
MATHEMATICS

9709/21

Paper 2

October/November 2019

MARK SCHEME

Maximum Mark: 50

Published

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- A** Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).
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Question	Answer	Marks	Guidance
1(i)	State or imply non-modular inequality $(2x - 7)^2 < (2x - 9)^2$ or corresponding equation or linear equation (with signs of $2x$ different)	M1	
	Obtain critical value 4	A1	
	State $x < 4$ only	A1	
		3	
1(ii)	Attempt to find n from $\ln n = \text{their critical value from part (i)}$	M1	
	Obtain or imply $n < e^4$ and hence 54	A1	
		2	

Question	Answer	Marks	Guidance
2	Expand integrand to obtain $4e^{4x} - 4e^{2x} + 1$	B1	
	Integrate to obtain at least two terms of form $k_1e^{4x} + k_2e^{2x} + k_3x$	*M1	
	Obtain correct $e^{4x} - 2e^{2x} + x$	A1	
	Apply both limits correctly to their integral	DM1	
	Obtain $e^8 - 3e^4 + 2e^2 + 1$	A1	
		5	

Question	Answer	Marks	Guidance
3	Use quotient rule (or product rule) to find first derivative	*M1	Must have correct u and v
	Obtain $-\frac{1}{x(1+\ln x)^2}$ or (unsimplified) equivalent	A1	
	Use $y = 4$ to obtain $\ln x = -\frac{1}{2}$ or exact equivalent for x	B1	
	Substitute for x in their first derivative	DM1	
	Obtain $-4e^{\frac{1}{2}}$ or exact equivalent	A1	Must be simplified to contain a single exponential term
		5	

Question	Answer	Marks	Guidance
4(i)	Substitute $x = 2$, equate to zero and attempt solution	M1	
	Obtain $a = 4$	A1	
		2	
4(ii)	Divide by $x - 2$ at least as far as the x term	M1	By inspection or use of identity
	Obtain $4x^2 + 12x + 9$	A1	
	Conclude $(x - 2)(2x + 3)^2$	A1	Each factor must be simplified to integer form
		3	

Question	Answer	Marks	Guidance
4(iii)	Attempt correct process to solve $e^{\sqrt{y}} = k$ where $k > 0$	M1	For $y = (\ln k)^2$
	Obtain 0.48 and no others	A1	AWRT
		2	

Question	Answer	Marks	Guidance
5(i)	Integrate to obtain form $x^3 + k_1 \sin 2x + k_2 \cos x$	*M1	
	Obtain correct $x^3 + 2 \sin 2x + \cos x$	A1	
	Apply limits correctly and equate to 2	DM1	
	Confirm given result	A1	AG; necessary detail needed
		4	
5(ii)	Consider sign of $a - \sqrt[3]{3 - 2 \sin 2a - \cos a}$ or equivalent for 0.5 and 0.75	M1	
	Obtain -0.26 and 0.10 or equivalents and justify conclusion	A1	AG; necessary detail needed
		2	

Question	Answer	Marks	Guidance
5(iii)	Use iterative process correctly at least once	M1	Need to see a correct x_3 , may be implied by $x_1 = 0.5$ so $x_3 = 0.65256$ or $x_1 = 0.75$ so $x_3 = 0.64897$ OE Must be working with radians
	Obtain final answer 0.651	A1	
	Show sufficient iterations to 5sf to justify answer or show a sign change in the interval [0.6505, 0.6515]	A1	
		3	

Question	Answer	Marks	Guidance
6(a)	Express equation as $\frac{1}{\cos \alpha \sin \alpha} = 7$	B1	OE; May be implied by subsequent work
	Attempt use of identity for $\sin 2\alpha$ or attempt to obtain a quadratic equation in terms of any one of the following: $\sin^2 \alpha$, $\cos^2 \alpha$, $\cot^2 \alpha$ or $\tan^2 \alpha$	M1	From equation of form $\sin 2\alpha = k$ where $0 < k < 1$ or from use of correct identities
	Obtain $\sin 2\alpha = \frac{2}{7}$ or a correct 3 term quadratic equation, equated to zero in any one of the following: $\sin^2 \alpha$, $\cos^2 \alpha$, $\cot^2 \alpha$ or $\tan^2 \alpha$	A1	
	Attempt correct process to find at least one correct value of α	M1	
	Obtain 8.3 and 81.7 and no others between 0 and 90	A1	
		5	

Question	Answer	Marks	Guidance
6(b)	Simplify left-hand side to obtain $2\sin\beta\cos 20^\circ$	B1	
	Attempt to form equation where $\tan\beta$ is only variable, $\tan\beta \neq 3$	M1	
	Obtain $\tan\beta = \frac{3}{\cos 20^\circ}$	A1	OE
	Obtain $\beta = 72.6$ and no others between 0 and 90	A1	
		5	

Question	Answer	Marks	Guidance
7(i)	Obtain $-4y - 4x\frac{dy}{dx}$ from use of the product rule	B1	
	Differentiate $-2y^2$ to obtain $-4y\frac{dy}{dx}$	B1	
	Obtain $2x, = 0$ with no extra terms	B1	
	Rearrange to obtain expression for $\frac{dy}{dx}$ and substitute $x = -1, y = 2$	M1	
	Obtain $\frac{dy}{dx} = \frac{2x-4y}{4x+4y}$ OE and hence $-\frac{5}{2}$	A1	
		5	

Question	Answer	Marks	Guidance
7(ii)	Equate numerator of derivative to zero to produce equation in x and y	M1	
	Substitute into equation of curve to produce equation in x or y	M1	
	Obtain $-6y^2 = 1$ or $-\frac{3}{2}x^2 = 1$ OE and conclude	A1	
		3	
7(iii)	Use denominator of derivative equated to zero with equation of curve to produce equation in x	M1	
	Obtain $3x^2 = 1$ and hence $x = \pm \frac{1}{\sqrt{3}}$	A1	OE
		2	

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1	Divide at least as far as the x term in the quotient	M1	Allow use of $(x^2 + 2)(x^2 + ax + b) + cx + d$
	Obtain at least $x^2 - 3x$	A1	
	Obtain $x^2 - 3x + 3$ and remainder 5	A1	
		3	

Question	Answer	Marks	Guidance
2(i)	State or imply non-modular equation $(4x + 5)^2 = (x - 7)^2$ or pair of different linear equations	B1	
	Attempt solution of 3-term quadratic equation or pair of linear equations	M1	
	Obtain $\frac{2}{5}$ and -4	A1	SC For $x = -4$ only, from correct work, allow B1
		3	
2(ii)	Apply logarithms and use power law for $2^y = k$ where $k > 0$ from (i)	M1	
	Obtain -1.32 only	A1	AWRT
		2	

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Question	Answer	Marks	Guidance
3	$\ln y = \ln k + a \ln x$	B1	SOI
	Equate gradient of line to a	M1	
	Obtain $a = -1.39$	A1	OE
	Substitute appropriate values into a correct equation to find $\ln k$	M1	
	Obtain $\ln k = 4.266\dots$ and $k = 71.2$	A1	SC1 for gradient = -1.39 and no other relevant working
	Alternative method for question 3		
	$\ln y = \ln k + a \ln x$	B1	SOI
	$3.96 = \ln k + 0.22a$	M1	For one correct equation
	$2.43 = \ln k + 1.32a$	M1	For a second correct equation and attempt to solve to find one unknown
	Obtain $a = -1.39$	A1	OE
	Obtain $\ln k = 4.266\dots$ and $k = 71.2$	A1	SC1 for gradient = -1.39 and no other relevant working
	Alternative method for question 3		
	$e^{3.96} = k \times 0.22^a$ and $e^{2.43} = k \times 1.32^a$	B1	
	Apply a correct method to obtain a	M1	
	Obtain $a = -1.39$	A1	OE
	Substitute appropriate values into a correct equation to find k	M1	
	Obtain $k = 71.2$	A1	AWRT
		5	

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Question	Answer	Marks	Guidance
4(i)	Use iteration correctly at least once	M1	Must see correct attempt at x_3
	Obtain final answer 1.359	A1	
	Show sufficient iterations to 6 sf to justify answer or show sign change in interval [1.3585, 1.3595]	A1	Answer required to exactly 4 sf Must see to at least x_5
		3	
4(ii)	Form correct equation in x (or α)	B1	$x = \frac{x}{\ln 2x}$ OE
	Obtain $\frac{1}{2}e$	B1	
		2	

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Question	Answer	Marks	Guidance
5	Differentiate using the product rule	*M1	Must have u and v correct in a correct formula with $\frac{du}{dx} = 2$ and $\frac{dv}{dx} = me^{-\frac{1}{2}x}$
	Obtain correct $2e^{-\frac{1}{2}x} - \frac{1}{2}e^{-\frac{1}{2}x}(2x+5)$	A1	OE
	Equate first derivative to zero and solve for x	DM1	Solution must come from linear terms
	Obtain $x = -\frac{1}{2}$ only	A1	
	Obtain $4e^{\frac{1}{2}}$ or exact equivalent only	A1	
		5	

Question	Answer	Marks	Guidance
6(a)	Obtain $\frac{3}{2} \ln x$ or $\frac{3}{2} \ln(2x)$ or $\frac{3}{2} \ln(kx)$	B1	
	Use subtraction law of logarithms correctly, showing sufficient detail	M1	$\ln 216 - \ln 8 = \ln\left(\frac{216}{8}\right)$
	Use power law of logarithms correctly	M1	$n \ln(kx) = \ln(kx)^n$
	Confirm $\ln 27$ with sufficient working and no incorrect working	A1	AG
		4	
6(b)	Use appropriate identity to express integrand in form $k_1 + k_2 \cos 3x$	*M1	$k_1 \neq 0$. Allow $2 \times \frac{3}{2}x$ for $3x$
	Obtain correct $2 - 2 \cos 3x$	A1	
	Integrate to obtain form $k_3 x + k_4 \sin 3x$	DM1	
	Obtain correct $2x - \frac{2}{3} \sin 3x$	A1	
	Use limits to obtain $\frac{1}{3}\pi - \frac{2}{3}$ or exact equivalent	A1	
		5	

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Question	Answer	Marks	Guidance
7(i)	Obtain $\frac{dx}{d\theta} = 6\cos 2\theta$	B1	
	Obtain $\frac{dy}{d\theta} = 4\sec^2 2\theta$	B1	
	Divide $\frac{dy}{d\theta}$ by $\frac{dx}{d\theta}$ with θ equated to $\frac{1}{6}\pi$	M1	
	Obtain $\frac{16}{3}$ or exact equivalent	A1	Allow FT on A1 if $\frac{dx}{d\theta} = 3\cos 2\theta$ and $\frac{dy}{d\theta} = 2\sec^2 2\theta$
		4	
7(ii)	Equate expression for $\frac{dy}{dx}$ to 2 with only one trigonometry ratio used	*M1	Either $\cos 2\theta$ or $\sec 2\theta$
	Obtain $\cos^3 2\theta = \frac{1}{3}$ or $\sec^3 = 3$	A1	
	Attempt correct steps to find a value of θ from $\cos^3 2\theta = m$, $0 < m < 1$	DM1	
	Obtain $\theta = 0.402$ and no others within the range	A1	AWRT SC: Allow FT if $\frac{dx}{d\theta} = 3\cos 2\theta$ and $\frac{dy}{d\theta} = 2\sec^2 2\theta$
		4	

Question	Answer	Marks	Guidance
8(i)	State $R = 1.3$ or $\frac{10}{3}$	B1	Not $\sqrt{1.69}$
	Use appropriate trigonometry to find α	M1	AWRT ± 1.18 rads, AWRT ± 0.391 rads, AWRT $\pm 67.4^\circ$, AWRT $\pm 22.6^\circ$
	Obtain 67.38 with no errors seen	A1	AWRT
		3	
8(ii)	Carry out correct method to find one value of θ between 0 and 360	M1	
	Obtain 240.6 (or 344.6)	A1	
	Carry out correct method to find second value of θ between 0 and 360	M1	Must be using either degrees throughout or radians throughout for M marks
	Obtain 344.6 (or 240.6)	A1	
		4	
8(iii)	Recognise expression as $[3 - 2R \cos(\theta + \alpha)]^2$	M1	
	Obtain $[3 - 2 \times (-1.3)]^2$ and hence 31.36 or 31.4	A1	
	Obtain $[3 - 2 \times 1.3]^2$ and hence 0.16	A1	
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	Obtain or imply $n < e^4$ and hence 54	A1	
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	Integrate to obtain at least two terms of form $k_1e^{4x} + k_2e^{2x} + k_3x$	*M1	
	Obtain correct $e^{4x} - 2e^{2x} + x$	A1	
	Apply both limits correctly to their integral	DM1	
	Obtain $e^8 - 3e^4 + 2e^2 + 1$	A1	
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Question	Answer	Marks	Guidance
3	Use quotient rule (or product rule) to find first derivative	*M1	Must have correct u and v
	Obtain $-\frac{1}{x(1+\ln x)^2}$ or (unsimplified) equivalent	A1	
	Use $y = 4$ to obtain $\ln x = -\frac{1}{2}$ or exact equivalent for x	B1	
	Substitute for x in their first derivative	DM1	
	Obtain $-4e^{\frac{1}{2}}$ or exact equivalent	A1	Must be simplified to contain a single exponential term
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	Obtain $a = 4$	A1	
		2	
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	Obtain $4x^2 + 12x + 9$	A1	
	Conclude $(x - 2)(2x + 3)^2$	A1	Each factor must be simplified to integer form
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4(iii)	Attempt correct process to solve $e^{\sqrt{y}} = k$ where $k > 0$	M1	For $y = (\ln k)^2$
	Obtain 0.48 and no others	A1	AWRT
		2	

Question	Answer	Marks	Guidance
5(i)	Integrate to obtain form $x^3 + k_1 \sin 2x + k_2 \cos x$	*M1	
	Obtain correct $x^3 + 2 \sin 2x + \cos x$	A1	
	Apply limits correctly and equate to 2	DM1	
	Confirm given result	A1	AG; necessary detail needed
		4	
5(ii)	Consider sign of $a - \sqrt[3]{3 - 2 \sin 2a - \cos a}$ or equivalent for 0.5 and 0.75	M1	
	Obtain -0.26 and 0.10 or equivalents and justify conclusion	A1	AG; necessary detail needed
		2	

Question	Answer	Marks	Guidance
5(iii)	Use iterative process correctly at least once	M1	Need to see a correct x_3 , may be implied by $x_1 = 0.5$ so $x_3 = 0.65256$ or $x_1 = 0.75$ so $x_3 = 0.64897$ OE Must be working with radians
	Obtain final answer 0.651	A1	
	Show sufficient iterations to 5sf to justify answer or show a sign change in the interval [0.6505, 0.6515]	A1	
		3	

Question	Answer	Marks	Guidance
6(a)	Express equation as $\frac{1}{\cos \alpha \sin \alpha} = 7$	B1	OE; May be implied by subsequent work
	Attempt use of identity for $\sin 2\alpha$ or attempt to obtain a quadratic equation in terms of any one of the following: $\sin^2 \alpha$, $\cos^2 \alpha$, $\cot^2 \alpha$ or $\tan^2 \alpha$	M1	From equation of form $\sin 2\alpha = k$ where $0 < k < 1$ or from use of correct identities
	Obtain $\sin 2\alpha = \frac{2}{7}$ or a correct 3 term quadratic equation, equated to zero in any one of the following: $\sin^2 \alpha$, $\cos^2 \alpha$, $\cot^2 \alpha$ or $\tan^2 \alpha$	A1	
	Attempt correct process to find at least one correct value of α	M1	
	Obtain 8.3 and 81.7 and no others between 0 and 90	A1	
		5	

Question	Answer	Marks	Guidance
6(b)	Simplify left-hand side to obtain $2\sin\beta\cos 20^\circ$	B1	
	Attempt to form equation where $\tan\beta$ is only variable, $\tan\beta \neq 3$	M1	
	Obtain $\tan\beta = \frac{3}{\cos 20^\circ}$	A1	OE
	Obtain $\beta = 72.6$ and no others between 0 and 90	A1	
		5	

Question	Answer	Marks	Guidance
7(i)	Obtain $-4y - 4x\frac{dy}{dx}$ from use of the product rule	B1	
	Differentiate $-2y^2$ to obtain $-4y\frac{dy}{dx}$	B1	
	Obtain $2x, = 0$ with no extra terms	B1	
	Rearrange to obtain expression for $\frac{dy}{dx}$ and substitute $x = -1, y = 2$	M1	
	Obtain $\frac{dy}{dx} = \frac{2x-4y}{4x+4y}$ OE and hence $-\frac{5}{2}$	A1	
		5	

Question	Answer	Marks	Guidance
7(ii)	Equate numerator of derivative to zero to produce equation in x and y	M1	
	Substitute into equation of curve to produce equation in x or y	M1	
	Obtain $-6y^2 = 1$ or $-\frac{3}{2}x^2 = 1$ OE and conclude	A1	
		3	
7(iii)	Use denominator of derivative equated to zero with equation of curve to produce equation in x	M1	
	Obtain $3x^2 = 1$ and hence $x = \pm \frac{1}{\sqrt{3}}$	A1	OE
		2	