# 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.

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 *Mirifici Logarithmorum canonis descriptio* (A Description of the Marvellous Rule of Logarithms). Although he did not introduce the natural logarithmic function, it is sometimes called the Napierian logarithm.

## The Natural Logarithmic Function

Recall that the General Power Rule

$$\int x^n\,dx = \frac{x^{n+1}}{n+1} + C, \quad n \neq -1$$ 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 $\ln x > 0$.

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

**Figure 5.1**

**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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**Table of Contents Larson Edwards Calculus 9th Edition Answers**


1. Understanding the eBook Larson Edwards Calculus 9th Edition Answers
    - The Rise of Digital Reading Larson Edwards Calculus 9th Edition Answers
    - Advantages of eBooks Over Traditional Books
2. Identifying Larson Edwards Calculus 9th Edition Answers
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Larson Edwards Calculus 9th Edition Answers
    - User-Friendly Interface
4. Exploring eBook Recommendations from Larson Edwards Calculus 9th Edition Answers
    - Personalized Recommendations
    - Larson Edwards Calculus 9th Edition Answers User Reviews and Ratings
    - Larson Edwards Calculus 9th Edition Answers and Bestseller Lists
5. Accessing Larson Edwards Calculus 9th Edition Answers Free and Paid eBooks
    - Larson Edwards Calculus 9th Edition Answers Public Domain eBooks
    - Larson Edwards Calculus 9th Edition Answers eBook Subscription Services
    - Larson Edwards Calculus 9th Edition Answers Budget-Friendly Options

6. Navigating Larson Edwards Calculus 9th Edition Answers eBook Formats
    - ePub, PDF, MOBI, and More
    - Larson Edwards Calculus 9th Edition Answers Compatibility with Devices
    - Larson Edwards Calculus 9th Edition Answers Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Larson Edwards Calculus 9th Edition Answers
    - Highlighting and Note-Taking Larson Edwards Calculus 9th Edition Answers
    - Interactive Elements Larson Edwards Calculus 9th Edition Answers
8. Staying Engaged with Larson Edwards Calculus 9th Edition Answers
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Larson Edwards Calculus 9th Edition Answers
9. Balancing eBooks and Physical Books Larson Edwards Calculus 9th Edition Answers
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Larson Edwards Calculus 9th Edition Answers
10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
11. Cultivating a Reading Routine Larson Edwards Calculus 9th Edition Answers
    - Setting Reading Goals Larson Edwards Calculus 9th Edition Answers
    - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Larson Edwards Calculus 9th Edition Answers
    - Fact-Checking eBook Content of Larson Edwards Calculus 9th Edition Answers
    - Distinguishing Credible Sources
13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
14. Embracing eBook Trends
    - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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