

5.1 The Natural Logarithmic Function: Differentiation

- Develop and use properties of the natural logarithmic function.
- Understand the definition of the number e .
- Find derivatives of functions involving the natural logarithmic function.

The Natural Logarithmic Function

Recall that the General Power Rule

$$\int x^n dx = \frac{x^{n+1}}{n+1} + C, \quad n \neq -1 \quad \text{General Power Rule}$$

has an important disclaimer—it doesn't apply when $n = -1$. Consequently, you have not yet found an antiderivative for the function $f(x) = 1/x$. In this section, you will use the Second Fundamental Theorem of Calculus to define such a function. This antiderivative is a function that you have not encountered previously in the text. It is neither algebraic nor trigonometric, but falls into a new class of functions called *logarithmic functions*. This particular function is the **natural logarithmic function**.

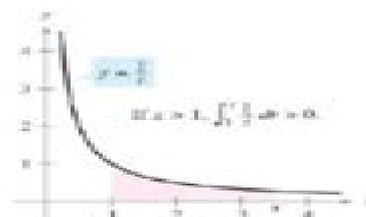
DEFINITION OF THE NATURAL LOGARITHMIC FUNCTION

The **natural logarithmic function** is defined by

$$\ln x = \int_1^x \frac{1}{t} dt, \quad x > 0.$$

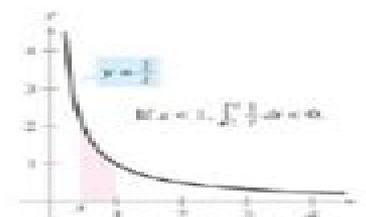
The domain of the natural logarithmic function is the set of all positive real numbers.

From this definition, you can see that $\ln x$ is positive for $x > 1$ and negative for $0 < x < 1$, as shown in Figure 5.1. Moreover, $\ln 1 = 0$, because the upper and lower limits of integration are equal when $x = 1$.



If $x > 1$, then $\ln x > 0$.

Figure 5.1



If $0 < x < 1$, then $\ln x < 0$.

EXPLORATION

Graphing the Natural Logarithmic Function Using only the definition of the natural logarithmic function, sketch a graph of the function. Explain your reasoning.



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JOHN NAPIER (1550–1617)

Logarithms were invented by the Scottish mathematician John Napier. Napier coined the term *logarithm*, from the two Greek words *logos* (or ratio) and *arithmos* (or number), to describe the theory that he spent 20 years developing and that first appeared in the book *Mirificae Logarithmorum canonis descriptio* (A Description of the Wonderful Rule of Logarithms). Although he did not introduce the natural logarithmic function, it is sometimes called the **Napierian logarithm**.

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