
MATHEMATICS

9709/21

Paper 2

October/November 2018

MARK SCHEME

Maximum Mark: 50

Published

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GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

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- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

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- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
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GENERIC MARKING PRINCIPLE 6:

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Mark Scheme Notes

Marks are of the following three types:

- M Method mark, awarded for a valid method applied to the problem. Method marks are not lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.
 - 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).
 - B Mark for a correct result or statement independent of method marks.
- When a part of a question has two or more “method” steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly when there are several B marks allocated. The notation DM or DB (or dep*) is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.
 - The symbol FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only. A and B marks are not given for fortuitously “correct” answers or results obtained from incorrect working.
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CAO Correct Answer Only (emphasising that no “follow through” from a previous error is allowed)

CWO Correct Working Only – often written by a ‘fortuitous’ answer

ISW Ignore Subsequent Working

SOI Seen or implied

SR Special Ruling (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)

Penalties

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PA –1 This is deducted from A or B marks in the case of premature approximation. The PA –1 penalty is usually discussed at the meeting.

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Question	Answer	Marks	Guidance
1(i)	State or imply non-modular equation $(9x - 2)^2 = (3x + 2)^2$ or pair of linear equations	B1	
	Attempt solution of quadratic equation or of 2 linear equations	M1	
	Obtain 0 and $\frac{2}{3}$	A1	SC: B1 for one correct solution
		3	
1(ii)	Apply logarithms and use power law for $3^y = k$ where $k > 0$	M1	Must be using their answers to part (i)
	Obtain -0.369	A1	
		2	

Question	Answer	Marks	Guidance
2	Integrate to obtain form $k \ln(2x + 1)$	M1	
	Obtain correct $3 \ln(2x + 1)$	A1	
	Use subtraction law of logarithms correctly	M1	Dependent on first M1
	Use power law of logarithms correctly	M1	Dependent on first M1
	Confirm $\ln 125$	A1	
		5	

Question	Answer	Marks	Guidance
3	State $\frac{1}{\cos^2 \theta} = \frac{3}{\sin \theta}$ or $1 + \tan^2 \theta = \frac{3}{\sin \theta}$	B1	
	Produce quadratic equation in $\sin \theta$	M1	Dependent on B1
	Solve 3-term quadratic equation to find value between -1 and 1 for $\sin \theta$	M1	Dependent on first M1
	Obtain $\sin \theta = \frac{1}{6}(-1 + \sqrt{37})$ and hence 57.9	A1	
	Obtain 122.1 and no others between 0 and 180	A1	
		5	

Question	Answer	Marks	Guidance
4(i)	Substitute -2 and simplify	M1	
	Obtain $16 - 16 + 8 + 24 - 32$ and hence zero and conclude	A1	AG; necessary detail needed
		2	
4(ii)	Attempt division by $x + 2$ to reach at least partial quotient $x^3 + kx$ or use of identity or inspection	M1	
	Obtain $x^3 + 2x - 16$	A1	
	Equate to zero and obtain $x = \sqrt[3]{16 - 2x}$	A1	
		3	

Question	Answer	Marks	Guidance
4(iii)	Use iteration process correctly at least once	M1	
	Obtain final answer 2.256	A1	
	Show sufficient iterations to 6 sf to justify answer or show a sign change in the interval (2.2555, 2.2565)	A1	
		3	

Question	Answer	Marks	Guidance
5(i)	Use product rule to differentiate y obtaining $k_1e^{2t} + k_2te^{2t}$	M1	
	Obtain correct $3e^{2t} + 6te^{2t}$	A1	
	State derivative of x is $1 + \frac{1}{t+1}$	B1	
	Use $\frac{dy}{dx} = \frac{dy}{dt} / \frac{dx}{dt}$ with $t = 0$ to find gradient	M1	
	Obtain $y = \frac{3}{2}x$ or equivalent	A1	
		5	

Question	Answer	Marks	Guidance
5(ii)	Equate $\frac{dy}{dx}$ or $\frac{dy}{dt}$ to zero and solve for t	M1	Allow full marks if correct solution is obtained but $\frac{dx}{dt}$ is incorrect
	Obtain $t = -\frac{1}{2}$	A1	
	Obtain $x = -1.19$	A1	
	Obtain $y = -0.55$	A1	
		4	

Question	Answer	Marks	Guidance
6(i)	Use y values 2, $\sqrt{2.5}$, 1 or equivalents	B1	
	Use correct formula, or equivalent, with $h = \frac{1}{2}\pi$ and three y values	M1	
	Obtain $\frac{1}{2} \times \frac{1}{2} \pi (2 + 2\sqrt{2.5} + 1)$ or equivalent and hence 4.84	A1	
		3	

Question	Answer	Marks	Guidance
6(ii)	State or imply volume is $\int \pi(1 + 3\cos^2 \frac{1}{2}x) dx$	B1	Allow if π appears later; condone omission of dx
	Use appropriate identity to express integrand in form $k_1 + k_2 \cos x$	M1	
	Obtain $\int \pi(\frac{5}{2} + \frac{3}{2}\cos x) dx$ or $\int (\frac{5}{2} + \frac{3}{2}\cos x) dx$	A1	Condone omission of dx
	Integrate to obtain $\pi(\frac{5}{2}x + \frac{3}{2}\sin x)$ or $\frac{5}{2}x + \frac{3}{2}\sin x$	A1	
	Obtain $\frac{5}{2}\pi^2$ with no errors seen	A1	
		5	

Question	Answer	Marks	Guidance
7(i)	State expression of form $k_1 \cos 2x + k_2 \sin 2x$	M1	
	State correct $2 \cos 2x - 6 \sin 2x$	A1	
		2	

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Question	Answer	Marks	Guidance
7(ii)	State $R = \sqrt{40}$ or 6.324...	B1 FT	Following their derivative
	Use appropriate trigonometry to find α	M1	
	Obtain 1.249...	A1	Allow α in degrees at this point
	Equate their $R \cos(2x + \alpha)$ to 3 and find $\cos^{-1}(3 \div R)$	*M1	
	Carry out correct process to find one value of α	M1	Dependent on *M1, allow for -0.086....
	Obtain 1.979	A1	
	Carry out correct process to find second value of α within the range	M1	Dependent on *M1
	Obtain 3.055	A1	Allow 3.056
		8	

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1	<u>Either</u>		
	State or imply non-modular inequality $(3x-5)^2 < 4x^2$ or corresponding equation or pair of linear equations	B1	SC: Common error $(3x-5)^2 < 2x^2$
	Attempt solution of 3-term quadratic equation or solution of 2 linear equations	M1	
	Obtain critical values 1 and 5	A1	Critical values $\frac{15 \pm 5\sqrt{2}}{7}$ or 3.15, 1.13 allow B1
	State correct answer $1 < x < 5$	A1	$\frac{15-5\sqrt{2}}{7} < x < \frac{15+5\sqrt{2}}{7}$ or $1.13 < x < 3.15$ B1 Max 2/4 Allow M1 for $(7x \pm 5)(x \pm 5)$
	<u>Or</u>		
	Obtain $x = 5$ by solving linear equation or inequality or from graphical method or inspection	B1	Allow B1 for 5 seen, maybe in an inequality
	Obtain $x = 1$ similarly	B2	Allow B2 for 1 seen, maybe in an inequality
	State correct answer $1 < x < 5$	B1	
		4	

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Question	Answer	Marks	Guidance
2	Recognise 9^x as $(3^x)^2$ or 3^{2x}	B1	May be implied by $3^x(3^x + 1)(= 240)$
	Attempt solution of quadratic equation in 3^x	*M1	Perhaps using substitution $u = 3^x$
	Obtain, finally, $3^x = 15$ only	A1	
	Apply logarithms and use power law for $3^x = k$ where $k > 0$	M1	Dependent *M, need to see $x \ln 3 = \ln k$, $x = \log_3 k$ oe
	Obtain 2.465	A1	May be done using $9^{\frac{x}{2}}$, same processes
		5	

Question	Answer	Marks	Guidance
3	Differentiate to obtain $10\cos 2x$	B1	
	Differentiate to obtain $-6\sec^2 2x$	B1	
	Equate first derivative to zero and find value for $\cos^3 2x$	M1	
	Use correct process for finding x from $\cos^3 2x = k$	M1	
	Obtain 0.284 nfw	A1	Or greater accuracy
		5	

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Question	Answer	Marks	Guidance
4	Obtain $6ye^{2x} + 3e^{2x} \frac{dy}{dx}$ as derivative of $3ye^{2x}$	B1	Allow unsimplified
	Obtain $2y \frac{dy}{dx}$ as derivative of y^2	B1	
	Obtain 4 as a derivative of $4x$ and zero as a derivative of 10	B1	Dependent B mark, must have at least one of the two previous B marks
	Substitute 0 and 2 to find gradient of curve	M1	Dependent on at least one B1
	Obtain $-\frac{16}{7}$ or -2.29	A1	Allow greater accuracy
		5	

Question	Answer	Marks	Guidance
5(i)	Rearrange at least as far as $2x = \ln(\dots)$	M1	Allow if in terms of p , need to see y equated to 0
	Obtain $x = \frac{1}{2} \ln(1.6x^2 + 4)$	A1	AG; necessary detail needed
		2	

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Question	Answer	Marks	Guidance
5(ii)	<u>Either</u>		
	Consider sign of $x - \frac{1}{2}\ln(1.6x^2 + 4)$ for 0.75 and 0.85 or equivalent	M1	Need to see substitution of numbers
	Obtain –0.04 and 0.03 or equivalents and justify conclusion	A1	AG; necessary detail needed, change of sign or equivalent must be mentioned
	<u>Or</u>		
	Consider sign of $5e^{2x} - 8x^2 - 20$ for 0.75 and 0.85	M1	Need to see substitution of numbers
	Obtain –2.09... and 1.58... or equivalents and justify conclusion	A1	AG; necessary detail needed, change of sign or equivalent must be mentioned
		2	
5(iii)	Use iteration process correctly at least once	M1	Starting with value such that iterations converge to correct values
	Obtain final value 0.80956	A1	Must be 5sf for the final answer
	Show sufficient iterations to justify value or show sign change in interval (0.809555, 0.809565)	A1	
		3	

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Question	Answer	Marks	Guidance
5(iv)	Obtain first derivative $10e^{2x} - 16x$	B1	
	Substitute value from iteration to find gradient, must be in the form $pe^{2x} + qx$	M1	
	Obtain 37.5	A1	Or greater accuracy, allow awrt 37.5 from use of $x = 0.8096, 0.80955$ oe
		3	

Question	Answer	Marks	Guidance
6(a)	Integrate to obtain form $k \ln(3x + 2)$	*M1	Condone poor use of brackets if recovered later
	Obtain correct $4 \ln(3x + 2)$	A1	
	Substitute limits correctly	M1	Dependent *M, must see $k \ln 20 - k \ln 5$ oe
	Apply relevant logarithm properties correctly	M1	Dependent *M, do not allow $\frac{4 \ln 20}{4 \ln 5}$ oe, must be using both the subtraction and power laws correctly
	Obtain $\ln 256$ nfw	A1	AG; necessary detail needed
		5	

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Question	Answer	Marks	Guidance
6(b)	Use identity to obtain $4(1 - \cos 2x)$ oe	B1	
	Use identity to obtain $\sec^2 2x - 1$	B1	
	Integrate to obtain form $k_1x + k_2 \sin 2x + k_3 \tan 2x$	*M1	Allow M1 if integrand contains $p \cos 2x + q \sec^2 2x$ and no other trig terms
	Obtain correct $3x - 2 \sin 2x + \frac{1}{2} \tan 2x$	A1	
	Apply limits correctly retaining exactness	M1	Dependent *M, allow $\sin \frac{\pi}{3}$, $\tan \frac{\pi}{3}$
	Obtain $\frac{1}{2}\pi - \frac{1}{2}\sqrt{3}$ or exact equivalent	A1	
		6	

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Question	Answer	Marks	Guidance
7(i)	Substitute $-\frac{3}{2}$ and simplify	M1	Allow use of identity assuming a factor of $2x + 3$ to obtain a quadratic factor. Need to see use of 4 equations to verify quadratic for M1, A1 for conclusion. Allow verification by expansion. Allow use of identity including a remainder to obtain a quadratic factor and a remainder of zero. Need to see use of 4 equations for M1, A1 for conclusion. Allow verification by expansion. Allow use of long division, must reach a remainder of zero for M1
	Obtain $-27 + 9 + 15 + 3$ or equivalent, hence zero and conclude, may have explanation at start of working	A1	Need powers of $-\frac{3}{2}$ evaluating for A1 AG; necessary detail needed
		2	
7(ii)	Use $\cos 2\theta = 2\cos^2 \theta - 1$	B1	
	Simplify $a\cos^2 \theta + b = \frac{6\cos \theta - 5}{2\cos \theta + 1}$ to polynomial form	M1	
	Obtain $8\cos^3 \theta + 4\cos^2 \theta - 10\cos \theta + 3 = 0$	A1	AG; necessary detail needed, must be completely correct with no poor use of brackets for A1
		3	

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Question	Answer	Marks	Guidance
7(iii)	Attempt either division by $2x + 3$ and reach partial quotient $x^2 + kx$ or use of identity or inspection	*M1	Or equivalent using $\cos \theta$ or c
	Obtain quotient $4x^2 - 4x + 1$	A1	Or equivalent
	Obtain factorised form $(2x + 3)(2x - 1)^2$	A1	Or equivalent, may be implied by later work
	Solve for $\cos \theta = k$ to find at least one value between 0 and 360	M1	Dependent *M
	Obtain 60 and 300 and no others	A1	SC1: Equation solver used to obtain 60 and 300 and no others, then 5/5 SC2: Equation solver used to obtain 60 then 4/5 SC 3: $\cos \theta = 0.5$, ($\cos \theta = -1.5$) seen implies first 3 marks.
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The marks indicated in the scheme may not be subdivided. If there is genuine doubt whether a candidate has earned a mark, allow the candidate the benefit of the doubt. Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored.

- Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.
- For a numerical answer, allow the A or B mark if a value is obtained which is correct to 3 s.f., or which would be correct to 3 s.f. if rounded (1 d.p. in the case of an angle). As stated above, an A or B mark is not given if a correct numerical answer arises fortuitously from incorrect working. For Mechanics questions, allow A or B marks for correct answers which arise from taking g equal to 9.8 or 9.81 instead of 10.

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The following abbreviations may be used in a mark scheme or used on the scripts:

AEF/OE Any Equivalent Form (of answer is equally acceptable) / Or Equivalent

AG Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)

CAO Correct Answer Only (emphasising that no “follow through” from a previous error is allowed)

CWO Correct Working Only – often written by a ‘fortuitous’ answer

ISW Ignore Subsequent Working

SOI Seen or implied

SR Special Ruling (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)

Penalties

MR –1 A penalty of MR –1 is deducted from A or B marks when the data of a question or part question are genuinely misread and the object and difficulty of the question remain unaltered. In this case all A and B marks then become “follow through” marks. MR is not applied when the candidate misreads his own figures – this is regarded as an error in accuracy. An MR –2 penalty may be applied in particular cases if agreed at the coordination meeting.

PA –1 This is deducted from A or B marks in the case of premature approximation. The PA –1 penalty is usually discussed at the meeting.

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Question	Answer	Marks	Guidance
1(i)	State or imply non-modular equation $(9x - 2)^2 = (3x + 2)^2$ or pair of linear equations	B1	
	Attempt solution of quadratic equation or of 2 linear equations	M1	
	Obtain 0 and $\frac{2}{3}$	A1	SC: B1 for one correct solution
		3	
1(ii)	Apply logarithms and use power law for $3^y = k$ where $k > 0$	M1	Must be using their answers to part (i)
	Obtain -0.369	A1	
		2	

Question	Answer	Marks	Guidance
2	Integrate to obtain form $k \ln(2x + 1)$	M1	
	Obtain correct $3 \ln(2x + 1)$	A1	
	Use subtraction law of logarithms correctly	M1	Dependent on first M1
	Use power law of logarithms correctly	M1	Dependent on first M1
	Confirm $\ln 125$	A1	
		5	

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Question	Answer	Marks	Guidance
3	State $\frac{1}{\cos^2 \theta} = \frac{3}{\sin \theta}$ or $1 + \tan^2 \theta = \frac{3}{\sin \theta}$	B1	
	Produce quadratic equation in $\sin \theta$	M1	Dependent on B1
	Solve 3-term quadratic equation to find value between -1 and 1 for $\sin \theta$	M1	Dependent on first M1
	Obtain $\sin \theta = \frac{1}{6}(-1 + \sqrt{37})$ and hence 57.9	A1	
	Obtain 122.1 and no others between 0 and 180	A1	
		5	

Question	Answer	Marks	Guidance
4(i)	Substitute -2 and simplify	M1	
	Obtain $16 - 16 + 8 + 24 - 32$ and hence zero and conclude	A1	AG; necessary detail needed
		2	
4(ii)	Attempt division by $x + 2$ to reach at least partial quotient $x^3 + kx$ or use of identity or inspection	M1	
	Obtain $x^3 + 2x - 16$	A1	
	Equate to zero and obtain $x = \sqrt[3]{16 - 2x}$	A1	
		3	

Question	Answer	Marks	Guidance
4(iii)	Use iteration process correctly at least once	M1	
	Obtain final answer 2.256	A1	
	Show sufficient iterations to 6 sf to justify answer or show a sign change in the interval (2.2555, 2.2565)	A1	
		3	

Question	Answer	Marks	Guidance
5(i)	Use product rule to differentiate y obtaining $k_1e^{2t} + k_2te^{2t}$	M1	
	Obtain correct $3e^{2t} + 6te^{2t}$	A1	
	State derivative of x is $1 + \frac{1}{t+1}$	B1	
	Use $\frac{dy}{dx} = \frac{dy}{dt} / \frac{dx}{dt}$ with $t = 0$ to find gradient	M1	
	Obtain $y = \frac{3}{2}x$ or equivalent	A1	
		5	

Question	Answer	Marks	Guidance
5(ii)	Equate $\frac{dy}{dx}$ or $\frac{dy}{dt}$ to zero and solve for t	M1	Allow full marks if correct solution is obtained but $\frac{dx}{dt}$ is incorrect
	Obtain $t = -\frac{1}{2}$	A1	
	Obtain $x = -1.19$	A1	
	Obtain $y = -0.55$	A1	
		4	

Question	Answer	Marks	Guidance
6(i)	Use y values 2, $\sqrt{2.5}$, 1 or equivalents	B1	
	Use correct formula, or equivalent, with $h = \frac{1}{2}\pi$ and three y values	M1	
	Obtain $\frac{1}{2} \times \frac{1}{2} \pi (2 + 2\sqrt{2.5} + 1)$ or equivalent and hence 4.84	A1	
		3	

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Question	Answer	Marks	Guidance
6(ii)	State or imply volume is $\int \pi(1 + 3\cos^2 \frac{1}{2}x) dx$	B1	Allow if π appears later; condone omission of dx
	Use appropriate identity to express integrand in form $k_1 + k_2 \cos x$	M1	
	Obtain $\int \pi(\frac{5}{2} + \frac{3}{2}\cos x) dx$ or $\int (\frac{5}{2} + \frac{3}{2}\cos x) dx$	A1	Condone omission of dx
	Integrate to obtain $\pi(\frac{5}{2}x + \frac{3}{2}\sin x)$ or $\frac{5}{2}x + \frac{3}{2}\sin x$	A1	
	Obtain $\frac{5}{2}\pi^2$ with no errors seen	A1	
		5	

Question	Answer	Marks	Guidance
7(i)	State expression of form $k_1 \cos 2x + k_2 \sin 2x$	M1	
	State correct $2 \cos 2x - 6 \sin 2x$	A1	
		2	

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Question	Answer	Marks	Guidance
7(ii)	State $R = \sqrt{40}$ or 6.324...	B1 FT	Following their derivative
	Use appropriate trigonometry to find α	M1	
	Obtain 1.249...	A1	Allow α in degrees at this point
	Equate their $R \cos(2x + \alpha)$ to 3 and find $\cos^{-1}(3 \div R)$	*M1	
	Carry out correct process to find one value of α	M1	Dependent on *M1, allow for -0.086....
	Obtain 1.979	A1	
	Carry out correct process to find second value of α within the range	M1	Dependent on *M1
	Obtain 3.055	A1	Allow 3.056
		8	