

## ***Solution***      **Section 1.5 – Exponential and Logarithmic Equations**

### ***Exercise***

Express the following in terms of sums and differences of logarithms:  $\log_3(ab)$

### **Solution**

$$\underline{\log_3(ab) = \log_3 a + \log_3 b}$$

### ***Exercise***

Express the following in terms of sums and differences of logarithms:  $\log_7(7x)$

### **Solution**

$$\begin{aligned}\log_7(7x) &= \log_7 7 + \log_7 x \\ &= 1 + \log_7 x\end{aligned}$$

### ***Exercise***

Express the following in terms of sums and differences of logarithms:  $\log \frac{x}{1000}$

### **Solution**

$$\begin{aligned}\log \frac{x}{1000} &= \log x - \log 10^3 \\ &= \log x - 3\end{aligned}$$

### ***Exercise***

Express the following in terms of sums and differences of logarithms  $\log_5 \left( \frac{125}{y} \right)$

### **Solution**

$$\begin{aligned}\log_5 \left( \frac{125}{y} \right) &= \log_5 5^3 - \log_5 y \\ &= 3 - \log_5 y\end{aligned}$$

### ***Exercise***

Express the following in terms of sums and differences of logarithms  $\log_b x^7$

### **Solution**

$$\log_b x^7 = 7 \log_b x$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\ln \sqrt[7]{x}$

### Solution

$$\begin{aligned} \ln \sqrt[7]{x} &= \ln x^{1/7} \\ &= \frac{1}{7} \ln x \end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_a \frac{x^2 y}{z^4}$

### Solution

$$\begin{aligned} \log_a \frac{x^2 y}{z^4} &= \log_a x^2 y - \log_a z^4 \\ &= \log_a x^2 + \log_a y - \log_a z^4 \\ &= 2 \log_a x + \log_a y - 4 \log_a z \end{aligned}$$

*Quotient Rule*

*Product Rule*

*Power Rule*

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_b \frac{x^2 y}{b^3}$

### Solution

$$\begin{aligned} \log_b \left( \frac{x^2 y}{b^3} \right) &= \log_b x^2 y - \log_b b^3 \\ &= \log_b x^2 + \log_b y - \log_b b^3 \\ &= 2 \log_b x + \log_b y - 3 \log_b b \\ &= 2 \log_b x + \log_b y - 3 \end{aligned}$$

**Exercise**

Express the following in terms of sums and differences of logarithms  $\log_b \left( \frac{x^3 y}{z^2} \right)$

**Solution**

$$\begin{aligned} \log_b \left( \frac{x^3 y}{z^2} \right) &= \log_b (x^3 y) - \log_b z^2 \\ &= \log_b x^3 + \log_b y - \log_b z^2 \\ &= \underline{3 \log_b x + \log_b y - 2 \log_b z} \end{aligned}$$

**Exercise**

Express the following in terms of sums and differences of logarithms  $\log_b \left( \frac{\sqrt[3]{xy^4}}{z^5} \right)$

**Solution**

$$\begin{aligned} \log_b \left( \frac{\sqrt[3]{xy^4}}{z^5} \right) &= \log_b (\sqrt[3]{xy^4}) - \log_b (z^5) \\ &= \underline{\log_b (x^{1/3}) + \log_b (y^4) - \log_b (z^5)} \end{aligned}$$

**Exercise**

Express the following in terms of sums and differences of logarithms  $\log \left( \frac{100x^3 \sqrt[3]{5-x}}{3(x+7)^2} \right)$

**Solution**

$$\begin{aligned} \log \left( \frac{100x^3 \sqrt[3]{5-x}}{3(x+7)^2} \right) &= \log (100x^3 \sqrt[3]{5-x}) - \log (3(x+7)^2) \\ &= \log 10^2 + \log x^3 + \log (5-x)^{1/3} - \left[ \log 3 + \log ((x+7)^2) \right] \\ &= 2 \log 10 + 3 \log x + \frac{1}{3} \log (5-x) - \log 3 - 2 \log (x+7) \\ &= \underline{2 + 3 \log x + \frac{1}{3} \log (5-x) - \log 3 - 2 \log (x+7)} \end{aligned}$$

**Exercise**

Express the following in terms of sums and differences of logarithms  $\log_a \sqrt[4]{\frac{m^8 n^{12}}{a^3 b^5}}$

**Solution**

$$\begin{aligned}
\log_a \sqrt[4]{\frac{m^8 n^{12}}{a^3 b^5}} &= \log_a \left( \frac{m^8 n^{12}}{a^3 b^5} \right)^{1/4} && \text{Power Rule} \\
&= \frac{1}{4} \log_a \left( \frac{m^8 n^{12}}{a^3 b^5} \right) && \text{Quotient Rule} \\
&= \frac{1}{4} \left[ \log_a m^8 n^{12} - \log_a a^3 b^5 \right] && \text{Product Rule} \\
&= \frac{1}{4} \left[ \log_a m^8 + \log_a n^{12} - \left( \log_a a^3 + \log_a b^5 \right) \right] && \text{Power Rule} \\
&= \frac{1}{4} [8 \log_a m + 12 \log_a n - 3 - 5 \log_a b] \\
&= \underline{2 \log_a m + 3 \log_a n - \frac{3}{4} - \frac{5}{4} \log_a b}
\end{aligned}$$

### Exercise

Use the properties of logarithms to rewrite:  $\log_p \sqrt[3]{\frac{m^5 n^4}{t^2}}$

### Solution

$$\begin{aligned}
\log_p \sqrt[3]{\frac{m^5 n^4}{t^2}} &= \log_p \left( \frac{m^5 n^4}{t^2} \right)^{1/3} && \text{Power Rule} \\
&= \frac{1}{3} \log_p \left( \frac{m^5 n^4}{t^2} \right) && \text{Quotient Rule} \\
&= \frac{1}{3} \left( \log_p m^5 n^4 - \log_p t^2 \right) && \text{Product Rule} \\
&= \frac{1}{3} \left( \log_p m^5 + \log_p n^4 - \log_p t^2 \right) && \text{Power Rule} \\
&= \frac{1}{3} \left( 5 \log_p m + 4 \log_p n - 2 \log_p t \right) \\
&= \underline{\frac{5}{3} \log_p m + \frac{4}{3} \log_p n - \frac{2}{3} \log_p t}
\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_b \sqrt[n]{\frac{x^3 y^5}{z^m}}$

### Solution

$$\log_b \sqrt[n]{\frac{x^3 y^5}{z^m}} = \log_b \left( \frac{x^3 y^5}{z^m} \right)^{1/n}$$

$$\begin{aligned}
&= \frac{1}{n} \log_b \left( \frac{x^3 y^5}{z^m} \right) && \text{Power Rule} \\
&= \frac{1}{n} \left( \log_b x^3 y^5 - \log_b z^m \right) && \text{Quotient Rule} \\
&= \frac{1}{n} \left( \log_b x^3 + \log_b y^5 - \log_b z^m \right) && \text{Product Rule} \\
&= \frac{1}{n} \left( 3 \log_b x + 5 \log_b y - m \log_b z \right) && \text{Power Rule} \\
&= \frac{3}{n} \log_b x + \frac{5}{n} \log_b y - \frac{m}{n} \log_b z
\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_a \sqrt[3]{\frac{a^2 b}{c^5}}$

### Solution

$$\begin{aligned}
\log_a \sqrt[3]{\frac{a^2 b}{c^5}} &= \log_a \left( \frac{a^2 b}{c^5} \right)^{1/3} && \text{Convert the radical to power} \\
&= \frac{1}{3} \log_a \left( \frac{a^2 b}{c^5} \right) && \text{Power Rule} \\
&= \frac{1}{3} \left[ \log_a a^2 b - \log_a c^5 \right] && \text{Quotient Rule} \\
&= \frac{1}{3} \left[ \log_a a^2 + \log_a b - \log_a c^5 \right] && \text{Product Rule} \\
&= \frac{1}{3} \left[ 2 \log_a a + \log_a b - 5 \log_a c \right] && \text{Power Rule} \\
&= \frac{2}{3} \log_a a + \frac{1}{3} \log_a b - \frac{5}{3} \log_a c \\
&= \frac{2}{3} + \frac{1}{3} \log_a b - \frac{5}{3} \log_a c
\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_b \left( x^4 \sqrt[3]{y} \right)$

### Solution

$$\begin{aligned}
\log_b \left( x^4 \sqrt[3]{y} \right) &= \log_b \left( x^4 \right) + \log_b \left( \sqrt[3]{y} \right) \\
&= \log_b \left( x^4 \right) + \log_b \left( y^{1/3} \right)
\end{aligned}$$

$$\underline{= 4 \log_b x + \frac{1}{3} \log_b y}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_5 \left( \frac{\sqrt{x}}{25y^3} \right)$

### Solution

$$\begin{aligned} \log_5 \left( \frac{\sqrt{x}}{25y^3} \right) &= \log_5 \left( x^{1/2} \right) - \log_5 \left( 25y^3 \right) \\ &= \log_5 \left( x^{1/2} \right) - \left[ \log_5 \left( 5^2 \right) + \log_5 \left( y^3 \right) \right] \\ &= \log_5 \left( x^{1/2} \right) - \log_5 \left( 5^2 \right) - \log_5 \left( y^3 \right) \\ &= \frac{1}{2} \log_5 (x) - 2 \log_5 (5) - 3 \log_5 (y) \\ &= \underline{\frac{1}{2} \log_5 (x) - 2 - 3 \log_5 (y)} \end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_a \frac{x^3 w}{y^2 z^4}$

### Solution

$$\begin{aligned} \log_a \frac{x^3 w}{y^2 z^4} &= \log_a x^3 w - \log_a y^2 z^4 && \text{Quotient rule} \\ &= \log_a x^3 + \log_a w - \left( \log_a y^2 + \log_a z^4 \right) && \text{Product rule} \\ &= \log_a x^3 + \log_a w - \log_a y^2 - \log_a z^4 && \text{Distribute minus} \\ &= \underline{3 \log_a x + \log_a w - 2 \log_a y - 4 \log_a z} && \text{Power rule} \end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms  $\log_a \frac{\sqrt{y}}{x^4 \sqrt[3]{z}}$

### Solution

$$\begin{aligned} \log_a \frac{\sqrt{y}}{x^4 \sqrt[3]{z}} &= \log_a y^{1/2} - \log_a x^4 z^{1/3} && \text{Quotient rule} \\ &= \log_a y^{1/2} - \left( \log_a x^4 + \log_a z^{1/3} \right) && \text{Product rule} \end{aligned}$$

$$= \log_a y^{1/2} - \log_a x^4 - \log_a z^{1/3}$$

*Distribute minus*

$$= \frac{1}{2} \log_a y - 4 \log_a x - \frac{1}{3} \log_a z$$

*Power rule*

### ***Exercise***

Express the following in terms of sums and differences of logarithms  $\ln \sqrt[4]{\frac{x^7}{y^5 z}}$

### ***Solution***

$$\ln \sqrt[4]{\frac{x^7}{y^5 z}} = \ln \left( \frac{x^7}{y^5 z} \right)^{1/4}$$

$$= \frac{1}{4} \ln \left( \frac{x^7}{y^5 z} \right)$$

*Power rule*

$$= \frac{1}{4} (\ln x^7 - \ln y^5 z)$$

*Quotient rule*

$$= \frac{1}{4} (\ln x^7 - (\ln y^5 + \ln z))$$

*Product rule*

$$= \frac{1}{4} (\ln x^7 - \ln y^5 - \ln z)$$

$$= \frac{1}{4} (7 \ln x - 5 \ln y - \ln z)$$

*Power rule*

$$= \frac{7}{4} \ln x - \frac{5}{4} \ln y - \frac{1}{4} \ln z$$

### ***Exercise***

Express the following in terms of sums and differences of logarithms  $\ln x \sqrt[3]{\frac{y^4}{z^5}}$

### ***Solution***

$$\ln x \sqrt[3]{\frac{y^4}{z^5}} = \ln x + \ln \left( \frac{y^4}{z^5} \right)^{1/3}$$

*Product rule*

$$= \ln x + \ln \left( \frac{y^{4/3}}{z^{5/3}} \right)$$

$$= \ln x + \ln y^{4/3} - \ln z^{5/3}$$

*Quotient rule*

$$= \ln x + \frac{4}{3} \ln y - \frac{5}{3} \ln z$$

*Power rule*

### Exercise

Express the following in terms of sums and differences of logarithms

$$\log_b \sqrt[5]{\frac{m^4 n^5}{x^2 ab^{10}}}$$

### Solution

$$\begin{aligned}\log_b \sqrt[5]{\frac{m^4 n^5}{x^2 ab^{10}}} &= \log_b \left( \frac{m^4 n^5}{x^2 ab^{10}} \right)^{1/5} \\&= \frac{1}{5} \log_b \left( \frac{m^4 n^5}{x^2 ab^{10}} \right) \\&= \frac{1}{5} \left( \log_b (m^4 n^5) - \log_b (x^2 ab^{10}) \right) \\&= \frac{1}{5} \left( \left( \log_b (m^4) + \log_b (n^5) \right) - \left( \log_b (x^2) + \log_b (a) + \log_b (b^{10}) \right) \right) \\&= \frac{1}{5} \left( 4 \log_b m + 5 \log_b n - 2 \log_b x - \log_b a - 10 \right) \\&= \underline{\underline{\frac{4}{5} \log_b m + \log_b n - \frac{2}{5} \log_b x - \frac{1}{5} \log_b (a) - 2}}}\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\log_b \frac{a^5 b^{10}}{c^2 \sqrt[4]{d^3}}$$

### Solution

$$\begin{aligned}\log_b \frac{a^5 b^{10}}{c^2 \sqrt[4]{d^3}} &= \log_b (a^5 b^{10}) - \log_b (c^2 d^{3/4}) \\&= \log_b (a^5) + \log_b (b^{10}) - \left( \log_b (c^2) + \log_b (d^{3/4}) \right) \\&= \underline{\underline{5 \log_b a + 10 - 2 \log_b c - \frac{3}{4} \log_b d}}\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \left( x^2 \sqrt{x^2 + 1} \right)$$

### Solution

$$\begin{aligned}\ln \left( x^2 \sqrt{x^2 + 1} \right) &= \ln x^2 + \ln (x^2 + 1)^{1/2} \\&= \underline{\underline{2 \ln x + \frac{1}{2} \ln (x^2 + 1)}}\end{aligned}$$



### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \frac{x^2}{x^2 + 1}$$

### Solution

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

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \left( \frac{x^2 (x+1)^3}{(x+3)^{1/2}} \right)$$

### Solution

$$\begin{aligned}\ln \left( \frac{x^2 (x+1)^3}{(x+3)^{1/2}} \right) &= \ln(x^2 (x+1)^3) - \ln(x+3)^{1/2} \\ &= \ln x^2 + \ln(x+1)^3 - \frac{1}{2} \ln(x+3) \\ &= 2 \ln x + 3 \ln(x+1) - \frac{1}{2} \ln(x+3)\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \sqrt{\frac{(x+1)^5}{(x+2)^{20}}}$$

### Solution

$$\begin{aligned}\ln \sqrt{\frac{(x+1)^5}{(x+2)^{20}}} &= \ln \left( \frac{(x+1)^5}{(x+2)^{20}} \right)^{1/2} \\ &= \frac{1}{2} \ln \left( \frac{(x+1)^5}{(x+2)^{20}} \right) \\ &= \frac{1}{2} (\ln(x+1)^5 - \ln(x+2)^{20}) \\ &= \frac{1}{2} (5 \ln(x+1) - 20 \ln(x+2)) \\ &= \frac{5}{2} \ln(x+1) - 10 \ln(x+2)\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \frac{(x^2 + 1)^5}{\sqrt{1-x}}$$

### Solution

$$\begin{aligned} \ln \frac{(x^2 + 1)^5}{\sqrt{1-x}} &= \ln (x^2 + 1)^5 - \ln (1-x)^{1/2} \\ &= \underline{5 \ln (x^2 + 1) - \frac{1}{2} \ln (1-x)} \end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \left( \sqrt[3]{\frac{x(x+1)(x-2)}{(x^2+1)(2x+3)}} \right)$$

### Solution

$$\begin{aligned} \ln \left( \sqrt[3]{\frac{x(x+1)(x-2)}{(x^2+1)(2x+3)}} \right) &= \ln \left( \frac{x(x+1)(x-2)}{(x^2+1)(2x+3)} \right)^{1/3} \\ &= \frac{1}{3} \ln \left( \frac{x(x+1)(x-2)}{(x^2+1)(2x+3)} \right) \\ &= \frac{1}{3} \left( \ln (x(x+1)(x-2)) - \ln ((x^2+1)(2x+3)) \right) \\ &= \frac{1}{3} \left( \ln x + \ln (x+1) + \ln (x-2) - (\ln (x^2+1) + \ln (2x+3)) \right) \\ &= \frac{1}{3} \left( \ln x + \ln (x+1) + \ln (x-2) - \ln (x^2+1) - \ln (2x+3) \right) \\ &= \underline{\frac{1}{3} \ln x + \frac{1}{3} \ln (x+1) + \frac{1}{3} \ln (x-2) - \frac{1}{3} \ln (x^2+1) - \frac{1}{3} \ln (2x+3)} \end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln \left( \sqrt{\frac{1}{x(x+1)}} \right)$$

### Solution

$$\ln \left( \sqrt{\frac{1}{x(x+1)}} \right) = \ln \left( \frac{1}{x(x+1)} \right)^{1/2}$$

$$\begin{aligned}
&= \frac{1}{2}(\ln 1 - \ln(x(x+1))) \\
&= -\frac{1}{2}(\ln x + \ln(x+1)) \\
&= -\frac{1}{2}\ln x - \frac{1}{2}\ln(x+1) \quad |
\end{aligned}$$

### Exercise

Express the following in terms of sums and differences of logarithms

$$\ln\left(\sqrt{(x^2+1)(x-1)^2}\right)$$

### Solution

$$\begin{aligned}
\ln\left(\sqrt{(x^2+1)(x-1)^2}\right) &= \ln\left((x^2+1)(x-1)^2\right)^{1/2} \\
&= \frac{1}{2}\ln\left((x^2+1)(x-1)^2\right) \\
&= \frac{1}{2}\left(\ln(x^2+1) + \ln(x-1)^2\right) \\
&= \frac{1}{2}\left(\ln(x^2+1) + 2\ln(x-1)\right) \\
&= \frac{1}{2}\ln(x^2+1) + \ln(x-1) \quad |
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\log(x+5) + 2\log x$$

### Solution

$$\begin{aligned}
\log(x+5) + 2\log x &= \log(x+5) + \log x^2 \\
&= \log(x^2(x+5)) \quad |
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $3\log_b x - \frac{1}{3}\log_b y + 4\log_b z$

### Solution

$$\begin{aligned}
3\log_b x - \frac{1}{3}\log_b y + 4\log_b z &= \log_b x^3 + \log_b z^4 - \log_b y^{1/3} \\
&= \log_b (x^3 z^4) - \log_b \sqrt[3]{y} \\
&= \log_b \left( \frac{x^3 z^4}{\sqrt[3]{y}} \right) \quad |
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $\frac{1}{2}\log_b (x+5) - 5\log_b y$

### Solution

$$\begin{aligned}\frac{1}{2}\log_b (x+5) - 5\log_b y &= \log_b (x+5)^{1/2} - \log_b y^5 \\ &= \log_b \left( \frac{\sqrt{x+5}}{y^5} \right)\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $\ln(x^2 - y^2) - \ln(x - y)$

### Solution

$$\begin{aligned}\ln(x^2 - y^2) - \ln(x - y) &= \ln \frac{x^2 - y^2}{x - y} \\ &= \ln \frac{(x - y)(x + y)}{x - y} \\ &= \ln(x + y)\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $\ln(xz) - \ln(x\sqrt{y}) + 2\ln\frac{y}{z}$

### Solution

$$\begin{aligned}\ln(xz) - \ln(x\sqrt{y}) + 2\ln\frac{y}{z} &= \ln(xz) + \ln\left(\frac{y}{z}\right)^2 - \ln(x\sqrt{y}) \\ &= \ln\left(\frac{xzy^2}{z^2}\right) - \ln(x\sqrt{y}) \\ &= \ln\left(\frac{xy^2}{z} \cdot \frac{1}{x\sqrt{y}}\right) \\ &= \ln\left(\frac{y^{3/2}}{z}\right)\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $\log(x^2 y) - \log z$

### Solution

$$\log(x^2 y) - \log z = \log\left(\frac{x^2 y}{z}\right)$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:  $\log(z^2 \sqrt{y}) - \log z^{1/2}$

### Solution

$$\begin{aligned}\log(z^2 \sqrt{y}) - \log z^{1/2} &= \log\left(\frac{z^2 \sqrt{y}}{z^{1/2}}\right) \\ &= \log(z^{3/2} \sqrt{y}) \\ &= \log(\sqrt{z^3 y})\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$2\log_a x + \frac{1}{3}\log_a (x-2) - 5\log_a (2x+3)$$

### Solution

$$\begin{aligned}2\log_a x + \frac{1}{3}\log_a (x-2) - 5\log_a (2x+3) &= \log_a x^2 + \log_a (x-2)^{1/3} - \log_a (2x+3)^5 \\ &= \log_a x^2 (x-2)^{1/3} - \log_a (2x+3)^5 \\ &= \log_a \frac{x^2 (x-2)^{1/3}}{(2x+3)^5}\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$5\log_a x - \frac{1}{2}\log_a (3x-4) - 3\log_a (5x+1)$$

### Solution

$$\begin{aligned}
5\log_a x - \frac{1}{2}\log_a (3x-4) - 3\log_a (5x+1) &= \log_a x^5 - \log_a (3x-4)^{1/2} - \log_a (5x+1)^3 \\
&= \log_a x^5 - \left[ \log_a (3x-4)^{1/2} + \log_a (5x+1)^3 \right] \\
&= \log_a x^5 - \left[ \log_a (3x-4)^{1/2} (5x+1)^3 \right] \\
&= \log_a \frac{x^5}{(3x-4)^{1/2} (5x+1)^3}
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\log(x^3 y^2) - 2\log(x\sqrt[3]{y}) - 3\log\left(\frac{x}{y}\right)$$

### Solution

$$\begin{aligned}
\log(x^3 y^2) - 2\log(x\sqrt[3]{y}) - 3\log\left(\frac{x}{y}\right) &= \log(x^3 y^2) - \log(xy^{1/3})^2 - \log(xy^{-1})^3 \\
&= \log(x^3 y^2) - \left[ \log(x^2 y^{2/3}) + \log(x^3 y^{-3}) \right] \\
&= \log(x^3 y^2) - \log(x^2 y^{2/3} x^3 y^{-3}) \\
&= \log(x^3 y^2) - \log(x^5 y^{-7/3}) \\
&= \log\left(\frac{x^3 y^2}{x^5 y^{-7/3}}\right) \\
&= \log\left(\frac{y^2 y^{7/3}}{x^2}\right) \\
&= \log\left(\frac{y^{13/3}}{x^2}\right) \\
&= \log\left(\frac{\sqrt[3]{y^{13}}}{x^2}\right) \\
&= \log\left(\frac{y^4 \sqrt[3]{y}}{x^2}\right)
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\ln y^3 + \frac{1}{3}\ln(x^3 y^6) - 5\ln y$$

### Solution

$$\begin{aligned}\ln y^3 + \frac{1}{3}\ln(x^3 y^6) - 5\ln y &= \ln y^3 + \ln(x^3 y^6)^{1/3} - \ln y^5 \\&= \ln y^3 + \ln(x^{3/3} y^{6/3}) - \ln y^5 \\&= \ln y^3 + \ln(xy^2) - \ln y^5 \\&= \ln(y^3 xy^2) - \ln y^5 \\&= \ln\left(\frac{y^5 x}{y^5}\right) \\&= \ln x\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$2\ln x - 4\ln\left(\frac{1}{y}\right) - 3\ln(xy)$$

### Solution

$$\begin{aligned}2\ln x - 4\ln\left(\frac{1}{y}\right) - 3\ln(xy) &= \ln x^2 - \ln\left(\frac{1}{y}\right)^4 - \ln(xy)^3 \\&= \ln x^2 - \left[\ln(y^{-4}) + \ln(x^3 y^3)\right] \\&= \ln x^2 - \ln(y^{-4} x^3 y^3) \\&= \ln x^2 - \ln(y^{-1} x^3) \\&= \ln \frac{x^2}{y^{-1} x^3} \\&= \ln \frac{y}{x}\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$4 \ln x + 7 \ln y - 3 \ln z$$

### Solution

$$\begin{aligned} 4 \ln x + 7 \ln y - 3 \ln z &= \ln x^4 + \ln y^7 - \ln z^3 \\ &= \ln(x^4 y^7) - \ln z^3 \\ &= \ln\left(\frac{x^4 y^7}{z^3}\right) \end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{1}{3} \left[ 5 \ln(x+6) - \ln x - \ln(x^2 - 25) \right]$$

### Solution

$$\begin{aligned} \frac{1}{3} \left[ 5 \ln(x+6) - \ln x - \ln(x^2 - 25) \right] &= \frac{1}{3} \left[ 5 \ln(x+6) - (\ln x + \ln(x^2 - 25)) \right] \\ &= \frac{1}{3} \left[ \ln(x+6)^5 - \ln x(x^2 - 25) \right] \\ &= \frac{1}{3} \left[ \ln \frac{(x+6)^5}{x(x^2 - 25)} \right] \\ &= \ln \left( \frac{(x+6)^5}{x(x^2 - 25)} \right)^{1/3} \end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{2}{3} \left[ \ln(x^2 - 4) - \ln(x+2) \right] + \ln(x+y)$$

### Solution

$$\begin{aligned} \frac{2}{3} \left[ \ln(x^2 - 4) - \ln(x+2) \right] + \ln(x+y) &= \frac{2}{3} \left[ \ln \frac{x^2 - 4}{x+2} \right] + \ln(x+y) \\ &= \frac{2}{3} \left[ \ln \frac{(x+2)(x-2)}{x+2} \right] + \ln(x+y) \\ &= \frac{2}{3} \ln(x-2) + \ln(x+y) \end{aligned}$$



$$\begin{aligned}
&= \ln(x-2)^{2/3} + \ln(x+y) \\
&= \ln(x-2)^{2/3}(x+y) \\
&= \ln(x+y) \sqrt[3]{(x-2)^2}
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{1}{2}\log_b m + \frac{3}{2}\log_b 2n - \log_b m^2 n$$

### Solution

$$\begin{aligned}
\frac{1}{2}\log_b m + \frac{3}{2}\log_b 2n - \log_b m^2 n &= \log_b m^{1/2} + \log_b (2n)^{3/2} - \log_b m^2 n \\
&= \log_b \left( m^{1/2} (2n)^{3/2} \right) - \log_b m^2 n \\
&= \log_b \frac{m^{1/2} 2^{3/2} n^{3/2}}{m^2 n} \\
&= \log_b \frac{2^{3/2} n^{1/2}}{m^{3/2}} \\
&= \log_b \left( \frac{2^3 n}{m^3} \right)^{1/2} \\
&= \log_b \sqrt{\frac{8n}{m^3}}
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{1}{2}\log_y p^3 q^4 - \frac{2}{3}\log_y p^4 q^3$$

### Solution

$$\begin{aligned}
\frac{1}{2}\log_y p^3 q^4 - \frac{2}{3}\log_y p^4 q^3 &= \log_y \left( p^3 q^4 \right)^{1/2} - \log_y \left( p^4 q^3 \right)^{2/3} \\
&= \log_y \frac{\left( p^3 q^4 \right)^{1/2}}{\left( p^4 q^3 \right)^{2/3}} \\
&= \log_y \frac{\left( p^3 \right)^{1/2} \left( q^4 \right)^{1/2}}{\left( p^4 \right)^{2/3} \left( q^3 \right)^{2/3}}
\end{aligned}$$

$$\begin{aligned}
&= \log_y \frac{p^{3/2} q^2}{p^{8/3} q^2} \\
&= \log_y \frac{p^{3/2}}{p^{8/3}} \\
&= \log_y \frac{1}{p^{8/3-3/2}} \\
&= \log_y \frac{1}{p^{7/6}}
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{1}{2} \log_a x + 4 \log_a y - 3 \log_a x$$

### Solution

$$\begin{aligned}
\frac{1}{2} \log_a x + 4 \log_a y - 3 \log_a x &= 4 \log_a y - \frac{5}{2} \log_a x \\
&= \log_a y^4 - \log_a x^{5/2} \\
&= \log_a \frac{y^4}{\sqrt{x^5}}
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{2}{3} \left[ \ln(x^2 - 9) - \ln(x + 3) \right] + \ln(x + y)$$

### Solution

$$\begin{aligned}
\frac{2}{3} \left[ \ln(x^2 - 9) - \ln(x + 3) \right] + \ln(x + y) &= \frac{2}{3} \ln \frac{x^2 - 9}{x + 3} + \ln(x + y) \\
&= \frac{2}{3} \ln \frac{(x + 3)(x - 3)}{x + 3} + \ln(x + y) \\
&= \frac{2}{3} \ln(x - 3) + \ln(x + y) \\
&= \ln(x - 3)^{2/3} + \ln(x + y) \\
&= \ln \left( (x - 3)^{2/3} (x + y) \right) \\
&= \ln \left( (x + y) \sqrt[3]{(x - 3)^2} \right)
\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\frac{1}{4}\log_b x - 2\log_b 5 - 10\log_b y$$

### Solution

$$\begin{aligned}\frac{1}{4}\log_b x - 2\log_b 5 - 10\log_b y &= \log_b x^{1/4} - \log_b 5^2 - \log_b y^{10} \\ &= \log_b x^{1/4} - \left[ \log_b 5^2 + \log_b y^{10} \right] \\ &= \log_b x^{1/4} - \log_b (5^2 y^{10}) \\ &= \log_b \frac{\sqrt[4]{x}}{25y^{10}}\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$2\ln(x+4) - \ln x - \ln(x^2 - 3)$$

### Solution

$$\begin{aligned}2\ln(x+4) - \ln x - \ln(x^2 - 3) &= \ln(x+4)^2 - (\ln x + \ln(x^2 - 3)) \\ &= \ln(x+4)^2 - \ln(x(x^2 - 3)) \\ &= \ln \frac{(x+4)^2}{x(x^2 - 3)}\end{aligned}$$

### Exercise

Write the expression as a single logarithm and simplify if necessary:

$$\ln x + \ln(y+3) + \ln(y+2) - \ln(y^2 + 5y + 6)$$

### Solution

$$\begin{aligned}\ln x + \ln(y+3) + \ln(y+2) - \ln(y^2 + 5y + 6) &= \ln(x(y+3)(y+2)) - \ln((y+3)(y+2)) \\ &= \ln\left(\frac{x(y+3)(y+2)}{(y+3)(y+2)}\right) \\ &= \ln x\end{aligned}$$

### ***Exercise***

Write the expression as a single logarithm and simplify if necessary:

$$\ln x + \ln(x+4) + \ln(x+1) - \ln(x^2 + 5x + 4)$$

### ***Solution***

$$\begin{aligned}\ln x + \ln(x+4) + \ln(x+1) - \ln(x^2 + 5x + 4) &= \ln(x(x+4)(x+1)) - \ln((x+4)(x+1)) \\ &= \ln\left(\frac{x(x+4)(x+1)}{(x+4)(x+1)}\right) \\ &= \ln x\end{aligned}$$

### ***Exercise***

Write the expression as a single logarithm and simplify if necessary:

$$\ln(x^2 - 25) - 2\ln(x+5) + \ln(x-5)$$

### ***Solution***

$$\begin{aligned}\ln(x^2 - 25) - 2\ln(x+5) + \ln(x-5) &= \ln(x^2 - 25) + \ln(x-5) - \ln(x+5)^2 \\ &= \ln\frac{(x-5)(x+5)(x-5)}{(x+5)^2} \\ &= \ln\left(\frac{(x-5)^2}{x+5}\right)\end{aligned}$$

### ***Exercise***

Solve the equation:  $2^x = 128$

### ***Solution***

$$\begin{aligned}2^x &= 2^7 \\ x &= 7\end{aligned}$$

### ***Exercise***

Solve the equation:  $3^x = 243$

### ***Solution***

$$3^x = 3^5$$

$$\underline{x = 5}$$

### ***Exercise***

Solve the equation:  $5^x = 70$

### **Solution**

$$\underline{x = \log_5 70}$$

### ***Exercise***

Solve the equation:  $6^x = 50$

### **Solution**

$$\underline{x = \log_6 50}$$

### ***Exercise***

Solve the equation:  $5^x = 134$

### **Solution**

$$\underline{x = \log_5 134}$$

***Exercise***

Solve the equation:  $7^x = 12$

**Solution**

$$\underline{x = \log_7 12}$$

***Exercise***

Solve the equation:  $9^x = \frac{1}{\sqrt[3]{3}}$

**Solution**

$$(3^2)^x = \frac{1}{3^{1/3}}$$

$$3^{2x} = 3^{-1/3}$$

$$2x = -\frac{1}{3}$$

$$\underline{x = -\frac{1}{6}}$$

***Exercise***

Solve the equation:  $49^x = \frac{1}{343}$

**Solution**

$$(7^2)^x = \frac{1}{7^3}$$

$$7^{2x} = 7^{-3}$$

$$2x = -3$$

$$\underline{x = -\frac{3}{2}}$$

***Exercise***

Solve the equation:  $2^{5x+3} = \frac{1}{16}$

**Solution**

$$2^{5x+3} = 2^{-4}$$

$$5x + 3 = -4$$

$$5x = -7$$

$$\underline{x = -\frac{7}{5}}$$

### ***Exercise***

Solve the equation:  $\left(\frac{2}{5}\right)^x = \frac{8}{125}$

#### **Solution**

$$\left(\frac{2}{5}\right)^x = \left(\frac{2}{5}\right)^3$$

$$\underline{x = 3}$$

### ***Exercise***

Solve the equation:  $2^{3x-7} = 32$

#### **Solution**

$$2^{3x-7} = 32$$

$$= 2^5$$

$$3x - 7 = 5$$

*add 7 on both sides*

$$3x = 12$$

*Divide by 3*

$$\underline{x = 4}$$

### ***Exercise***

Solve the equation:  $4^{2x-1} = 64$

#### **Solution**

$$4^{2x-1} = 4^3$$

$$2x - 1 = 3$$

$$2x = 4$$

$$\underline{x = 2}$$

### ***Exercise***

Solve the equation:  $3^{1-x} = \frac{1}{27}$

#### **Solution**

$$3^{1-x} = \frac{1}{3^3}$$

$$3^{1-x} = 3^{-3}$$

$$1 - x = -3$$

$$\underline{x = 4}$$

### ***Exercise***

Solve the equation:  $2^{-x^2} = 5$

### **Solution**

$$\ln 2^{-x^2} = \ln 5$$

$$-x^2 \ln 2 = \ln 5$$

$$x^2 = -\frac{\ln 5}{\ln 2} \Rightarrow \text{No Solution}$$

### ***Exercise***

Solve the equation:  $2^{-x} = 8$

### **Solution**

$$2^{-x} = 2^3$$

$$-x = 3$$

$$\underline{x = -3}$$

### ***Exercise***

Solve the equation:  $\left(\frac{1}{3}\right)^x = 81$

### **Solution**

$$\left(\frac{1}{3}\right)^x = 81$$

$$\left(3^{-1}\right)^x = 3^4$$

$$3^{-x} = 3^4$$

$$-x = 4$$

$$\underline{x = -4}$$

### ***Exercise***

Solve the equation:  $3^{-x} = 120$

### **Solution**

$$-x = \log_3 120$$

*Convert to Log*

$$x = -\log_3 120$$



$$\left. = \log_3 \frac{1}{120} \right|$$

### Exercise

Solve the equation:  $27 = 3^{5x} 9^{x^2}$

### Solution

$$\begin{aligned} 3^3 &= 3^{5x} (3^2)^{x^2} \\ &= 3^{5x} 3^{2x^2} \\ &= 3^{5x+2x^2} \end{aligned}$$

$$2x^2 + 5x = 3$$

$$2x^2 + 5x - 3 = 0$$

$$x = \frac{-5 \pm \sqrt{25 + 24}}{6}$$

$$x = \left\{ \begin{array}{l} \frac{-5-7}{6} = -2 \\ \frac{-5+7}{6} = \frac{1}{3} \end{array} \right|$$

### Exercise

Solve the equation:  $4^{x+3} = 3^{-x}$

### Solution

$$\ln 4^{x+3} = \ln 3^{-x}$$

$$(x+3) \ln 4 = -x \ln 3$$

$$x \ln 4 + 3 \ln 4 = -x \ln 3$$

$$x \ln 4 + x \ln 3 = -3 \ln 4$$

$$x(\ln 4 + \ln 3) = -3 \ln 4$$

$$\left. x = \frac{-3 \ln 4}{(\ln 4 + \ln 3)} \right|$$

### Exercise

Solve the equation:  $2^{x+4} = 8^{x-6}$

### Solution

$$2^{x+4} = (2^3)^{x-6}$$

$$2^{x+4} = 2^{3x-18}$$

$$x + 4 = 3x - 18$$

$$2x = 22$$

$$\underline{x = 11}$$

### ***Exercise***

Solve the equation:  $8^{x+2} = 4^{x-3}$

#### **Solution**

$$(2^3)^{x+2} = (2^2)^{x-3}$$

$$2^{3(x+2)} = 2^{2(x-3)}$$

$$3(x+2) = 2(x-3)$$

$$3x + 6 = 2x - 6$$

$$3x - 2x = -6 - 6$$

$$\underline{x = -12}$$

### ***Exercise***

Solve the equation:  $7^x = 12$

#### **Solution**

$$\underline{x = \log_7 12}$$

*Convert to Log*

### ***Exercise***

Solve the equation:  $5^{x+4} = 4^{x+5}$

#### **Solution**

$$\ln 5^{x+4} = \ln 4^{x+5}$$

$$(x+4) \ln 5 = (x+5) \ln 4$$

$$x \ln 5 + 4 \ln 5 = x \ln 4 + 5 \ln 4$$

$$(\ln 5 - \ln 4)x = 5 \ln 4 - 4 \ln 5$$

$$\underline{x = \frac{5 \ln 4 - 4 \ln 5}{\ln 5 - \ln 4}}$$

### ***Exercise***

Solve the equation:  $5^{x+2} = 4^{1-x}$

**Solution**

$$\ln 5^{x+2} = \ln 4^{1-x}$$

$$(x+2)\ln 5 = (1-x)\ln 4$$

$$x\ln 5 + 2\ln 5 = \ln 4 - x\ln 4$$

$$(\ln 5 + \ln 4)x = \ln 4 - 2\ln 5$$

$$x = \frac{\ln 4 - 2\ln 5}{\ln 5 + \ln 4}$$

***Exercise***

Solve the equation:  $3^{2x-1} = 0.4^{x+2}$

**Solution**

$$\ln 3^{2x-1} = \ln(0.4^{x+2})$$

$$(2x-1)\ln 3 = (x+2)\ln \frac{4}{10}$$

$$2x\ln 3 - \ln 3 = x\ln \frac{2}{5} + 2\ln \frac{2}{5}$$

$$\left(2\ln 3 - \ln \frac{2}{5}\right)x = \ln 3 + 2\ln \frac{2}{5}$$

$$x = \frac{\ln 3 + 2\ln 0.4}{2\ln 3 - \ln 0.4}$$

***Exercise***

Solve the equation:  $4^{3x-5} = 16$

**Solution**

$$4^{3x-5} = 4^2$$

$$3x - 5 = 2$$

$$3x = 7$$

$$x = \frac{7}{3}$$

***Exercise***

Solve the equation:  $4^{x+3} = 3^{-x}$

**Solution**

$$\ln 4^{x+3} = \ln 3^{-x}$$

$$\begin{aligned}(x+3)\ln 4 &= -x\ln 3 \\ x\ln 4 + 3\ln 4 &= -x\ln 3 \\ (\ln 4 + \ln 3)x &= -3\ln 4 \\ x &= -\frac{3\ln 4}{\ln 4 + \ln 3}\end{aligned}$$

### ***Exercise***

Solve the equation:  $7^{2x+1} = 3^{x+2}$

### **Solution**

$$\begin{aligned}\ln 7^{2x+1} &= \ln 3^{x+2} \\ (2x+1)\ln 7 &= (x+2)\ln 3 \\ 2x\ln 7 + \ln 7 &= x\ln 3 + 2\ln 3 \\ 2x\ln 7 - x\ln 3 &= 2\ln 3 - \ln 7 \\ x(2\ln 7 - \ln 3) &= 2\ln 3 - \ln 7 \\ x &= \frac{2\ln 3 - \ln 7}{2\ln 7 - \ln 3}\end{aligned}$$

### ***Exercise***

Solve the equation:  $3^{x-1} = 7^{2x+5}$

### **Solution**

$$\begin{aligned}\ln 3^{x-1} &= \ln 7^{2x+5} \\ (x-1)\ln 3 &= (2x+5)\ln 7 \\ x\ln 3 - \ln 3 &= 2x\ln 7 + 5\ln 7 \\ x\ln 3 - 2x\ln 7 &= \ln 3 + 5\ln 7 \\ x(\ln 3 - 2\ln 7) &= \ln 3 + 5\ln 7 \\ x &= \frac{\ln 3 + 5\ln 7}{\ln 3 - 2\ln 7}\end{aligned}$$

### ***Exercise***

Solve the equation:  $4^{x-2} = 2^{3x+3}$

### **Solution**

$$\left(2^2\right)^{x-2} = 2^{3x+3}$$

$$2^{2x-4} = 2^{3x+3}$$

$$2x - 4 = 3x + 3$$

$$2x - 3x = 4 + 3$$

$$-x = 7$$

$$\underline{x = -7}$$

### Exercise

Solve the equation:  $3^{5x-8} = 9^{x+2}$

### Solution

$$3^{5x-8} = \left(3^2\right)^{x+2}$$

$$3^{5x-8} = 3^{2x+4}$$

$$5x - 8 = 2x + 4$$

$$5x - 2x = 8 + 4$$

$$3x = 12$$

$$\underline{x = 4}$$

### Exercise

Solve the equation:  $3^{x+4} = 2^{1-3x}$

### Solution

$$\ln 3^{x+4} = \ln 2^{1-3x}$$

$$(x+4) \ln 3 = (1-3x) \ln 2$$

$$x \ln 3 + 4 \ln 3 = \ln 2 - 3x \ln 2$$

$$x \ln 3 + 3x \ln 2 = \ln 2 - 4 \ln 3$$

$$x(\ln 3 + 3 \ln 2) = \ln 2 - 4 \ln 3$$

$$\underline{x = \frac{\ln 2 - 4 \ln 3}{\ln 3 + 3 \ln 2}}$$

*'ln' both sides*

*Power Rule*

*Distribute*

### Exercise

Solve the equation:  $3^{2-3x} = 4^{2x+1}$

### Solution

$$\ln 3^{2-3x} = \ln 4^{2x+1}$$

*'ln' both sides*

$$(2-3x)\ln 3 = (2x+1)\ln 4$$

*Power Rule*

$$2\ln 3 - 3x\ln 3 = 2x\ln 4 + \ln 4$$

$$-3x\ln 3 - 2x\ln 4 = \ln 4 - 2\ln 3$$

$$-x(3\ln 3 + 2\ln 4) = \ln 4 - 2\ln 3$$

$$x = -\frac{\ln 4 - 2\ln 3}{3\ln 3 + 2\ln 4}$$

$$= -\frac{\ln 4 - \ln 3^2}{\ln 3^3 + \ln 4^2}$$

$$= \frac{\ln 9 - \ln 4}{\ln 27 + \ln 16}$$

$$= \frac{\ln \frac{9}{4}}{\ln 432}$$

$$= \log_{432} \frac{9}{4}$$

### ***Exercise***

Solve the equation:  $4^{x+3} = 3^{-x}$

### **Solution**

$$\ln 4^{x+3} = \ln 3^{-x}$$

$$(x+3)\ln 4 = -x\ln 3$$

$$x\ln 4 + 3\ln 4 = -x\ln 3$$

$$x\ln 4 + x\ln 3 = -3\ln 4$$

$$x(\ln 4 + \ln 3) = -3\ln 4$$

$$x = \frac{-3\ln 4}{(\ln 4 + \ln 3)}$$

### ***Exercise***

Solve the equation:  $7^{x+6} = 7^{3x-4}$

### **Solution**

$$x+6 = 3x-4$$

$$4+6 = 3x-x$$

$$10 = 2x$$

$$x = 5$$

### Exercise

Solve the equation:  $2^{-100x} = (0.5)^{x-4}$

#### Solution

$$2^{-100x} = \left(\frac{1}{2}\right)^{x-4}$$

$$2^{-100x} = \left(2^{-1}\right)^{x-4}$$

$$2^{-100x} = 2^{-x+4}$$

$$-100x = -x + 4$$

$$-100x + x = 4$$

$$-99x = 4$$

$$\underline{x = -\frac{4}{99}}$$

### Exercise

Solve the equation:  $4^x \left(\frac{1}{2}\right)^{3-2x} = 8 \cdot (2^x)^2$

#### Solution

$$\left(2^2\right)^x \left(2^{-1}\right)^{3-2x} = 2^3 \cdot 2^{2x}$$

$$2^{2x} 2^{2x-3} = 2^{3+2x}$$

$$2^{2x+2x-3} = 2^{3+2x}$$

$$2^{4x-3} = 2^{3+2x}$$

$$4x - 3 = 3 + 2x$$

$$4x - 2x = 3 + 3$$

$$2x = 6$$

$$\underline{x = 3}$$

### Exercise

$5^x + 125(5^{-x}) = 30$

#### Solution

$$5^x 5^x + 125(5^{-x}) 5^x = 30(5^x)$$

$$5^{2x} + 125 = 30(5^x)$$

$$5^{2x} - 30(5^x) + 125 = 0 \quad \text{Solve for } 5^x$$

$$5^x = 5 \quad 5^x = 25 = 5^2$$

$$x = 1 \quad x = 2$$

$$\underline{x = 1, 2}$$

### Exercise

$$4^x - 3(4^{-x}) = 8$$

### Solution

$$4^x 4^x - 3(4^{-x}) 4^x = 8(4^x)$$

$$4^{2x} - 3 = 8(4^x)$$

$$4^{2x} - 8(4^x) - 3 = 0 \quad \text{Solve for } 4^x$$

$$4^x = 4 + \sqrt{19} \quad 4^x = 4 - \sqrt{19} < 0$$

$$x \ln 4 = \ln(4 + \sqrt{19})$$

$$\underline{x = \frac{\ln(4 + \sqrt{19})}{\ln 4}}$$

### Exercise

$$\text{Solve the equation: } 5^{3x-6} = 125$$

### Solution

$$5^{3x-6} = 5^3$$

$$3x - 6 = 3$$

$$3x = 9$$

$$\underline{x = 3}$$

### Exercise

$$\text{Solve the equation: } e^x = 15$$

### Solution

$$\underline{x = \ln 5}$$

Convert to Log



### ***Exercise***

Solve the equation:  $e^{x+1} = 20$

#### **Solution**

$$x + 1 = \ln 20$$

*Convert to Log*

$$\underline{x = -1 + \ln 20}$$

### ***Exercise***

Solve the equation:  $9e^x = 107$

#### **Solution**

$$e^x = \frac{107}{9}$$

$$\ln e^x = \ln\left(\frac{107}{9}\right)$$

$$x \ln e = \ln\left(\frac{107}{9}\right)$$

$$\underline{x = \ln\left(\frac{107}{9}\right)}$$

### ***Exercise***

Solve the equation:  $e^{x \ln 3} = 27$

#### **Solution**

$$x \ln 3 = \ln 27$$

*Convert to Log*

$$x \ln 3 = \ln 3^3$$

$$x = \frac{3 \ln 3}{\ln 3}$$

$$\underline{= 3}$$

### ***Exercise***

Solve the equation:  $e^{x^2} = e^{7x-12}$

#### **Solution**

$$e^{x^2} = e^{7x-12}$$

$$x^2 = 7x - 12$$

$$x^2 - 7x + 12 = 0$$

$$\underline{x = 3, 4}$$

### Exercise

Solve the equation:  $f(x) = xe^x + e^x$

#### Solution

$$xe^x + e^x = 0$$

$$e^x(x+1) = 0$$

$$e^x \neq 0 \quad x+1 = 0$$

$$\underline{x = -1} \quad (\text{Only solution})$$

### Exercise

Solve the equation  $f(x) = x^3(4e^{4x}) + 3x^2e^{4x}$

#### Solution

$$x^3(4e^{4x}) + 3x^2e^{4x} = 0$$

$$x^2e^{4x}(4x+3) = 0$$

$$x^2 = 0 \quad 4x+3 = 0$$

$$x = 0, 0 \quad x = -\frac{3}{4}$$

$$\text{The solutions are: } \underline{x = 0, 0, -\frac{3}{4}}$$

### Exercise

Solve the equation:  $e^{2x} - 2e^x - 3 = 0$

#### Solution

$$(e^x)^2 - 2e^x - 3 = 0$$

$$\begin{cases} e^x = -1 \quad \times \rightarrow \text{Impossible} \\ e^x = 3 \quad \rightarrow \underline{x = \ln 3} \end{cases}$$

### Exercise

Solve the equation:  $e^{0.08t} = 2500$

#### Solution

$$\ln(e^{0.08t}) = \ln 2500$$

$$0.08t = \ln(50)^2$$

$$t = \frac{200 \ln 50}{8}$$

$$= 25 \ln 50$$

### Exercise

Solve the equation:  $e^{x^2} = 200$

#### Solution

$$\ln e^{x^2} = \ln 200 \quad \text{Natural Log both sides}$$

$$x^2 = \ln 200 \quad \ln e = 1$$

$$x = \pm \sqrt{\ln 200}$$

### Exercise

Solve the equation:  $e^{2x+1} \cdot e^{-4x} = 3e$

#### Solution

$$e^{2x+1-4x} = 3e$$

$$e^{-2x+1} = 3e$$

$$e^{-2x}e = 3e \quad \text{Divide by } e$$

$$e^{-2x} = 3$$

$$\ln e^{-2x} = \ln 3$$

$$-2x = \ln 3$$

$$x = -\frac{1}{2} \ln 3$$

### Exercise

Solve the equation:  $e^{2x} - 8e^x + 7 = 0$

#### Solution

$$(e^x)^2 - 8e^x + 7 = 0 \quad a + b + c = 0 \rightarrow x = 1, \frac{c}{a}$$

$$\begin{cases} e^x = 1 \rightarrow x = 0 \\ e^x = 7 \rightarrow x = \ln 7 \end{cases}$$

### Exercise

Solve the equation without using the calculator:  $e^{2x} + 2e^x - 15 = 0$

#### Solution

$$(e^x)^2 + 2e^x - 15 = 0 \quad \text{Solve for } e^x$$

$$e^x = 3$$

$$e^x \not= -5 < 0$$

$$\underline{x = \ln 3}$$

### Exercise

Solve the equation:  $e^x + e^{-x} - 6 = 0$

#### Solution

$$e^x e^x + e^x e^{-x} - e^x 6 = e^x 0$$

$$e^{2x} + 1 - 6e^x = 0$$

$$(e^x)^2 - 6e^x + 1 = 0$$

$$e^x = \frac{6 \pm \sqrt{36 - 4}}{2}$$

$$= \frac{6 \pm 4\sqrt{2}}{2}$$

$$e^x = 3 \pm 2\sqrt{2}$$

$$\underline{x = \ln(3 \pm 2\sqrt{2})}$$

### Exercise

Solve the equation:  $e^{1-3x} \cdot e^{5x} = 2e$

#### Solution

$$e^{1-3x+5x} = 2e$$

$$e^{1+2x} = 2e$$

$$e^1 e^{2x} = 2e$$

Divide by  $e$

$$e^{2x} = 2$$

Natural Log both sides

$$\ln e^{2x} = \ln 2$$

$$2x = \ln 2$$

$$\underline{x = \frac{1}{2} \ln 2}$$

### ***Exercise***

Solve the equation:  $6 \ln(2x) = 30$

#### **Solution**

$$\ln(2x) = \frac{30}{6}$$

$$\ln(2x) = 5$$

$$2x = e^5$$

$$\underline{x = \frac{1}{2}e^5}$$

### ***Exercise***

Solve the equation:  $\log_5(x - 7) = 2$

#### **Solution**

$$x - 7 = 5^2$$

$$x = 25 + 7$$

$$\underline{x = 32}$$

### ***Exercise***

Solve the equation:  $\log_4(5 + x) = 3$

#### **Solution**

$$5 + x = 4^3$$

$$x = 64 - 5$$

$$\underline{= 59}$$

**Check:**  $\log_4(5 + 59)$

### ***Exercise***

Solve the equation:  $\log(4x - 18) = 1$

#### **Solution**

$$4x - 18 = 10$$

$$4x = 28$$

$$\underline{x = 7}$$

### Exercise

Solve the equation:  $\log(x^2 + 19) = 2$

#### Solution

$$x^2 + 19 = 10^2$$

$$x^2 = 81$$

$$\underline{x = \pm 9} \quad (\pm 9)^2 + 19 > 0$$

### Exercise

Solve the equation:  $\ln(x^2 - 12) = \ln x$

#### Solution

$$\ln(x^2 - 12) = \ln x$$

$$x^2 - 12 = x$$

$$x^2 - x - 12 = 0$$

$$\underline{x = -3, 4}$$

$$\text{Check: } x = -3 \quad \ln(9 - 12) = \ln(-3) \quad \times$$

$$x = 4 \quad \ln(16 - 12) = \ln(4)$$

$$\therefore \text{Solution: } \underline{x = 4}$$

### Exercise

Solve the equation:  $\log(2x^2 + 3x) = \log(10x + 30)$

#### Solution

$$\log(2x^2 + 3x) = \log(10x + 30)$$

$$2x^2 + 3x = 10x + 30$$

$$2x^2 - 7x - 30 = 0$$

$$x = \frac{7 \pm \sqrt{49 + 240}}{4}$$

$$= \begin{cases} \frac{7-17}{4} = -\frac{5}{2} \\ \frac{7+17}{4} = 6 \end{cases}$$

**Check:**  $x = -\frac{5}{2} \quad \log\left(\frac{25}{2} - \frac{15}{2}\right) = \log(-25 + 30)$

$x = 4 \quad \log(32 + 12) = \log(40 + 30)$

$\therefore$  **Solution:**  $x = -\frac{5}{2}, 4$

### Exercise

Solve the equation:  $\log_5(2x + 3) = \log_5 11 + \log_5 3$

#### Solution

$\log_5(2x + 3) = \log_5(11 \times 3)$

$2x + 3 = 33$

$2x = 30$

$x = 15$

**Check:**  $\log_5(30 + 3)$

### Exercise

Solve the equation:  $\log_3 x - \log_9(x + 42) = 0$

#### Solution

$\frac{\log x}{\log 3} - \frac{\log(x + 42)}{\log 9} = 0$

$\frac{\log x}{\log 3} - \frac{\log(x + 42)}{\log 3^2} = 0$

$\frac{\log x}{\log 3} - \frac{1}{2} \frac{\log(x + 42)}{\log 3} = 0$

$\log x - \frac{1}{2} \log(x + 42) = 0$

$2 \log x = \log(x + 42)$

$\log x^2 = \log(x + 42)$

$x^2 = x + 42$

$x^2 - x - 42 = 0$

$x = -6, 7$

**Check:**  $x = -6 \quad \log_3(-6) - \log_9(-6 + 42) \quad \times$

$x = 7 \quad \log_3 7 - \log_9(7 + 42) = 0$

$\therefore$  **Solution:**  $x = 7$

### Exercise

Solve the equation:  $\log_5 x + \log_5 (4x - 1) = 1$

#### Solution

$$\log_5 x(4x - 1) = 1$$

$$4x^2 - x = 5$$

$$4x^2 - x - 5 = 0 \quad a - b + c = 0 \rightarrow x = -1, -\frac{c}{a}$$

$$\underline{x = -\frac{5}{2}, 4}$$

$$\text{Check: } x = -\frac{5}{2} \quad \log_5 \left(-\frac{5}{2}\right) + \log_5 (10 - 1) \quad \times$$

$$x = 4 \quad \log_5 (4) + \log_5 (15)$$

$$\therefore \text{Solution: } \underline{x = 4}$$

### Exercise

Solve the equation:  $\log x - \log (x + 3) = 1$

#### Solution

$$\log \frac{x}{x+3} = 1$$

$$\frac{x}{x+3} = 10$$

$$x = 10x + 30$$

$$9x = -30$$

$$\underline{x = -\frac{10}{9}}$$

$$\text{Check: } x = -\frac{10}{9} \quad \log \left(-\frac{10}{9}\right) - \log (x + 3) \quad \times$$

$$\therefore \text{No Solution}$$

### Exercise

Solve the equation:  $\log x + \log (x - 9) = 1$

#### Solution

$$\log x(x - 9) = 1$$

$$x^2 - 9x = 10$$

$$x^2 - 9x - 10 = 0 \quad a - b + c = 0 \rightarrow x = -1, -\frac{c}{a}$$

$$\underline{x = -1, 10}$$



**Check:**  $x = -1 \quad \log(-1) + \log(x-9) \quad \times$

$x = 10 \quad \log(10) + \log(10-9)$

$\therefore \text{Solution: } \underline{x = 10}$

### Exercise

Solve the equation:  $\log_2(x+1) + \log_2(x-1) = 3$

#### Solution

$$\log_2(x+1)(x-1) = 3$$

$$x^2 - 1 = 2^3$$

$$x^2 = 9$$

$$\underline{x = \pm 3}$$

**Check:**  $x = -3 \quad \log_2(-2) + \log_2(x-1) \quad \times$

$x = 3 \quad \log_2(4) + \log_2(2)$

$\therefore \text{Solution: } \underline{x = 3}$

### Exercise

Solve the equation:  $\log_8(x+1) - \log_8 x = 2$

#### Solution

$$\log_8 \frac{x+1}{x} = 2$$

$$\frac{x+1}{x} = 8^2$$

$$x+1 = 64x$$

$$63x = 1$$

$$\underline{x = \frac{1}{63}}$$

**Check:**  $x = \frac{1}{63} \quad \log_8\left(\frac{1}{63} + 1\right) - \log_8 \frac{1}{63}$

$\therefore \text{Solution: } \underline{x = \frac{1}{63}}$

### Exercise

Solve the equation:  $\ln(x+8) + \ln(x-1) = 2\ln x$

#### Solution

$$\ln(x+8)(x-1) = \ln x^2$$

$$x^2 + 7x - 8 = x^2$$

$$7x - 8 = 0$$

$$x = \frac{8}{7} \quad |$$

$$\text{Check: } x = \frac{8}{7} \quad \ln\left(\frac{8}{7} + 8\right) + \ln\left(\frac{8}{7} - 1\right) = 2\ln \frac{8}{7}$$

$$\therefore \text{Solution: } x = \frac{8}{7} \quad |$$

### Exercise

Solve the equation:  $\ln(4x+6) - \ln(x+5) = \ln x$

#### Solution

$$\ln \frac{4x+6}{x+5} = \ln x$$

$$\frac{4x+6}{x+5} = x$$

$$4x+6 = x^2 + 5x$$

$$x^2 + x - 6 = 0$$

$$x = -3, 2 \quad |$$

$$\text{Check: } x = -3 \quad \ln(-6) - \ln(x+5) = \ln x \quad \times$$

$$x = 2 \quad \ln(14) - \ln(7) = \ln 2$$

$$\therefore \text{Solution: } x = 2 \quad |$$

### Exercise

Solve the equation:  $\ln(5+4x) - \ln(x+3) = \ln 3$

#### Solution

$$\ln \frac{5+4x}{x+3} = \ln 3$$

$$\frac{5+4x}{x+3} = 3$$

$$5+4x = 3x+9$$

$$x = 4 \quad |$$

**Check:**  $x = 4 \quad \ln(21) - \ln(7) = \ln 3$

**∴ Solution:**  $\underline{x = 4}$

### Exercise

Solve the equation:  $\ln \sqrt[4]{x} = \sqrt{\ln x}$

#### Solution

**Domain:**  $\underline{x \geq 1}$

$$\ln x^{1/4} = \sqrt{\ln x}$$

$$\frac{1}{4} \ln x = \sqrt{\ln x}$$

$$\left(\frac{1}{4} \ln x\right)^2 = (\sqrt{\ln x})^2$$

$$\frac{1}{6} \ln^2 x = \ln x$$

$$\ln^2 x = 6 \ln x$$

$$\ln^2 x - 6 \ln x = 0$$

$$(\ln x)(\ln x - 6) = 0$$

$$\begin{cases} \ln x = 0 \rightarrow \underline{x = 1} \\ \ln x = 6 \rightarrow \underline{x = e^6} \end{cases}$$

**∴ Solution:**  $\underline{x = 1, e^6}$

### Exercise

Solve the equation:  $\sqrt{\ln x} = \ln \sqrt{x}$

#### Solution

**Domain:**  $\underline{x \geq 1}$

$$\sqrt{\ln x} = \ln x^{1/2}$$

$$\sqrt{\ln x} = \frac{1}{2} \ln x$$

$$(\sqrt{\ln x})^2 = \left(\frac{1}{2} \ln x\right)^2$$

$$\ln x = \frac{1}{4} \ln^2 x$$

$$4 \ln x = \ln^2 x$$

$$\ln^2 x - 4 \ln x = 0$$

$$\ln x(\ln x - 4) = 0$$

$$\begin{cases} \ln x = 0 \rightarrow \underline{x=1} \\ \ln x = 4 \rightarrow \underline{x=e^4} \end{cases}$$

$\therefore$  **Solution:**  $\underline{x=1, e^4}$

### Exercise

Solve the equation:  $\log x^2 = (\log x)^2$

#### Solution

**Domain:**  $\underline{x \geq 1}$

$$2 \log x = (\log x)^2$$

$$(\log x)^2 - 2 \log x = 0$$

$$\log x (\log x - 2) = 0$$

$$\begin{cases} \log x = 0 \rightarrow \underline{x=1} \\ \log x = 2 \rightarrow \underline{x=100} \end{cases}$$

$\therefore$  **Solution:**  $\underline{x=1, 100}$

### Exercise

Solve the equation:  $\log x^3 = (\log x)^2$

#### Solution

**Domain:**  $\underline{x \geq 1}$

$$3 \log x = (\log x)^2$$

$$(\log x)^2 - 3 \log x = 0$$

$$\log x (\log x - 3) = 0$$

$$\begin{cases} \log x = 0 \rightarrow \underline{x=1} \\ \log x = 3 \rightarrow \underline{x=10^3} \end{cases}$$

*Convert to exponential*

$\therefore$  **Solution:**  $\underline{x=1, 10^3}$

### Exercise

Solve the equation:  $\log(\log x) = 1$

#### Solution

$$\log x = 10 \quad \text{Convert to exponential}$$

$$\therefore \text{Solution: } \underline{x = 10^{10}} \quad |$$

### Exercise

$$\text{Solve the equation: } \log(\log x) = 2$$

#### Solution

$$\log x = 10^2 \quad \text{Convert to exponential}$$

$$\therefore \text{Solution: } \underline{x = 10^{100}} \quad |$$

### Exercise

$$\text{Solve the equation: } \ln(\ln x) = 2$$

#### Solution

$$\ln x = e^2 \quad \text{Convert to exponential}$$

$$\therefore \text{Solution: } \underline{x = e^{e^2}} \quad |$$

### Exercise

$$\text{Solve the equation: } \ln\left(e^{x^2}\right) = 64$$

#### Solution

$$e^{x^2} = e^{64} \quad \text{Convert to exponential}$$

$$x^2 = 64$$

$$\therefore \text{Solution: } \underline{x = \pm 8} \quad |$$

### Exercise

$$\text{Solve the equation: } e^{\ln(x-1)} = 4$$

#### Solution

$$x - 1 = 4$$

$$\therefore \text{Solution: } \underline{x = 5} \quad |$$

### ***Exercise***

Solve the equation:  $10^{\log(2x+5)} = 9$

#### **Solution**

$$2x + 5 = 9$$

$$2x = 4$$

$$\therefore \text{Solution: } \underline{x = 2}$$

### ***Exercise***

Solve the equation:  $\log \sqrt{x^3 - 9} = 2$

#### **Solution**

$$\sqrt{x^3 - 9} = 10^2$$

$$x^3 - 9 = 10^4$$

$$x^3 = 10,009$$

$$\therefore \text{Solution: } \underline{x = \sqrt[3]{10,009}}$$

### ***Exercise***

Solve the equation:  $\log \sqrt{x^3 - 17} = \frac{1}{2}$

#### **Solution**

$$\log(x^3 - 17)^{1/2} = \frac{1}{2}$$

$$\frac{1}{2} \log(x^3 - 17) = \frac{1}{2}$$

$$\log(x^3 - 17) = 1$$

$$x^3 - 17 = 10$$

$$x^3 = 27$$

$$\underline{x = 3}$$

$$\text{Check: } x = 3 \quad \log \sqrt{27 - 17}$$

$$\therefore \text{Solution: } \underline{x = 3}$$

### Exercise

Solve the equation:  $\log_4 x = \log_4 (8 - x)$

#### Solution

$$x = 8 - x$$

$$x + x = 8$$

$$2x = 8$$

$$\underline{x = 4}$$

$$\text{Check: } x = 4 \quad \log_4 4 = \log_4 (8 - 4)$$

$$\therefore \text{Solution: } \underline{x = 4}$$

### Exercise

Solve the equation:  $\log_7 (x - 5) = \log_7 (6x)$

#### Solution

$$x - 5 = 6x$$

$$x - 6x = 5$$

$$-5x = 5$$

$$\underline{x = -1}$$

$$\text{Check: } x = -1 \quad \log_7 (-6) = \log_7 (6x) \quad \times$$

$$\therefore \text{No Solution}$$

### Exercise

Solve the equation:  $\ln x^2 = \ln(12 - x)$

#### Solution

$$\ln x^2 = \ln(12 - x)$$

$$x^2 = 12 - x$$

$$x^2 + x - 12 = 0$$

$$\underline{x = -4, 3}$$

$$\text{Check: } x = -4 \quad \ln(16) = \ln(16)$$

$$x = 3 \quad \ln(9) = \ln(12 - 3)$$

$$\therefore \text{Solution: } \underline{x = -4, 3}$$

### Exercise

Solve the equation  $\log_2 (x+7) + \log_2 x = 3$

#### Solution

$$\log_2 x(x+7) = 3$$

$$x(x+7) = 2^3$$

*Convert to Exponential Form*

$$x^2 + 7x = 8$$

$$x^2 + 7x - 8 = 0$$

$$x = 1, -8$$

**Check:**  $x = -8 \quad \log_2 (x+7) + \log_2 (-8) \quad \times$

$$x = 1 \quad \log_2 (1+7) + \log_2 1$$

$\therefore$  **Solution:**  $x = 1$

### Exercise

Solve the equation  $\ln x = 1 - \ln(x+2)$

#### Solution

$$\ln x + \ln(x+2) = 1$$

$$\ln x(x+2) = 1$$

$$x^2 + 2x = e$$

$$x^2 + 2x - e = 0$$

$$x = \frac{-2 \pm \sqrt{4+4e}}{2}$$

$$= \frac{-2 \pm 2\sqrt{1+e}}{2}$$

$$= \begin{cases} -1 - \sqrt{1+e} < 0 \\ -1 + \sqrt{1+e} > 0 \end{cases}$$

$\therefore$  **Solution:**  $x = -1 + \sqrt{1+e}$

### Exercise

Solve the equation  $\ln x = 1 + \ln(x+1)$

#### Solution

$$\ln x - \ln(x+1) = 1$$



$$\ln \frac{x}{x+1} = 1$$

$$\frac{x}{x+1} = e^1$$

$$x = (x+1)e$$

$$x = ex + e$$

$$x - ex = e$$

$$x(1 - e) = e$$

$$x = \frac{e}{1 - e} < 0$$

$\therefore$  *No solution*

### Exercise

Solve the equation  $\log_6 (2x - 3) = \log_6 12 - \log_6 3$

#### Solution

$$\log_6 (2x - 3) = \log_6 \frac{12}{3}$$

$$\log_6 (2x - 3) = \log_6 4$$

$$2x - 3 = 4$$

$$2x = 7$$

$$x = \frac{7}{2}$$

**Check:**  $x = \frac{7}{2}$   $\log_6 (7 - 3) = \log_6 12 - \log_6 3$

$\therefore$  **Solution:**  $x = \frac{7}{2}$

### Exercise

Solve the equation:  $\log (3x + 2) + \log (x - 1) = 1$

#### Solution

**Domain:**  $x > 1$

$$\log (3x + 2)(x - 1) = 1$$

*Convert to exponential form*

$$3x^2 - x - 2 = 10$$

$$3x^2 - x - 12 = 0$$

*Solve for x*

$$x = \frac{1 \pm \sqrt{1 + 144}}{6}$$

$$= \begin{cases} \frac{1-\sqrt{145}}{6} < 0 \\ \frac{1+\sqrt{145}}{6} > 1 \end{cases}$$

$$\therefore \text{Solution: } x = \frac{1+\sqrt{145}}{6} \quad |$$

### Exercise

Solve the equation:  $\log_5 (x+2) + \log_5 (x-2) = 1$

#### Solution

$$\log_5 (x+2)(x-2) = 1$$

$$(x+2)(x-2) = 5^1$$

$$x^2 - 4 = 5$$

$$x^2 = 5 + 4$$

$$x^2 = 9$$

$$x = \pm 3 \quad |$$

$$\text{Check: } x = -3 \quad \log_5 (-1) + \log_5 (x-2) \quad \times$$

$$x = 3 \quad \log_5 (3+2) + \log_5 (3-2)$$

$$\therefore \text{Solution: } x = 3 \quad |$$

### Exercise

Solve the equation:  $\log_2 x + \log_2 (x-4) = 2$

#### Solution

Domain:  $x > 4$

$$\log_2 x(x-4) = 2$$

$$x^2 - 4x = 2^2$$

$$x^2 - 4x - 4 = 0$$

$$x = \frac{4 \pm \sqrt{32}}{2}$$

$$= \begin{cases} 2 - 2\sqrt{2} < 4 \quad \times \\ 2 + 2\sqrt{2} > 4 \end{cases}$$

$$\therefore \text{Solution: } x = 2 + 2\sqrt{2} \quad |$$

### Exercise

Solve the equation:  $\log_3 x + \log_3 (x+6) = 3$

#### Solution

**Domain:**  $x > 0$

$$\log_3 x(x+6) = 3$$

$$x^2 + 6x = 3^3$$

$$x^2 + 6x - 27 = 0$$

$$x = \frac{-6 \pm \sqrt{36 + 108}}{2}$$

$$= \begin{cases} \frac{-6-12}{2} = -9 < 0 \text{ X} \\ \frac{-6+12}{2} = 3 > 0 \end{cases}$$

$\therefore$  **Solution:**  $x = 3$  |

### Exercise

Solve the equation:  $\log_3 (x+3) + \log_3 (x+5) = 1$

#### Solution

**Domain:**  $x > -3$

$$\log_3 (x+3)(x+5) = 1$$

$$x^2 + 8x + 15 = 3$$

$$x^2 + 8x + 12 = 0$$

$$x = \frac{-8 \pm \sqrt{64 - 48}}{2}$$

$$= \begin{cases} \frac{-8-4}{2} = -6 < -3 \text{ X} \\ \frac{-8+4}{2} = -2 > -3 \end{cases}$$

$\therefore$  **Solution:**  $x = -2$  |

### Exercise

Solve the equation:  $\ln x = \frac{1}{2} \ln \left( 2x + \frac{5}{2} \right) + \frac{1}{2} \ln 2$

#### Solution

**Domain:**  $x > 0$

$$2 \ln x = \ln \left( 2x + \frac{5}{2} \right) + \ln 2$$

$$\ln x^2 = \ln 2 \left( 2x + \frac{5}{2} \right)$$

$$x^2 = 4x + 5$$

$$x^2 - 4x - 5 = 0$$

$$a - b + c = 0 \rightarrow x = -1, -\frac{c}{a}$$

$$\underline{x = -1, 5}$$

$$\therefore \text{Solution: } \underline{x = 5}$$

### Exercise

Solve the equation  $\ln(-4 - x) + \ln 3 = \ln(2 - x)$

#### Solution

**Domain:**  $x < 5$

$$\ln 3(-4 - x) = \ln(2 - x)$$

$$-12 - 3x = 2 - x$$

$$-12 - 2 = 3x - x$$

$$-14 = 2x$$

$$\therefore \text{Solution: } \underline{x = -7}$$

### Exercise

Solve the equation:  $\log_4 x + \log_4 (x - 2) = \log_4 (15)$

#### Solution

**Domain:**  $x > 2$

$$\log_4 x(x - 2) = \log_4 (15)$$

$$x^2 - 2x = 15$$

$$x^2 - 2x - 15 = 0$$

$$x = \frac{2 \pm \sqrt{4 + 60}}{2}$$

$$= \begin{cases} \frac{2-8}{2} = -4 < 2 \times \\ \frac{2+8}{2} = 5 > 2 \end{cases}$$

$$\therefore \text{Solution: } \underline{x = 5}$$

### Exercise

Solve the equation:  $\ln(x-5) - \ln(x+4) = \ln(x-1) - \ln(x+2)$

### Solution

**Domain:**  $x > 5$

$$\ln \frac{x-5}{x+4} = \ln \frac{x-1}{x+2}$$

$$\frac{x-5}{x+4} = \frac{x-1}{x+2}$$

$$(x-5)(x+2) = (x-1)(x+4)$$

$$x^2 + 2x - 5x - 10 = x^2 + 4x - x - 4$$

$$x^2 - 3x - 10 = x^2 + 3x - 4$$

$$x^2 - 3x - 10 - x^2 - 3x + 4 = 0$$

$$-6x - 6 = 0$$

$$x = -1$$

$\therefore$  **No solution**

### Exercise

Solve the equation:  $\log(x^2 + 4) - \log(x+2) = 2 + \log(x-2)$

### Solution

**Domain:**  $x > -2$

$$\log(x^2 + 4) - \log(x+2) - \log(x-2) = 2$$

$$\log(x^2 + 4) - [\log(x+2) + \log(x-2)] = 2$$

$$\log(x^2 + 4) - \log(x+2)(x-2) = 2$$

$$\log\left(\frac{x^2 + 4}{x^2 - 4}\right) = 2$$

$$\frac{x^2 + 4}{x^2 - 4} = 10^2$$

$$x^2 + 4 = 100x^2 - 400$$

$$400 + 4 = 100x^2 - x^2$$

$$99x^2 = 404$$

$$x^2 = \frac{404}{99}$$

$\therefore$  **Solution:**  $x = \frac{2\sqrt{101}}{3\sqrt{11}}$  is the only solution

### Exercise

Solve the equation  $\log_3 (x-2) = \log_3 27 - \log_3 (x-4) - 5^{\log_5 1}$

#### Solution

**Domain:**  $x > 4$

$$\log_3 (x-2) + \log_3 (x-4) = \log_3 3^3 - 1$$

$$\log_3 (x-2)(x-4) = 3 - 1$$

$$\log_3 (x^2 - 6x + 8) = 2$$

$$x^2 - 6x + 8 = 3^2$$

$$x^2 - 6x + 8 = 9$$

$$x^2 - 6x - 1 = 0$$

$$\rightarrow \underline{x = 3 \pm \sqrt{10}}$$

$$\text{Check: } x = 3 + \sqrt{10} > 4$$

$$x = 3 - \sqrt{10} < 4 \quad \times$$

$$\therefore \text{Solution: } \underline{x = 3 + \sqrt{10}}$$

### Exercise

Solve the equation  $\log_2 (x+3) = \log_2 (x-3) + \log_3 9 + 4^{\log_4 3}$

#### Solution

**Domain:**  $x > 3$

$$\log_2 (x+3) - \log_2 (x-3) = 2 + 3$$

$$\log_2 \frac{x+3}{x-3} = 5$$

$$\frac{x+3}{x-3} = 2^5$$

$$x+3 = 32(x-3)$$

$$x+3 = 32x-96$$

$$96+3 = 32x-x$$

$$31x = 99$$

$$x = \frac{99}{31} > 3$$

$$\therefore \text{Solution: } \underline{x = \frac{99}{31}}$$

### Exercise

Solve the equation  $\frac{10^x - 10^{-x}}{2} = 20$

#### Solution

$$\frac{10^x - 10^{-x}}{2} = 20$$

$$10^x - 10^{-x} = 40$$

$$10^x \times 10^x - 40 - 10^{-x} = 0$$

$$(10^x)^2 - 40(10^x) - 1 = 0$$

$$10^x = \frac{40 \pm \sqrt{1604}}{2}$$

$$= \frac{40 \pm 2\sqrt{401}}{2}$$

$$= \begin{cases} 20 - \sqrt{401} < 0 \times \\ 20 + \sqrt{401} > 0 \end{cases}$$

$$10^x = 20 + \sqrt{401}$$

$$x = \log(20 + \sqrt{401})$$

### Exercise

Solve the equation  $\frac{10^x + 10^{-x}}{2} = 8$

#### Solution

$$10^x - 10^{-x} = 16$$

$$10^x \times 10^x - 40 - 10^{-x} = 0$$

$$(10^x)^2 - 16(10^x) - 1 = 0$$

$$10^x = \frac{16 \pm \sqrt{260}}{2}$$

$$= \frac{16 \pm 2\sqrt{65}}{2}$$

$$= \begin{cases} 16 - \sqrt{65} < 0 \times \\ 16 + \sqrt{65} > 0 \end{cases}$$

$$10^x = 16 + \sqrt{65}$$

$$x = \log(16 + \sqrt{65})$$

### Exercise

Solve the equation  $\frac{10^x + 10^{-x}}{10^x - 10^{-x}} = 5$

#### Solution

$$10^x + 10^{-x} = 5(10^x) - 5(10^{-x})$$

$$10^x \times 4(10^x) = 6(10^{-x})$$

$$(10^x)^2 = \frac{3}{2}$$

$$10^x = \pm\sqrt{\frac{3}{2}}$$

$$10^x = \sqrt{\frac{3}{2}} \qquad 10^x = -\sqrt{\frac{3}{2}} \times$$

$$x = \log\left(\frac{3}{2}\right)^{1/2}$$

$$= \frac{1}{2} \log \frac{3}{2} \Big|$$

### Exercise

Solve the equation  $\frac{10^x + 10^{-x}}{10^x - 10^{-x}} = 2$

#### Solution

$$10^x + 10^{-x} = 2(10^x) - 2(10^{-x})$$

$$10^x \times (10^x) = 3(10^{-x})$$

$$(10^x)^2 = 3$$

$$10^x = \pm\sqrt{3}$$

$$10^x = \sqrt{3} \qquad 10^x = -\sqrt{3} \times$$

$$\therefore \text{Solution: } x = \log \sqrt{3} \Big|$$

### Exercise

Solve the equation  $\frac{e^x + e^{-x}}{2} = 15$

#### Solution

$$e^x + e^{-x} = 30$$



$$e^x \times e^x - 30 + e^{-x} = 0$$

$$(e^x)^2 - 30e^x + 1 = 0$$

$$e^x = \frac{30 \pm \sqrt{896}}{2}$$

$$= \frac{30 \pm 8\sqrt{14}}{2}$$

$$= 15 \pm 4\sqrt{14}$$

$$\therefore \text{Solution: } x = \ln(15 \pm 4\sqrt{14})$$

### Exercise

Solve the equation  $\frac{e^x - e^{-x}}{2} = 15$

#### Solution

$$e^x - e^{-x} = 30$$

$$e^x \times e^x - 30 - e^{-x} = 0$$

$$(e^x)^2 - 30e^x - 1 = 0$$

$$e^x = \frac{30 \pm \sqrt{904}}{2}$$

$$= \frac{30 \pm 2\sqrt{226}}{2}$$

$$15 - \sqrt{226} < 0$$

$$e^x = 15 + \sqrt{226}$$

$$\therefore \text{Solution: } x = \ln(15 + \sqrt{226})$$

### Exercise

Solve the equation  $\frac{1}{e^x - e^{-x}} = 4$

#### Solution

$$4e^x - 4e^{-x} = 1$$

$$e^x \times 4e^x - 1 - 4e^{-x} = 0$$

$$4(e^x)^2 - e^x - 4 = 0$$

$$e^x = \frac{1 \pm \sqrt{65}}{2}$$

$$\therefore \text{Solution: } x = \ln \left( \frac{1 \pm \sqrt{65}}{2} \right)$$

### Exercise

Solve the equation  $\frac{e^x + e^{-x}}{e^x - e^{-x}} = 3$

#### Solution

$$e^x + e^{-x} = 3e^x - 3e^{-x}$$

$$-2e^x = -4e^{-x}$$

$$e^x \times e^x = 2e^{-x}$$

$$(e^x)^2 = 2$$

Since,  $e^x$  can't be negative, then

$$e^x = \sqrt{2}$$

$$\therefore \text{Solution: } x = \ln \sqrt{2}$$

### Exercise

Solve the equation  $\frac{e^x - e^{-x}}{e^x + e^{-x}} = 6$

#### Solution

$$e^x - e^{-x} = 6e^x + 6e^{-x}$$

$$-5e^x = 7e^{-x}$$

$$e^x \times -5e^x = 7e^{-x}$$

$$(e^x)^2 = -\frac{7}{5}$$

$\therefore$  No Solution

### Exercise

Use common logarithms to solve for  $x$  in terms of  $y$ :  $y = \frac{10^x + 10^{-x}}{2}$

### Solution

$$2y = 10^x + 10^{-x}$$

$$10^x (10^x) + 10^{-x} (10^x) - 2y (10^x) = 0$$

$$(10^x)^2 - 2y(10^x) + 1 = 0$$

Using the quadratic formula:

$$10^x = \frac{2y \pm \sqrt{(2y)^2 - 4(1)(1)}}{2(1)}$$

$$= \frac{2y \pm \sqrt{4y^2 - 4}}{2}$$

$$= \frac{2y \pm 2\sqrt{y^2 - 1}}{2}$$

$$= y \pm \sqrt{y^2 - 1}$$

$$y - \sqrt{y^2 - 1} > 0 \Rightarrow y > \sqrt{y^2 - 1} \Rightarrow y^2 > y^2 - 1 \text{ (True for any } y > 1)$$

$$y^2 - 1 \geq 0 \Rightarrow \cancel{y \leq -1} \text{ or } y \geq 1$$

$$10^x = y - \sqrt{y^2 - 1}$$

$$10^x = y + \sqrt{y^2 - 1}$$

$$\underline{x = \log \left( y - \sqrt{y^2 - 1} \right)}$$

$$\underline{x = \log \left( y + \sqrt{y^2 - 1} \right)}$$

### Exercise

Use common logarithms to solve for  $x$  in terms of  $y$ :  $y = \frac{10^x - 10^{-x}}{10^x + 10^{-x}}$

### Solution

$$y(10^x + 10^{-x}) = 10^x - 10^{-x}$$

$$y10^x + y10^{-x} = 10^x - 10^{-x}$$

$$y10^x - 10^x = -10^{-x} - y10^{-x}$$

$$10^x(y - 1) = -10^{-x}(1 + y)$$

$$10^x 10^x (y - 1) = -10^x 10^{-x} (1 + y)$$

$$(10^x)^2 (y - 1) = -(1 + y)$$

$$\left(10^x\right)^2 = -\frac{y+1}{y-1}$$

$$\left(10^x\right)^2 = \frac{y+1}{1-y}$$

$$10^x = \left(\frac{y+1}{1-y}\right)^{1/2}$$

$$\underline{x = \log\left(\frac{y+1}{1-y}\right)^{1/2}}$$

### ***Exercise***

Use natural logarithms to solve for  $x$  in terms of  $y$ :  $y = \frac{e^x - e^{-x}}{2}$

### **Solution**

$$2y = e^x - e^{-x}$$

$$2ye^x = e^x e^x - e^{-x} e^x$$

$$2ye^x = \left(e^x\right)^2 - 1$$

$$\left(e^x\right)^2 - 2ye^x - 1 = 0$$

$$e^x = \frac{2y \pm \sqrt{4y^2 + 4}}{2}$$

$$= \frac{2y \pm 2\sqrt{y^2 + 1}}{2}$$

$$= y \pm \sqrt{y^2 + 1}$$

$$e^x = y - \sqrt{y^2 + 1} < 0 \text{ (not a solution)}$$

$$e^x = y + \sqrt{y^2 + 1}$$

$$\underline{x = \ln\left(y + \sqrt{y^2 + 1}\right)}$$

### ***Exercise***

Use natural logarithms to solve for  $x$  in terms of  $y$ :  $y = \frac{e^x - e^{-x}}{e^x + e^{-x}}$

### **Solution**

$$ye^x + ye^{-x} = e^x - e^{-x}$$

$$ye^{-x} + e^{-x} = e^x - ye^x$$

$$(y+1)e^{-x} = (1-y)e^x$$

$$(y+1)e^{-x}e^x = (1-y)e^xe^x$$

$$y+1 = (1-y)(e^x)^2$$

$$(e^x)^2 = \frac{y+1}{1-y}$$

$$e^x = \pm \sqrt{\frac{y+1}{1-y}}$$

$$e^x = -\sqrt{\frac{y+1}{1-y}} < 0 \text{ (not a solution)}$$

$$e^x = \sqrt{\frac{y+1}{1-y}}$$

$$\boxed{x = \ln \sqrt{\frac{y+1}{1-y}}}$$

### Exercise

Solve for  $t$  using logarithms with base  $a$ :  $2a^{t/3} = 5$

### Solution

$$a^{t/3} = \frac{5}{2}$$

$$\log a^{t/3} = \log \frac{5}{2}$$

$$\frac{t}{3} \log a = \log \frac{5}{2}$$

$$\frac{t}{3} = \frac{\log \frac{5}{2}}{\log a}$$

$$\frac{t}{3} = \log_a \frac{5}{2}$$

$$\boxed{t = 3 \log_a \frac{5}{2}}$$

### Exercise

Solve for  $t$  using logarithms with base  $a$ :  $K = H - Ca^t$

### Solution

$$Ca^t = H - K$$

$$a^t = \frac{H - K}{C}$$

$$\log a^t = \log \frac{H - K}{C}$$

$$t \log a = \log \frac{H - K}{C}$$

$$t = \frac{\log \frac{H - K}{C}}{\log a}$$

$$= \log_a \frac{H - K}{C}$$