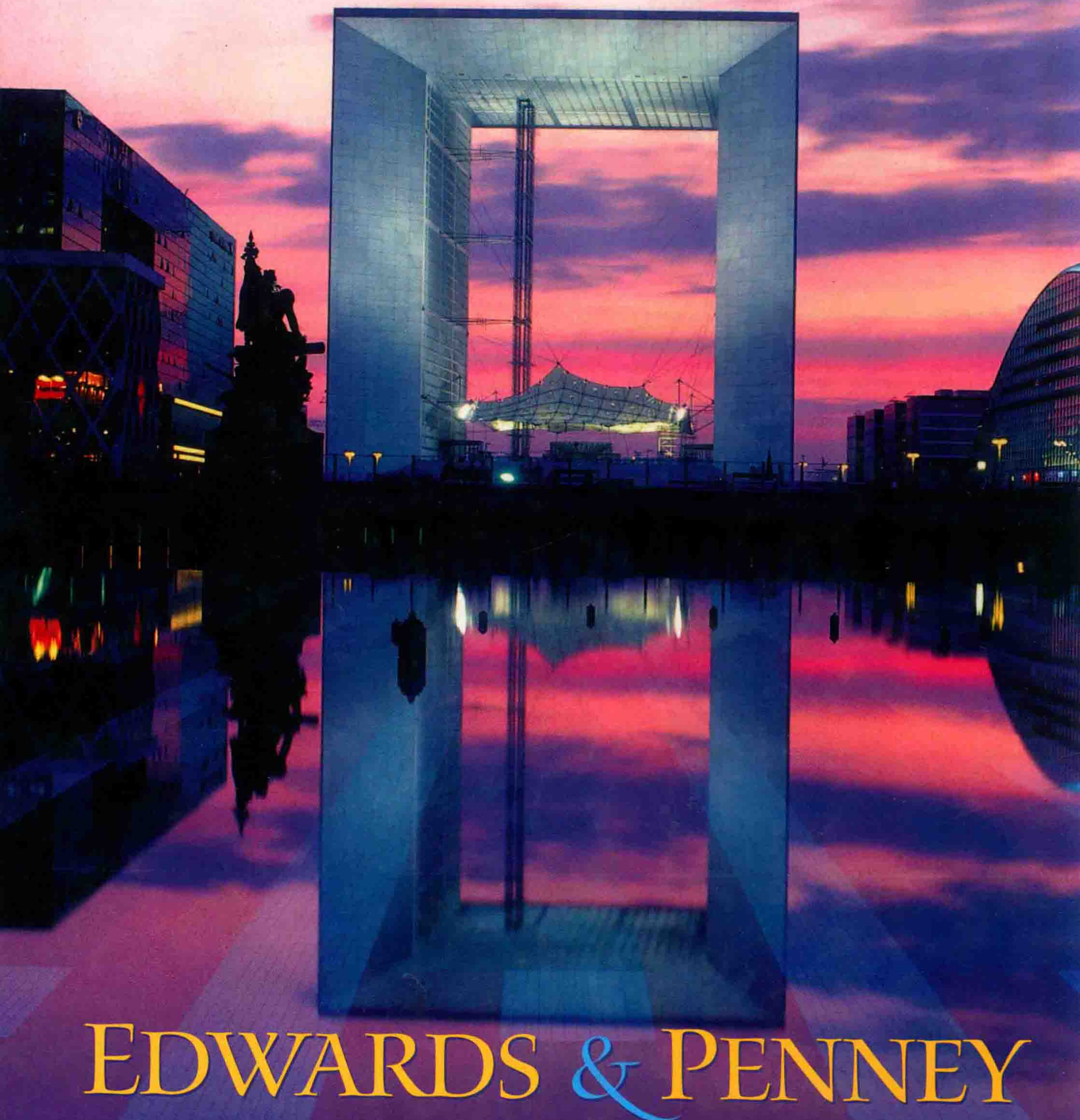
CALCULUS 6e

Early Transcendentals
Matrix Version



EDWARDS & PENNEY

INSTRUCTOR'S EDITION

Selected answers omitted from text; Contact your Prentice Hall Sales Rep for full Solutions Manual

CALCULUS

Sixth Edition

Early Transcendentals
Matrix Version
Instructor's Edition

C. HENRY EDWARDS
The University of Georgia, Athens

DAVID E. PENNEY
The University of Georgia, Athens

Prentice Hall

Prentice Hall, Upper Saddle River, New Jersey 07458

Editor in Chief: Sally Yagan
Vice President/Director of Production and Manufacturing: David W. Riccardi
Executive Managing Editor: Kathleen Schiaparelli
Senior Managing Editor: Linda Mihatov Behrens
Production Editor: Barbara Mack
Assistant Managing Editor, Math Media Production: John Matthews
Media Production Editors: Donna Crilly, Wendy Perez
Manufacturing Buyer: Alan Fischer
Manufacturing Manager: Trudy Pisciotti
Marketing Manager: Angela Battle
Marketing Assistant: Rachel Beckman
Development Editor: Ed Millman
Editor in Chief, Development: Carol Trueheart
Acquisition Editor: George Lobell
Assistant Editor of Media: Vince Jansen
Editorial Assistant/Supplements Editor: Melanie Van Benthuysen
Art Director: Jonathan Boylan
Assistant to the Art Director: John Christiana
Interior Designer: Donna Young
Cover Designer: Bruce Kenselaar
Art Editor: Thomas Benfatti
Managing Editor, Audio/Video Assets: Grace Hazeldine
Creative Director: Carole Anson
Director of Creative Services: Paul Belfanti
Photo Researcher: Karen Pugliano
Photo Editor: Beth Boyd
Cover Photo: Antonio Martinelli/Arche De La Defense, Sunset View–Paris, Arch. J. O. Spreckelsen-P. Andreu
Art Studio: Network Graphics

Prentice Hall

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

ISBN 0-13-093711-8
Student Edition ISBN 0-13-093700-2

Pearson Education LTD., *London*
Pearson Education Australia PTY, Limited, *Sydney*
Pearson Education Singapore, Pte. Ltd
Pearson Education North Asia Ltd, *Hong Kong*
Pearson Education Canada, Ltd., *Toronto*
Pearson Educacion de Mexico, S.A. de C.V.
Pearson Education–Japan, *Tokyo*
Pearson Education Malaysia, Pte. Ltd

ALGEBRA

Quadratic Formula

The solutions of the quadratic equation $ax^2 + bx + c = 0$ are given by

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

Factorial notation

For each positive integer n,

$$n! = n(n-1)(n-2) \cdots 3 \cdot 2 \cdot 1;$$

by definition, $0! = 1$.

Radicals

$$\sqrt[n]{x^m} = \left(\sqrt[n]{x}\right)^m = x^{m/n}$$

Exponents

$(ab)^r = a^r b^r \qquad a^r a^s = a^{r+s} \qquad x^{-n} = \dfrac{1}{x^n}$

$(a^r)^s = a^{rs} \qquad \dfrac{a^r}{a^s} = a^{r-s}$

Binomial Formula

$$(x+y)^2 = x^2 + 2xy + y^2$$
$$(x+y)^3 = x^3 + 3x^2y + 3xy^2 + y^3$$
$$(x+y)^4 = x^4 + 4x^3y + 6x^2y^2 + 4xy^3 + y^4$$

In general, $(x+y)^n = x^n + \binom{n}{1}x^{n-1}y + \binom{n}{2}x^{n-2}y^2 + \cdots + \binom{n}{k}x^{n-k}y^k + \cdots + \binom{n}{n-1}xy^{n-1} + y^n,$

where the binomial coefficient $\binom{n}{m}$ is the integer $\dfrac{n!}{m!(n-m)!}$.

Factoring

If n is a positive integer, then

$$x^n - y^n = (x-y)(x^{n-1} + x^{n-2}y + x^{n-3}y^2 + \cdots + x^{n-k-1}y^k + \cdots + xy^{n-2} + y^{n-1}).$$

If n is an *odd* positive integer, then

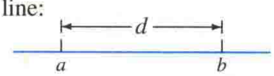
$$x^n + y^n = (x+y)(x^{n-1} - x^{n-2}y + x^{n-3}y^2 - \cdots \pm x^{n-k-1}y^k \mp \cdots - xy^{n-2} + y^{n-1}).$$

GEOMETRY

Distance Formulas

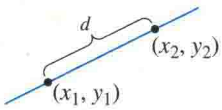
Distance on the real number line:

$d = |a - b|$



Distance in the coordinate plane:

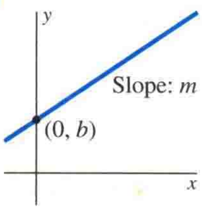
$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$



Equations of Lines and Circles

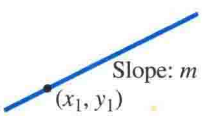
Slope-intercept equation:

$y = mx + b$



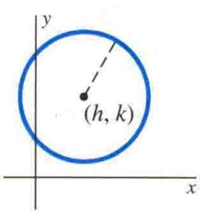
Point-slope equation:

$y - y_1 = m(x - x_1)$



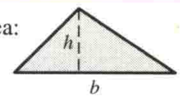
Circle with center (h, k) and radius r:

$(x-h)^2 + (y-k)^2 = r^2$



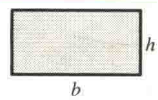
Triangle area:

$A = \frac{1}{2}bh$



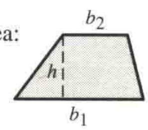
Rectangle area:

$A = bh$



Trapezoid area:

$A = \dfrac{b_1 + b_2}{2}h$

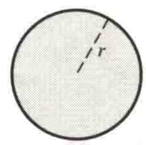


Circle area:

$A = \pi r^2$

Circumference:

$C = 2\pi r$

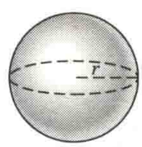


Sphere volume:

$V = \frac{4}{3}\pi r^3$

Surface area:

$A = 4\pi r^2$

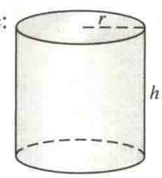


Cylinder volume:

$V = \pi r^2 h$

Curved surface area:

$A = 2\pi rh$

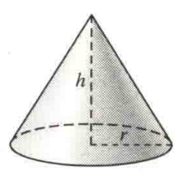


Cone volume:

$V = \frac{1}{3}\pi r^2 h$

Curved surface area:

$A = \pi r\sqrt{r^2 + h^2}$



TRIGONOMETRY

$\sin^2 A + \cos^2 A = 1$ (the *fundamental identity*)

$\tan^2 A + 1 = \sec^2 A$

$\cos 2A = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A = 2\cos^2 A - 1$

$\sin 2A = 2 \sin A \cos A$

$\cos(A + B) = \cos A \cos B - \sin A \sin B$

$\cos(A - B) = \cos A \cos B + \sin A \sin B$

$\sin(A + B) = \sin A \cos B + \cos A \sin B$

$\sin(A - B) = \sin A \cos B - \cos A \sin B$

$\cos^2 A = \dfrac{1 + \cos 2A}{2} \qquad \sin^2 A = \dfrac{1 - \cos 2A}{2}$

See the Appendices for more reference formulas.

PROJECTS

Note: The icon indicates projects that are supported by additional Maple/*Mathematica*/MATLAB/graphing-calculator resources on the CD-ROM that accompanies this textbook.

CHAPTER

Chapter		
1	1.1 Project:	A Square Wading Pool (p. 11)
	1.2 Project:	A Broken Tree (p. 23)
	1.3 Project:	A Leaning Ladder (p. 33)
	1.4 Project:	A Spherical Asteroid (p. 45)
2	2.1 Project:	Numerical Slope Investigations (p. 63)
	2.2 Project:	Limits, Slopes, and Logarithms (p. 74)
	2.3 Project:	Numerical Epsilon-Delta Limit Investigations (p. 87)
3	3.5 Project:	When Is Your Coffee Cup Stablest? (p. 149)
	3.8 Project:	Discovering the Number *e* for Yourself (p. 188)
	3.9 Project:	Investigating the Folium of Descartes (p. 199)
	3.10 Project:	How Deep Does a Floating Ball Sink? (p. 211)
4	4.4 Project:	Constructing a Candy Box with Lid (p. 247)
	4.7 Project:	Locating Special Points on Exotic Graphs (p. 283)
5	5.4 Project:	Calculator/Computer Riemann Sums (p. 338)
	5.9 Project:	Trapezoidal and Simpson Approximations (p. 391)
6	6.3 Project:	Design Your Own Ring! (p. 427)
	6.7 Project:	Natural Functional Equations (p. 466)
8	8.2 Project:	Computer-Assisted Slope Fields and Euler's Method (p. 569)
	8.5 Project:	Predator-Prey Equations and Your Own Game Preserve (p. 599)
9	9.4 Project:	Trochoid Investigations (p. 654)
	9.5 Project:	Moon Orbits and Race Tracks (p. 662)
10	10.2 Project:	Nested Radicals and Continued Fractions (p. 693)
	10.3 Project:	Numerical Summation and Geometric Series (p. 703)
	10.4 Project:	Calculating Logarithms on a Deserted Island (p. 717)
	10.5 Project:	The Number π, Once and for All (p. 724)
	10.9 Project:	Calculating Trigonometric Functions on a Deserted Island (p. 760)
11	11.5 Project:	Automated Row Reduction (p. 816)
	11.6 Project:	Automated Solution of Linear Systems (p. 831)
	11.7 Project:	Eigenvalues and Rotated Conics (p. 842)
12	12.1 Project:	Does a Pitched Baseball Really Curve? (p. 859)
13	13.6 Project:	Computer Algebra Implementation of Newton's Method (p. 943)
	13.9 Project:	Numerical Solution of Lagrange Multiplier Systems (p. 977)
	13.10 Project:	Critical Point Investigations (p. 988)
14	14.1 Project:	Midpoint Sums Approximating Double Integrals (p. 1001)
	14.5 Project:	Optimal Design of Downhill Race-Car Wheels (p. 1032)
	14.6 Project:	Archimedes' Floating Paraboloid (p. 1041)
15	15.5 Project:	Surface Integrals and Rocket Nose Cones (p. 1111)

CALCULUS

Early Transcendentals
Matrix Version
Instructor's Edition

ABOUT THE AUTHORS

C. Henry Edwards is emeritus professor of mathematics at the University of Georgia. He earned his Ph.D. at the University of Tennessee in 1960, and recently retired after 40 years of classroom teaching (including calculus or differential equations almost every term) at the universities of Tennessee, Wisconsin, and Georgia, with a brief interlude at the Institute for Advanced Study (Princeton) as an Alfred P. Sloan Research Fellow. He has received numerous teaching awards, including the University of Georgia's *honoratus* medal in 1983 (for sustained excellence in honors teaching), its Josiah Meigs award in 1991 (the institution's highest award for teaching), and the 1997 state-wide Georgia Regents award for research university faculty teaching excellence. His scholarly career has ranged from research and dissertation direction in topology to the history of mathematics to computing and technology in the teaching and applications of mathematics. In addition to being author or co-author of calculus, advanced calculus, linear algebra, and differential equations textbooks, he is well-known to calculus instructors as author of *The Historical Development of the Calculus* (Springer-Verlag, 1979). During the 1990s he served as a principal investigator on three NSF-supported projects: (1) A school mathematics project including Maple for beginning algebra students, (2) A Calculus-with-*Mathematica* program, and (3) A MATLAB-based computer lab project for numerical analysis and differential equations students.

David E. Penney, University of Georgia, completed his Ph.D. at Tulane University in 1965 (under the direction of Prof. L. Bruce Treybig) while teaching at the University of New Orleans. Earlier he had worked in experimental biophysics at Tulane University and the Veteran's Administration Hospital in New Orleans under the direction of Robert Dixon McAfee, where Dr. McAfee's research team's primary focus was on the active transport of sodium ions by biological membranes. Penney's primary contribution here was the development of a mathematical model (using simultaneous ordinary differential equations) for the metabolic phenomena regulating such transport, with potential future applications in kidney physiology, management of hypertension, and treatment of congestive heart failure. He also designed and constructed servomechanisms for the accurate monitoring of ion transport, a phenomenon involving the measurement of potentials in microvolts at impedances of millions of megohms. Penney began teaching calculus at Tulane in 1957 and taught that course almost every term with enthusiasm and distinction until his retirement at the end of the last millennium. During his tenure at the University of Georgia he received numerous University-wide teaching awards as well as directing several doctoral dissertations and seven undergraduate research projects. He is the author of research papers in number theory and topology and is the author or co-author of textbooks on calculus, computer programming, differential equations, linear algebra, and liberal arts mathematics.

Please turn to page xxi to see other text versions.

PREFACE

Contemporary calculus instructors and students face traditional challenges as well as new ones that result from changes in the role and practice of mathematics by scientists and engineers in the world at large. As a consequence, this sixth edition of our calculus textbook is its most extensive revision since the first edition appeared in 1982.

Two entire chapters of the fifth edition have been replaced in the table of contents by two new ones; most of the remaining chapters have been extensively rewritten. Nearly 160 of the book's over 800 worked examples are new for this edition and the 1850 figures in the text include 250 new computer-generated graphics. Almost 800 of its 7250 problems are new, and these are augmented by over 330 new conceptual discussion questions that now precede the problem sets. Moreover, almost 1100 new true/false questions are included in the Study Guides on the new CD-ROM that accompanies this edition. In summary, almost 2200 of these 8650-plus problems and questions are new, and the text discussion and explanations have undergone corresponding alteration and improvement.

PRINCIPAL NEW FEATURES

The current revision of the text features

- **Early transcendentals** fully integrated in Semester I.
- **Differential equations** and applications in Semester II.
- **Linear systems and matrices** in Semester III.

Complete coverage of the calculus of transcendental functions is now fully integrated in Chapters 1 through 6—with the result that the Chapter 7 and 8 titles in the 5th edition table of contents do not appear in this 6th edition.

A new chapter on differential equations (Chapter 8) now appears immediately after Chapter 7 on techniques of integration. It includes both direction fields and Euler's method together with the more elementary symbolic methods (which exploit techniques from Chapter 7) and interesting applications of both first- and second-order equations. Chapter 10 (Infinite Series) now ends with a new section on power series solutions of differential equations, thus bringing full circle a unifying focus of second-semester calculus on elementary differential equations.

Linear systems and matrices, ending with an elementary treatment of eigenvalues and eigenvectors, are now introduced in Chapter 11. The subsequent coverage of multivariable calculus now integrates matrix methods and terminology with the traditional notation and approach—including (for instance) introduction and extensive application of the chain rule in matrix-product form.

Please turn to page xxi to see other text versions.

NEW LEARNING RESOURCES

Conceptual Discussion Questions The set of problems that concludes each section is now preceded by a brief **Concepts: Questions and Discussion** set consisting of several open-ended conceptual questions that can be used for either individual study or classroom discussion.

The Text CD-ROM The content of the new CD-ROM that accompanies this text is fully integrated with the textbook material, and is designed specifically for use hand-in-hand with study of the book itself. This CD-ROM features the following resources to support learning and teaching:

- **Interactive True/False Study Guides** that reinforce and encourage student reading of the text. Ten author-written questions for each section carefully guide students through the section, and students can request individual hints suggesting where in the section to look for needed information.
- **Live Examples** feature dynamic multimedia and computer algebra presentations—many accompanied by audio explanations—which enhance student intuition and understanding. These interactive examples expand upon many of the textbook's principal examples; students can change input data and conditions and then observe the resulting changes in step-by-step solutions and accompanying graphs and figures. **Walkthrough videos** demonstrate how students can interact with these live examples.
- **Homework Starters** for the principal types of computational problems in each textbook section, featuring both interactive presentations similar to the live examples and (web-linked) voice-narrated videos of pencil-and-paper investigations illustrating typical initial steps in the solution of selected textbook problems.
- **Computing Project Resources** support most of the over three dozen projects that follow key sections in the text. For each such project marked in the text by a CD-ROM icon, more extended discussions illustrating Maple, *Mathematica,* MATLAB, and graphing calculator investigations are provided. Computer algebra system commands can be copied and pasted for interactive execution.
- **Hyperlinked Maple Worksheets** contributed by Harald Pleym of Telemark University College (Norway) constitute an interactive version of essentially the whole textbook. Students and faculty using Maple can change input data and conditions in most of the text examples to investigate the resulting changes in step-by-step solutions and accompanying graphs and figures.
- **PowerPoint Presentations** provide classroom projection versions of about 350 of the figures in the text that would be least convenient to reproduce on a blackboard.
- **Website** The contents of the CD-ROM together with additional learning and teaching resources are maintained and updated at the textbook website **www.prenhall.com/edwards,** which includes a Comments and Suggestions center where we invite response from both students and instructors.

Computerized Homework Grading System About 2000 of the textbook problems are incorporated in an automated grading system that is now available. Each problem solution in the system is structured algorithmically so that students can work in a computer lab setting to submit homework assignments for automatic grading. (There is a small annual fee per participating student.)

New Solutions Manuals The entirely new 1900-page **Instructor's Solutions Manual** (available in two volumes) includes a detailed solution for every problem in the book. These solutions were written exclusively by the authors and have been checked independently by others.

Please turn to page xxi to see other text versions.

The entirely new 950-page **Student Solutions Manual** (available in two volumes) includes a detailed solution for every odd-numbered problem in the text. The answers (alone) to most of these odd-numbered problems are included in the answers section at the back of this book.

New Technology Manuals Each of the following manuals is available shrink-wrapped with any version of the text for half the normal price of the manual (all of which are inexpensive):

- Jensen, *Using MATLAB in Calculus* (0-13-027268-X)
- Freese/Stegenga, *Calculus Concepts Using Derive* (0-13-085152-3)
- Gresser, *TI Graphing Calculator Approach, 2e* (0-13-092017-7)
- Gresser, *A Mathematica Approach, 2e* (0-13-092015-0)
- Gresser, *A Maple Approach, 2e* (0-13-092014-2)

THE TEXT IN MORE DETAIL . . .

In preparing this edition, we have taken advantage of many valuable comments and suggestions from users of the first five editions. This revision was so pervasive that the individual changes are too numerous to be detailed in a preface, but the following paragraphs summarize those that may be of widest interest.

▼ **New Problems** Most of the almost 800 new problems lie in the intermediate range of difficulty, neither highly theoretical nor computationally routine. Many of them have a new technology flavor, suggesting (if not requiring) the use of technology ranging from a graphing calculator to a computer algebra system.

▼ **Discussion Questions and Study Guides** We hope the 330 conceptual discussion questions and 1080 true/false study-guide questions constitute a useful addition to the traditional fare of student exercises and problems. The True/False Study Guide for each section provides a focus on the key ideas of the section, with the single goal of motivating guided student reading of the section.

▼ **Examples and Explanations** About 20% of the book's worked examples are either new or significantly revised, together with a similar percentage of the text discussion and explanations. Additional computational detail has been inserted in worked examples where students have experienced difficulty, together with additional sentences and paragraphs in similar spots in text discussions.

▼ **Project Material** Many of the text's almost 40 projects are new for this edition. These appear following the problem sets at the ends of key sections throughout the text. Most (but not all) of these projects employ some aspect of modern computational technology to illustrate the principal ideas of the preceding section, and many contain additional problems intended for solution with the use of a graphing calculator or computer algebra system. Where appropriate, project discussions are significantly expanded in the CD-ROM versions of the projects.

▼ **Historical Material** Historical and biographical chapter openings offer students a sense of the development of our subject by real human beings. Indeed, our exposition of calculus frequently reflects the historical development of the subject—from ancient times to the ages of Newton and Leibniz and Euler to our own era of new computational power and technology.

Please turn to page xxi to see other text versions.

TEXT ORGANIZATION

▼ **Introductory Chapters** Instead of a routine review of precalculus topics, Chapter 1 concentrates specifically on functions and graphs for use in mathematical modeling. It includes a section cataloging informally the elementary transcendental functions of calculus, as background to their more formal treatment using calculus itself. Chapter 1 concludes with a section addressing the question "What *is* calculus?" Chapter 2 on limits begins with a section on tangent lines to motivate the official introduction of limits in Section 2.2. Trigonometric limits are treated throughout Chapter 2 in order to encourage a richer and more visual introduction to the limit concept.

▼ **Differentiation Chapters** The sequence of topics in Chapters 3 and 4 differs a bit from the most traditional order. We attempt to build student confidence by introducing topics more nearly in order of increasing difficulty. The chain rule appears quite early (in Section 3.3) and we cover the basic techniques for differentiating algebraic functions before discussing maxima and minima in Sections 3.5 and 3.6. Section 3.7 treats the derivatives of all six trigonometric functions, and Section 3.8 (much strengthened for this edition) introduces the exponential and logarithmic functions. Implicit differentiation and related rates are combined in a single section (Section 3.9). The authors' fondness for Newton's method (Section 3.10) will be apparent.

The mean value theorem and its applications are deferred to Chapter 4. In addition, a dominant theme of Chapter 4 is the use of calculus both to construct graphs of functions and to explain and interpret graphs that have been constructed by a calculator or computer. This theme is developed in Sections 4.4 on the first derivative test and 4.6 on higher derivatives and concavity. But it may also be apparent in Sections 4.8 and 4.9 on l'Hôpital's rule, which now appears squarely in the context of differential calculus and is applied here to round out the calculus of exponential and logarithmic functions.

▼ **Integration Chapters** Chapter 5 begins with a section on antiderivatives—which could logically be included in the preceding chapter, but benefits from the use of integral notation. When the definite integral is introduced in Sections 5.3 and 5.4, we emphasize endpoint and midpoint sums rather than upper and lower and more general Riemann sums. This concrete emphasis carries through the chapter to its final section on numerical integration.

Chapter 6 begins with a largely new section on Riemann sum approximations, with new examples centering on fluid flow and medical applications. Section 6.6 is a new treatment of centroids of plane regions and curves. Section 6.7 gives the integral approach to logarithms, and Sections 6.8 and 6.9 cover both the differential and the integral calculus of inverse trigonometric functions and of hyperbolic functions.

Chapter 7 (Techniques of Integration) is organized to accommodate those instructors who feel that methods of formal integration now require less emphasis, in view of modern techniques for both numerical and symbolic integration. Integration by parts (Section 7.3) precedes trigonometric integrals (Section 7.4). The method of partial fractions appears in Section 7.5, and trigonometric substitutions and integrals involving quadratic polynomials follow in Sections 7.6 and 7.7. Improper integrals appear in Section 7.8, with new and substantial subsections on special functions and probability and random sampling. This rearrangement of Chapter 7 makes it more convenient to stop wherever the instructor desires.

▼ **Differential Equations** This entirely new chapter begins with the most elementary differential equations and applications (Section 8.1) and then proceeds to

Please turn to page xxi to see other text versions.

introduce both graphical (slope field) and numerical (Euler) methods in Section 8.2. Subsequent sections of the chapter treat separable and linear first-order differential equations and (in more depth than usual in a calculus course) applications such as population growth (including logistic and predator-prey populations) and motion with resistance. The final two sections of Chapter 8 treat second-order linear equations and applications to mechanical vibrations. Instructors desiring still more coverage of differential equations can arrange with the publisher to bundle and use appropriate sections of Edwards and Penney, **Differential Equations: Computing and Modeling 2/e** (Prentice Hall, 2000).

- **Parametric Curves and Polar Coordinates** The principal change in Chapter 9 is the replacement of three separate sections in the 5th edition on parabolas, ellipses, and hyperbolas with a single Section 9.6 that provides a unified treatment of all the conic sections.

- **Infinite Series** After the usual introduction to convergence of infinite sequences and series in Sections 10.2 and 10.3, a combined treatment of Taylor polynomials and Taylor series appears in Section 10.4. This makes it possible for the instructor to experiment with a briefer treatment of infinite series, but still offer exposure to the Taylor series that are so important for applications. The principal change in Chapter 10 is the addition of a new final section on power series methods and their use to introduce new transcendental functions, thereby concluding the middle third of the book with a return to differential equations.

- **Vectors and Matrices** After covering vectors in its first four sections, Chapter 11 continues with three sections on solution of linear systems (through elementary Gaussian elimination), matrices (through calculation of inverse matrices), and eigenvalues and eigenvectors and their use in classification of rotated conics. This introduction of linear systems and matrices provides the preparation required for the matrix-oriented multivariable calculus of Chapter 13. The intervening Chapter 12 (Curves and Surfaces in Space) includes discussion of Kepler-Newton motion of planets and satellites. The chapter includes also a brief application of eigenvalues to the discussion of rotated quadric surfaces in space.

- **Multivariable Calculus** Appropriately enough, the introduction and initial application of partial derivatives is traditional. But, beginning with the introduction of the multivariable chain rule in matrix-product form, matrix notation and terminology is used consistently in the remainder of Chapter 13. This approach affords a more clear-cut treatment of differentiability and linear approximation of multivariable functions, as well as of directional derivatives and Lagrange multipliers. We conclude Chapter 13 with a classification of critical points based on eigenvalues of the (Hessian) matrix of second derivatives (thereby generalizing directly the second derivative test of single-variable calculus). As a final illustration of the utility of matrix methods, this approach unifies the standard discriminant-based classification of two-variable critical points with the analogous classification of critical points for functions of three or more variables. Matrix methods (naturally) are needed less frequently in Chapters 14 (Multiple Integrals) and 15 (Vector Calculus), but appear whenever a change of variables in a multiple integral is involved.

OPTIONS IN TEACHING CALCULUS

The present version of the text is accompanied by a more traditional version that treats transcendental functions later in single variable calculus and omits matrices in multivariable calculus. Both versions of the complete text are also available in

Please turn to page xxi to see other text versions.

two-volume split editions. By appropriate selection of first and second volumes, the instructor can therefore construct a complete text for a calculus sequence with

- Early transcendentals in single variable calculus and matrices in multivariable calculus;
- Early transcendentals in single variable calculus but traditional coverage of multivariable calculus;
- Transcendental functions delayed until after the integral in single variable calculus, but matrices used in multivariable calculus;
- Neither early transcendentals in single variable calculus nor matrices in multivariable calculus.

ACKNOWLEDGMENTS

All experienced textbook authors know the value of critical reviewing during the preparation and revision of a manuscript. In our work on this edition we have profited greatly from the unusually detailed and constructive advice of the following very able reviewers:

- Kenzu Abdella—Trent University
- Martina Bode—Northwestern University
- David Caraballo—Georgetown University
- Tom Cassidy—Bucknell University
- Lucille Croom—Hunter College
- Yuanan Diao—University of North Carolina at Charlotte
- Victor Elias—University of Western Ontario
- Haitao Fan—Georgetown University
- James J. Faran, V—The State University of New York at Buffalo
- K. N. Gowrisankaran—McGill University
- Qing Han—University of Notre Dame
- Melvin D. Lax—California State University, Long Beach
- Robert H. Lewis—Fordham University
- Allan B. MacIsaac—University of Western Ontario
- Rudolph M. Najar—California State University, Fresno
- Bill Pletsch—Albuquerque Technical and Vocational Institute
- Nancy Rallis—Boston College
- Robert C. Reilly—University of California, Irvine
- James A. Reneke—Clemson University
- Alexander Retakh—Yale University
- Carl Riehm—McMaster University
- Ira Sharenow—University of Wisconsin, Madison
- Kay Strangman—University of Wisconsin, Madison
- Sophie Tryphonas—University of Toronto at Scarborough
- Kamran Vakili—Princeton University
- Cathleen M. Zucco-Teveloff—Trinity College

Many of the best improvements that have been made must be credited to colleagues and users of the previous five editions throughout the United States, Canada, and abroad. We are grateful to all those, especially students, who have written to us, and hope they will continue to do so. We thank the accuracy checkers of M. and N. Toscano, who verified the solution of every worked-out example and odd-numbered answer, as well as all of the solutions in the Instructor's and Student Solutions Manuals. We believe that the appearance and quality of the finished book is clear testimony to the skill, diligence, and talent of an exceptional staff at Prentice Hall. We owe special thanks to George Lobell, our mathematics editor, whose advice and criticism guided and shaped this revision in many significant and

Please turn to page xxi to see other text versions.

tangible ways, as did the constructive comments and suggestions of Ed Millman, our developmental editor. We also thank Gale Epps and Melanie Van Benthuysen for their highly varied and detailed services in aid of editors and authors throughout the work of revision. The visual graphics of this text have been widely praised in previous editions, and it is time for us to thank Ron Weickart of Network Graphics, who has worked with us through the past three editions. Barbara Mack, our production editor, expertly combined varied sources of graphic and text material and smoothly managed the whole process of book production. Our art director, Jonathan Boylan, supervised and coordinated the attractive design and layout of the text and cover for this edition. Vince Jansen coordinated the production of the CD-ROM, for which we thank especially Robert Curtis and Lee Wayand for their interactive examples and Harald Pleym for his Maple worksheets. Finally, we again are unable to thank Alice Fitzgerald Edwards and Carol Wilson Penney adequately for their unrelenting assistance, encouragement, support, and patience extending through six editions and over two decades of work on this textbook.

C. Henry Edwards
hedwards@math.uga.edu

David E. Penney
dpenney@math.uga.edu

Please turn to page xxi to see other text versions.

WALK-THROUGH CONTENTS

ADDITIONAL TEXTBOOK OPTIONS

Hardcovers:

Calculus 6e xxii
Calculus, Matrix Version 6e xxiv
Calculus, Early Transcendentals 6e xxvi

Paperbacks:

Single Variable Calculus, Early Transcendentals 6e xxviii
Multivariable Calculus with Matrices 6e xxx
Single Variable Calculus 6e xxxii
Multivariable Calculus 6e xxxiv

MEDIA RESOURCES FOR INSTRUCTORS

PH Homework Grader xxxvi
Instructor's Resource CD-ROM xxxvii

MEDIA RESOURCES FOR STUDENTS

Student CD-ROM xxxviii
Student Website xxxix

PRINT SUPPLEMENTS

For Instructors xl
For Students xli

FEATURES WALK-THROUGH

xlii

Edwards & Penney

TEXTBOOK OPTIONS

This edition of Edwards/Penney Calculus, Early Transcendentals, Matrix Version is one of four hardcover versions. The other three are outlined here. There are also two different Single Variable Calculus paperbacks (ET and non-ET) and two different Multivariable Calculus paperbacks (with and without Matrices), also outlined here.

CALCULUS

0-13-092071-1

INSTRUCTOR'S SOLUTIONS MANUAL TO ACCOMPANY *SINGLE VARIABLE CALCULUS*
0-13-066158-9

INSTRUCTOR'S SOLUTIONS MANUAL TO ACCOMPANY *MULTIVARIABLE CALCULUS*
0-13-066145-7

STUDENT SOLUTIONS MANUAL TO ACCOMPANY *SINGLE VARIABLE CALCULUS*
0-13-092077-0

STUDENT SOLUTIONS MANUAL TO ACCOMPANY *MULTIVARIABLE CALCULUS*
0-13-062023-8

TEST ITEM FILE
0-13-066162-7

TEST GEN EQ
0-13-066161-9

THIS TEXT COVERS TRANSCENDENTAL FUNCTIONS IN CALC II AND DOES NOT INCLUDE MATRICES

Contents

1. Functions, Graphs, and Models
- 1.1 Functions and Mathematical Modeling
- 1.2 Graphs of Equations and Functions
- 1.3 Polynomials and Algebraic Functions
- 1.4 Transcendental Functions
- 1.5 Preview: What *Is* Calculus?

2. Prelude to Calculus
- 2.1 Tangent Lines and Slope Predictors
- 2.2 The Limit Concept
- 2.3 More About Limits
- 2.4 The Concept of Continuity

3. The Derivative
- 3.1 The Derivative and Rates of Change
- 3.2 Basic Differentiation Rules
- 3.3 The Chain Rule
- 3.4 Derivatives of Algebraic Functions
- 3.5 Maxima and Minima of Functions on Closed Intervals
- 3.6 Applied Optimization Problems
- 3.7 Derivatives of Trigonometric Functions
- 3.8 Successive Approximations and Newton's Method

4. Additional Applications of the Derivative
- 4.1 Implicit Functions and Related Rates
- 4.2 Increments, Differentials, and Linear Approximation
- 4.3 Increasing and Decreasing Functions and the Mean Value Theorem
- 4.4 The First Derivative Test and Applications
- 4.5 Simple Curve Sketching
- 4.6 Higher Derivatives and Concavity
- 4.7 Curve Sketching and Asymptotes

5. The Integral
- 5.1 Introduction
- 5.2 Antiderivatives and Initial Value Problems
- 5.3 Elementary Area Computations
- 5.4 Riemann Sums and the Integral
- 5.5 Evaluation of Integrals
- 5.6 The Fundamental Theorem of Calculus
- 5.7 Integration by Substitution

5.8 Areas of Plane Regions
5.9 Numerical Integration

6. Applications of the Integral

6.1 Riemann Sum Approximations
6.2 Volumes by the Method of Cross Sections
6.3 Volumes by the Method of Cylindrical Shells
6.4 Arc Length and Surface Area of Revolution
6.5 Force and Work
6.6 Centroids of Plane Regions and Curves

7. Calculus of Transcendental Functions

7.1 Exponential and Logarithmic Functions
7.2 Indeterminate Forms and L'Hôpital's Rule
7.3 More Indeterminate Forms
7.4 The Natural Logarithm as an Integral
7.5 Inverse Trigonometric Functions
7.6 Hyperbolic Functions

8. Techniques of Integration

8.1 Introduction
8.2 Integral Tables and Simple Substitutions
8.3 Integration by Parts
8.4 Trigonometric Integrals
8.5 Rational Functions and Partial Fractions
8.6 Trigonometric Substitutions
8.7 Integrals Involving Quadratic Polynomials
8.8 Improper Integrals

9. Differential Equations

9.1 Simple Equations and Models
9.2 Slope Fields and Euler's Method
9.3 Separable Equations and Applications
9.4 Linear Equations and Applications
9.5 Population Models
9.6 Linear Second-Order Equations
9.7 Mechanical Vibrations

10. Polar Coordinates and Parametric Curves

10.1 Analytic Geometry and the Conic Sections
10.2 Polar Coordinates
10.3 Area Computations in Polar Coordinates
10.4 Parametric Curves
10.5 Integral Computations with Parametric Curves
10.6 Conic Sections and Applications

11. Infinite Series

11.1 Introduction
11.2 Infinite Sequences
11.3 Infinite Series and Convergence
11.4 Taylor Series and Taylor Polynomials
11.5 The Integral Test
11.6 Comparison Tests for Positive-Term Series
11.7 Alternating Series and Absolute Convergence
11.8 Power Series
11.9 Power Series Computations
11.10 Series Solutions of Differential Equations

12. Vectors, Curves, and Surfaces in Space

12.1 Vectors in the Plane
12.2 Three-Dimensional Vectors
12.3 The Cross Product of Two Vectors
12.4 Lines and Planes in Space
12.5 Curves and Motion in Space
12.6 Curvature and Acceleration
12.7 Cylinders and Quadric Surfaces
12.8 Cylindrical and Spherical Coordinates

13. Partial Differentiation

13.1 Introduction
13.2 Functions of Several Variables
13.3 Limits and Continuity
13.4 Partial Derivatives
13.5 Multivariable Optimization Problems
13.6 Increments and Linear Approximation
13.7 The Multivariable Chain Rule
13.8 Directional Derivatives and the Gradient Vector
13.9 Lagrange Multipliers and Constrained Optimization
13.10 Critical Points of Functions of Two Variables

14. Multiple Integrals

14.1 Double Integrals
14.2 Double Integrals over More General Regions
14.3 Area and Volume by Double Integration
14.4 Double Integrals in Polar Coordinates
14.5 Applications of Double Integrals
14.6 Triple Integrals
14.7 Integration in Cylindrical and Spherical Coordinates
14.8 Surface Area
14.9 Change of Variables in Multiple Integrals

15. Vector Calculus

15.1 Vector Fields
15.2 Line Integrals
15.3 The Fundamental Theorem and Independence of Path
15.4 Green's Theorem
15.5 Surface Integrals
15.6 The Divergence Theorem
15.7 Stokes' Theorem