EXAMPLE 3 Finding the Derivative by the Limit Process

Find the derivative of $f(x) = x^3 + 2x$.

Solution

Total Line

12 (M. 1881)

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and in the

verid i

$$f'(x) = \lim_{\Delta x} \frac{f(x + \Delta x) - f(x)}{\Delta x}$$
Definition of determine
$$= \lim_{\Delta x} \frac{(x + \Delta x)^3 + 2(x + \Delta x) - (x^5 + 2x)}{\Delta x}$$

$$= \lim_{\Delta x} \frac{x^5 + 3x^2\Delta x + 3x(\Delta x)^2 + (\Delta x)^3 + 2x + 2\Delta x - x^2 - 2x}{\Delta x}$$

$$= \lim_{\Delta x} \frac{3x^2\Delta x + 3x(\Delta x)^2 + (\Delta x)^3 + 2\Delta x}{\Delta x}$$

$$= \lim_{\Delta x} \frac{4x([3x^2 + 3x\Delta x + (\Delta x)^2 + 2]}{\Delta x}$$

$$= \lim_{\Delta x} [3x^2 + 3x\Delta x + (\Delta x)^2 + 2]$$

$$= 3x^4 + 2$$

STUDY TIE

When using the definition to find a derivative of a function, the key, is to rewrite the difference quotient so that Δx does not occur as a Eachor of the decorranator.

Remember that the derivative of a function f is uself a function, which can be used to find the slope of the tangent line at the point (x, f(x)) on the graph of f.

EXAMPLE 4 Using the Derivative to Find the Slope at a Point

Find f'(x) for $f(x) = \sqrt{x}$. Then find the slopes of the graph of f at the points (1, 1) and (4, 2). Discuss the behavior of f at #O. Ob.

Use the procedure for rationalizing municiators, as discussed in Section 1.3. Seduction

$$\begin{split} f'(x) &= \lim_{\Delta x} \frac{f(x + \Delta x) - f(x)}{\Delta x} &= \lim_{\Delta x} \frac{\sqrt{x} + \Delta x - \sqrt{x}}{\Delta x} \\ &= \lim_{\Delta x \to 0} \left(\frac{\sqrt{x} + \Delta x}{\Delta x} - \sqrt{x} \right) \left(\frac{\sqrt{x} + \Delta x}{\sqrt{x} + \Delta x} + \frac{\sqrt{x}}{\sqrt{x}} \right) \\ &= \lim_{\Delta x \to 0} \frac{\left(x + \Delta x \right) - x}{\Delta x \left(\sqrt{x} + \Delta x + \sqrt{x} \right)} \\ &= \lim_{\Delta x \to 0} \frac{\Delta x}{\Delta x \left(\sqrt{x} + \Delta x + \sqrt{x} \right)} \\ &= \lim_{\Delta x \to 0} \frac{\Delta x}{\Delta x \left(\sqrt{x} + \Delta x + \sqrt{x} \right)} \\ &= \lim_{\Delta x \to 0} \frac{1}{\sqrt{x} + \Delta x + \sqrt{x}} \\ &= \frac{1}{2\sqrt{x}}, \quad x \ge 0 \end{split}$$

At the point (1, 1), the slope is $f(1) = \frac{1}{2}$. At the point (4, 2), the slope is $f(4) = \frac{1}{2}$. See Figure 2.8. At the point (0, 0), the alope is undefined. Moreover, the graph of flux a vertical tangent line at (0, 0).



The slope of fat triffell, a rest, is pe = 1/12 c/ v k Figure 2.8

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