Pure

Contents

Binomial Expansion

Definitions

The factorial $n! \equiv n \times (n-1) \times (n-2) \times \cdots \times 3 \times 2 \times 1.$

The falling factorial $n^{\underline{k}} \equiv n \times (n-1) \times (n-2) \times \cdots \times (n-(k-2)) \times (n-(k-1)).$ It has k terms.

$$\boxed{0! = n^{\underline{0}} = 1}$$

The choose function ${}^nC_r \equiv \boxed{\binom{n}{r} \equiv \frac{n!}{r!(n-r)!}}$

Expansions

For a natural number n, the expansion of $(a+b)^n$ is

$$a^n + na^{n-1}b + \binom{n}{2}a^{n-2}b^2 + \cdots \binom{n}{r}a^{n-r}b^r + \cdots b^n$$

In general, $\boxed{(a+b)^n = \sum_{r=0}^{n} \binom{n}{r} a^{n-r}b^r}$ $(n \in \mathbb{N})$

That's true if n is a natural number, but there is a version that works for all real numbers. For an expression $(a+bx)^n$, it should first be normalised to $a^n(1+\frac{b}{a}x)^n$. Let $y = \frac{b}{a}x$. Then the expansion of $(1+y)^n$ is given by

$$1 + ny + \frac{n(n-1)}{2!}y^2 + \frac{n(n-1)(n-2)}{3!}y^3 + \cdots + \frac{n(n-1)(n-2)\cdots(n-(r-1))}{r!}y^r + \cdots$$

In general, $\boxed{(a+bx)^n = a^n \sum_{r=0}^{\infty} \frac{n^{\underline{r}}}{r!}\left(\frac{b}{a}x\right)^r}$ $(n \in \mathbb{R})$

Calculus

Elementary Derivatives

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

f	C	x^n	$\sin x$	$\cos x$	a^x	$\ln x$
f'	0	nx^{n-1}	$\cos x$	$-\sin x$	$a^x \ln a$	$\frac{1}{x}$

Composition Laws

Let f and g be differentiable functions over x.

The $'$ mark denotes the derivative with respect to x, so $f' = \dfrac{df}{dx}$ and $g' = \dfrac{dg}{dx}$.

The $\circ$ symbol denotes function composition, so $(f \circ g)(x) = f(g(x))$.

$$(f \pm g)' = f' \pm g'$$

$$(fg)' = fg' + f'g$$

$$(f \circ g)' = (f' \circ g)g'$$

$$\left(\frac{f}{g}\right)' = \frac{f'g - fg'}{g^2}$$

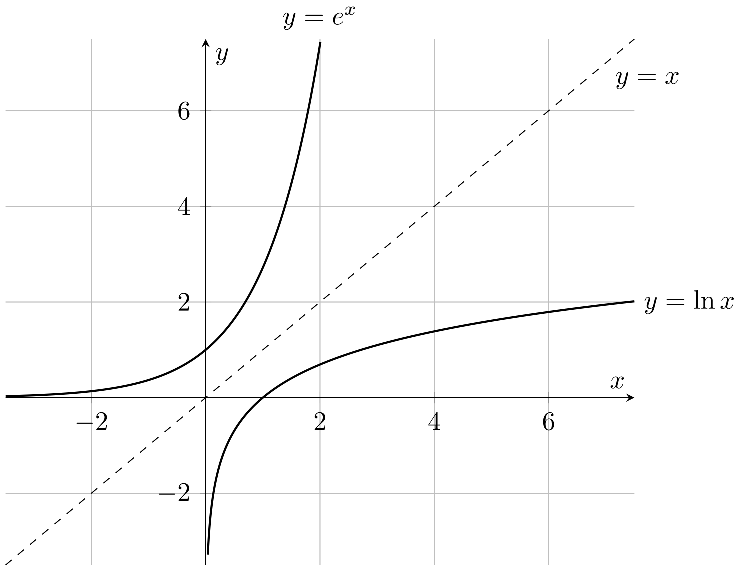
Integral Tricks

For integrals of the form on the left, consider the function on the right.

$\int kf'f^n \ dx$	f^{n+1}
$\int k\frac{f'}{f} \ dx$	$\ln \lvert f \rvert$

Exponentials and Logarithms

Exponentials



$$\frac{d}{dx}e^x = e^x$$

$$\frac{d}{dx}e^{kx} = ke^{kx}$$

$$\frac{d}{dx}e^{f(x)} = f'(x)e^{f(x)}$$

$\ln x$ is the inverse of e^x, meaning its graph is reflected in the line $y = x$.

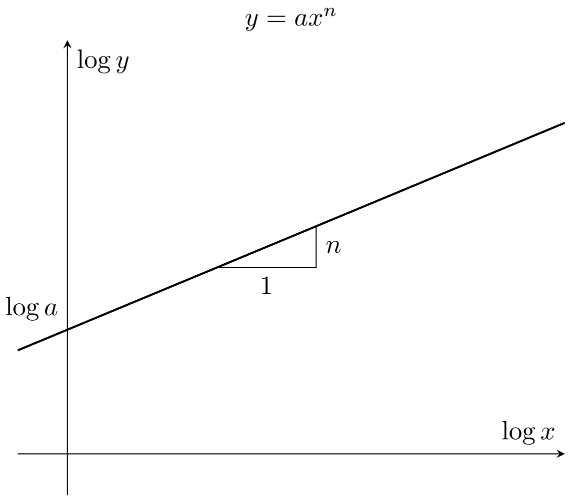
Log Laws

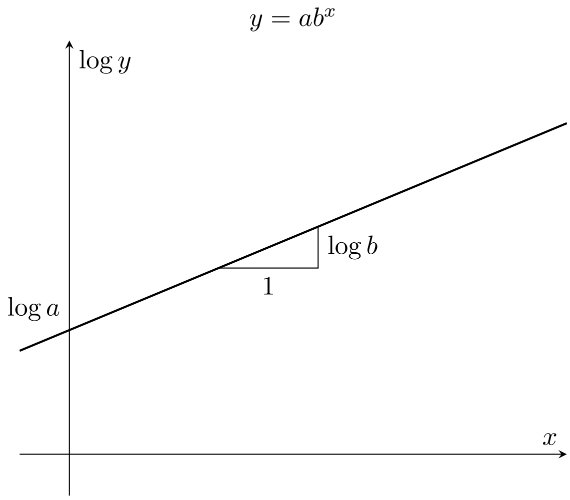
$$\log_a b \equiv \frac{\ln b}{\ln a}$$

$$\log xy \equiv \log x + \log y \qquad \log \frac{x}{y} \equiv \log x - \log y \qquad \log x^y \equiv y \log x$$

$$\log_a a \equiv 1 \qquad \log 1 \equiv 0 \qquad \log \frac{1}{x} \equiv -\log x$$

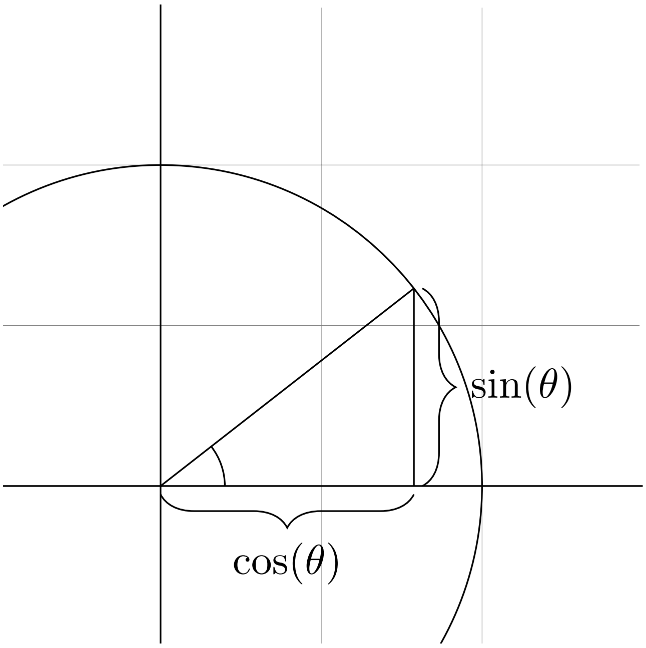
Log Plots





Trigonometry

Definitions



$$\tan\theta \equiv \frac{\sin\theta}{\cos\theta}$$

$$\sec\theta \equiv \frac{1}{\cos\theta}$$

$$\operatorname{cosec}\theta \equiv \frac{1}{\sin\theta}$$

$$\cot\theta \equiv \frac{1}{\tan\theta} \equiv \frac{\cos\theta}{\sin\theta}$$

Identities

$$\sin^2\theta + \cos^2\theta \equiv 1$$

$$1 + \tan^2\theta \equiv \sec^2\theta$$

$$1 + \cot^2\theta \equiv \operatorname{cosec}^2\theta$$

$$\sin(\alpha \pm \beta) \equiv \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$$

$$\cos(\alpha \pm \beta) \equiv \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$$

$$\tan(\alpha \pm \beta) \equiv \frac{\tan\alpha \pm \tan\beta}{1 \mp \tan\alpha\tan\beta}$$

$$\sin 2\theta \equiv 2\sin\theta\cos\theta$$

$$\tan 2\theta \equiv \frac{2\tan\theta}{1 - \tan^2\theta}$$

$$\begin{aligned}\cos 2\theta &\equiv \cos^2\theta - \sin^2\theta \\ &\equiv 2\cos^2\theta - 1 \\ &\equiv 1 - 2\sin^2\theta\end{aligned}$$

Calculus

$$\frac{d}{dx}\sin x = \cos x \qquad \int \sin x \; dx = -\cos x + C$$

$$\frac{d}{dx}\cos x = -\sin x \qquad \int \cos x \; dx = \sin x + C$$

$$\frac{d}{dx}\tan x = \sec^2 x \qquad \int \tan x \; dx = \ln|\sec x| + C$$

$$\frac{d}{dx}\sec x = \sec x \tan x \qquad \int \sec x \; dx = \ln|\tan x + \sec x| + C$$

$$\frac{d}{dx}\operatorname{cosec} x = -\operatorname{cosec} x \cot x \qquad \int \operatorname{cosec} x \; dx = -\ln|\cot x + \operatorname{cosec} x| + C$$

$$\frac{d}{dx}\cot x = -\operatorname{cosec}^2 x \qquad \int \cot x \; dx = \ln|\sin x| + C$$

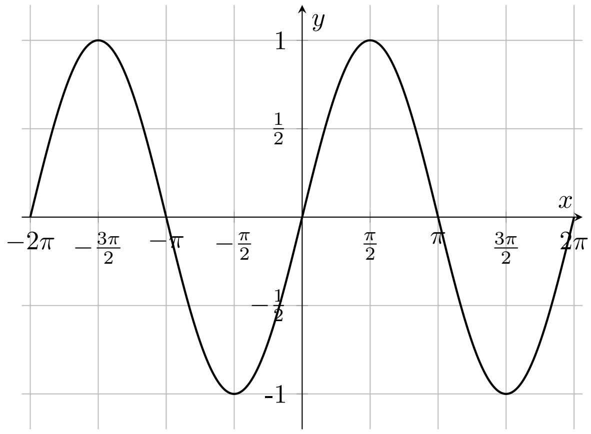
$$\frac{d}{dx}\arcsin x = \frac{1}{\sqrt{1-x^2}} \qquad \int \arcsin x \; dx = x \arcsin x + \sqrt{1-x^2} + C$$

$$\frac{d}{dx}\arccos x = -\frac{1}{\sqrt{1-x^2}} \qquad \int \arccos x \; dx = x \arccos x - \sqrt{1-x^2} + C$$

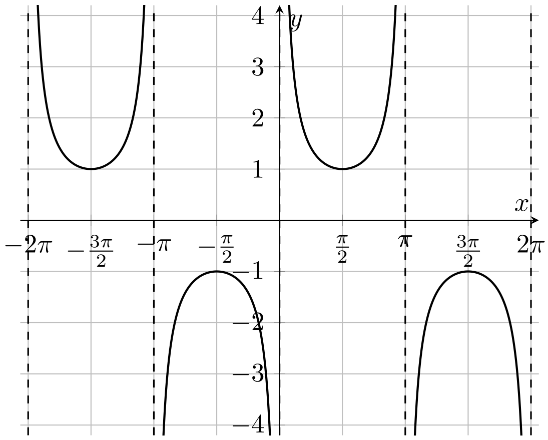
$$\frac{d}{dx}\arctan x = \frac{1}{x^2+1} \qquad \int \arctan x \; dx = x \arctan x - \frac{\ln(x^2+1)}{2} + C$$

Graphs

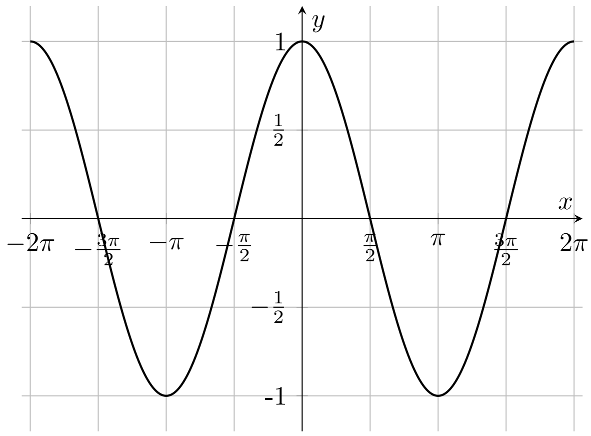
$y = \sin(x)$



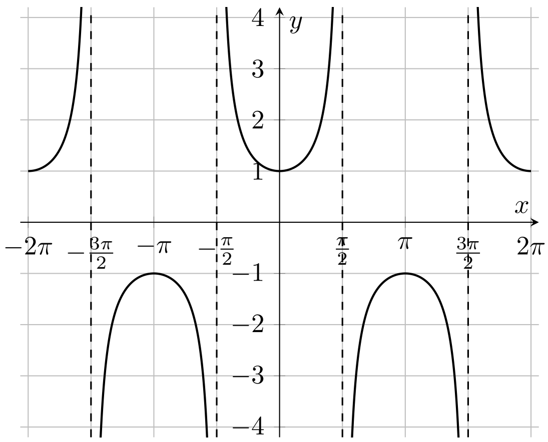
$y = \text{cosec}(x)$



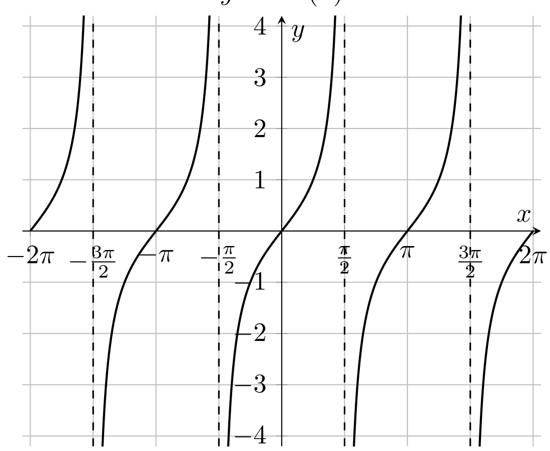
$y = \cos(x)$



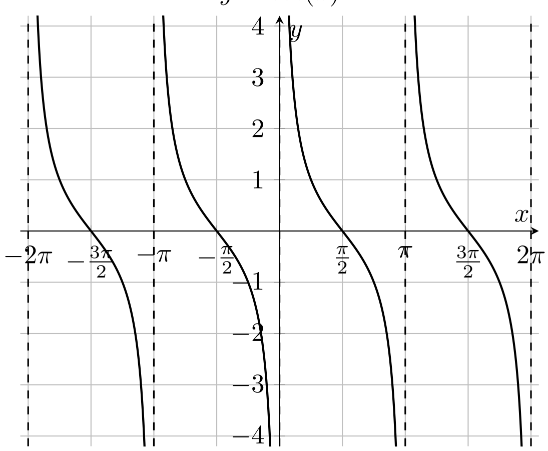
$y = \sec(x)$



$y = \tan(x)$



$y = \cot(x)$



Sequences and Series

Arithmetic

a is the first term. d is the common difference. Counting starts from $n = 1$.

The nth term of the sequence is given by:

$$\boxed{u_n = a + (n-1)d}$$

The sum of the first n terms (inclusive) of the series is given by:

$$\boxed{S_n = \frac{n}{2}(2a + (n-1)d)}$$

Or $\boxed{S_n = \frac{n}{2}(a + l)}$ where l is the last term.

Geometric

a is the first term. r is the common ratio. Counting starts from $n = 1$.

The nth term of the sequence is given by:

$$\boxed{u_n = ar^{n-1}}$$

The sum of the first n terms (inclusive) of the series is given by:

$$\boxed{S_n = \frac{a(1-r^n)}{1-r} = \frac{a(r^n - 1)}{r-1}} \quad (r \neq 1)$$

The sum to infinity of a geometric series is **only valid** when $|r| < 1$ and is given by:

$$\boxed{S_\infty = \frac{a}{1-r}} \quad (|r| < 1)$$