6 APPLICATIONS OF THE INTEGRAL

6.1 Area Between Two Curves

Preliminary Questions

1. What is the area interpretation of $\int_a^b (f(x) - g(x))\,dx$ if $f(x) \geq g(x)$?

SOLUTION Because $f(x) \geq g(x)$, $\int_a^b (f(x) - g(x))\,dx$ represents the area of the region bounded between the graphs of $y = f(x)$ and $y = g(x)$, bounded on the left by the vertical line $x = a$ and on the right by the vertical line $x = b$.

2. Is $\int_a^b (f(x) - g(x))\,dx$ still equal to the area between the graphs of f and g if $f(x) \geq 0$ but $g(x) \leq 0$?

SOLUTION Yes. Since $f(x) \geq 0$ and $g(x) \leq 0$, it follows that $f(x) - g(x) \geq 0$.

3. Suppose that $f(x) \geq g(x)$ on $[0, 3]$ and $g(x) \geq f(x)$ on $[3, 5]$. Express the area between the graphs over $[0, 5]$ as a sum of integrals.

SOLUTION Remember that to calculate an area between two curves, one must subtract the equation for the lower curve from the equation for the upper curve. Over the interval $[0, 3]$, $y = f(x)$ is the upper curve. On the other hand, over the interval $[3, 5]$, $y = g(x)$ is the upper curve. The area between the graphs over the interval $[0, 5]$ is therefore given by

$$\int_0^3 (f(x) - g(x))\,dx + \int_3^5 (g(x) - f(x))\,dx.$$

4. Suppose that the graph of $x = f(y)$ lies to the left of the y-axis. Is $\int_a^b f(y)\,dy$ positive or negative?

SOLUTION If the graph of $x = f(y)$ lies to the left of the y-axis, then for each value of y, the corresponding value of x is less than zero. Hence, the value of $\int_a^b f(y)\,dy$ is negative.

Exercises

1. Find the area of the region between $y = 3x^2 + 12$ and $y = 4x + 4$ over $[-3, 3]$ (Figure 1).

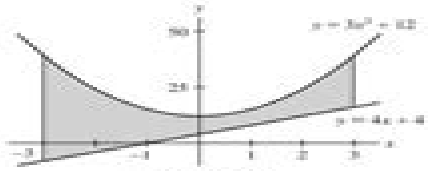

FIGURE 1

SOLUTION As the graph of $y = 3x^2 + 12$ lies above the graph of $y = 4x + 4$ over the interval $[-3, 3]$, the area between the graphs is

$$\int_{-3}^{3} \left((3x^2 + 12) - (4x + 4)\right) dx = \int_{-3}^{3} (3x^2 - 4x + 8)\,dx = \left(x^3 - 2x^2 + 8x\right)\Big|_{-3}^{3} = 102.$$

2. Find the area of the region between the graphs of $f(x) = 3x + 8$ and $g(x) = x^2 + 2x + 2$ over $[0, 2]$.

SOLUTION From the diagram below, we see that the graph of $f(x) = 3x + 8$ lies above the graph of $g(x) = x^2 + 2x + 2$ over the interval $[0, 2]$. Thus, the area between the graphs is

$$\int_0^2 \left[(3x + 8) - \left(x^2 + 2x + 2\right)\right] dx = \int_0^2 \left(-x^2 + x + 6\right) dx = \left(-\frac{1}{3}x^3 + \frac{1}{2}x^2 + 6x\right)\Big|_0^2 = \frac{34}{3}.$$

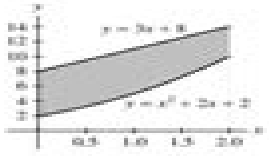

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Table of Contents Chapter 6 Solutions Rogawski

1. Understanding the eBook Chapter 6 Solutions Rogawski
    - The Rise of Digital Reading Chapter 6 Solutions Rogawski
    - Advantages of eBooks Over Traditional Books
2. Identifying Chapter 6 Solutions Rogawski
    - 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 Chapter 6 Solutions Rogawski
    - User-Friendly Interface
4. Exploring eBook Recommendations from Chapter 6 Solutions Rogawski
    - Personalized Recommendations
    - Chapter 6 Solutions Rogawski User Reviews and Ratings
    - Chapter 6 Solutions Rogawski and Bestseller Lists
5. Accessing Chapter 6 Solutions Rogawski Free and Paid eBooks
    - Chapter 6 Solutions Rogawski Public Domain eBooks
    - Chapter 6 Solutions Rogawski eBook Subscription Services
    - Chapter 6 Solutions Rogawski Budget-Friendly Options

6. Navigating Chapter 6 Solutions Rogawski eBook Formats
    - ePub, PDF, MOBI, and More
    - Chapter 6 Solutions Rogawski Compatibility with Devices
    - Chapter 6 Solutions Rogawski Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Chapter 6 Solutions Rogawski
    - Highlighting and Note-Taking Chapter 6 Solutions Rogawski
    - Interactive Elements Chapter 6 Solutions Rogawski
8. Staying Engaged with Chapter 6 Solutions Rogawski
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Chapter 6 Solutions Rogawski
9. Balancing eBooks and Physical Books Chapter 6 Solutions Rogawski
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Chapter 6 Solutions Rogawski
10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
11. Cultivating a Reading Routine Chapter 6 Solutions Rogawski
    - Setting Reading Goals Chapter 6 Solutions Rogawski
    - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Chapter 6 Solutions Rogawski
    - Fact-Checking eBook Content of Chapter 6 Solutions Rogawski
    - 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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