# Section 3.1: Derivative

DEFINITION 1. *The* **Derivative** *of a function* $f(x)$ *at* $x = a$ *is*

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

*Other common notations for the derivative of* $y = f(x)$ *are* $f'$, $\dfrac{\mathrm{d}}{\mathrm{d}x} f(x)$.

It follows from the definition that the derivative $f'(a)$ measures:

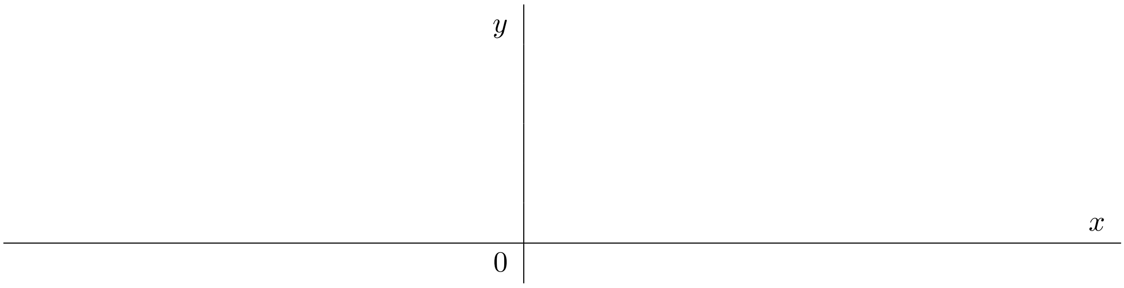
- The slope of the tangent line to the graph of $f(x)$ at $(a, f(a))$;
- The instantaneous rate of change of $f(x)$ at $x = a$;
- The instantaneous velocity of the object at time at $t = a$ (if $f(t)$ is the position of an object at time $t$).

EXAMPLE 2. *Given* $f(x) = \dfrac{3}{x+5}$.

**(a)** *Find the derivative of* $f(x)$ *at* $x = -3$.

**(b)** *Find the equation of the tangent line of* $y = f(x)$ *at* $x = -3$.

**Question:** Where does a derivative not exist for a function?



DEFINITION 3. *A function $f(x)$ is said to be* **differentiable** *at $x = a$ if $f'(a)$ exists.*

EXAMPLE 4. *Refer to the graph above to determine where f(x) is not differentiable.*

*CONCLUSION:* A function $f(x)$ is NOT differentiable at $x = a$ if

- $f(x)$ is not continuous at $x = a$;

- $f(x)$ has a sharp turn at $x = a$ (left and right derivatives are not the same );

- $f(x)$ has a vertical tangent at $x = a$.

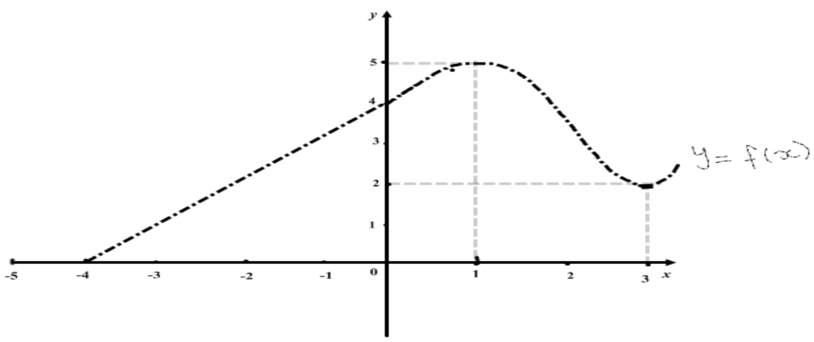
THEOREM 5. *If $f$ is differentiable at $a$ then $f$ is continuous at $a$.*

**The derivative as a function:** If we replace $a$ by $x$ in Definition 1 we get:

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

A new function $g(x) = f'(x)$ is called the **derivative of** $f$.

EXAMPLE 6. *Use the graph of $f(x)$ below to sketch the graph of the derivative $f'(x)$.*



EXAMPLE 7. *Use the definition of the derivative to find* $f'(x)$ *for* $f(x) = \sqrt{1+3x}$.

EXAMPLE 8. *Each limit below represents the derivative of function* $f(x)$ *at* $x = a$. *State* $f$ *and* $a$ *in each case.*

**(a)** $\lim\limits_{h\to 0} \dfrac{(3+h)^4 - 81}{h}$

**(b)** $\lim\limits_{x\to \frac{3\pi}{2}} \dfrac{\sin x + 1}{x - \frac{3\pi}{2}}$