OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL AS
FURTHER MATHEMATICS
FM2P2

Further Pure Mathematics 2

Mark scheme

Specimen

Version: 1.0

Mark schemes are prepared by the Lead Assessment Writer 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 associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

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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
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
NMS	No method shown
PI	Possibly implied
sf	Significant figure(s)
dp	Decimal place(s)
ISW	Ignore subsequent working

Mark Scheme Alignment

Marks in the Marks column will typically align with the relevant line of mathematics in the Answer column where the mark is awarded. If two or more marks are awarded for the same line of mathematics, then the Guidance column will give further details as to how each mark is awarded.

Square Brackets

Where square brackets appear in a line of the mark scheme where one or more marks are awarded, the mathematics inside the square bracket is not required for marks to be awarded. Instead, they are intended to be helpful to users of the mark scheme.

Exceptions to this include integration, vectors and matrices where square brackets carry a different mathematical meaning.

Q	Answer	Marks	Guidance
1(a)	$(k-2)(k-3)-5\times 6$ or $k^2-5k-24$	M1	**oe** Correct expression for the determinant. Simplified or unsimplified.
	$[k^2-5k-24=0\Rightarrow]$ $[k=]\ -3$ or $[k=]\ 8$	A1	Both correct values.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
1(b)(i)	$[\mathbf{B}^2=]\quad \begin{bmatrix} 0 & 6 \\ -6 & 0 \end{bmatrix}$	M1	Correctly finds $\mathbf{B}^2$
	$(\mathbf{B}^2)^2=\begin{bmatrix} -36 & 0 \\ 0 & -36 \end{bmatrix}$ and $\mathbf{B}^4=-36\mathbf{I}$	A1	**oe** Shows intention of squaring $\mathbf{B}^2$ before giving correct final answer in the correct form. Matrix $\mathbf{B}^2$ must be seen at some stage in the working. Must be convincingly shown.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
1(b)(ii)	$\mathbf{B}^8=(-36)^2\mathbf{I}$	M1	**oe** An appreciation that $\mathbf{B}^8=(-36)^2\mathbf{I}$ **ft** their -36 provided it is an integer.
	$[\mathbf{B}^9=(-36)^2\mathbf{I}\mathbf{B}=]$ $1296\begin{bmatrix} \sqrt{3} & \sqrt{3} \\ -\sqrt{3} & \sqrt{3} \end{bmatrix}$	A1ft	**oe** **ft** their -36 provided it is an integer.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
1(b) (iii)	$1296^2\left(\left(\sqrt{3}\right)\left(\sqrt{3}\right)-\left(\sqrt{3}\right)\left(-\sqrt{3}\right)\right)$ or $\left(\frac{1}{18}\right)^2\times 1296^2\left(\left(\sqrt{3}\right)\left(\sqrt{3}\right)-\left(\sqrt{3}\right)\left(-\sqrt{3}\right)\right)$	M1	**oe** Correct method for finding the determinant of $\mathbf{B}^9$ or **C** **ft** their 1296 provided it is an integer.
	31104	A1ft	Correct value for the determinant of **C** **ft** their 1296 provided it is an integer. **PI** by correct final answer.
	$[\text{Area} = 31104\times 3 =]$ 93312 [square units]	A1ft	Correct area. **ft** their 31104 provided it is an integer and **M1** has been awarded.
	Subtotal	**3**	
	Question 1 Total	**9**	

Q	Answer	Marks	Guidance
2(a)	$f(2) = -6$ and $f(3) = 2.5$ Since there is a change of sign and the function is continuous then the root α lies in the interval $2 < x < 3$	M1 A1	Correct evaluation of a suitable interval. Must state that there is a change of sign and that the curve is continuous before concluding that α lies in the interval.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
2(b)	$f(2.5) = -4.125$ $[< 0]$ so $2.5 < \alpha < 3$	M1	$f(2.5)$ evaluated and correct interval stated. Allow value of $f(2.5)$ rounded or truncated.
	$f(2.75) = -1.5$	m1	$f(2.75)$ correctly evaluated.
	$2.75 < \alpha < 3$	A1	**CAO**
	Subtotal	**3**	

Q	Answer	Marks	Guidance
2(c)	$[f'(x) =]$ $6x^2 - 11x - 2$	B1	Correct first derivative. **PI** in later working.
	$[f'(2.5) =]$ $6(2.5)^2 - 11(2.5) - 2$ $[= 8]$	M1	Substitutes $x = 2.5$ into their first derivative. **PI** by correct value of $f'(2.5)$ or in later working.
	$[x_2 =]$ $2.5 - \frac{-4.125}{8}$ $[= 3.015625]$	M1	Correct use of the Newton–Raphson formula. **PI** by correct value rounded or truncated to four or more decimal places.
	$[x_2 =]$ 3.016	A1	**AWRT** 3.016
	Subtotal	**4**	

Q	Answer	Marks	Guidance
2(d)	The point on the curve $y = \mathrm{f}(x)$ at $x = 2$ is a stationary point. The tangent at the point where $x = 2$ will not intersect the x-axis.	**E1** **E1**	Explains that the point is a stationary point. **PI** by stating that the tangent is horizontal. **E0E1** not possible.
	Subtotal	**2**	

	Question 2 Total	**11**	

Q	Answer	Marks	Guidance
3(a)	$\left[y = ax^b \Rightarrow\right]$ $\log_{10} y = \log_{10}\left(ax^b\right)$ and $\log_{10} y = \log_{10} a + \log_{10} x^b$ $\log_{10} y = \log_{10} a + b\log_{10} x$ and $Y = \log_{10} a + bX$ which is a linear relationship between X and Y	**M1** **A1**	Takes logarithms of both sides and applies one logarithm rule correctly. **PI** Correctly applies a second logarithm rule and forms a correct equation in terms of X, Y, a and b Must have base 10 Must be convincingly shown.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
3(b)	$[b =]\ -\frac{5}{7}$ $\log_{10} a = 5$ $[a =]$ 100 000 or 10^5	**B1** **M1** **A1**	Equates the constant term in $Y = \log_{10} a + bX$ to the value of the Y-intercept. Must have base 10 **CAO**
	Subtotal	**3**	

	Question 3 Total	**5**	

Q	Answer	Marks	Guidance
4(a)	$\cos\left(\frac{\pi}{6}\right)=\frac{\sqrt{3}}{2}$	B1	$\cos\left(\frac{\pi}{6}\right)=\frac{\sqrt{3}}{2}$ stated or used.
	$\frac{3}{2}x-\frac{\pi}{4}=2n\pi+\frac{\pi}{6}$ or $\frac{3}{2}x-\frac{\pi}{4}=2n\pi-\frac{\pi}{6}$	M1	**oe** Shows correct use of $2n\pi$ in forming a general solution with at least one equation.
	$x=\frac{2}{3}\left(2n\pi+\frac{\pi}{6}+\frac{\pi}{4}\right)$ and $x=\frac{2}{3}\left(2n\pi-\frac{\pi}{6}+\frac{\pi}{4}\right)$	m1	**oe** Correct rearrangement making x the subject in a full set of solutions.
	$x=\frac{24n\pi+5\pi}{18}$ and $x=\frac{24n\pi+\pi}{18}$	M1 A1	**oe** **M1**: At least one correct in terms of π, in radians and in a simplified form. Ignoring all others. **A1**: A full set of solutions in terms of π, in radians and in a simplified form.
	Subtotal	**5**	

Q	Answer	Marks	Guidance
4(b)	For the general solutions in the given range come from $n = 0$ to $n = 11$	**B1**	Deduces the correct range for the values of n **PI** in later working.
	Either $\left[\sum_{n=0}^{11}\left(\frac{24n\pi + 5\pi}{18}\right) =\right]$ $\left(\frac{24\pi}{18}\right)\left(\frac{11}{2}\right)(12) + (12)\left(\frac{5\pi}{18}\right)$ or $\left[\sum_{n=0}^{11}\left(\frac{24n\pi + \pi}{18}\right) =\right]$ $\left(\frac{24\pi}{18}\right)\left(\frac{11}{2}\right)(12) + \frac{2}{3}\pi$	**M1**	**oe** A correct method for calculating either $\sum_{n=0}^{11}\left(\frac{24n\pi + 5\pi}{18}\right)$ or $\sum_{n=0}^{11}\left(\frac{24n\pi + \pi}{18}\right)$ with values substituted
	[Required summation =] $\left(\frac{24\pi}{18}\right)\left(\frac{11}{2}\right)(12) + (12)\left(\frac{5\pi}{18}\right)$ $+\left(\frac{24\pi}{18}\right)\left(\frac{11}{2}\right)(12) + \frac{2}{3}\pi$	**M1**	**oe** A correct method with values substituted for finding the required sum of all the solutions.
	180π	**A1**	**CAO**
	Subtotal	**4**	
	Question 4 Total	**9**	

Q	Answer	Marks	Guidance
5(a)(i)	$[\mathbf{M}=]\ \begin{bmatrix} \frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & -\frac{1}{2} \end{bmatrix}$	B1	
	Subtotal	1	

Q	Answer	Marks	Guidance
5(a)(ii)	$\cos 2\theta = \frac{1}{2}$ and $\sin 2\theta = \frac{\sqrt{3}}{2} \Rightarrow$ $\tan 2\theta = \sqrt{3}$ $2\theta = 60^\circ$ $\theta = 30^\circ$	M1	**PI** Attempts to find the angle for the equation of the line of reflection. Must obtain at least a value for $\tan 2\theta$ **ft** their answer to **part (a)(i)**
	$y = (\tan 30^\circ)x$ or $y = \frac{1}{\sqrt{3}}x$	A1ft	**oe** Equation of the line of reflection. **ft** their answer to **part (a)(i)**
	Reflection in the line $y = \frac{1}{\sqrt{3}}x$ $\left(\text{or } y = \frac{\sqrt{3}}{3}x\right)$	E1	Must have 'reflection' and correct equation of the line of reflection.
	Subtotal	3	

Q	Answer	Marks	Guidance
5(b)(i)	$\begin{bmatrix} -c & d \\ d & c \end{bmatrix}\begin{bmatrix} 2 \\ 2\sqrt{3} \end{bmatrix} = \begin{bmatrix} 2 \\ 2\sqrt{3} \end{bmatrix}$	M1	**PI** Correct matrix equation.
	$-2c + 2\sqrt{3}d = 2$ and $2d + 2\sqrt{3}c = 2\sqrt{3}$	M1	**oe** Obtains both correct simultaneous equations. **PI**
	$[c=]\ \frac{1}{2}$ and $[d=]\ \frac{\sqrt{3}}{2}$	A1	Both correct exact values.
	Subtotal	3	

Q	Answer	Marks	Guidance
5(b)(ii)	$[\mathbf{NM}=]\ \begin{bmatrix} -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} \frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & -\frac{1}{2} \end{bmatrix}$ $\begin{bmatrix} \frac{1}{2} & -\frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{2} & \frac{1}{2} \end{bmatrix}$	**M1** **A1**	Correct calculation using the correct order of multiplication. **PI** **ft** their c and d **CAO**
	Subtotal	**2**	

Q	Answer	Marks	Guidance
5(b)(iii)	$\cos\theta = \frac{1}{2}$ and $\sin\theta = \frac{\sqrt{3}}{2} \Rightarrow$ $\theta = 60^\circ$ Rotation 60° anticlockwise about the origin.	**M1** **B1** **A1**	Correct method to find θ **PI** by the correct value of the angle. **B1**: Correctly names the type of transformation. **A1**:**oe** Correct description of the rotation including angle, direction and centre of rotation.
	Subtotal	**3**	

	Question 5 Total	**12**	

Q	Answer	Marks	Guidance
6(a)(i)	$\left[y_Q = 9(3+h) - 2(3+h)^2 =\right]$ $27 + 9h - 18 - 12h - 2h^2$ $\left[= 9 - 3h - 2h^2\right]$	B1	**oe** Correct expression for y_Q with all brackets expanded. Simplified or unsimplified. **PI** in later working.
	$\left[\frac{y_Q - y_P}{x_Q - x_P} =\right] \quad \frac{9 - 3h - 2h^2 - 9}{3 + h - 3}$	M1	**oe** Correct expression for the gradient.
	$\left[\frac{y_Q - y_P}{x_Q - x_P} =\right] \quad \frac{-3h - 2h^2}{h}$ and $-3 - 2h$	A1	**oe** Extra line of working before **AG** Must be convincingly shown.
	Subtotal	**3**	

Q	Answer	Marks	Guidance
6(a)(ii)	As $h \to 0$ the gradient of *PQ* tends to the gradient of the tangent at *P*, i.e. -3	E1	Explains that as $h \to 0$ the gradient of *PQ* tends to the gradient of the tangent, and concludes that the limit is -3
	The gradient of $3x + y = 10$ is also -3 so the tangent to *C* at *P* is parallel to the line $3x + y = 10$	E1	Compares the gradient of the tangent to the gradient of $3x + y = 10$ before giving a final conclusion **E0E1** not possible.
	Subtotal	**2**	

Q	Answer	Marks	Guidance
6(b)(i)	One of the limits is infinite.	E1	**oe** Such as the range of integration is infinite.
	Subtotal	1	

Q	Answer	Marks	Guidance
6(b)(ii)	$I = \lim_{a\to\infty} \int_3^a x^{-4}\left(9x - 2x^2\right)\mathrm{d}x$ or $I = \lim_{a\to\infty} \int_3^a 9x^{-3} - 2x^{-2}\,\mathrm{d}x$	M1	Limiting process seen in the solution.
	$I = \lim_{a\to\infty} \left[-\frac{9}{2}x^{-2} + 2x^{-1}\right]_3^a$	m1	**oe** Correct Integration.
	$\left[I = 0 - \left(-\frac{1}{2} + \frac{2}{3}\right) =\right] \quad -\frac{1}{6}$	A1	**CAO** No limiting process shown is awarded zero marks.
	Subtotal	3	

	Question 6 Total	9	

Q	Answer	Marks	Guidance
7	$[x' =]\ 0.5x + 1.25(mx + c)$ $[y' =]\ -0.2x + 1.5(mx + c)$	M1	Condone sign errors. Condone x for x' and y for y'
	$-0.2x + 1.5(mx + c)$ $= m(0.5x + 1.25(mx + c)) + c$	m1	**ft** their x'
	$1.25m^2 - m + 0.2 = 0$ $1.5c - 1.25mc - c = 0$	m1	**oe** Attempt to find m and c by comparing coefficients or setting coefficients to equal zero. Condone one error.
	$[m =]\ \frac{2}{5}$	B1	Correct value of m
	[The invariant lines are] $y = \frac{2}{5}x + c$ [where c is a real number].	A1	Correct equation. **ACF**
	Subtotal	**5**	

	Question 7 Total	**5**	