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MA03

(9660/MA03) Unit P2 Pure Mathematics

Mark scheme

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Key to mark scheme abbreviations

M	Mark is for method
m	Mark is dependent on one or more M marks and is for method
A	Mark is dependent on M or m marks and is for accuracy
B	Mark is independent of M or m marks and is for method and accuracy
E	Mark is for explanation
√ **or ft**	Follow through from previous incorrect result
CAO	Correct answer only
CSO	Correct solution only
AWFW	Anything which falls within
AWRT	Anything which rounds to
ACF	Any correct form
AG	Answer given
SC	Special case
oe	Or equivalent
A2, 1	2 or 1 (or 0) accuracy marks
–*x* EE	Deduct *x* marks for each error
NMS	No method shown
PI	Possibly implied
SCA	Substantially correct approach
sf	Significant figure(s)
dp	Decimal place(s)
ISW	Ignore subsequent working

Q	Answer	Marks	Comments
1(a)	$f(x) = \ln(2x+1) + 6x - 5$ $f(0.6) = -0.6...$ $f(0.7) = 0.07...$ or 0.08 Change of sign, $0.6 < \alpha < 0.7$	M1 A1	Or reverse Both values rounded or truncated to at least 1sf **oe** Must have both statement and interval in words or symbols **or** comparing 2 sides: at 0.6, $\left[\ln(2.2) =\right]\ 0.7[88...] < 1.4$; at 0.7, $\left[\ln(2.4) =\right]\ 0.87[5...] > 0.8$ Accuracy as before **(M1)** Conclusion as before **(A1)**
		2	

Q	Answer	Marks	Comments
1(b)	$x_2 = 0.687$ $x_3 = 0.689$	B1 B1	**CAO** **CAO**
		2	

	Question 1 Total	**4**	

Q	Answer	Marks	Comments
2	Stretch + either I or II	M1	
	Parallel to y-axis I	A1	
	SF 5 II		
	Translation	M1	
	$\begin{bmatrix} -360° \left[\pm 1440° n\right] \\ 0 \end{bmatrix}$ or $\begin{bmatrix} -2\pi \left[\pm 8n\pi\right] \\ 0 \end{bmatrix}$	A1	
		4	

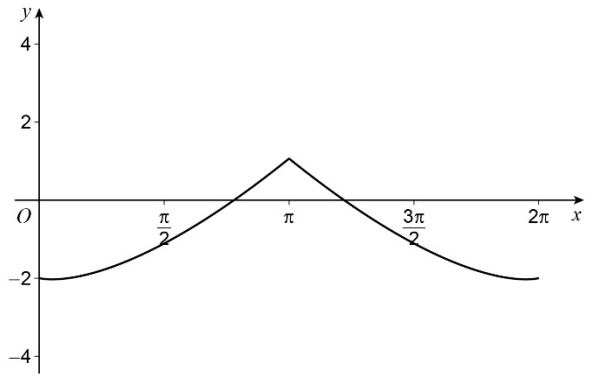
	Question 2 Total	**4**	

Q	Answer	Marks	Comments
3(a)	$-3 \leq \mathrm{f}(x) \leq 3$	M1 A1	**oe** eg $\mathrm{f}(x) \in [-3, 3]$ Condone 'y' for $\mathrm{f}(x)$ For strict inequalities **M1A0**
		2	

Q	Answer	Marks	Comments
3(b)(i)	$x = 3\cos\left(\frac{y}{2}\right)$	M1	'Swap' x and y
	$\frac{x}{3} = \cos\left(\frac{y}{2}\right)$	M1	Attempt to rearrange
	$\mathrm{f}^{-1}(x) = 2\cos^{-1}\left(\frac{x}{3}\right)$	A1	
		3	

Q	Answer	Marks	Comments
3(b)(ii)	$\left[2\cos^{-1}\left(\frac{x}{3}\right) = \frac{3\pi}{2}\right] \quad \frac{x}{3} = \cos\left(\frac{3\pi}{4}\right)$	M1	$X = \cos\left(\frac{\frac{3\pi}{2}}{2}\right) \quad \left[= \cos\left(\frac{3\pi}{4}\right)\right]$
	$x = -\frac{3}{\sqrt{2}}$ oe	A1	$x = 3\times\left(-\frac{1}{\sqrt{2}}\right) = -\frac{3}{\sqrt{2}}$
		2	

Q	Answer	Marks	Comments
3(c)(i)	$\left[\mathrm{h}(x) =\right] 1 - \left\lvert 3\cos\left(\frac{x}{2}\right)\right\rvert$	B1	or $3\left\lvert\cos\left(\frac{x}{2}\right)\right\rvert$
		1	

Q	Answer	Marks	Comments
3(c)(ii)		B1 B1 B1	Correct symmetry, intersecting x-axis between π/2 and π Correct cusp and curvature Range from −2 to 1 with curve crossing axis exactly twice
		3	

	Question 3 Total	**11**	

Q	Answer	Marks	Comments
4(a)	$\begin{bmatrix} p \\ 1 \\ -1 \end{bmatrix}.\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} = p-1$	B1	
	$\cos 60° = \dfrac{p-1}{\sqrt{\left(p^2+2\right)}\times\sqrt{2}}$	M1	
	$\left(2p-2\right) = \sqrt{2p^2+4}$	A1	**oe**
	$\left(2p-2\right)^2 = 2p^2+4$	m1	Attempt to solve for p
	$2p^2-8p=0$		
	$p=4 \quad [\text{as } p>0]$	A1	If p = 0 seen, then must be rejected
		5	

Q	Answer	Marks	Comments
4(b)	$2+p\lambda = -1+\mu$	M1	Equating 'x' and 'y'
	$3+\lambda = 4$		
	$\lambda = 1, \quad \mu = 3+p[=7]$	A1ft	Correct λ and their correct μ
	$5-\lambda = q+\mu$		
	$q = 4-(3+p)$		
	$q=-3$	A1	
		3	

	Question 4 Total	**8**	

Q	Answer	Marks	Comments
5(a)(i)	$a+b+c-6=45$ $-a+b-c-6=-5$ $\left[a(-0.5)^3+b(-0.5)^2-0.5c-6=-9\right]$ $a+b+c=51$ $-a+b-c=1$ $b=26$	**M1** **A1** **A1**	One correct substitution OR for **M1** use of long division Two substitutions correct or $2b-12=40$ $b=26$ **AG** Must be convincingly shown
		3	

Q	Answer	Marks	Comments
5(a)(ii)	$-a+2b-4c=-24$ $-a-4c=-76$ $a+c=25$ $a=8$ $c=17$	**M1** **A1** **A1**	Attempt to solve **PI**
		3	

Q	Answer	Marks	Comments
5(b)(i)	$\left[8\times(-2)^3+26\times(-2)^2+17\times(-2)-6\right]$ $-64+104-34-6=0$	**B1**	**AG** Must be convincingly shown
		1	

Q	Answer	Marks	Comments
5(b)(ii)	$\mathrm{f}(x) = (x+2)(8x^2+10x-3)$ $\dfrac{\mathrm{f}(x)}{(4x+1)(x+2)} = \dfrac{(x+2)(8x^2+10x-3)}{(4x+1)(x+2)}$ $= \dfrac{(4x+1)(ax+b)+c}{(4x+1)}$ $= 2x+2-\dfrac{5}{4x+1}$ $2(x+1)+\dfrac{-5}{4x+1}$	**B1** **M1** **A1**	
		3	

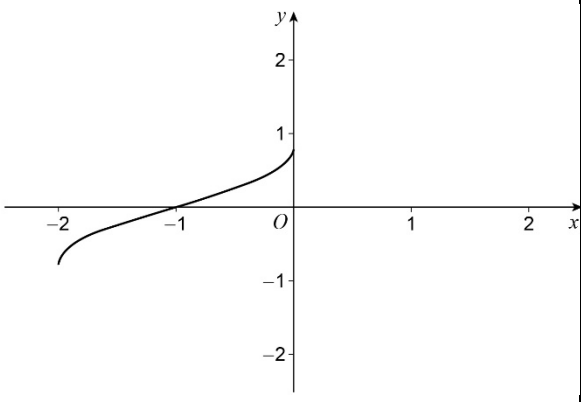
	Question 5 Total	**10**	

Q	Answer	Marks	Comments
6(a)	x | y 0 | $\left(1-\left(0^3\right)\right)^{\frac{1}{2}} = 1$ 0.25 | $\left(1-\left(0.5\times0.25^3\right)\right)^{\frac{1}{2}} = 0.99608609$ 0.5 | $\left(1-\left(0.5\times0.5^3\right)\right)^{\frac{1}{2}} = 0.9682458$ 0.75 | $\left(1-\left(0.5\times0.75^3\right)\right)^{\frac{1}{2}} = 0.8882919$ 1 | $\left(1-\left(0.5\times1^3\right)\right)^{\frac{1}{2}} = 0.70710678$ $\frac{1}{3}\times0.25\times\left(1+0.70710678+4\left(0.99608609+0.8882919\right)+2\times0.9682458\right)$ $= 0.9318$	B1 M1 m1 A1	All 5 correct x values (and no extra used) **PI** by 5 correct y values At least 4 correct y values in exact form or decimals, rounded or truncated to 3 dp or better (in table or formula) (**PI** by **AWRT** correct answer) Correct sub into formula with $h = 0.25$ **oe** and at least 4 correct y values either listed, with + signs, or totalled. (**PI** by **AWRT** correct answer) **CAO**, must see this value exactly and no error seen
		4	

Q	Answer	Marks	Comments
6(b)	$1+\frac{1}{2}\left(-\frac{1}{2}x^3\right)+\frac{\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{1}{2}x^3\right)^2}{2}$ $=1-\frac{1}{4}x^3-\frac{1}{32}x^6$	M1 A1	$1+px^3+qx^6$ with p or q correct, may be unsimplified
		2	

	Question 6 Total	**6**	

Q	Answer	Marks	Comments
7(a)	$P\left(-1,-\frac{\pi}{2}\right)$ $Q\left(1,\frac{\pi}{2}\right)$	B1	
		1	

Q	Answer	Marks	Comments
7(b)		M1 A1	Correct shape AND Either passing through (–1, 0) or range between $\left(...,\ -\frac{\pi}{4}\right)$ and $\left(....,\ \frac{\pi}{4}\right)$ approx All correct, including range between $\left(-2,\ -\frac{\pi}{4}\right)$ and $\left(0,\ \frac{\pi}{4}\right)$ approx. and passing through (–1, 0)
		2	

Q	Answer	Marks	Comments
7(c)(i)	$2y = \sin^{-1}(x+1)$ $x = -1+\sin 2y$	M1 A1	
		2	

Q	Answer	Marks	Comments
7(c)(ii)	$x = -1+\sin 2y$ $\frac{dx}{dy} = 2\cos 2y$ $y = \frac{\pi}{12}$, $\frac{dx}{dy}\left[= 2\cos\left(2\times\frac{\pi}{12}\right)\right] = \sqrt{3}$	M1 A1	$k\cos 2y$
		2	

	Question 7 Total	**7**	

Q	Answer	Marks	Comments
8(a)(i)	28°	B1	
		1	

Q	Answer	Marks	Comments
8(a)(ii)	$\frac{2}{3}$	B1	oe
		1	

Q	Answer	Marks	Comments
8(b)	$\tan^2 X + 9 = 6\sec X$ $\sec^2 X - 6\sec X + 8 = 0$ $(\sec X - 4)(\sec X - 2) = 0$ or $\begin{bmatrix} 8\cos^2 X - 6\cos X + 1 = 0 \\ (4\cos X - 1)(2\cos X - 1) = 0 \end{bmatrix}$ $\sec X = 2,\ 4$ $X = 1.05 \text{ or } \frac{\pi}{3},\ 1.32$ $x = 0.87,\ 1.01,\ 2.83,\ 2.97$	M1 A1 A1 B2	Correct use of trig identity and rearranged into equation =0 X could be Y PI All values rounded to at least 2dp and no others in the interval **B1** for three correct
		5	

	Question 8 Total	7	

Q	Answer	Marks	Comments
9	$\dfrac{14}{2-x-6x^2}=\dfrac{14}{(2+3x)(1-2x)}$	B1	
	$\dfrac{14}{(2+3x)(1-2x)}=\dfrac{A}{2+3x}+\dfrac{B}{1-2x}$		
	$x=\dfrac{1}{2};\ 14=\dfrac{7}{2}B$	M1	Attempt at partial fractions
	$x=-\dfrac{2}{3};\ 14=\dfrac{7}{3}A$		
	$B=4 \quad A=6$	A1	All correct
	$\displaystyle\int\frac{14}{2-x-6x^2}\mathrm{d}x=\int\frac{A}{2+3x}+\frac{B}{1-2x}\mathrm{d}x$		
	$=\dfrac{6}{3}\ln\lvert 2+3x\rvert+\dfrac{4}{-2}\ln\lvert 1-2x\rvert$	m1	Attempt at integration $p\ln\left(their\lvert 2+3x\rvert\right)+q\ln\left(their\lvert 1-2x\rvert\right)$
		A1	All correct Condone use of other brackets
	$=2\ln\left\lvert\dfrac{2+3x}{1-2x}\right\rvert+c$	A1	Condone use of other brackets and omission of $+c$
		6	

	Question 9 Total	**6**	

Q	Answer	Marks	Comments
10(a)	$4x + y = (x - y)^2$ $4 + \frac{dy}{dx} = 2(x-y)\left(1 - \frac{dy}{dx}\right)$ or $4 + \frac{dy}{dx} = 2x - 2y - 2x\frac{dy}{dx} + 2y\frac{dy}{dx}$	**M1** **A1**	Attempt at implicit differentiation, at least two terms in $\frac{dy}{dx}$ correct All correct
	$\frac{dy}{dx} + 2x\frac{dy}{dx} - 2y\frac{dy}{dx} = 2x - 2y - 4$ $\frac{dy}{dx} = \frac{2x - 2y - 4}{1 + 2x - 2y}$	**A1**	**AG** Must be convincingly shown
		3	

Q	Answer	Marks	Comments
10(b)	$\left[\frac{dy}{dx} = 0\right]\ 2x - 2y = 4$	**B1**	Oe
	$x - y = 2$ $4x + y = 2^2$	**M1**	Substitution into original equation
	$5x = 6$ or $5y = -4$	**m1**	Equation in one variable
	$x = 1.2, \quad y = -0.8$ $(1.2, -0.8)$	**A1**	Both correct
		4	

Q	Answer	Marks	Comments
10(c)	$\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{2x-2y-4}{1+2x-2y}\right)=$ $\frac{(1+2x-2y)\left(2-2\frac{\mathrm{d}y}{\mathrm{d}x}\right)-(2x-2y-4)\left(2-2\frac{\mathrm{d}y}{\mathrm{d}x}\right)}{(1+2x-2y)^2}$ $=\frac{(1+2x-2y-2x+2y+4)\left(2-2\frac{\mathrm{d}y}{\mathrm{d}x}\right)}{(1+2x-2y)^2}$ At $(1.2, -0.8)$: $\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{2x-2y-4}{1+2x-2y}\right)=\frac{10\left(1-\frac{\mathrm{d}y}{\mathrm{d}x}\right)}{(1+2.4+1.6)^2}=0.4>0$ As >0, point is a minimum	**M1** **A1** **m1** **A1** **E1**	Attempt to differentiate, condone one error All correct Attempt to evaluate Must see 10 as numerator and denominator as positive Must have been awarded the previous four marks
		5	

Q	Answer	Marks	Comments
10(c) ALT	$\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{2x-2y-4}{1+2x-2y}\right)=\frac{\mathrm{d}}{\mathrm{d}x}\left(1-\frac{5}{1+2x-2y}\right)$ $=5(1+2x-2y)^{-2}\left(2-2\frac{\mathrm{d}y}{\mathrm{d}x}\right)$ $=\frac{10\left(1-\frac{\mathrm{d}y}{\mathrm{d}x}\right)}{(1+2x-2y)^2}$ At $(1.2, -0.8)$: $\frac{\mathrm{d}}{\mathrm{d}x}\left(\frac{2x-2y-4}{1+2x-2y}\right)=\frac{10\left(1-\frac{\mathrm{d}y}{\mathrm{d}x}\right)}{(1+2.4+1.6)^2}=0.4>0$ As >0, point is a minimum	**M1** **A1** **m1** **A1** **E1**	Attempt to differentiate, condone one error All correct Attempt to evaluate Must see 10 as numerator and denominator as positive Must have been awarded the previous four marks
		5	

	Question 10 Total	**12**	

Q	Answer	Marks	Comments
11(a)	$\frac{\mathrm{d}x}{\mathrm{d}t}=\frac{(t-1)2p-2pt}{(t-1)^2}$ $\frac{\mathrm{d}y}{\mathrm{d}t}=\frac{(t-1)2pt-pt^2}{(t-1)^2}$ $\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{(t-1)2pt-pt^2}{(t-1)2p-2pt}$	**M1** **A1** **A1**	Either correct Both correct **ACF** eg $\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{1}{2}t(2-t)$
		3	

Q	Answer	Marks	Comments
11(b)	$t=3$ $\frac{\mathrm{d}y}{\mathrm{d}x}=-\frac{3}{2}$ $x=3p,\quad y=\frac{9p}{2}$ $y-\frac{9p}{2}=-\frac{3}{2}(x-3p)$ $2y-9p=-3x+9p$ $3x+2y-18p=0$	**B1** **B1** **M1** **A1**	Both correct Correct subst *their* values into a tangent equation
		4	

Q	Answer	Marks	Comments
11(c)	$x = \dfrac{2pt}{t-1}$ $(t-1)x = 2pt$	**M1**	Attempt to isolate t
	$t = \dfrac{x}{x-2p}$	**A1**	
	$y = \dfrac{pt^2}{t-1} \quad y = p\left(\dfrac{x}{x-2p}\right)^2\left(\dfrac{x-2p}{2p}\right)$	**m1**	Attempt to eliminate t
	$y = \dfrac{1}{2}\left(\dfrac{x^2}{x-2p}\right)$	**A1**	**ACF** for $\mathrm{f}(x)$
		4	

Q	Answer	Marks	Comments
11(c) ALT	$x = \dfrac{2pt}{t-1}$ $y = \dfrac{1}{2}xt$	**M1**	
	$t = \dfrac{2y}{x}$	**A1**	
	$x = \dfrac{2p\dfrac{2y}{x}}{\dfrac{2y}{x}-1} = \dfrac{4py}{2y-x}$ $2yx - x^2 = 4py$ $y(2x-4p) = x^2$	**m1**	
	$y = \dfrac{1}{2}\left(\dfrac{x^2}{x-2p}\right)$	**A1**	
		4	

	Question 11 Total	**11**	

Q	Answer	Marks	Comments
12(a)	$\frac{dy}{dx} = \frac{(5x+3)\times 5 - 5x\times 5}{(5x+3)^2}$ $= \frac{15}{(5x+3)^2}$	M1 A1	Clear use of quotient rule All correct
		2	

Q	Answer	Marks	Comments
12(b)(i)	$\frac{dy}{dx} = \ln(5x+3) + x\times\frac{5}{(5x+3)}$	M1 M1 A1	Correct differentiation of ln Correct use of product rule All correct **ACF**
		3	

Q	Answer	Marks	Comments
12(b)(ii)	$x=1, \left[\frac{dy}{dx}=\right] \ln(8)+\frac{5}{8}=\frac{5+8\ln 8}{8}$	M1	Correctly finding their gradient
	Grad normal = $-\frac{8}{(5+8\ln 8)}$	M1	Correctly finding their grad normal
	$x=1, y=\ln 8,$ Equ normal $y-\ln 8 = -\frac{8}{(5+8\ln 8)}(x-1)$	A1	All correct **ACF**
		3	

Q	Answer	Marks	Comments
12(c)(i)	$u = 5x+3,\ \mathrm{d}u = 5\mathrm{d}x$	B1	oe
	$\int \frac{5x}{5x+3}\mathrm{d}x = \int \frac{u-3}{u}\frac{\mathrm{d}u}{5}$	M1	all in terms of u and $\mathrm{d}u$
	$= \frac{1}{5}\int\left(1-\frac{3}{u}\right)\mathrm{d}u$		
	$= \frac{1}{5}u - \frac{3}{5}\ln u$	A1	or $\frac{1}{5}u - \frac{3}{5}\ln 5u$
	$= \frac{1}{5}(5x+3) - \frac{3}{5}\ln(5x+3)\ \ [+c]$	A1	ACF
		4	

Q	Answer	Marks	Comments
12(c)(ii)	$\int \ln(5x+3)\,\mathrm{d}x$		
	$u = \ln(5x+3),\ \mathrm{d}v = 1$	M1	Attempt at parts
	$\mathrm{d}u = \frac{5}{5x+3},\ v = x$	A1	All correct
	$\int \ln(5x+3)\,\mathrm{d}x = x\ln(5x+3) - \int \frac{5x}{5x+3}\mathrm{d}x$	m1	Correct subst into parts formula
	$= x\ln(5x+3) - \frac{1}{5}(5x+3) + \frac{3}{5}\ln(5x+3) + c$	A1	ACF – including $+c$
		4	

	Question 12 Total	**16**	

Q	Answer	Marks	Comments
13	$(1+\sin^2 x)\dfrac{dy}{dx} = e^{-0.5y}\sin 2x$		
	$\int \dfrac{1}{e^{-0.5y}}dy = \int \dfrac{\sin 2x}{(1+\sin^2 x)}dx$	**M1**	Separate variables **oe** must use double angle
	$\int e^{0.5y}dy = \int \dfrac{2\sin x\cos x}{(1+\sin^2 x)}dx$	**A1**	eg $\left[\int e^{0.5y}dy = \right] \int \dfrac{2\sin 2x}{(3-\cos 2x)}dx$
	$2e^{0.5y} = \ln(1+\sin^2 x) + c$	**m1** **A1**	$p\,e^{0.5y} = q\ln(1+\sin^2 x)\,[+c]$ **oe** All correct, condone omission of $+c$
	$(0, 4)\ \ 2e^2 = \ln(1) + c$	**M1**	Attempt to find c, must have been awarded **M1m1**
	$c = 2e^2$	**A1**	
	$2e^{0.5y} = \ln(1+\sin^2 x) + 2e^2$		
	$x = \dfrac{\pi}{4}$		
	$2e^{0.5y} = \ln\left(1+\dfrac{1}{2}\right) + 2e^2$		
	$e^{0.5y} = \dfrac{1}{2}\ln\left(\dfrac{3}{2}\right) + e^2$		
	$0.5y = \ln\left(\dfrac{1}{2}\ln\left(\dfrac{3}{2}\right) + e^2\right)$	**M1**	Correct subst and attempt to isolate y from $ae^{0.5y} = p\ln q + c$
	$y = 2\ln\left(\dfrac{1}{2}\ln\left(\dfrac{3}{2}\right) + e^2\right)$	**A1**	**ACF**
		8	

	Question 13 Total	**8**	

Q	Answer	Marks	Comments
14(a)(i)	$y = \dfrac{1}{\cos x}$ $\dfrac{\mathrm{d}y}{\mathrm{d}x} = \dfrac{[\cos x \times 0] - 1(-\sin x)}{\cos^2 x} = \dfrac{\sin x}{\cos^2 x}$ $= \sec x \tan x$	**M1** **A1**	Must be quotient rule **AG** Must be convincingly shown
		2	

Q	Answer	Marks	Comments
14(a)(ii)	$y = \ln(\sec x + \tan x)$ $\dfrac{\mathrm{d}y}{\mathrm{d}x} = \dfrac{\sec x \tan x + \sec^2 x}{(\sec x + \tan x)}$ $= \dfrac{\sec x(\tan x + \sec x)}{(\sec x + \tan x)} = \sec x$	**M1** **A1**	 **AG** Must be convincingly shown
		2	

Q	Answer	Marks	Comments
14(b)	$[\text{Vol} =]\ \pi\int_0^{\frac{\pi}{6}} (\tan x + 2\sin x)^2\ \mathrm{d}x$	**B1**	Correct volume statement **PI**
	$(\tan x + 2\sin x)^2 = \tan^2 x + 4\sin x \tan x + 4\sin^2 x$	**B1**	Correct expansion **oe**
	$[V = \pi]\int \tan^2 x + 4\sin^2 x \sec x + 4\sin^2 x\ \mathrm{d}x$ $= [\pi]\int \left(\sec^2 x - 1\right) + \frac{4\left(1-\cos^2 x\right)}{\cos x} + 2(1-\cos 2x)\ \mathrm{d}x$ $= [\pi]\int \sec^2 x + 1 + 4\sec x - 4\cos x - 2\cos 2x\,\mathrm{d}x$	**M1**	Correct use of three trig identities
	$= [\pi]\left[\left(\tan x + x + 4\ln(\sec x + \tan x) - 4\sin x - \sin 2x\right)\right]_0^{\frac{\pi}{6}}$	**m1**	Correct form of integration
	$= [\pi]\left(\frac{1}{\sqrt{3}} + \frac{\pi}{6} + 4\ln\left(\frac{2}{\sqrt{3}} + \frac{1}{\sqrt{3}}\right) - 2 - \frac{\sqrt{3}}{2}\right) - 0$	**m1**	Correct subst of limits into their expression (must have been awarded M1m1)
	$= \frac{\pi}{6}\left(\pi - 12 - \sqrt{3} + 12\ln 3\right)$	**A1**	
		6	

	Question 14 Total	**10**	