Integral-differentiation rules

Type	$y = f(x)$	derivative $\frac{dy}{dx}$	$\int f(x)dx$
Basic rules	c	0	$\int c\,dx = cx + c'$
	1	0	$\int 1\,dx = \int dx = x + c$
	x	1	$\int x\,dx = \frac{1}{2}x^2 + c$
	x^n	nx^{n-1}	$\int x^n\,dx = \frac{x^{n+1}}{n+1} + c$
	$c.f(x)$	$c.f'(x)$	$\int c\,f'(x)dx = cf(x) + c'$
Trigonometric function	$\sin x$	$\cos x$	$\int cosx\,dx = sinx + c$
	$\cos x$	$-\sin x$	$\int sinx\,dx = -cosx + c$
	$\tan x$	sec^2x	$\int sec^2x\,dx = tanx + c$
	$\cot x$	$-csc^2x$	$\int csc^2x\,dx = -cotx + c$
	$\sec x$	$secx\,tanx$	$\int secx\,tanx\,dx = secx + c$
	$\csc x$	$-cscx\,cotx$	$\int cscx\,cotx\,dx = -cscx + c$
	$\sin[f(x)]$	$\cos\,[f(x)]f'(x)$	$\int \cos[f(x)]\,f'(x)dx = \sin[f(x)] + c$
	$\cos[f(x)]$	$-\sin[f(x)]\,f'(x)$	$\int sin[f(x)]\,f'(x)\,dx = -cos[f(x)] + c$
	$\tan[f(x)]$	$sec^2[f(x)]f'(x)$	$\int sec^2[f(x)]f'(x)\,dx = tan[f(x)] + c$
	$\cot[f(x)]$	$-csc^2[f(x)]f'(x)$	$\int csc^2[f(x)]f'(x)dx = -cot[f(x)] + c$
	$\sec[f(x)]$	$sec[f(x)]\,tan[f(x)]f'(x)$	$\int sec[f(x)]tan[f(x)]f'(x)dx = sec[f(x)] + c$
	$\csc[f(x)]$	$-csc[f(x)]\,cot[f(x)]f'(x)$	$\int csc[f(x)]cot[f(x)]f'(x)dx = -csc[f(x)] + c$
Logarithmic functions	lnx	$\frac{1}{x}$	$\int \frac{1}{x}dx = lnx + c$
	$ln[f(x)]$	$\frac{f'(x)}{f(x)}$	$\int \frac{f'(x)}{f(x)}dx = ln\lvert f(x)\rvert + c$
Exponential functions	e^x	e^x	$\int e^x dx = e^x + c$
	$e^{f(x)}$	$e^{f(x)}f'(x)$	$\int e^{f(x)}f'(x) = e^{f(x)} + c$
	a^x	$a^x lna$	$\int a^x dx = \frac{a^x}{lna} + c$
	$a^{f(x)}$	$a^{f(x)}.f'(x).lna$	$\int a^{f(x)}.f'(x) = \frac{a^{f(x)}}{lna} + c$
Radical functions	$\sqrt{x}$	$\frac{1}{2\sqrt{x}}$	$\int \frac{1}{\sqrt{x}}dx = 2\sqrt{x} + c$
	$\sqrt{f(x)}$	$\frac{f'(x)}{2\sqrt{f(x)}}$	$\int \frac{f'(x)}{\sqrt{f(x)}}dx = 2\sqrt{f(x)} + c$

Type	$y = f(x)$	derivative $\frac{dy}{dx}$	$\int f(x)dx$
Inverse trigonometric	$sin^{-1}(x)$	$\frac{1}{\sqrt{1-x^2}}$	$\int \frac{1}{\sqrt{1-x^2}} dx = sin^{-1}(x) + c$
	$cos^{-1}(x)$	$\frac{-1}{\sqrt{1-x^2}}$	$\int \frac{-1}{\sqrt{1-x^2}} dx = cos^{-1}(x) + c$
	$tan^{-1}(x)$	$\frac{1}{1+x^2}$	$\int \frac{1}{1+x^2} dx = tan^{-1}(x) + c$
	$cot^{-1}(x)$	$\frac{-1}{1+x^2}$	$\int \frac{-1}{1+x^2} dx = cot^{-1}(x) + c$
	$sec^{-1}(x)$	$\frac{1}{x\sqrt{x^2-1}}$	$\int \frac{1}{x\sqrt{x^2-1}} dx = sec^{-1}(x) + c$
	$csc^{-1}(x)$	$\frac{-1}{x\sqrt{x^2-1}}$	$\int \frac{-1}{x\sqrt{x^2-1}} dx = csc^{-1}(x) + c$
	$sin^{-1}[f(x)]$	$\frac{f'(x)}{\sqrt{1-[f(x)]^2}}$	$\int \frac{f'(x)}{\sqrt{a^2-[f(x)]^2}} dx = sin^{-1}\left(\frac{f(x)}{a}\right) + c$
	$cos^{-1}[f(x)]$	$\frac{-f'(x)}{\sqrt{1-[f(x)]^2}}$	$\int \frac{-f'(x)}{\sqrt{a^2-[f(x)]^2}} dx = cos^{-1}\left(\frac{f(x)}{a}\right) + c$
	$tan^{-1}[f(x)]$	$\frac{f'(x)}{1+[f(x)]^2}$	$\int \frac{f'(x)}{a^2+[f(x)]^2} dx = \frac{1}{a} tan^{-1}\left(\frac{f(x)}{a}\right) + c$
	$cot^{-1}[f(x)]$	$\frac{-f'(x)}{1+[f(x)]^2}$	$\int \frac{-f'(x)}{a^2+[f(x)]^2} dx = \frac{1}{a} cot^{-1}\left(\frac{f(x)}{a}\right) + c$
	$sec^{-1}[f(x)]$	$\frac{f'(x)}{f(x)\sqrt{[f(x)]^2-1}}$	$\int \frac{f'(x)}{f(x)\sqrt{[f(x)]^2-a^2}} dx = \frac{1}{a} sec^{-1}\left(\frac{f(x)}{a}\right) + c$
	$csc^{-1}[f(x)]$	$\frac{-f'(x)}{f(x)\sqrt{[f(x)]^2-1}}$	$\int \frac{-f'(x)}{f(x)\sqrt{[f(x)]^2-a^2}} dx = \frac{1}{a} csc^{-1}\left(\frac{f(x)}{a}\right) + c$
Hyperbolic functions	$\sinh x$	$\cosh x$	$\int coshx\ dx = sinhx + c$
	$\cosh x$	$\sinh x$	$\int sinhx\ dx = coshx + c$
	$\tanh x$	$sech^2x$	$\int sech^2x\ dx = tanhx + c$
	$\coth x$	$-csch^2x$	$\int csch^2x\ dx = -cothx + c$
	$\text{sech}\, x$	$-sechx\ tanhx$	$\int sechx\ tanhx\ dx = -sechx + c$
	$\text{csch}\, x$	$-cschx\ cothx$	$\int cschx\ cothx\ dx = -cschx + c$
	$\sinh[f(x)]$	$\cosh\,[f(x)]f'(x)$	$\int \cosh[f(x)]\,f'(x)dx = \sinh[f(x)] + c$
	$\cosh[f(x)]$	$\sinh[f(x)]\,f'(x)$	$\int sinh[f(x)]\,f'(x)\ dx = cosh[f(x)] + c$
	$\tanh[f(x)]$	$sech^2[f(x)]f'(x)$	$\int sech^2[f(x)]f'(x)\ dx = tanh[f(x)] + c$
	$\coth[f(x)]$	$-csch^2[f(x)]f'(x)$	$\int csch^2[f(x)]f'(x)dx = -coth[f(x)] + c$
	$\text{sech}[f(x)]$	$-sech[f(x)]\ tanh[f(x)]f'(x)$	$\int sech[f(x)]tanh[f(x)]f'(x)d = -sech[f(x)] + c$
	$\text{csch}[f(x)]$	$-csch[f(x)]\ coth[f(x)]f'(x)$	$\int csch[f(x)]coth[f(x)]f'(x)dx = -csch[f(x)] + c$

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Type	$y = f(x)$	$\frac{dy}{dx}$	$\int f(x)dx$
Inverse Hyperbolic functions	$sinh^{-1}x$	$\frac{1}{\sqrt{1+x^2}}$	$\int \frac{1}{\sqrt{1+x^2}}dx = sinh^{-1}x + c$
	$cosh^{-1}x$	$\frac{1}{\sqrt{x^2-1}}$	$\int \frac{1}{\sqrt{x^2-1}}dx = cosh^{-1}x + c$
	$tanh^{-1}x$	$\frac{1}{1-x^2}$	$\int \frac{1}{1-x^2}dx = tanh^{-1}x + c; \lvert x\rvert < 1$
	$coth^{-1}x$	$\frac{1}{1-x^2}$	$\int \frac{1}{1-x^2}dx = tanh^{-1}x + c; \lvert x\rvert > 1$
	$sech^{-1}x$	$\frac{1}{x\sqrt{1-x^2}}$	$\int \frac{1}{x\sqrt{1-x^2}}dx = sech^{-1}x + c$
	$csch^{-1}x$	$\frac{1}{\lvert x\rvert\sqrt{1+x^2}}$	$\int \frac{1}{\lvert x\rvert\sqrt{1+x^2}}dx = csch^{-1}x + c$
	$sinh^{-1}[f(x)]$	$\frac{1}{\sqrt{1+[f(x)]^2}}$	$\int \frac{f'(x)}{\sqrt{a^2+[f(x)]^2}}dx = sinh^{-1}\left(\frac{f(x)}{a}\right) + c$
	$cosh^{-1}[f(x)]$	$\frac{1}{\sqrt{[f(x)]^2-1}}$	$\int \frac{f'(x)}{\sqrt{[f(x)]^2-a^2}}dx = cosh^{-1}\left(\frac{f(x)}{a}\right) + c$
	$tanh^{-1}[f(x)]$	$\frac{1}{1-[f(x)]^2}$	$\int \frac{f'(x)}{a^2-[f(x)]^2}dx = \frac{1}{a}tanh^{-1}\left(\frac{f(x)}{a}\right) + c; f(x) < a$
	$coth^{-1}[f(x)]$	$\frac{1}{1-[f(x)]^2}$	$\int \frac{f'(x)}{a^2-[f(x)]^2}dx = \frac{1}{a}coth^{-1}\left(\frac{f(x)}{a}\right) + c; f(x) > a$
	$sech^{-1}[f(x)]$	$\frac{1}{[f(x)]\sqrt{1-[f(x)]^2}}$	$\int \frac{f'(x)}{[f(x)]\sqrt{a^2-[f(x)]^2}}dx = \frac{1}{a}sech^{-1}\left(\frac{f(x)}{a}\right) + c$
	$csch^{-1}[f(x)]$	$\frac{1}{\lvert[f(x)]\rvert\sqrt{1+[f(x)]^2}}$	$\int \frac{f'(x)}{\lvert[f(x)]\rvert\sqrt{a^2+[f(x)]^2}}dx = \frac{1}{a}csch^{-1}\left(\frac{f(x)}{a}\right) + c$

Additional formulas
$\int tanx\, dx = -\ln\lvert cosx\rvert + c$
$\int cotx\, dx = \ln\lvert sinx\rvert + c$
$\int secx\, dx = \ln\lvert secx + tanx\rvert + c$
$\int cscx\, dx = \ln\lvert cscx - cotx\rvert + c$
$\int sinax\, cosbx\, dx = \frac{1}{2}\int \sin(ax+bx)\, dx + \frac{1}{2}\int \sin(ax-bx)\, dx$
$\int sinax\, sinbx\, dx = \frac{1}{2}\int \cos(ax-bx)\, dx - \frac{1}{2}\int \cos(ax+bx)\, dx$
$\int cosax\, cosbx\, dx = \frac{1}{2}\int \cos(ax+bx)\, dx + \frac{1}{2}\int \cos(ax-bx)\, dx$
$\int sin^n x dx = -\frac{1}{n}sin^{n-1}x\, cosx + \frac{n-1}{n}\int sin^{n-2}x\, dx$
$\int cos^n x dx = \frac{1}{n}cos^{n-1}x\, sinx + \frac{n-1}{n}\int cos^{n-2}x\, dx$
$\int tan^n x dx = \frac{1}{n-1}tan^{n-1}x - \int tan^{n-2}x\, dx$
$\int sec^n x dx = \frac{1}{n-1}sec^{n-2}x\, tanx + \frac{n-2}{n-1}\int sec^{n-2}x\, dx$

Integration by parts

التكامل بالتجزيء

$$\int u\, dv = uv - \int v\, du$$

how to choose u??

Logarithmic,
inverse trigonometric, Algebraic,
trigonometric
Exponential

Rational Integration

تكامل الدوال الكسرية (النسبية)

- $-$*partial fractions*
- $-$*completing the square of denominator*
- $-$*long division* (or *factoring*)

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Product of power sine and cosine $\int \sin^m x \cos^n x$	
n odd	split $cosx$ use $\sin^2 x = 1 - \cos^2 x$ take $u = \sin x$
m odd	split $sinx$ use $\cos^2 x = 1 - \sin^2 x$ take $u = \cos x$
$\begin{cases} m \text{ even} \\ n \text{ even} \end{cases}$	use $\begin{cases} \cos^2(x) = \frac{1}{2}(1 + \cos 2x) \\ \sin^2(x) = \frac{1}{2}(1 - \cos 2x) \end{cases}$

Product of power tan and sec $\int \tan^m x \sec^n x$	
n even	split $\sec^2 x$ use $\sec^2 x = \tan^2 x + 1$ take $u = \tan x$
m odd	split $secx\, tanx$ use $\tan^2 x = \sec^2 x - 1$ take $u = \sec x$
$\begin{cases} m \text{ even} \\ n \text{ odd} \end{cases}$	$secx$ alone use $\tan^2 x = \sec^2 x - 1$

	Fundamental theorem of calculus
Part 1	$\int_a^b \frac{d}{dx} G(x)dt = G(a) - G(b)$
Part 2	$\frac{d}{dx}\int_a^x f(t)dt = f(x)$
Part 3	$\frac{d}{dx}\int_{g(x)}^{h(x)} f(t)dt = f(h(x))h'(x) - f(g(x))g'(x)$

Trigonometric substitutions	
$\sqrt{a^2 - x^2}$	$\to x = a\sin\theta$ $dx = a\cos\theta\, d\theta$
$\sqrt{a^2 + x^2}$	$\to x = a\tan\theta$ $dx = a\sec^2\theta\, d\theta$
$\sqrt{x^2 - a^2}$	$\to x = a\sec\theta$ $dx = a\sec\theta\tan\theta\, d\theta$

Trigonometric Identities	Hyperbolic Identities
$secx = \frac{1}{\cos x}$, $cscx = \frac{1}{sinx}$	$\operatorname{sech} x = \frac{1}{\cosh x}$, $\operatorname{csch} x = \frac{1}{\sinh x}$, $\tanh x = \frac{\sinh x}{\cosh x}$
$\tan x = \frac{\sin x}{\cos x}$, $cotx = \frac{\cos x}{\sin x}$	$\cosh x + \sinh x = e^x$ $\cosh x - \sinh x = e^{-x}$
$\sin^2 x + \cos^2 x = 1$, $\sin^2 x = 1 - \cos^2 x$ $\cos^2 x = 1 - \sin^2 x$	$\cosh^2 x - \sinh^2 x = 1$
$\tan^2 x + 1 = \sec^2 x$, $\tan^2 x = \sec^2 x - 1$	$\tanh^2 x = 1 - \operatorname{sech}^2 x$
$1 + \cot^2 x = \csc^2 x$, $\cot^2 x = \csc^2 x - 1$	$\coth^2 x = 1 + \operatorname{csch}^2 x$
$\sin 2x = 2\sin x \cos x$	$\sinh 2x = 2\sinh x \cosh x$
$\cos 2x = \cos^2 x - \sin^2 x$ $= 2\cos^2 x - 1$ $= 1 - 2\sin^2 x$	$\cosh 2x = \cosh^2 x + \sinh^2 x$ $= 2\cosh^2 x - 1$ $= 2\sinh^2 x + 1$
$\sin^2 x = \frac{1}{2}(1 - \cos 2x)$ $\cos^2 x = \frac{1}{2}(1 + \cos 2x)$	$\sinh^2 x = \frac{1}{2}(\cosh 2x - 1)$ $\cosh^2 x = \frac{1}{2}\cosh 2x + 1$

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Hyperbolic Derivatives

$\sinh x = \frac{e^x - e^{-x}}{2}$	$\operatorname{csch} x = \frac{2}{e^x - e^{-x}}$
$\cosh x = \frac{e^x + e^{-x}}{2}$	$\operatorname{sech} x = \frac{2}{e^x + e^{-x}}$
$\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$	$\coth x = \frac{e^x + e^{-x}}{e^x - e^{-x}}$

Summation and Riemann sum

$\sum_{i=1}^{n} c = cn$	$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$
$\sum_{i=1}^{n} ca_i = c\sum_{i=1}^{n} a_i$	$\sum_{i=1}^{n} i^2 = \frac{n(n+1)(2n+1)}{6}$
$\sum_{i=1}^{n} ca_i = cn$	$\sum_{i=1}^{n} i^3 = \left(\frac{n(n+1)}{2}\right)^2$
$\sum_{i=1}^{n} (a_i \pm b_i) = \sum_{i=1}^{n} a_i \pm \sum_{i=1}^{n} b_i$	**Riemann sum** $R_n = \sum_{i=1}^{n} f(c_i)\Delta x$

area under curve

$$A = \lim_{n\to\infty} \sum_{i=1}^{n} f(c_i)\Delta x \quad , \quad \Delta x = \frac{b-a}{n} \quad , \quad c_i = a + i\Delta x$$

Average value function	Mean value theorem
f *continous on* $[a,b]$ $f_{av} = \frac{\int_a^b f(x)dx}{b-a}$	f *continous on* $[a,b]$ *there exists number c on* (a,b) $f(c) = \frac{\int_a^b f(x)dx}{b-a}$

Trapezoidal rule

$$\int_a^b f(x)dx \approx \frac{b-a}{2n}[f(x_0) + 2f(x_1) + \cdots + 2f(x_{n-1}) + f(x_n)]$$

Simpson's rule

$$\int_a^b f(x)dx \approx \frac{b-a}{3n}[f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + 2f(x_4) + \cdots + 2f(x_{n-2}) + 4f(x_{n-1}) + f(x_n)]$$

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التكامل المعتل Imperator integrals

$\int_a^{\infty} f(x)dx = \lim_{t\to\infty} \int_a^t f(x)dx$	$\int_{-\infty}^{a} f(x)dx = \lim_{t\to-\infty} \int_t^a f(x)dx$

$$\int_{-\infty}^{\infty} f(x)dx = \lim_{t\to-\infty} \int_t^a f(x)dx + \lim_{t\to\infty} \int_a^t f(x)dx$$

Area between two curves	Volume of Revolution
With respect to X-Axis $A = \int_a^b [f(x) - g(x)]dx \quad , f(x) \geq g(x)$	Rotation about X-Axis $V = \pi \int_a^b ([f(x)]^2 - [g(x)]^2)dx \quad , f(x) \geq g(x)$
With respect to Y-Axis $A = \int_c^d [w(y) - v(y)]\, dy \quad , w(y) \geq v(y)$	Rotation about Y-Axis $V = \pi \int_c^d ([w(y)]^2 - [v(y)]^2)dy \quad , w(y) \geq v(y)$

Arc length	Surface Area
With respect to X-Axis $y = f(x)\, , a \leq x \leq b$ $L = \int_a^b \sqrt{1 + (\frac{dy}{dx})^2}dx$	Rotation about X-Axis $y = f(x)\ \ , a \leq x \leq b$ $S = \int_a^b 2\pi y \sqrt{1 + (\frac{dy}{dx})^2}dx$
With respect to Y-Axis $x = g(y)\, , c \leq y \leq d$ $L = \int_c^d \sqrt{1 + (\frac{dx}{dy})^2}\ dy$	With respect to Y-Axis $x = g(y)\, , c \leq y \leq d$ $S = \int_c^d 2\pi x \sqrt{1 + (\frac{dx}{dy})^2}\ dy$

The slope of tangent line of parametric curve $y = y(t)$ at t_0

$$m = \frac{dy}{dx}\Big|_{t=t_0} = \frac{\left(\frac{dy}{dt}\right)}{\left(\frac{dy}{dx}\right)}\Big|_{t=t_0}$$

Arc length of parametric curve

$$l = \int_a^b \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}\ dt$$

Surface area of parametric curve

$SA = 2\pi \int_a^b \lvert y(t)\rvert \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}\ dt$	$SA = 2\pi \int_a^b \lvert x(t)\rvert \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}\ dt$

To convert from polar to rectangular coordinates

$$x = r\cos\theta \quad , \quad y = r\sin\theta$$

To convert from rectangular to polar coordinates

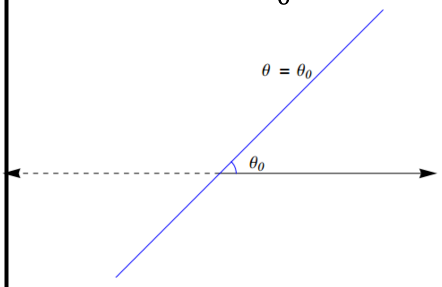
$$r^2 = x^2 + y^2 \quad , \quad \tan\theta = \frac{y}{x}$$

Polar curves

❶ lines

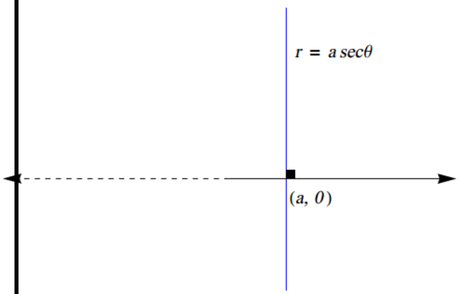
Lines passing through the pole

$\theta = \theta_0$



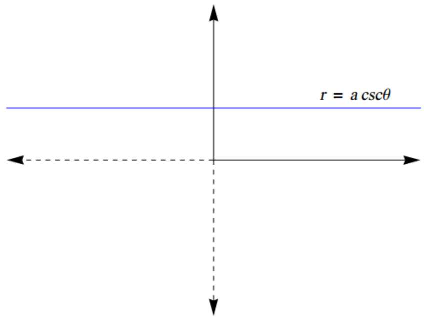
Lines perpendicular to the polar axis

$r = a \sec\theta$



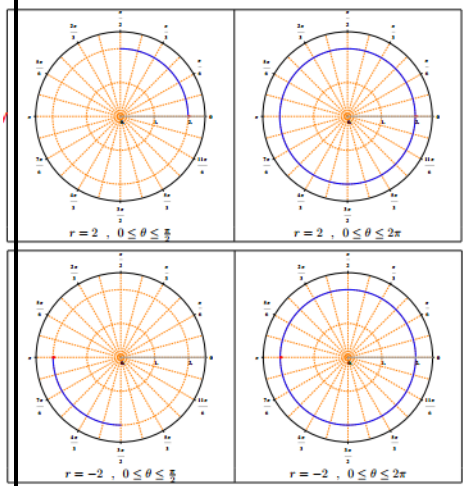
Lines parallel to the polar axis

$r = a \csc\theta$

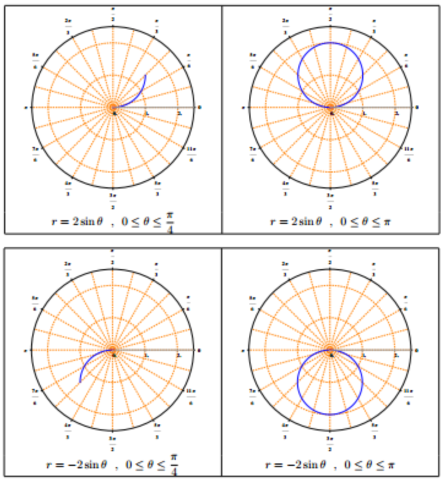


❷ circles

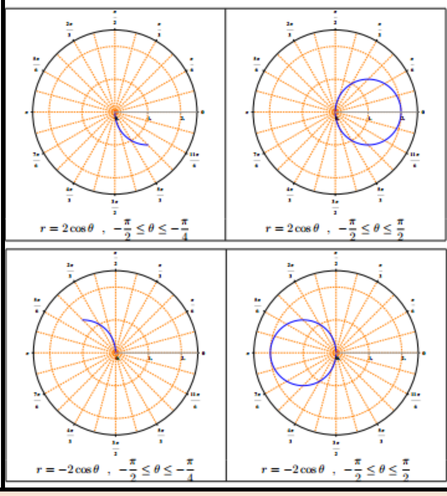
$r = a$



$r = a \sin\theta$



$r = a \cos\theta$

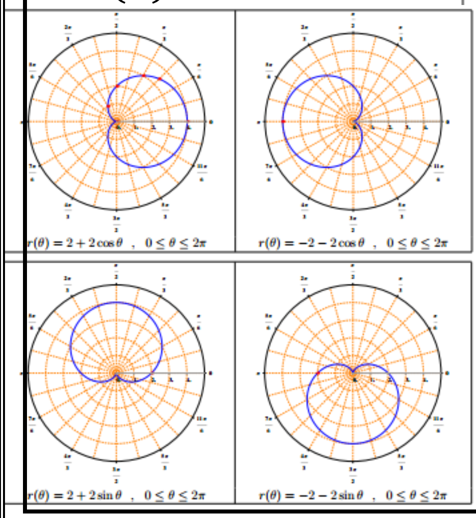


❸ Lima con curves

Cardioid (heart shape)

$r(\theta) = a + a\sin\theta$

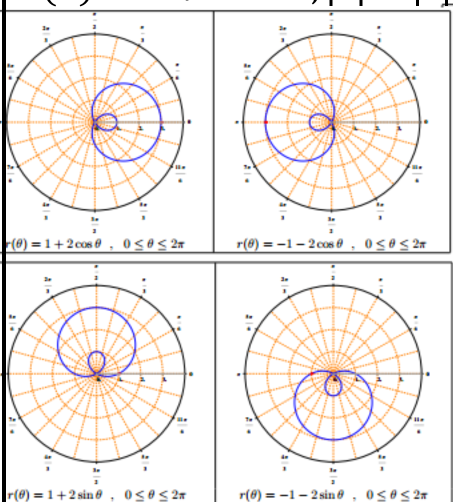
$r(\theta) = a + a\cos\theta$



Lima con with inner loop

$r(\theta) = a + b\sin\theta, |a| < |b|$

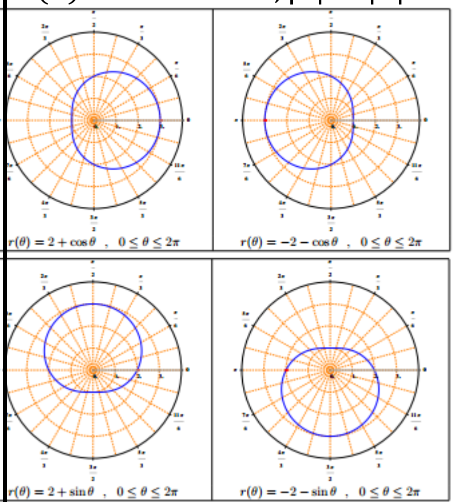
$r(\theta) = a + b\cos\theta, |a| < |b|$



Dimpled Lima con

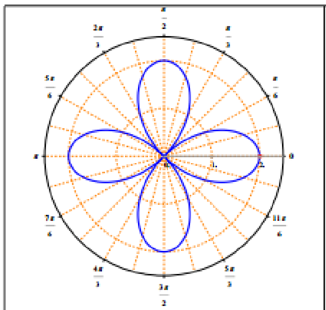
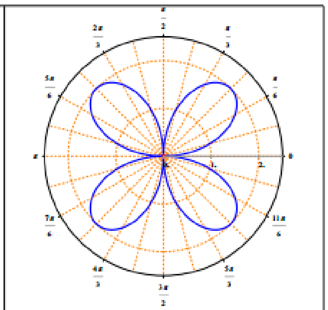
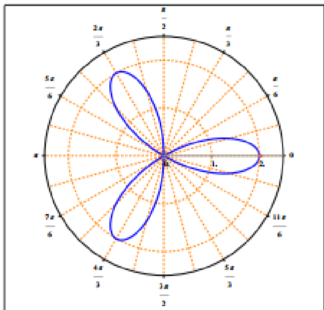
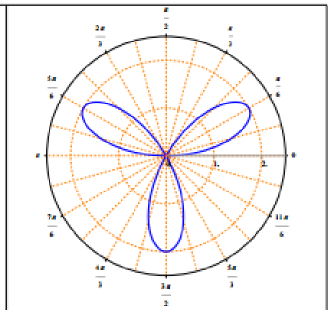
$r(\theta) = a + b\sin\theta, |a| > |b|$

$r(\theta) = a + b\cos\theta, |a| > |b|$



4 Rose curves

$r(\theta) = a\cos(n\theta)$, $r(\theta) = a\sin(n\theta)$

n even		n odd	
 $r(\theta) = 2\cos(2\theta)$, $0 \le \theta \le 2\pi$	 $r(\theta) = 2\sin(2\theta)$, $0 \le \theta \le 2\pi$	 $r(\theta) = 2\cos(3\theta)$, $0 \le \theta \le \pi$	 $r(\theta) = 2\sin(3\theta)$, $0 \le \theta \le \pi$

Test of symmetry

With respect to the polar axis	With respect to the line $\theta = \frac{\pi}{2}$	With respect to the pole
$r(\theta) = r(-\theta)$	$r(\theta) = -r(-\theta)$ $r(\theta) = r(\pi - \theta)$	$r(\theta) = r(\pi + \theta)$

Area inside-between polar Axis	Arc length of a polar Axis
bounded by Curves $r = r(\theta)$, $\theta = \theta_1$, $\theta = \theta_2$	Curve $r = r(\theta)$, $from\ \theta_1 to\ \theta_2$
$A = \int_{\theta_1}^{\theta_2} [r(\theta)]^2 d\theta$	$A = \int_{\theta_1}^{\theta_2} \sqrt{[r(\theta)]^2 + \left(\frac{dr}{d\theta}\right)^2}\, d\theta$

Surface area generated by Revolving a polar curve $r = r(\theta)$, $\theta_1 \le \theta \le \theta_2$

Around the polar axis	Around the line $\theta = \frac{\pi}{2}$
$A = 2\pi \int_{\theta_1}^{\theta_2} r(\theta)\sin\theta \sqrt{[r(\theta)]^2 + \left(\frac{dr}{d\theta}\right)^2}\, d\theta$	$A = 2\pi \int_{\theta_1}^{\theta_2} r(\theta)\cos\theta \sqrt{[r(\theta)]^2 + \left(\frac{dr}{d\theta}\right)^2}\, d\theta$

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