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EDEXCEL A LEVEL FURTHER MATHEMATICS: QUESTIONS BY TOPIC

Polar Coordinates (7)

Core Pure Mathematics 2 · Topic 7

4 questions · 33 marks · Mark schemes included

Pearson Edexcel A Level Further Mathematics (9FM0), June 2019 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
7.2 SKETCHING POLAR CURVES		1 Qs · 7 marks	3
1. Q4	Paper 2: Core Pure Mathematics 2 June2023	7	4
7.3 AREAS AND TANGENTS OF POLAR CURVES		3 Qs · 26 marks	8
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QUESTIONS

4 questions · 33 marks · 2 sub-topics



SUB-TOPIC 7.2

SKETCHING POLAR CURVES

Sub-topic 7.2 · 1 question · 7 marks · lowest tariff first







SUB-TOPIC 7.3

AREAS AND TANGENTS OF POLAR CURVES

Sub-topic 7.3 · 3 questions · 26 marks · lowest tariff first



Question 1 continued

(Total for Question 1 is 4 marks)



Question 7 continued



Question 7 continued



Question 7 continued

(Total for Question 7 is 10 marks)



Question 7 continued



Question 7 continued

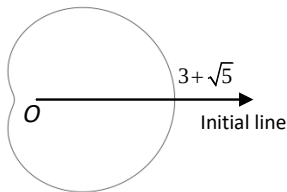


Question 7 continued

MARK SCHEMES

official mark schemes



Question	Scheme	Marks	AOs
4(a)		Recalls correct shape for the type of curve, including 'dimple'	B1 1.2
		Correct position with labelling of pole, initial line and point.	B1 1.1b
		(2)	
(b)	$\frac{d}{d\theta}(r \sin \theta) = \frac{d}{d\theta}(3 \sin \theta + \sqrt{5} \sin \theta \cos \theta) = A \cos \theta + B \cos 2\theta$ $\frac{d}{d\theta}(r \sin \theta) = \frac{d}{d\theta}((3 + \sqrt{5} \cos \theta) \sin \theta) = A \sin^2 \theta + B \cos \theta + C \cos^2 \theta$	M1	1.1b
	$\frac{d}{d\theta}(r \sin \theta) = \frac{d}{d\theta}(3 \sin \theta + \sqrt{5} \sin \theta \cos \theta) = 3 \cos \theta + \sqrt{5} \cos 2\theta$ $\frac{d}{d\theta}(r \sin \theta) = \frac{d}{d\theta}((3 + \sqrt{5} \cos \theta) \sin \theta) = -\sqrt{5} \sin^2 \theta + 3 \cos \theta + \sqrt{5} \cos^2 \theta$	A1	1.1b
	$\frac{dy}{dx} = 0 \Rightarrow 3 \cos \theta + \sqrt{5}(2 \cos^2 \theta - 1) = 0$ or $-\sqrt{5}(1 - \cos^2 \theta) + 3 \cos \theta + \sqrt{5} \cos^2 \theta = 0$ Leading to a quadratic in $\cos \theta$ $\{2\sqrt{5} \cos^2 \theta + 3 \cos \theta - \sqrt{5} = 0\}$	M1	3.1a
	$\cos \theta = \frac{1}{\sqrt{5}}$ following a correct quadratic, any extra solutions are rejected $\{\cos \theta = \frac{-3 \pm 7}{4\sqrt{5}}, \text{ quadrant 1 needs } \cos \theta > 0\}$	A1	2.3
		(4)	
(c)	$r = 4$	B1	1.1b
		(1)	
(7 marks)			
Notes:			
(a) B1: Recalls the correct cardioid shape for this type of polar curve. B1: Correctly placed with the pole, initial line and point where curve crosses the initial line all indicated in some way.			

(b)

M1: Uses $y = r \sin \theta$ with the curve and attempts to differentiate. Accept any correct form but may have slips in coefficients, so e.g. as shown or $A \cos \theta + B \cos^2 \theta + C \sin^2 \theta$ can score M1.

A1: Correct differentiation. Accept equivalents, e.g. $3 \cos \theta + \sqrt{5} \cos^2 \theta - \sqrt{5} \sin^2 \theta$

M1: Sets their derivative equal to zero (may be implied), using trig identities to form a quadratics for $\cos \theta$

Allow this mark form the use of $r \cos \theta$ leads to $-3 \sin \theta - 2\sqrt{5} \sin \theta \cos \theta = 0$, score M1 for factorising out $\sin \theta$ and finds a value for $\cos \theta$

A1: Solves their quadratic and selects the correct value for $\cos \theta$. If the other value is given it is A0 unless clearly rejected.

(c)

B1: Correct value for r



Question	Scheme	Marks	AOs
1	$\text{Area} = \frac{1}{2} \int_0^{\pi} r^2 \, d\theta = \frac{1}{2} \int_0^{\pi} \left[2\sqrt{\sinh \theta + \cosh \theta} \right]^2 \{d\theta\}$ or $\frac{1}{2} \int_0^{\pi} 4(\sinh \theta + \cosh \theta) \{d\theta\}$	B1	1.1b
	$= 2 \left[\cosh \theta + \sinh \theta \right]_0^{\pi}$ or $2 \int_0^{\pi} \left(\frac{e^{\theta} - e^{-\theta}}{2} + \frac{e^{\theta} + e^{-\theta}}{2} \right) d\theta = 2 \int_0^{\pi} e^{\theta} \, d\theta = 2 \left[e^{\theta} \right]_0^{\pi}$	M1	1.1b
	$= 2 \left((\cosh \pi + \sinh \pi) - (\cosh 0 + \sinh 0) \right)$ $= 2 \left(\left(\frac{e^{\pi} + e^{-\pi}}{2} + \frac{e^{\pi} - e^{-\pi}}{2} \right) - (1 + 0) \right)$ or $= 2(e^{\pi} - e^0)$	M1	3.1a
	$= 2e^{\pi} - 2 \text{ or } 2(e^{\pi} - 1)$	A1	2.1
		(4)	
(4 marks)			
Notes:			
B1: Correct area formula applied, including the $\frac{1}{2}$ and correct limits, may be seen later, $d\theta$ may be implied. M1: Attempts the integration $\sinh \theta \rightarrow \pm \cosh \theta$ and $\cosh \theta \rightarrow \pm \sinh \theta$ or in terms of exponentials $\int e^{\lambda \theta} \, d\theta = \frac{1}{\lambda} e^{\lambda \theta}$ M1: Applies their limits to the integral, subtracts (there must be an attempt to integrate) and uses exponential definitions to achieve answer in suitable form. Condone the inclusion of i or a missing $\frac{1}{2}$ from the definitions. This can be implied. A1: Correct exact answer, no i			

Question	Scheme	Marks	AOs
7(a)	$x = r \cos \theta = (1 + \tan \theta) \cos \theta = \cos \theta + \sin \theta$ $= \cos \theta + \tan \theta \cos \theta$ $\frac{dx}{d\theta} = \alpha(1 + \tan \theta) \sin \theta + \beta \sec^2 \theta \cos \theta \quad \text{or} \quad \frac{dx}{d\theta} = \alpha \sin \theta + \beta \cos \theta$ $\frac{dx}{d\theta} = \alpha \sin \theta + \beta \sec^2 \theta \cos \theta + \delta \tan \theta \sin \theta$	M1	3.1a
	$\frac{dx}{d\theta} = -(1 + \tan \theta) \sin \theta + \sec^2 \theta \cos \theta \quad \text{or} \quad \frac{dx}{d\theta} = -\sin \theta + \cos \theta$ $\frac{dx}{d\theta} = -\sin \theta + \sec^2 \theta \cos \theta - \tan \theta \sin \theta \quad \text{or} \quad \frac{dx}{d\theta} = -\sin \theta + \sec \theta - \tan \theta \sin \theta$	A1	1.1b
	For example $\left\{ \frac{dx}{d\theta} = \right\} -\sin \theta + \cos \theta = 0 \Rightarrow \tan \theta = 1 \Rightarrow \theta = \dots$ $\left\{ \frac{dx}{d\theta} = \right\} -\sin \theta + \cos \theta = 0 \Rightarrow \sin \theta = \cos \theta \Rightarrow \theta = \dots$ $\left\{ \frac{dx}{d\theta} = \right\} -\sin \theta + \cos \theta = \sqrt{2} \cos \left(\theta + \frac{\pi}{4} \right) = \theta = \dots$ or $\left\{ \frac{dx}{d\theta} = \right\} - (1 + \tan \theta) \sin \theta + \sec^2 \theta \cos \theta = 0$ $\Rightarrow -\sin \theta - \frac{\sin^2 \theta}{\cos \theta} + \frac{1}{\cos \theta} = 0 \Rightarrow -\sin \theta + \frac{1 - \sin^2 \theta}{\cos \theta} = 0$ $\Rightarrow -\sin \theta + \cos \theta = 0 \Rightarrow \tan \theta = 1 \Rightarrow \theta = \dots$ or $\left\{ \frac{dx}{d\theta} = \right\} -\sin \theta - \tan \theta \sin \theta + \sec \theta = 0$ $\Rightarrow -\frac{1}{2} \sin 2\theta - \sin^2 \theta + 1 = 0 \Rightarrow \sin 2\theta + 2 \sin^2 \theta - 1 = 1$ $\Rightarrow \sin 2\theta - \cos 2\theta = 1 \Rightarrow \sqrt{2} \sin \left(2\theta - \frac{\pi}{4} \right) = 1 \Rightarrow \theta = \dots$ or $\left\{ \frac{dx}{d\theta} = \right\} -\sin \left(\frac{\pi}{4} \right) + \cos \left(\frac{\pi}{4} \right) = 0$ $\left\{ \frac{dx}{d\theta} = \right\} - \left(1 + \tan \left(\frac{\pi}{4} \right) \right) \sin \left(\frac{\pi}{4} \right) + \sec^2 \left(\frac{\pi}{4} \right) \cos \left(\frac{\pi}{4} \right) = 0$ $\left\{ \frac{dx}{d\theta} = \right\} -\sin \left(\frac{\pi}{4} \right) + \sec^2 \left(\frac{\pi}{4} \right) \cos \left(\frac{\pi}{4} \right) - \tan \left(\frac{\pi}{4} \right) \sin \left(\frac{\pi}{4} \right) = 0$	dM1	3.1a
	$r = 1 + \tan \left(\frac{\pi}{4} \right) = 2 \quad \text{therefore } A \left(2, \frac{\pi}{4} \right)^*$	A1*	2.1
		(4)	
	Area bounded by the curve $= \frac{1}{2} \int (1 + \tan \theta)^2 \{d\theta\}$	M1	3.1a

(b)	$= \frac{1}{2} \int (1 + 2 \tan \theta + \tan^2 \theta) \{d\theta\}$ $= \frac{1}{2} \int (1 + 2 \tan \theta + [\sec^2 \theta - 1]) \{d\theta\} = \dots$		
	$= \frac{1}{2} [2 \ln \sec \theta + \tan \theta] \text{ or } \ln \sec \theta + \frac{1}{2} \tan \theta \text{ or } -\ln \cos \theta + \frac{1}{2} \tan \theta \text{ or } = \frac{1}{2} [-2 \ln \cos \theta + \tan \theta]$	A1	1.1b
	$= \frac{1}{2} \left[2 \ln \left \sec \left(\frac{\pi}{4} \right) \right + \tan \left(\frac{\pi}{4} \right) \right] - \frac{1}{2} [2 \ln \sec(0) + \tan(0)]$ $= \left(\ln \left \sec \left(\frac{\pi}{4} \right) \right + \frac{1}{2} \tan \left(\frac{\pi}{4} \right) \right) - \left(\ln \sec 0 + \frac{1}{2} \tan 0 \right)$ $\left\{ = \ln \sqrt{2} + \frac{1}{2} \right\}$	dM1	1.1b
	Area of triangle $= \frac{1}{2} xy = \frac{1}{2} \left(2 \cos \frac{\pi}{4} \right) \left(2 \sin \frac{\pi}{4} \right) = \dots \left\{ \frac{1}{2} \times \sqrt{2} \times \sqrt{2} = 1 \right\}$ The equation of the tangent is $r = \sqrt{2} \sec \theta$ then applies Area bounded of triangle $= \frac{1}{2} \int_0^{\frac{\pi}{4}} (\sqrt{2} \sec \theta)^2 \{d\theta\}$	M1	1.1b
	Finds the required area = area of triangle – area bounded by the curve $= 1 - \left[\ln \sqrt{2} + \frac{1}{2} \right]$ May be seen within an integral $= \frac{1}{2} \int (\sqrt{2} \sec \theta)^2 \{d\theta\} - \frac{1}{2} \int (1 + \tan \theta)^2 \{d\theta\}$	M1	3.1a
	$= \frac{1}{2} (1 - \ln 2) \text{ * cso}$	A1*	2.1
		(6)	
	Alternative Area bounded by the curve $= \frac{1}{2} \int (1 + \tan \theta)^2 \{d\theta\}$ $= \frac{1}{2} \int (1 + 2 \tan \theta + \tan^2 \theta) \{d\theta\} \text{ let } u = \tan \theta \Rightarrow \frac{du}{d\theta} = \sec^2 \theta$ Leading to $= \frac{1}{2} \int \frac{(1 + 2u + u^2)}{1 + u^2} \{du\} = \frac{1}{2} \int 1 + \frac{2u}{1 + u^2} \{du\} = \dots$	M1	3.1a
	$\frac{1}{2} [u + \ln(1 + u^2)]$	A1	1.1b
	$\frac{1}{2} [(1 + \ln(1 + (1)^2)) - (0 + \ln 1)] \text{ or } \frac{1}{2} \left[\left(\tan \left(\frac{\pi}{4} \right) + \ln \left(1 + \tan^2 \left(\frac{\pi}{4} \right) \right) \right) - (\tan(0) + \ln(1 + \tan^2(0))) \right]$ $\left\{ = \frac{1}{2} \ln 2 + \frac{1}{2} \right\}$	dM1	1.1b
	Area of triangle $= \frac{1}{2} xy = \frac{1}{2} \left(2 \cos \frac{\pi}{4} \right) \left(2 \sin \frac{\pi}{4} \right) = \dots \left\{ \frac{1}{2} \times \sqrt{2} \times \sqrt{2} = 1 \right\}$	M1	1.1b

	Finds the required area = area of triangle – area bounded by the curve $= 1 - \left[\ln \sqrt{2} + \frac{1}{2} \right]$	M1	3.1a
	$= \frac{1}{2}(1 - \ln 2) *$	A1*	2.1
		(6)	
(10 marks)			
Notes:			
(a) M1: Substitutes the equation of C into $x = r \cos \theta$ and differentiates to the required form A1: Fully correct differentiation dm1: Dependent on previous method mark. Sets their $\frac{dx}{d\theta} = 0$ and uses correct trig identities to find a value for θ. Alternatively substitutes $\theta = \frac{\pi}{4}$ into their $\frac{dx}{d\theta}$ and shows equals 0. A1*: Shows that $r = 2$ and hence the polar coordinates $\left(2, \frac{\pi}{4}\right)$ from correct working			
(b) M1: Applies area $= \frac{1}{2} \int r^2 \theta \, d\theta$, multiplies out, uses the identity $\pm 1 \pm \tan^2 \theta = \sec^2 \theta$ to get into an integrable form and integrates. Condone missing $d\theta$, limits are not required for this mark A1: Correct integration. Note may include $\theta - \theta$ if the one's were not cancelled earlier. dm1: Dependent on the first method mark. Applies the limits of $\theta = 0$ and $\theta = \frac{\pi}{4}$ and subtracts the correct way round. Since substitution of the limit $\theta = 0$ is 0 so may be implied M1: Correct method to find the area of triangle seen. This may be minimal but area = 1 only is M0, they need to show some method. M1: Finds the required area = area of triangle – area bounded by the curve A1*: Correct answer, with no errors or omissions. cso Alternative M1: Applies area $= \frac{1}{2} \int r^2 \theta \, d\theta$, multiplies out, uses the substitution $u = \tan \theta$ to get into an integrable form and integrates. Limits are not required for this mark A1: Correct integration dm1: Dependent on the first method mark. Applies the limits of $u = 0$ and $u = 1$ or substitutes back using $u = \tan \theta$ and uses the limits $\theta = 0$ and $\theta = \frac{\pi}{4}$ and subtracts the correct way round. Since substitution of the limit $\theta = 0$ is 0 so may be implied M1: Correct method to find the area of triangle M1: Finds the required area = area of triangle – area bounded by the curve A1*: Correct answer, with no errors or omissions. cso			

Question	Scheme	Marks	AOs
7(a)	$x = r \cos \theta = a(1 + \sin \theta) \cos \theta = a(\cos \theta + \sin \theta \cos \theta)$ $\frac{dx}{d\theta} = A \cos \theta \cos \theta + B(1 + \sin \theta) \sin \theta$ or $A \sin \theta + B \cos^2 \theta + C \sin^2 \theta$ or $x = r \cos \theta = a(1 + \sin \theta) \cos \theta = a(\cos \theta + 0.5 \sin 2\theta)$ $\frac{dx}{d\theta} = A \sin \theta + B \cos 2\theta$	M1	3.1a
	$\frac{dx}{d\theta} = a(-\sin \theta + \cos 2\theta)$ or $a(\cos^2 \theta - (1 + \sin \theta) \sin \theta)$ or $a(-\sin \theta + \cos^2 \theta - \sin^2 \theta)$	A1	1.1b
	$\frac{dx}{d\theta} = a(-\sin \theta + \cos 2\theta) = 0 \Rightarrow -\sin \theta + 1 - 2 \sin^2 \theta = 0$ $2 \sin^2 \theta + \sin \theta - 1 \Rightarrow \sin \theta = \dots$ or $\frac{dx}{d\theta} = a(-\sin \theta + \cos^2 \theta - \sin^2 \theta) = 0 \Rightarrow -\sin \theta + 1 - \sin^2 \theta - \sin^2 \theta = 0$ $2 \sin^2 \theta + \sin \theta - 1 = 0 \Rightarrow \sin \theta = \dots$	M1	3.1a
	$\sin \theta = \frac{1}{2} \{-1\}$	A1	1.1b
	$r = a \left(1 + \frac{1}{2}\right)$ and $\theta = \sin^{-1} \left(\frac{1}{2}\right)$	M1	1.1b
	$\left(\frac{3}{2}a, \frac{\pi}{6}\right)$ and $\left(\frac{3}{2}a, \frac{5\pi}{6}\right)$	A1	2.2a
		(6)	
(b)	E.g. $x = \frac{3}{2}a \cos \left(\frac{\pi}{6}\right) \Rightarrow 2 \times \frac{3\sqrt{3}}{4}a = 10 \Rightarrow a = \dots$ or $\sin \frac{\pi}{3} = \frac{5}{3a/2} \Rightarrow a = \dots$ or $\Rightarrow 10^2 = \left(\frac{3a}{2}\right)^2 + \left(\frac{3a}{2}\right)^2 - 2\left(\frac{3a}{2}\right)^2 \cos \frac{2\pi}{3} \Rightarrow a = \dots$ or $\frac{10}{\sin \frac{2\pi}{3}} = \frac{\frac{3a}{2}}{\sin \frac{\pi}{6}} \Rightarrow a = \dots$ or $y = \frac{3}{2}a \sin \frac{\pi}{6} \Rightarrow 5^2 + \left(\frac{3a}{4}\right)^2 = \left(\frac{3a}{2}\right)^2 \Rightarrow a = \dots$	M1	3.3
	$a = \frac{20\sqrt{3}}{9} *$	A1*	2.1
		(2)	

(c)	$\left(\frac{1}{2}\right) \int r^2 d\theta = K \int (1 + 2\sin\theta + \sin^2\theta) d\theta$ $= K \int \left(1 + 2\sin\theta + \left[\frac{1}{2} - \frac{1}{2}\cos 2\theta\right]\right) d\theta = K[p\theta \pm q\cos\theta \pm r\sin 2\theta]$	M1	3.4
	$= \left(\frac{1}{2} \times\right) \frac{400}{27} \left[\frac{3}{2}\theta - 2\cos\theta - \frac{1}{4}\sin 2\theta\right]$	A1	1.1b
	Area bounded by the curve $= \frac{1}{2} \int_{-\pi}^{\pi} \left[\frac{20\sqrt{3}}{9}(1 + \sin\theta)\right]^2 d\theta \text{ or } = \frac{1}{2} \int_0^{2\pi} \left[\frac{20\sqrt{3}}{9}(1 + \sin\theta)\right]^2 d\theta$ $\frac{200}{27} \left[\left(\frac{3}{2}(2\pi) - 2\cos(2\pi) - \frac{1}{4}\sin(4\pi)\right) - \left(\frac{3}{2}(0) - 2\cos(0) - \frac{1}{4}\sin(0)\right)\right]$ or $\frac{200}{27} \left[\left(\frac{3}{2}(\pi) - 2\cos(\pi) - \frac{1}{4}\sin(2\pi)\right) - \left(\frac{3}{2}(-\pi) - 2\cos(-\pi) - \frac{1}{4}\sin(-\pi)\right)\right]$	dM1	3.4
	$\frac{200}{9}\pi \text{ or awrt } 69.8 \text{ (m}^2\text{)}$	A1	1.1b
		(4)	
(12 marks)			
Notes:			
(a) M1: Substitutes the equation of C into $x = r \cos \theta$ and differentiates to the required form. The $\frac{dx}{d\theta}$ need not be seen – if it is a clear attempt at differentiation allow the marks. A1: Fully correct differentiation. M1: Uses correct trig work to solve $\frac{dx}{d\theta} = 0$ to achieve a value for $\sin \theta$ via a 3 TQ in $\sin$ (oe) A1: Correct values for $\sin \theta$. The -1 need not be stated but any other values found will be A0. M1: Uses $r = a(1 + \sin \theta)$ and their $\theta = \sin^{-1}(\dots)$ (or $\cos^{-1}$ if by error they ended up with a value for $\cos \theta$ – and may have come from $\frac{dy}{d\theta} = 0$) to find a polar coordinate. May be implied by a correct coordinate following $\sin \theta = \frac{1}{2}$ having been found. A1: Deduces the correct polar coordinates from correct work for A and B with no incorrect extras. May be listed, or may given as (θ, r). You may ignore values from $\sin \theta = -1$ that are not used. NB: Allow the final two marks in (a) if it is initially forgotten but the correct work is done as part of answering part (b).			

(b)

M1: Uses $2x = 10$ where $x = r \cos \theta$ to find a value for a by any valid method. Several are shown in the scheme, there may be variations on these.

A1: Correct value achieved with no errors cso. Must see a correct unsimplified equation in a with trig terms evaluated before the final answer.

(c)

M1: Attempts to use the model and area $= \left(\frac{1}{2}\right) \int r^2 d\theta$, multiplies out, uses the identity

$\sin^2 \theta = \frac{1}{2}(\pm 1 \pm \cos 2\theta)$ to get into an integrable form and integrates. Limits are not required and the $\frac{1}{2}$ may be missing for this mark. Condone the a not being squared.

NB: There may be less direct methods attempted (e.g. integration by parts). Such attempts must be complete attempts reaching an integral of the correct form. If you are unsure in any cases then use the review system.

A1: Correct integration of $\left(\frac{1}{2}\right) \int r^2 d\theta$ condoning the $\frac{1}{2}$ not being present at this stage. Allow with a^2 used instead of the value.

dM1: Dependent on the first method mark. Full method for the area, with correct $\frac{1}{2} \int_{\alpha}^{\beta} r^2 d\theta$ and applies correct limits over 2π ($\theta = 0$ and $\theta = 2\pi$ or $\theta = -\pi$ and $\theta = \pi$), or applies $\int_{\alpha}^{\beta} r^2 d\theta$ with limits $-\frac{\pi}{2}$ to $\frac{\pi}{2}$. Accept equivalent combinations of limits split as two integrals and summed, but must be a full method. If no evidence of the substitution of limits is seen accept answers following the integral as long as suitable limits were linked to the integral. Condone if just -0 is shown for a lower limit of 0 substituted.

A1: Correct area. Must have substituted for the a .