Question	Answer	Marks	Guidance
11(a)	Multiply numerator and denominator by $(3-ai)$	**M1**	Must perform complete multiplications but need not simplify i^2. Can have errors but no term duplicated or missing. $\frac{(5a-2i)(3-ai)}{9-a^2} = \frac{13a-i(5a^2+6)}{9-a^2}$ M0 M1 A0 No working so unsure if denominator multiplied by $3-ai$ M1 M1 A0
	Use $i^2=-1$ at least once and separate real and imaginary parts	**M1**	
	Obtain $\frac{13a-i(5a^2+6)}{9+a^2}$ or $\frac{13a-5a^2i-6i}{9+a^2}$	**A1**	OE If $15a-2a=13a$ seen later award this A1.
	Use $\arg z$ to form equation in a $-\frac{5a^2+6}{13a}=\pm\tan\left(\pm\frac{\pi}{4}\right)$ or $-\frac{13a}{5a^2+6}=\pm\tan\left(\pm\frac{\pi}{4}\right)$ or $\tan^{-1}\left(-\frac{5a^2+6}{13a}\right)=\pm\frac{\pi}{4}$ or $\tan^{-1}\left(-\frac{13a}{5a^2+6}\right)=\pm\frac{\pi}{4}$	**M1**	Allow expression given in answer column or $5a^2+6=\pm 13a$ or use $-(x\pm xi)=(13a-i(5a^2+6))/(9+a^2)$ and eliminate x so $5a^2+6=\pm 13a$ M1.
	Obtain $a=2$	**A1**	Need to reject $a=\frac{3}{5}$ or ignore it in future work. May not see second root, but if present, must be $\frac{3}{5}$.
	Obtain $z=2-2i$ only	**A1**	Allow $z=-2i+2$.

Question	Answer	Marks	Guidance
11(b)	State $\arg(z^3)=-\frac{3}{4}\pi$ or evaluate from $z=b-bi$ or from $-2b^3(1+i)$	**B1**	If 2 different values given award B0. Do not ISW.
	Complete method to obtain r from *their* z	**M1**	$\lvert z^3\rvert=\left(\sqrt{x^2+y^2}\right)^3$. If z correct, may see $\lvert z^3\rvert=\left(\sqrt{2^2+(-2)^2}\right)^3$ or $\lvert z^3\rvert=\sqrt{(-16)^2+(-16)^2}$.
	$r=16\sqrt{2}$	**A1**	CAO A1 if $z=2-2i$ obtained correctly. or $z=$ used with $a=2$ found correctly, otherwise A0XP. May see arg and r given in a final answer i.e. $16\sqrt{2}e^{-\frac{3}{4}\pi i}$. Allow this form for arg and r to collect full marks, even if i missing. Ignore answers outside the given interval. If 2 different values given award A0.
		3	

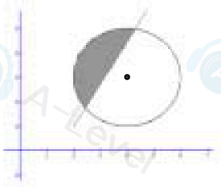
Question Number	Scheme	Marks
6(a)	$\theta=75, t=0 \Rightarrow 75=21+A \Rightarrow A=...$	M1
	$A=54$	A1
		(2)
(b)	$\theta=21+54e^{-kt} \Rightarrow 25=21+54e^{-5k}$	M1
	$54e^{-5k}=4 \Rightarrow e^{-5k}=\frac{2}{27} \Rightarrow -5k=\ln\frac{2}{27} \Rightarrow k=...$	M1
	$k=-\frac{1}{5}\ln\frac{2}{27}=0.521$	A1
		(3)

10(a)	Substitute $-1+\sqrt{2}\mathrm{i}$ and attempt expansions of the z^2 and z^4 terms	**M1**	
	Use $\mathrm{i}^2 = -1$ at least once	**M1**	
	Complete the verification correctly	**A1**	
		3	
10(b)	State second root $-1-\sqrt{2}\mathrm{i}$	**A1**	
	Carry out a method to find a quadratic factor with zeros $-1\pm\sqrt{2}\mathrm{i}$	**M1**	
	Obtain z^2+2z+3	**A1**	
	Commence division and reach partial quotient z^2+kz	**M1**	
	Obtain second quadratic factor z^2-2z+4	**A1**	
	Solve a 3-term quadratic and use $\mathrm{i}^2=-1$	**M1**	
	Obtain roots $1+\sqrt{3}\mathrm{i}$ and $1-\sqrt{3}\mathrm{i}$	**A1**	
		7	

Question	Answer	Marks	Guidance
2	Show a circle with centre the origin and radius 2	**B1**	
	Show the point representing 1 – i	**B1**	
	Show a circle with centre 1 – i and radius 1	**B1 FT**	The FT is on the position of 1 – i.
	Shade the appropriate region	**B1 FT**	The FT is on the position of 1 – i. Shaded region outside circle with centre the origin and radius 2 and inside circle with centre $\pm1 \pm \mathrm{i}$ and radius 1
		4	

4(a)	$A = 93$	B1
		(1)
(b)	$100 = 125 - "93"\mathrm{e}^{-0.109T} \Rightarrow A\mathrm{e}^{-0.109T} = \ldots$	M1
	$A\mathrm{e}^{kT} = B \Rightarrow T = \dfrac{\ln\left(\dfrac{B}{A}\right)}{k}$	dM1
	$T = 12.05$	A1
		(3)
(c)	$\dfrac{\mathrm{d}N}{\mathrm{d}t} = 0.109 \times "93"\mathrm{e}^{-0.109\times7}$	M1
	4 730 (total sales per month)	A1
		(2)
(d)	The limit is 125 000 / the model has a limit below 150 000	B1
		(1)
		(7 marks)

Question	Answer	Marks	Guidance
4	Obtain final answers $\frac{3}{5}+\frac{4}{5}\mathrm{i}$ and $-\mathrm{i}$ Accept 0.6 + 0.8i and 0 – i	**A1**	**SC** Both correct final answers from $10w^2 - 2(3-\mathrm{i})w + (3-\mathrm{i})^2 = 0$ with no working then **SC B1** for both. Allow $x = \frac{3}{5}$, $y = \frac{4}{5}$ or $x = 0$, $y = -1$. A0 for $\frac{3+4\mathrm{i}}{5}$.

Question	Answer	Marks	Guidance
6(a)	Show a circle centre (4, 3) Allow dashes for coordinates on axes	**B1**	Note full circle is not required but must show centre and include relevant arc.
	Show a circle with radius 2. Can be implied by at least two of the points (2, 3), (6, 3), (4, 1) and (4, 5) being correct	**B1FT**	FT centre not at the origin.
	Point representing (2, 1)	**B1**	Half-line or 'correct' full line extending into the third quadrant implies point (2, 1).
	Show a half-line at their (2, 1) at an angle of $\frac{1}{3}\pi$, cutting top of circle between $x = 3$ and $x = 5$	**B1FT**	FT the point (±2, ±1) or (±1, ±2).
	Shade the correct region Needs correct half-line or "correct" full line extending into the third quadrant **AND** correct circle	**B1**	
		5	
6(b)	Carry out a correct method for finding the greatest value of arg z in the correct region in (a)	**M1**	E.g. $\sin^{-1}(2/\sqrt{(25)}) + \tan^{-1}(3/4)$ or $\sin^{-1}(2/\sqrt{(25)}) + \sin^{-1}(3/5)$. Or, e.g., substitute $y = kx$ in circle equation, solve when discriminant = 0, to get $\tan^{-1}\left(\frac{6+\sqrt{21}}{6}\right)$.
	Obtain answer 1.06, or 1.05 or 1.055 or 1.056 or 60.4° or 60.5°	**A1**	The marks in **(b)** are available even if errors in **(a)**. No working seen scores 0/2 marks.
		2	

Question	Answer	Marks	Guidance
5(a)	Show a circle with centre -2	**B1**	
	Show a circle with radius 2 and centre not the origin	**B1**	
	Show the line $y = 1$	**B1**	
	Shade the correct region	**B1**	
		4	
5(b)	Identify the correct point and carry out a correct method to find the argument	**M1**	
	Obtain answer $\frac{11}{12}\pi$	**A1**	2.88 radians or 165°.
		2	

Question	Answer	Marks	Guidance
3	Square $x + iy$ obtaining three terms when simplified and equate real and imaginary parts to 24 and −7 respectively	**M1**	Having used $i^2 = -1$.
	Obtain equations $x^2 - y^2 = 24$ and $2xy = -7$	**A1**	Allow $2xyi = -7i$.
	Eliminate one variable by correct method and find a horizontal equation in the other	**M1**	All powers of x or y are positive and are in the numerator.
	Obtain $4x^4 - 96x^2 - 49 = 0$ or $4y^4 + 96y^2 - 49 = 0$ or 3-term equivalents	**A1**	
	Obtain answers $\frac{7\sqrt{2}}{2} - \frac{\sqrt{2}}{2}i$ and $-\frac{7\sqrt{2}}{2} + \frac{\sqrt{2}}{2}i$ or exact equivalents and no others	**A1**	E.g. $\pm\left(\frac{7\sqrt{2}}{2} - \frac{\sqrt{2}}{2}i\right)$, but not $\pm\left(\frac{7\sqrt{2}}{2} \mp \frac{\sqrt{2}}{2}i\right)$ or $\left(\pm\frac{7\sqrt{2}}{2} \mp \frac{\sqrt{2}}{2}i\right)$. Allow coordinates or $x = \ldots$, $y = \ldots$ paired correctly. ISW converting to different form. Must simplify $\sqrt{49}$.
		5	