



Cambridge International AS & A Level

MATHEMATICS

9709/21

Paper 2 Pure Mathematics 2

October/November 2021

MARK SCHEME

Maximum Mark: 50

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- 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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GENERIC MARKING PRINCIPLE 3:

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- marks are awarded when candidates clearly demonstrate what they know and can do
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- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

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Mathematics Specific Marking Principles	
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3	Allow alternative conventions for notation if used consistently throughout the paper, e.g. commas being used as decimal points.
4	Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored (isw).
5	Where a candidate has misread a number in the question and used that value consistently throughout, provided that number does not alter the difficulty or the method required, award all marks earned and deduct just 1 mark for the misread.
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Types of mark

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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).
- B** Mark for a correct result or statement independent of method marks.
- DM or DB** 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 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.
- 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 or B marks are given for correct work only (not for results obtained from incorrect working) unless follow through is allowed (see abbreviation FT above).
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AWRT	Answer Which Rounds To

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Question	Answer	Marks	Guidance
1	Integrate to obtain $2e^{2x}$	B1	
	Integrate to obtain $2e^{-x}$	B1	
	Apply limits correctly to integral of the form $k_1e^{2x} + k_2e^{-x}$	M1	$k_1 \neq 4$. Condone one error.
	Obtain $2e^4 - 2e$	A1	or exact equivalent.
		4	

Question	Answer	Marks	Guidance
2(a)	Draw V-shaped graph with vertex on positive x -axis	B1	Must be straight lines.
	Draw straight line through origin with positive gradient greater than gradient of first graph, together with a V shaped graph	B1	Must have the first B1 .
		2	
2(b)	Solve linear equation with signs of $3x$ and x different or solve non-modulus equation $(3x)^2 = (x - 3)^2$	M1	
	Obtain $x = \frac{3}{4}$	A1	
	Obtain $y = \frac{9}{4}$	A1	And no other point.
		3	
2(c)	State $x < \frac{3}{4}$	B1 FT	Following <i>their</i> (single) x -coordinate from part (b) .
		1	

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Question	Answer	Marks	Guidance
3	State or imply equation is $y \ln a = \ln k + \ln x$	B1	
	Equate gradient of line to $\frac{1}{\ln a}$	M1	Or eliminate $\ln k$ from simultaneous equations.
	Obtain $\frac{1}{\ln a} = \frac{2.64}{1.55}$ or equivalent and hence $a = 1.8$	A1	AWRT
	Substitute appropriate values to find $\ln k$	M1	
	Obtain $\ln k = 2.7...$ and hence $k = 15$	A1	AWRT
	Alternative method for question 3		
	$a^{6.36} = ke^{1.03}$ and $a^9 = ke^{2.58}$	B1	For both.
	Elimination of k to obtain an equation in a only ($a^{2.64} = e^{1.55}$)	M1	Must have previous B1 .
	Use of a correct method to obtain a	M1	Allow for $a = e^{0.59}$.
	$a = 1.8$	A1	
	$k = 15$	A1	
		5	

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Question	Answer	Marks	Guidance
4(a)	Attempt use of product rule to differentiate xe^{2x}	M1	
	Obtain $e^{2x} + 2xe^{2x} - 5e^{-x}$	A1	
	Equate first derivative to zero and multiply by e^x to obtain an equation involving e^{3x}	M1	
	Obtain $e^{3x}(1 + 2x) = 5$ or equivalent	A1	
	Confirm given result $x = \frac{1}{3}\ln 5 - \frac{1}{3}\ln(1 + 2x)$ with sufficient detail	A1	AG
		5	
4(b)	Use iteration process correctly at least once	M1	Need 0.35 and 2 correct values.
	Obtain final answer 0.357	A1	Answer required to exactly 3sf. Allow recovery.
	Show sufficient iterations to 5sf to justify answer or show sign change in interval [0.3565, 0.3575]	A1	
		3	

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Question	Answer	Marks	Guidance
5(a)	Obtain $\frac{dx}{dt} = \frac{2}{2t+3}$	B1	
	Use quotient rule, or equivalent, to find $\frac{dy}{dt}$	M1	
	Obtain $\frac{dy}{dt} = \frac{2(2t+3) - 2(2t-3)}{(2t+3)^2}$	A1	OE
	Divide to confirm $\frac{dy}{dx} = \frac{6}{2t+3}$	A1	AG
		4	
5(b)	Attempt to find value of t corresponding to $x=0$	M1	
	Obtain $t=-1$ and hence gradient is 6	A1	
		2	
5(c)	Attempt to find value of t corresponding to $y=0$	M1	
	Obtain $t=\frac{3}{2}$ and hence gradient is 1	A1	
		2	

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Question	Answer	Marks	Guidance
6(a)	Substitute $x = -3$, equate to zero and attempt solution for a	M1	Allow attempt at synthetic division, must be a complete method. Allow one sign error carried through. Allow attempt at algebraic long division, must be complete with the remainder equated to zero.
	Obtain $a = 13$	A1	
		2	
6(b)	Substitute $x = 2$, equate to 40 and attempt solution for b	M1	
	Obtain $b = 9$	A1	
		2	
6(c)	Identify $x + 3$ as factor of $f(x) - g(x)$	B1	May be implied by synthetic division. If working backwards from solutions from a calculator then B0 M0.
	Attempt, by division or equivalent, to find quadratic factor	M1	$k(x + 3)(2x + 1)(2x - 1)$ where $k \neq 1$ gets B1 M1.
	Obtain $(x + 3)(2x - 1)(2x + 1)$	A1	
		3	
6(d)	Attempt correct process to find at least 1 value from $\operatorname{cosec} \theta = k$ where $k < -1$	M1	Allow for 199.5° or -19.5° .
	Obtain 3.48 or 5.94	A1	
	Obtain a second correct solution	A1	And no others within the range.
		3	

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Question	Answer	Marks	Guidance
7(a)	State $\cos 2\theta \cos \theta - \sin 2\theta \sin \theta$	B1	
	Attempt correct relevant identities to express in terms of $\cos \theta$ only	M1	M0 if moving terms from side to side.
	Confirm $4\cos^3 \theta - 3\cos \theta$ with sufficient detail	A1	AG
		3	
7(b)	Use identity with $\theta = \frac{5}{18}\pi$	M1	
	Obtain $\frac{1}{2}\cos \frac{5}{6}\pi$ and hence $-\frac{1}{4}\sqrt{3}$	A1	
		2	
7(c)	Express integrand in form $k_1(\cos 3x + 3\cos x) + k_2(\cos 9x + 3\cos 3x)$	M1	
	Obtain correct integrand $9\cos x - \cos 9x$	A1	OE (allow unsimplified).
	Integrate to obtain form $k_3 \sin x + k_4 \sin 9x$	M1	
	Obtain correct $9\sin x - \frac{1}{9}\sin 9x$	A1	Now simplified; condone missing $\dots + c$.
		4	



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1(a)	Substitute $x = -2$ and equate to zero	*M1	
	Substitute $x = -3$ and equate to -55	*M1	
	Obtain $-8a - 2b - 10 = 0$ and $-27a - 3b - 10 = -55$	A1	OE
	Solve a pair of relevant simultaneous linear equations to find a or b	DM1	Dependent at least one M1.
	Obtain $a = 4$ and $b = -21$	A1	
		5	
1(b)	Divide by $x + 2$ at least as far as the x term	M1	Or using identity or inspection.
	Obtain $4x^2 - 8x - 5$	A1	
	Conclude $(x + 2)(2x + 1)(2x - 5)$	A1	Condone inclusion of $= 0$.
		3	

Question	Answer	Marks	Guidance
2(a)	Draw V-shaped graph with vertex on positive x -axis	*B1	Must be straight lines.
	Draw (more or less) correct graph of $y = x + 3$ with smaller gradient together with a V shaped graph	DB1	And crossing y -axis above y -intercept of first graph. Intersection in the first quadrant may be implied.
		2	

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Question	Answer	Marks	Guidance
2(b)	Solve $x+3=2x-1$ to obtain $x=4$	B1	
	Attempt solution of linear equation where signs of $2x$ and x are different	M1	
	Obtain $x = -\frac{2}{3}$	A1	
	Alternative method for question 2(b)		
	State or imply non-modulus equation $(x+3)^2 = (2x-1)^2$	B1	
	Attempt solution of 3-term quadratic equation obtained from squaring both terms.	M1	Must have B1.
	Obtain $-\frac{2}{3}$ and 4	A1	
		3	
2(c)	Apply logarithms and use power law for $5^{\frac{1}{2}y} = k$ where $k > 0$	M1	Using <i>their</i> positive root from part (b). Allow M1 for $y = 2 \log_5 4$.
	Obtain $y = 1.72$	A1	AWRT; and no other values.
		2	

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Question	Answer	Marks	Guidance
3	Differentiate to obtain first derivative of form $k_1 + k_2 \sec^2 2x$	M1	Where $k_1 k_2 \neq 0$.
	Obtain correct $5 - 4 \sec^2 2x$	A1	
	Equate first derivative of form $k_1 + k_2 \sec^2 2x$ to zero and obtain value for $\cos^2 2x$	M1	OE Or value for $\tan^2 2x$ which must be > 0 . $-1 \leq \cos 2x \leq 1$.
	Obtain $\cos 2x = \frac{2}{\sqrt{5}}$ or (decimal) equivalent	A1	Or $\tan 2x = \frac{1}{2}$
	Obtain $x = 0.232$	A1	AWRT
	Obtain $y = 0.159$	A1	AWRT
		6	

Question	Answer	Marks	Guidance
4	Integrate to obtain form $k \ln x$ or $k \ln(3x)$	M1	
	Apply limits and obtain $\frac{1}{3} \ln(a+14) - \frac{1}{3} \ln a = \ln 2$ or $\frac{1}{3} \ln(3a+42) - \frac{1}{3} \ln(3a) = \ln 2$	A1	OE
	Use one relevant logarithm property correctly	M1	
	Apply correct process to obtain equation without logarithms	M1	OE. M0 if incorrect logarithm property used.
	Obtain $\frac{a+14}{a} = 8$ or equivalent and hence $a = 2$	A1	
		5	

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Question	Answer	Marks	Guidance
5	Use product rule to differentiate $4x \cos 3y$ to obtain $k_1 \cos 3y + k_2 x \sin 3y \frac{dy}{dx}$	*M1	$k_1 k_2 \neq 0$
	Obtain $4 \cos 3y - 12x \sin 3y \frac{dy}{dx}$	A1	Allow unsimplified.
	Obtain $2x + 4 \cos 3y - 12x \sin 3y \frac{dy}{dx} = 0$	A1	Allow unsimplified.
	Substitute x - and y -values to find value of first derivative	DM1	
	Apply $-1 / \frac{dy}{dx}$ to find gradient of normal	M1	
	Obtain $-\frac{3}{\sqrt{2}}$ or $-\frac{3}{2}\sqrt{2}$ or exact equivalent	A1	
		6	

Question	Answer	Marks	Guidance
6(a)	Draw correct sketch of $y = \ln x$ or $y = 2e^{-x}$	B1	$y = \ln x$ must extend into 1 st and 4 th quadrants. $y = 2e^{-x}$ must extend into 1 st and 2 nd quadrants.
	Draw correct sketch of second curve and indicate one root	B1	Point of intersection must be circled/identified or a statement such that ‘there is only one point of intersection so one root only’ or similar.
		2	

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Question	Answer	Marks	Guidance
6(b)	Consider sign of $\ln x - 2e^{-x}$, or equivalent, for 1.5 and 1.6	M1	
	Obtain $-0.04...$ and $0.06...$ or equivalents and justify conclusion	A1	
		2	
6(c)	Replace x_{n+1} and x_n by x and apply logarithms to confirm result	B1	AG Allow if done ‘in reverse’ but x_n and x_{n+1} need to be seen in the final statement.
		1	
6(d)	Use iteration process correctly at least once	M1	Need to see 3 correct values.
	Obtain final answer 1.54	A1	Answer required to exactly 3sf
	Show sufficient iterations to 5sf to justify answer or show sign change in interval $[1.535, 1.545]$	A1	
		3	

Question	Answer	Marks	Guidance
7(a)	State $4\sin x(\sin x \cos \frac{1}{6}\pi + \cos x \sin \frac{1}{6}\pi)$	B1	Allow marks if completed correctly, starting with RHS.
	Attempt relevant identities to express at least one term in terms of $\cos 2x$ and $\sin 2x$	M1	
	Confirm $\sqrt{3} - \sqrt{3} \cos 2x + \sin 2x$ with sufficient detail	A1	AG
		3	

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Question	Answer	Marks	Guidance
7(b)	Integrate to obtain form $k_1x + k_2 \sin 2x + k_3 \cos 2x$	*M1	Where $k_1k_2k_3 \neq 0$
	Obtain correct $\sqrt{3}x - \frac{1}{2}\sqrt{3} \sin 2x - \frac{1}{2} \cos 2x$	A1	
	Apply limits correctly and attempt simplification, retaining exactness	DM1	Condone one sign slip.
	Obtain $\frac{5\sqrt{3}}{6}\pi + 1$ or exact equivalent	A1	
		4	
7(c)	Apply identity with x replaced by $2y$	M1	May be implied later.
	Attempt solution of $\tan 4y = \sqrt{3}$	M1	
	Obtain $4y = \frac{1}{3}\pi$ and hence $y = \frac{1}{12}\pi$	A1	
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Types of mark

- 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.
- DM or DB** 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 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.
- 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 or B marks are given for correct work only (not for results obtained from incorrect working) unless follow through is allowed (see abbreviation FT above).
 - For a numerical answer, allow the A or B mark if the answer is correct to 3 significant figures or would be correct to 3 significant figures if rounded (1 decimal place for angles in degrees).
 - The total number of marks available for each question is shown at the bottom of the Marks column.
 - Wrong or missing units in an answer should not result in loss of marks unless the guidance indicates otherwise.
 - Square brackets [] around text or numbers show extra information not needed for the mark to be awarded.

Abbreviations

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
ISW	Ignore Subsequent Working
SOI	Seen Or Implied
SC	Special Case (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)
WWW	Without Wrong Working
AWRT	Answer Which Rounds To

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Question	Answer	Marks	Guidance
1	Integrate to obtain $2e^{2x}$	B1	
	Integrate to obtain $2e^{-x}$	B1	
	Apply limits correctly to integral of the form $k_1e^{2x} + k_2e^{-x}$	M1	$k_1 \neq 4$. Condone one error.
	Obtain $2e^4 - 2e$	A1	or exact equivalent.
		4	

Question	Answer	Marks	Guidance
2(a)	Draw V-shaped graph with vertex on positive x -axis	B1	Must be straight lines.
	Draw straight line through origin with positive gradient greater than gradient of first graph, together with a V shaped graph	B1	Must have the first B1 .
		2	
2(b)	Solve linear equation with signs of $3x$ and x different or solve non-modulus equation $(3x)^2 = (x-3)^2$	M1	
	Obtain $x = \frac{3}{4}$	A1	
	Obtain $y = \frac{9}{4}$	A1	And no other point.
		3	
2(c)	State $x < \frac{3}{4}$	B1 FT	Following <i>their</i> (single) x -coordinate from part (b).
		1	

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Question	Answer	Marks	Guidance
3	State or imply equation is $y \ln a = \ln k + \ln x$	B1	
	Equate gradient of line to $\frac{1}{\ln a}$	M1	Or eliminate $\ln k$ from simultaneous equations.
	Obtain $\frac{1}{\ln a} = \frac{2.64}{1.55}$ or equivalent and hence $a = 1.8$	A1	AWRT
	Substitute appropriate values to find $\ln k$	M1	
	Obtain $\ln k = 2.7...$ and hence $k = 15$	A1	AWRT
	Alternative method for question 3		
	$a^{6.36} = ke^{1.03}$ and $a^9 = ke^{2.58}$	B1	For both.
	Elimination of k to obtain an equation in a only ($a^{2.64} = e^{1.55}$)	M1	Must have previous B1 .
	Use of a correct method to obtain a	M1	Allow for $a = e^{0.59}$.
	$a = 1.8$	A1	
	$k = 15$	A1	
		5	

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Question	Answer	Marks	Guidance
4(a)	Attempt use of product rule to differentiate xe^{2x}	M1	
	Obtain $e^{2x} + 2xe^{2x} - 5e^{-x}$	A1	
	Equate first derivative to zero and multiply by e^x to obtain an equation involving e^{3x}	M1	
	Obtain $e^{3x}(1+2x)=5$ or equivalent	A1	
	Confirm given result $x = \frac{1}{3}\ln 5 - \frac{1}{3}\ln(1+2x)$ with sufficient detail	A1	AG
		5	
4(b)	Use iteration process correctly at least once	M1	Need 0.35 and 2 correct values.
	Obtain final answer 0.357	A1	Answer required to exactly 3sf. Allow recovery.
	Show sufficient iterations to 5sf to justify answer or show sign change in interval [0.3565, 0.3575]	A1	
		3	

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Question	Answer	Marks	Guidance
5(a)	Obtain $\frac{dx}{dt} = \frac{2}{2t+3}$	B1	
	Use quotient rule, or equivalent, to find $\frac{dy}{dt}$	M1	
	Obtain $\frac{dy}{dt} = \frac{2(2t+3) - 2(2t-3)}{(2t+3)^2}$	A1	OE
	Divide to confirm $\frac{dy}{dx} = \frac{6}{2t+3}$	A1	AG
		4	
5(b)	Attempt to find value of t corresponding to $x = 0$	M1	
	Obtain $t = -1$ and hence gradient is 6	A1	
		2	
5(c)	Attempt to find value of t corresponding to $y = 0$	M1	
	Obtain $t = \frac{3}{2}$ and hence gradient is 1	A1	
		2	

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Question	Answer	Marks	Guidance
6(a)	Substitute $x = -3$, equate to zero and attempt solution for a	M1	Allow attempt at synthetic division, must be a complete method. Allow one sign error carried through. Allow attempt at algebraic long division, must be complete with the remainder equated to zero.
	Obtain $a = 13$	A1	
		2	
6(b)	Substitute $x = 2$, equate to 40 and attempt solution for b	M1	
	Obtain $b = 9$	A1	
		2	
6(c)	Identify $x + 3$ as factor of $f(x) - g(x)$	B1	May be implied by synthetic division. If working backwards from solutions from a calculator then B0 M0.
	Attempt, by division or equivalent, to find quadratic factor	M1	$k(x + 3)(2x + 1)(2x - 1)$ where $k \neq 1$ gets B1 M1.
	Obtain $(x + 3)(2x - 1)(2x + 1)$	A1	
		3	
6(d)	Attempt correct process to find at least 1 value from $\operatorname{cosec} \theta = k$ where $k < -1$	M1	Allow for 199.5° or -19.5° .
	Obtain 3.48 or 5.94	A1	
	Obtain a second correct solution	A1	And no others within the range.
		3	

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Question	Answer	Marks	Guidance
7(a)	State $\cos 2\theta \cos \theta - \sin 2\theta \sin \theta$	B1	
	Attempt correct relevant identities to express in terms of $\cos \theta$ only	M1	M0 if moving terms from side to side.
	Confirm $4\cos^3 \theta - 3\cos \theta$ with sufficient detail	A1	AG
		3	
7(b)	Use identity with $\theta = \frac{5}{18}\pi$	M1	
	Obtain $\frac{1}{2}\cos\frac{5}{6}\pi$ and hence $-\frac{1}{4}\sqrt{3}$	A1	
		2	
7(c)	Express integrand in form $k_1(\cos 3x + 3\cos x) + k_2(\cos 9x + 3\cos 3x)$	M1	
	Obtain correct integrand $9\cos x - \cos 9x$	A1	OE (allow unsimplified).
	Integrate to obtain form $k_3 \sin x + k_4 \sin 9x$	M1	
	Obtain correct $9\sin x - \frac{1}{9}\sin 9x$	A1	Now simplified; condone missing $\dots + c$.
		4	