# Exponential and Index Functions

## Index laws

$$\begin{aligned} a^m \times a^n &= a^{m+n} \\ a^m \div a^n &= a^{m-n}4 \\ (a^m)^n &= a^{m^n} \\ (ab)^m &= a^m b^m \\ (\frac{a}{b})^m &= \frac{a^m}{b^m} \end{aligned} \tag{1}$$

## Fractional indices

$$\sqrt[n]{x} = x^{1/n}$$

## Logarithms

$$\log_b(x) = n \quad \text{where} \;\; b^n = x$$

## Using logs to solve index eq's

Used for equations without common base exponent

Or change base:

$$\log_b c = \frac{\log_a c}{\log_a b}$$

If $a < 1, \quad \log_b a < 0$ (flip inequality operator)

## Exponential functions

$e^x$ - natural exponential function

$$\lim_{h \to 0} \frac{e^h - 1}{h} = 1$$

## Logarithm laws

$$\begin{aligned} \log_a(mn) &= \log_a m + \log_a n \\ \log_a(\frac{m}{n}) &= \log_a m - \log_a \\ \log_a(m^p) &= p \log_a m \\ \log_a(m^{-1}) &= -\log_a m \\ \log_a 1 = 0 &\text{ and } \log_a a = 1 \end{aligned} \tag{2}$$

## Inverse functions

For $f: \mathbb{R} \to \mathbb{R}, f(x) = a^x$, inverse is:

$$f^{-1}: \mathbb{R}^+ \to \mathbb{R}, f^{-1} = log_a x$$

## Euler's number

$$e = \lim_{n \to \infty} (1 + \frac{1}{n})^n$$

## Literal equations

*Literal equation* - no numerical solutions

## Exponential and logarithmic modelling

$$A = A_0 e^{kt}$$

where
$A_0$ is initial value
$t$ is time taken
$k$ is a constant
For continuous growth, $k > 0$
For continuous decay, $k < 0$

## Graphing exponential functions

$$f(x) = Aa^{k(x-b)} + c, \quad | \, a > 1$$

- **$y$-intercept** at $(0, A \cdot a^{-kb} + c)$ as $x \to \infty$
- **horizontal asymptote** at $y = c$
- **domain** is $\mathbb{R}$
- **range** is $(c, \infty)$
- dilation of factor $A$ from $x$-axis
- dilation of factor $\frac{1}{k}$ from $y$-axis

## Graphing logarithmic functions

$log_e x$ is the inverse of $e^x$ (reflection across $y = x$)

$$f(x) = A \log_a k(x - b) + c$$

where

- **domain** is $(b, \infty)$
- **range** is $\mathbb{R}$
- **vertical asymptote** at $x = b$
- $y$-intercept exists if $b < 0$
- dilation of factor $A$ from $x$-axis
- dilation of factor $\frac{1}{k}$ from $y$-axis

## Finding equations

Solve simultaneous equations on CAS: $\left.\begin{cases} f(3)=9 \\ g(3)=0 \end{cases}\right|_{a,b}$