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Dedicated to the memory of my mother and father, Sophia and John Swokowski

ADDITIONAL CALCULUS TEXTBOOKS BY EARL W. SWOKOWSKI

CALCULUS, FIFTH EDITION This text contains the same material as *Calculus of a Single Variable* in addition to chapters on vectors, multivariable calculus, and differential equations.

CALCULUS WITH ANALYTIC GEOMETRY, FOURTH EDITION This text provides a review of trigonometry and complete coverage of the trigonometric functions in Chapter 8. Consequently, there is a slightly different treatment of limits, derivatives, and integrals.

PREFACE

This book, consisting of the first 13 chapters of *Calculus*, *Fifth Edition*, was prepared with three objectives in mind. The first was to make the book more student-oriented by expanding discussions and providing more examples and figures to help clarify concepts. To further aid students, guidelines for solving problems were added in many sections of the text. The second objective was to stress the usefulness of calculus by means of modern applications of derivatives and integrals. The third objective, to make the text as error-free as possible, was accomplished by a careful examination of the exposition, combined with a thorough checking of each example and exercise.

CHANGES FOR THIS EDITION

Suggestions for improvements from instructors and reviewers resulted in a great deal of rewriting and reorganization. The principal changes are highlighted in the following list.

CHAPTER 1 The number of review sections has been reduced from six to three, with proofs of results from precalculus replaced by examples on inequalities, equations, and graphs.

CHAPTER 2 There is more emphasis on the graphical significance of limits. A physical application and tolerance statements are used to motivate the ϵ - δ definition. Limits involving ∞ (formerly in Chapter 4) are discussed in Section 2.4.

CHAPTER 3 The interpretations of the derivative as the slope of a tangent line and as the rate of change of a function are considered simultaneously instead of in separate sections. The power rule for rational numbers and the concept of higher derivatives are introduced in Section 3.2. Greater emphasis is given to the use of differentials for linear approximations of function values.

CHAPTER 4 The definition of concavity has been changed to make it easier to relate the sign of a second derivative to the shape of a graph. A new section titled *Summary of Graphical Methods* includes a list of guidelines for sketching the graph of a function.

CHAPTER 5 Antiderivatives and indefinite integrals are discussed in the first two sections instead of in different chapters. There are fifteen new examples pertaining to definite integrals.

CHAPTER 6 Almost every example on applications of definite integrals has been rewritten so as to replace formal limits of sums with a more intuitive method using differentials. Guidelines are stated that contain strategies for finding areas and volumes.

CHAPTER 7 The formula for the derivative of an inverse function is proved in the first section instead of the last. Integrals of the tangent, cotangent, secant, and cosecant functions (formerly in Chapter 8) are discussed in Section 7.4.

CHAPTER 8 The topics considered are restricted to inverse trigonometric and hyperbolic functions.

CHAPTER 9 Explanations and guidelines for methods of integration have been improved.

CHAPTER 10 For easy reference, definitions and notations for indeterminate forms are stated in tables. The discussion of Taylor's formula has been moved to Chapter 11.

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CHAPTER 11 More emphasis is given to the differences between sequences, partial sums, sums of infinite series, and the fact that tests for convergence do not determine the sum of a series. The material on power series representations of functions and Taylor series has been completely reorganized.

CHAPTER 12 Additional calculus applications involving conic sections are included so that the discussion is not simply a review of precalculus topics.

CHAPTER 13 The concept of *orientation* of a curve has been added and incorporated into examples and exercises.

FEATURES OF THE TEXT

APPLICATIONS The previous edition contained applied problems from fields such as engineering, physics, chemistry, biology, economics, physiology, sociology, psychology, ecology, oceanography, meteorology, radiotherapy, astronautics, and transportation. This already extensive list was augmented with examples and exercises that include modern applications of calculus to the design of computers, the analysis of temperature grids, and the measurement of the thickness of the ozone layer, the greenhouse effect, vertical wind shear, the circulation of winds inside tornados and hurricanes, the energy released by earthquakes, the density of the atmosphere, the movement of robot arms, and the health hazards of radon gas.

EXAMPLES Well-structured and graded examples provide detailed solutions of problems similar to those that appear in exercise sets. Many examples contain graphs, charts, or tables to help readers understand procedures and solutions. There are also labeled *illustrations*, which are brief demonstrations of the use of definitions, laws, or theorems. Whenever feasible, applications are included that indicate the usefulness of a topic.

EXERCISES Exercise sets begin with routine drill problems and progress gradually to more difficult types. Many exercises containing graphs were added to this edition. Applied problems generally appear near the end of a set, to allow students to gain confidence in manipulations and new ideas before attempting questions that require analyses of practical situations.

A new feature in this edition is over 300 exercises, designated by the symbol [c], specifically designed to be solved with the aid of a scientific calculator or computer. Graphics capabilities are required for

some of these exercises (see the remarks that follow under *Calculators*).

Review exercises at the end of each chapter except the first may be used to prepare for examinations.

ANSWERS The answer section at the end of the text provides answers for most of the odd-numbered exercises. Considerable thought and effort were devoted to making this section a learning device instead of merely a place to check answers. To illustrate, if an answer is the area of a region or the volume of a solid, a suitable (set-up) definite integral is often given along with its value. Numerical answers for many exercises are stated in both an exact and an approximate form. Graphs, proofs, and hints are included whenever appropriate.

CALCULATORS Since students may have access to a variety of calculators or computers, no attempt was made to categorize the exercises that are designated by c. The statement of a problem should provide sufficient information for determining whether a particular calculator or available computer software can be used to obtain a numerical solution. For example, if an exercise states that the trapezoidal rule with n = 4should be applied, then almost any calculator is suitable, provided the function is not too complicated. However, for n = 20, a programmable calculator or computer is recommended. If the solution of an exercise involves a graph, a graphics calculator may be adequate; however, complicated functions or surfaces may require sophisticated computer software. Since numerical accuracy is also dependent on the type of computational device used, some answers are rounded to two decimal places, but in other cases eight-decimalplace accuracy may be given.

TEXT DESIGN AND FIGURES The text has been completely redesigned to make discussions easier to follow and to highlight important concepts. All graphics have been redone. Graphs of functions of one or two variables were computer-generated and plotted to a high degree of accuracy using the latest technology. Colors are used to distinguish between different parts of figures. For example, the graph of a function may be shown in blue and a tangent line to the graph in red. Labels are in the same color as the parts of the figure they identify. The use of several colors should help readers visualize surfaces and solids more readily than in previous editions.

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I am indebted to Jeffery Cole, of Anoka-Ramsey Community College, for his excellent work on the exercise sets, the answer section, and artwork preparation for the figures. Jeff also carefully read the manuscript and offered many suggestions that helped make discussions and examples more student-oriented. He often reminded me of the motto I adopted when I started on this revision: "Teach the Class."

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Their comments on pedagogy and their specific recommendations about the content of calculus courses helped me to improve the book.

I am thankful for the excellent cooperation of the staff of PWS-KENT. Two people in the company deserve special mention. Managing Editor Dave Geggis supervised the project, contacted many reviewers and users of the text, and was a constant source of information and advice. Dave is also responsible for finding the authors who developed the excellent ancillaries that accompany this book. Elise Kaiser redesigned the book, coordinated the production of the text, and kept the schedule running smoothly and on time. Sally Lifland, of Lifland et al., Bookmakers, took exceptional care in seeing that no editorial inconsistencies occurred.

Finally, I am deeply grateful to my wife Maureen—for her understanding, patience, support, and love.

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SUPPLEMENTS

STUDENT STUDY GUIDE Richard M. Grassl's Student Study Guide leads students through all major topics in the text and reinforces their understanding through review sections, drills, and self-tests.

A. Cole and Gary K. Rockswold's *Student Solutions Manual* contains solutions, worked out in detail, to a subset of the odd-numbered exercises from the text.

INSTRUCTOR'S SOLUTIONS MANUAL, VOLUMES I AND II Jeffery A. Cole and Gary K. Rockswold's *Instructor's Solutions Manual* gives solutions or answers for all exercises in the text.

EVEN-NUMBERED ANSWER BOOK Jeffery A. Cole and Gary K. Rockswold's *Even-Numbered Answer Book* is for both instructor and student use.

PRINTED TEST BANK Available to instructors, the Printed Test Bank contains sample tests for each chapter.

TRANSPARENCY MASTERS Also available to instructors are *Transparency Masters* of selected figures from the text.

SOFTWARE

MATHEMATICS PLOTTING PACKAGE Available for IBM-PCs and compatibles, the Mathematics Plotting Package combines superb plotting and graphing software. This public domain program developed at the United States Naval Academy is accompanied by a text-specific Instructor's Resource Guide to MPP, by Howard Penn and Craig Bailey. The guide provides instructors with notes on how to teach key concepts by using MPP to illustrate examples and problems from the text. Also included are Example Files for

MPP—disks containing examples and problems from the Resource Guide.

PC:SOLVE Available for IBM-PCs and compatibles, PC:SOLVE is an interactive mathematical language with scratchpad that supports calculations and graphics, combined with a calculus curriculum library of key concepts to promote critical thinking and problem solving. A course license for PC:SOLVE is available upon adoption of this text.

GRAPHER Steve Scarborough's Grapher, for the Macintosh, is a flexible program that can be used to generate several types of graphs. In addition to plotting rectangular and polar curves and interpolating polynomials, it handles parametric equations, systems of two first-order differential equations, series, and direction fields.

TrueBASIC CALCULUS Available for IBM-PCs and compatibles and for the Macintosh, TrueBASIC Calculus is a disk and manual package that is equally useful for self-study, free exploration of topics, and solutions of problems. The record and playback feature make the package ideal for classroom demonstrations.

COMPUTERIZED TESTING

EXPTest This testing program for IBM-PCs and compatibles allows users to view and edit all tests, adding to, deleting from, and modifying existing questions. Any number of student tests can be created—multiple forms for larger sections or single tests for individual use. Users can create a question bank using mathematical symbols and notation. A graphics importation feature permits display and printing of graphs, diagrams, and maps provided with the test banks. The

SUPPLEMENTS

package includes easy-to-follow documentation, with a quick-start guide. A demonstration disk is available.

LXRTest This Macintosh testing program allows users to create, view, and edit tests. Questions can be stored by objectives, and the user can create questions using multiple-choice, true/false, fill-in-the-blank, essay, and matching formats. The order of alternatives and the order of questions can be scrambled. A demonstration disk is available (the user must have HyperCard to run the demo disk).

GRAPHIC CALCULATOR SUPPLEMENTS

CALCULUS ACTIVITIES FOR GRAPHIC CALCULATORS

Dennis Pence's Calculus Activities for Graphic Calculators, for students and instructors, offers exercises and examples utilizing the graphing calculator (Sharp, Casio, and HP28S). Classroom tested, these varied activities will enhance understanding of calculus topics for those using graphing calculators.

CALCULUS ACTIVITIES FOR THE TI-81 GRAPHIC CALCULATOR For students and instructors using the TI-81 graphic calculator, Dennis Pence provides calculus exercises and examples in *Calculus Activities for the TI-81 Graphic Calculator*.

FOR THE STUDENT

Calculus was invented in the seventeenth century as a tool for investigating problems that involve motion. Algebra and trigonometry may be used to study objects that move at constant speeds along linear or circular paths, but calculus is needed if the speed varies or if the path is irregular. An accurate description of motion requires precise definitions of *velocity* (the rate at which distance changes per unit time) and *acceleration* (the rate at which velocity changes). These definitions may be obtained by using one of the fundamental concepts of calculus—the *derivative*.

Although calculus was developed to solve problems in physics, its power and versatility have led to uses in many diverse fields of study. Modern-day applications of the derivative include investigating the rate of growth of bacteria in a culture, predicting the outcome of a chemical reaction, measuring instantaneous changes in electrical current, describing the behavior of atomic particles, estimating tumor shrinkage in radiation therapy, forecasting economic profits and losses, and analyzing vibrations in mechanical systems.

The derivative is also useful in solving problems that involve maximum or minimum values, such as manufacturing the least expensive rectangular box that has a given volume, calculating the greatest distance a rocket will travel, obtaining the maximum safe flow of traffic across a long bridge, determining the number of wells to drill in an oil field for the most efficient production, finding the point between two light sources at which illumination will be greatest, and maximizing corporate revenue for a particular product. Mathematicians often employ derivatives to find tangent lines to curves and to help analyze graphs of complicated functions.

Another fundamental concept of calculus—the definite integral—is motivated by the problem of finding areas of regions that have curved boundaries. Definite integrals are employed as extensively as derivatives and in as many different fields. Some applications are finding the center of mass or moment of inertia of a solid, determining the work required to send a space probe to another planet, calculating the blood flow through an arteriole, estimating depreciation of equipment in a manufacturing plant, and interpreting the amount of dye dilution in physiological tests that involve tracer methods. We can also use definite integrals to investigate mathematical concepts such as area of a curved surface, volume of a geometric solid, or length of a curve.

The concepts of derivative and definite integral are defined by limiting processes. The notion of *limit* is the initial idea that separates calculus from elementary mathematics. Sir Isaac Newton (1642–1727) and Gottfried Wilhelm Leibniz (1646–1716) independently discovered the connection between derivatives and integrals and are both credited with the invention of calculus. Many other mathematicians have added greatly to its development in the last 300 years.

The applications of calculus mentioned here represent just a few of the many considered in this book. We can't possibly discuss all the uses of calculus, and more are being developed with every advance in technology. Whatever your field of interest, calculus is probably used in some pure or applied investigations. Perhaps *you* will discover a new application for this branch of science.



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