

Complex Analysis

Md. Aquil Khan

Example

- $f(z) = z^2$.

Example

- $f(z) = z^2$.
- $f(z) = f(x + iy) = (x + iy)^2 =$

Example

- $f(z) = z^2$.

- $f(z) = f(x + iy) = (x + iy)^2 = \underbrace{x^2 - y^2}_{\text{real part}} + i \underbrace{2xy}_{\text{imaginary part}}$

Example

- $f(z) = z^2$.
- $f(z) = f(x + iy) = (x + iy)^2 = \underbrace{x^2 - y^2}_{\text{real part}} + i \underbrace{2xy}_{\text{imaginary part}}$
- $f = u + iv$, where
 $u(x, y) = x^2 - y^2, \quad v(x, y) = 2xy$

Example

- $f(z) = \frac{1}{z}$.

Example

- $f(z) = \frac{1}{z}$.
- $f(z) = f(x + iy) = \frac{1}{x+iy} =$

Example

- $f(z) = \frac{1}{z}$.

- $f(z) = f(x + iy) = \frac{1}{x+iy} = \underbrace{\frac{x}{x^2 + y^2}}_{\text{real part}} + i \underbrace{\frac{-y}{x^2 + y^2}}_{\text{imaginary part}}$

Example

- $f(z) = \frac{1}{z}$.
- $f(z) = f(x + iy) = \frac{1}{x+iy} = \underbrace{\frac{x}{x^2 + y^2}}_{\text{real part}} + i \underbrace{\frac{-y}{x^2 + y^2}}_{\text{imaginary part}}$
- $f = u + iv$, where
 $u(x, y) = \frac{x}{x^2 + y^2}, \quad v(x, y) = \frac{-y}{x^2 + y^2}$

Real and Imaginary Part of a Function

- $f : D \rightarrow \mathbb{C}$, where $D \subseteq \mathbb{C}$.

Real and Imaginary Part of a Function

- $f : D \rightarrow \mathbb{C}$, where $D \subseteq \mathbb{C}$.
- $f(z) = \underbrace{u(x, y)}_{\text{real part}} + i \underbrace{v(x, y)}_{\text{imaginary part}}, \quad z = x + iy$

where u and v are real functions of the two real variables x and y .

Real and Imaginary Part of a Function

- $f : D \rightarrow \mathbb{C}$, where $D \subseteq \mathbb{C}$.
- $f(z) = \underbrace{u(x, y)}_{\text{real part}} + i \underbrace{v(x, y)}_{\text{imaginary part}}, \quad z = x + iy$

where u and v are real functions of the two real variables x and y .

- $u \longrightarrow \text{Real part of } f$
 $v \longrightarrow \text{Imaginary part of } f$

Real and Imaginary Part of a Function

- $f : D \rightarrow \mathbb{C}$, where $D \subseteq \mathbb{C}$.
- $f(z) = \underbrace{u(x, y)}_{\text{real part}} + i \underbrace{v(x, y)}_{\text{imaginary part}}, \quad z = x + iy$

where u and v are real functions of the two real variables x and y .

- $u \longrightarrow \text{Real part of } f$
- $v \longrightarrow \text{Imaginary part of } f$
- $f = u + iv$

Limit

- $f : D \rightarrow \mathbb{C}$, $D \subseteq \mathbb{C}$, and z_0 is a limit point of \mathbb{C} .

Limit

- $f : D \rightarrow \mathbb{C}$, $D \subseteq \mathbb{C}$, and z_0 is a limit point of \mathbb{C} .
- $\lim_{z \rightarrow z_0} f(z) = l$ (f has the limit l as z approaches z_0)



Limit

- $f : D \rightarrow \mathbb{C}$, $D \subseteq \mathbb{C}$, and z_0 is a limit point of \mathbb{C} .
- $\lim_{z \rightarrow z_0} f(z) = l$ (f has the limit l as z approaches z_0)



For a given $\epsilon > 0$, there exists a $\delta_\epsilon > 0$ such that

$$z \in D \quad \& \quad 0 < |z - z_0| < \delta_\epsilon \quad \Rightarrow$$

Limit

- $f : D \rightarrow \mathbb{C}$, $D \subseteq \mathbb{C}$, and z_0 is a limit point of \mathbb{C} .
- $\lim_{z \rightarrow z_0} f(z) = l$ (f has the limit l as z approaches z_0)



For a given $\epsilon > 0$, there exists a $\delta_\epsilon > 0$ such that

$$z \in D \quad \& \quad 0 < |z - z_0| < \delta_\epsilon \quad \Rightarrow \quad |f(z) - l| < \epsilon$$

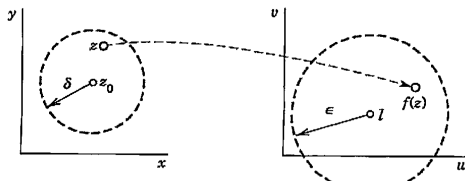
Limit

- $f : D \rightarrow \mathbb{C}$, $D \subseteq \mathbb{C}$, and z_0 is a limit point of \mathbb{C} .
- $\lim_{z \rightarrow z_0} f(z) = l$ (f has the limit l as z approaches z_0)



For a given $\epsilon > 0$, there exists a $\delta_\epsilon > 0$ such that

$$z \in D \ \& \ 0 < |z - z_0| < \delta_\epsilon \Rightarrow |f(z) - l| < \epsilon$$



Facts

- The limit l , if exists, must be unique.

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$
- Along the positive direction of x-axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} =$

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$
- Along the positive direction of x -axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = 1$.

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$
- Along the positive direction of x-axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = 1$.
- Along the positive direction of y-axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} =$

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$
- Along the positive direction of x -axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = 1$.
- Along the positive direction of y -axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = -1$

Facts

- The limit l , if exists, must be unique.
- The value of l is independent of the direction along which $z \rightarrow z_0$.

Example

- consider $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$
- Along the positive direction of x-axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = 1$.
- Along the positive direction of y-axis, $\lim_{z \rightarrow 0} \frac{z}{\bar{z}} = -1$
- $\lim_{z \rightarrow 0} \frac{z}{\bar{z}}$ does not exist.

Continuity

- $f : D \rightarrow \mathbb{C}$ is said to be continuous at $z_0 \in D$



Continuity

- $f : D \rightarrow \mathbb{C}$ is said to be continuous at $z_0 \in D$



$$\lim_{z \rightarrow z_0} f(z) =$$

Continuity

- $f : D \rightarrow \mathbb{C}$ is said to be continuous at $z_0 \in D$



$$\lim_{z \rightarrow z_0} f(z) = f(z_0)$$

Continuity

- $f : D \rightarrow \mathbb{C}$ is said to be continuous at $z_0 \in D$



$$\lim_{z \rightarrow z_0} f(z) = f(z_0)$$

A complex function is said to be continuous in a region R if it is continuous at every point in R .

Theorem

$f = u + iv$ is continuous at $z_0 = x_0 + iy_0$



Theorem

$f = u + iv$ is continuous at $z_0 = x_0 + iy_0$



$u(x, y)$ and $v(x, y)$ are both continuous at (x_0, y_0)

Example

- $f(x + iy) = e^x \cos y + ie^x \sin y.$

Example

- $f(x + iy) = e^x \cos y + ie^x \sin y.$
- $u(x, y) =$

Example

- $f(x + iy) = e^x \cos y + ie^x \sin y.$
- $u(x, y) = e^x \cos y, v(x, y) = e^x \sin y$

Example

- $f(x + iy) = e^x \cos y + ie^x \sin y$.
- $u(x, y) = e^x \cos y$, $v(x, y) = e^x \sin y$
- u and v are both continuous in \mathbb{R}^2

Example

- $f(x + iy) = e^x \cos y + ie^x \sin y$.
- $u(x, y) = e^x \cos y$, $v(x, y) = e^x \sin y$
- u and v are both continuous in \mathbb{R}^2
- f is continuous in \mathbb{C}

Example

- $f(z) = |z|^2$

Example

- $f(z) = |z|^2$
- $u(x, y) =$

Example

- $f(z) = |z|^2$
- $u(x, y) = x^2 + y^2, v(x, y) = 0$

Example

- $f(z) = |z|^2$
- $u(x, y) = x^2 + y^2, v(x, y) = 0$
- u and v are both continuous in \mathbb{R}^2

Example

- $f(z) = |z|^2$
- $u(x, y) = x^2 + y^2, v(x, y) = 0$
- u and v are both continuous in \mathbb{R}^2
- f is continuous in \mathbb{C}

Example

- $f(z) = \frac{\operatorname{Re} z}{z}$ for $z \neq 0$, and $f(0) = 0$.

Example

- $f(z) = \frac{\operatorname{Re} z}{z}$ for $z \neq 0$, and $f(0) = 0$.
- $u(x, y) =$

Example

- $f(z) = \frac{\operatorname{Re} z}{z}$ for $z \neq 0$, and $f(0) = 0$.
- $u(x, y) = \frac{x^2}{x^2+y^2}$, $v(x, y) = \frac{-xy}{x^2+y^2}$, for $(x, y) \neq (0, 0)$
 $u(0, 0) = v(0, 0) = 0$

Example

- $f(z) = \frac{\operatorname{Re} z}{z}$ for $z \neq 0$, and $f(0) = 0$.
- $u(x, y) = \frac{x^2}{x^2 + y^2}$, $v(x, y) = \frac{-xy}{x^2 + y^2}$, for $(x, y) \neq (0, 0)$
 $u(0, 0) = v(0, 0) = 0$
- u and v are not continuous at $(0, 0)$ as $\lim_{(x, y) \rightarrow (0, 0)} u(x, y)$, and $\lim_{(x, y) \rightarrow (0, 0)} v(x, y)$ does not exist.

Example

- $f(z) = \frac{\operatorname{Re} z}{z}$ for $z \neq 0$, and $f(0) = 0$.
- $u(x, y) = \frac{x^2}{x^2+y^2}$, $v(x, y) = \frac{-xy}{x^2+y^2}$, for $(x, y) \neq (0, 0)$
 $u(0, 0) = v(0, 0) = 0$
- u and v are not continuous at $(0, 0)$ as $\lim_{(x,y) \rightarrow (0,0)} u(x, y)$, and $\lim_{(x,y) \rightarrow (0,0)} v(x, y)$ does not exist.
- f is not continuous at $z = 0$.

Theorems on real continuous functions can be extended to complex continuous functions

- Sum, difference and product of continuous functions are also continuous