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# Continuity

## 1. DEFINITION

If the graph of a function has no break or jump, then it is said to be continuous function. A function which is not continuous is called a discontinuous function.

## 2. CONTINUITY OF A FUNCTION AT A POINT

A Function  $f(x)$  is said to be continuous at some point  $x=a$  of its domain if

$$\lim_{x \rightarrow a} f(x) = f(a)$$

i.e., If  $\lim_{x \rightarrow a-0} f(x) = \lim_{x \rightarrow a+0} f(x) = f(a)$

i.e., If  $f(a-0) = f(a+0) = f(a)$

i.e., If  $\{\text{LHL at } x=a\} = \{\text{RHL at } x=a\} = \{\text{value of the function at } x=a\}$ .

## 3. CONTINUITY FROM LEFT AND RIGHT

Function  $f(x)$  is said to be

(i) Left Continuous at  $x=a$  if  $\lim_{x \rightarrow a-0} f(x) = f(a)$  i.e.  $f(a-0) = f(a)$

(ii) Right Continuous at  $x=a$  if  $\lim_{x \rightarrow a+0} f(x) = f(a)$  i.e.  $f(a+0) = f(a)$

Thus a function  $f(x)$  is continuous at a point  $x=a$  if it is left continuous as well as right continuous at  $x=a$ .

## 4. CONTINUITY IN AN INTERVAL

(1) A function  $f(x)$  is continuous in an open interval  $(a, b)$  if it is continuous at every point of the interval.

(2) A function  $f(x)$  is continuous in a closed interval  $[a, b]$  if it is

- (i) continuous in  $(a, b)$
- (ii) right continuous at  $x=a$
- (iii) left continuous at  $x=b$

## 5. CONTINUOUS FUNCTIONS

A function is said to be continuous function if it is continuous at every point in its domain. Following are examples of some continuous functions:

- (i)  $f(x) = x$  (Identify function)
- (ii)  $f(x) = c$  (Constant function)
- (iii)  $f(x) = a_0x^n + a_1x^{n-1} + \dots + a^n$  (Polynomial function)
- (iv)  $f(x) = \sin x, \cos x$  (Trigonometric function)
- (v)  $f(x) = a^x, e^x, e^{-x}$  (Exponential function)
- (vi)  $f(x) = \log x$  (Logarithmic function)

(vii)  $f(x) = \sinh x, \cosh x, \tanh x$  (Hyperbolic function)

(viii)  $f(x) = |x|, x + |x|, x - |x|, x|x|$  (Absolute value functions)

## 6. DISCONTINUOUS FUNCTIONS

A function is said to be a discontinuous function if it is discontinuous at atleast one point in its domain. Following are examples of some discontinuous functions:

No.	Functions	Points of discontinuity
(i)	$[x]$	Every Integers
(ii)	$x - [x]$	Every Integers
(iii)	$\frac{1}{x}$	$x = 0$
(iv)	$\tan x, \sec x$	$x = \pm \frac{\pi}{2}, \pm \frac{3\pi}{2}, \dots$
(v)	$\cot x, \operatorname{cosec} x$	$x = 0, \pm \pi, \pm 2\pi, \dots$
(vi)	$\sin \frac{1}{x}, \cos \frac{1}{x}$	$x = 0$
(vii)	$e^{1/x}$	$x = 0$
(viii)	$\coth x, \operatorname{cosech} x$	$x = 0$

## 7. PROPERTIES OF CONTINUOUS FUNCTIONS

The sum, difference, product, quotient (if  $D_r \neq 0$ ) and composite of two continuous functions are always continuous functions. Thus if  $f(x)$  and  $g(x)$  are continuous functions then following are also continuous functions:

- |  |   |
|--|---|
| (i) $f(x) + g(x)$                          | (ii) $f(x) - g(x)$                                  |
| (iii) $f(x) \cdot g(x)$                    | (iv) $\lambda f(x)$ , where $\lambda$ is a constant |
| (v) $\frac{f(x)}{g(x)}$ , if $g(x) \neq 0$ | (vi) $f[g(x)]$                                      |

## 8. IMPORTANT POINT

The discontinuity of a function  $f(x)$  at  $x = a$  can arise in two ways

- (i) If  $\lim_{x \rightarrow a^-} f(x)$  exist but  $\neq f(a)$  or  $\lim_{x \rightarrow a^+} f(x)$  exist but  $\neq f(a)$ , then the function  $f(x)$  is said to have a removable discontinuity.
- (ii) The function  $f(x)$  is said to have an unremovable discontinuity when  $\lim_{x \rightarrow a} f(x)$  does not exist.

$$\text{i.e. } \lim_{x \rightarrow a^-} f(x) \neq \lim_{x \rightarrow a^+} f(x)$$

Differentiability at a point

Let  $f(x)$  be a real valued function defined on an open interval  $(a, b)$  and let  $c \in (a, b)$ . Then  $f(x)$  is said to be

differentiable or derivable at  $x = c$ , iff  $\lim_{x \rightarrow c} \frac{f(x) - f(c)}{x - c}$  exists finitely.

This limit is called the derivative or differential coefficient of the function  $f(x)$  at  $x = c$ , and is denoted by  $f'(c)$  or

$$Df(c) \text{ or } \left\{ \frac{d}{dx} f(x) \right\}_{x=c}$$

$$\lim_{x \rightarrow c^-} \frac{f(x) - f(c)}{-h} = \lim_{h \rightarrow 0} \frac{f(c+h) - f(c)}{-h}$$

is called the left hand derivative of  $f(x)$  at  $x = c$  and is denoted by  $f'(c^-)$  or  $Lf'(c)$  while.

$$\lim_{x \rightarrow c^+} \frac{f(x) - f(c)}{x - c} \text{ or } \lim_{h \rightarrow 0} \frac{f(c+h) - f(c)}{h}$$

is called the right hand derivative of  $f(x)$  at  $x = c$  and is denoted by  $f'(c^+)$  or  $Rf'(c)$ .

Thus,  $f(x)$  is differentiable at  $x = c \Leftrightarrow Lf'(c) = Rf'(c)$ .

If  $Lf'(c) \neq Rf'(c)$  we say that  $f(x)$  is not differentiable at  $x = c$ .

**Differentiability in a set**

A function  $f(x)$  defined on an open interval  $(a, b)$  is said to be differentiable or derivable in open interval  $(a, b)$  if it is differentiable at each point of  $(a, b)$

Quizrr