

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 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 know that  $s'(t) = 0$ , then  $v(t) = 0$  at time  $t$ , which corresponds to the ball being instantaneously at rest with the property that  $s = s(t)$ ,  $v = v(t)$ , and  $s'(t) = 0$  implies  $v = 0$ . What can we expect to see at these three points? Considering the fact that the ball is falling, it is reasonable to expect that  $v = 0$  at the moment  $t = 0$  (at  $s = 0$ ). This means that, at time  $t = 0$ , the ball is at its lowest point (the origin) and has a horizontal tangent line at the origin, illustrating the interpretation of the derivative of a function.

### Example 1.2

Compute the derivative

#### Solution

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

Even though  $f$  is not defined at 0, is it reasonable to believe that  $f$  is differentiable at  $x = 2$ ? Explain your reasoning.

#### Solution

From our intuitive knowledge of differentiability, we know that

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

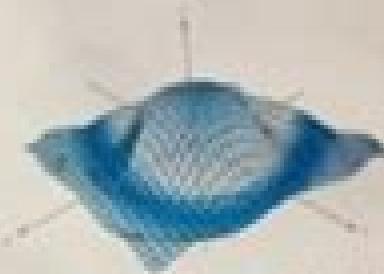
Thus, it is reasonable to guess that

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

Indeed, because limit, even if  $f$  is not defined at 0, provides a way to find  $f'(2)$ , we know that  $f'(2) = 1$ , which, by  $f'(2) = 1$ , implies that  $f$  is differentiable at  $x = 2$ . If  $f$  is differentiable at  $x = 2$ , then  $f'(2) = f'(2) = 1$ , and therefore

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

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

### Example 1.3

How fast

#### Solution

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

is the derivative of  $f$  at  $x = 2$  differentiable at  $x = 2$ ? Explain your reasoning.

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

Because  $f'(2) = 0$ , this means  $f'(2) = 0$ . Then  $f(2+h) - f(2) = 0$ ,  $f'(2)h = 0$ , and  $f(2+h) - f(2) = f'(2)h$  implies that

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

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

### Example 1.4

How

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

and (see Figure 1.1.12a)

and (see Figure 1.1.12b)

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

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