Question	Answer	Marks	Guidance
1	$p^0q^{-5}r^{-\frac{2}{3}}$	**3**	**B1** for $a=0$ **B1** for $b=-5$ **B1** for $c=-\frac{2}{3}$
2(a)		**2**	**B1** for symmetrical V shape in the correct quadrant, touching the x-axis. Must have straight lines. **B1** for $x=\frac{4}{3}$ and $y=4$ only, either seen or stated on a modulus graph.
2(b)	$x\leqslant -1,\ x\geqslant\frac{11}{3}$ or 3.67 or better	**3**	**B1** for –1 from a correct method. **B1** for $\frac{11}{3}$ or 3.67 or better, from a correct method.
3(a)	$\overrightarrow{AC}=\mathbf{c}-\mathbf{a}$	**B1**	May be implied
	$\overrightarrow{OP}=\mathbf{a}+\frac{3}{5}\overrightarrow{AC}$ or $\mathbf{c}-\frac{2}{5}\overrightarrow{AC}$	**M1**	Maybe implied, for correct use of ratio $\overrightarrow{OP}=\mathbf{a}+\frac{3}{5}\left(their\,\overrightarrow{AC}\right)$ or $\mathbf{c}-\frac{2}{5}\left(their\,\overrightarrow{AC}\right)$
	$\overrightarrow{OP}=\frac{2}{5}\mathbf{a}+\frac{3}{5}\mathbf{c}$	**A1**	Allow unsimplified
3(b)	$\overrightarrow{OP}=\frac{2}{5}\mathbf{b}$ oe	**B1**	
	$\frac{2}{5}\mathbf{b}=\frac{2}{5}\mathbf{a}+\frac{3}{5}\mathbf{c}$ $2\mathbf{b}=2\mathbf{a}+3\mathbf{c}$	**B1**	**Dep** on previous B mark for equating vectors and rearrangement to obtain **AG**
	Alternative $\mathbf{b}=\frac{2}{5}\mathbf{a}+\frac{3}{5}\mathbf{c}+\frac{3}{5}\mathbf{b}$	**(B1)**	Need a clear indication of the method used, in the form of a correct unsimplified statement.
	$2\mathbf{b}=2\mathbf{a}+3\mathbf{c}$	**(B1)**	**Dep** for simplification to obtain AG

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4	$\left(\frac{dy}{dx}=\right)\ \frac{1}{2}(3x+2)^{\frac{2}{3}}\ \ (+c)$	**M1**	For $k_1(3x+2)^{\frac{2}{3}}$ where k_1 a constant.
	$4=2+c$	**M1**	**Dep** for use of 4 and $x=2$ in *their* $\frac{dy}{dx}$ to obtain c
	$\left(\frac{dy}{dx}=\right)\ \frac{1}{2}(3x+2)^{\frac{2}{3}}+2$	**A1**	May be implied by subsequent integration or by $c=2$
	$y=\frac{1}{10}(3x+2)^{\frac{5}{3}}\ \ \ (+2x+d)$	**M1**	For $k_2(3x+2)^{\frac{5}{3}}$ where k_2 is a constant.
	$6.2=\frac{1}{10}(32)+4+d$	**M1**	**Dep** on previous M1 for use of $x=2$ and $y=6.2$ in *their y*
	$y=\frac{1}{10}(3x+2)^{\frac{5}{3}}+2x-1$	**A1**	Must be an equation
5(a)	$p=16$	**2**	**B1** for $\log_a\frac{5p}{4}=\log_a 20$ oe **B1** for 16, nfww
5(b)	$\left(3\left(3^x\right)-1\right)\left(3^x+3\right)=0$	**M1**	For recognition of a correct quadratic in 3^x and attempt to factorise or use quadratic formula
	$3^x=\frac{1}{3}$ $x=-1$	**2**	**M1 dep** for a correct attempt to solve $3^x=k,\ k>0$ **A1** for one solution only, must be from a correct solution.

Question	Answer	Marks	Guidance
5(c)	$\log_y 2 = \dfrac{1}{\log_2 y}$ or $\log_2 y = \dfrac{1}{\log_y 2}$ or $\log_y 2 = \dfrac{\log_a 2}{\log_a y}$ **and** $\log_2 y = \dfrac{\log_a y}{\log_a 2}$	**B1**	May be implied
	$4(\log_y 2)^2 - 4(\log_y 2) + 1 = 0$ $(2\log_y 2 - 1)^2 = 0$, $\log_y 2 = \dfrac{1}{2}$ or $(\log_2 y)^2 - 4(\log_2 y) + 4 = 0$ $(\log_2 y - 2)^2 = 0$, $\log_2 y = 2$ or $(\log_a y)^2 - 4(\log_a 2)(\log_a 4)\log_a y$ $+4(\log_a 2)^2 = 0$ $(\log_a y - 2\log_a 2)^2 = 0$ $\log_a y = 2\log_a 2$	**M1**	For obtaining a 3 term quadratic equation in either $\log_y 2$ or $\log_2 y$ and solving to obtain $\log_y 2 = k$ or $\log_2 y = k$, may be implied or equivalent using an alternative base.
	$y = 4$	**A1**	nfww
6(a)	$\dfrac{dy}{dx} = 2(3+\sqrt{5})x - 8\sqrt{5}$ or $x = \dfrac{8\sqrt{5}}{2(3+\sqrt{5})}$	**M1**	Either For differentiation must have one correct term. or for use of '$b^2 - 4ac = 0$', so $x = -\dfrac{b}{2a}$ at the stationary point.
	$x = \dfrac{4\sqrt{5}}{3+\sqrt{5}} \times \dfrac{(3-\sqrt{5})}{(3-\sqrt{5})}$ oe leading to $\dfrac{12\sqrt{5}-20}{4}$ oe, this is the minimum acceptable working for this method.	**M1**	**Dep** for equating *their* $\dfrac{dy}{dx}$ to zero with attempt to solve and rationalisation using a two term factor, or rationalisation of $x = -\dfrac{b}{2a}$, using a two term factor with sufficient detail to imply no use of a calculator. Allow multiple equivalents. Allow one numerical slip or sign error.
	$x = -5 + 3\sqrt{5}$	**2**	**A1** for -5 **A1** for $3\sqrt{5}$

Question	Answer	Marks	Guidance
6(b)	$y=\left(3+\sqrt{5}\right)\left(3\sqrt{5}-5\right)^2$ $-8\sqrt{5}\left(3\sqrt{5}-5\right)+60$ $=\left(3+\sqrt{5}\right)\left(45+25-30\sqrt{5}\right)$ $-120+40\sqrt{5}+60$ $=210+70\sqrt{5}-90\sqrt{5}-150$ $-120+40\sqrt{5}+60$	**M1**	For substitution of *their x* and simplification with sufficient detail to imply no use of a calculator. Allow one numerical slip or sign error in the expansion of $\left(3+\sqrt{5}\right)\left(3\sqrt{5}-5\right)^2$ or one sign error in the other terms.
	$=20\sqrt{5}$	**2**	**A1** for all non surd terms = 0 **A1** for $20\sqrt{5}$
7(a)(i)	20160	**B1**	
7(a)(ii)	7200	**2**	**B1** for ${}^6\mathrm{P}_4$ or $6\times5\times4\times3\left(=360\right)$ for 'inner' characters or ${}^5\mathrm{P}_2$ or $4\times5\left(=20\right)$ for 'outer' characters Must be part of a product
7(a)(iii)	360	**2**	**B1** for ${}^3\mathrm{P}_3$ or 3! or 6 for arrangements of symbols or ${}^5\mathrm{P}_3$ or $5\times4\times3$ (= 60) for the digits Must be part of a product
7(b)	$\frac{n!}{(n-5)!5!}=\frac{6(n-1)!}{((n-1)-4)!4!}$	**B1**	May be implied by simplification e.g. $\frac{n!}{5!}=6\frac{(n-1)!}{4!}$ or $\frac{n(n-1)(n-2)(n-3)(n-4)}{5!}$ $=\frac{6(n-1)(n-2)(n-3)(n-4)}{4!}$
	Simplification of either the numerical factorials or the algebraic factorials	**M1**	
	$n=30$	**A1**	

Question	Answer	Marks	Guidance
8(a)	$\lg y = b\lg x + \lg A$	**B1**	May be implied by subsequent work
	$4.37 = 5.36b + \lg A$ $0.57 = 0.61b + \lg A$	**M1**	For at least one correct equation
	$b = 0.8$	**A1**	
	$\lg A = k \quad (0.082)$ $A = 10^k$	**M1**	**Dep** for substitution to obtain $\lg A = k$ and hence A
	$A = 1.21$	**A1**	
	Alternative 1 $\lg y = b\lg x + \lg A$	**(B1)**	May be implied by subsequent work
	Gradient = $\dfrac{4.37 - 0.57}{5.36 - 0.61}$	**(M1)**	
	$b = 0.8$	**(A1)**	
	$\lg A = k \quad (0.082)$ $A = 10^k$	**(M1)**	**Dep** for substitution into a correct equation to obtain $\lg A = k$ and hence A
	$A = 1.21$	**(A1)**	
	Alternative 2 $10^{4.37} = A \times 10^{5.36b}$ or $10^{0.57} = A \times 10^{0.61b}$	**(B1)**	
	$3.8 = 4.75b$	**(M1)**	For eliminating A correctly Must have B1.
	$b = 0.8$	**(A1)**	
	$A = 10^{4.37 - (5.36 \times (their b))}$ oe	**(M1)**	For a correct attempt to find A. Must have B1
	$A = 1.21$	**(A1)**	
8(b)	$y = 1.21(3)^{0.8}$ or $\lg y = 0.8\lg 3 + 0.082$	**B1**	**FT** for substitution into *their* equation
	y = awrt 2.9	**B1**	
8(c)	$3 = 1.21x^{0.8}$ or $\lg 3 = 0.8\lg x + 0.082$	**B1**	**FT** for substitution into *their* equation
	x = awrt 3.1	**B1**	

Question	Answer	Marks	Guidance
9(a)	$d = 12$	**B1**	
	$\frac{n}{2}\left(-8+(n-1)12\right) > 2000$ $3n^2 - 5n - 1000 > 0$	**M1**	For use of sum formula to obtain a three term quadratic inequality or equation
	$n = \frac{5 \pm \sqrt{25+12000}}{6}$ $n = 19.1$	**M1**	**Dep** for attempt at critical value(s) using *their* quadratic, may be using a calculator, so may be implied by a correct answer of 20.
	$n = 20$	**A1**	
9(b)(i)	$r = 3$	**2**	**M1** For $ar^6 = 27$ and $ar^8 = 243$ with an attempt to eliminate a to obtain r^2. Allow other valid methods.
9(b)(ii)	3^{26}	**2**	**B1** for $a = \frac{1}{27}$ or 3^{-3} nfww
9(c)	Common ratio or $r = \sin\theta$	**B1**	May be implied by e.g. $\frac{1}{1-\sin\theta}$ or $\frac{1-\sin^n\theta}{1-\sin\theta}$
	$-1 < \sin\theta < 1$ or $\lvert\sin\theta\rvert < 1$ or $-1 < r < 1$ or $\lvert r\rvert < 1$ with no incorrect statements seen.	**B1**	**Dep** on previous B1
10(a)	$\frac{1}{\sin\alpha} + \frac{1}{\cos\alpha} \quad (=0)$	**B1**	For dealing correctly with $\text{cosec}^2\alpha$ and $\sec^2\alpha$ to obtain an expression in $\sin\alpha$ and $\cos\alpha$ only
	$\tan\alpha = -1$ or $\sin\alpha = -\cos\alpha$	**B1**	For an equation in $\tan\alpha$, may be implied by a correct solution.
	$\alpha = -\frac{\pi}{4}$ or -0.785 $\alpha = \frac{3\pi}{4}$ or 2.36	**2**	**B1** for one correct solution **B1** for a second correct solution and no extra solutions in the range.

Question	Answer	Marks	Guidance
10(b)(i)	$\frac{\cos^2\theta+1-2\sin\theta+\sin^2\theta}{\cos\theta(1-\sin\theta)}$	**M1**	For dealing with the fractions correctly and expansion of $(1-\sin\theta)^2$
	$\frac{1+1-2\sin\theta}{\cos\theta(1-\sin\theta)}$ or better	**M1**	**Dep** for use of identity, may be implied by $\frac{2(1-\sin\theta)}{\cos\theta(1-\sin\theta)}$
	$\frac{2(1-\sin\theta)}{\cos\theta(1-\sin\theta)}$	**M1**	**Dep** on previous M mark for simplification
	$\frac{2}{\cos\theta}=2\sec\theta$	**A1**	Need to see this detail for A1 Need to have had θ in every trigonometric ratio.
	Alternative 1 $\left(\frac{\cos\theta}{1-\sin\theta}\times\frac{1+\sin\theta}{1+\sin\theta}\right)+\frac{1-\sin\theta}{\cos\theta}$	**(M1)**	
	$\frac{\cos\theta(1+\sin\theta)}{\cos^2\theta}+\frac{1-\sin\theta}{\cos\theta}$	**(M1)**	**Dep** for use of identity
	$\frac{1+\sin\theta}{\cos\theta}+\frac{1-\sin\theta}{\cos\theta}$	**(M1)**	**Dep** on previous M mark for simplification
	$\frac{2}{\cos\theta}=2\sec\theta$	**(A1)**	Need to see this detail for A1 Need to have had θ in every trigonometric ratio.
	Alternative 2 $\frac{(1-\sin^2\theta)+(1-\sin\theta)^2}{\cos\theta(1-\sin\theta)}$	**(M1)**	For dealing with the fractions and using $\cos^2\theta=1-\sin^2\theta$.
	$\frac{(1-\sin\theta)(1+\sin\theta)+(1-\sin\theta)^2}{\cos\theta(1-\sin\theta)}$	**(M1)**	**Dep** for factorising $1-\sin^2\theta$
	$\frac{1+\sin\theta+1-\sin\theta}{\cos\theta}$	**(M1)**	**Dep** for simplification
	$\frac{2}{\cos\theta}=2\sec\theta$	**(A1)**	Need to see this detail for A1 Need to have had θ in every trigonometric ratio.

Question	Answer	Marks	Guidance
10(b)(ii)	$\cos 3\phi = \frac{1}{2}$	**B1**	
	$\phi = 20^\circ, 100^\circ, 140^\circ$	**3**	**M1** for one correct solution of *their* $\cos 3\phi = k$ using a correct order of operations **A1** for 2 correct solutions **A1** for a third correct solution with no extra solutions in the range
11	$\frac{dy}{dx} = \frac{(2x-3)\frac{2x}{x^2+2} - 2\ln(x^2+2)}{(2x-3)^2}$	**3**	**B1** for $\frac{2x}{x^2+2}$ **M1** for differentiation of a quotient
	When $x = 2$, $\frac{dy}{dx} = \frac{4}{6} - 2\ln 6$, –2.92 Gradient of normal = 0.3428	**M1**	For $-\frac{1}{\textit{their } \frac{dy}{dx}}$
	When $x = 2$, $y = \ln 6$ or $1.79(176)$	**B1**	
	Equation of normal: $y - \ln 6 = -\frac{1}{\textit{their } \frac{dy}{dx}}(x-2)$ or $\ln 6 = -\frac{1}{\textit{their } \frac{dy}{dx}} \times (2) + c$	**M1**	**Dep** for equation of normal using $-\frac{1}{\textit{their } \frac{dy}{dx}}$ and *their y* with $x = 2$.
	When $x = 0$, $y =$ awrt 1.11	**A1**	Must be evaluated.