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Q1.

1	Use logarithms to linearise an equation	M1	
	Obtain $\dfrac{x}{y} = \dfrac{\ln 5}{\ln 2}$ or equivalent	A1	
	Obtain answer 2.32	A1	3

Q2.

2	(a) Obtain a linear equation, e.g. $x \log 3 = \log 8$	B1	
	Obtain final answer 1.89	B1	2
	(b) Use $2 \ln y = \ln(y^2)$	M1	
	Use law for addition or subtraction of logarithms	M1	
	Obtain answer $z = \dfrac{y+2}{y^2}$	A1	3

Q3.

2	(i)	State or imply $y \ln 3 = (x+2)\ln 4$	B1	
		State that this is of the form $ay = bx + c$ and thus a straight line, or equivalent	B1	
		State gradient is $\dfrac{\ln 4}{\ln 3}$, or equivalent (allow 1.26)	B1	[3]
	(ii)	Substitute $y = 2x$ and obtain a linear equation in x	M1*	
		Solve for x	M1(dep*)	
		Obtain answer 3.42	A1	[3]

Q4.

2	Use law for the logarithm of a product, a quotient or a power	M1*	
	Obtain $x\ln 4 = \ln 2 + x\ln 3$, or equivalent	A1	
	Solve for x	M1 (dep*)	
	Obtain answer $x = 2.41$	A1	[4]

Q5.

1	Use logarithms to linearise an equation	M1	
	Obtain $\dfrac{x}{y} = \dfrac{\ln 2.5}{\ln 1.25}$, or equivalent	A1	
	Obtain answer 4.11	A1√	[3]

Q6.

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5 (i) State or imply $2^{-x} = \dfrac{1}{y}$, or $2^{-x} = y^{-1}$ B1

Substitute and obtain a 3-term quadratic in y M1
Obtain the given answer correctly   A1   [3]

(ii) Solve the given quadratic and carry out correct method for solving an equation of the form
$2^x = a$, where $a > 0$ M1
Obtain answer $x = 1.58$ or 1.585 A1
Obtain answer $x = 0$ B1   [3]

Q7.

1 State or imply $y \log 2.8 = x \log 13$ B1

Rearrange into form $y = \dfrac{\log 13}{\log 2.8} x$ or equivalent   B1

Obtain answer $k = 2.49$ B1   [3]

Q8.

3 State or imply that $\ln y = \ln K + m \ln x$ B1
Equate intercept on axis for $\ln y$ to $\ln K$ M1
Obtain 7.39 for K A1
Attempt calculation of gradient of line   M1
Obtain 1.37 for m A1   [5]

Q9.

1 Attempt use of power law for logarithms   M1*
Obtain $x\log 3 = x\log 2 + 2\log 2$ or equivalent   A1
Attempt solution for x of linear equation   M1 dep*
Obtain 3.42   A1   [4]

Q10.

2 State or imply that $\ln y = \ln A + x \ln b$ B1
Equate intercept on y-axis to $\ln A$ M1
Obtain $\ln A = 2.14$ and hence $A = 8.5$ A1
Attempt gradient of line or equivalent (or use of correct substitution)   M1
Obtain $0.47 = \ln b$ or equivalent and hence $b = 1.6$ A1   [5]

Q11.

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2	(i)	State or imply equation in the form $(5^x)^2 + 5^x - 12 = 0$	B1	
		Attempt solution of quadratic equation for 5^x	M1	
		Obtain $5^x = 3$ only	A1	[3]
	(ii)	Use logarithms to solve equation of the form $5^x = k$ where $k > 0$	M1	
		Obtain 0.683	A1	[2]

Q12.

2	Use $2 \ln x = \ln(x^2)$	M1	
	Use law for addition or subtraction of logarithms	M1	
	Obtain correct quadratic equation in x	A1	
	Make reasonable solution attempt at a 3-term quadratic (dependent on previous M marks)	DM1	
	State $x = \dfrac{3}{5}$ and no other solutions	A1	[5]

Q13.

4	(i)	State or imply $(y + 1) \log 5 = 3x \log 2$	M1	
		State that this is of the form $ay = bx + c$ and thus a straight line, or equivalent	A1	[2]
	(ii)	State gradient is $\dfrac{3 \ln 2}{\ln 5}$, or equivalent, e.g. $3\log_5 2$	B1	
		State $(0, -1)$	B1	[2]

Q14.

3	(i)	State or imply that $9^x = y^2$	B1	1
	(ii)	Carry out recognisable solution method for quadratic in y	M1	
		Obtain $y = \frac{1}{2}$ and $y = 3$ from $2y^2 - 7y + 3 = 0$	A1	
		Use log method to solve an equation of the form $3^x = k$	M1	
		Obtain answer $x = -\dfrac{\ln 2}{\ln 3}$, or exact equivalent { ⊢. ᴧNᵞ bᴀsᴇ }	A1'	⊙
		State exact answer $x = 1$ (no penalty if logs used)	B1	5

Q15.

2	State or imply at any stage $\ln y = \ln k - x \ln a$	B1	
	Equate estimate of $\ln y$- intercept to $\ln k$	M1	
	Obtain value for k in the range 9.97 ± 0.51	A1	
	Calculate gradient of the line of data points	M1	
	Obtain value for a in the range 2.12 ± 0.11	A1	
			[5]

Q16.

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2   Use logarithms to obtain an equation in $\ln x$ M1

Obtain $\ln x = \dfrac{\ln 11}{(3.9 - 3.2)}$, or equivalent   A1

Obtain answer $x = 31$ (accept 30.7, 30.74)   A1   3

Q17.

2   (i) State or imply that $4^x = y^2$ $(=2^{2x})$ B1   1

   (ii) Carry out recognizable solution method for a quadratic equation in y M1

     Obtain $y = 3$ and $y = \frac{1}{3}$ from $3y^2 - 10y + 3 = 0$ A1

     Use logarithmic method to solve an equation of the form $2^x = k$, where $k > 0$ M1

     State answer 1.58   A1

     State answer -1.58 (A1 √ if ± 1.59)   A1   5

Q18.

3   State or imply $\ln y = \ln A - x \ln b$ B1

   State $\ln A = 1.3$ B1

   Obtain $A = 3.67$ B1

   Form a numerical expression for the gradient of the line   M1

   Obtain $b = 1.28$ A1   [5]

Q19.

2   Use $\ln x^2 = 2\ln x$ B1

   Obtain $3 - x^2 = x^2$, or equivalent   B1

   Solve for x M1

   Obtain answer $x - 1.22$, having rejected $x = -1.22$ A1   [4]

Q20.

2   State or imply $2 \ln x = \ln(x^2)$ B1

   Use law for the logarithm of a quotient or a product   M1

   Remove logarithms and obtain $yx^2 = y + 5$, or equivalent   A1

   Obtain answer $y = \dfrac{5}{x^2 - 1}$ A1   [4]

Q21.

2   Use law for the logarithm of a product, a quotient or a power   M1*

   Obtain $x \log 5 = (2x + 1)\log 2$, or equivalent   A1

   Solve for x, via correct manipulative technique(s)   M1(dep*)

   Obtain answer $x = 3.11$. Allow $x \in [3.10, 3.11]$ A1   [4]

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Q22.

5	State or imply $\ln y = \ln A + x \ln b$	B1	
	Form a numerical expression for the gradient of the line	M1	
	Obtain $b = 1.65$	A1	
	Use gradient and one point correctly to find In A	M1	
	Obtain $\ln A = 0.1$	A1	
	Obtain $A = 1.11$	A1	[6]

Q23.

4	Carry out recognizable solution method for quadratic in 3^x	M1	
	Obtain $3^x = 5$ and $3^x = 2$	A1	
	Use logarithmic method to solve an equation of the form $3^x = k$, where $k > 0$	M1	
	State answer 1.46	A1	
	State answer 0.631	A1	[5]

Q24.

2	Use law for the logarithm of a product, a quotient or a power	M1*	
	Obtain $(x+1)\log 4 = (2x-3)\log 5$, or equivalent	A1	
	Solve for x	M1(dep*)	
	Obtain answer $x = 3.39$	A1	[4]

Q25.

3	Use $2\ln(x+3) = \ln(x+3)^2$	M1	
	Use law for addition or subtraction of logarithms	M1	
	Obtain correct quadratic expression in x	A1	
	Make reasonable solution attempt at a 3-term quadratic	M1	
	State $x = 9$ and no other solutions (condone $x = -1$ not deleted)	A1	[5]

Q26.

2	Use law for the logarithm of a product, a quotient or a power	M1*	
	Obtain $x \log 5 = (2x-1) \log 3$ or equivalent	A1	
	Solve for x	M1(dep*)	
	Obtain answer $x = 1.87$	A1	[4]

Q27.

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5	State or imply $\ln y = \ln A - x \ln b$	B1	
	Form a numerical expression for the gradient of the line	M1	
	Obtain $b = 1.82$	A1	
	Use gradient and one point correctly to find $\ln A$	M1	
	Obtain $\ln A = 3.5$	A1	
	Obtain $A = 33.12$	A1	[6]

Q28.

5	State or imply $\ln y = \ln K + px \ln 2$	B1	
	Obtain at least one of		
	$1.87 = \ln K + 1.35p \ln 2, \quad 3.81 = \ln K + 3.35p \ln 2, \quad p \ln 2 = \dfrac{3.81 - 1.87}{3.35 - 1.35}$		
	or equivalents	B1	
	Solve equation(s) to find one constant, dependent on previous B1	M1	
	Obtain $p = 1.40$	A1	
	Substitute to attempt value of K	DM1	
	Obtain $\ln K = 0.5605$ and hence $K = 1.75$	A1	[6]

Q29.

2	State or imply $\ln y = \ln a + x \ln b$	B1	
	Equate $\ln b$ to numerical gradient of line	M1	
	Obtain $b = 1.85$	A1	
	Substitute to find value of a	M1	
	Obtain $a = 3.45$	A1	[5]

Q30.

4	(a)	Use power law to produce $\ln(x-4)^2$	B1	
		Apply logarithm laws to produce equation without logarithms	M1	
		Obtain $(x-4)^2 = 2x$ or equivalent	A1	
		Solve 3-term quadratic equation	DM1	
		Obtain (finally) $x = 8$ only	A1	[5]
	(b)	Apply logarithms and use power law (once)	M1	
		Obtain $\dfrac{\ln 10^{10}}{\ln 1.4}$ or equivalent as part of inequality or equation	A1	
		Conclude with single integer 69	A1	[3]

P3 (variant1 and 3)

Q1.

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3	(i)	*EITHER:*	State or imply $n\ln x + \ln y = \ln C$	B1	
			Substitute x- and y-values and solve for n	M1	
			Obtain $n = 1.50$	A1	
			Solve for C	M1	
			Obtain $C = 6.00$	A1	
		OR:	Obtain two correct equations by substituting x- and y-values in $x^n y = C$	B1	
			Solve for n	M1	
			Obtain $n = 1.50$	A1	
			Solve for C	M1	
			Obtain $C = 6.00$	A1	[5]

(ii) State that the graph of $\ln y$ against $\ln x$ has equation $n\ln x + \ln y = \ln C$ which is *linear* in $\ln y$ and $\ln x$, or has equation of the form $nX + Y = \ln C$, where $X = \ln x$ and $Y = \ln y$, and is thus a straight line   B1   [1]

Q2.

2	(i)	State or imply $3\ln y = \ln A + 2x$ at any stage	B1	
		State gradient is $\dfrac{2}{3}$, or equivalent	B1	[2]
	(ii)	Substitute $x = 0$, $\ln y = 0.5$ and solve for A	M1	
		Obtain $A = 4.48$	A1	[2]

Q3.

1	Use law for the logarithm of a product, power or quotient	M1*	
	Obtain a correct linear equation, e.g. $(2x-1)\ln 5 = \ln 2 + x\ln 3$	A1	
	Solve a linear equation for x	M1(dep*)	
	Obtain answer $x = 1.09$	A1	[4]

[SR: Reduce equation to the form $a^x = b$ M1*, obtain $\left(\dfrac{25}{3}\right)^x = 10$ A1, use correct method to calculate value of x M1(dep*), obtain answer 1.09 A1.]

Q4.

2	Use law of the logarithm of a power and a product or quotient and remove logarithms	M1	
	Obtain a correct equation in any form, e.g. $\dfrac{2x+3}{x^2} = 3$	A1	
	Solve 3-term quadratic obtaining at least one root	M1	
	Obtain final answer 1.39 only	A1	[4]

Q5.

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2	Use law for the logarithm of a product, quotient or power	M1	
	Use $\ln e = 1$ or $\exp(1) = 3$	M1	
	Obtain correct equation free of logarithms in any form, e.g. $\dfrac{y+1}{y} = ex^3$	A1	
	Rearrange as $y = (ex^3 - 1)^{-1}$, or equivalent	A1	[4]

Q6.

2	*EITHER:*	Use laws of indices correctly and solve a linear equation for 3^x, or for 3^{-x}	M1	
		Obtain 3^x, or 3^{-x} in any correct form, e.g. $3^x = \dfrac{3^2}{(3^2 - 1)}$	A1	
		Use correct method for solving $3^{\pm x} = a$ for x, where $a > 0$	M1	
		Obtain answer $x = 0.107$	A1	
	OR:	State an appropriate iterative formula, e.g. $x_{n+1} = \dfrac{\ln(3^{x_n} + 9)}{\ln 3} - 2$	B1	
		Use the formula correctly at least once	M1	
		Obtain answer $x = 0.107$	A1	
		Show that the equation has no other root but 0.107	A1	[4]
		[For the solution 0.107 with no relevant working, award B1 and a further B1 if 0.107 is shown to be the only root.]		

Q7.

2	Use law for the logarithm of a power, a quotient, or a product correctly at least once	M1	
	Use $\ln e = 1$ or $e = \exp(1)$	M1	
	Obtain a correct equation free of logarithms, e.g. $1 + x^2 = ex^2$	A1	
	Solve and obtain answer $x = 0.763$ only	A1	[4]
	[For the solution $x = 0.763$ with no relevant working give B1, and a further B1 if 0.763 is shown to be the only root.]		
	[Treat the use of logarithms to base 10 with answer 0.333 only, as a misread.]		
	[SR: Allow iteration, giving B1 for an appropriate formula, e.g. $x_{n+1} = \exp((\ln(1 + x_n^2) - 1)/2)$, M1 for using it correctly once, A1 for 0.763, and A1 for showing the equation has no other root but 0.763.]		

Q8.

1	Rearrange as $e^{2x} - e^x - 6 = 0$, or $u^2 - u - 6 = 0$, or equivalent	B1	
	Solve a 3-term quadratic for e^x or for u	M1	
	Obtain simplified solution $e^x = 3$ or $u = 3$	A1	
	Obtain final answer $x = 1.10$ and no other	A1	[4]

Q9.

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2   *EITHER*   Use laws of indices correctly and solve for 5^x or for 5^{-x} or for 5^{x-1} M1

$$\frac{5}{1-\frac{1}{\sqrt{5}}}$$

Obtain 5^x or for 5^{-x} or for 5^{x-1} in any correct form, e.g. $5^x =$ A1

Use correct method for solving $5^x = a$, or $5^{-x} = a$, or $5^{x-1} = a$, where $a > 0$ M1

Obtain answer $x = 1.14$ A1

OR   Use an appropriate iterative formula, e.g. $x_{n+1} =$, correctly, at least onceM1

Obtain answer 1.14   A1

Show sufficient iterations to at least 3 d.p. to justify 1.14 to 2 d.p., or show

there is a sign change in the interval (1.135, 1.145)   A1

Show there is no other root   A1   [4]

[For the solution $x = 1.14$ with no relevant working give B1, and a further B1 if

1.14 is shown to be the only solution.]

Q10.

1   State or imply $\ln e = 1$ B1

Apply at least one logarithm law for product or quotient correctly   M1

(or exponential equivalent)

Obtain $x + 5 = ex$ or equivalent and hence $\dfrac{5}{e-1}$ A1   [3]

Q11.

2   *EITHER:* State or imply non-modular equation $2^2(3^x - 1)^2 = (3^x)^2$, or pair of equations

$2(3^x - 1) = \pm 3^x$ M1

Obtain $3^x = 2$ and $3^x = \dfrac{2}{3}$ (or $3^{x+1} = 2$)   A1

OR: Obtain $3^x = 2$ by solving an equation or by inspection   B1

Obtain $3^x = \dfrac{2}{3}$ (or $3^{x+1} = 2$) by solving an equation or by inspection   B1

Use correct method for solving an equation of the form $3^x = a$ (or $3^{x+1} = a$), where $a > 0$ M1

Obtain final answers 0.631 and –0.369   A1   [4]

Q12.

1   Apply at least one logarithm property correctly   *M1

Obtain $\dfrac{(x+4)^2}{x} = x + a$ or equivalent **without logarithm** involved   A1

Rearrange to express x in terms of a M1   d*M

Obtain $\dfrac{16}{a-8}$ or equivalent   A1   [4]

Q13.

9

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6 (i) Use law for the logarithm for a product or quotient or exponentiation
        AND for a power   M1
        Obtain $(4x - 5)^2(x + 1) = 27$ B1
        Obtain given equation correctly $16x^3 - 24x^2 - 15x - 2 = 0$ A1   [3]

   (ii) Obtain $x = 2$ is root or $(x - 2)$ is a factor, or likewise with $x = -\dfrac{1}{4}$ B1

         Divide by $(x - 2)$ to reach a quotient of the form $16x^2 + kx$ M1
         Obtain quotient $16x^2 + 8x + 1$ A1

         Obtain $(x - 2)(4x + 1)^2$ or $(x - 2), (4x + 1), (4x + 1)$ A1   [4]

   (iii) State $x = 2$ only   A1   [1]

Q14.

1   Use law of the logarithm of a quotient or product or $2 = \log_{10} 100$ M1
    Remove logarithms and obtain $x + 9 = 100x$, or equivalent   A1
    Obtain answer $x = \frac{1}{11}$ A1   3

Q15.

1   Use law of the logarithm of a power   M1
    Obtain a correct linear equation in any form, e.g. $x = (x - 2)\ln 3$ A1
    Obtain answer $x = 22.281$ A1   [3]

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