

Section 1.1
The derivative of a function



To illustrate the relationship of the previous definition to Theorem 1.1, we will use the following example.

Example 1.1

How fast does a falling ball fall?

Solution

Suppose that $s = s(t)$ represents the position of a falling ball at time t , where s is in feet and t is in seconds. Then $s'(t) = v(t)$ is the velocity of the ball at time t . If we have the property that $s'(t) = 0$, then $v(t) = 0$ implies $s'(t) = 0$. What can we expect to see if these two properties hold? We can see that when $s'(t) = 0$, then $s(t) = s_0$ for some constant s_0 . This means that the ball is at rest at time t . In this case, we can say that the ball has stopped falling. This illustrates the importance of the definition of a limit.

Example 1.2

Compute the derivative

Solution

$$\lim_{h \rightarrow 0} \frac{f(2+h) - f(2)}{h}$$

From Figure 1.1.10, we cannot determine whether $f(x)$ approaches some number as x approaches 2.

From our intuitive knowledge of limits, we know that

$$\lim_{h \rightarrow 0} \frac{h}{h} = 1$$

Thus, it is reasonable to guess that

$$\lim_{h \rightarrow 0} \frac{f(2+h) - f(2)}{h} = 1.$$

Indeed, because limit, $\lim_{h \rightarrow 0} \frac{h}{h} = 1$, provides a limit for $\frac{f(2+h) - f(2)}{h}$, $f'(2) = 1$, and that $f'(2) = 1$ implies that f is continuous at $x = 2$ if $f(2) = 1$, then $f(2) = 1$, $f'(2) = 1$, and therefore

$$\lim_{h \rightarrow 0} \frac{f(2+h) - f(2)}{h} = \lim_{h \rightarrow 0} \frac{f(2+h) - f(2)}{h} \cdot \frac{h}{h} = 1.$$

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Figure 1.1.11 shows the function $f(x, y) = x^2 - y^2$ plotted over a rectangular region. The surface has a saddle point at the origin. It rises in the x -direction and dips in the y -direction. A sketch of the surface is shown in Figure 1.1.12.

Example 1.3

How fast

Solution

$$\lim_{h \rightarrow 0} \frac{f(2+h) - f(2)}{h}$$

We cannot determine that $f'(2)$ is a constant value, so it is clear that the surface has a saddle point at the origin. See Figure 1.1.11.

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

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

Because $f'(2)$ does not exist, then $f'(2) = 0$, $f'(2) = 0$, $f'(2) = 0$, and $f'(2) = 0$, implying that $f'(2) = 0$. Thus, $f'(2) = 0$, $f'(2) = 0$, $f'(2) = 0$, and $f'(2) = 0$, implying that

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

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

Example 1.4

as θ

$$\lim_{\theta \rightarrow 0} \frac{\sin \theta}{\theta}$$

and (see Figure 1.1.13)

as θ (see Figure 1.1.14)

$$\lim_{\theta \rightarrow 0} \frac{\sin \theta}{\theta} = 0$$

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