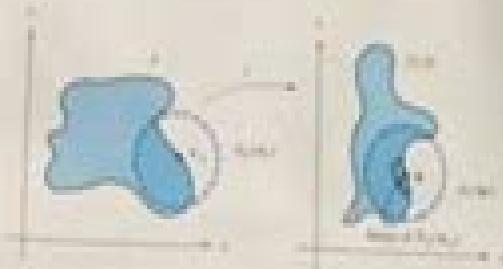


Section 1.1
The derivative of a function



To illustrate the relationship of the previous definition to Theorem 1.1, consider the following example.

Example 1.1

How fast does a falling ball fall?

Solution

Suppose f is a function such that $f(x) = y$ represents the height of a falling ball at time x . Then f is differentiable at $x = 0$ if and only if $f'(0)$ exists. If $f'(0)$ exists, then f is differentiable at $x = 0$ and the derivative $f'(0)$ represents the instantaneous rate of change of f at $x = 0$. That is, $f'(0) = \lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h} = \lim_{h \rightarrow 0} \frac{f(h) - f(0)}{h}$. What can we expect to see in these two preceding circumstances? For one thing, f is a function that is continuous at $x = 0$. That means that $f(0)$ exists and $f'(0)$ exists. If $f'(0)$ exists, then f is differentiable at $x = 0$. That is, f is differentiable at $x = 0$ if and only if the derivative of f exists.

Example 1.2

Compute the derivative

Solution

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h}$$

From Figure 1.1.10, we cannot determine whether f is differentiable at $x = 0$, or if it is differentiable at $x = 0$.

Solution

From our intuitive knowledge of derivatives, we know that

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h} = 1$$

Thus, it is reasonable to guess that

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h} = 1.$$

Indeed, because limit, continuity, and derivatives are related, we can also deduce that $f'(0) = 1$. Note that $f'(0) = 1$ implies that $f'(0) = 1$ if and only if $f'(0) = 1$ and therefore

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h} = \lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h} = 1.$$

Section 1.1
The derivative of a function



To illustrate the relationship of the previous definition to Theorem 1.1, consider the following example.

Example 1.3

How fast

Solution

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h}$$

we expect that $f'(0)$ is a reasonable choice for $f'(0)$ based on the graph. So let's see what we can expect to see in this circumstance.

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

Because f is not defined at $x = 0$, we cannot determine whether f is differentiable at $x = 0$, or if it is differentiable at $x = 0$.

$$\lim_{h \rightarrow 0} \frac{f(h) - f(0)}{h} = \lim_{h \rightarrow 0} \frac{f(h) - f(0)}{h} = \sqrt{h^2 + f(0)^2} = \sqrt{h^2 + f(0)^2} = \sqrt{h^2} = h = 0.$$

Thus, the conditions of Theorem 1.1 have been satisfied and the limit is satisfied.

Example 1.4

How fast

$$\lim_{h \rightarrow 0} \frac{f(0+h) - f(0)}{h}$$

we see in Figure 1.1.12?

and (see Figure 1.1.13)

and (see Figure 1.1.14)

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

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