} \right] - 12 (= 0)$			M1ft (dep on 1 st M1) for the correct x value (of 6) – ignore other x value OR for solving their 3 term quadratic equation using any correct method (if factorising, allow brackets which expanded give 2 out of 3 terms correct) (if using formula allow one sign error and some simplification – allow as far as $\frac{16 \pm \sqrt{256+144}}{6}$) (if completing the square then as far as shown on LHS) The award of this mark implies the previous M mark
	eg $6^3 - 8 \times 6^2 - 12 \times 6 + 5 (= -139)$			M1ft (dep on 1 st M1) for $x = 6$ substituted into correct equation for curve C OR (dep on 1 st M1 and 2 values for x) for their greatest x value substituted into correct equation for curve C (ignore any attempt to substitute their least x value)
	Working required	(6, -139)		A1 (dep on M2) cao
				Total 5 marks



20	(a)	$2\left(x^2 - \frac{11}{2}x\right) + \dots$ or $2\left(x^2 - \frac{11}{2}x + \dots\right)$ oe		3	M1	for taking out a factor of 2
		$2\left[\left(x - \frac{11}{4}\right)^2 - \frac{11^2}{4^2}\right] + \dots$ or $2\left[\left(x - \frac{11}{4}\right)^2 - \frac{11^2}{4^2} + \dots\right]$ oe			M1	for correctly completing square
		Correct answer scores full marks (unless from obvious incorrect working)	$2\left(x - \frac{11}{4}\right)^2 - \frac{49}{8}$		A1	oe, eg $2(x - 2.75)^2 - 6.125$ allow $a = 2$, $b = \frac{11}{4}$ oe, $c = \frac{49}{8}$ oe if no other marks awarded, award SCB1 for $2\left(x - \frac{11}{4}\right)^2 + \dots$
		ALTERNATIVE				
ALT	(a)	$ax^2 - 2bax + b^2a - c$		3	M1	for correctly expanding $a(x - b)^2 - c$ to give $ax^2 - 2bax + b^2a - c$
		$-2ba = -11$ or $2ba = 11$ and $b^2a - c = 9$			M1	for setting up 2 equations using the coefficient of x and the numerical term
		Correct answer scores full marks (unless from obvious incorrect working)	$2\left(x - \frac{11}{4}\right)^2 - \frac{49}{8}$		A1	oe, eg $2(x - 2.75)^2 - 6.125$ allow $a = 2$, $b = \frac{11}{4}$ oe, $c = \frac{49}{8}$ oe if no other marks awarded, award SCB1 for $2\left(x - \frac{11}{4}\right)^2 + \dots$
	(b)		$\left(\frac{23}{4}, -\frac{49}{8}\right)$		B2ft	oe, eg (5.75, -6.125)
					(B1ft	for one correct coordinate)
Total 5 marks						



22	$(V =) x(x)(15 - 4x) \quad (= 15x^2 - 4x^3)$		5	M1	for a correct expression for the volume (condone missing $V = \dots$)
	$\left(\frac{dV}{dx} =\right) 30x - 12x^2$			M1ft	ft dep on a V of the form $ax^3 + bx^2$ where $a, b \neq 0$ for a two-term derivative with at least one term correct for their V eg $15(2)x$ or $30x$ or $-3(4)x^2$ or $-12x^2$
	$30x - 12x^2 = 0 \Rightarrow x = \dots$ or $(x =) 2.5$ oe			M1ft	dep on previous M mark for equating their 2-term first derivative to 0 and solving to get a value of x (the value of x obtained must be greater than 0 and must not be where their second derivative is equal to 0) or the correct value of x
	$(V =) "2.5" \times "2.5" \times (15 - 4 \times "2.5")$ or $(V =) 15("2.5")^2 - 4("2.5")^3$			M1	dep on M3 for a full and correct substitution of their value of x
	Correct answer only scores full marks (unless from obviously incorrect working)	31.25		A1	oe eg $\frac{125}{4}$ ignore any units on the answer line
				Total 5 marks	

18	$SQ^2 = 8^2 + 12^2 - 2 \times 8 \times 12 \times \cos 120^\circ$	91.4	6	M1	If this mark is awarded then fit on the remaining M marks
	$(SQ) = \sqrt{304}$			M1	for correct order of operations e.g. $64 + 144 + 96$ or 304 or $17.4\dots$ or $4\sqrt{19}$
	$\frac{\sin R}{\sqrt{304}} = \frac{\sin 27^\circ}{9}$			M1	
	$R = \sin^{-1} \left(\frac{\sin 27^\circ \times \sqrt{304}}{9} \right)$			M1	can be implied by 61.5833...
	61.58			A1	for 61.58 - 61.6
				B1	fit dep M3 $180 - "61.6" - 27$
					Total 6 marks

19	$\frac{dy}{dx} = 3x^2 - 27$	108		M1	for at least one of $3x^2$ or 27
	$3x^2 - 27 = 0$			M1	(dep) for a 2 or 3 term quadratic =0
	$x = \pm 3$			A1	
	When $x = -3$, $b = (-3)^3 - 27(-3) + k (= 54 + k)$ When $x = 3$, $d = 3^3 - 27(3) + k (= -54 + k)$			M1	for either substituting $x = 3$ or $x = -3$ into the y expression. Only award this mark if k or a number representing k is in the expression for b or d
	$b - d = 54 + k - (-54 + k)$			M1	dep on all previous M marks Expressions for b and d must have k or the same number representing k
				A1	
					Total 6 marks

22	a		2	M1 for one correct value
		2.5, -60		A1 oe e.g. -2.5 & 120
				SC M1 for drawing cos curve
	bi	(2, 5)	1	B1
	bii	(4, -2)	1	B1
Total 4 marks				

23	$(v =) 3t^2 + 2 \times 4t - 5$			M1 2 out of 3 terms differentiated correctly
	$3T^2 + 8T - 5 = V$ OR $3T^2 + 8T - 5 - V = 0$			A1 correct equation
	$3(T^2 + \frac{8}{3}T) - 5$ OR $3(T^2 + \frac{8}{3}T - \frac{5}{3})$	$(T =) \frac{-8 \pm \sqrt{8^2 - 4 \times 3 \times (-5 - V)}}{2 \times 3}$		M1 attempt to complete the square OR use quadratic formula (condone one sign error in a , b or c and ft their quadratic with mistake in a or b) (condone + instead of $\pm$)
	$\left(T + \frac{4}{3}\right)^2 = \left(\frac{4}{3}\right)^2 + \frac{V+5}{3}$	$(T =) \frac{-8 \pm \sqrt{124 + 12V}}{6}$		M1 sight of this method mark implies the previous M1 (condone + instead of $\pm$) (ft their quadratic with mistake in a or b)
	$T = \frac{-4}{3} \pm \frac{1}{3}\sqrt{16 + 3V + 15}$	$(T =) \frac{-8 \pm 2\sqrt{31 + 3V}}{6}$		M1 (condone + instead of $\pm$) (ft their quadratic with mistake in a or b)
		$\frac{-4 + \sqrt{31 + 3V}}{3}$	6	A1 accept $k = 31$ and $m = 3$
Total 6 marks				



23	$3t^2 - 2 \times 4t + 5$ or $3t^2 - 8t + 5$		6	M1 for differentiation of s with 2 out of 3 terms correct (can be implied by subsequent working)
	$3t^2 - 2 \times 4t + 5 = 0$ or $3t^2 - 8t + 5 = 0$			M1 (dep on previous M1) for equating at least a 2TQ to zero (allow inequality signs), E.g. $3t^2 - 8t = 0$ or $3t^2 + 5 = 0$ (can be implied by subsequent working)
	$(t =) \frac{5}{3}$ oe (and $t = 1$)			A1 for $\frac{5}{3}$ (and $t = 1$ may be crossed out or absent) (allow $\frac{5}{3} = 1.6(66666)$ to 2 sf truncated or rounded)
	$2t - 4 = 0$			M1 for differentiation of x to find $at + b = 0$ (allow inequality signs) where $a = 2$ and $b = -4$
	$(t =) 2$			A1 for a correct value of t
		$(1 <) t < \frac{5}{3}$ and $t > 2$		A1 oe $(t > 1) t < \frac{5}{3}$ and $t > 2$
Total 6 marks				

Question	Working	Answer	Mark	Notes
17(a)	Two of $12x^2 + 10x + 2$		2	M1 for differentiating 2 or 3 terms correctly
		$12x^2 + 10x + 2$		A1 for all 3 terms correct
(b)	$(3x + 1)(4x + 2) (= 0)$ or $(6x + 2)(2x + 1) (= 0)$ or $2(3x + 1)(2x + 1) (= 0)$ or $(3x + 1)(2x + 1) (= 0)$ $\frac{-10 \pm \sqrt{10^2 - 4 \times 12 \times 2}}{2 \times 12}$ or $\frac{-5 \pm \sqrt{5^2 - 4 \times 6 \times 1}}{2 \times 6}$ or $12 \left[\left(x + \frac{10}{24} \right)^2 - \left(\frac{10}{24} \right)^2 \right] + 2 (= 0)$ oe or $6 \left[\left(x + \frac{5}{12} \right)^2 - \left(\frac{5}{12} \right)^2 \right] + 1 (= 0)$ oe		4	M1 ft dep on M1 for a correct method to solve their 3 term quadratic equation (with at least 2 correct coefficients) using any correct method (if factorising, allow brackets which expanded give 2 out of 3 terms correct) (if using formula allow one sign error and some simplification – allow as far as $\frac{-10 \pm \sqrt{100 - 96}}{24}$) Derivative must be a 3 term quadratic for this M mark NB Can be implied by answers of $(x =) -\frac{1}{2}$ and $(x =) -\frac{1}{3}$
		$-\frac{1}{2}, -\frac{1}{3}$		A1 oe dep on previous M1 Allow $-0.33(333)$ or -0.3 for correct x values
	$(y =) 4 \times \left(-\frac{1}{2} \right)^3 + 5 \left(-\frac{1}{2} \right)^2 + 2 \left(-\frac{1}{2} \right) \left(= -\frac{1}{4} \right)$ or $(y =) 4 \times \left(-\frac{1}{3} \right)^3 + 5 \left(-\frac{1}{3} \right)^2 + 2 \left(-\frac{1}{3} \right) \left(= -\frac{7}{27} \right)$			M1 ft dep on previous M1 for substituting at least one x value into y NB Can be implied by one correct value of y
	Working required	$\left(-\frac{1}{2}, -\frac{1}{4} \right)$ $\left(-\frac{1}{3}, -\frac{7}{27} \right)$		A1 oe dep on M1 for correct coordinates $(-0.5, -0.25), (-0.33, -0.25(9...))$
Total 6 marks				

Question	Working	Answer	Mark	Notes
13 (a)		$3x^2 - 2x - 8$	2	B2 (B1 for at least 1 correct non zero term)
(b)	$"3x^2 - 2x - 8" = 0$ $(3x + 4)(x - 2) (=0)$ or $x = \frac{2 \pm \sqrt{100}}{2 \times 3}$ or $x = \frac{2 \pm \sqrt{(-2)^2 - 4 \times 3 \times (-8)}}{2 \times 3}$	$-\frac{4}{3}, 2$	3	M1 Dep on at least B1, ft on M marks only dep on $\frac{dy}{dx}$ being a 3 term quadratic M1
(c)	At $x = 2, y = 2^3 - 2^2 - 8 \times 2 + 12 (=0)$ or at $x = -\frac{4}{3},$ $y = \left(-\frac{4}{3}\right)^3 - \left(-\frac{4}{3}\right)^2 - 8 \times \left(-\frac{4}{3}\right) + 12$ $\left(= \frac{500}{27}\right)$	Shown	2	A1 (dep 2nd M1) M1 Substitutes at least one of $-\frac{4}{3}$ or 2 or their answer from (b) into $(y =)x^3 - x^2 - 8x + 12$ A1 must show that (2,0) is a turning point on the curve and give concluding statement



22	(a)	$\left(\frac{dy}{dx} = \right) 2x + px^{-2}$ oe		4	M2 Both terms correct (M1 for one term correct)
		$2(-3) + p(-3)^{-2}(= 0)$			M1 (dep on M1) substitute -3 into a derivative of the form $ax + bx^{-2}$
			54		A1
	(b)	$\left(\frac{dy}{dx} = \right) 2x + 16x^{-2} = 0$		3	M1 set $\frac{dy}{dx} = 0$, at least one term correct
		eg $2x^3 + 16 = 0$ or $2x^3 = -16$ or $x^3 = -8$ or $x = \sqrt[3]{-8}$ or $x = -2$			M1 rearrangement of the correct equation to remove the negative power of x
		12	A1		
					Total 7 marks

23	(a)	$2(x^2 - 6x) + 3$ or $2(x^2 - 6x + \frac{3}{2})$		3	M1 or for one of a, b or c correct OR expanding $a(x^2 + 2bx + b^2) + c$
		$2\left[(x-3)^2 - 9\right] + 3$ or $2\left[(x-3)^2 - 3^2 + \frac{3}{2}\right]$ oe			M1 or for two of a, b or c correct OR $-12 = 2ab$ or $3 = ab^2 + c$
			$2(x-3)^2 - 15$		A1 accept $a = 2, b = -3, c = -15$
	(b)		$(-1, -15)$	2	B2ft eg accept [their $-b - 4$] for the x -coordinate or [their c] for the y -coordinate (B1 ft for one correct coordinate)
Total 5 marks					

15	(b)	$\left(\frac{dV}{dx} = \right) 16 - 2x + (3 \times -2x^2)$ oe		5	M1 for the correct differentiation of at least 2 correct terms from 16 or $-2x$ or $(3 \times -2x^2)$
		$\left(\frac{dV}{dx} = \right) 16 - 2x - 6x^2$ oe			A1 for a correct differentiated expression
		' $16 - 2x - 6x^2 = 0$ ' oe			M1 (dep on M1) for equating their differentiated expression to zero
		E.g. $(x =) \frac{-2 \pm \sqrt{2^2 - 4 \times 6 \times -16}}{2 \times 6}$ oe (accept + in place of $\pm$) or E.g. $6 \left(\left(x + \frac{1}{6} \right)^2 - \left(\frac{1}{6} \right)^2 \right) - 16 (= 0)$ oe			M1 (dep on M1) for a complete method to solve their 3-term quadratic equation (allow one sign error and some simplification – allow as far as $\frac{-2 \pm \sqrt{4 + 384}}{12}$)
			1.47		A1 dep on M1 for answer in range 1.47 – 1.5 from correct working (Must reject -1.80 to -1.81 if calculated)
Total 8 marks					

