Algebraic Expressions- Answers

May 2019 Mathematics Advanced Paper 1: Pure Mathematics 1

1.

Question	Scheme		Marks	AOs
2(i)	$16a^2 = 2\sqrt{a} \Rightarrow a^{\frac{3}{2}} = \frac{1}{8}$	$16a^2 - 2\sqrt{a} = 0$ $\Rightarrow 2a^{\frac{1}{2}}\left(8a^{\frac{3}{2}} - 1\right) = 0$ $\Rightarrow a^{\frac{3}{2}} = \frac{1}{8}$	M1	1.1b
	$\Rightarrow a = \left(\frac{1}{8}\right)^{\frac{2}{3}}$	$\Rightarrow a = \left(\frac{1}{8}\right)^{\frac{2}{3}}$	M1	1.1b
	$\Rightarrow a = \frac{1}{4}$	$\Rightarrow a = \frac{1}{4}$	A1	1.1b
	Deduces that $a = 0$ is a solution		B1	2.2a
			(4)	
(ii)	$b^4 + 7b^2 - 18 = 0 \Rightarrow \left(b^2 + 9\right)\left(b^2 - 2\right) = 0$		M1	1.1b
	$b^2 = -9, 2$		A1	1.1b
	$b^2 = k \Rightarrow b = \sqrt{k}, k > 0$		dM1	2.3
	$b = \sqrt{2}$, $-\sqrt{2}$ only		A1	1.1b
			(4)	
				(8 marks)

(i)

M1: Combines the two algebraic terms to reach $a^{\pm\frac{3}{2}} = C$ or equivalent such as $\left(\sqrt{a}\right)^3 = C$ $(C \neq 0)$

An alternative is via squaring and combining the algebraic terms to reach $a^{\pm 3} = k, k > 0$

Eg. $...a^4 = ...a \Rightarrow a^{\pm 3} = k$ or $...a^4 = ...a \Rightarrow ...a^4 - ...a = 0 \Rightarrow ...a\left(a^3 - ...\right) = 0 \Rightarrow a^3 = ...$

Allow for slips on coefficients.

M1: Undoes the indices correctly for their $a^{\frac{m}{n}} = C$ (So M0 M1 A0 is possible)
You may even see logs used.

A1: $a = \frac{1}{4}$ and no other solutions apart from 0 Accept exact equivalents Eg 0.25

B1: Deduces that $a = 0$ is a solution.

(ii)

M1: Attempts to solve as a quadratic equation in b^2

Accept $(b^2+m)(b^2+n)=0$ with $mn=\pm 18$ or solutions via the use of the quadratic formula Also allow candidates to substitute in another variable, say $u=b^2$ and solve for u

A1: Correct solution. Allow for $b^2=2$ or $u=2$ with no incorrect solution given.

Candidates can choose to omit the solution $b^2=-9$ or $u=-9$ and so may not be seen

dM1: Finds at least one solution from their $b^2=k \Rightarrow b=\sqrt{k}, k>0$. Allow $b=1.414$

A1: $b=\sqrt{2}$, $-\sqrt{2}$ only. The solution asks for real values so if $3i$ is given then score A0

Answers with minimal or no working:

In part **(i)**

- no working, just answer(s) with they can score the B1
- If they square and proceed to the quartic equation $256a^4=4a$ oe, and then write down the answers they can have access to all marks.

In part (ii)

- Accept for 4 marks $b^2=2 \Rightarrow b=\pm\sqrt{2}$
- No working, no marks.

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2.

Question Number	Scheme		Marks
6.(a)	Replaces 2^{2x+1} with $2^{2x}\times 2$ or states $2^{2x+1}=2^{2x}\times 2$ or states $(2^x)^2=2^{2x}$	Uses the addition **or** power law of indices on 2^{2x} or 2^{2x+1}. E.g. $2^x\times 2^x=2^{2x}$ or $(2^x)^2=2^{2x}$ or $2^{2x+1}=2\times 2^{2x}$ or $2^{x+0.5}=2^x\times\sqrt{2}$ or $2^{2x+1}=(2^{x+0.5})^2$.	M1
	$2^{2x+1}-17\times 2^x+8=0$ $\Rightarrow 2y^2-17y+8=0$*	Cso. Complete proof that includes explicit statements for the addition **and** power law of indices on 2^{2x+1} with no errors. The equation needs to be as printed including the "= 0". If they work backwards, they do not need to write down the printed answer first but must end with the version in 2^x including '= 0'.	A1*

	The following are examples of acceptable proofs.	
	$2^{2x+1}=\left(2^{x+0.5}\right)^2=\left(2^x\sqrt{2}\right)^2=\left(y\sqrt{2}\right)^2=2y^2$ $\Rightarrow 2^{2x+1}-17\left(2^x\right)+8=2y^2-17y+8=0$	
	$2y^2=2\times2^x\times2^x=2^{2x+1}$ $\Rightarrow 2^{2x+1}-17\left(2^x\right)+8=2y^2-17y+8=0$	
	$2y^2-17y+8=0\Rightarrow 2\left(2^x\right)^2-17\left(2^x\right)+8=0$ $\Rightarrow 2\times2^{2x}-17\left(2^x\right)+8=0\Rightarrow 2^{2x+1}-17\left(2^x\right)+8=0$	
	$2^{2x+1}=2\times2^{2x}\Rightarrow 2\times2^{2x}-17\left(2^x\right)+8=0$ $\Rightarrow 2y^2-17y+8=0$ Scores **M1A0** as $2^{2x}=\left(2^x\right)^2$ has not been shown explicitly	
	Special Case: $2^{2x+1}=2^1\times\left(2^x\right)^2$ or $2^{2x+1}=\left(2^x\right)^2\times2^1$ **With or without the multiplication signs and with no subsequent explicit evidence of the power law scores M1A0**	
	Example of insufficient working: $2^{2x+1}=2\left(2^x\right)^2=2y^2$ **scores no marks as neither rule has been shown explicitly.**	
		(2)

(b)	$2y^2-17y+8=0\Rightarrow(2y-1)(y-8)(=0)\Rightarrow y=...$ or $2\left(2^x\right)^2-17\left(2^x\right)+8=0\Rightarrow\left(2\left(2^x\right)-1\right)\left(\left(2^x\right)-8\right)(=0)\Rightarrow 2^x=...$ Solves the **given** quadratic either in terms of y or in terms of 2^x See General Principles for solving a 3 term quadratic Note that completing the square on e.g. $y^2-\frac{17}{2}y+4=0$ requires $\left(y\pm\frac{17}{4}\right)^2\pm q\pm4=0\Rightarrow y=...$		M1
	$(y=)\frac{1}{2},8$ or $\left(2^x=\right)\frac{1}{2},8$	Correct values	A1
	$\Rightarrow 2^x=\frac{1}{2},8\Rightarrow x=-1,3$	M1: Either finds one correct value of x for their 2^x or obtains a correct numerical expression in terms of logs e.g. for $k>0$ $2^x=k\Rightarrow x=\log_2 k$ or $\frac{\log k}{\log 2}$ A1: $x=-1,3$ only. Must be values of x.	M1 A1
			(4)
			(6 marks)

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3.

Question Number	Scheme	Notes	Marks
2	9^{3x+1} = for example $3^{2(3x+1)}$ or $(3^2)^{3x+1}$ or $(3^{(3x+1)})^2$ or $3^{3x+1}\times 3^{3x+1}$ or $(3\times3)^{3x+1}$ or $3^2\times(3^2)^{3x}$ or $(9^{\frac{1}{2}})^y$ or $9^{\frac{1}{2}y}$ or $y=2(3x+1)$	Expresses 9^{3x+1} correctly as a power of 3 or expresses 3^y correctly as a power of 9 or expresses y correctly in terms of x **(This mark is <u>not</u> for just $3^2=9$)**	M1
	$= 3^{6x+2}$ or $y=6x+2$ or $a=6, b=2$	Cao (isw if necessary)	A1
	Providing there is no incorrect work, allow sight of $6x+2$ to score both marks Correct answer only implies both marks **Special case:** 3^{6x+1} **only** scores M1A0		
			[2]
	Alternative using logs		
	$9^{3x+1}=3^y \Rightarrow \log 9^{3x+1}=\log 3^y$		
	$(3x+1)\log 9 = y\log 3$	Use power law correctly on both sides	M1
	$y=\dfrac{\log 9}{\log 3}(3x+1)$		
	$y=6x+2$	cao	A1
			2 marks

4.

Question Number	Scheme	Notes	Marks
3.(a)	$\sqrt{50}-\sqrt{18}=5\sqrt{2}-3\sqrt{2}$	$\sqrt{50}=5\sqrt{2}$ or $\sqrt{18}=3\sqrt{2}$ **and** the other term in the form $k\sqrt{2}$. This mark may be implied by the correct answer $2\sqrt{2}$	M1
	$=2\sqrt{2}$	Or $a=2$	A1
			[2]
(b) **WAY 1**	$\dfrac{12\sqrt{3}}{\sqrt{50}-\sqrt{18}}=\dfrac{12\sqrt{3}}{"2"\sqrt{2}}$	Uses part (a) by replacing denominator by their $a\sqrt{2}$ where a is numeric. This is all that is required for this mark.	M1
	$=\dfrac{12\sqrt{3}}{"2"\sqrt{2}}\times\dfrac{\sqrt{2}}{\sqrt{2}}=\dfrac{12\sqrt{6}}{4}$	Rationalises the denominator by a correct method e.g. multiplies numerator and denominator by $k\sqrt{2}$ to obtain a multiple of $\sqrt{6}$. Note that multiplying numerator and denominator by $2\sqrt{2}$ or $-2\sqrt{2}$ is quite common and is acceptable for this mark. May be implied by a correct answer. **This is dependent on the first M1.**	dM1
	$=3\sqrt{6}$ or $b=3, c=6$	Cao and cso	A1
			[3]

(b) WAY 2	$\frac{12\sqrt{3}}{\sqrt{50}-\sqrt{18}} \times \frac{\sqrt{50}+\sqrt{18}}{\sqrt{50}+\sqrt{18}}$ **or** $\frac{12\sqrt{3}}{5\sqrt{2}-3\sqrt{2}} \times \frac{5\sqrt{2}+3\sqrt{2}}{5\sqrt{2}+3\sqrt{2}}$	For rationalising the denominator by a correct method i.e. multiplying numerator and denominator by $k\left(\sqrt{50}+\sqrt{18}\right)$	M1
	$\frac{60\sqrt{6}+36\sqrt{6}}{50-18}$	For replacing numerator by $\alpha\sqrt{6} + \beta\sqrt{6}$. **This is dependent on the first M1 and there is no need to consider the denominator for this mark.**	dM1
	$= 3\sqrt{6}$ or $b = 3, c = 6$	Cao and cso	A1
			[3]
(b) WAY 3	$\frac{12\sqrt{3}}{\sqrt{50}-\sqrt{18}} = \frac{12\sqrt{3}}{"2"\sqrt{2}}$	Uses part (a) by replacing denominator by their $a\sqrt{2}$ where a is numeric. This is all that is required for this mark.	M1
	$= \frac{12\sqrt{3}}{2\sqrt{2}} = \frac{6\sqrt{3}}{\sqrt{2}} = \frac{\sqrt{108}}{\sqrt{2}} = \sqrt{54} = \sqrt{9}\sqrt{6}$	Cancels to obtain a multiple of $\sqrt{6}$. **This is dependent on the first M1.**	dM1
	$= 3\sqrt{6}$ Or $b = 3, c = 6$	Cao and cso	A1
			[3]
(b) WAY 4	$\frac{12\sqrt{3}}{\sqrt{50}-\sqrt{18}} = \frac{12\sqrt{3}}{"2"\sqrt{2}}$	Uses part (a) by replacing denominator by their $a\sqrt{2}$ where a is numeric. This is all that is required for this mark.	M1
	$\left(\frac{12\sqrt{3}}{"2"\sqrt{2}}\right)^2 = \frac{432}{8}$		
	$\sqrt{54} = \sqrt{9}\sqrt{6}$	Obtains a multiple of $\sqrt{6}$. **This is dependent on the first M1.**	dM1
	$= 3\sqrt{6}$ Or $b = 3, c = 6$	Cao and cso (do not allow $\pm 3\sqrt{6}$)	A1
			5 marks

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5.

Question Number	Scheme		Marks
1.(a)	20	Sight of 20. (4×5 is not sufficient)	B1
			(1)
(b)	$\frac{\sqrt{2}}{2\sqrt{5}-3\sqrt{2}} \times \frac{2\sqrt{5}+3\sqrt{2}}{2\sqrt{5}+3\sqrt{2}}$	Multiplies top and bottom by a **correct** expression. This statement is sufficient. NB $2\sqrt{5}+3\sqrt{2} \equiv \sqrt{20}+\sqrt{18}$	M1
	(Allow to multiply top and bottom by $k(2\sqrt{5}+3\sqrt{2})$)		
	$= \frac{\cdots}{2}$	Obtains a denominator of 2 or sight of $\left(2\sqrt{5}-3\sqrt{2}\right)\left(2\sqrt{5}+3\sqrt{2}\right) = 2$ with no errors seen in this expansion. May be implied by $\frac{\cdots}{2k}$	A1
	Note that M0A1 is not possible. The 2 must come from a correct method.		
	Note that if M1 is scored there is no need to consider the numerator. e.g. $\frac{2(MR?)}{2\sqrt{5}-3\sqrt{2}} \times \frac{2\sqrt{5}+3\sqrt{2}}{2\sqrt{5}+3\sqrt{2}} = \frac{\cdots}{2}$ scores M1A1		

	Numerator = $\sqrt{2}(2\sqrt{5}\pm 3\sqrt{2}) = 2\sqrt{10}\pm 6$	An attempt to multiply the numerator by $\pm\left(2\sqrt{5}\pm 3\sqrt{2}\right)$ and obtain an expression of the form $p+q\sqrt{10}$ where p and q are integers. This may be implied by e.g. $2\sqrt{10}+3\sqrt{4}$ or by their final answer.	M1
	(Allow attempt to multiply the numerator by $k(2\sqrt{5}\pm 3\sqrt{2})$)		
	$\frac{\sqrt{2}}{2\sqrt{5}-3\sqrt{2}} = \frac{2\sqrt{10}+6}{2} = 3+\sqrt{10}$	Cso. For the answer as written or $\sqrt{10}+3$ or a statement that $a = 3$ and $b = 10$. Score when first seen and ignore any subsequent attempt to 'simplify'. Allow $1\sqrt{10}$ for $\sqrt{10}$	A1
			(4)
			(5 marks)
	Alternative for (b)		
	$\frac{\sqrt{2}}{2\sqrt{5}-3\sqrt{2}} = \frac{1}{\sqrt{10}-3}$ or $\frac{2}{2\sqrt{10}-6}$	M1: Divides or multiplies top and bottom by $\sqrt{2}$ A1: $\frac{k}{k\left(\sqrt{10}-3\right)}$	M1A1
	$= \frac{1}{\sqrt{10}-3} \times \frac{\sqrt{10}+3}{\sqrt{10}+3}$	M1: Multiplies top and bottom by $\sqrt{10}+3$	M1
	$= 3+\sqrt{10}$		A1

6.

Question Number	Scheme		Marks
7.(a)	$\left(4^x =\right) y^2$	Allow y^2 or $y \times y$ or "y squared" "$4^x =$" not required	B1
	Must be seen in part (a)		
			(1)
(b)	$8y^2 - 9y + 1 = (8y-1)(y-1) = 0 \Rightarrow y = ...$ or $(8(2^x)-1)((2^x)-1) = 0 \Rightarrow 2^x = ...$	For attempting to solve the given equation as a **3 term quadratic** in y or as a **3 term quadratic** in 2^x leading to a value of y or 2^x (Apply usual rules for solving the quadratic – see general guidance) Allow x (or any other letter) instead of y for this mark e.g. an attempt to solve $8x^2 - 9x + 1 = 0$	M1
	$2^x (\text{or } y) = \frac{1}{8},\ 1$	Both correct answers of $\frac{1}{8}$ (oe) and 1 for 2^x or y or their letter but **<u>not</u> *<u>x</u>*** unless $2^x (\text{or } y)$ is implied later	A1

	$x=-3 \quad x=0$	M1: A correct attempt to find one **numerical value** of x from their 2^x (or y) **which must have come from a 3 term quadratic equation**. If logs are used then they must be evaluated.	M1A1
		A1: Both $x=-3$ and/or $x=0$ May be implied by e.g. $2^{-3}=\frac{1}{8}$ and $2^0=1$ **and no extra values.**	
			(4)
			(5 marks)

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7.

Question Number	Scheme	Marks
2.	(a) $32^{\frac{1}{5}}=2$	B1 (1)
	(b) For 2^{-2} or $\frac{1}{4}$ or $\left(\frac{1}{2}\right)^2$ or 0.25 as coefficient of x^k, for any value of k including $k=0$	M1
	Correct index for x so Ax^{-2} or $\frac{A}{x^2}$ o.e. for any value of A	B1
	$=\frac{1}{4x^2}$ or $0.25x^{-2}$	A1 cao (3)
		4 Marks

Notes

(a) B1 Answer 2 must be in part (a) for this mark

(b) Look at their final answer

M1 For 2^{-2} or $\frac{1}{4}$ or $\left(\frac{1}{2}\right)^2$ or 0.25 in their answer as coefficient of x^k for numerical value of k (including $k=0$) so final answer $\frac{1}{4}$ is M1 B0 A0

B1 Ax^{-2} or $\frac{A}{x^2}$ or equivalent e.g. $Ax^{-\frac{10}{5}}$ or $Ax^{-\frac{50}{25}}$ i.e. correct power of x seen in final answer

May have a bracket provided it is $(Ax)^{-2}$ or $\left(\frac{A}{x}\right)^2$

A1 $\frac{1}{4x^2}$ or $\frac{1}{4}x^{-2}$ or $0.25x^{-2}$ oe but must be correct power **and** coefficient combined correctly and must not be followed by a different wrong answer.

Poor bracketing: $2x^{-2}$ earns M0 B1 A0 as correct power of x is seen in this solution (They can recover if they follow this with $\frac{1}{4x^2}$ etc)

Special case $(2x)^{-2}$ as a **final** answer and $\left(\frac{1}{2x}\right)^2$ can have M0 B1 A0 if the correct expanded answer is not seen

The correct answer $\frac{1}{4x^2}$ etc. followed by $\left(\frac{1}{2x}\right)^2$ or $(2x)^{-2}$, treat $\frac{1}{4x^2}$ as final answer so M1 B1 A1 isw

But the correct answer $\frac{1}{4x^2}$ etc clearly followed by the wrong $2x^{-2}$ or $4x^{-2}$, gets M1 B1 A0 do not ignore subsequent wrong work here

8.

Question Number	Scheme (Method 1)	Scheme (Method 2)	Marks
6.	(a) $80 = 5\times16$		
	$\sqrt{80}=4\sqrt{5}$		B1
			(1)
	Method 1	Method 2	
	(b) $\frac{\sqrt{80}}{\sqrt{5}+1}$ or $\frac{c\sqrt{5}}{\sqrt{5}+1}$	$(p+q\sqrt{5})(\sqrt{5}+1)=\sqrt{80}$	B1ft
	$=\frac{\sqrt{80}}{\sqrt{5}+1}\times\frac{\sqrt{5}-1}{\sqrt{5}-1}$ or $\frac{\sqrt{80}}{1+\sqrt{5}}\times\frac{1-\sqrt{5}}{1-\sqrt{5}}$	$p\sqrt{5}+q\sqrt{5}+p+5q=4\sqrt{5}$	M1
	$=\frac{20-4\sqrt{5}}{4}$ or $\frac{4\sqrt{5}-20}{-4}$	$p+5q=0$ $p+q=4$	A1
	$=5-\sqrt{5}$	$p=5,\ q=-1$	A1cao
			(4)
			(5 marks)

Notes

(a) B1 Accept $4\sqrt{5}$ or $c = 4$ – no working necessary

(b)

(Method 1)

B1ft Only ft on c See $\frac{\sqrt{80}}{\sqrt{5}+1}$ or $\frac{c\sqrt{5}}{\sqrt{5}+1}$

M1 State intention to multiply by $\sqrt{5}-1$ or $1-\sqrt{5}$ in the numerator **and** the denominator

A1 Obtain denominator of 4 (for $\sqrt{5}-1$) **or** -4 (for $1-\sqrt{5}$) **or** correct simplified numerator of $20-4\sqrt{5}$ or $4(5-\sqrt{5})$ **or** $4\sqrt{5}-20$ or $4(\sqrt{5}-5)$ **So either numerator or denominator must be correct**

A1 Correct answer only. Both **numerator and denominator must have been correct and d**ivision of numerator and denominator by 4 has been performed.

Accept $p=5,\ q=-1$ or accept $5-\sqrt{5}$ or $-\sqrt{5}+5$ Also accept $5-1\sqrt{5}$

(Method 2)

B1ft Only ft on c $(p+q\sqrt{5})(\sqrt{5}+1)=\sqrt{80}$ or $c\sqrt{5}$

M1 Multiply out the lhs and replace $\sqrt{80}$ by $c\sqrt{5}$

A1 Compare rational and irrational parts to give $p+q=4$, **and** $p+5q=0$

A1 Solve equations to give $p=5,\ q=-1$

Common error:

$\frac{\sqrt{80}}{1+\sqrt{5}}\times\frac{1-\sqrt{5}}{1-\sqrt{5}}=\frac{4\sqrt{5}-20}{4}=\sqrt{5}-5$ gets B1 M1 A1 (for correct numerator – denominator is wrong for their product) then A0

Correct answer with no working – send to review – have they used a calculator?

Correct answer after trial and improvement with evidence that $(5-\sqrt{5})(\sqrt{5}+1)=\sqrt{80}$ could earn all four marks

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9.

Question Number	Scheme		Marks
1	$\frac{7+\sqrt{5}}{\sqrt{5}-1}\times\frac{(\sqrt{5}+1)}{(\sqrt{5}+1)}$	Multiplies top and bottom by a correct expression. This statement is sufficient.	M1
	(Allow to multiply top and bottom by $k(\sqrt{5}+1)$)		
	$=\frac{\dots}{4}$	Obtains a denominator of 4 or sight of $(\sqrt{5}-1)(\sqrt{5}+1)=4$	A1cso
	Note that M0A1 is not possible. The 4 must come from a correct method.		
	$(7+\sqrt{5})(\sqrt{5}+1)=7\sqrt{5}+5+7+\sqrt{5}$	An attempt to multiply the numerator by $(\pm\sqrt{5}\pm1)$ and get 4 terms with at least 2 correct for their $(\pm\sqrt{5}\pm1)$. (May be implied)	M1
	$3+2\sqrt{5}$	Answer as written or $a=3$ and $b=2$. (Allow $2\sqrt{5}+3$)	A1cso
	Correct answer with no working scores full marks		
			[4]

Way 2	$\frac{7+\sqrt{5}}{\sqrt{5}-1}\times\frac{(-\sqrt{5}-1)}{(-\sqrt{5}-1)}$	Multiplies top and bottom by a correct expression. This statement is sufficient.	M1
	(Allow to multiply top and bottom by $k(-\sqrt{5}-1)$)		
	$=\frac{\cdots}{-4}$	Obtains a denominator of -4	A1cso
	$(7+\sqrt{5})(-\sqrt{5}-1)=-7\sqrt{5}-5-7-\sqrt{5}$	An attempt to multiply the numerator by $(\pm\sqrt{5}\pm1)$ and get 4 terms with at least 2 correct for their $(\pm\sqrt{5}\pm1)$. (May be implied)	M1
	$3+2\sqrt{5}$	Answer as written or $a=3$ and $b=2$	A1cso
	Correct answer with no working scores full marks		
			[4]
	Alternative using Simultaneous Equations: $\frac{(7+\sqrt{5})}{\sqrt{5}-1}=a+b\sqrt{5}\Rightarrow 7+\sqrt{5}=(a-b)\sqrt{5}+5b-a$ M1 Multiplies and collects rational and irrational parts $a-b=1,\ \ 5b-a=7$ A1 Correct equations $a=3,\ b=2$ M1 for attempt to solve simultaneous equations A1 both answers correct		

10.

Question Number	Scheme		Marks
3(a)	$8^{\frac{1}{3}}=2$ or $8^5=32768$	A correct attempt to deal with the $\frac{1}{3}$ or the 5. $8^{\frac{1}{3}}=\sqrt[3]{8}$ or $8^5=8\times8\times8\times8\times8$	M1
	$\left(8^{\frac{5}{3}}=\right)$ 32	Cao	A1
	A correct answer with no working scores full marks		
	Alternative $8^{\frac{5}{3}}=8\times8^{\frac{2}{3}}=8\times2^2=$ M1 (Deals with the 1/3) $=32$ A1		
			(2)

(b)	$\left(2x^{\frac{1}{2}}\right)^3 = 2^3 x^{\frac{3}{2}}$	One correct power either 2^3 or $x^{\frac{3}{2}}$. $\left(2x^{\frac{1}{2}}\right)\times\left(2x^{\frac{1}{2}}\right)\times\left(2x^{\frac{1}{2}}\right)$ on its own is not sufficient for this mark.	M1
	$\frac{8x^{\frac{3}{2}}}{4x^2} = 2x^{-\frac{1}{2}}$ or $\frac{2}{\sqrt{x}}$	M1: Divides coefficients of x **and** subtracts their powers of x. **Dependent on the previous M1** A1: Correct answer	dM1A1
	Note that unless the power of x implies that they have subtracted their powers you would need to see evidence of subtraction. E.g. $\frac{8x^{\frac{3}{2}}}{4x^2} = 2x^{\frac{1}{2}}$ would score dM0 unless you see some evidence that 3/2 – 2 was intended for the power of x.		
	Note that there is a misconception that $\frac{\left(2x^{\frac{1}{2}}\right)^3}{4x^2} = \left(\frac{2x^{\frac{1}{2}}}{4x^2}\right)^3$ - this scores 0/3		
			(3)
			[5]

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11.

Question Number	Scheme	Marks
2.	$(8^{2x+3} = \left(2^3\right)^{2x+3}) = 2^{3(2x+3)}$ or 2^{ax+b} with $a = 6$ **or** $b = 9$ $= 2^{6x+9}$ *or* $= 2^{3(2x+3)}$ as **final** answer with no errors or $(y =) 6x + 9$ or $3(2x + 3)$	M1 A1 **[2]** **2 marks**
	Notes	
	M1: Uses $8 = 2^3$, and **multiplies** powers $3(2x+3)$. Does **not** add powers. (Just $8 = 2^3$ or $8^{\frac{1}{3}} = 2$ is M0) **A1:** Either 2^{6x+9} *or* $= 2^{3(2x+3)}$ or $(y =) 6x + 9$ or $3(2x + 3)$	
	Note: Examples: 2^{6x+3} scores M1A0 : $8^{2x+3} = \left(2^3\right)^{2x+3} = 2^{3+2x+3}$ gets M0A0 **Special case:** : $= 2^{6x}\,2^9$ without seeing as single power M1A0 **Alternative method using logs:** $8^{2x+3} = 2^y \Rightarrow (2x+3)\log 8 = y\log 2 \Rightarrow y = \frac{(2x+3)\log 8}{\log 2}$ **So** $(y =) 6x + 9$ or $3(2x + 3)$	**M1** **A1** **[2]**

12.

Question Number	Scheme	Marks
3. (i)	$\left(5-\sqrt{8}\right)\left(1+\sqrt{2}\right)$ $=5+5\sqrt{2}-\sqrt{8}-4$ $=5+5\sqrt{2}-2\sqrt{2}-4$ — $\sqrt{8}=2\sqrt{2}$, seen or implied at any point. $=1+3\sqrt{2}$ — $1+3\sqrt{2}$ or $a=1$ and $b=3$.	 M1 B1 A1 **[3]**
(ii)	**Method 1** **Either** $\sqrt{80}+\frac{30}{\sqrt{5}}\left(\frac{\sqrt{5}}{\sqrt{5}}\right)$ $=4\sqrt{5}+\ldots$ $=4\sqrt{5}+6\sqrt{5}$ **Method 2** **Or** $\left(\frac{\sqrt{400}+30}{\sqrt{5}}\right)\frac{\sqrt{5}}{\sqrt{5}}$ $=\left(\frac{20+..}{..}\right)\frac{..}{..}$ $=\left(\frac{50\sqrt{5}}{5}\right)$ $=10\sqrt{5}$ **Method 3** $\sqrt{80}+\frac{\sqrt{900}}{\sqrt{5}}=\sqrt{80}+\sqrt{180}$ $=4\sqrt{5}+\ldots$ $=4\sqrt{5}+6\sqrt{5}$	M1 B1 A1 **[3]**
Alternative for (i)	$\left(5-2\sqrt{2}\right)\left(1+\sqrt{2}\right)$ — This earns the B1 mark and is entered on epen as B1 $=5+5\sqrt{2}-2\sqrt{2}-2\sqrt{2}\sqrt{2}$ — Multiplies out correctly with $2\sqrt{2}$. This may be seen or implied and may be simplified e.g. $=5+3\sqrt{2}-2\sqrt{4}$ o.e. For earlier use of $2\sqrt{2}$ $=1+3\sqrt{2}$ — $1+3\sqrt{2}$ or $a=1$ and $b=3$.	 M1 B1 A1 **[3]** **6 marks**
	Notes	
(i) (ii)	**M1:** Multiplies out brackets correctly giving four correct terms or simplifying to correct expansion. (This may be implied by correct answer) – can appear as table **B1:** $\sqrt{8}=2\sqrt{2}$, seen or implied at any point **A1:** Fully and correctly simplified to $1+3\sqrt{2}$ or $a=1$ and $b=3$. **M1:** Rationalises denominator i.e. Multiplies $\left(\frac{k}{\sqrt{5}}\right)$ by $\left(\frac{\sqrt{5}}{\sqrt{5}}\right)$ or $\left(\frac{-\sqrt{5}}{-\sqrt{5}}\right)$, seen or implied or uses Method 3 or similar e.g. $\left(\frac{30}{\sqrt{5}}\right)=\frac{6\times5}{\sqrt{5}}=6\sqrt{5}$ **B1**: (Independent mark) States $\sqrt{80}=4\sqrt{5}$ Or either $\sqrt{400}=20$ *or* $\sqrt{80}\sqrt{5}=20$ at any point if they use Method 2. **A1:** $10\sqrt{5}$ or $c=10$.	
	N.B There are other methods e.g. $\sqrt{80}=\frac{20}{\sqrt{5}}$ (B1) then add $\frac{20}{\sqrt{5}}+\frac{30}{\sqrt{5}}=\frac{50}{\sqrt{5}}$ then M1 A1as before Those who multiply initial expression by $\sqrt{5}$ to obtain $\sqrt{400}+30=20+30=50$ earn M0 B1 A0	

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13.

Question Number	Scheme	Marks
2. (a)	$\left\{(32)^{\frac{3}{5}}\right\} = \left(\sqrt[5]{32}\right)^3$ or $\sqrt[5]{(32)^3}$ or 2^3 or $\sqrt[5]{32768}$	M1
	$= 8$	A1 [2]
(b)	$\left\{\left(\frac{25x^4}{4}\right)^{-\frac{1}{2}}\right\} = \left(\frac{4}{25x^4}\right)^{\frac{1}{2}}$ or $\left(\frac{5x^2}{2}\right)^{-1}$ or $\frac{1}{\left(\frac{25x^4}{4}\right)^{\frac{1}{2}}}$ ***See notes below***	M1
	$= \frac{2}{5x^2}$ or $\frac{2}{5}x^{-2}$ ***See notes for other alternatives***	A1 [2] 4

	Notes
(a)	**M1:** for a full correct interpretation of the fractional power. **Note:** $5\times(32)^3$ is M0. **A1:** for 8 only. **Note:** Award M1A1 for writing down 8.
(b)	**M1:** For use of $\frac{1}{2}$ OR use of -1 **Use of** $\frac{1}{2}$**:** Candidate needs to demonstrate the they have rooted all three elements in their bracket. **Use of -1:** Either Candidate has $\frac{1}{\text{Bracket}}$ or $\left(\frac{Ax^C}{B}\right)$ becomes $\left(\frac{B}{Ax^C}\right)$. Allow M1 for... • $\left(\frac{4}{25x^4}\right)^{\frac{1}{2}}$ or $\left(\frac{5x^2}{2}\right)^{-1}$ or $\frac{1}{\left(\frac{25x^4}{4}\right)^{\frac{1}{2}}}$ or $\sqrt{\left(\frac{4}{25x^4}\right)}$ or $\frac{1}{\sqrt{\left(\frac{25x^4}{4}\right)}}$ or $\left(\frac{\frac{1}{25x^4}}{\frac{1}{4}}\right)^{\frac{1}{2}}$ or $\frac{\frac{1}{5x^2}}{\frac{1}{2}}$ or $\frac{\frac{1}{5}x^{-2}}{\frac{1}{2}}$ or $-\left(\frac{5x^2}{2}\right)$ or $\left(\frac{-5x^{-2}}{-2}\right)$ or $-\left(\frac{5x^{-2}}{2}\right)$ or $\frac{5x^{-2}}{2}$ • $\left(\frac{4}{25x^4}\right)^K$ or $\left(\frac{5x^2}{2}\right)^C$ where K, C are any powers including 1. **A1:** for either $\frac{2}{5x^2}$ or $\frac{2}{5}x^{-2}$ or $0.4x^{-2}$ or $\frac{0.4}{x^2}$. **Note:** $\left(\sqrt{\left(\frac{25x^4}{4}\right)}\right)^{-1}$ is not enough work by itself for the method mark. **Note:** A final answer of $\frac{1}{\frac{5}{2}x^2}$ or $\frac{1}{2\frac{1}{2}x^2}$ or $\frac{1}{2.5x^2}$ is A0. **Note:** Also allow $\pm\frac{2}{5x^2}$ or $\pm\frac{2}{5}x^{-2}$ or $\pm 0.4x^{-2}$ or $\pm\frac{0.4}{x^2}$ for A1.

14.

Question Number	Scheme		Marks
3.	$\left\{\frac{2}{\sqrt{12}-\sqrt{8}}\right\} = \frac{2}{(\sqrt{12}-\sqrt{8})} \times \frac{(\sqrt{12}+\sqrt{8})}{(\sqrt{12}+\sqrt{8})}$	Writing this is sufficient for M1.	M1
	$= \frac{\{2(\sqrt{12}+\sqrt{8})\}}{12-8}$	For $12-8$. This mark can be implied.	A1
	$= \frac{2(2\sqrt{3}+2\sqrt{2})}{12-8}$		B1 B1
	$= \sqrt{3}+\sqrt{2}$		A1 **cso**
			5

Notes

M1: for a correct method to rationalise the denominator.

1st A1: $(\sqrt{12}-\sqrt{8})(\sqrt{12}+\sqrt{8}) \to 12-8$ or $(\sqrt{3}+\sqrt{2})(\sqrt{3}-\sqrt{2}) \to 3-2$

1st B1: for $\sqrt{12} = 2\sqrt{3}$ or $\sqrt{48} = 4\sqrt{3}$ seen or implied in candidate's working.

2nd B1: for $\sqrt{8} = 2\sqrt{2}$ or $\sqrt{32} = 4\sqrt{2}$ seen or implied in candidate's working.

2nd A1: for $\sqrt{3}+\sqrt{2}$. Note: $\frac{\sqrt{3}+\sqrt{2}}{1}$ as a final answer is A0.

Note: The first accuracy mark is dependent on the first method mark being awarded.

Note: $\frac{1}{2}\sqrt{12}+\frac{1}{2}\sqrt{8} = \sqrt{3}+\sqrt{2}$ with no intermediate working implies the B1B1 marks.

Note: $\sqrt{12} = \sqrt{4}\sqrt{3}$ or $\sqrt{8} = \sqrt{4}\sqrt{2}$ are not sufficient for the B1 marks.

Note: A candidate who writes down (by misread) $\sqrt{18}$ for $\sqrt{8}$ can potentially obtain M1A0B1B1A0, where the 2nd B1 will be awarded for $\sqrt{18} = 3\sqrt{2}$ or $\sqrt{72} = 6\sqrt{2}$

Note: The final accuracy mark is for a correct solution only.

Alternative 1 solution

$\left\{\frac{2}{\sqrt{12}-\sqrt{8}}\right\} = \frac{2}{(2\sqrt{3}-2\sqrt{2})}$ B1 B1

$= \frac{1}{(\sqrt{3}-\sqrt{2})} \times \frac{(\sqrt{3}+\sqrt{2})}{(\sqrt{3}+\sqrt{2})}$ M1

$= \frac{\{(\sqrt{3}+\sqrt{2})\}}{3-2}$ A1 for $3-2$

$= \sqrt{3}+\sqrt{2}$ A1

Please record the marks in the relevant places on the mark grid.

Alternative 2 solution

$\left\{\frac{2}{\sqrt{12}-\sqrt{8}}\right\} = \frac{2}{(2\sqrt{3}-2\sqrt{2})} = \frac{1}{(\sqrt{3}-\sqrt{2})} = \sqrt{3}+\sqrt{2}$, or $\frac{2}{(2\sqrt{3}-2\sqrt{2})} = \sqrt{3}+\sqrt{2}$

with no incorrect working seen is awarded M1A1B1B1A1.

15.

Question	Scheme	Marks
2. (a)	$\sqrt{32} = 4\sqrt{2}$ or $\sqrt{18} = 3\sqrt{2}$	B1
	$\left(\sqrt{32}+\sqrt{18}=\right)$ $\underline{7\sqrt{2}}$	B1 (2)
(b)	$\times\dfrac{3-\sqrt{2}}{3-\sqrt{2}}$ or $\times\dfrac{-3+\sqrt{2}}{-3+\sqrt{2}}$ seen	M1
	$\left[\dfrac{\sqrt{32}+\sqrt{18}}{3+\sqrt{2}}\times\dfrac{3-\sqrt{2}}{3-\sqrt{2}}=\right]$ $\dfrac{a\sqrt{2}\left(3-\sqrt{2}\right)}{[9-2]}$ $\rightarrow$ $\dfrac{3a\sqrt{2}-2a}{[9-2]}$ (or better)	dM1
	$=$ $\underline{3\sqrt{2},-2}$	A1, A1 (4)
ALT	$(b\sqrt{2}+c)(3+\sqrt{2}) = 7\sqrt{2}$ leading to: $3b+c=7$, $3c+2b=0$ e.g. $3(7-3b)+2b=0$ (o.e.)	M1 dM1
		6 marks

	Notes
(a)	1st B1 for either surd simplified 2nd B1 for $7\sqrt{2}$ or accept $a = 7$. Answer only scores B1B1 NB Common error is $\sqrt{32}+\sqrt{18}=\sqrt{50}=5\sqrt{2}$ this scores B0B0 but can use their "5" in (b) to get M1M1
(b)	1st M1 for an attempt to multiply by $\dfrac{3-\sqrt{2}}{3-\sqrt{2}}$ (o.e.) Allow poor use of brackets 2nd dM1 for using $a\sqrt{2}$ to correctly obtain a numerator of the form $p+q\sqrt{2}$ where p and q are non-zero integers. Allow arithmetic slips e.g. $21\sqrt{2}-28$ or $3\sqrt{2}\times\sqrt{2}=3$ Follow through their $a = 7$ or a new value found in (b). Ignore denominator. Allow use of letter a. Dependent on 1st M1 So $3\sqrt{32}-\sqrt{64}+3\sqrt{8}-\sqrt{36}$ is M0 until they reduce $p+q\sqrt{2}$ 1st A1 for $3\sqrt{2}$ or accept $b = 3$ from correct working 2nd A1 for -2 or accept $c = -2$ from correct working
ALT	**Simultaneous Equations** 1st M1 for $(b\sqrt{2}+c)(3+\sqrt{2}) = 7\sqrt{2}$ and forming 2 simultaneous equations. Ft their $a = 7$ 2nd dM1 for solving their simultaneous equations: reducing to a linear equation in one variable

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16.

Question Number	Scheme	Marks
1. **(a)**	5 (or ± 5)	B1 (1)
(b)	$25^{-\frac{3}{2}} = \frac{1}{25^{\frac{3}{2}}}$ **or** $25^{\frac{3}{2}} = 125$ or better	M1
	$\frac{1}{125}$ or 0.008 (or $\pm \frac{1}{125}$)	A1
		(2) **3**
	Notes	
	(a) Give B1 for 5 or ± 5 Anything else is B0 (including just -5) (b) M: Requires reciprocal OR $25^{\frac{3}{2}} = 125$ Accept $\frac{1}{5^3}, \frac{1}{\sqrt{15625}}, \frac{1}{25\times5}, \frac{1}{25\sqrt{25}}, \frac{1}{\sqrt{25^3}}$ for M1 Correct answer with no working (or notation errors in working) scores both marks i.e. M1 A1 M1A0 for - $\frac{1}{125}$ without $+\frac{1}{125}$	

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17.

Question Number	Scheme	Marks
1. **(a)**	$16^{\frac{1}{4}} = 2$ or $\frac{1}{16^{\frac{1}{4}}}$ or better	M1
	$\left(16^{-\frac{1}{4}} =\right) \frac{1}{2}$ or 0.5 (ignore $\pm$)	A1
		(2)
(b)	$\left(2x^{-\frac{1}{4}}\right)^4 = 2^4 x^{-\frac{4}{4}}$ or $\frac{2^4}{x^{\frac{4}{4}}}$ or equivalent	M1
	$x\left(2x^{-\frac{1}{4}}\right)^4 = 2^4$ or 16	A1 cao
		(2) **4**

	Notes	
(a)	M1 for a correct statement dealing with the $\frac{1}{4}$ or the $-$ power This may be awarded if 2 is seen or for reciprocal of their $16^{\frac{1}{4}}$ s.c ¼ is M1 A0 , also 2^{-1} is M1 A0 $\pm\frac{1}{2}$ is not penalised so M1 A1	
(b)	M1 for **correct** use of the power 4 on both the 2 and the x terms A1 for cancelling the x and simplifying to one of these two forms. Correct answers with no working get full marks	

18.

Question Number	Scheme	Marks
3.	$\frac{5-2\sqrt{3}}{\sqrt{3}-1}\times\frac{(\sqrt{3}+1)}{(\sqrt{3}+1)}$	M1
	$=\frac{\dots}{2}$ denominator of 2	A1
	Numerator $= 5\sqrt{3}+5-2\sqrt{3}\sqrt{3}-2\sqrt{3}$	M1
	So $\frac{5-2\sqrt{3}}{\sqrt{3}-1}=-\frac{1}{2}+\frac{3}{2}\sqrt{3}$	A1
		4
	Alternative: $(p+q\sqrt{3})(\sqrt{3}-1)=5-2\sqrt{3}$, and form simultaneous equations in p and q	M1
	$-p+3q=5$ and $p-q=-2$	A1
	Solve simultaneous equations to give $p=-\frac{1}{2}$ and $q=\frac{3}{2}$.	M1 A1
	Notes	
	1st M1 for multiplying numerator and denominator by same correct expression 1st A1 for a correct denominator as a single number (NB depends on M mark) 2nd M1 for an attempt to multiply the numerator by $(\sqrt{3}\pm1)$ and get 4 terms with at least 2 correct. 2nd A1 for the answer as written or $p=-\frac{1}{2}$ and $q=\frac{3}{2}$. Allow -0.5 and 1.5. (Apply isw if correct answer seen, then slip writing $p=$, $q=$)	
	Answer only (very unlikely) is full marks if correct – no part marks	

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19.

Question Number	Scheme	Marks
1.	$\left(\sqrt{75}-\sqrt{27}\right)=5\sqrt{3}-3\sqrt{3}$	M1
	$= 2\sqrt{3}$	A1 **2**
	Notes	
	M1 for $5\sqrt{3}$ from $\sqrt{75}$ or $3\sqrt{3}$ from $\sqrt{27}$ seen anywhere A1 for $2\sqrt{3}$; allow $\sqrt{12}$ or $k=2, x=3$ or allow $k=1, x=12$ Some Common errors $\sqrt{75}-\sqrt{27}=\sqrt{48}$ leading to $4\sqrt{3}$ is M0A0 $25\sqrt{3}-9\sqrt{3}=16\sqrt{3}$ is M0A0	

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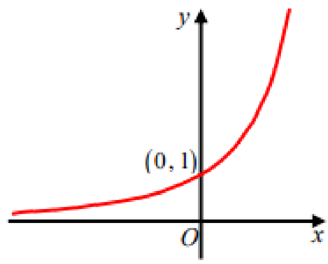
20.

Question number	Scheme	Marks
Q2	(a) $(7+\sqrt{5})(3-\sqrt{5})=21-5+3\sqrt{5}-7\sqrt{5}$ Expand to get 3 or 4 terms	M1
	$=16, \ -4\sqrt{5}$ (1[st] A for 16, 2[nd] A for $-4\sqrt{5}$) (i.s.w. if necessary, e.g. $16-4\sqrt{5} \to 4-\sqrt{5}$)	A1, A1 (3)
	(b) $\frac{7+\sqrt{5}}{3+\sqrt{5}}\times\frac{3-\sqrt{5}}{3-\sqrt{5}}$ (This is sufficient for the M mark)	M1
	Correct denominator without surds, i.e. $9-5$ or 4	A1
	$4-\sqrt{5}$ or $4-1\sqrt{5}$	A1 (3) **[6]**

	(a) M1: Allowed for an attempt giving 3 or 4 terms, with at least 2 correct (even if unsimplified). e.g. $21-\sqrt{5}^2+\sqrt{15}$ scores M1. Answer only: $16-4\sqrt{5}$ scores full marks One term correct scores the M mark by implication, e.g. $26-4\sqrt{5}$ scores M1 A0 A1 (b) Answer only: $4-\sqrt{5}$ scores full marks One term correct scores the M mark by implication, e.g. $4+\sqrt{5}$ scores M1 A0 A0 $16-\sqrt{5}$ scores M1 A0 A0 Ignore subsequent working, e.g. $4-\sqrt{5}$ so $a=4,\ b=1$ Note that, as always, A marks are dependent upon the preceding M mark, so that, for example, $\frac{7+\sqrt{5}}{3+\sqrt{5}}\times\frac{3+\sqrt{5}}{3-\sqrt{5}}=\frac{\dots\dots}{4}$ is M0 A0. <u>Alternative</u> $(a+b\sqrt{5})(3+\sqrt{5})=7+\sqrt{5}$, then form simultaneous equations in a and b. M1 Correct equations: $3a+5b=7$ and $3b+a=1$ A1 $a=4$ and $b=-1$ A1	

Question Number	Scheme		Marks
8.			
(a)	Graph of $y = 7^x, x \in \mathbb{R}$ and solving $7^{2x} - 4(7^x) + 3 = 0$		
		At least two of the three criteria correct. **(See notes below.)**	B1
		All three criteria correct. **(See notes below.)**	B1
			(2)
(b)	$y^2 - 4y + 3 \{= 0\}$	Forming a quadratic {using $"y" = 7^x$ }.	M1
		$y^2 - 4y + 3\{= 0\}$	A1
	$\{(y-3)(y-1) = 0$ or $(7^x - 3)(7^x - 1) = 0\}$		
	$y = 3,\ y = 1$ or $7^x = 3,\ 7^x = 1$	Both $y = 3$ and $y = 1$.	A1
	$\{7^x = 3 \Rightarrow\}\ x\log 7 = \log 3$ or $x = \dfrac{\log 3}{\log 7}$ or $x = \log_7 3$	A valid method for solving $7^x = k$ where $k > 0, k \neq 1$	dM1
	$x = 0.5645....$	0.565 or awrt 0.56	A1
	$x = 0$	$x = 0$ stated as a solution.	B1
			(6) **[8]**

	Notes
(a)	B1B0: Any two of the following three criteria below correct. B1B1: All three criteria correct. Criteria number 1: Correct shape of curve for $x \geq 0$. Criteria number 2: Correct shape of curve for $x < 0$. Criteria number 3: $(0, 1)$ stated or 1 marked on the y-axis. Allow $(1, 0)$ rather than $(0, 1)$ if marked in the "correct" place on the y-axis.
(b)	1st M1 is an attempt to form a quadratic equation {using $"y" = 7^x$.} 1st A1 mark is for the correct quadratic equation of $y^2 - 4y + 3\{= 0\}$. Can use any variable here, eg: y, x or 7^x. Allow M1A1 for $x^2 - 4x + 3\{= 0\}$. Writing $(7^x)^2 - 4(7^x) + 3 = 0$ is also sufficient for M1A1. Award M0A0 for seeing $7^{x^2} - 4(7^x) + 3 = 0$ by itself without seeing $y^2 - 4y + 3\{= 0\}$ or $(7^x)^2 - 4(7^x) + 3 = 0$. 1st A1 mark for both $y = 3$ and $y = 1$ or both $7^x = 3$ and $7^x = 1$. Do not give this accuracy mark for both $x = 3$ and $x = 1$, unless these are recovered in later working by candidate applying logarithms on these. Award M1A1A1 for $7^x = 3$ and $7^x = 1$ written down with no earlier working. 3rd dM1 for solving $7^x = k, k > 0, k \neq 1$ to give either $x\ln 7 = \ln k$ or $x = \dfrac{\ln k}{\ln 7}$ or $x = \log_7 k$. dM1 is dependent upon the award of M1. 2nd A1 for 0.565 or awrt 0.56. B1 is for the solution of $x = 0$, from ***any*** working.