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General Certificate of Education (A-level)
January 2011

# Mathematics (Pilot)	XMCA2

(Specification 6360)

Core A2

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Key to mark scheme abbreviations

M	mark is for method
m or dM	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 or F	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
c	candidate
sf	significant figure(s)
dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

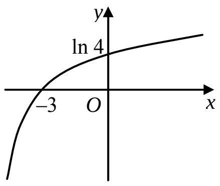
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

XMCA2

Q	Solution	Marks	Total	Comments
1	$1+\frac{1}{2}(4x)+\frac{\left(\frac{1}{2}\right)\left(-\frac{1}{2}\right)(4x)^2}{2!}+\frac{\left(\frac{1}{2}\right)\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)(4x)^3}{3!}$			
	$(1+4x)^{\frac{1}{2}}=1+2x-2x^2+4x^3\ldots;\quad a=2;\ b=-2,$	B1;B1		Condone if simplified terms left in form of expansion.
	$c=4$	B1	3	**SC** if 0/3 award B1 for two correct 'x'-terms unsimplified
	Total		**3**	
2	$x+1=3x \quad\Rightarrow\quad x=\frac{1}{2}$	B1		
	$x+1=-3x$	M1		PI or method to solve $8x^2-2x-1=0$ OE
	$x=-\frac{1}{4}$	A1	3	OE
	Total		**3**	
3(a)	x y			
	0 $\ln 3=1.0986\ldots$			
	0.5 $\ln 3.25=1.1786\ldots$	B1		x values PI
	1 $\ln 4=1.3862\ldots$			
	1.5 $\ln 5.25=1.6582\ldots$	B1		At least 4 correct y values PI; 'exact' or rounded or truncated to 2dp.
	2 $\ln 7=1.9459\ldots$			
	$\frac{1}{3}\times 0.5\{y(0)+y(2)+4[y(0.5)+y(1.5)]+2y(1)\}$	M1		Use of Simpson's rule. Must be for odd number of x-vals from 0
	$\frac{1}{3}\times 0.5\times 17.1646... \quad =2.86$ (to 2 d.p.)	A1	4	CAO Must be 2.86
(b)	$\int_0^2 \ln\sqrt{x^2+3}\ \mathrm{d}x=\frac{1}{2}\times\int_0^2 \ln(x^2+3)\ \mathrm{d}x$	M1		PI
	$\approx \frac{1}{2}\times 2.86...=1.43...$	A1F	2	Ft on 0.5 × c's "2.86" to 2dp or better even for NMS SC If **full** SR then B1 for 1.43
	Total		**6**	
4(a)	$1=A(x+1)^2+B(2x+1)(x+1)+C(2x+1)$	M1		PI
	$x=-\frac{1}{2} \qquad x=-1 \qquad x^2$ terms $0=A+2B$	m1		Subst values of x or comparing coefficients PI
	$A=4 \qquad C=-1 \qquad B=-2$	A3;2,1F	5	Ft value of previous incorrect constant if used to find other(s)
	$\int\left(\frac{4}{2x+1}-\frac{2}{x+1}-\frac{1}{(x+1)^2}\right)\mathrm{d}x$	M1		Use of (a)
	$=2\ln(2x+1)$	A1F		Ft on c's $A/2$ ie $0.5A\ln(2x+1)$
	$-2\ln(x+1)$	A1F		Ft on c's B ie $B\ln(x+1)$
	$+\frac{1}{x+1}\quad(+c)$	A1F	4	Ft on c's $-C$ ie $\frac{-C}{x+1}$
	Total		**9**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
5(a)		B1		Correct shape with graph **crossing** negative x-axis and positive y-axis only
	(−3, 0) and (0, ln 4)	B1;B1	3	Condone just values of intercepts marked on axes instead of coords. OE for ln4 eg 2ln2 Condone 1.38(6..) in place of ln4
(b)	$\frac{dy}{dx} = \frac{1}{x+4}$	M1		
	Gradient of given line = $\frac{1}{2}$	B1		Or $\frac{dy}{dx} = \frac{1}{2}$
	At A, $\frac{1}{x_A + 4} = \frac{1}{2}$	M1		Equating c's $\frac{dy}{dx}$ to c's const grad of line PI
	x-coord of A is −2	A1		$x_A = -2$
	So coords of A are (−2, ln2)			
	Eqn of tangent at A: $y - \ln 2 = \frac{1}{2}(x+2)$	A1	5	ACF. Condone 0.693 for ln2
	Total		**8**	
6(a)	$R = \sqrt{6^2 + (-8)^2}$ (= 10)	B1		
	$\cos\alpha = \frac{6}{R}$, or $\sin\alpha = \frac{8}{R}$ or $\tan\alpha = \frac{8}{6}$	M1		OE
	α = 0.927… and R = 10	A1	3	
(b)	$\cos(\theta + \alpha) = \frac{5}{R}$	M1		Using (a)
	$\cos(\theta + 0.927...) = 0.5 \Rightarrow \theta + 0.927... = \pm 1.047...$	m1		$\theta + \alpha = \pm\cos^{-1}(5/R)$
	$\theta = -1.9(74...)$; $\theta = -2.0$ (to 2sf)	A1F		Condone > 2sf. Ft on −1.047− c's α
	θ = 0.11(99..) = 0.12 (to 2sf)	A1F	4	Condone > 2sf. Ft on 1.047− c's α Penalise extras inside the given interval
(c)	$\frac{15}{6\cos x - 8\sin x} = \frac{15}{R\cos(x+\alpha)}$ $\{= \frac{15}{R}\sec(x+\alpha)\}$	M1		Using (a). PI Condone θ for x
	Translation	E1		Translation-transl.. or better but dep on no variables in the vector
	$\begin{bmatrix} -0.927... \\ 0 \end{bmatrix}$	B1F		Ft on c's α. Accept $\begin{bmatrix} -\alpha \\ 0 \end{bmatrix}$
	Stretch, **(I)** parallel to y-axis, **(II)** scale factor 1.5 OE	m1		'Stretch' with either **(I)** or **(II)** but dep on M. Accept '15/R' for '1.5'
		A1F	5	Complete description. Ft on c's R If >2 transformations, deduct 2 from any EBm and A marks awarded to min of 0
	Total		**12**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
7(a)	$\frac{dN}{dt} = kN$	M1		$\frac{dN}{dt}$ seen
		A1		ACF
	$\int N^{-1}\, dN = \int k\, dt$	m1		Separating variables with intention to then integrate
	$\ln N = kt \quad + c$	A1		Condone absence of $+c$ for this mark
	$\ln(1.6\times10^6) = k\times0 + c \Rightarrow c = \ln(1.6\times10^6)$ $\ln\left(\frac{N}{1.6\times10^6}\right) = kt \Rightarrow \frac{N}{1.6\times10^6} = e^{kt}$	m1		Substituting $N = 1.6\times10^6$ (condone N=1.6) and $t = 0$ in an attempt to find c **and** $\ln p = q \Rightarrow p = e^q$ applied at some stage in soln to (a)
	so $N = 1.6\times10^6 e^{kt}$	A1	6	CSO AG
(b)	$\ln(4\times10^6) = 2.5k + \ln(1.6\times10^6)$	M1		Substituting $N = 4\times10^6$ and $t = 2.5$ in an attempt to find k.
	$k = \frac{1}{2.5}\ln\left(\frac{4}{1.6}\right) = \frac{\ln 2.5}{2.5}$ $(= 0.366516\ldots)$	A1		ACF
	$\ln(13\times10^6) = \frac{\ln 2.5}{2.5}\times t + \ln(1.6\times10^6)$	m1		Substituting $N = 13\times10^6$ to reach a linear eqn with t as the only unknown
	$kt = \ln\left(\frac{13}{1.6}\right) = \ln 8.125 = 2.09(494\ldots)$	A1		A correct numerical expression or value for kt (PI)
	$t = \frac{2.5}{\ln 2.5}\times\ln\left(\frac{13}{1.6}\right) = \frac{2.09494....}{k}$			
	$t = 5.7158\ldots = 5.72$ (to 3 sf)	A1	5	Condone > 3sf. Accept 5.71 SC Substitution of N=4 and N=13 deduct maximum of 1 mark for MR.
	Total		**11**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
8(a)	$\frac{dx}{d\theta} = -\sin\theta + \cos\theta$, $\frac{dy}{d\theta} = -4\sin\theta\cos\theta$	M1 A1		Both derivatives OE attempted PI At least one correct
	$\frac{dy}{dx} = \frac{dy}{d\theta} \div \frac{dx}{d\theta}$	M1		Chain rule with some substitution
	$\frac{dy}{dx} = \frac{-4\sin\theta\cos\theta}{-\sin\theta + \cos\theta}$	A1	4	ACF in terms of θ.
(b)(i)	$x^2 = \cos^2\theta + \sin^2\theta + 2\sin\theta\cos\theta$	M1		Correct expn. and at least one correct identity used
	$x^2 = 1 + \sin 2\theta$	A1	2	Condone slipping into different letter for θ
(ii)	Greatest positive value of $x = \sqrt{2}$	B1F	1	Ft on $x^2 = p + q\sin 2\theta$ ie $x_{\max} = \sqrt{p+q}$ or ('or otherwise') award for $\sqrt{2}$. Condone " $x \le \sqrt{2}$ "
(c)	$y = \cos 2\theta$; $y^2 = \cos^2 2\theta = 1 - \sin^2 2\theta$	B1		$y = \cos 2\theta$ or $y = x(\cos\theta - \sin\theta)$ PI or a correct eqn involving y^2, x^2 (and/or x^4) and θ, with simplification.
	$y^2 = 1 - (x^2 - 1)^2$	M1		Attempt to eliminate θ completely with use of suitable trig identities
		A1	3	ACF of $g(x)$ in $y^2 = g(x)$
	ALT. $y = x(\cos\theta - \sin\theta)$; $\frac{y^2}{x^2} = \cos^2\theta + \sin^2\theta - 2\sin\theta\cos\theta$ $\frac{y^2}{x^2} + x^2 = 2(\cos^2\theta + \sin^2\theta) = 2$ $y^2 = x^2(2 - x^2)$			
	Total		**10**	
	Condone use of other letter for θ in 1st three marks of (a)			
9	$\frac{dy}{dx} = -2e^{-2x}\left(2x^2 + 2x + k\right) + e^{-2x}\left(4x + 2\right)$	M1 A1		Product rule applied ACF
	$\frac{dy}{dx} = 0 \Rightarrow -2e^{-2x}\left(2x^2 + k - 1\right) = 0$	m1		Reaching $pe^{-2x}\left(ax^2 + bx + c\right) = 0$ PI
	$e^{-2x} > 0$	E1		OE eg $e^{-2x} \ne 0$
	so $\left(2x^2 + k - 1\right) = 0 \Rightarrow x = \pm\sqrt{\frac{1-k}{2}}$	m1		OE eg considers equal roots of quadratic
	For exactly one point (one value of x), $k = 1$	A1	6	CSO $k = 1$ with full correct reasoning.
	Total		**6**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
10(a)(i)	$\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = \begin{bmatrix} 3-1 \\ 0-2 \\ 3-2 \end{bmatrix} = \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$	M1 A1	 2	$\pm(\overrightarrow{OB} - \overrightarrow{OA})$ implied by 2 'correct' components
(ii)	$AB = \sqrt{2^2 + (-2)^2 + 1^2} = 3$	B1	1	If incorrect allow ft on (a)(i)
(iii)	$\mathbf{r} = \begin{bmatrix} 1 \\ 2 \\ 2 \end{bmatrix} + \lambda \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$	B1F	1	OE Ft on (a)(i) $\mathbf{r}$ = or $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$ = required
(iv)	$\overrightarrow{OA} \bullet \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 2 \end{bmatrix} \bullet \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix} = 2 - 4 + 2$	M1		Scalar product with correct (ft) vectors; allow one component error
	$= 0$ (so $\overrightarrow{OA}$ is) perpendicular (to l_1)	A1	2	CSO with conclusion.
(b)	Putting **r**'s equal $1 + 2\lambda = 10\mu$ $2 - 2\lambda = -4\mu$ $2 + \lambda = \mu$	M1		Or any two components
	Solving two equations 1st and 2nd $\lambda = 2$, $\mu = 0.5$; [2nd and 3rd $\lambda = -5$, $\mu = -3$] [1st and 3rd $\lambda = -19/8$, $\mu = -3/8$]	m1		To find λ or μ
	Check in remaining equation	m1		Attempt to use c's solutions to check remaining equation or attempt to solve another relevant pair of equations and to compare solution(s). Not dependent on previous m
	(Since equation is not satisfied, lines do) not intersect	A1		CSO Fully correct with valid conclusion
	$\begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix} \neq k \begin{bmatrix} 10 \\ -4 \\ 1 \end{bmatrix}$ so (lines l_1 and l_2) not parallel. (*)			
	Lines do not intersect and are not parallel so l_1 and l_2 are skew lines. (**)	E2,1,0	6	E1 if either just (*) or just (**)
	Total		**12**	
	For conclusions accept equivalent preambles			

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
11(a)	$u = x$ and $\frac{dv}{dx} = e^{-3x}$	M1		Attempt to use parts formula in the 'correct direction'
	$\frac{du}{dx} = 1$ and $v = -\frac{1}{3}e^{-3x}$	A1		PI
	$\ldots\ldots = -x\frac{1}{3}e^{-3x} - \int -\frac{1}{3}e^{-3x}\,dx$	A1F		ft on wrong integration of e^{-3x} provided v is of the form ke^{-3x} ($k \neq \pm 1$)
	$= -\frac{1}{3}xe^{-3x} - \frac{1}{9}e^{-3x}$ $(+c)$	A1	4	CSO (Condone absence of $+c$)
(b)	Let $u = x^2 + 9$	M1		A relevant single substitution used
	$\frac{du}{dx} = 2x$	m1		'$du = 2x\,dx$' OE
	$\int \frac{x^3}{\sqrt{x^2+9}}\,dx = \int \frac{1}{2}\times\frac{(u-9)}{\sqrt{u}}\,du$	m1		In terms of u only, must deal with all parts integrand and dx; dep on prev 2 mks Condone no du provided not just dx missing
	$I = \frac{1}{2}\int (u^{0.5} - 9u^{-0.5})\,du$	m1		Integrand 'correct' form which can be integrated directly, dep on prev 3mks
	When x=4, u=25 and when x=0, u=9 $I = \frac{1}{2}\left[\frac{u^{1.5}}{1.5} - \frac{9u^{0.5}}{0.5}\right]_9^{25}$			
	$= \frac{1}{2}\left\{\left(\frac{125}{1.5} - \frac{45}{0.5}\right) - \left(\frac{27}{1.5} - \frac{27}{0.5}\right)\right\}$	m1		Following a **correct integration**, dealing correctly with correct limits, either for u or (after substituting back for x) for x
	$= \frac{1}{2}\left(-6\frac{2}{3} + 36\right) = 14\frac{2}{3}$	A1	6	Accept 14.6 or 14.7 or better provided full subst method seen and no obvious errors seen. **Altn substitution:** $u^2 = x^2 + 9$ so '$2u\,du = 2x\,dx$' OE (M1m1) leading to $\int \frac{(u^2-9)u}{u}\,du$ (m1) leading to $\int (u^2 - 9)\,du$ (m1)
	Total		**10**	
12	$V = \pi\int_0^{\frac{\pi}{4}} \tan^2 x\,dx$	B1		Must be completely correct including dx seen on this line or next line
	$= (\pi)\int_0^{\frac{\pi}{4}} (\sec^2 x - 1)\,dx$	M1		Explicitly seen using the identity $1 + \tan^2(x) = \sec^2(x)$ to simplify integrand
	$= (\pi)\left[\tan x - x\right]_0^{\frac{\pi}{4}}$	B1		Terms inside [ ]
	$= \pi\left(\tan\frac{\pi}{4} - \frac{\pi}{4}\right) = \pi\left(1 - \frac{\pi}{4}\right)$	A1	4	AG Be convinced
	Total		**4**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
13(a)(i)	$\frac{x+1}{x-1}=\sqrt{x}$; $\frac{(x+1)^2}{(x-1)^2}=x$; $(x+1)^2=x(x-1)^2$	M1		f(x)=g(x) and either elim of √ or elim of fraction or (x−1)=(x+1)/√x
		m1		Elim of both √ and fraction or $(x-1)^2=x+2+(1/x)$
	$x^2+2x+1=x^3-2x^2+x$; $x^3=3x^2+x+1$	m1		Valid methods to penultimate stage
	Dividing each term by x^2 gives $x=3+\frac{1}{x}+\frac{1}{x^2}$			
	So α satisfies the equation $x=3+\frac{1}{x}+\frac{1}{x^2}$	A1	4	CSO AG
(ii)	$x_2=3.444$	B1		AWRT 3.444. Condone exact value eg 31/9
	$x_3=3.375$	B1	2	CAO
(iii)	Let p(x) = $3+\frac{1}{x}+\frac{1}{x^2}-x$			
	p(3.3825) = 0.0005(4..) p(3.3835) = −0.0005(9..)	M1		Both p(3.3825) and p(3.3835) attempted OE **or** subst of these vals in given equation (a)(i)
	Since change of sign (and p is continuous close to α), α is 3.383 correct to 3 dp	A1	2	OE comparing sides of eqn. in (i) for the two values of x oe with a valid conclusion with explicit reference to 3.383
(b)(i)	(Range of f^{-1} is) $f^{-1}(x)>1$	B1	1	Allow y for $f^{-1}(x)$
(ii)	$y=f^{-1}(x) \Rightarrow f(y)=x$ $\Rightarrow \frac{y+1}{y-1}=x$	M1		$x \leftrightarrow y$ at any stage
	$y+1=xy-x \Rightarrow y(x-1)=x+1$	m1		Into a form where just one step is required
	$f^{-1}(x)=\frac{x+1}{x-1}$	A1	3	ACF [Accept y or f^{-1} for $f^{-1}(x)$]
(c)(i)	$0<2\theta<\frac{\pi}{2}$ so $0<\cos 2\theta<1$ so $\frac{1}{\cos 2\theta}>1$ ie $\sec 2\theta>1$	E2,1,0	2	Graphical approach also valid within explanation
(ii)	$\text{gf}\left(\sec 2\theta\right)=\text{g}\left(\frac{\sec 2\theta+1}{\sec 2\theta-1}\right)=\sqrt{\frac{\sec 2\theta+1}{\sec 2\theta-1}}$	B1		PI
	$\sec 2\theta=\frac{1}{\cos 2\theta}$; $\cos 2\theta=2\cos^2\theta-1$ and $\cos 2\theta=1-2\sin^2\theta$	M1		All three identities attempted-condone sign slips
	$\frac{\sec 2\theta+1}{\sec 2\theta-1}=\frac{1+\cos 2\theta}{1-\cos 2\theta}=\frac{1+2\cos^2\theta-1}{1-(1-2\sin^2\theta)}=\frac{\cos^2\theta}{\sin^2\theta}$	A1		
	$\text{gf}\left(\sec 2\theta\right)=\sqrt{\frac{\cos^2\theta}{\sin^2\theta}}=\cot\theta$.	A1	4	CSO AG
	Total		**18**	

XMCA2 (cont)

Q	Solution	Marks	Total	Comments
14(a)	Let p(k)=$k^3-3k-52$ p(4)=64−12−52=0 $\Rightarrow$ <u>$k-4$</u> is a <u>factor</u> of p(k)	B1	1	Must see $4^3-4(3)-52=0$ or better and the concluding statement.
(b)	$x^4+y^4=4xy+52$			
	$4x^3 \quad = \quad (+0)$	B1		Correct differentiation of x^4 & 52 within an equation and no spurious '$\frac{dy}{dx}=$' at the start. (Can be retrieved if clear recovery later)
	$+4y^3\frac{dy}{dx}$	B1		
	$=4\left(y+x\frac{dy}{dx}\right)$	M1 A1		Use of product rule
	At Stationary point $\frac{dy}{dx}=0 \Rightarrow y=x^3$	M1		Setting $\frac{dy}{dx}=0$ to obtain an eqn. in form $4y$=f(x) or better.
	$x^4+(x^3)^4=4x(x^3)+52$	m1		Substituting into eqn. of curve to obtain an eqn. in x (or in y) only
	$x^{12}-3x^4-52=0$ $\quad [\,y^4-3y^{\frac{4}{3}}-52=0\,]$			
	Let $X=x^4 \Rightarrow X^3-3X-52=0$ $[\text{Let } Y=y^{\frac{4}{3}} \Rightarrow Y^3-3Y-52=0\,]$			
	$(X-4)(X^2+4X+13)=0$	M1 A1		Recognising eqn as a cubic and taking out the linear factor. Correct factorisation
	$(X^2+4X+13)=0$ has no real roots since $4^2<4(1)(13)$	m1		Consideration of roots of quadratic factor $ax^2+bx+c=0$ OE for y; must see details
	Only real soln is $X=4 \Rightarrow x^4=4 \Rightarrow x^2=2$ (since $x^2\geq 0$) [Only real soln is $Y=4 \Rightarrow y^{\frac{4}{3}}=4 \Rightarrow y^2=8$ (since $y^2\geq 0$)]	A1		PI
	$x=\pm\sqrt{2}$ $\quad [y=\pm\sqrt{8}\,]$	A1		OE Condone 2sf values here
	Only stationary points are $(\sqrt{2},\,2\sqrt{2})$ and $(-\sqrt{2},\,-2\sqrt{2})$	A1	12	OE <u>**exact**</u> values
	Total		**13**	
	TOTAL		**125**	