### Trigonometric formulas

<table>
<thead>
<tr>
<th>Formula</th>
<th>Formula</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sin^2 \theta + \cos^2 \theta = 1$</td>
<td>$1 + \tan^2 \theta = \sec^2 \theta$</td>
<td>$1 + \cot^2 \theta = \csc^2 \theta$</td>
</tr>
<tr>
<td>$\sin(-\theta) = -\sin \theta$</td>
<td>$\cos(-\theta) = \cos \theta$</td>
<td>$\tan(-\theta) = -\tan \theta$</td>
</tr>
<tr>
<td>$\sin(A + B) = \sin A \cos B + \sin B \cos A$</td>
<td>$\sin(A - B) = \sin A \cos B - \sin B \cos A$</td>
<td>$\cos(A + B) = \cos A \cos B - \sin A \sin B$</td>
</tr>
<tr>
<td>$\cos(A + B) = \cos A \cos B - \sin A \sin B$</td>
<td>$\cos(A - B) = \cos A \cos B + \sin A \sin B$</td>
<td>$\sin 2\theta = 2\sin \theta \cos \theta$</td>
</tr>
<tr>
<td>$\cos 2\theta = \cos^2 \theta - \sin^2 \theta = 2\cos^2 \theta - 1 = 1 - 2\sin^2 \theta$</td>
<td>$\tan \theta = \frac{\sin \theta}{\cos \theta} = \frac{1}{\cot \theta}$</td>
<td>$\cot \theta = \frac{\cos \theta}{\sin \theta} = \frac{1}{\tan \theta}$</td>
</tr>
<tr>
<td>$\sec \theta = \frac{1}{\cos \theta}$</td>
<td>$\csc \theta = \frac{1}{\sin \theta}$</td>
<td>$\cos \left(\frac{\pi}{2} - \theta\right) = \sin \theta$</td>
</tr>
<tr>
<td>$\sin \left(\frac{\pi}{2} - \theta\right) = \cos \theta$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Differentiation formulas

| $\frac{d}{dx}(x^n) = nx^{n-1}$ | $\frac{d}{dx}(fg) = f'g + fg'$ | $\frac{d}{dx}\left(\frac{f}{g}\right) = \frac{g'f - fg'}{g^2}$ |
| $\frac{d}{dx}f(g(x)) = f'(g(x))g'(x)$ | $\frac{d}{dx}(\sin x) = \cos x$ | $\frac{d}{dx}(\cos x) = -\sin x$ |
| $\frac{d}{dx}(\tan x) = \sec^2 x$ | $\frac{d}{dx}(\cot x) = -\csc^2 x$ | $\frac{d}{dx}(\sec x) = \sec x \tan x$ |
| $\frac{d}{dx}(\csc x) = -\csc x \cot x$ | $\frac{d}{dx}(e^x) = e^x$ | $\frac{d}{dx}(a^x) = a^x \ln a$ |
| $\frac{d}{dx}(\ln x) = \frac{1}{x}$ | $\frac{d}{dx}(\sin^{-1} x) = \frac{1}{\sqrt{1-x^2}}$ | $\frac{d}{dx}(\cos^{-1} x) = -\frac{1}{\sqrt{1-x^2}}$ |
| $\frac{d}{dx}(\tan^{-1} x) = \frac{1}{1+x^2}$ |
### Integration Formulas

<table>
<thead>
<tr>
<th>Integral Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\int ax , dx = ax + C$</td>
</tr>
<tr>
<td>$\int e^x , dx = e^x + C$</td>
</tr>
<tr>
<td>$\int \sin x , dx = -\cos x + C$</td>
</tr>
<tr>
<td>$\int \cot x , dx = \ln(\sin x) + C$</td>
</tr>
<tr>
<td>$\int \sec^2 x , dx = \tan x + C$</td>
</tr>
<tr>
<td>$\int \csc x \cot x , dx = -\csc x + C$</td>
</tr>
<tr>
<td>$\int \tan x , dx = \ln(\sec x) + C$ or $-\ln(\cos x) + C$</td>
</tr>
</tbody>
</table>

### If the Integral Involves

<table>
<thead>
<tr>
<th>$a^2 - u^2$</th>
<th>$u = a \sin \theta$</th>
<th>$1 - \sin^2 \theta = \cos^2 \theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a^2 + u^2$</td>
<td>$u = a \tan \theta$</td>
<td>$1 + \tan^2 \theta = \sec^2 \theta$</td>
</tr>
<tr>
<td>$u^2 - a^2$</td>
<td>$u = a \sec \theta$</td>
<td>$\sec^2 \theta - 1 = \tan^2 \theta$</td>
</tr>
</tbody>
</table>

### Limits:

- $\lim_{x \to 0} \frac{\sin x}{x} = 1$
- $\lim_{x \to \infty} \frac{\sin x}{x} = 0$
- $\lim_{x \to 0} \frac{1 - \cos x}{x} = 0$

---

**y = D + A \sin B(x - C)**  
**A** is amplitude  
**B** is the affect on the period (stretch or shrink)  
**C** is vertical shift (left/right) and **D** is horizontal shift (up/down)
Exponential Growth and Decay

\[ y = Ce^{kt} \]

Rate of Change of a variable \( y \) is proportional to the value of \( y \)

\[ \frac{dy}{dx} = ky \quad \text{or} \quad y' = ky \]

Formulas and theorems

1. A function \( y=f(x) \) is continuous at \( x=a \) if
   - \( f(a) \) exists
   - \( \lim_{x \to a} f(x) \) exists, and
   - \( \lim_{x \to a} f(x) = f(a) \)

2. Even and odd functions
   - A function \( y = f(x) \) is even if \( f(-x) = f(x) \) for every \( x \) in the function's domain. Every even function is symmetric about the y-axis.
   - A function \( y = f(x) \) is odd if \( f(-x) = -f(x) \) for every \( x \) in the function's domain. Every odd function is symmetric about the origin.

3. Horizontal and vertical asymptotes
   - A line \( y = b \) is a horizontal asymptote of the graph of \( y = f(x) \) if either \( \lim_{x \to \infty} f(x) = b \) or \( \lim_{x \to -\infty} f(x) = b \).
   - A line \( x = a \) is a vertical asymptote of the graph of \( y = f(x) \) if either \( \lim_{x \to a^+} f(x) = \pm \infty \) or \( \lim_{x \to a^-} f(x) = \pm \infty \).

4. Definition of a derivative

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

5. To find the maximum and minimum values of a function \( y = f(x) \), locate
   - the points where \( f'(x) \) is zero or where \( f'(x) \) fails to exist
   - the end points, if any, on the domain of \( f(x) \).

Note: These are the only candidates for the value of \( x \) where \( f(x) \) may have a maximum or a minimum.
6. Let \( f \) be differentiable for \( a < x < b \) and continuous for \( a \leq x \leq b \).
   a. If \( f'(x) > 0 \) for every \( x \) in \( (a,b) \), then \( f \) is increasing on \( [a,b] \).
   b. If \( f'(x) < 0 \) for every \( x \) in \( (a,b) \), then \( f \) is decreasing on \( [a,b] \).

7. Suppose that \( f''(x) \) exists on the interval \( (a,b) \).
   a. If \( f''(x) > 0 \) in \( (a,b) \), then \( f \) is concave upward in \( (a,b) \).
   b. If \( f''(x) < 0 \) in \( (a,b) \), then \( f \) is concave downward in \( (a,b) \).

To locate the points of inflection of \( y = f(x) \), find the points where \( f''(x) = 0 \) or where \( f''(x) \) fails to exist. These are the only candidates where \( f(x) \) may have a point of inflection. Then test these points to make sure that \( f''(x) < 0 \) on one side and \( f''(x) > 0 \) on the other.

8. Mean value theorem

   If \( f \) is continuous on \([a,b]\) and differentiable on \((a,b)\), then there is at least one number \( c \)
   
   \[
   \frac{f(b) - f(a)}{b - a} = f'(c)
   \]

9. Continuity

   If a function is differentiable at a point \( x = a \), it is continuous at that point. The converse is false, i.e. continuity does not imply differentiability.

10. L'Hôpital's rule

    \[
    \lim_{x \to a} \frac{f(x)}{g(x)} = \begin{cases} 0 & \text{if } g(x) \text{ is of the form } 0 \text{ or } \infty, \\ \infty & \text{if } g(x) \text{ is of the form } \infty \end{cases}
    \]

    \[
    \lim_{x \to a} \frac{f'(x)}{g'(x)} = \lim_{x \to a} \frac{f(x)}{g(x)}
    \]

11. Area between curves

    If \( f \) and \( g \) are continuous functions such that \( f(x) \geq g(x) \) on \([a,b]\), then the area between
    
    the curves is \( \int_a^b (f(x) - g(x)) \, dx \).

12. Inverse functions

    a. If \( f \) and \( g \) are two functions such that \( f(g(x)) = x \) for every \( x \) in the domain of \( g \),
       and, \( g(f(x)) = x \), for every \( x \) in the domain of \( f \), then \( f \) and \( g \) are inverse functions
       of each other.
    b. A function \( f \) has an inverse if and only if no horizontal line intersects its graph
       more than once.
    c. If \( f \) is either increasing or decreasing in an interval, then \( f \) has an inverse.
    d. If \( f \) is differentiable at every point on an interval \( l \), and \( f'(x) \neq 0 \) on \( l \), then \( g = f^{-1}(x) \)
       is differentiable at every point of the interior of the interval \( f(l) \) and
       
       \[
       g'(f(x)) = \frac{1}{f'(x)}.
       \]
13. **Properties of** $y = e^x$
   a. The exponential function $y = e^x$ is the inverse function of $y = \ln x$.
   b. The domain is the set of all real numbers, $-\infty < x < \infty$.
   c. The range is the set of all positive numbers, $y > 0$.
   d. $\frac{d}{dx}(e^x) = e^x$
   e. $e^x \cdot e^x = e^{x+x}$.

14. **Properties of** $y = \ln x$
   a. The domain of $y = \ln x$ is the set of all positive numbers, $x > 0$.
   b. The range of $y = \ln x$ is the set of all real numbers, $-\infty < y < \infty$.
   c. $y = \ln x$ is continuous and increasing everywhere on its domain.
   d. $\ln(ab) = \ln a + \ln b$.
   e. $\ln(a/b) = \ln a - \ln b$.
   f. $\ln a^r = r \ln a$.

15. **Fundamental theorem of calculus**

   \[ \int_a^b f(x)\,dx = F(b) - F(a), \text{ where } F'(x) = f(x), \text{ or } \frac{d}{dx} \int_a^b f(x)\,dx = f(x). \]

16. **Volumes of solids of revolution**
   a. Let $f$ be nonnegative and continuous on $[a,b]$, and let $R$ be the region bounded above by $y = f(x)$, below by the $x$-axis, and the sides by the lines $x = a$ and $x = b$.
   b. When this region $R$ is revolved about the $x$-axis, it generates a solid (having circular cross sections) whose volume $V = \int_a^b \pi (f(x))^2 \,dx$.
   c. When $R$ is revolved about the $y$-axis, it generates a solid whose volume $V = \int_a^b 2\pi \cdot x \cdot f(x)\,dx$.

17. **Particles moving along a line**
   a. If a particle moving along a straight line has a positive function $x(t)$, then its instantaneous velocity $v(t) = x'(t)$ and its acceleration $a(t) = v'(t)$.
   b. $v(t) = \int a(t)\,dt$ and $x(t) = \int v(t)\,dt$.

18. **Average y-value**

   The average value of $f(x)$ on $[a,b]$ is $\frac{1}{b-a} \int_a^b f(x)\,dx$. 
# Summary of Convergence Tests for Series

<table>
<thead>
<tr>
<th>Test</th>
<th>Series</th>
<th>Convergence or Divergence</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n^{th}$ term test (or the zero test)</td>
<td>$\sum a_n$</td>
<td>Diverges if $\lim_{n\to\infty} a_n \neq 0$</td>
<td>Inconclusive if $\lim_{n\to\infty} a_n = 0$.</td>
</tr>
<tr>
<td>Geometric series</td>
<td>$\sum_{n=0}^{\infty} a z^n$ (or $\sum_{n=1}^{\infty} a z^{n-1}$)</td>
<td>Converges to $\frac{a}{1-z}$ only if $</td>
<td>z</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diverges if $</td>
<td>z</td>
</tr>
<tr>
<td>$p$-series</td>
<td>$\sum_{n=1}^{\infty} \frac{1}{n^p}$</td>
<td>Converges if $p &gt; 1$</td>
<td>Useful for comparison tests if the $n^{th}$ term $a_n$ of a series is similar to $\frac{1}{n^p}$.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diverges if $p \leq 1$</td>
<td></td>
</tr>
<tr>
<td>Integral</td>
<td>$\sum_{n=1}^{\infty} a_n$ $(c \geq 0)$</td>
<td>$\sum_{n=1}^{\infty} a_n = f(n)$ for all $n$</td>
<td>The function $f$ obtained from $a_n = f(n)$ must be continuous, positive, decreasing and readily integrable for $x \geq c$.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Converges if $\int_{c}^{\infty} f(x) , dx$ converges</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diverges if $\int_{c}^{\infty} f(x) , dx$ diverges</td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>$\sum a_n$ and $\sum b_n$ with $0 \leq a_n \leq b_n$ for all $n$</td>
<td>$\sum b_n$ converges $\Rightarrow$ $\sum a_n$ converges</td>
<td>The comparison series $\sum b_n$ is often a geometric series or a $p$-series.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sum a_n$ diverges $\Rightarrow$ $\sum b_n$ diverges</td>
<td></td>
</tr>
<tr>
<td>Limit Comparison*</td>
<td>$\sum a_n$ and $\sum b_n$ with $a_n, b_n &gt; 0$ for all $n$ and $\lim_{n\to\infty} \frac{a_n}{b_n} = L &gt; 0$</td>
<td>$\sum b_n$ converges $\Rightarrow$ $\sum a_n$ converges</td>
<td>The comparison series $\sum b_n$ is often a geometric series or a $p$-series. To find $b_n$ consider only the terms of $a_n$ that have the greatest effect on the magnitude.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sum b_n$ diverges $\Rightarrow$ $\sum a_n$ diverges</td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td>$\sum a_n$ with $\lim_{n\to\infty} \frac{</td>
<td>a_{n+1}</td>
<td>}{</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diverges if $L &gt; 1$ or if $L$ is infinite</td>
<td></td>
</tr>
<tr>
<td>Root*</td>
<td>$\sum a_n$ with $\lim_{n\to\infty} \sqrt[n]{</td>
<td>a_n</td>
<td>} = L$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diverges if $L &gt; 1$ or if $L$ is infinite</td>
<td></td>
</tr>
<tr>
<td>Absolute Value</td>
<td>$\sum</td>
<td>a_n</td>
<td>$</td>
</tr>
<tr>
<td>Alternating series</td>
<td>$\sum_{n=1}^{\infty} (-1)^{n-1} a_n$ $(a_n &gt; 0)$</td>
<td>Converges if $0 &lt; a_{n+1} &lt; a_n$ for all $n$ and $\lim_{n\to\infty} a_n = 0$</td>
<td>Applicable only to series with alternating terms.</td>
</tr>
</tbody>
</table>
Sequence and Series Summary
Formulas

1. If a sequence \( \{a_n\} \) has a limit \( L \), that is, \( \lim_{n \to \infty} a_n = L \), then the sequence is said to converge to \( L \). If there is no limit, the series diverges. If the sequence \( \{a_n\} \) converges, then its limit is unique. Keep in mind that
\[
\lim_{n \to \infty} \frac{\ln n}{n} = 0; \quad \lim_{n \to \infty} \frac{1}{\sqrt[n]{n}} = 1; \quad \lim_{n \to \infty} \frac{n^r}{n!} = 0. \quad \text{These limits are useful and arise frequently.}
\]

2. The harmonic series \( \sum_{n=1}^{\infty} \frac{1}{n} \) diverges; the geometric series \( \sum_{n=0}^{\infty} ar^n \) converges to \( \frac{a}{1-r} \) if \( |r| < 1 \) and diverges if \( |r| \geq 1 \) and \( a \neq 0 \).

3. The p-series \( \sum_{n=1}^{\infty} \frac{1}{n^p} \) converges if \( p > 1 \) and diverges if \( p \leq 1 \).

4. **Limit Comparison Test**: Let \( \sum_{n=1}^{\infty} a_n \) and \( \sum_{n=1}^{\infty} b_n \) be a series of nonnegative terms, with \( a_n \neq 0 \) for all sufficiently large \( n \), and suppose that \( \lim_{n \to \infty} \frac{b_n}{a_n} = c > 0 \). Then the two series either both converge or both diverge.

5. **Alternating Series**: Let \( \sum_{n=1}^{\infty} a_n \) be a series such that
i) the series is alternating
ii) \( |a_{n+1}| \leq |a_n| \) for all \( n \), and
iii) \( \lim_{n \to \infty} a_n = 0 \)

Then the series converges.

6. A series \( \sum a_n \) is absolutely convergent if the series \( \sum |a_n| \) converges. If \( \sum a_n \) converges, but \( \sum |a_n| \) does not converge, then the series is conditionally convergent. Keep in mind that if \( \sum |a_n| \) converges, then \( \sum a_n \) converges.
7. **Comparison Test**: If \( 0 \leq a_n \leq b_n \) for all sufficiently large \( n \), and \( \sum_{n=1}^{\infty} b_n \) converges,

then \( \sum_{n=1}^{\infty} a_n \) converges. If \( \sum_{n=1}^{\infty} a_n \) diverges, then \( \sum_{n=1}^{\infty} b_n \) diverges.

8. **Integral Test**: If \( f(x) \) is a positive, continuous, and decreasing function on \([1, \infty)\) and let

\[ a_n = f(n) \]. Then the series \( \sum_{n=1}^{\infty} a_n \) will converge if the improper integral \( \int_1^{\infty} f(x) \, dx \)

converges. If the improper integral \( \int_1^{\infty} f(x) \, dx \) diverges, then the infinite series \( \sum_{n=1}^{\infty} a_n \)

diverges.

9. **Ratio Test**: Let \( \sum_{n=1}^{\infty} a_n \) be a series with nonzero terms.

i) If \( \lim_{n \to \infty} \left| \frac{a_{n+1}}{a_n} \right| < 1 \), then the series converges absolutely.

ii) If \( \lim_{n \to \infty} \left| \frac{a_{n+1}}{a_n} \right| > 1 \), then the series is divergent.

iii) If \( \lim_{n \to \infty} \left| \frac{a_{n+1}}{a_n} \right| = 1 \), then the test is inconclusive (and another test

must be used).

10. **Power Series**: A power series is a series of the form

\[ \sum_{n=0}^{\infty} c_n x^n = c_0 + c_1 x + c_2 x^2 + \ldots + c_n x^n + \ldots \] or

\[ \sum_{n=0}^{\infty} c_n (x-a)^n = c_0 + c_1 (x-a) + c_2 (x-a)^2 + \ldots + c_n (x-a)^n + \ldots \] in which the

center \( a \) and the coefficients \( c_0, c_1, c_2, \ldots, c_n, \ldots \) are constants. The set of all numbers \( x \)

for which the power series converges is called the interval of convergence.

11. **Taylor Series**: Let \( f \) be a function with derivatives of all orders throughout some interval

containing \( a \) as an interior point. Then the Taylor series generated by \( f \) at \( a \) is

\[ \sum_{k=0}^{\infty} \frac{f^{(k)}(a)}{k!} (x-a)^k = f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \ldots + \frac{f^{(n)}(a)}{n!}(x-a)^n + \ldots \]

The remaining terms after the term containing the \( n \)th derivative can be expressed as a

remainder to Taylor's Theorem:

\[ f(x) = f(a) + \sum_{n=1}^{\infty} \frac{f^{(n)}(a)(x-a)^n}{n!} + R_n(x) \text{ where } R_n(x) = \frac{1}{n!} \int_0^x (x-t)^n f^{(n+1)}(t) \, dt \]

Lagrange's form of the remainder: \( R_n(x) = \frac{f^{(n+1)}(c)(x-a)^{n+1}}{(n+1)!} \), where \( a < c < x \). The

series will converge for all values of \( x \) for which the remainder goes to zero.
12. **Frequently Used Series**

\[
\frac{1}{1-x} = 1 + x + x^2 + \ldots + x^n + \ldots = \sum_{n=0}^{\infty} x^n, \quad |x| < 1
\]

\[
\frac{1}{1+x} = 1 - x + x^2 - \ldots + (-x)^n + \ldots = \sum_{n=0}^{\infty} (-1)^n x^n, \quad |x| < 1
\]

\[e^x = 1 + x + \frac{x^2}{2!} + \ldots + \frac{x^n}{n!} + \ldots = \sum_{n=0}^{\infty} \frac{x^n}{n!}, \quad |x| < \infty
\]

\[
\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots + (-1)^n \frac{x^{2n+1}}{(2n+1)!} + \ldots = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!}, \quad |x| < \infty
\]

\[
\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots + (-1)^n \frac{x^{2n}}{(2n)!} + \ldots = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!}, \quad |x| < \infty
\]

\[
\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \ldots + (-1)^{n-1} \frac{x^n}{n} + \ldots = \sum_{n=1}^{\infty} (-1)^{n-1} \frac{x^n}{n}, \quad -1 < x \leq 1
\]

\[
	ext{Arc tan } x = x - \frac{x^3}{3} + \frac{x^5}{5} - \ldots + (-1)^n \frac{x^{2n+1}}{2n+1} + \ldots = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{2n+1}, \quad |x| \leq 1
\]
Indeterminate Form:

\[
\frac{0}{0}, \frac{\infty}{\infty} \implies \text{Apply L’Hopital Directly}
\]

\[
0 \cdot \infty \implies \text{Rewrite as either } \frac{0}{0} \text{ or } \frac{\infty}{\infty}
\]
Then apply L’Hopital

\[1^\infty, 0^0, \infty^0 \implies 1. \text{ Consider the limit of the } \ln \text{ of the function.}
2. \text{ Use laws of logs to rewrite in the form } 0 \cdot \infty.
3. \text{ Rewrite as either } \frac{0}{0} \text{ or } \frac{\infty}{\infty}.
4. \text{ Apply L’Hopital.}
5. \text{ Exponentiate your answer.}
\]

\[\infty - \infty \implies \text{Try to rewrite so that you can use one of the previous forms.}\]

To convert polar coordinates into rectangular coordinates, we use the basic relations
\[x = r \cos \theta, \quad y = r \sin \theta\]

Converting in the opposite direction we use
\[r^2 = x^2 + y^2, \quad \tan \theta = \frac{y}{x} \text{ if } x \neq 0\]
What does the graph look like?

\[ r = a \quad \Rightarrow \quad \text{Circle} \]

\[ r = 0 \quad \Rightarrow \quad \text{Line} \]

\[ r = a + b \sin \theta \quad \text{OR} \quad r = a + b \cos \theta \]

\[ a > b \quad \Rightarrow \quad \text{Dimpled Limacon} \]

\[ a < b \quad \Rightarrow \quad \text{Limacon with an inner loop} \]

\[ a = b \quad \Rightarrow \quad \text{Cardiod} \]

\[ r = a \cos n\theta \quad \text{OR} \quad r = a \sin n\theta \]

\[ n \text{ even } (n \geq 2) \quad \Rightarrow \quad \text{Rose with } 2n \text{ petals.} \]

\[ n \text{ odd } (n \geq 3) \quad \Rightarrow \quad \text{Rose with } n \text{ petals.} \]