1	$3^4 = \frac{3^x}{9^{3x}}$ **or** $81 = \frac{3^x}{(3^2)^{3x}}$	$9^2 = \frac{3^x}{9^{3x}}$ **or** $81 = \frac{(9^{0.5})^x}{9^{3x}}$			M1	replacing 81 with 3^4 **or** 9^{3x} with $(3^2)^{3x}$ (or 3^{6x}) **or** replacing 81 with 9^2 **or** 3^x with $(9^{0.5})^x$ (in an equation)
	eg $4 + 6x = x$ or $4 = x - 2(3x)$ oe	eg $2 = 0.5x - 3x$ oe			M1	a correct equation using powers
			-0.8	3	A1	oe, dep on at least M1
						Total 3 marks

2	(b)	$(8^{5y} =) 2^{15y}$ or $(4^n =) 2^{2n}$ or 2^{5y+2}		4	M1	
		$2^{5y+2} = 2^{15y-2n}$ oe			M1	e.g. $2^{2n} = 2^{15y-5y-2}$
		$5y + 2 = 15y - 2n$ oe			M1	Correct equation using the powers
			$n = 5y - 1$		A1	Dep on M2 (accept $5y - 1$)

3	(a)	$2^{\frac{1}{2}} \times 2^4$ **or** eg $2 \times (2^4)^2 = (2^x)^2$ or $2^9 = 2^{2x}$		2	M1	for a correct expression in powers of 2 that is equivalent to 2^x eg $2^{\frac{1}{2}} \times 2^4$ **or** for showing $\sqrt{2} = 2^{\frac{1}{2}}$ **and** $16 = 2^4$ **or** for writing the equation in powers of 2 eg $2 \times (2^4)^2 = (2^x)^2$ or $2^9 = 2^{2x}$
		Working required	$\frac{9}{2}$		A1	**or** 4.5 **or** 4½ dependent on M1
	(b)	$\frac{11^{-30}}{11^4}$ **or** $-30 - 4 = n$ **or** $-30 = n + 4$ oe		2	M1	For $(11^{-6})^5$ written as 11^{-30} in the equation or $(11^{-6})^5 = 11^{-30}$ shown in working **or** a correct equation with indices only (no marks for $3.914....\times 10^{-36}$)
		Working required	-34		A1	dep on M1 (as we have asked for working)
						Total 4 marks

4		$\frac{4y^5}{3x^2}$	3	B3	Accept $\frac{4}{3}x^{-2}y^5$ or $\frac{4x^{-2}y^5}{3}$ or $1.\dot{3}x^{-2}y^5$ oe NB: Must see 4 and 3 and not $16^{\frac{1}{2}}$ or $9^{\frac{1}{2}}$ or $16^{-\frac{1}{2}}$ or $9^{-\frac{1}{2}}$ (allow use of 1.3[33..])
					If not B3 then B2 for 2 of: correct fraction ($\frac{4}{3}$ or $1.\dot{3}$)(allow use of 1.3[33..]) **or** x term correct (x^2 on denominator or x^{-2} on numerator) **or** y term correct (y^5 on numerator or y^{-5} on denominator)
					If not B2 then **B1** for 1 of : correct fraction **or** x term correct **or** y term correct **or** for one of applying negative power to at least 3 out of 4 of $9, x^4, 16, y^{10}$ **or** applying square root to at least 3 out of 4 of $9, x^4, 16, y^{10}$ eg at least 3 of the 4 parts of $\frac{16y^{10}}{9x^4}$ **or** $\frac{16x^{-4}}{9y^{-10}}$ **or** $\frac{\frac{1}{9}x^{-4}}{\frac{1}{16}y^{-10}}$ **or** $\frac{3x^2}{4y^5}$ oe
					Total 3 marks

5	(a)	eg $(2^3)^2\times\sqrt[3]{(2^2)^6}$ **or** $(2^3)^2\times(4)^{\frac{6}{3}}$ **or** $4^3\times4^2$ **or** 2^6 or 2^4 seen **or** $2^6\times16$ or 64×4^2 or $8^2\times4^2$ or $8^2\times16$ or 64×16		3	M1	a correct first stage.
		$2^6\times(2^{12})^{\frac{1}{3}}$ **or** 1024 **or** 32^2 **or** 4^5 or $2^6\times2^4$			M1	dep on 1st M mark.
			2^{10}		A1	dependent on first M1 isw if 2^{10} seen but then 10 given as answer.
	(b)	$(n^{-\frac{4}{5}}=)\frac{1}{16}$ or 0.0625 oe	eg $\left(n^{-\frac{1}{5}}\right)^4=\left(\frac{1}{2}\right)^4$		4	M1	for sight of $\frac{1}{16}$ oe, even if raised to an incorrect power. **or** for algebraic approach, separating out the 4, or 5 or -1 in the power
		$(n=)\ 16^{\frac{5}{4}}$ or $0.0625^{-\frac{5}{4}}$ oe $(n=)\ 2^5$ or $\sqrt[4]{1048576}$ oe or $\frac{1}{0.0625^{\frac{5}{4}}}$ or $\left(\frac{1}{16}\right)^{-\frac{5}{4}}$	eg $(n=)\ \left(\frac{1}{2}\right)^{-5}$			M2	for a correct expression for n (M1 for one correct algebraic stage eg $n^{-\frac{1}{5}}=\frac{1}{2}$)
			32		A1	
						Total 7 marks

6	$(4^n=)(2^2)^n$ **or** $(4^n=)2^{2n}$ oe eg $2^k\div2^{2n}=2^x$ **or** $2^k=4^{\frac{1}{2}k}$ **and** $2^x=4^{\frac{1}{2}x}$ oe eg $\frac{4^{\frac{1}{2}k}}{4^n}=4^{\frac{1}{2}x}$		2	M1	for writing 4^n as $\left(2^2\right)^n$ or 2^{2n} or for writing each term in terms of 4 ie $2^k=4^{\frac{1}{2}k}$ **and** $2^x=4^{\frac{1}{2}x}$ If these things are seen in working, award this mark even if followed by incorrect working – if not a choice of methods
		$k-2n$		A1	allow 2^{k-2n}
					Total 2 marks

7	(a)		$-\frac{4}{3}$	1	B1	

8	216 or 2.16 or 10^{120} or 10^{122} or $6^3\times10^{40\times3}$		3	M1	or for digits 216
	216×10^{120} oe or or 2.16×10^n where $n\neq122$			M1	
		2.16×10^{122}		A1	
					Total 3 marks

9	$2^{-4x}=2^5$ or $-4x=5$ or $-\frac{4}{5}x=1$ oe		2	M1	
	Correct answer scores full marks (unless from obvious incorrect working)	$-\frac{5}{4}$		A1	oe allow eg $\frac{5}{-4}$
					Total 2 marks

10	2^3 **and** 2^{4x} or $(2^4)^x$		5	M1	for writing 16^x **and** 8 as a power of 2 (or all as powers of 4,8 or 16)
	$n = x^2 + 4x + 3$ oe or $x^2 + 4x + 3 - n = 0$			A1	for writing n in terms of x correct expression implies first M1
	$(n =)(x+2)^2 - 2^2$..... oe or $(x =) -2 \pm \sqrt{n+1}$ $(x =) \dfrac{-4 \pm \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe			M1	for a correct first step in completing the square or using the quadratic formula correctly ft their 3 term quadratic
	$(x =) -2 + \sqrt{n+1}$ oe or $(x =) \dfrac{-4 + \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe			A1	for correctly rearranging to make x the subject (must be positive square root)
	Correct answer scores full marks (unless from obvious incorrect working)	$(x =) -2 + \sqrt{n+1}$ **and** $n > 3$		A1	must be positive square root Accept $(x =)\sqrt{n+1} - 2$ oe and $3 < n$ Accept $(x =) \dfrac{-4 + \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe **and** $n > 3$ or $3 < n$
					Total 5 marks

10 ALT	$4^{\frac{1}{2^n}}$, $4^{\frac{1}{2^{x^2}}}$, 4^{2x} **and** $4^{\frac{3}{2}}$	$8^{\frac{1}{3^n}}$, $8^{\frac{1}{3^{x^2}}}$ **and** $8^{\frac{4}{3^x}}$	$16^{\frac{1}{4^n}}$, $16^{\frac{1}{4^{x^2}}}$ **and** $16^{\frac{3}{4}}$	5	M1	for all as powers of 4 or 8 or 16
	$n = x^2 + 4x + 3$ oe or $x^2 + 4x + 3 - n = 0$				A1	for writing n in terms of x correct expression implies first M1
	$(n =)(x+2)^2 - 2^2$..... oe or $(x =) -2 \pm \sqrt{n+1}$ $(x =) \dfrac{-4 \pm \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe				M1	for a correct first step in completing the square or using the quadratic formula correctly ft their 3 term quadratic
	$(x =) -2 + \sqrt{n+1}$ oe or $(x =) \dfrac{-4 + \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe				A1	for correctly rearranging to make x the subject (must be positive square root)
	Correct answer scores full marks (unless from obvious incorrect working)	$(x =) -2 + \sqrt{n+1}$ **and** $n > 3$			A1	must be positive square root Accept $(x =)\sqrt{n+1} - 2$ oe and $3 < n$ Accept $(x =) \dfrac{-4 + \sqrt{4^2 - 4\times1\times(3-n)}}{2}$ oe **and** $n > 3$ or $3 < n$
						Total 5 marks

11		$\dfrac{m^9k^{15}}{125}$	2	B2 oe for all 3 correct eg $125^{-1}m^9k^{15}$ or $\dfrac{1}{125}m^9k^{15}$ Accept $a = 9$, $b = 15$ and $c = 125$ B1 for a quotient in the form of $\dfrac{m^pk^q}{r}$ or a product in the form $r^{-1}m^pk^q$ where 2 from p or q or r are correct eg $\dfrac{m^9k^{15}}{25}$ or $125m^9k^{15}$ Allow m^9k^{15} or $\dfrac{m^9}{125}$ or $125^{-1}m^9$ or $\dfrac{k^{15}}{125}$ or $125^{-1}k^{15}$ so long as not added to any other terms Accept two from $a = 9$ or $b = 15$ or $c = 125$ Accept $y125^{-1}m^9k^{15}$ or $\dfrac{ym^9k^{15}}{125}$ where y is constant
				Total 2 marks

12	(a)	$\sqrt{2}=2^{\frac{1}{2}}$ or $8^3=2^9$ or $16^{\frac{3}{2}}=2^6$		3	M1	for one of $\sqrt{2}=2^{\frac{1}{2}}$ or $8^3=2^9$ or $16^{\frac{3}{2}}=2^6$
					M1	for all of $\sqrt{2}=2^{\frac{1}{2}}$ and $8^3=2^9$ and $16^{\frac{3}{2}}=2^6$ **OR** $2^{\frac{1}{2}}\div 2^3$
		Working required	-2.5		A1	oe, dep on M1
	(b)	$0.04\times 4.5\times 10^{157}$ oe		3	M1	
		$4\times 10^{-2}\times 4.5\times 10^{157}$ $(=18\times 10^{155})$ **or** 0.18×10^{157} oe			M1	
		Correct answer scores full marks (unless from obvious incorrect working)	1.8×10^{156}		A1	SCB1 for $18\times 10^{156}=1.8\times 10^{157}$ **or** $18\times 10^{157}=1.8\times 10^{158}$
						Total 6 marks

13	(a)		$8a^9$	2	B2	for a fully correct answer. if not B2, then B1 for 8 or a^9 as part of a product in answer, or final line of working
	(b)		$1000x^3$	2	B2	for a fully correct answer. (B1 for final answer or final line of working with: 1000 or x^3 as part of a product or $(10x)^3$ or $\frac{1}{1000x^3}$)
	(c)	eg $30\times\frac{1-2y}{3}=30\times\frac{4}{5}-30\times\frac{2y-1}{2}$ oe or eg $\frac{10(1-2y)}{30}=\frac{6\times 4}{30}-\frac{15(2y-1)}{30}$ oe or eg $\frac{1-2y}{3}=\frac{2\times 4}{10}-\frac{5(2y-1)}{10}$ oe or eg $10(1-2y)=3\times 2\times 4-3\times 5(2y-1)$ oe or eg $\frac{10(1-2y)+15(2y-1)}{30}=\frac{4}{5}$ or $\frac{2(1-2y)}{6}+\frac{3(2y-1)}{6}=\frac{4}{5}$ oe (as above)		3	M1	For clear intention to multiply all terms by 30 (or $3\times 5\times 2$) or a multiple of 30 oe in an equation or to express all terms over 30 (or $3\times 5\times 2$) or a multiple of 30 oe in an equation **or** writing RHS over 10 or a multiple of 10 or 'cross multiplying' in an equation **or** bringing terms in y on LHS side and leaving $\frac{4}{5}$ on RHS and writing terms on LHS over 6 or a multiple of 6 in an equation [if expanded numerators, allow one error]
		eg $10-20y=24-30y+15$ oe eg $10y=29$ or $50-100y+150y-75=120$ oe or $10-20y+30y-15=24$ oe $2-4y+6y-3=4.8$			M1	(ft if only one error) Expanding brackets and multiplying by denominator with no more than one error in total
		Working required	2.9		A1	oe eg $\frac{29}{10}$ or $2\frac{9}{10}$ dep on M2
						Total 7 marks