

Indices, Surds and Logarithms

Indices

- $a^m \times a^n = a^{m+n}$
- $a^m \div a^n = a^{m-n}$
- $a^{-n} = \frac{1}{a^n}$
- $\left(\frac{a}{b}\right)^n = \frac{a^n}{b^n}$
- $\left(\frac{a}{b}\right)^{-n} = \left(\frac{b}{a}\right)^n = \frac{1}{a^n/b^n}$
- $\frac{a^m}{a^n} = \frac{a^m \times a^{-n}}{a^{-n} \times a^n} = \frac{a^{m-n}}{a^0} = a^{m-n}$
- $a^0 = 1$
- $a^{\frac{1}{n}} = \sqrt[n]{a}$
- $a^{\frac{m}{n}} = \sqrt[n]{a^m}$
- $a^m \times b^m = (ab)^m$

Solving by substitution

Express the indices into its component powers before doing the substitution

Example

By using a suitable substitution, solve the following equation:

$$\begin{aligned} 3^{2x+1} + 3^{x-1} &= 1 + 3^x \\ 3^x(3^{x+1}) + 3(3^x) &= 1 + 3^x \\ 17(3^x) + 3(3^x) - 1 &= 0 \end{aligned}$$

Let $y = 3^x$

$$\begin{aligned} 17y^2 + 3y - 1 &= 0 \\ y &= 0.1589 \text{ or } -0.2330 \text{ (N.A.)} \\ \text{(Exponentials are always positive)} \\ 3^x &= 0.1589 \end{aligned}$$

Take 'lg' both sides

$$\begin{aligned} x \lg 3 &= \lg 0.1589 \\ \lg 0.1589 \\ x &= \frac{\lg 0.1589}{\lg 3} = -0.4771 \end{aligned}$$

Surds

Common Laws

$$\begin{aligned} \sqrt{a} \times \sqrt{b} &= \sqrt{ab} \\ \frac{\sqrt{a}}{\sqrt{b}} &= \sqrt{\frac{a}{b}} \\ \sqrt{a} \times \sqrt{a} &= a \\ a\sqrt{b} \times c\sqrt{b} &= ac\sqrt{bb} \\ (a + \sqrt{b})(c + \sqrt{d}) &= ac + a\sqrt{d} + c\sqrt{b} + \sqrt{bd} \\ (1 + \sqrt{a})(1 - \sqrt{a}) &= 1^2 - (\sqrt{a})^2 = 1 - a \end{aligned}$$

Rationalising the denominator

To remove the surd from the denominator, multiply the entire fraction by the conjugate surd

Example:

$$\begin{aligned} \frac{3}{4 - 2\sqrt{6}} &= \frac{3}{4 - 2\sqrt{6}} \times \frac{4 + 2\sqrt{6}}{4 + 2\sqrt{6}} \\ &= \frac{12 + 6\sqrt{6}}{4^2 - (2\sqrt{6})^2} \\ &= \frac{6(2 + \sqrt{6})}{16 - 24} \\ &= -\frac{3(2 + \sqrt{6})}{4} \end{aligned}$$

Simplifying surds

Split the surd into a square root of a perfect square times another surd

Example:

$$\begin{aligned} \sqrt{100} &= \sqrt{100} \times \sqrt{1} = 10\sqrt{1} \\ \sqrt{700} &= \sqrt{100} \times \sqrt{7} = 10\sqrt{7} \\ \sqrt{125} &= \sqrt{25} \times \sqrt{5} = 5\sqrt{5} \end{aligned}$$

Logarithms

Common Laws

$$\begin{aligned} \log_a b + \log_a c &= \log_a (bc) \\ \log_a b - \log_a c &= \log_a \left(\frac{b}{c}\right) \\ \log_a b^r &= r \log_a b \\ \log_a c &= \frac{\log_b c}{\log_b a} \text{ (b can take any value)} \end{aligned}$$

Converting from log from to index Form

$$\log_a b = r \iff b = a^r$$

Example

$$\log_2 8 = 3 \iff 8 = 2^3$$

Common & Natural logarithms

$$\begin{aligned} \log_{10} a &= \lg a \\ \log_e a &= \ln a \end{aligned}$$

(Use "ln" when there is e, otherwise always use "lg")

Solving Equations

2 scenarios to watch

1. A single log on both sides with the same base

Example

$$\begin{aligned} \log_2(2x + 1) &= \log_2(x - 3) \\ 2x + 1 &= x - 3 \\ -2 - 1 \\ x &= \frac{-3 - 1}{1} = -2 \end{aligned}$$

2. A single log on one side of the equation

Example

$$\begin{aligned} \log_2(2x + 1) &= 2 \\ 2x + 1 &= 2^2 \\ x &= \frac{2^2 - 1}{1} = 4 \end{aligned}$$

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