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Core Mathematics C4

Advanced

Friday 23 June 2017 – Morning

Time: 1 hour 30 minutes

Paper Reference

6666/01**You must have:**

Mathematical Formulae and Statistical Tables (Pink)

Total Marks

Candidates may use any calculator allowed by the regulations of the Joint Council for Qualifications. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- When a calculator is used, the answer should be given to an appropriate degree of accuracy.

Information

- The total mark for this paper is 75.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

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- $$x = 3t - 4, \quad y = 5 - \frac{6}{t}, \quad t > 0$$

- (a) Find $\frac{dy}{dx}$ in terms of t (2)

The point P lies on C where $t = \frac{1}{2}$

- (b) Find the equation of the tangent to C at the point P . Give your answer in the form $y = px + q$, where p and q are integers to be determined.
- (3)**

- (c) Show that the cartesian equation for C can be written in the form

$$y = \frac{ax + b}{x + 4}, \quad x > -4$$

where a and b are integers to be determined. (3)



Summer 2017 Past Paper (Mark Scheme) Scheme		www.mystudybro.com This resource was created and owned by Pearson Edexcel		Mathematics C4 Marks
Question Number				
1.	$x = 3t - 4, y = 5 - \frac{6}{t}, t > 0$			
(a)	$\frac{dx}{dt} = 3, \frac{dy}{dt} = 6t^{-2}$			
	$\frac{dy}{dx} = \frac{6t^{-2}}{3} \left\{ = \frac{6}{3t^2} = 2t^{-2} = \frac{2}{t^2} \right\}$	their $\frac{dy}{dt}$ divided by their $\frac{dx}{dt}$ to give $\frac{dy}{dx}$ in terms of t or their $\frac{dy}{dt}$ multiplied by their $\frac{dt}{dx}$ to give $\frac{dy}{dx}$ in terms of t	M1	
		$\frac{6t^{-2}}{3}$, simplified or un-simplified, in terms of t . See note.	A1 isw	
	Award Special Case 1st M1 if both $\frac{dx}{dt}$ and $\frac{dy}{dt}$ are stated correctly and explicitly .			[2]
Note: You can recover the work for part (a) in part (b).				
(a) Way 2	$y = 5 - \frac{18}{x+4} \Rightarrow \frac{dy}{dx} = \frac{18}{(x+4)^2} = \frac{18}{(3t)^2}$	Writes $\frac{dy}{dx}$ in the form $\frac{\pm \lambda}{(x+4)^2}$, and writes $\frac{dy}{dx}$ as a function of t .	M1	
		Correct un-simplified or simplified answer, in terms of t . See note.	A1 isw	
				[2]
(b)	$\left\{ t = \frac{1}{2} \Rightarrow \right\} P\left(-\frac{5}{2}, -7\right)$	$x = -\frac{5}{2}, y = -7$ or $P\left(-\frac{5}{2}, -7\right)$ seen or implied.	B1	
	$\frac{dy}{dx} = \frac{2}{\left(\frac{1}{2}\right)^2}$ and either <ul style="list-style-type: none">$y - "-7" = "8"(x - "-\frac{5}{2}")$$"-7" = ("8")("-\frac{5}{2}") + c$ So, $y = (\text{their } m_T)x + "c"$	Some attempt to substitute $t = 0.5$ into their $\frac{dy}{dx}$ which contains t in order to find m_T and either applies $y - (\text{their } y_p) = (\text{their } m_T)(x - \text{their } x_p)$ or finds c from $(\text{their } y_p) = (\text{their } m_T)(\text{their } x_p) + c$ and uses their numerical c in $y = (\text{their } m_T)x + c$	M1	
	T: $y = 8x + 13$	$y = 8x + 13$ or $y = 13 + 8x$	A1 cso	
	Note: their x_p , their y_p and their m_T must be numerical values in order to award M1			[3]
(c) Way 1	$\left\{ t = \frac{x+4}{3} \Rightarrow \right\} y = 5 - \frac{6}{\left(\frac{x+4}{3}\right)}$	An attempt to eliminate t . See notes.	M1	
		Achieves a correct equation in x and y only	A1 o.e.	
	$\supset y = 5 - \frac{18}{x+4} \supset y = \frac{5(x+4) - 18}{x+4}$			
	So, $y = \frac{5x+2}{x+4}, \{x > -4\}$	$y = \frac{5x+2}{x+4}$ (or implied equation)	A1 cso	
				[3]
(c) Way 2	$\left\{ t = \frac{6}{5-y} \Rightarrow \right\} x = \frac{18}{5-y} - 4$	An attempt to eliminate t . See notes.	M1	
		Achieves a correct equation in x and y only	A1 o.e.	
	$\supset (x+4)(5-y) = 18 \supset 5x - xy + 20 - 4y = 18$			
	$\left\{ \supset 5x + 2 = y(x+4) \right\}$ So, $y = \frac{5x+2}{x+4}, \{x > -4\}$	$y = \frac{5x+2}{x+4}$ (or implied equation)	A1 cso	
				[3]
Note: Some or all of the work for part (c) can be recovered in part (a) or part (b)				8

Summer 2017		www.mystudybro.com		Mathematics C4	
Question Number	Mark Scheme	This resource was created and owned by Pearson Edexcel		Notes	Marks
1. (c) Way 3	$y = \frac{3at - 4a + b}{3t - 4 + 4} = \frac{3at}{3t} - \frac{4a - b}{3t} = a - \frac{4a - b}{3t} \Rightarrow a = 5$		A full method leading to the value of a being found		M1
			$y = a - \frac{4a - b}{3t}$ and $a = 5$		A1
	$\frac{4a - b}{3} = 6 \Rightarrow b = 4(5) - 6(3) = 2$		Both $a = 5$ and $b = 2$		A1
					[3]
Question 1 Notes					
1. (a)	Note	Condone $\frac{dy}{dx} = \left(\frac{6}{t^2}\right)$ for A1			
	Note	You can ignore subsequent working following on from a correct expression for $\frac{dy}{dx}$ in terms of t .			
(b)	Note	Using a changed gradient (i.e. applying $\frac{-1}{\text{their } \frac{dy}{dx}}$ or $\frac{1}{\text{their } \frac{dy}{dx}}$ or $-\left(\text{their } \frac{dy}{dx}\right)$) is M0.			
	Note	Final A1: A correct solution is required from a correct $\frac{dy}{dx}$.			
	Note	Final A1: You can ignore subsequent working following on from a correct solution.			
(c)	Note	1st M1: A full attempt to eliminate t is defined as either <ul style="list-style-type: none">rearranging one of the parametric equations to make t the subject and substituting for t in the other parametric equation (only the RHS of the equation required for M mark)rearranging both parametric equations to make t the subject and putting the results equal to each other.			
	Note	Award M1A1 for $\frac{6}{5 - y} = \frac{x + 4}{3}$ or equivalent.			

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The binomial expansion of $f(x)$, in ascending powers of x , up to and including the term in x^2 is

$$A + Bx + \frac{243}{16}x^2$$

where A and B are constants.

- (a) Write down the value of A . (1)
- (b) Find the value of k . (3)
- (c) Find the value of B . (2)

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Past Paper (Mark Scheme)					This resource was created and owned by Pearson Edexcel					6666	
Question Number		Scheme					Notes		Marks		
2.		$\left\{ (2 + kx)^{-3} = 2^{-3} \left(1 + \frac{kx}{2} \right)^{-3} = \frac{1}{8} \left(1 + (-3) \left(\frac{kx}{2} \right) + \frac{(-3)(-3-1)}{2!} \left(\frac{kx}{2} \right)^2 + \dots \right) \right\}, k > 0$									
(a)		$\left\{ A = \right\} \frac{1}{8}$	$\frac{1}{8}$ or 2^{-3} or 0.125, clearly identified as A or as their answer to part (a)							B1 cao	
										[1]	
(b)		$\left(\frac{1}{8} \right) \frac{(-3)(-4)}{2!} \left(\frac{k}{2} \right)^2$	Uses the x^2 term of the binomial expansion to give								
			either $\frac{(-3)(-4)}{2!}$ or $\left(\frac{k}{2} \right)^2$ or $\left(\frac{kx}{2} \right)^2$ or $\frac{(-3)(-4)}{2}$ or 6							M1	
			either (their A) $\frac{(-3)(-4)}{2!} \left(\frac{k}{2} \right)^2$ or (their A) $\frac{(-3)(-4)}{2!} \left(\frac{kx}{2} \right)^2$, where (their A) $\neq 1$, or $\frac{3}{16}k^2$ or $\frac{3}{16}k^2x^2$ or $(2^{-5}) \frac{(-3)(-4)}{2!} (kx)^2$ or $(2^{-5}) \frac{(-3)(-4)}{2!} (k)^2$							M1 o.e.	
		$\left\{ \text{So, } \left(\frac{1}{8} \right) \frac{(-3)(-4)}{2!} \left(\frac{k}{2} \right)^2 = \frac{243}{16} \Rightarrow \frac{3}{16}k^2 = \frac{243}{16} \Rightarrow k^2 = 81 \right\}$									
		So, $k = 9$					$k = 9$ cao		A1 cso		
		Note: $k = \pm 9$ with no reference to $k = 9$ only is A0							[3]		
(c)		$\left(\frac{1}{8} \right) (-3) \left(\frac{k}{2} \right)$	Uses the x term of the binomial expansion to give either (their A) $(-3) \left(\frac{k}{2} \right)$ or (their A) $(-3) \left(\frac{kx}{2} \right)$; where (their A) $\neq 1$, or $(2)^{-4}(-3)(k)$ or $(2)^{-4}(-3)(kx)$ or $-\frac{3k}{16}$							M1	
		$\left\{ \text{So, } B = \left(\frac{1}{8} \right) (-3) \left(\frac{9}{2} \right) \Rightarrow \right\} B = -\frac{27}{16}$			$-\frac{27}{16}$ or $-1 \frac{11}{16}$ or -1.6875			A1 cso			
								[2]			
										6	

Question 2 Notes

NOTE IN THIS QUESTION IGNORE LABELLING AND MARK ALL PARTS TOGETHER.**Note**

$$(2 + kx)^{-3} = \frac{1}{8} \left(1 - \frac{3}{2}kx + \frac{3}{2}k^2x^2 + \dots \right) = \frac{1}{8} - \frac{3}{16}kx + \frac{3}{16}k^2x^2 + \dots$$

Note

$$\text{Writing down } \left\{ \left(1 + \frac{kx}{2} \right)^{-3} \right\} = 1 + (-3) \left(\frac{kx}{2} \right) + \frac{(-3)(-3-1)}{2!} \left(\frac{kx}{2} \right)^2 + \dots$$

gets (b) 1st M1

Note

$$\text{Writing down } \left\{ (2 + kx)^{-3} \right\} = \frac{1}{8} \left(1 + (-3) \left(\frac{kx}{2} \right) + \frac{(-3)(-3-1)}{2!} \left(\frac{kx}{2} \right)^2 + \dots \right)$$

gets (b) 1st M1 2nd M1 and (c) M1

Note

$$\text{Writing down } \left\{ (2 + kx)^{-3} \right\} = 2^{-3} + (-3)(2^{-4})(kx) + \frac{(-3)(-4)}{2} (2^{-5})(kx)^2$$

gets (b) 1st M1 2nd M1 and (c) M1

Note

$$\text{Writing down } \left\{ (2 + kx)^{-3} \right\} = (\text{their A}) \left(1 + (-3) \left(\frac{kx}{2} \right) + \frac{(-3)(-3-1)}{2!} \left(\frac{kx}{2} \right)^2 + \dots \right)$$

where (their A) $\neq 1$, gets (b) 1st M1 2nd M1 and (c) M1

Question 2 Notes

2. (b), (c)	Note	(their A) is defined as either <ul style="list-style-type: none"> • their answer to part (a) • their stated $A = \dots$ • their "2^{-3}" in their stated $2^{-3} \left(1 + \frac{kx}{2}\right)^{-3}$
	Note	Give 2 nd M0 in part (b) if (their A) = 1
	Note	Give M0 in part (c) if (their A) = 1
2. (c)	Note	Allow M1 for (their A)(-3) $\left(\frac{\text{their } k \text{ from (b)}}{2}\right)$
	Note	Award A0 for $B = -\frac{27}{16}x$
	Note	Allow A1 for $B = -\frac{27}{16}x$ followed by $B = -\frac{27}{16}$ or $-1\frac{11}{16}$ or -1.6875
	Note	$k = -9$ leading to $B = \frac{27}{16}$ or $1\frac{11}{16}$ or 1.6875 is A0
	Note	Give A0 for finding both $B = -\frac{27}{16}$ and $B = \frac{27}{16}$ (without rejecting $B = \frac{27}{16}$) as their final answer.
	Note	The A1 mark in part (c) is for a correct solution only.
	Note	<p>Be careful! It is possible to award M0A0 in part (c) for a solution leading to $B = -\frac{27}{16}$. E.g.</p> $f(x) = (2 + kx)^{-3} = 2^{-3}(1 + kx)^{-3} = \frac{1}{8} \left(1 + (-3)(kx) + \frac{(-3)(-4)}{2!}(kx)^2 + \dots \right) = \frac{1}{8} - \frac{3k}{8}x + \frac{3k^2}{4}x^2 + \dots$ <p>leading to (a) $A = \frac{1}{8}$, (b) $k = \frac{9}{2}$, (c) $B = -\frac{27}{16}$, gets (a) B1, (b) M1M0A0 (c) M0A0</p>
2. (b), (c)	Note	${}^{-3}C_0(2)^{-3} + {}^{-3}C_1(2)^{-4}(kx) + {}^{-3}C_2(2)^{-5}(kx)^2$ with the C terms not evaluated gets (b) 1 st M0 2 nd M0 and (c) M0

3.

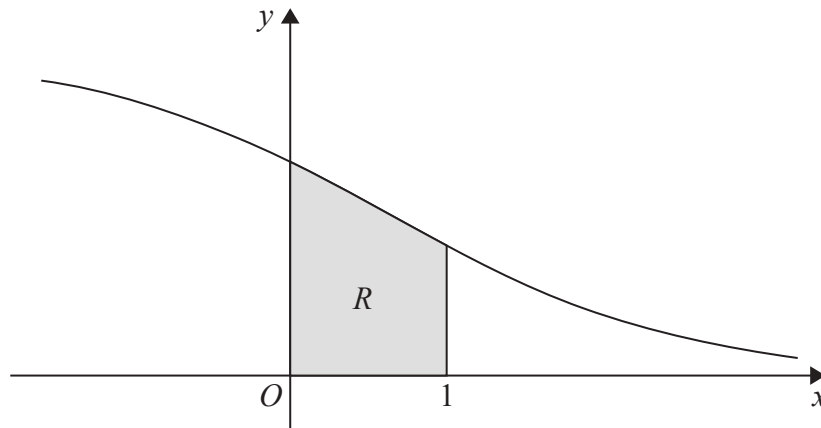


Figure 1

Figure 1 shows a sketch of part of the curve with equation $y = \frac{6}{(e^x + 2)}$, $x \in \mathbb{R}$

The finite region R , shown shaded in Figure 1, is bounded by the curve, the y -axis, the x -axis and the line with equation $x = 1$

The table below shows corresponding values of x and y for $y = \frac{6}{(e^x + 2)}$

x	0	0.2	0.4	0.6	0.8	1
y	2		1.71830	1.56981	1.41994	1.27165

(a) Complete the table above by giving the missing value of y to 5 decimal places. (1)

(b) Use the trapezium rule, with all the values of y in the completed table, to find an estimate for the area of R , giving your answer to 4 decimal places. (3)

(c) Use the substitution $u = e^x$ to show that the area of R can be given by

$$\int_a^b \frac{6}{u(u+2)} du$$

where a and b are constants to be determined.

(2)

(d) Hence use calculus to find the exact area of R .
[Solutions based entirely on graphical or numerical methods are not acceptable.] (6)

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Question Number	Mark Scheme	Notes	6666 Marks														
3.	<table><tr><td>$\frac{x}{y}$</td><td>0</td><td>0.2</td><td>0.4</td><td>0.6</td><td>0.8</td><td>1</td></tr><tr><td></td><td>2</td><td>1.8625426...</td><td>1.71830</td><td>1.56981</td><td>1.41994</td><td>1.27165</td></tr></table>	$\frac{x}{y}$	0	0.2	0.4	0.6	0.8	1		2	1.8625426...	1.71830	1.56981	1.41994	1.27165	$y = \frac{6}{(2 + e^x)}$	
$\frac{x}{y}$	0	0.2	0.4	0.6	0.8	1											
	2	1.8625426...	1.71830	1.56981	1.41994	1.27165											
(a)	{At $x = 0.2$,} $y = 1.86254$ (5 dp)		1.86254	B1 cao													
	Note: Look for this value on the given table or in their working.			[1]													
(b)	$\frac{1}{2}(0.2)\left[2 + 1.27165 + 2\left(\text{their } 1.86254 + 1.71830 + 1.56981 + 1.41994\right)\right]$				Outside brackets $\frac{1}{2} \times (0.2)$ or $\frac{1}{10}$ or $\frac{1}{2} \times \frac{1}{5}$	B1 o.e.											
					For structure of [.....]	M1											
	$\left\{ = \frac{1}{10}(16.41283) \right\} = 1.641283 = 1.6413$ (4 dp)		anything that rounds to 1.6413		A1												
					[3]												
(c)	$\{u = e^x \text{ or } x = \ln u \supset\}$																
	$\frac{du}{dx} = e^x$ or $\frac{du}{dx} = u$ or $\frac{dx}{du} = \frac{1}{u}$ or $du = u dx$ etc., and $\int \frac{6}{(e^x + 2)} dx = \int \frac{6}{(u + 2)u} du$			See notes	B1 *												
	$\{x = 0\} \supset a = e^0 \supset a = 1$ $\{x = 1\} \supset b = e^1 \supset b = e$		$a = 1$ and $b = e$ or $b = e^1$ or evidence of $0 \rightarrow 1$ and $1 \rightarrow e$		B1												
	NOTE: 1 st B1 mark CANNOT be recovered for work in part (d) NOTE: 2 nd B1 mark CAN be recovered for work in part (d)				[2]												
(d) Way 1	$\frac{6}{u(u + 2)} \circ \frac{A}{u} + \frac{B}{(u + 2)}$ $\supset 6 \circ A(u + 2) + Bu$ $u = 0 \supset A = 3$ $u = -2 \supset B = -3$		Writing $\frac{6}{u(u + 2)} \circ \frac{A}{u} + \frac{B}{(u + 2)}$, o.e. or $\frac{1}{u(u + 2)} \circ \frac{P}{u} + \frac{Q}{(u + 2)}$, o.e., and a complete method for finding the value of at least one of their A or their B (or their P or their Q)		M1												
			Both their A = 3 and their B = -3 . (Or their P = $\frac{1}{2}$ and their Q = $-\frac{1}{2}$ with the factor of 6 in front of the integral sign)		A1												
	$\int \frac{6}{u(u + 2)} du = \int \left(\frac{3}{u} - \frac{3}{(u + 2)} \right) du$ $= 3\ln u - 3\ln(u + 2)$ or $= 3\ln 2u - 3\ln(2u + 4)$		Integrates $\frac{M}{u} \pm \frac{N}{u \pm k}$, $M, N, k \neq 0$; (i.e. a two term partial fraction) to obtain either $\pm \ln(au)$ or $\pm \ln(b(u \pm k))$; $l, m, a, b \neq 0$		M1												
			Integration of both terms is correctly followed through from their M and from their N .		A1 ft												
	$\left\{ \text{So } [3\ln u - 3\ln(u + 2)]_1^e \right\}$ $= (3\ln(e) - 3\ln(e + 2)) - (3\ln 1 - 3\ln 3)$ [Note: A proper consideration of the limit of $u = 1$ is required for this mark]		dependent on the 2nd M mark Applies limits of e and 1 (or their b and their a, where $b > 0, b \neq 1, a > 0$) in u or applies limits of 1 and 0 in x and subtracts the correct way round.		dM1												
	$= 3 - 3\ln(e + 2) + 3\ln 3$ or $3(1 - \ln(e + 2) + \ln 3)$ or $3 + 3\ln\left(\frac{3}{e + 2}\right)$ or $3\ln\left(\frac{e}{e + 2}\right) - 3\ln\left(\frac{1}{3}\right)$ or $3 - 3\ln\left(\frac{e + 2}{3}\right)$ or $3\ln\left(\frac{3e}{e + 2}\right)$ or $\ln\left(\frac{27e^3}{(e + 2)^3}\right)$		see notes		A1 cso												
Note: Allow e^1 in place of e for the final A1 mark.				[6]													
	Note: Give final A0 for $3 - 3\ln e + 2 + 3\ln 3$ (i.e. bracketing error) unless recovered.				12												
	Note: Give final A0 for $3 - 3\ln(e + 2) + 3\ln 3 - 3\ln 1$, where $3\ln 1$ has not been simplified to 0																
	Note: Give final A0 for $3\ln e - 3\ln(e + 2) + 3\ln 3$, where $3\ln e$ has not been simplified to 3																

Question 3 Notes

3. (b)	Note	M1: Do not allow an extra y-value or a repeated y value in their [...] Do not allow an omission of a y-ordinate in their [...] for M1 unless they give the correct answer of awrt 1.6413, in which case both M1 and A1 can be scored.
	Note	A1: Working must be seen to demonstrate the use of the trapezium rule. (Actual area is 1.64150274...)
	Note	Full marks can be gained in part (b) for awrt 1.6413 even if B0 is given in part (a)
	Note	Award B1M1A1 for $\frac{1}{10}(2+1.27165) + \frac{1}{5}(\text{their } 1.86254 + 1.71830 + 1.56981 + 1.41994) = \text{awrt } 1.6413$
	<p><u>Bracketing mistakes:</u> Unless the final answer implies that the calculation has been done correctly</p> <p>Award B1M0A0 for $\frac{1}{2}(0.2) + 2 + 2(\text{their } 1.86254 + 1.71830 + 1.56981 + 1.41994) + 1.27165$ (=16.51283)</p> <p>Award B1M0A0 for $\frac{1}{2}(0.2)(2 + 1.27165) + 2(\text{their } 1.86254 + 1.71830 + 1.56981 + 1.41994)$ (=13.468345)</p> <p>Award B1M0A0 for $\frac{1}{2}(0.2)(2) + 2(\text{their } 1.86254 + 1.71830 + 1.56981 + 1.41994) + 1.27165$ (=14.61283)</p> <p><u>Alternative method: Adding individual trapezia</u></p> $\text{Area} \approx 0.2 \times \left[\frac{2 + "1.86254"}{2} + \frac{"1.86254" + 1.71830}{2} + \frac{1.71830 + 1.56981}{2} + \frac{1.56981 + 1.41994}{2} + \frac{1.41994 + 1.27165}{2} \right]$ $= 1.641283$ <p>B1 0.2 and a divisor of 2 on all terms inside brackets M1 First and last ordinates once and two of the middle ordinates inside brackets ignoring the 2 A1 anything that rounds to 1.6413</p>	
3. (c)	1st B1	Must start from either <ul style="list-style-type: none"> $\int y \, dx$, with integral sign and dx $\int \frac{6}{(e^x + 2)} \, dx$, with integral sign and dx $\int \frac{6}{(e^x + 2)} \frac{dx}{du} du$, with integral sign and $\frac{dx}{du} du$ <p>and state either $\frac{du}{dx} = e^x$ or $\frac{du}{dx} = u$ or $\frac{dx}{du} = \frac{1}{u}$ or $du = u \, dx$</p> <p>and end at $\int \frac{6}{u(u+2)} \, du$, with integral sign and du, with no incorrect working.</p>
	Note	So, just writing $\frac{du}{dx} = e^x$ and $\int \frac{6}{(e^x + 2)} \, dx = \int \frac{6}{u(u+2)} \, du$ is sufficient for 1 st B1
	Note	Give 2 nd B0 for $b = 2.718...$, without reference to $a = 1$ and $b = e$ or $b = e^1$
	Note	You can also give the 1 st B1 mark for using a reverse process. i.e. <p>Proceeding from $\int \frac{6}{u(u+2)} \, du$ to $\int \frac{6}{(e^x + 2)} \, dx$, with no incorrect working.</p> <p>and stating either $\frac{du}{dx} = e^x$ or $\frac{du}{dx} = u$ or $\frac{dx}{du} = \frac{1}{u}$ or $du = u \, dx$</p>
3. (d)	Note	Give final A0 for $3 - 3\ln(e+2) + 3\ln 3$ simplifying to $1 - \ln(e+2) + \ln 3$ (i.e. dividing their correct final answer by 3) Otherwise, you can ignore incorrect working (isw) following on from a correct exact value.
	Note	A decimal answer of 1.641502724... (without a correct exact answer) is final A0
	Note	$[-3\ln(u+2) + 3\ln u]_1^e$ followed by awrt 1.64 (without a correct exact answer) is final M1A0

Question 3 Notes Continued

3. (d)	Note	BE CAREFUL! Candidates will assign their own “A” and “B” for this question.
	Note	Writing down $\frac{6}{(u+2)u}$ in the form $\frac{A}{(u+2)} + \frac{B}{u}$ with at least one of A or B correct is 1 st M1
	Note	Writing down $\frac{6}{(u+2)u}$ as $\frac{-3}{(u+2)} + \frac{3}{u}$ is 1 st M1 1 st A1.
	Note	Condone $\int \left(\frac{3}{u} - \frac{3}{(u+2)} \right) du$ to give $3\ln u - 3\ln(u+2)$ (poor bracketing) for 2 nd A1.
	Note	Award M0A0M1A1ft for a candidate who writes down e.g. $\int \frac{6}{u(u+2)} du = \int \left(\frac{6}{u} + \frac{6}{(u+2)} \right) du = 6\ln u + 6\ln(u+2)$ AS EVIDENCE OF WRITING $\frac{6}{u(u+2)}$ AS PARTIAL FRACTIONS.
	Note	Award M0A0M0A0 for a candidate who writes down $\int \frac{6}{u(u+2)} du = 6\ln u + 6\ln(u+2)$ or $\int \frac{6}{u(u+2)} du = \ln u + 6\ln(u+2)$ WITHOUT ANY EVIDENCE OF WRITING $\frac{6}{u(u+2)}$ as partial fractions.
	Note	Award M1A1M1A1 for a candidate who writes down $\int \frac{6}{u(u+2)} du = 3\ln u - 3\ln(u+2)$ WITHOUT ANY EVIDENCE OF WRITING $\frac{6}{u(u+2)}$ as partial fractions.
	Note	If they lose the “6” and find $\int_1^e \frac{1}{u(u+2)} du$ we can allow a maximum of M1A0M1A1ftM1A0

Question 3 Notes Continued

Question 3 Notes Continued				
3. (d) Way 2	$\left\{ \int \frac{6}{u^2 + 2u} du = \int \frac{3(2u + 2)}{u^2 + 2u} du - \int \frac{6u}{u^2 + 2u} du \right\}$			
	$= \int \frac{3(2u + 2)}{u^2 + 2u} du - \int \frac{6}{u + 2} du$		$\int \frac{\pm a(2u + 2)}{u^2 + 2u} \{du\} \pm \int \frac{d}{u + 2} \{du\}, \alpha, \beta, \delta \neq 0$	M1
			Correct expression	
	$= 3\ln(u^2 + 2u) - 6\ln(u + 2)$	Integrates $\frac{\pm M(2u + 2)}{u^2 + 2u} \pm \frac{N}{u \pm k}, M, N, k \neq 0$, to obtain any one of $\pm \int \ln(u^2 + 2u)$ or $\pm m\ln(b(u \pm k));$ $l, m, b \neq 0$		M1
		Integration of both terms is correctly followed through from their M and from their N		A1 ft
	$\left\{ \text{So, } \left[3\ln(u^2 + 2u) - 6\ln(u + 2) \right]_1^e \right\}$ $= \left(3\ln(e^2 + 2e) - 6\ln(e + 2) \right) - \left(3\ln 3 - 6\ln 3 \right)$		dependent on the 2nd M mark Applies limits of e and 1 (or their b and their a , where $b > 0, b \neq 1, a > 0$) in u or applies limits of 1 and 0 in x and subtracts the correct way round.	dM1
	$= 3\ln(e^2 + 2e) - 6\ln(e + 2) + 3\ln 3$		$3\ln(e^2 + 2e) - 6\ln(e + 2) + 3\ln 3$	A1 o.e.
				[6]
3. (d) Way 3	Applying $u = \theta - 1$			
	$\left\{ \int_1^e \frac{6}{u(u + 2)} du = \right\} \int_2^{1+e} \frac{6}{(\theta - 1)(\theta + 1)} d\theta = \int_2^{1+e} \frac{6}{\theta^2 - 1} du = \left[3\ln \left(\frac{\theta - 1}{\theta + 1} \right) \right]_2^{1+e}$			M1A1M1A1
	$= 3\ln \left(\frac{1 + e - 1}{e + 1 + 1} \right) - 3\ln \left(\frac{2 - 1}{2 + 1} \right) = 3\ln \left(\frac{e}{e + 2} \right) - 3\ln \left(\frac{1}{3} \right)$		3 rd M mark is dependent on 2 nd M mark	dM1A1
				[6]

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- $$4x^2 - y^3 - 4xy + 2^y = 0$$

(a) Find the exact value of $\frac{dy}{dx}$ at the point P .

(6)

(b) Find the y coordinate of A , giving your answer in the form $p + q \ln 2$, where p and q are constants to be determined.

(3)



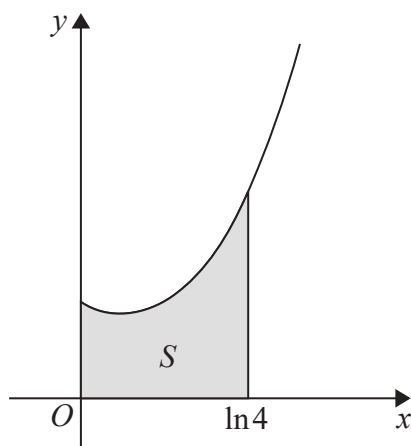
Question Number	Scheme		Notes	Marks
4.	$4x^2 - y^3 - 4xy + 2^y = 0$			
(a) Way 1	$\left\{ \frac{dy}{dx} \times \right\} 8x - 3y^2 \frac{dy}{dx} - 4y - 4x \frac{dy}{dx} + 2^y \ln 2 \frac{dy}{dx} = 0$			M1 <u>A1</u> <u>M1</u> <u>B1</u>
	$8(-2) - 3(4)^2 \frac{dy}{dx} - 4(4) - 4(-2) \frac{dy}{dx} + 2^4 \ln 2 \frac{dy}{dx} = 0$		dependent on the first M mark	dM1
	$-16 - 48 \frac{dy}{dx} - 16 + 8 \frac{dy}{dx} + 16 \ln 2 \frac{dy}{dx} = 0$			
	$\frac{dy}{dx} = \frac{32}{-40 + 16 \ln 2}$ or $\frac{-32}{40 - 16 \ln 2}$ or $\frac{4}{-5 + 2 \ln 2}$ or $\frac{4}{-5 + \ln 4}$ or exact equivalent			A1 cso
	NOTE: You can recover work for part (a) in part (b)			[6]
(b)	e.g. $m_N = \frac{-40 + 16 \ln 2}{-32}$ or $\frac{40 - 16 \ln 2}{32}$		Applying $m_N = \frac{-1}{m_T}$ to find a numerical m_N Can be implied by later working	M1
	<ul style="list-style-type: none">$y - 4 = \left(\frac{40 - 16 \ln 2}{32} \right) (x - -2)$ Cuts y-axis $\Rightarrow x = 0 \Rightarrow y - 4 = \left(\frac{40 - 16 \ln 2}{32} \right) (2)$		Using a numerical m_N ($^1 m_T$), either $y - 4 = m_N(x - -2)$ and sets $x = 0$ in their normal equation or $4 = (\text{their } m_N)(-2) + c$	M1
	<ul style="list-style-type: none">$4 = \left(\frac{40 - 16 \ln 2}{32} \right) (-2) + c$			
	$\left\{ \Rightarrow c = 4 + \frac{40 - 16 \ln 2}{16}, \text{ so } y = \frac{104 - 16 \ln 2}{16} \Rightarrow \right\}$			
	$y \text{ (or } c) = \frac{13}{2} - \ln 2$		$\frac{104}{16} - \ln 2$ or $\frac{13}{2} - \ln 2$ or $-\ln 2 + \frac{13}{2}$	A1 cso isw
	Note: Allow exact equivalents in the form $p - \ln 2$ for the final A mark			[3]
				9
(a) Way 2	$\left\{ \frac{dx}{dy} \times \right\} 8x \frac{dx}{dy} - 3y^2 - 4y \frac{dx}{dy} - 4x + 2^y \ln 2 = 0$			M1 <u>A1</u> <u>M1</u> <u>B1</u>
	$8(-2) \frac{dx}{dy} - 3(4)^2 - 4(4) \frac{dx}{dy} - 4(-2) + 2^4 \ln 2 = 0$		dependent on the first M mark	dM1
	$\frac{dy}{dx} = \frac{32}{-40 + 16 \ln 2}$ or $\frac{-32}{40 - 16 \ln 2}$ or $\frac{4}{-5 + 2 \ln 2}$ or $\frac{4}{-5 + \ln 4}$ or exact equivalent			A1 cso
	Note: You must be clear that Way 2 is being applied before you use this scheme			[6]
Question 4 Notes				
4. (a)	Note	For the first four marks		
		Writing down from no working		
		<ul style="list-style-type: none">$\frac{dy}{dx} = \frac{4y - 8x}{-3y^2 - 4x + 2^y \ln 2}$ or $\frac{8x - 4y}{3y^2 + 4x - 2^y \ln 2}$ scores M1A1M1B1$\frac{dy}{dx} = \frac{8x - 4y}{-3y^2 - 4x + 2^y \ln 2}$ or $\frac{4y - 8x}{3y^2 + 4x - 2^y \ln 2}$ scores M1A0M1B1		
		Writing $8x dx - 3y^2 dy - 4y dx - 4x dy + 2^y \ln 2 dy = 0$ scores M1A1M1B1		

Question 4 Notes Continued

4. (a)	1st M1	Differentiates implicitly to include <i>either</i> $\pm 4x \frac{dy}{dx}$ <i>or</i> $-y^3 \rightarrow \pm \lambda y^2 \frac{dy}{dx}$ <i>or</i> $2^y \rightarrow \pm m 2^y \frac{dy}{dx}$ (Ignore $\left(\frac{dy}{dx} = \right)$). λ, m are constants which can be 1
	1st A1	Both $4x^2 - y^3 \rightarrow 8x - 3y^2 \frac{dy}{dx}$ and $= 0 \rightarrow = 0$
	Note	e.g. $8x - 3y^2 \frac{dy}{dx} - 4y - 4x \frac{dy}{dx} + 2^y \ln 2 \frac{dy}{dx} \rightarrow -3y^2 \frac{dy}{dx} - 4x \frac{dy}{dx} + 2^y \ln 2 \frac{dy}{dx} = 4y - 8x$ or e.g. $-16 - 48 \frac{dy}{dx} - 16 + 8 \frac{dy}{dx} + 16 \ln 2 \frac{dy}{dx} \rightarrow -48 \frac{dy}{dx} + 8 \frac{dy}{dx} + 16 \ln 2 \frac{dy}{dx} = 32$ will get 1 st A1 (implied) as the " $= 0$ " can be implied by the rearrangement of their equation.
	2nd M1	$-4xy \rightarrow -4y - 4x \frac{dy}{dx}$ <i>or</i> $4y - 4x \frac{dy}{dx}$ <i>or</i> $-4y + 4x \frac{dy}{dx}$ <i>or</i> $4y + 4x \frac{dy}{dx}$
	B1	$2^y \rightarrow 2^y \ln 2 \frac{dy}{dx}$ <i>or</i> $2^y \rightarrow e^{y \ln 2} \ln 2 \frac{dy}{dx}$
	Note	If an extra term appears then award 1 st A0
	3rd dM1	dependent on the first M mark For substituting $x = -2$ and $y = 4$ into an equation involving $\frac{dy}{dx}$
	Note	M1 can be gained by seeing at least one example of substituting $x = -2$ and at least one example of substituting $y = 4$ unless it is clear that they are instead applying $x = 4$ and $y = -2$. Otherwise, you will NEED to check (with your calculator) that $x = -2, y = 4$ that has been substituted into their equation involving $\frac{dy}{dx}$
	Note	A1 cso: If the candidate's solution is not completely correct, then do not give this mark.
(b)	Note	isw: You can, however, ignore subsequent working following on from correct solution.
	Note	The 2 nd M1 mark can be implied by later working. Eg. Award 1st M1 and 2nd M1 for $\frac{y-4}{2} = \frac{-1}{\text{their } m_T \text{ evaluated at } x = -2 \text{ and } y = 4}$
	Note	A1: Allow the alternative answer $\left\{y = \right\} \ln\left(\frac{1}{2}\right) + \frac{13}{2 \ln 2}(\ln 2)$ which is in the form $p + q \ln 2$
4. (a) Way 2	1st M1	Differentiates implicitly to include <i>either</i> $\pm 4y \frac{dx}{dy}$ <i>or</i> $4x^2 \rightarrow \pm / x \frac{dx}{dy}$ (Ignore $\left(\frac{dx}{dy} = \right)$). $/$ is a constant which can be 1
	1st A1	Both $4x^2 - y^3 \rightarrow 8x \frac{dx}{dy} - 3y^2$ and $= 0 \rightarrow = 0$
	2nd M1	$-4xy \rightarrow -4y \frac{dx}{dy} - 4x$ <i>or</i> $4y \frac{dx}{dy} - 4x$ <i>or</i> $-4y \frac{dx}{dy} + 4x$ <i>or</i> $4y \frac{dx}{dy} + 4x$
	B1	$2^y \rightarrow 2^y \ln 2$
	3rd dM1	dependent on the first M mark For substituting $x = -2$ and $y = 4$ into an equation involving $\frac{dx}{dy}$

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Diagram not
drawn to scale**Figure 2**

The finite region S , shown shaded in Figure 2, is bounded by the y -axis, the x -axis, the line with equation $x = \ln 4$ and the curve with equation

$$y = e^x + 2e^{-x}, \quad x \geq 0$$

The region S is rotated through 2π radians about the x -axis.

Use integration to find the exact value of the volume of the solid generated.
Give your answer in its simplest form.

[Solutions based entirely on graphical or numerical methods are not acceptable.]

(7)

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Question Number	Scheme	Notes	Marks
5. Way 1	$y = e^x + 2e^{-x}, x \geq 0$		
	$\{V = \} \rho \int_0^{\ln 4} (e^x + 2e^{-x})^2 dx$	For $\pi \int (e^x + 2e^{-x})^2$ Ignore limits and dx. Can be implied.	B1
	$= \{\pi\} \int_0^{\ln 4} (e^{2x} + 4e^{-2x} + 4) dx$	Expands $(e^x + 2e^{-x})^2 \rightarrow \pm ae^{2x} \pm be^{-2x} \pm d$ where $\alpha, \beta, \delta \neq 0$. Ignore π , integral sign, limits and dx. This can be implied by later work.	M1
	$= \{\rho\} \left[\frac{1}{2} e^{2x} - 2e^{-2x} + 4x \right]_0^{\ln 4}$	Integrates at least one of either $\pm ae^{2x}$ to give $\pm \frac{a}{2} e^{2x}$ or $\pm be^{-2x}$ to give $\pm \frac{b}{2} e^{-2x}$ $a, b \neq 0$	M1
		dependent on the 2nd M mark $e^{2x} + 4e^{-2x} \rightarrow \frac{1}{2} e^{2x} - 2e^{-2x}$, which can be simplified or un-simplified	A1
		$4 \rightarrow 4x$ or $4e^0 x$	B1 cao
	$= \{\rho\} \left(\left(\frac{1}{2} e^{2(\ln 4)} - 2e^{-2(\ln 4)} + 4(\ln 4) \right) - \left(\frac{1}{2} e^0 - 2e^0 + 4(0) \right) \right)$	dependent on the previous method mark. Some evidence of applying limits of $\ln 4$ o.e. and 0 to a changed function in x and subtracts the correct way round. Note: A proper consideration of the limit of 0 is required.	dM1
	$= \{\pi\} \left(\left(8 - \frac{1}{8} + 4\ln 4 \right) - \left(\frac{1}{2} - 2 \right) \right)$		
	$= \frac{75}{8} \rho + 4\rho \ln 4$ or $\frac{75}{8} \rho + 8\rho \ln 2$ or $\pi \left(\frac{75}{8} + 4\ln 4 \right)$ or $\pi \left(\frac{75}{8} + 8\ln 2 \right)$ or $\frac{75}{8} \rho + \ln 2^{8\rho}$ or $\frac{75}{8} \rho + \rho \ln 256$ or $\ln \left(2^{8\rho} e^{\frac{75}{8}\rho} \right)$ or $\frac{1}{8} \rho (75 + 32\ln 4)$, etc		A1 isw
			[7]
			7

Question 5 Notes

5.	Note	π is only required for the 1 st B1 mark and the final A1 mark.
	Note	Give 1 st B0 for writing $\rho \int y^2 dx$ followed by $2\rho \int (e^x + 2e^{-x})^2 dx$
	Note	Give 1 st M1 for $(e^x + 2e^{-x})^2 \rightarrow e^{2x} + 4e^{-2x} + 2e^0 + 2e^0$ because $d = 2e^0 + 2e^0$
	Note	A decimal answer of 46.8731... or $\rho(14.9201...)$ (without a correct exact answer) is A0
	Note	$\rho \left[\frac{1}{2} e^{2x} - 2e^{-2x} + 4x \right]_0^{\ln 4}$ followed by awrt 46.9 (without a correct exact answer) is final dM1A0
	Note	Allow exact equivalents which should be in the form $a\rho + b\rho \ln c$ or $\rho(a + b \ln c)$, where $a = \frac{75}{8}$ or $9\frac{3}{8}$ or 9.375. Do not allow $a = \frac{150}{16}$ or $9\frac{6}{16}$
	Note	Give B1M0M1A1B0M1A0 for the common response $\rho \int_0^{\ln 4} (e^x + 2e^{-x})^2 dx \rightarrow \rho \int_0^{\ln 4} (e^{2x} + 4e^{-2x}) dx = \rho \left[\frac{1}{2} e^{2x} - 2e^{-2x} \right]_0^{\ln 4} = \frac{75}{8} \rho$

Question Number	Scheme	Notes	Marks
5. Way 2	$y = e^x + 2e^{-x}, x \geq 0$		
	$\{V = \rho \int_0^{\ln 4} (e^x + 2e^{-x})^2 dx$	For $\pi \int (e^x + 2e^{-x})^2$ Ignore limits and dx. Can be implied.	B1
	$u = e^x \Rightarrow \frac{du}{dx} = e^x = u$ and $x = \ln 4 \Rightarrow u = 4, x = 0 \Rightarrow u = e^0 = 1$		
	$V = \{\rho\} \int_1^4 \left(u + \frac{2}{u}\right)^2 \frac{1}{u} du = \{\rho\} \int_1^4 \left(u^2 + \frac{4}{u^2} + 4\right) \frac{1}{u} du$		
	$= \{\rho\} \int_1^4 \left(u + \frac{4}{u^3} + \frac{4}{u}\right) du$	$(e^x + 2e^{-x})^2 \rightarrow \pm au \pm bu^{-3} \pm du^{-1}$ where $u = e^x, a, b, d \neq 0$. Ignore π , integral sign, limits and du . This can be implied by later work.	<u>M1</u>
	$= \{\rho\} \left[\frac{1}{2}u^2 - \frac{2}{u^2} + 4\ln u \right]_1^4$	Integrates at least one of either $\pm au$ to give $\pm \frac{a}{2}u^2$ or $\pm bu^{-3}$ to give $\pm \frac{b}{2}u^{-2}$, $a, b \neq 0$, where $u = e^x$	M1
		dependent on the 2nd M mark $u + 4u^{-3} \rightarrow \frac{1}{2}u^2 - 2u^{-2}$, simplified or un-simplified, where $u = e^x$	A1
		$4u^{-1} \rightarrow 4\ln u$, where $u = e^x$	B1 cao
	$= \{\rho\} \left(\left(\frac{1}{2}(4)^2 - \frac{2}{(4)^2} + 4\ln 4 \right) - \left(\frac{1}{2}(1)^2 - \frac{2}{(1)^2} + 4\ln 1 \right) \right)$	dependent on the previous method mark. Some evidence of applying limits of 4 and 1 to a changed function in u [or $\ln 4$ o.e. and 0 to an integrated function in x] and subtracts the correct way round.	dM1
	$= \{\pi\} \left(\left(8 - \frac{1}{8} + 4\ln 4 \right) - \left(\frac{1}{2} - 2 \right) \right)$		
	$= \frac{75}{8}\rho + 4\rho \ln 4$ or $\frac{75}{8}\rho + 8\rho \ln 2$ or $\pi \left(\frac{75}{8} + 4\ln 4 \right)$ or $\pi \left(\frac{75}{8} + 8\ln 2 \right)$ or $\frac{75}{8}\rho + \ln 2^{8\rho}$ or $\frac{75}{8}\rho + \rho \ln 256$ or $\ln \left(2^{8\rho} e^{\frac{75}{8}\rho} \right)$ or $\frac{1}{8}\rho (75 + 32\ln 4)$, etc		A1 isw
			[7]

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6. With respect to a fixed origin O , the lines l_1 and l_2 are given by the equations

$$l_1 : \mathbf{r} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + \lambda \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}, \quad l_2 : \mathbf{r} = \begin{pmatrix} 5 \\ 3 \\ 1 \end{pmatrix} + \mu \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}$$

where λ and μ are scalar parameters.

The lines l_1 and l_2 intersect at the point X .

- (a) Find the coordinates of the point X . (3)
- (b) Find the size of the acute angle between l_1 and l_2 , giving your answer in degrees to 2 decimal places. (3)

The point A lies on l_1 and has position vector $\begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix}$

- (c) Find the distance AX , giving your answer as a surd in its simplest form. (2)

The point Y lies on l_2 . Given that the vector \overrightarrow{YA} is perpendicular to the line l_1

- (d) find the distance YA , giving your answer to one decimal place. (2)

The point B lies on l_1 where $|\overrightarrow{AX}| = 2|\overrightarrow{AB}|$.

- (e) Find the two possible position vectors of B . (3)



Question Number	Mark Scheme	Notes	Mathematics C4
6.	$l_1: \mathbf{r} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + \lambda \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}, \quad l_2: \mathbf{r} = \begin{pmatrix} 5 \\ 3 \\ 1 \end{pmatrix} + \mu \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}; \quad \overrightarrow{OA} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix}$ lies on l_1	Let q_{Acute} be the acute angle between l_1 and l_2	
(a)	$\{l_1 = l_2 \Rightarrow\} 28 - 5\lambda = 3 \Rightarrow \lambda = 5$ or $4 - \lambda = 5 + 3\mu$ and $4 + \lambda = 1 - 4\mu \Rightarrow \mu = -2$	$28 - 5\lambda = 3$ or $4 - \lambda = 5 + 3\mu$ and $4 + \lambda = 1 - 4\mu$ or $\lambda = 5$ or $\mu = -2$ (Can be implied).	B1
	$\{\overrightarrow{OX} = \} \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + 5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}$ or $\begin{pmatrix} 5 \\ 3 \\ 1 \end{pmatrix} - 2 \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}$	Puts $l_1 = l_2$ and solves to find λ and/or μ and substitutes their value for λ into l_1 or their value for μ into l_2	M1
	So, $X(-1, 3, 9)$	$(-1, 3, 9)$ or $\begin{pmatrix} -1 \\ 3 \\ 9 \end{pmatrix}$ or $-\mathbf{i} + 3\mathbf{j} + 9\mathbf{k}$ or condone	A1 cao
			[3]
(b) Way 1	$\mathbf{d}_1 = \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}, \quad \mathbf{d}_2 = \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix} \Rightarrow \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} \bullet \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}$	Realisation that the dot product is required between \mathbf{d}_1 and \mathbf{d}_2 or a multiple of \mathbf{d}_1 and \mathbf{d}_2	M1
	$\pm \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} \bullet \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}$ $\cos \theta = \frac{\pm \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} \bullet \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}}{\sqrt{(-1)^2 + (-5)^2 + (1)^2} \cdot \sqrt{(3)^2 + (0)^2 + (-4)^2}} \left\{ = \frac{-7}{\sqrt{27} \cdot \sqrt{25}} \right\}$	dependent on the 1 st M mark. Applies dot product formula between \mathbf{d}_1 and \mathbf{d}_2 or a multiple of \mathbf{d}_1 and \mathbf{d}_2	dM1
	$\{q = 105.6303588... \supset\} \theta_{\text{Acute}} = 74.36964117... = 74.37$ (2 dp)	awrt 74.37 seen in (b) only	A1
			[3]
(c)	$\overrightarrow{AX} = \overrightarrow{OX} - \overrightarrow{OA} = \begin{pmatrix} -1 \\ 3 \\ 9 \end{pmatrix} - \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} = \begin{pmatrix} -3 \\ -15 \\ 3 \end{pmatrix}$ or $A_{\lambda=2}, X_{\lambda=5} \supset AX = 3 \mathbf{d}_1 , \{ \mathbf{d}_1 = \sqrt{27}\}$		
	$AX = \sqrt{(-3)^2 + (-15)^2 + (3)^2}$ or $3\sqrt{27} \left\{ = \sqrt{243} \right\} = 9\sqrt{3}$	Full method for finding AX or XA	M1
		$9\sqrt{3}$ seen in (c) only	A1 cao
	Note: You cannot recover work for part (c) in either part (d) or part (e).		[2]
(d) Way 1	$\frac{YA}{9\sqrt{3}} = \tan(74.36964...)$	$\frac{YA}{\text{their } \overrightarrow{AX} } = \tan \theta$ or $YA = (\text{their } \overrightarrow{AX}) \tan \theta$, where θ is their acute or obtuse angle between l_1 and l_2	M1
	$YA = 55.71758... = 55.7$ (1 dp)	anything that rounds to 55.7	A1
			[2]
(e) Way 1	$\{A_{\lambda=2}, X_{\lambda=5} \Rightarrow \text{So } AX = 2AB \Rightarrow \text{So at } B, \lambda = 3.5 \text{ or } \lambda = 0.5\}$		
	$\overrightarrow{OB} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + 3.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}; = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Substitutes either $\lambda = \frac{(\text{their } \lambda \text{ found in (a)}) + 2}{2}$ or $\lambda = 3 - \frac{(\text{their } \lambda \text{ found in (a)})}{2}$ into l_1	M1;
	$\overrightarrow{OB} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + 0.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}; = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct. (Also allow coordinates).	A1
		Both position vectors are correct. (Also allow coordinates).	A1
			[3]
			13

Question Number	Scheme	Notes	Marks
6. (e)	$\{AX = 2AB \Rightarrow AB = \frac{1}{2}AX. \text{ So, } \overrightarrow{OB} = \overrightarrow{OA} \pm \overrightarrow{AB} \Rightarrow \overrightarrow{OB} = \overrightarrow{OA} \pm \frac{1}{2}\overrightarrow{AX}\}$		
Way 2	$\overrightarrow{OB} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} + 0.5 \begin{pmatrix} -3 \\ -15 \\ 3 \end{pmatrix} = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Applies either $\overrightarrow{OA} + 0.5\overrightarrow{AX}$ or $\overrightarrow{OA} - 0.5\overrightarrow{AX}$ where (their \overrightarrow{AX}) = $\pm[(\text{their } \overrightarrow{OX}) - \overrightarrow{OA}]$	M1;
	$\overrightarrow{OB} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} - 0.5 \begin{pmatrix} -3 \\ -15 \\ 3 \end{pmatrix} = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct (Also allow coordinates)	A1
		Both position vectors are correct (Also allow coordinates)	A1
			[3]
6. (e) Way 3	$\overrightarrow{AB} = \begin{pmatrix} 4-\lambda \\ 28-5\lambda \\ 4+\lambda \end{pmatrix} - \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} = \begin{pmatrix} 2-\lambda \\ 10-5\lambda \\ -2+\lambda \end{pmatrix} = \begin{pmatrix} 1(2-\lambda) \\ 5(2-\lambda) \\ -1(2-\lambda) \end{pmatrix}; \overrightarrow{AX} = \begin{pmatrix} -3 \\ -15 \\ 3 \end{pmatrix}$ $AX^2 = 243 \Rightarrow AB^2 = 27(2-\lambda)^2$ $AX = 2AB \Rightarrow AX^2 = 4AB^2 \Rightarrow 243 = 4(27)(2-\lambda)^2 \Rightarrow (2-\lambda)^2 = \frac{9}{4}$ or $27\lambda^2 - 108\lambda + \frac{189}{4} = 0$ or $108\lambda^2 - 432\lambda + 189 = 0$ or $4\lambda^2 - 16\lambda + 7 = 0 \Rightarrow \lambda = 3.5$ or $\lambda = 0.5$		
	$\overrightarrow{OB} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + 3.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Full method of solving for λ the equation $AX^2 = 4AB^2$ using (their \overrightarrow{AX}) and \overrightarrow{AB} and substitutes at least one of their values for λ into l_1	M1;
	$\overrightarrow{OB} = \begin{pmatrix} 4 \\ 28 \\ 4 \end{pmatrix} + 0.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct (Also allow coordinates)	A1
		Both position vectors are correct (Also allow coordinates)	A1
	Note: $AX = 2AB \Rightarrow \overrightarrow{AX} = \pm 2\overrightarrow{AB}$. Hence, $\lambda = 3.5$ or $\lambda = 0.5$ can be found from solving either $x: -3 = \pm 2(2-\lambda)$ or $y: -15 = \pm 2(10-5\lambda)$ or $z: -3 = \pm 2(-2+\lambda)$		[3]
6. (e) Way 4	$\overrightarrow{OB} = \begin{pmatrix} -1 \\ 3 \\ 9 \end{pmatrix} + 0.5 \begin{pmatrix} 3 \\ 15 \\ -3 \end{pmatrix} = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Applies either (their \overrightarrow{OX}) + $0.5\overrightarrow{XA}$ or (their \overrightarrow{OX}) + $1.5\overrightarrow{XA}$ where (their \overrightarrow{XA}) = $\overrightarrow{OA} - (\text{their } \overrightarrow{OX})$	M1;
	$\overrightarrow{OB} = \begin{pmatrix} -1 \\ 3 \\ 9 \end{pmatrix} + 1.5 \begin{pmatrix} 3 \\ 15 \\ -3 \end{pmatrix} = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct (Also allow coordinates)	A1
		Both position vectors are correct (Also allow coordinates)	A1
			[3]
6. (e) Way 5	$\overrightarrow{OB} = 0.5 \left(\begin{pmatrix} -1 \\ 3 \\ 9 \end{pmatrix} + \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} \right) = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Applies $\frac{1}{2}[(\text{their } \overrightarrow{OX}) + \overrightarrow{OA}]$	M1;
	$\overrightarrow{OB} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} - 0.5 \begin{pmatrix} -3 \\ -15 \\ 3 \end{pmatrix} = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct (Also allow coordinates)	A1
		Both position vectors are correct (Also allow coordinates)	A1
			[3]

Question Number	Scheme	Notes	Marks
6. (e) Way 6	$\left\{ \overrightarrow{AX} = 9\sqrt{3}, d_1 = 3\sqrt{3} \Rightarrow K = \frac{9\sqrt{3}}{3\sqrt{3}} = 3 \Rightarrow \overrightarrow{AX} = 3\mathbf{d}_1; \text{ So, } \overrightarrow{OB} = \overrightarrow{OA} \pm \frac{1}{2}\overrightarrow{AX} = \overrightarrow{OA} \pm \frac{1}{2}(3\mathbf{d}_1) \right\}$		
	$\overrightarrow{OB} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} + 0.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} = \begin{pmatrix} 0.5 \\ 10.5 \\ 7.5 \end{pmatrix}$	Applies either $\overrightarrow{OA} + 0.5(K\mathbf{d}_1)$ or $\overrightarrow{OA} - 0.5(K\mathbf{d}_1)$, where $K = \frac{\text{their } \overrightarrow{AX} }{3\sqrt{3}}$	M1;
	$\overrightarrow{OB} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} - 0.5 \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} = \begin{pmatrix} 3.5 \\ 25.5 \\ 4.5 \end{pmatrix}$	At least one position vector is correct (Also allow coordinates)	A1
		Both position vectors are correct (Also allow coordinates)	A1
			[3]
Question 6 Notes			
6. (a)	Note	M1 can be implied by at least two correct follow through coordinates from their / or from their m	
(b)	Note	Evaluating the dot product (i.e. $(-1)(3) + (-5)(0) + (1)(-4)$) is not required for the M1, dM1 marks.	
	Note	For M1 dM1: Allow one slip in writing down their direction vectors, \mathbf{d}_1 and \mathbf{d}_2	
	Note	Allow M1 dM1 for $\left(\sqrt{(-1)^2 + (-5)^2 + (1)^2} \cdot \sqrt{(3)^2 + (0)^2 + (-4)^2} \right) \cos q = \pm \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} \cdot \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix}$	
	Note	$q = 1.297995...^\circ$, (without evidence of awrt 74.37) is A0	
6. (b) Way 2	Alternative Method: Vector Cross Product		
	Only apply this scheme if it is clear that a vector cross product method is being applied.		
	$\mathbf{d}_1 \times \mathbf{d}_2 = \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} \times \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -1 & -5 & 1 \\ 3 & 0 & -4 \end{vmatrix} = 20\mathbf{i} - \mathbf{j} + 15\mathbf{k}$	Realisation that the vector cross product is required between \mathbf{d}_1 and \mathbf{d}_2 or a multiple of \mathbf{d}_1 and \mathbf{d}_2	M1
	$\sin q = \frac{\sqrt{(20)^2 + (-1)^2 + (15)^2}}{\sqrt{(-1)^2 + (-5)^2 + (1)^2} \cdot \sqrt{(3)^2 + (0)^2 + (-4)^2}}$	Applies the vector product formula between \mathbf{d}_1 and \mathbf{d}_2 or a multiple of \mathbf{d}_1 and \mathbf{d}_2	dM1
	$\sin q = \frac{\sqrt{626}}{\sqrt{27} \cdot \sqrt{25}} \Rightarrow q = 74.36964117... = 74.37 \text{ (2 dp)}$	awrt 74.37 seen in (b) only	A1
			[3]
6. (c)	M1	Finds the difference between their \overrightarrow{OX} and \overrightarrow{OA} and applies Pythagoras to the result to find AX or XA OR applies $\left \left(\text{their } /_x \text{ found in (a)} \right) - 2 \right \cdot \sqrt{(-1)^2 + (-5)^2 + (1)^2}$	
	Note	For M1: Allow one slip in writing down their \overrightarrow{OX} and \overrightarrow{OA}	
	Note	Allow M1A1 for $\begin{pmatrix} 3 \\ 15 \\ 3 \end{pmatrix}$ leading to $AX = \sqrt{(3)^2 + (15)^2 + (3)^2} = \sqrt{243} = 9\sqrt{3}$	
(e)	Note	Imply M1 for no working leading to any two components of one of the \overrightarrow{OB} which are correct.	

Question Number	Scheme	Notes	Marks
6. (d) Way 2	$\frac{"9\sqrt{3}"}{YA} = \tan(90 - "74.36964...")$	$\frac{\text{their } \overrightarrow{AX} }{YA} = \tan(90 - \theta)$ or $AY = \frac{\text{their } \overrightarrow{AX} }{\tan(90 - \theta)}$, where θ is the acute or obtuse angle between l_1 and l_2	M1
	$YA = 55.71758... = 55.7$ (1 dp)	anything that rounds to 55.7	A1
			[2]
6. (d) Way 3	$\frac{YA}{\sin("74.36964...")} = \frac{"9\sqrt{3}"}{\sin(90 - "74.36964...")}$	$\frac{YA}{\sin \theta} = \frac{\text{their } \overrightarrow{AX} }{\sin(90 - \theta)}$ o.e., where θ is the acute or obtuse angle between l_1 and l_2	M1
	$YA = \frac{9\sqrt{3} \sin(74.36964...)}{\sin(15.63036...)} = 55.71758... = 55.7$ (1 dp)	anything that rounds to 55.7	A1
			[2]
6. (d) Way 4	$\mathbf{d}_1 = \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix}, \quad \overrightarrow{OY} = \begin{pmatrix} 5 \\ 3 \\ 1 \end{pmatrix} + \mu \begin{pmatrix} 3 \\ 0 \\ -4 \end{pmatrix} = \begin{pmatrix} 5+3\mu \\ 3 \\ 1-4\mu \end{pmatrix}$		
	$\overrightarrow{YA} = \begin{pmatrix} 2 \\ 18 \\ 6 \end{pmatrix} - \begin{pmatrix} 5+3\mu \\ 3 \\ 1-4\mu \end{pmatrix} = \begin{pmatrix} -3-3\mu \\ 15 \\ 5+4\mu \end{pmatrix}$ $\overrightarrow{YA} \bullet \mathbf{d}_1 = 0 \Rightarrow \begin{pmatrix} -3-3\mu \\ 15 \\ 5+4\mu \end{pmatrix} \bullet \begin{pmatrix} -1 \\ -5 \\ 1 \end{pmatrix} = 0$ $\Rightarrow 3+3m-75+5+4m=0 \Rightarrow m = \frac{67}{7}$ $YA^2 = \left(-3-3\left(\frac{67}{7}\right)\right)^2 + (15)^2 + \left(5+4\left(\frac{67}{7}\right)\right)^2$	(Allow a sign slip in copying \mathbf{d}_1) Applies $\overrightarrow{YA} \bullet \mathbf{d}_1 = 0$ or $\overrightarrow{AY} \bullet \mathbf{d}_1 = 0$ or $\overrightarrow{YA} \bullet (K\mathbf{d}_1) = 0$ or $\overrightarrow{AY} \bullet (K\mathbf{d}_1) = 0$ to find m and applies Pythagoras to find a numerical expression for AY^2 or for the distance AY	M1
	So, $YA = \sqrt{\left(-\frac{222}{7}\right)^2 + (15)^2 + \left(\frac{303}{7}\right)^2}$		
	$= 55.71758... = 55.7$ (1 dp)	anything that rounds to 55.7	A1
	Note: $\overrightarrow{OY} = \frac{236}{7}\mathbf{i} + 3\mathbf{j} - \frac{261}{7}\mathbf{k}, \quad \overrightarrow{AY} = -\frac{222}{7}\mathbf{i} + 15\mathbf{j} + \frac{303}{7}\mathbf{k}$		[2]

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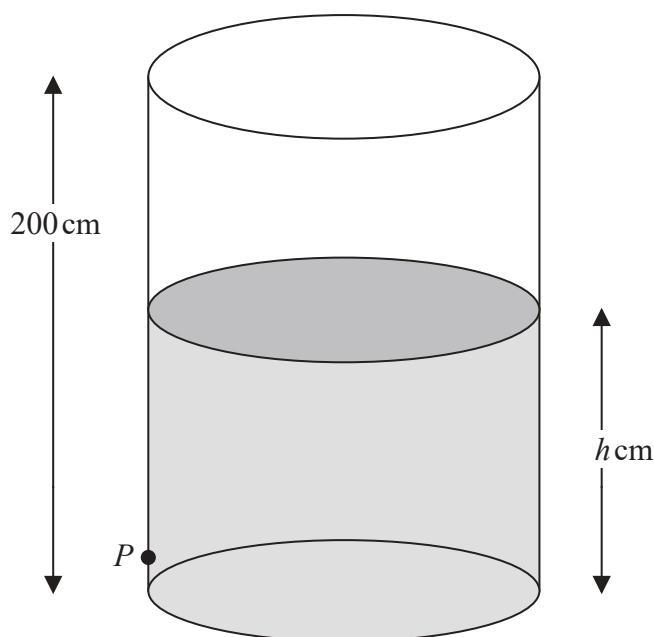


Diagram not
drawn to scale

Figure 3

Figure 3 shows a vertical cylindrical tank of height 200 cm containing water. Water is leaking from a hole P on the side of the tank.

At time t minutes after the leaking starts, the height of water in the tank is h cm.

The height h cm of the water in the tank satisfies the differential equation

$$\frac{dh}{dt} = k(h - 9)^{\frac{1}{2}}, \quad 9 < h \leq 200$$

where k is a constant.

Given that, when $h = 130$, the height of the water is falling at a rate of 1.1 cm per minute,

(a) find the value of k .

(2)

Given that the tank was full of water when the leaking started,

(b) solve the differential equation with your value of k , to find the value of t when $h = 50$

(6)

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Question Number	Scheme	Notes	Marks
7.	$\frac{dh}{dt} = k\sqrt{h-9}$, $9 < h \leq 200$; $h = 130$, $\frac{dh}{dt} = -1.1$		
(a)	$-1.1 = k\sqrt{(130-9)} \Rightarrow k = \dots$	Substitutes $h = 130$ and either $\frac{dh}{dt} = -1.1$ or $\frac{dh}{dt} = 1.1$ into the printed equation and rearranges to give $k = \dots$	M1
	so, $k = -\frac{1}{10}$ or -0.1	$k = -\frac{1}{10}$ or -0.1	A1
			[2]
(b) Way 1	$\int \frac{dh}{\sqrt{h-9}} = \int k dt$	Separates the variables correctly. dh and dt should not be in the wrong positions, although this mark can be implied by later working. Ignore the integral signs.	B1
	$\int (h-9)^{-\frac{1}{2}} dh = \int k dt$		
	$\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} = kt (+c)$	Integrates $\frac{\pm \lambda}{\sqrt{h-9}}$ to give $\pm m\sqrt{h-9}$; $l, m \neq 0$	M1
		$\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} = kt$ or $\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} = (\text{their } k)t$, with/without $+c$, or equivalent, which can be un-simplified or simplified.	A1
	$\{t = 0, h = 200 \Rightarrow\} 2\sqrt{(200-9)} = k(0) + c$	Some evidence of applying both $t = 0$ and $h = 200$ to changed equation containing a constant of integration, e.g. c or A	M1
	$\Rightarrow c = 2\sqrt{191} \Rightarrow 2(h-9)^{\frac{1}{2}} = -0.1t + 2\sqrt{191}$ $\{h = 50 \Rightarrow\} 2\sqrt{(50-9)} = -0.1t + 2\sqrt{191}$ $t = \dots$	dependent on the previous M mark Applies $h = 50$ and their value of c to their changed equation and rearranges to find the value of $t = \dots$	dM1
	$t = 20\sqrt{191} - 20\sqrt{41}$ or $t = 148.3430145\dots = 148$ (minutes) (nearest minute)	$t = 20\sqrt{191} - 20\sqrt{41}$ isw or awrt 148	A1 cso
			[6]
	$\int_{200}^{50} \frac{dh}{\sqrt{h-9}} = \int_0^T k dt$	Separates the variables correctly. dh and dt should not be in the wrong positions, although this mark can be implied by later working. Integral signs and limits not necessary.	B1
	$\int_{200}^{50} (h-9)^{-\frac{1}{2}} dh = \int_0^T k dt$		
	$\left[\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} \right]_{200}^{50} = [kt]_0^T$	Integrates $\frac{\pm \lambda}{\sqrt{h-9}}$ to give $\pm m\sqrt{h-9}$; $l, m \neq 0$	M1
		$\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} = kt$ or $\frac{(h-9)^{\frac{1}{2}}}{(\frac{1}{2})} = (\text{their } k)t$, with/without limits, or equivalent, which can be un-simplified or simplified.	A1
	$2\sqrt{41} - 2\sqrt{191} = kt$ or kT	Attempts to apply limits of $h = 200$, $h = 50$ and (can be implied) $t = 0$ to their changed equation	M1
	$t = \frac{2\sqrt{41} - 2\sqrt{191}}{-0.1}$	dependent on the previous M mark Then rearranges to find the value of $t = \dots$	dM1
	$t = 20\sqrt{191} - 20\sqrt{41}$ or $t = 148.3430145\dots = 148$ (minutes) (nearest minute)	$t = 20\sqrt{191} - 20\sqrt{41}$ or awrt 148 or 2 hours and awrt 28 minutes	A1 cso
			[6]
			8

Question 7 Notes		
7. (b)	Note	Allow first B1 for writing $\frac{dt}{dh} = \frac{1}{k\sqrt{(h-9)}}$ or $\frac{dt}{dh} = \frac{1}{(\text{their } k)\sqrt{(h-9)}}$ or equivalent
	Note	$\frac{dt}{dh} = \frac{1}{k\sqrt{(h-9)}}$ leading to $t = \frac{2}{k}\sqrt{(h-9)}$ (+ c) with/without + c is B1M1A1
	Note	After finding $k = 0.1$ in part (a), it is only possible to gain full marks in part (b) by initially writing $\frac{dh}{dt} = -k\sqrt{(h-9)}$ or $\int \frac{dh}{\sqrt{(h-9)}} = \int -k dt$ or $\frac{dh}{dt} = -0.1\sqrt{(h-9)}$ or $\int \frac{dh}{\sqrt{(h-9)}} = \int -0.1 dt$ Otherwise, those candidates who find $k = 0.1$ in part (a), should lose at least the final A1 mark in part (b).

8.

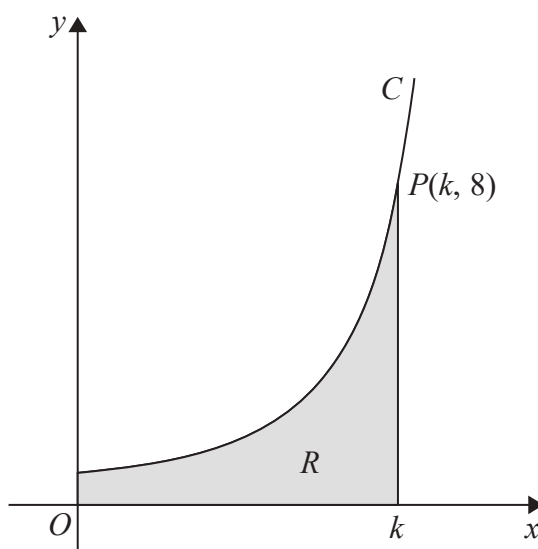


Diagram not
drawn to scale

Figure 4

Figure 4 shows a sketch of part of the curve C with parametric equations

$$x = 3\theta \sin \theta, \quad y = \sec^3 \theta, \quad 0 \leq \theta < \frac{\pi}{2}$$

The point $P(k, 8)$ lies on C , where k is a constant.

(a) Find the exact value of k .

(2)

The finite region R , shown shaded in Figure 4, is bounded by the curve C , the y -axis, the x -axis and the line with equation $x = k$.

(b) Show that the area of R can be expressed in the form

$$\lambda \int_{\alpha}^{\beta} (\theta \sec^2 \theta + \tan \theta \sec^2 \theta) d\theta$$

where λ , α and β are constants to be determined.

(4)

(c) Hence use integration to find the exact value of the area of R .

(6)

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(Mark Scheme)		This resource was created and owned by Pearson Edexcel		Notes	
Question Number		Scheme		6666 Marks	
8.	$x = 3q \sin q, y = \sec^3 q, 0 \leq q < \frac{\rho}{2}$				
(a)	$\{ \text{When } y = 8, \} 8 = \sec^3 \theta \Rightarrow \cos^3 \theta = \frac{1}{8} \Rightarrow \cos \theta = \frac{1}{2} \Rightarrow \theta = \frac{\pi}{3}$ $k \text{ (or } x) = 3 \left(\frac{\pi}{3} \right) \sin \left(\frac{\pi}{3} \right)$		Sets $y = 8$ to find θ and attempts to substitute their θ into $x = 3q \sin q$		M1
	$\text{so } k \text{ (or } x) = \frac{\sqrt{3} \pi}{2}$		$\frac{\sqrt{3} \rho}{2}$ or $\frac{3 \rho}{2 \sqrt{3}}$		A1
	Note: Obtaining two value for k without accepting the correct value is final A0				[2]
(b)	$\frac{dx}{d\theta} = 3 \sin \theta + 3 \theta \cos \theta$		$3 \theta \sin \theta \rightarrow 3 \sin \theta + 3 \theta \cos \theta$ Can be implied by later working		B1
	$\left\{ \int y \frac{dx}{dq} \{dq\} \right\} = \int (\sec^3 q)(3 \sin q + 3 q \cos q) \{dq\}$		Applies $(\pm K \sec^3 q) \left(\text{their } \frac{dx}{dq} \right)$ Ignore integral sign and dq ; $K \neq 0$		M1
	$= 3 \int q \sec^2 q + \tan q \sec^2 q dq$	Achieves the correct result no errors in their working, e.g. bracketing or manipulation errors. Must have integral sign and $d\theta$ in their final answer.			A1 *
	$x = 0 \text{ and } x = k \Rightarrow \underline{\alpha = 0} \text{ and } \underline{\beta = \frac{\pi}{3}}$	$\alpha = 0 \text{ and } \beta = \frac{\pi}{3} \text{ or evidence of } 0 \rightarrow 0 \text{ and } k \rightarrow \frac{\pi}{3}$			B1
	Note: The work for the final B1 mark must be seen in part (b) only.				[4]
(c) Way 1	$\left\{ \int q \sec^2 q dq \right\} = q \tan q - \int \tan q \{dq\}$		$q \sec^2 q \rightarrow A q g(q) - B \int g(q), A > 0, B > 0,$ where $g(q)$ is a trigonometric function in q and $g(q) = \text{their } \int \sec^2 q dq$. [Note: $g(q) \neq \sec^2 q$]		M1
			dependent on the previous M mark Either $\int q \sec^2 q \rightarrow A q \tan q - B \int \tan q, A > 0, B > 0$ or $q \sec^2 q \rightarrow q \tan q - \int \tan q$		dM1
	$= q \tan q - \ln(\sec q)$ or $= q \tan q + \ln(\cos q)$		$q \sec^2 q \rightarrow q \tan q - \ln(\sec q) \text{ or } q \tan q + \ln(\cos q)$ or $\int q \sec^2 q \rightarrow \int q \tan q - \int \ln(\sec q) \text{ or } \int q \tan q + \int \ln(\cos q)$		A1
	Note: Condone $q \sec^2 q \rightarrow q \tan q - \ln(\sec x) \text{ or } q \tan q + \ln(\cos x)$ for A1				
	$\left\{ \int \tan q \sec^2 q dq \right\}$ $= \frac{1}{2} \tan^2 q \text{ or } \frac{1}{2} \sec^2 q$ or $\frac{1}{2u^2}$ where $u = \cos q$ or $\frac{1}{2} u^2$ where $u = \tan q$		$\tan \theta \sec^2 \theta \text{ or } \int \tan q \sec^2 q \rightarrow \pm C \tan^2 q \text{ or } \pm C \sec^2 q$ or $\pm C u^{-2}$, where $u = \cos q$		M1
			$\tan q \sec^2 q \rightarrow \frac{1}{2} \tan^2 q \text{ or } \frac{1}{2} \sec^2 q \text{ or } \frac{1}{2 \cos^2 q} \text{ or } \tan^2 q - \frac{1}{2} \sec^2 q$ or $0.5 u^{-2}$, where $u = \cos q$ or $0.5 u^2$, where $u = \tan q$ or $\lambda \tan \theta \sec^2 \theta \rightarrow \frac{\lambda}{2} \tan^2 \theta \text{ or } \frac{\lambda}{2} \sec^2 \theta \text{ or } \frac{\lambda}{2 \cos^2 \theta}$ or $0.5 / u^{-2}$, where $u = \cos q$ or $0.5 / u^2$, where $u = \tan q$		A1
	$\{ \text{Area}(R) \} = \left[3 q \tan q - 3 \ln(\sec q) + \frac{3}{2} \tan^2 q \right]_0^{\frac{\rho}{3}} \text{ or } \left[3 q \tan q - 3 \ln(\sec q) + \frac{3}{2} \sec^2 q \right]_0^{\frac{\rho}{3}}$				
	$= \left(3 \left(\frac{\pi}{3} \right) \sqrt{3} - 3 \ln 2 + \frac{3}{2} (3) \right) - (0) \text{ or } \left(3 \left(\frac{\pi}{3} \right) \sqrt{3} - 3 \ln 2 + \frac{3}{2} (4) \right) - \left(\frac{3}{2} \right)$				
	$= \frac{9}{2} + \sqrt{3} \rho - 3 \ln 2 \text{ or } \frac{9}{2} + \sqrt{3} \rho + 3 \ln \left(\frac{1}{2} \right) \text{ or } \frac{9}{2} + \sqrt{3} \pi - \ln 8 \text{ or } \ln \left(\frac{1}{8} e^{\frac{3}{2} + \sqrt{3} \rho} \right)$				A1 o.e.
					[6]
					12

Question Number	Scheme		Notes	Marks
8. (c) Way 2	Way 2 for the first 5 marks: Applying integration by parts on $\int (q + \tan q) \sec^2 q \, dq$			
	$\int (q \sec^2 q + \tan q \sec^2 q) \, dq = \int (q + \tan q) \sec^2 q \, dq, \quad \left\{ \begin{array}{l} u = q + \tan q \Rightarrow \frac{du}{dq} = 1 + \sec^2 q \\ \frac{dv}{dq} = \sec^2 q \Rightarrow v = \tan q = g(q) \end{array} \right\}$			
	$h(q)$ and $g(q)$ are trigonometric functions in q and $g(q) = \int \sec^2 q \, dq$. [Note: $g(q) \neq \sec^2 q$]			
	$= (q + \tan q) \tan q - \int (1 + \sec^2 q) \tan q \{dq\}$		$A(q + \tan q)g(q) - B \int (1 + h(q))g(q), A > 0, B > 0$	M1
			dependent on the previous M mark Either $\int [(q + \tan q) \sec^2 q] \rightarrow$ $A(q + \tan q) \tan q - B \int (1 + h(q)) \tan q, A \neq 0, B > 0$ or $(q + \tan q) \tan q - \int (1 + h(q)) \tan q$	dM1
	$= (q + \tan q) \tan q - \int (\tan q + \tan q \sec^2 q) \{dq\}$			
	$= (q + \tan q) \tan q - \ln(\sec q) - \int \tan q \sec^2 q \{dq\}$		$(q + \tan q) \tan q - \ln(\sec q)$ o.e. or $\int [(q + \tan q) \tan q - \ln(\sec q)]$ o.e.	A1
	$= (q + \tan q) \tan q - \ln(\sec q) - \frac{1}{2} \tan^2 q$ or $= (q + \tan q) \tan q - \ln(\sec q) - \frac{1}{2} \sec^2 q$ etc.		$\tan q \sec^2 q \rightarrow \pm C \tan^2 q$ or $\pm C \sec^2 q$	M1
			$(q + \tan q) \tan q - \frac{1}{2} \tan^2 q$ or $(q + \tan q) \tan q - \frac{1}{2} \sec^2 q$	A1
	Note	Allow the first two marks in part (c) for $q \tan q - \int \tan q$ embedded in their working		
	Note	Allow the first three marks in part (c) for $q \tan q - \ln(\sec q)$ embedded in their working		
	Note	Allow 3 rd M1 2 nd A1 marks for either $\tan^2 q - \frac{1}{2} \tan^2 q$ or $\tan^2 q - \frac{1}{2} \sec^2 q$ embedded in their working		
Question 8 Notes				
8. (a)	Note	Allow M1 for an answer of $k = \arctan 2.72$ without reference to $\frac{\sqrt{3}p}{2}$ or $\frac{3p}{2\sqrt{3}}$		
	Note	Allow M1 for an answer of $k = 3\left(\arccos\left(\frac{1}{2}\right)\right)\sin\left(\arccos\left(\frac{1}{2}\right)\right)$ without reference to $\frac{\sqrt{3}p}{2}$ or $\frac{3p}{2\sqrt{3}}$		
	Note	E.g. allow M1 for $q = 60^\circ$, leading to $k = 3(60)\sin(60)$ or $k = 90\sqrt{3}$		

Question 8 Notes Continued

8. (b)	Note	To gain A1, $\int dq$ does not need to appear until they obtain $3\int(q\sec^2 q + \tan q \sec^2 q) dq$		
	Note	For M1, their $\frac{dx}{dq}$, where their $\frac{dx}{dq} = 3q \sin q$, needs to be a trigonometric function in q		
	Note	Writing $\int (\sec^3 q)(3\sin q + 3q \cos q) = 3\int(q\sec^2 q + \tan q \sec^2 q) dq$ is sufficient for B1M1A1		
	Note	Writing $\frac{dx}{d\theta} = 3\sin \theta + 3\theta \cos \theta$ followed by writing $\int y \frac{dx}{dq} dq = 3\int(q\sec^2 q + \tan q \sec^2 q) dq$ is sufficient for B1M1A1		
	Note	The final A mark would be lost for $\int \frac{1}{\cos^3 q} 3\sin q + 3q \cos q = 3\int(q\sec^2 q + \tan q \sec^2 q) dq$ [lack of brackets in this particular case].		
	Note	Give 2 nd B0 for $a = 0$ and $b = 60^\circ$, without reference to $b = \frac{\rho}{3}$		
(c)	Note	A decimal answer of 7.861956551... (without a correct exact answer) is A0.		
	Note	First three marks are for integrating $\theta \sec^2 \theta$ with respect to θ		
	Note	Fourth and fifth marks are for integrating $\tan \theta \sec^2 \theta$ with respect to θ		
	Note	Candidates are not penalised for writing $\ln \sec q $ as either $\ln(\sec q)$ or $\ln \sec q$		
	Note	$q \sec^2 q \rightarrow q \tan q + \ln(\sec q)$ WITH NO INTERMEDIATE WORKING is M0M0A0		
	Note	$q \sec^2 q \rightarrow q \tan q - \ln(\cos q)$ WITH NO INTERMEDIATE WORKING is M0M0A0		
	Note	$q \sec^2 q \rightarrow q \tan q - \ln(\sec q)$ WITH NO INTERMEDIATE WORKING is M1M1A1		
	Note	$q \sec^2 q \rightarrow q \tan q + \ln(\cos q)$ WITH NO INTERMEDIATE WORKING is M1M1A1		
	Note	Writing a correct $uv - \int v \frac{du}{dx}$ with $u = q$, $\frac{dv}{dq} = \tan q$, $\frac{du}{dq} = 1$ and $v =$ their $g(q)$ and making one error in the direct application of this formula is 1 st M1 only.		
8. (c)	Alternative method for finding $\int \tan q \sec^2 q dq$			
	$\left\{ \begin{array}{l} u = \tan q \quad \Rightarrow \frac{du}{dq} = \sec^2 q \\ \frac{dv}{dq} = \sec^2 q \quad \Rightarrow v = \tan q \end{array} \right\}$			
	$\int \tan q \sec^2 q dq = \tan^2 q - \int \tan q \sec^2 q dq$ $\Rightarrow 2\int \tan q \sec^2 q dq = \tan^2 q$			
	$\int \tan q \sec^2 q dq = \frac{1}{2} \tan^2 q$		$\tan \theta \sec^2 \theta$ or $\rightarrow \pm C \tan^2 q$	M1
			$\tan q \sec^2 q \rightarrow \frac{1}{2} \tan^2 q$	A1
	or $\left\{ \begin{array}{l} u = \sec q \quad \Rightarrow \frac{du}{dq} = \sec q \tan q \\ \frac{dv}{dq} = \sec q \tan q \quad \Rightarrow v = \sec q \end{array} \right\}$			
	$\Rightarrow \int \tan q \sec^2 q dq = \sec^2 q - \int \sec^2 q \tan q dq$ $\Rightarrow 2\int \tan q \sec^2 q dq = \sec^2 q$			
	$\int \tan q \sec^2 q dq = \frac{1}{2} \sec^2 q$		$\tan \theta \sec^2 \theta$ or $\rightarrow \pm C \sec^2 q$	M1
			$\tan q \sec^2 q \rightarrow \frac{1}{2} \sec^2 q$	A1