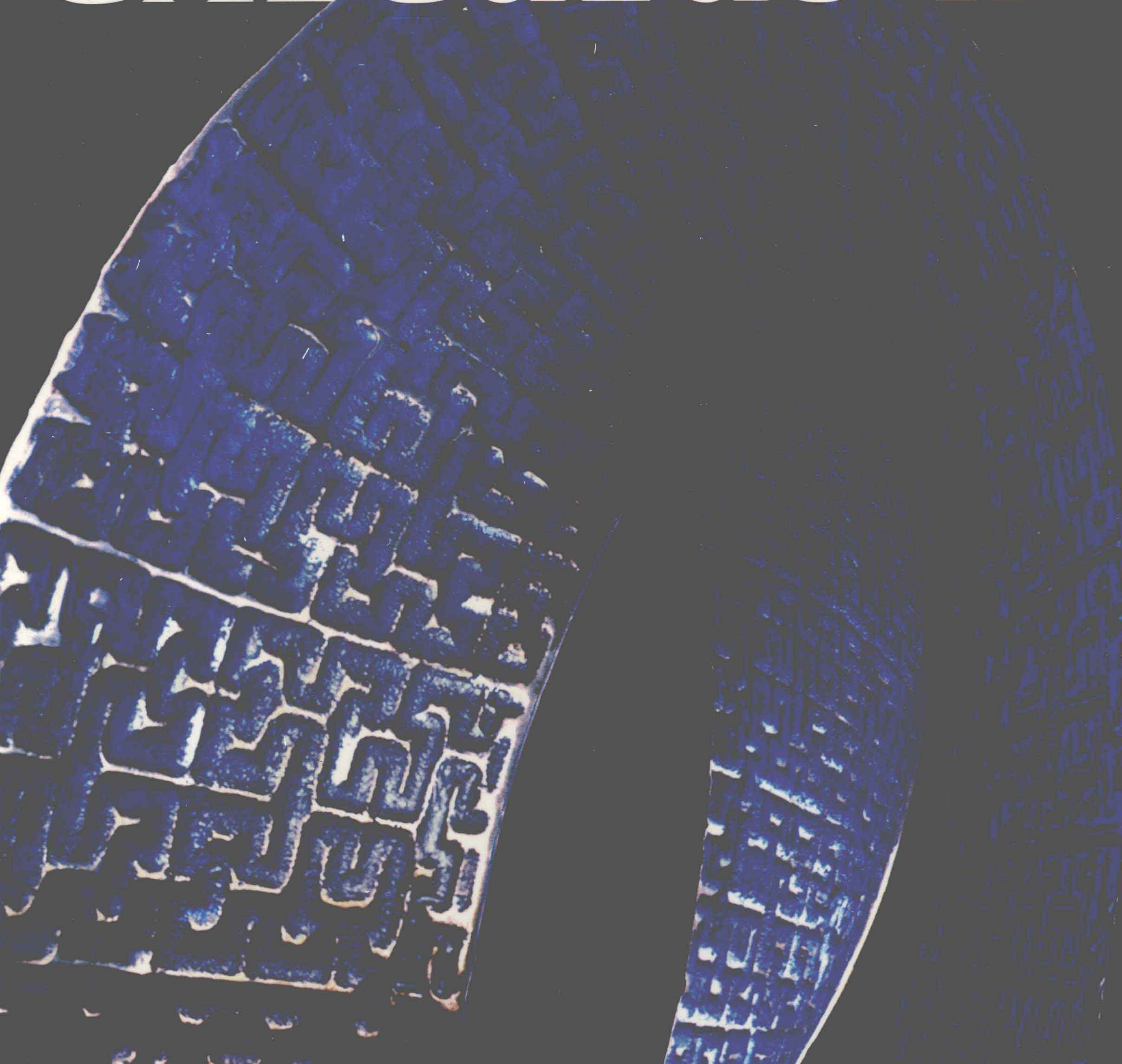
LARSON HOSTETLER EDWARDS

CALCULUS II



Calculus II

Seventh Edition

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We have included examples and exercises that use real-life data as well as technology output from a variety of software. This would not have been possible without the help of many people and organizations. Our wholehearted thanks goes to all for their time and effort.

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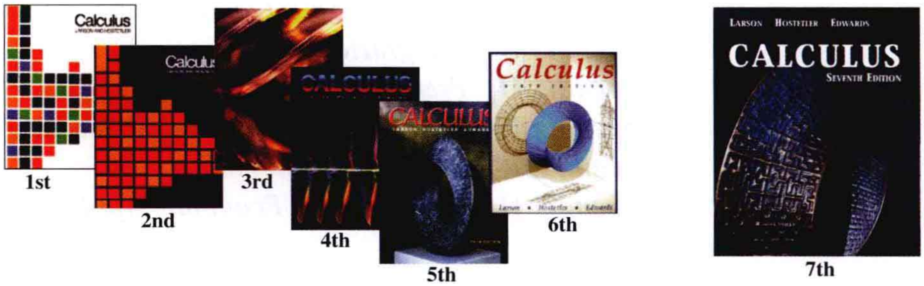
A Word from the Authors

Welcome to *Calculus II*, Seventh Edition. Much has changed since we wrote the first edition of *Calculus*—nearly 25 years ago. With each edition, we have listened to you, our users, and have tried to incorporate your suggestions for improvement.



A Text Formed by Its Users

Through your support and suggestions, the text has evolved over seven editions to include these extensive enhancements:

- Expanded exercise sets containing a greater variety of tasks such as skill building, applications, explorations, writing, critical thinking, and theoretical problems
- Additional applications more accurately represent the diverse uses of calculus in the world
- Many more open-ended activities and investigations
- Clearer, less cluttered text, full of annotations and labels—carefully planned page layout
- Additional art, composed with more color, accuracy, and realism
- A more comprehensive and more mathematically rigorous text, particularly the third semester of the Seventh Edition, which is quite different when compared with the First Edition
- Increased technology use, as both a problem-solving tool and an investigative tool
- References to the history of calculus and to the mathematicians who developed it
- Updated references to current mathematical journals
- Considerably more help in the supplements package for both students and instructors
- Alternatives to the traditional print medium, particularly in the CD-ROM version
- Five different volumes from which to choose your preferred teaching approach—a great development in flexibility from the single volume in the First Edition

What's New and Different in the Seventh Edition

In the Seventh Edition, we continue to offer instructors and students a text that is pedagogically sound, mathematically precise, and comprehensible. There are many minor changes in the mathematics, prose, art, and design. The more significant changes are noted here.

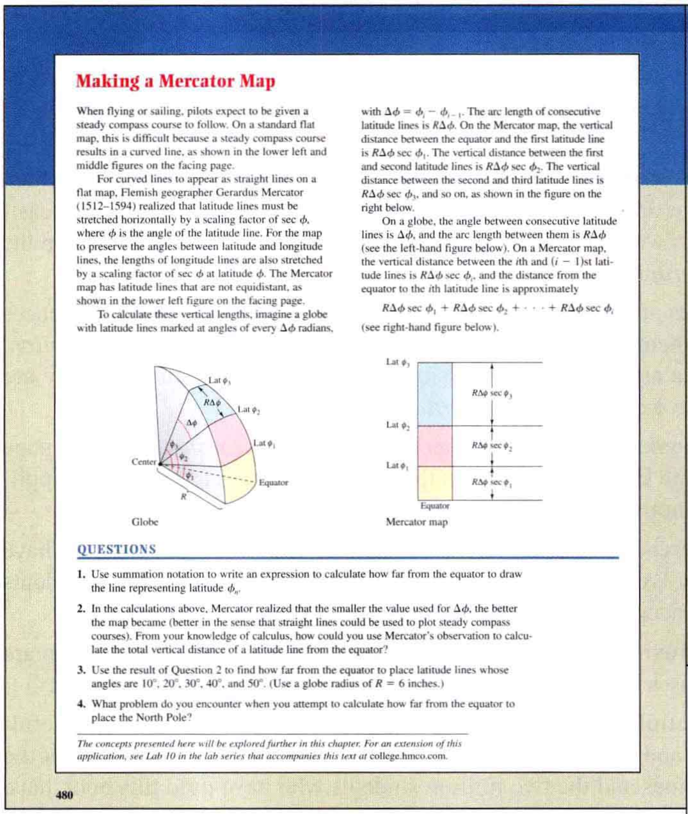
- ***New* P.S. Problem Solving** At the end of each chapter, we have included a two-page collection of new applied and theoretical exercises. These exercises offer problems that have some unusual characteristics that set them apart from exercises in a regular exercise set.
- ***New* Getting at the Concept** Midway through each section exercise set we have added a set of problems that check a student's understanding of the basic concepts presented in the section.
- ***New* Section Objectives** Each section in the Seventh Edition begins with a list of learning objectives. These enable students to identify and focus on the key points of the section.
- ***New* Downloadable Graphs** Many exercise sets contain problems in which students are asked to draw on the graph that is provided. Because this is not feasible in the actual text, we now provide printable enlargements of these graphs on the website *www.mathgraphs.com*.
- ***New* Journal Articles on the Web** The Seventh Edition contains over 60 references to articles from mathematics journals noted in the feature *For Further Information*. In order to make the articles easily accessible to instructors and students, they are now available on the website *www.matharticles.com*.
- ***Revised* Chapter Openers** The chapter openers have been redesigned as two-page spreads in the Seventh Edition. Included in the chapter openers is a real-world application designed to motivate the calculus topics of the chapter.
- ***Revised* Review Exercises** In order to provide a more effective study tool, we have grouped the Review Exercises by text section. This reorganization allows students to target specific concepts that may require additional study and review.
- **Exercise Sets** Approximately 20 percent of the exercises in the Seventh Edition are new. The new exercises include skill, concept, applied, and theoretical problems.

Although we carefully and thoroughly revised the text by enhancing the usefulness of some features and topics and by adding others, we did not change many of the things that our colleagues and the two million students who have used this book have told us work for them. We still offer comprehensive coverage of the material required by students in a three-semester or four-quarter calculus course, including carefully stated theories and proofs.

We hope you will enjoy the Seventh Edition. We are proud to have it as our first calculus book to be published in the twenty-first century.

PREFACE

Features



Making a Mercator Map

When flying or sailing, pilots expect to be given a steady compass course to follow. On a standard flat map, this is difficult because a steady compass course results in a curved line, as shown in the lower left and middle figures on the facing page.

For curved lines to appear as straight lines on a flat map, Flemish geographer Gerardus Mercator (1512–1594) realized that latitude lines must be stretched horizontally by a scaling factor of sec ϕ, where ϕ is the angle of the latitude line. For the map to preserve the angles between latitude and longitude lines, the lengths of longitude lines are also stretched by a scaling factor of sec ϕ at latitude ϕ. The Mercator map has latitude lines that are not equidistant, as shown in the lower left figure on the facing page.

To calculate these vertical lengths, imagine a globe with latitude lines marked at angles of every $\Delta\phi$ radians, with $\Delta\phi = \phi_i - \phi_{i-1}$. The arc length of consecutive latitude lines is $R\Delta\phi$. On the Mercator map, the vertical distance between the equator and the first latitude line is $R\Delta\phi \sec \phi_1$. The vertical distance between the first and second latitude lines is $R\Delta\phi \sec \phi_2$. The vertical distance between the second and third latitude lines is $R\Delta\phi \sec \phi_3$, and so on, as shown in the figure on the right below.

On a globe, the angle between consecutive latitude lines is $\Delta\phi$, and the arc length between them is $R\Delta\phi$ (see the left-hand figure below). On a Mercator map, the vertical distance between the ith and $(i - 1)$st latitude lines is $R\Delta\phi \sec \phi_i$, and the distance from the equator to the ith latitude line is approximately

$$R\Delta\phi \sec \phi_1 + R\Delta\phi \sec \phi_2 + \cdots + R\Delta\phi \sec \phi_i$$

(see right-hand figure below).

Globe

Mercator map

QUESTIONS

1. Use summation notation to write an expression to calculate how far from the equator to draw the line representing latitude ϕ_n.
2. In the calculations above, Mercator realized that the smaller the value used for $\Delta\phi$, the better the map became (better in the sense that straight lines could be used to plot steady compass courses). From your knowledge of calculus, how could you use Mercator's observation to calculate the total vertical distance of a latitude line from the equator?
3. Use the result of Question 2 to find how far from the equator to place latitude lines whose angles are 10°, 20°, 30°, 40°, and 50°. (Use a globe radius of $R = 6$ inches.)
4. What problem do you encounter when you attempt to calculate how far from the equator to place the North Pole?

The concepts presented here will be explored further in this chapter. For an extension of this application, see Lab 10 in the lab series that accompanies this text at college.hmco.com.

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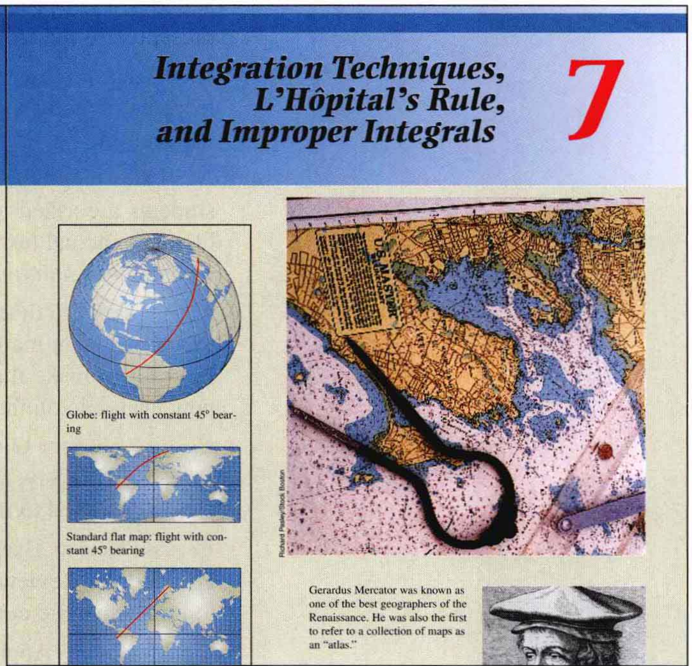
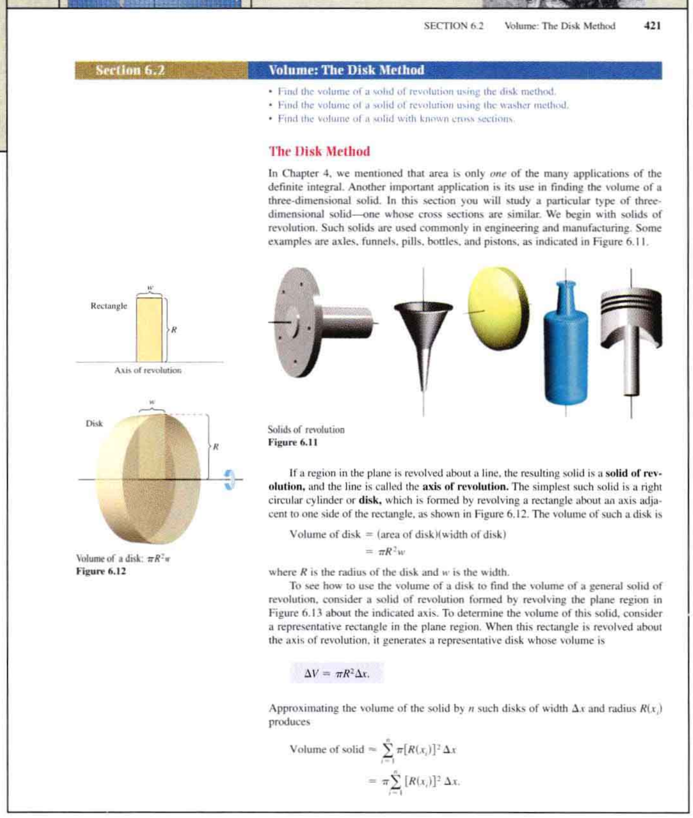


Integration Techniques, L'Hôpital's Rule, and Improper Integrals 7

Globe: flight with constant 45° bearing

Standard flat map: flight with constant 45° bearing

Gerardus Mercator was known as one of the best geographers of the Renaissance. He was also the first to refer to a collection of maps as an "atlas."



SECTION 6.2 Volume: The Disk Method 421

Section 6.2 Volume: The Disk Method

- Find the volume of a solid of revolution using the disk method.
- Find the volume of a solid of revolution using the washer method.
- Find the volume of a solid with known cross sections.

The Disk Method

In Chapter 4, we mentioned that area is only *one* of the many applications of the definite integral. Another important application is its use in finding the volume of a three-dimensional solid. In this section you will study a particular type of three-dimensional solid—one whose cross sections are similar. We begin with solids of revolution. Such solids are used commonly in engineering and manufacturing. Some examples are axles, funnels, pills, bottles, and pistons, as indicated in Figure 6.11.

Solids of revolution
Figure 6.11

Volume of a disk: $\pi R^2 w$
Figure 6.12

If a region in the plane is revolved about a line, the resulting solid is a **solid of revolution,** and the line is called the **axis of revolution.** The simplest such solid is a right circular cylinder or **disk,** which is formed by revolving a rectangle about an axis adjacent to one side of the rectangle, as shown in Figure 6.12. The volume of such a disk is

$$\text{Volume of disk} = (\text{area of disk})(\text{width of disk}) = \pi R^2 w$$

where R is the radius of the disk and w is the width.

To see how to use the volume of a disk to find the volume of a general solid of revolution, consider a solid of revolution formed by revolving the plane region in Figure 6.13 about the indicated axis. To determine the volume of this solid, consider a representative rectangle in the plane region. When this rectangle is revolved about the axis of revolution, it generates a representative disk whose volume is

$$\Delta V = \pi R^2 \Delta x.$$

Approximating the volume of the solid by n such disks of width Δx and radius $R(x_i)$ produces

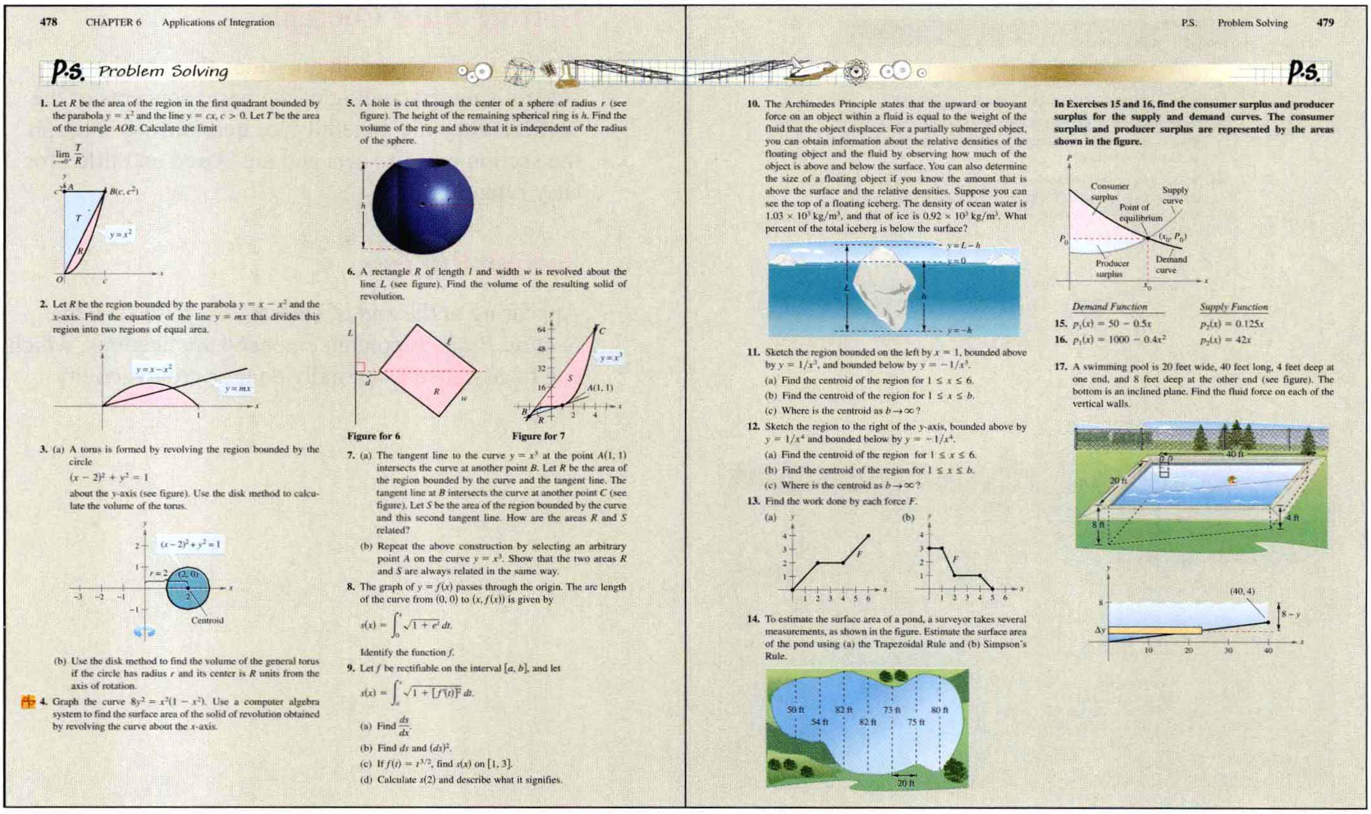
$$\text{Volume of solid} \approx \sum_{i=1}^{n} \pi[R(x_i)]^2 \Delta x = \pi \sum_{i=1}^{n} [R(x_i)]^2 \Delta x.$$

Chapter Openers

Each chapter opens with a real-world application designed to motivate the calculus concepts covered in the chapter. Following a brief introduction, open-ended questions guide students through an introduction to the main themes of the chapter. In addition, photographs and interesting facts related to the application are included in the chapter opener.

Section Objectives

Every section begins with a list of learning objectives that outline the key concepts of the section. This list helps instructors with class planning and provides students a study guide for the section.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P.S. Problem Solving

1. Let R be the area of the region in the first quadrant bounded by the parabola $y = x^2$ and the line $y = cx$, $c > 0$. Let T be the area of the triangle AOB. Calculate the limit

$$\lim_{c\to 0^+} \frac{T}{R}$$

2. Let R be the region bounded by the parabola $y = x - x^2$ and the x-axis. Find the equation of the line $y = mx$ that divides this region into two regions of equal area.

3. (a) A torus is formed by revolving the region bounded by the circle

$$(x-2)^2 + y^2 = 1$$

about the y-axis (see figure). Use the disk method to calculate the volume of the torus.

(b) Use the disk method to find the volume of the general torus if the circle has radius r and its center is R units from the axis of rotation.

4. Graph the curve $8y^2 = x^2(1 - x^2)$. Use a computer algebra system to find the surface area of the solid of revolution obtained by revolving the curve about the x-axis.

5. A hole is cut through the center of a sphere of radius r (see figure). The height of the remaining spherical ring is h. Find the volume of the ring and show that it is independent of the radius of the sphere.

6. A rectangle R of length l and width w is revolved about the line L (see figure). Find the volume of the resulting solid of revolution.

Figure for 6 Figure for 7

7. (a) The tangent line to the curve $y = x^3$ at the point $A(1, 1)$ intersects the curve at another point B. Let R be the area of the region bounded by the curve and the tangent line. The tangent line at B intersects the curve at another point C (see figure). Let S be the area of the region bounded by the curve and this second tangent line. How are the areas R and S related?

(b) Repeat the above construction by selecting an arbitrary point A on the curve $y = x^3$. Show that the two areas R and S are always related in the same way.

8. The graph of $y = f(x)$ passes through the origin. The arc length of the curve from $(0, 0)$ to $(x, f(x))$ is given by

$$s(x) = \int_0^x \sqrt{1 + e^t}\, dt.$$

Identify the function f.

9. Let f be rectifiable on the interval $[a, b]$, and let

$$s(x) = \int_a^x \sqrt{1 + [f'(t)]^2}\, dt.$$

(a) Find $\frac{ds}{dx}$.

(b) Find ds and $(ds)^2$.

(c) If $f(t) = t^{3/2}$, find $s(x)$ on $[1, 3]$.

(d) Calculate $s(2)$ and describe what it signifies.

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10. The Archimedes Principle states that the upward or buoyant force on an object within a fluid is equal to the weight of the fluid that the object displaces. For a partially submerged object, you can obtain information about the relative densities of the floating object and the fluid by observing how much of the object is above and below the surface. You can also determine the size of a floating object if you know the amount that is above the surface and the relative densities. Suppose you can see the top of a floating iceberg. The density of ocean water is 1.03×10^3 kg/m^3, and that of ice is 0.92×10^3 kg/m^3. What percent of the total iceberg is below the surface?

11. Sketch the region bounded on the left by $x = 1$, bounded above by $y = 1/x^3$, and bounded below by $y = -1/x^3$.

(a) Find the centroid of the region for $1 \le x \le 6$.

(b) Find the centroid of the region for $1 \le x \le b$.

(c) Where is the centroid as $b \to \infty$?

12. Sketch the region to the right of the y-axis, bounded above by $y = 1/x^4$ and bounded below by $y = -1/x^4$.

(a) Find the centroid of the region for $1 \le x \le 6$.

(b) Find the centroid of the region for $1 \le x \le b$.

(c) Where is the centroid as $b \to \infty$?

13. Find the work done by each force F.

14. To estimate the surface area of a pond, a surveyor takes several measurements, as shown in the figure. Estimate the surface area of the pond using (a) the Trapezoidal Rule and (b) Simpson's Rule.

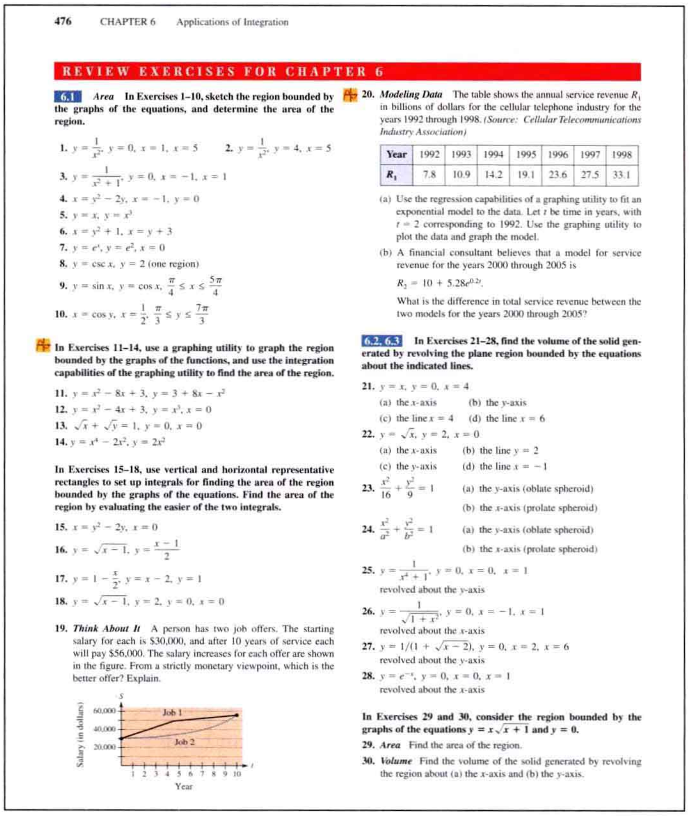
In Exercises 15 and 16, find the consumer surplus and producer surplus for the supply and demand curves. The consumer surplus and producer surplus are represented by the areas shown in the figure.

Demand Function	Supply Function
15. $p_1(x) = 50 - 0.5x$	$p_2(x) = 0.125x$
16. $p_1(x) = 1000 - 0.4x^2$	$p_2(x) = 42x$

17. A swimming pool is 20 feet wide, 40 feet long, 4 feet deep at one end, and 8 feet deep at the other end (see figure). The bottom is an inclined plane. Find the fluid force on each of the vertical walls.

New! P.S. Problem Solving

Each chapter concludes with a collection of thought-provoking and challenging exercises that further explore and expand upon the concepts of the chapter. These exercises have unusual characteristics that set them apart from traditional calculus exercises.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REVIEW EXERCISES FOR CHAPTER 6

6.1 *Area* In Exercises 1–10, sketch the region bounded by the graphs of the equations, and determine the area of the region.

1. $y = \frac{1}{x^2}, y = 0, x = 1, x = 5$
2. $y = \frac{1}{x^2}, y = 4, x = 5$
3. $y = \frac{1}{x^2 + 1}, y = 0, x = -1, x = 1$
4. $x = y^2 - 2y, x = -1, y = 0$
5. $y = x, y = x^3$
6. $x = y^2 + 1, x = y + 3$
7. $y = e^x, y = e^2, x = 0$
8. $y = \csc x, y = 2$ (one region)
9. $y = \sin x, y = \cos x, \frac{\pi}{4} \le x \le \frac{5\pi}{4}$
10. $x = \cos y, x = \frac{1}{2}, \frac{\pi}{3} \le y \le \frac{7\pi}{3}$

In Exercises 11–14, use a graphing utility to graph the region bounded by the graphs of the functions, and use the integration capabilities of the graphing utility to find the area of the region.

11. $y = x^2 - 8x + 3, y = 3 + 8x - x^2$
12. $y = x^2 - 4x + 3, y = x^3, x = 0$
13. $\sqrt{x} + \sqrt{y} = 1, y = 0, x = 0$
14. $y = x^4 - 2x^2, y = 2x^2$

In Exercises 15–18, use vertical and horizontal representative rectangles to set up integrals for finding the area of the region bounded by the graphs of the equations. Find the area of the region by evaluating the easier of the two integrals.

15. $x = y^2 - 2y, x = 0$
16. $y = \sqrt{x - 1}, y = \frac{x-1}{2}$
17. $y = 1 - \frac{x}{2}, y = x - 2, y = 1$
18. $y = \sqrt{x - 1}, y = 2, y = 0, x = 0$

19. *Think About It* A person has two job offers. The starting salary for each is \$30,000, and after 10 years of service each will pay \$56,000. The salary increases for each offer are shown in the figure. From a strictly monetary viewpoint, which is the better offer? Explain.

20. *Modeling Data* The table shows the annual service revenue R_1 in billions of dollars for the cellular telephone industry for the years 1992 through 1998. (*Source: Cellular Telecommunications Industry Association*)

Year	1992	1993	1994	1995	1996	1997	1998
R_1	7.8	10.9	14.2	19.1	23.6	27.5	33.1

(a) Use the regression capabilities of a graphing utility to fit an exponential model to the data. Let t be time in years, with $t = 2$ corresponding to 1992. Use the graphing utility to plot the data and graph the model.

(b) A financial consultant believes that a model for service revenue for the years 2000 through 2005 is

$$R_2 = 10 + 5.28e^{0.2t}.$$

What is the difference in total service revenue between the two models for the years 2000 through 2005?

6.2, 6.3 In Exercises 21–28, find the volume of the solid generated by revolving the plane region bounded by the equations about the indicated lines.

21. $y = x, y = 0, x = 4$
(a) the x-axis (b) the y-axis
(c) the line $x = 4$ (d) the line $x = 6$

22. $y = \sqrt{x}, y = 2, x = 0$
(a) the x-axis (b) the line $y = 2$
(c) the y-axis (d) the line $x = -1$

23. $\frac{x^2}{16} + \frac{y^2}{9} = 1$ (a) the y-axis (oblate spheroid)
(b) the x-axis (prolate spheroid)

24. $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ (a) the y-axis (oblate spheroid)
(b) the x-axis (prolate spheroid)

25. $y = \frac{1}{x^4 + 1}, y = 0, x = 0, x = 1$
revolved about the y-axis

26. $y = \frac{1}{\sqrt{1 + x^2}}, y = 0, x = -1, x = 1$
revolved about the x-axis

27. $y = 1/(1 + \sqrt{x - 2}), y = 0, x = 2, x = 6$
revolved about the y-axis

28. $y = e^{-x}, y = 0, x = 0, x = 1$
revolved about the x-axis

In Exercises 29 and 30, consider the region bounded by the graphs of the equations $y = x\sqrt{x + 1}$ and $y = 0$.

29. *Area* Find the area of the region.

30. *Volume* Find the volume of the solid generated by revolving the region about (a) the x-axis and (b) the y-axis.

Review Exercises

A set of *Review Exercises* is included at the end of each chapter. In order to provide students with a more useful study tool, these exercises are grouped by section. This organization allows students to identify specific problem types related to chapter concepts for study and review.

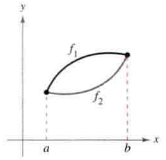
Getting at the Concept

41. Define a rectifiable curve.

42. What precalculus formula and representative element are used to develop the integration formula for arc length?

43. What precalculus formula and representative element are used to develop the integration formula for the area of a surface of revolution?

44. The graphs of the functions f_1 and f_2 on the interval $[a, b]$ are shown in the figure. The graph of each is revolved about the x-axis. Which surface of revolution has the greater surface area? Explain.



SECTION PROJECT **DISTANCES IN SPACE**

We have developed two distance formulas in this section—the distance between a point and a plane, and the distance between a point and a line. In this project you will study a third distance problem—the distance between two skew lines. Two lines in space are *skew* if they are neither parallel nor intersecting (see figure).

(a) Consider the following two lines in space.

$L_1: x = 4 + 5t,\ y = 5 + 5t,\ z = 1 - 4t$

$L_2: x = 4 + s,\ y = -6 + 8s,\ z = 7 - 3s$

(i) Show that these lines are not parallel.

(ii) Show that these lines do not intersect, and hence are skew lines.

(iii) Show that the two lines lie in parallel planes.

(iv) Find the distance between the parallel planes from part (iii). This is the distance between the original skew lines.

(b) Use the procedure in part (a) to find the distance between the lines.

$L_1: x = 2t,\ y = 4t,\ z = 6t$

$L_2: x = 1 - s,\ y = 4 + s,\ z = -1 + s$

(c) Use the procedure in part (a) to find the distance between the lines.

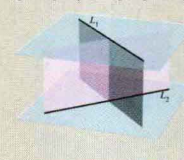
$L_1: x = 3t,\ y = 2 - t,\ z = -1 + t$

$L_2: x = 1 + 4s,\ y = -2 + s,\ z = -3 - 3s$

(d) Develop a formula for finding the distance between the skew lines.

$L_1: x = x_1 + a_1t,\ y = y_1 + b_1t,\ z = z_1 + c_1t$

$L_2: x = x_2 + a_2s,\ y = y_2 + b_2s,\ z = z_2 + c_2s$



Getting at the Concept

These exercises contain questions that check a student's understanding of the basic concepts of the section. They are generally located midway through the section exercise sets and are boxed and titled for easy reference.

Section Projects

Appearing at the end of selected exercise sets, the *Section Projects* contain extended applications, which can be assigned as an individual or group activity.

SECTION 6.1 Area of a Region Between Two Curves 415

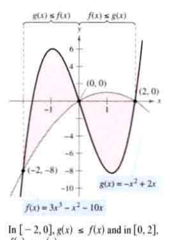
If two curves intersect at *more* than two points, then to find the area of the region between the curves, you must find all points of intersection and check to see which curve is above the other in each interval determined by these points.

Example 4 **Curves That Intersect at More Than Two Points**

Find the area of the region between the graphs of $f(x) = 3x^3 - x^2 - 10x$ and $g(x) = -x^2 + 2x$.

Solution Begin by setting $f(x)$ and $g(x)$ equal to each other and solving for x. This yields the x-values at each point of intersection of the two graphs.

$$3x^3 - x^2 - 10x = -x^2 + 2x \qquad \text{Set } f(x) \text{ equal to } g(x).$$
$$3x^3 - 12x = 0 \qquad \text{Write in general form.}$$
$$3x(x^2 - 4) = 0 \qquad \text{Factor.}$$
$$x = -2, 0, 2 \qquad \text{Solve for } x.$$



In $[-2, 0]$, $g(x) \le f(x)$, and in $[0, 2]$, $f(x) \le g(x)$.
Figure 6.8

So, the two graphs intersect when $x = -2, 0,$ and 2. In Figure 6.8, notice that $g(x) \le f(x)$ on the interval $[-2, 0]$. However, the two graphs switch at the origin, and $f(x) \le g(x)$ on the interval $[0, 2]$. Hence, you need two integrals—one for the interval $[-2, 0]$ and one for the interval $[0, 2]$.

$$\begin{aligned} A &= \int_{-2}^{0} [f(x) - g(x)]\,dx + \int_{0}^{2} [g(x) - f(x)]\,dx \\ &= \int_{-2}^{0} (3x^3 - 12x)\,dx + \int_{0}^{2} (-3x^3 + 12x)\,dx \\ &= \left[\frac{3x^4}{4} - 6x^2\right]_{-2}^{0} + \left[\frac{-3x^4}{4} + 6x^2\right]_{0}^{2} \\ &= -(12 - 24) + (-12 + 24) \\ &= 24 \end{aligned}$$

NOTE In Example 4, notice that you get an incorrect result if you integrate from -2 to 2. Such integration produces

$$\int_{-2}^{2} [f(x) - g(x)]\,dx = \int_{-2}^{2} (3x^3 - 12x)\,dx = 0.$$

If the graph of a function of y is a boundary of a region, it is often convenient to use representative rectangles that are *horizontal* and find the area by integrating with respect to y. In general, to determine the area between two curves, you can use

$$A = \int_{x_1}^{x_2} \underbrace{[(\text{top curve}) - (\text{bottom curve})]}_{\text{in variable } x}\,dx \qquad \text{Vertical rectangles}$$

$$A = \int_{y_1}^{y_2} \underbrace{[(\text{right curve}) - (\text{left curve})]}_{\text{in variable } y}\,dy \qquad \text{Horizontal rectangles}$$

where (x_1, y_1) and (x_2, y_2) are either adjacent points of intersection of the two curves involved or points on the specified boundary lines.

The symbol [iC icon] *indicates that in the* Interactive *CD-ROM version of this text (available at* college.hmco.com) *you will find an Open Exploration, which further explores this example using the computer algebra systems* Maple, Mathcad, Mathematica, *and* Derive.

Open Explorations

The *Interactive* CD-ROM version of this text contains open explorations, which further investigate selected examples throughout the text using computer algebra systems (*Maple*, *Mathematica*, *Derive*, and *Mathcad*). The icon [iC icon] identifies an example for which an open exploration exists.

Additional Features

Additional teaching and learning resources can be found throughout the text. These resources include explorations, technology notes, historical vignettes, study tips, journal references, lab series, and notes. For a complete description of these resources, go to the text-specific website at *college.hmco.com*.

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If you have suggestions for improving this text, please feel free to write to us. Over the past 25 years we have received many useful comments from both instructors and students, and we value these very much.

Ron Larson
Robert P. Hostetler
Bruce H. Edwards

Supplements

Resources

Website (*college.hmco.com*)

Many additional text-specific study and interactive features for students and instructors can be found at the Houghton Mifflin website.

For the Student

Study and Solutions Guide, Volumes I and II by Bruce H. Edwards (University of Florida)

Graphing Technology Guide for Precalculus and Calculus by Benjamin N. Levy and Laurel Technical Services

*Graphing Calculator Videotap*e by Dana Mosely

Calculus, 7E, *Videotapes* by Dana Mosely

For the Instructor

Complete Solutions Guide, Volumes I and II by Bruce H. Edwards (University of Florida)

Test Item File by Ann Rutledge Kraus (The Pennsylvania State University, The Behrend College)

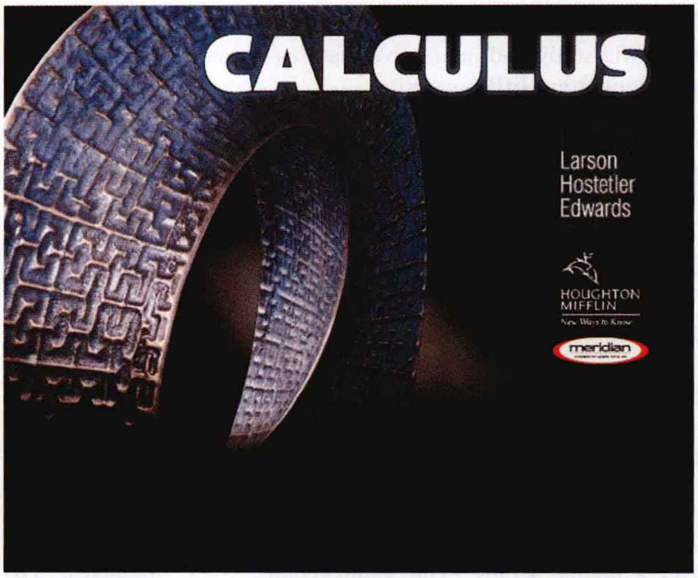
Instructor's Resource Guide by Ann Rutledge Kraus (The Pennsylvania State University, The Behrend College)

Computerized Testing (WIN, Macintosh)

HMClassPrep™ (Instructor's CD-ROM)

Interactive Calculus 3.0

To accommodate a wide variety of teaching and learning styles, *Calculus* is also available as *Interactive Calculus 3.0* on an interactive CD-ROM. This version incorporates live mathematics throughout the entire program. Live mathematics helps students visualize and explore—leading to a deeper understanding of calculus concepts than has ever before been possible.

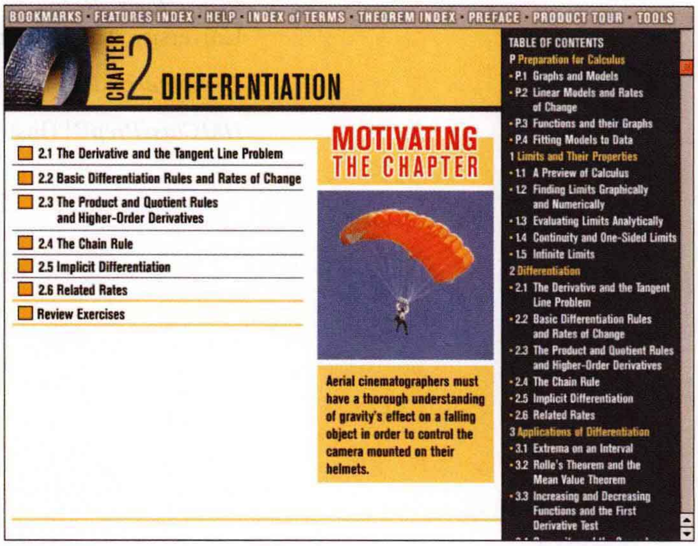


Live Mathematics Throughout

- Open Explorations give students the opportunity to explore using computer algebra systems.
- Section Quizzes require students to enter free-response answers and to click-and-drag answers into place.
- Editable two-dimensional graphs, featured throughout the entire program, provide additional opportunities to explore and investigate.
- Rotatable three-dimensional graphs allow for a whole new level of visualization.
- New and enhanced explorations, simulations, and animations make concepts come alive.

Classroom Management Tool and Syllabus Builder

All of the content of the Seventh Edition text—a wealth of applications, exercises, worked-out examples, and detailed explanations—is included in *Interactive Calculus 3.0*. Instructors have the flexibility of customizing content and interactive features for students as desired. Instructors may simply add dates to a default syllabus or may modify the order of topics. Either way, a customized syllabus is easy to distribute electronically and update instantly. This tool is particularly useful for managing distance learning courses.



Features

Exercises with solutions to all odd exercises provide immediate feedback for students.

Try Its allow students to try problems similar to the examples and to check their work using the worked-out solutions provided.

Quizzes with responses require students to enter free responses, click-and-drag answers, and choose multiple choice answers.

Editable Graphs encourage students to explore concepts by graphing "editable" graphs as well as to change the viewing window and to use *zoom* and *trace* features.

Rotatable Graphs allow students to view three-dimensional graphs as they rotate, greatly enhancing visualization.

Simulations encourage exploration and hands-on interaction with mathematical concepts.

Animations, which use motion and sound to explain concepts, can be played and replayed, or viewed one step at a time.

Complete searchable text-specific **Content, Index, Theorem Index,** and **Features Index** facilitate cross-referencing.

Video Clips engage student interest and show connections between mathematics and other disciplines.

Syllabus Builder enables instructors to save administrative time and to convey important information online.

Bookmarking capability provides fast, efficient navigation of the site.

Other special features include:

Articles • Calculus Capsules • Connections • History • Look Ahead • Math Trends • Projects • Technology Pitfalls

Contents

Appendices A1

Constructing an Arch Dam

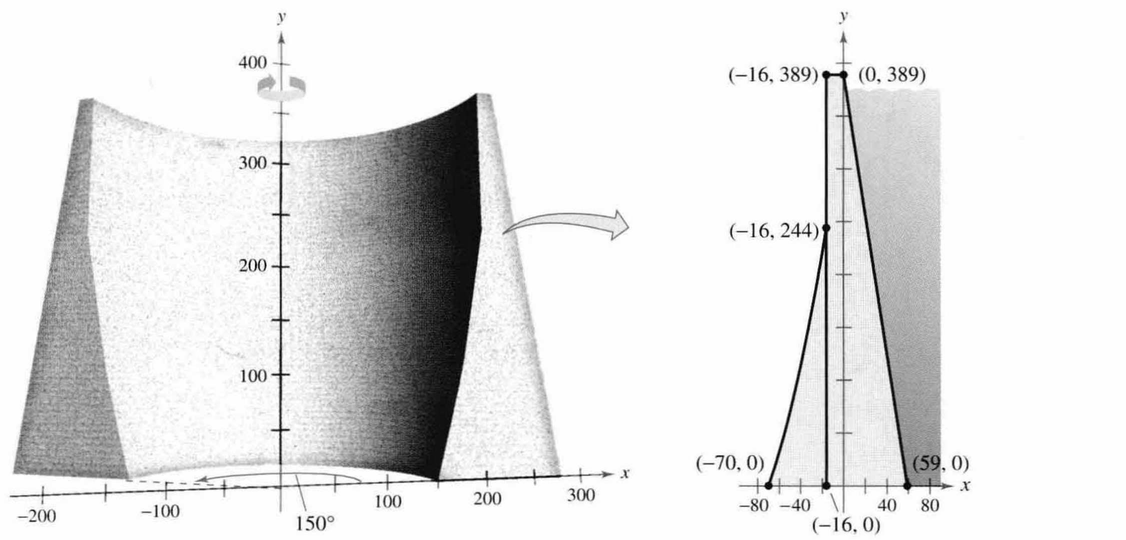
Dams were originally built to ensure water supplies during dry seasons. As technical knowledge has increased, they have begun serving other functions. Today, dams may be built to create recreational lakes, to power generators, and to prevent flooding. Every new dam creates concerns. A dam may upset an area's ecology and force the relocation of people and wildlife. Also, a poorly constructed dam endangers the entire surrounding region, creating the possibility of a massive disaster.

There are several designs used in dam construction, one of which is the arch dam. This design curves toward the water it contains, and is usually built in narrow canyons. The force of the water presses the edges of the dam against the walls of the canyon, so that the natural rock helps support the structure. This added support means that the arch dam can be built with less construction materials than its gravity-supported counterpart.

A cross section of a typical arch dam can be modeled as shown in the figure below. The model for this cross section is as follows.

$$f(x) = \begin{cases} 0.03x^2 + 7.1x + 350, & -70 \le x \le -16 \\ 389, & -16 < x < 0 \\ -6.593x + 389, & 0 \le x \le 59 \end{cases}$$

To form the arch dam, this cross section is swung through an arc, rotating it about the y-axis. The number of degrees through which it is rotated and the length of the axis of rotation vary, depending primarily on how much the water level varies. A possible configuration shows a rotation of 150° and an axis of rotation of 150 feet.



QUESTIONS

1. Find the area of a cross section of the dam.
2. Describe a strategy for estimating the volume of concrete that would be needed to build this dam.
3. Use the strategy to estimate the volume of concrete needed to build the dam described on this page.

The concepts presented here will be explored further in this chapter. For an extension of this application, see Lab 9 of the lab series that accompanies this text at college.hmco.com.