Question	Scheme	Marks	AOs
4	$4+\cos 2\theta=\frac{9}{2}\Rightarrow\theta=...$	M1	3.1a
	$\theta=\frac{\pi}{6}$	A1	1.1b
	$\frac{1}{2}\int(4+\cos 2\theta)^2\,\mathrm{d}\theta=\frac{1}{2}\int\left(16+8\cos 2\theta+\cos^2 2\theta\right)\mathrm{d}\theta$	M1	3.1a
	$\cos^2 2\theta=\frac{1}{2}+\frac{1}{2}\cos 4\theta\Rightarrow A=\frac{1}{2}\int\left(16+8\cos 2\theta+\frac{1}{2}+\frac{1}{2}\cos 4\theta\right)\mathrm{d}\theta$	M1	3.1a
	$=\frac{1}{2}\left[16\theta+4\sin 2\theta+\frac{\sin 4\theta}{8}+\frac{\theta}{2}\right]$	A1	1.1b
	Using limits 0 and their $\frac{\pi}{6}$: $\frac{1}{2}\left[\frac{33\pi}{12}+2\sqrt{3}+\frac{\sqrt{3}}{16}-(0)\right]$	M1	1.1b
	Area of triangle $=\frac{1}{2}(r\cos\theta)(r\sin\theta)=\frac{1}{2}\times\frac{81}{4}\times\frac{1}{2}\times\frac{\sqrt{3}}{2}$	M1	3.1a
	Area of $R=\frac{33\pi}{24}+\frac{33\sqrt{3}}{32}-\frac{81\sqrt{3}}{32}$	M1	1.1b
	$=\frac{11}{8}\pi-\frac{3\sqrt{3}}{2}\left(p=\frac{11}{8},\ q=-\frac{3}{2}\right)$	A1	1.1b
			(9 marks)

Notes:

M1: Realises the angle for A is required and attempts to find it
A1: Correct angle
M1: Uses a correct area formula and squares r to achieve a 3TQ integrand in $\cos 2\theta$
M1: Use of the correct double angle identity on the integrand to achieve a suitable form for integration
A1: Correct integration
M1: Correct use of limits
M1: Identifies the need to subtract the area of a triangle and so finds the area of the triangle
M1: Complete method for the area of R
A1: Correct final answer

A1ft: Integrates $\int \frac{px}{2x^2+3} - \frac{q}{x+1} \, \mathrm{d}x = \frac{p}{4}\ln\left(2x^2+3\right) - q\ln\left(x+1\right)$ and no extra terms

M1: Combines two algebraic log terms correctly.

B1: Correct upper limit for $x \to \infty$ by recognising the dominant terms. (Simply replacing x with ∞ scores B0). This can be implied.

A1: Deduces the correct value for the improper integral in the correct form, cao A0 for $2\ln\frac{2}{3}$

Correct answer with no working seen is no marks.

Note: Incorrect partial fraction form,

$\frac{A}{2x^2+3} + \frac{B}{x+1}$ or $\frac{Ax}{2x^2+3} + \frac{B}{x+1}$ the maximum it can score is M0M0A0A0M1B1A0

Question	Scheme	Marks	AOs
3(a)(i)	$2(0.4+a)=1.2$ or $0.4+a=0.6$ or $0.4+a\cos 0=0.6$ $\Rightarrow a = ...$	M1	3.4
	$a = 0.2$ * cso	A1*	1.1b
		(2)	
(b)	Area of rectangle is $1.2\times 0.6 (=0.72)$	B1	1.1b
	Area enclosed by curve = $\frac{1}{2}\int (0.4+0.2\cos 2\theta)^2 (\mathrm{d}\theta)$	M1	3.1a
	$(0.4+0.2\cos 2\theta)^2 = 0.16+0.16\cos 2\theta+0.04\cos^2 2\theta$ $= 0.16+0.16\cos 2\theta + 0.04\left(\frac{\cos 4\theta+1}{2}\right)$	M1	2.1
	$\frac{1}{2}\int (0.4+0.2\cos 2\theta)^2 \,\mathrm{d}\theta = \frac{1}{2}\left[0.18\theta+0.08\sin 2\theta+0.005\sin 4\theta(+c)\right]$ $= 0.09\theta+0.04\sin 2\theta+0.0025\sin 4\theta(+c)$ o.e.	A1ft	1.1b
	Area enclosed by curve = $\left[0.09\theta+0.04\sin 2\theta+0.0025\sin 4\theta\right]_0^{2\pi}$ or Area enclosed by curve = $2\left[0.09\theta+0.04\sin 2\theta+0.0025\sin 4\theta\right]_0^{\pi}$ or Area enclosed by curve = $4\left[0.09\theta+0.04\sin 2\theta+0.0025\sin 4\theta\right]_0^{\pi/2}$	dM1	3.1a
	$= \frac{9}{50}\pi$ or $0.18\pi (=0.5654...)$	A1	1.1b

	Area of wood $=1.2\times0.6-0.18\pi$	M1	1.1b
	$=$ awrt 0.155 (m^2)	A1	1.1b
		(8)	
(10 marks)			

Notes

(a)
M1: Interprets the information from the model and realises that the maximum value of *r* gives half the length of the table top (or equivalent) and solves to find a value for *a*. Use $\theta=0$ and $r=0.6$ or $\theta=\pi$ and $r=-0.6$ to find a value for *a*.
Using $\theta=2\pi$ is M0
A1*: Correct value for *a*.

Alternative
M1: Uses $a = 0.2$ and $\theta=0$ to find a value for *r*
A1: Finds $r = 0.6$ and concludes that $a = 0.2$

(b)
B1: 1.2×0.6 or 0.72
M1: A correct strategy identified for finding an area enclosed by the polar curve using a correct formula with *r* substituted. Attempt at area $=\frac{1}{2}\int(0.4+0.2\cos2\theta)^2\,d\theta=...$

Look for $=\lambda\times\frac{1}{2}\int(0.4+0.2\cos2\theta)^2\,d\theta=...$

If the $\frac{1}{2}$ is not explicitly seen then look at the limits and it must be either

$$=\int_0^{\pi}(0.4+0.2\cos2\theta)^2\,d\theta=... \text{ or } =2\int_0^{\frac{\pi}{2}}(0.4+0.2\cos2\theta)^2\,d\theta=...$$

Condone missing $d\theta$

M1: Squares to achieve three terms and uses $\cos^2 2\theta=\frac{\pm1\pm\cos4\theta}{2}$ to obtain an expression in an integrable form.
A1ft: Correct follow through integration as long as the previous two method marks have been awarded.
dM1: Dependent of first method mark. Finds the required area enclosed by the curve using the correct limits.

There are only three cases either $\frac{1}{2}\int_0^{2\pi}(0.4+0.2\cos2\theta)^2\,d\theta$ or $\int_0^{\pi}(0.4+0.2\cos2\theta)^2\,d\theta$ or $2\int_0^{\frac{\pi}{2}}(0.4+0.2\cos2\theta)^2\,d\theta$

The use of the limit 0 can be implied if it gives 0 but the use of 0 must been seen or implied if it does not result in 0 (just writing 0 is insufficient)

Question	Scheme	Marks	AOs
3	$3(1-\sin\theta)=1+\sin\theta \Rightarrow \sin\theta=\frac{1}{2} \Rightarrow \theta=...$	M1	3.1a
	$\theta=\frac{\pi}{6}\left(\text{or } \frac{5\pi}{6}\right)$	A1	1.1b
	Use of $\frac{1}{2}\int(1+\sin\theta)^2\,\mathrm{d}\theta$ or $\frac{1}{2}\int\{3(1-\sin\theta)\}^2\,\mathrm{d}\theta$	M1	1.1a
	$\left(\frac{1}{2}\right)\int\left[(1+\sin\theta)^2-9(1-\sin\theta)^2\right]\mathrm{d}\theta$ $=\left(\frac{1}{2}\right)\int\left[1+2\sin\theta+\sin^2\theta-9+18\sin\theta-9\sin^2\theta\right]\mathrm{d}\theta$ or $\int(1+\sin\theta)^2\,\mathrm{d}\theta=\int(1+2\sin\theta+\sin^2\theta)\,\mathrm{d}\theta$ **and** $\int 9(1-\sin\theta)^2\,\mathrm{d}\theta=9\int(1-2\sin\theta+\sin^2\theta)\,\mathrm{d}\theta$	M1 A1	2.1 1.1b
	$\int\sin^2\theta\,\mathrm{d}\theta=\frac{1}{2}\int(1-\cos2\theta)\,\mathrm{d}\theta \Rightarrow$ $\int\left[(1+\sin\theta)^2-9(1-\sin\theta)^2\right]\mathrm{d}\theta=2\sin2\theta-12\theta-20\cos\theta$	M1 A1	3.1a 1.1b
	$A=\frac{1}{2}\int_{\frac{\pi}{6}}^{\frac{5\pi}{6}}\left[(1+\sin\theta)^2-9(1-\sin\theta)^2\right]\mathrm{d}\theta$ or $A=2\times\frac{1}{2}\int_{\frac{\pi}{6}}^{\frac{\pi}{2}}\left[(1+\sin\theta)^2-9(1-\sin\theta)^2\right]\mathrm{d}\theta$ $=\frac{1}{2}\left\{\left(-\sqrt{3}-10\pi+10\sqrt{3}\right)-\left(\sqrt{3}-2\pi-10\sqrt{3}\right)\right\}=...$	DM1	3.1a
	$=9\sqrt{3}-4\pi$	A1	1.1b
		(9)	

(9 marks)

Notes

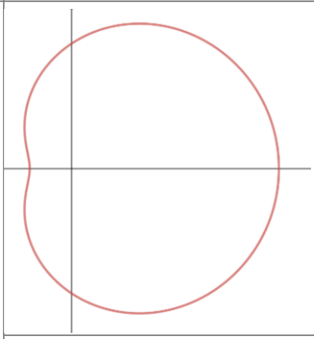
M1: Realises that the angles at the intersection are required and solves $C_1 = C_2$ to obtain a value for θ

A1: Correct value for θ. Must be in radians – if given in degrees you may need to check later to see if they convert to radians before substitution.

M1: Evidence selecting the correct polar area formula on either curve

M1: Fully expands both expressions for r^2 either as parts of separate integrals or as one complete integral. (Can be scored from incorrect polar area formula, e.g. missing the ½)

A1: Correct expansions for both curves (may be unsimplified)

Question	Scheme	Marks	AOs
6(a)	$x = r\cos\theta = a(p + 2\cos\theta)\cos\theta$ Leading to $\frac{dx}{d\theta} = \alpha\sin\theta\cos\theta + \beta\sin\theta(p + 2\cos\theta)$ or $\frac{dx}{d\theta} = \alpha\sin\theta\cos\theta + \beta\sin\theta$ or $x = a(p\cos\theta + 2\cos^2\theta) = a(\cos 2\theta + p\cos\theta + 1)$ leading to $\frac{dx}{d\theta} = \alpha\sin 2\theta + \beta\sin\theta$	M1	3.1a
	$\frac{dx}{d\theta} = a[-2\sin\theta\cos\theta - \sin\theta(p + 2\cos\theta)]$ or $\frac{dx}{d\theta} = -4a\sin\theta\cos\theta - ap\sin\theta$ or $\frac{dx}{d\theta} = -2a\sin 2\theta - ap\sin\theta$	A1	1.1b
	$a[-2\sin\theta\cos\theta - \sin\theta(p + 2\cos\theta)] = 0$ $\pm a(4\sin\theta\cos\theta + p\sin\theta) = 0$ $a\sin\theta(4\cos\theta + p) = 0$ Either $\sin\theta = 0$ or $\cos\theta = -\frac{p}{4}$	M1	3.1a
	$\sin\theta = 0$ implies 2 solutions (tangents which are perpendicular to the initial line) e.g. $\theta = 0, \pi$	B1	2.2a
	Therefore two solutions to $\cos\theta = -\frac{p}{4}$ are required $-\frac{p}{4} > -1 \Rightarrow p < 4$ as p is a positive constant $2 < p < 4$*	A1*	2.4
		(5)	
(b)	 Correct shape and position. Condone cusp	B1	2.2a
		(1)	
(c)	Area = $2\times\frac{1}{2}\int_0^{\pi}[20(3+2\cos\theta)]^2\, d\theta = 400\int_0^{\pi}(9 + 12\cos\theta + 4\cos^2\theta)\, d\theta$ or $= \int_0^{\pi}(3600 + 4800\cos\theta + 1600\cos^2\theta)\, d\theta$	M1	3.4

	or $\frac{1}{2}\int_0^{2\pi}\left[20(3+2\cos\theta)\right]^2 \mathrm{d}\theta = 200\int_0^{2\pi}\left(9+12\cos\theta+4\cos^2\theta\right)\mathrm{d}\theta$ or $=\int_0^{2\pi}\left(1800+2400\cos\theta+800\cos^2\theta\right)\mathrm{d}\theta$		
	$\cos^2\theta = \frac{1}{2}+\frac{1}{2}\cos 2\theta \Rightarrow$ $A = ...\int\left(9+12\cos\theta+2+2\cos 2\theta\right)\mathrm{d}\theta = \alpha\theta \pm \beta\sin\theta \pm \lambda\sin 2\theta$	M1	3.1a
	$=400\left[11\theta+12\sin\theta+\sin 2\theta\right]$ or $=200\left[11\theta+12\sin\theta+\sin 2\theta\right]$	A1	1.1b
	Using limits $\theta=0$ and $\theta=\pi$ or $\theta=0$ and $\theta=2\pi$ as appropriate and subtracts the correct way round provided there is an attempt at integration $=400\left[11\pi-0\right]=4400\pi=13823.0\left(\text{cm}^2\right)$ or $=200\left[11(2\pi)-0\right]=4400\pi=13823.0\left(\text{cm}^2\right)$	M1	1.1b
	Volume $=$ area $\times 90 = 396\ 000\pi = 1\ 244\ 070.691\left(\text{cm}^3\right)$	M1	3.4
	time = $\frac{1\,244\,070.691}{50\,000} = ...$ or volume = 1244 litres therefore time = $\frac{1244}{50} = ...$	M1	2.2b
	25 (minutes)	A1	3.2a
		(7)	
(d)	For example Polar equation is not likely to be accurate. Some comment that the sides will not be smooth and draws an appropriate conclusion. The hole may not be uniform depth The pond may leak/ ground may absorb some water	B1	3.5b
		(1)	
			(14 marks)

Notes:

(a)

M1: Complete method to find the correct form for $\frac{\mathrm{d}x}{\mathrm{d}\theta}$

A1: Correct $\frac{\mathrm{d}x}{\mathrm{d}\theta}$

M1: Sets $\frac{\mathrm{d}x}{\mathrm{d}\theta}=0$ and factorises to find values for either $\sin\theta$ or $\cos\theta$.

B1: Deduces that as $\sin\theta=0$ this provides two tangents. This can be implied by 2 values for θ

A1*: Concludes that as $\cos\theta = -\frac{p}{4} > -1 \Rightarrow p<4$ and p is a positive constant $\therefore\ 0<p<4$

Question	Scheme	Marks	AOs
7(a)	$x = r\cos\theta = (1+\tan\theta)\cos\theta = \cos\theta + \sin\theta$ $= \cos\theta + \tan\theta\cos\theta$ $\frac{dx}{d\theta} = \alpha(1+\tan\theta)\sin\theta + \beta\sec^2\theta\cos\theta$ or $\frac{dx}{d\theta} = \alpha\sin\theta + \beta\cos\theta$ $\frac{dx}{d\theta} = \alpha\sin\theta + \beta\sec^2\theta\cos\theta + \delta\tan\theta\sin\theta$	M1	3.1a
	$\frac{dx}{d\theta} = -(1+\tan\theta)\sin\theta + \sec^2\theta\cos\theta$ or $\frac{dx}{d\theta} = -\sin\theta + \cos\theta$ $\frac{dx}{d\theta} = -\sin\theta + \sec^2\theta\cos\theta - \tan\theta\sin\theta$ or $\frac{dx}{d\theta} = -\sin\theta + \sec\theta - \tan\theta\sin\theta$	A1	1.1b
	For example $\left\{\frac{dx}{d\theta} =\right\} -\sin\theta + \cos\theta = 0 \Rightarrow \tan\theta = 1 \Rightarrow \theta = \ldots$ $\left\{\frac{dx}{d\theta} =\right\} -\sin\theta + \cos\theta = 0 \Rightarrow \sin\theta = \cos\theta \Rightarrow \theta = \ldots$ $\left\{\frac{dx}{d\theta} =\right\} -\sin\theta + \cos\theta = \sqrt{2}\cos\left(\theta + \frac{\pi}{4}\right) = \theta = \ldots$ or $\left\{\frac{dx}{d\theta} =\right\} -(1+\tan\theta)\sin\theta + \sec^2\theta\cos\theta = 0$ $\Rightarrow -\sin\theta - \frac{\sin^2\theta}{\cos\theta} + \frac{1}{\cos\theta} = 0 \Rightarrow -\sin\theta + \frac{1-\sin^2\theta}{\cos\theta} = 0$ $\Rightarrow -\sin\theta + \cos\theta = 0 \Rightarrow \tan\theta = 1 \Rightarrow \theta = \ldots$ or $\left\{\frac{dx}{d\theta} =\right\} -\sin\theta - \tan\theta\sin\theta + \sec\theta = 0$ $\Rightarrow -\frac{1}{2}\sin 2\theta - \sin^2\theta + 1 = 0 \Rightarrow \sin 2\theta + 2\sin^2\theta - 1 = 1$ $\Rightarrow \sin 2\theta - \cos 2\theta = 1 \Rightarrow \sqrt{2}\sin\left(2\theta - \frac{\pi}{4}\right) = 1 \Rightarrow \theta = \ldots$ 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
	$r = 1 + \tan\left(\frac{\pi}{4}\right) = 2$ 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)	$= \frac{1}{2}\int (1 + 2\tan\theta + \tan^2\theta)\ \{d\theta\}$ $= \frac{1}{2}\int (1 + 2\tan\theta + [\sec^2\theta - 1])\ \{d\theta\} = \ldots$		
	$= \frac{1}{2}[2\ln\lvert\sec\theta\rvert + \tan\theta]$ or $\ln\lvert\sec\theta\rvert + \frac{1}{2}\tan\theta$ or $-\ln\cos\theta + \frac{1}{2}\tan\theta$ or $= \frac{1}{2}[-2\ln\lvert\cos\theta\rvert + \tan\theta]$	A1	1.1b
	$= \frac{1}{2}\left[2\ln\left\lvert\sec\left(\frac{\pi}{4}\right)\right\rvert + \tan\left(\frac{\pi}{4}\right)\right] - \frac{1}{2}[2\ln\lvert\sec(0)\rvert + \tan(0)]$ $= \left(\ln\left\lvert\sec\left(\frac{\pi}{4}\right)\right\rvert + \frac{1}{2}\tan\left(\frac{\pi}{4}\right)\right) - \left(\ln\lvert\sec 0\rvert + \frac{1}{2}\tan 0\right)$ $\left\{= \ln\sqrt{2} + \frac{1}{2}\right\}$	dM1	1.1b
	Area of triangle $= \frac{1}{2}xy = \frac{1}{2}\left(2\cos\frac{\pi}{4}\right)\left(2\sin\frac{\pi}{4}\right) = \ldots \left\{\frac{1}{2}\times\sqrt{2}\times\sqrt{2} = 1\right\}$ 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
	$= \frac{1}{2}(1 - \ln 2)$ * cso	A1*	2.1
		(6)	
	Alternative Area bounded by the curve $= \frac{1}{2}\int(1 + \tan\theta)^2\ \{d\theta\}$ $= \frac{1}{2}\int(1 + 2\tan\theta + \tan^2\theta)\ \{d\theta\}$ let $u = \tan\theta \Rightarrow \frac{du}{d\theta} = \sec^2\theta$ Leading to $= \frac{1}{2}\int \frac{(1 + 2u + u^2)}{1 + u^2}\{du\} = \frac{1}{2}\int 1 + \frac{2u}{1 + u^2}\{du\} = \ldots$	M1	3.1a
	$\frac{1}{2}[u + \ln(1 + u^2)]$	A1	1.1b
	$\frac{1}{2}[(1 + \ln(1 + (1)^2)) - (0 + \ln 1)]$ 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 $= \frac{1}{2}xy = \frac{1}{2}\left(2\cos\frac{\pi}{4}\right)\left(2\sin\frac{\pi}{4}\right) = \ldots \left\{\frac{1}{2}\times\sqrt{2}\times\sqrt{2} = 1\right\}$	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 θ – θ 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
1	Area $=\frac{1}{2}\int_0^{\pi} r^2\ \mathrm{d}\theta = \frac{1}{2}\int_0^{\pi}\left[2\sqrt{\sinh\theta+\cosh\theta}\right]^2\{\mathrm{d}\theta\}$ or $\frac{1}{2}\int_0^{\pi} 4\left(\sinh\theta+\cosh\theta\right)\{\mathrm{d}\theta\}$	B1	1.1b
	$=2\left[\cosh\theta+\sinh\theta\right]_0^{\pi}$ or $2\int_0^{\pi}\left(\frac{e^{\theta}-e^{-\theta}}{2}+\frac{e^{\theta}+e^{-\theta}}{2}\right)\mathrm{d}\theta = 2\int_0^{\pi} e^{\theta}\ \mathrm{d}\theta = 2\left[e^{\theta}\right]_0^{\pi}$	M1	1.1b
	$=2\left(\left(\cosh\pi+\sinh\pi\right)-\left(\cosh 0+\sinh 0\right)\right)$ $=2\left(\left(\frac{e^{\pi}+e^{-\pi}}{2}+\frac{e^{\pi}-e^{-\pi}}{2}\right)-\left(1+0\right)\right)$ or $=2\left(e^{\pi}-e^{0}\right)$	M1	3.1a
	$=2e^{\pi}-2$ or $2\left(e^{\pi}-1\right)$	A1	2.1
		(4)	
			(4 marks)

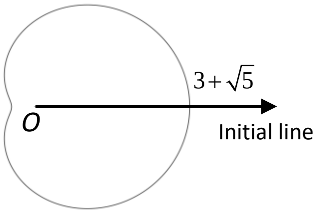
Notes:

B1: Correct area formula applied, including the $\frac{1}{2}$ and correct limits, may be seen later, $\mathrm{d}\theta$ may be implied.

M1: Attempts the integration $\sinh\theta \to \pm\cosh\theta$ and $\cosh\theta \to \pm\sinh\theta$ or in terms of exponentials $\int e^{\lambda\theta}\ \mathrm{d}\theta = \frac{1}{\lambda}e^{\lambda\theta}$

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 ½ from the definitions. This can be implied.

A1: Correct exact answer, no i

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)	$\frac{\mathrm{d}}{\mathrm{d}\theta}(r\sin\theta)=\frac{\mathrm{d}}{\mathrm{d}\theta}\left(3\sin\theta+\sqrt{5}\sin\theta\cos\theta\right)=A\cos\theta+B\cos 2\theta$ $\frac{\mathrm{d}}{\mathrm{d}\theta}(r\sin\theta)=\frac{\mathrm{d}}{\mathrm{d}\theta}\left(\left(3+\sqrt{5}\cos\theta\right)\sin\theta\right)=A\sin^2\theta+B\cos\theta+C\cos^2\theta$		**M1**	1.1b
	$\frac{\mathrm{d}}{\mathrm{d}\theta}(r\sin\theta)=\frac{\mathrm{d}}{\mathrm{d}\theta}\left(3\sin\theta+\sqrt{5}\sin\theta\cos\theta\right)=3\cos\theta+\sqrt{5}\cos 2\theta$ $\frac{\mathrm{d}}{\mathrm{d}\theta}(r\sin\theta)=\frac{\mathrm{d}}{\mathrm{d}\theta}\left(\left(3+\sqrt{5}\cos\theta\right)\sin\theta\right)=-\sqrt{5}\sin^2\theta+3\cos\theta+\sqrt{5}\cos^2\theta$		**A1**	1.1b
	$\frac{\mathrm{d}y}{\mathrm{d}x}=0\Rightarrow 3\cos\theta+\sqrt{5}\left(2\cos^2\theta-1\right)=0$ or $-\sqrt{5}\left(1-\cos^2\theta\right)+3\cos\theta+\sqrt{5}\cos^2\theta=0$ Leading to a quadratic in $\cos\theta$ $\left\{2\sqrt{5}\cos^2\theta+3\cos\theta-\sqrt{5}=0\right\}$		**M1**	3.1a
	$\cos\theta=\frac{1}{\sqrt{5}}$ following a correct quadratic, any extra solutions are rejected $\{\cos\theta=\frac{-3\pm 7}{4\sqrt{5}}$, 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.