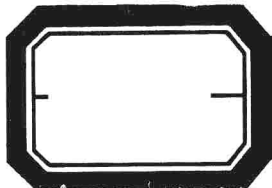
The background of the cover is a photograph of a modern building. The building features dark, angular walls and a prominent, curved, light-colored walkway or ramp that spirals upwards. There are several windows, some with dark frames and others with lighter, possibly metallic or glass, frames. The overall aesthetic is architectural and geometric.

Mathematics with Applications

SIXTH EDITION

**LIAL
HUNGERFORD
MILLER**



Chapter 1

Mathematics with Applications

**IN THE MANAGEMENT, NATURAL,
AND SOCIAL SCIENCES**

Margaret L. Lial

American River College

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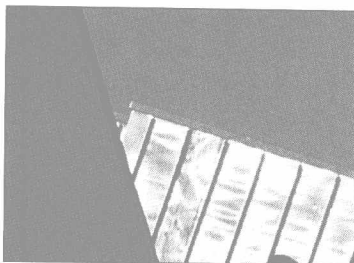
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Preface

Mathematics with Applications, Sixth Edition, is designed to provide mathematical topics needed by students in the fields of business management, social science, and natural science. The book is written at a level that makes it accessible to such students. Topics are presented by proceeding from what is already known to new material, from concrete examples to general rules and formulas. Almost every section includes pertinent applications. The only prerequisite we assume is a course in algebra. Chapter 1 provides a thorough review of algebra, and a pretest is included in the *Instructor's Guide* that accompanies the text to help determine how much review is needed for a particular student or class.

We have retained popular features from earlier editions: extensive examples; exercises keyed to the text; realistic and timely applications; end-of-chapter case studies; margin problems; highlighted rules, definitions, and summaries; and pedagogical use of color.


Use of Technology

In this new edition, we have introduced boxes with references to graphers (graphing calculators or computers), and we discuss how they apply to the topic at hand. These are designed so an instructor may or may not choose to integrate them into the course. Where appropriate, exercise sets include clearly labeled exercises especially for graphers. Each such exercise is identified with . The opening page of each applicable chapter includes a list of available technology resources that are appropriate for the chapter.

New Exercises

More than one-third of the exercises are new to this edition, including drill and practice problems as well as a variety of interesting applications. Many of the applications are based on current real data and come from a variety of areas of interest to students. Several new case studies that explore contemporary issues and themes are included as well. This edition includes new conceptual and



NEW CONTENT HIGHLIGHTS

writing exercises that require students to demonstrate an understanding of the concepts that goes beyond computational skill. Several exercise sets also include connection exercises, identified by , that integrate concepts and skills developed earlier with those just introduced or that connect the concepts presented within a chapter. Four answer checkers helped ensure that the highest level of accuracy was maintained.

- The material in Chapter 2 was rearranged to flow from topics that are familiar to those that are not. The chapter now begins with linear equations and slope, then discusses functions and their applications. The introduction to functions has been enhanced.
- The general discussion of graphing polynomials by hand has been expanded to help students better understand the shape of these graphs.
- The section on logarithmic functions has been rewritten to emphasize base 10 and base e logarithms.
- In Chapter 6, we rewrote the introduction to systems of equations to reflect current terminology and to include examples of “nonsquare” systems.
- The presentation of linear programming in Section 7.4 has been revised so the mechanics are discussed first, then the reasons given. The applications are presented separately in the next section. We now introduce duality and minimization problems in Section 7.6, before nonstandard problems are covered in Section 7.7.
- The topics within some of the sections in Chapter 8 were rearranged to improve the flow and keep related topics together.
- Limits at infinity and horizontal asymptotes are now discussed in Chapter 12 with curve sketching.

NEW FEATURES

Several new features, designed to assist students in the learning process, have been integrated into this edition. These features are illustrated on the following two pages. In addition, changes in format enhance the book’s pedagogical features and increase its accessibility.

- *For Graphers* These notes permit the integration of graphing calculators and computers into the courses using this text.
- *Conceptual and Writing Exercises* To complement the drill and application exercises, several exercises that require a deeper understanding of the concepts introduced in a section are included in almost every exercise set. Nearly half of these require the student to respond by writing a few sentences.
- *Connection Exercises* Exercises that require students to use skills or techniques covered in previous sections or chapters are included in some section exercises and review exercise sets. These exercises are identified with .
- *Graphing Calculator/Computer Exercises* Exercises identified with  are included in appropriate exercise sets for those using graphers. These exercises demonstrate how graphers can be used to clarify and illustrate concepts.

5 Solve each inequality. Graph each solution.

- $|y - 2| > 5$
- $|3k - 1| \geq 2$
- $|2 + 5r| - 4 \geq 1$

Answers:

- All numbers in $(-\infty, -3)$ or $(7, \infty)$



- All numbers in $(-\infty, -\frac{1}{3})$ or $[1, \infty)$



- All numbers in $(-\infty, -\frac{7}{5})$ or $[\frac{3}{5}, \infty)$



FOR GRAPHERS

One method for solving absolute value equations with a grapher is to graph each side of the equation simultaneously. Some graphers have a key labeled ABS that gives the absolute value of a quantity. This function is accessed through a special menu on other graphers. For instance, in Example 2, graph $y_1 = |x - 4|$ and $y_2 = 2$. Remember to key in $\text{ABS}(x - 4)$, not $\text{ABS } x - 4$. Then locate the x -values of the points where these two graphs intersect (are equal). Figure 1.20 shows the x -values of the intersection points are 2 and 6. To solve the inequality $|x - 4| < 2$, from the graph in Figure 1.20 decide on which intervals the graph of $y_1 = |x - 4|$ is below (and therefore less than) the graph of $y_2 = 2$. As the figure shows, this happens for $2 < x < 6$. You could also solve this inequality by graphing $y = |x - 4| - 2$ and locating the intersection points with the x -axis.

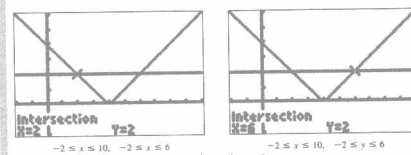


FIGURE 1.20

EXAMPLE 6 Solve $|2 - 7m| - 1 > 4$.

First add 1 on both sides.

$$|2 - 7m| > 5$$

Now use property (4) from above to solve $|2 - 7m| > 5$ by solving the inequality

$$2 - 7m < -5 \quad \text{or} \quad 2 - 7m > 5.$$

Solve each part separately.

$$\begin{aligned} -7m &< -7 & \text{or} & \quad -7m > 3 \\ m &> 1 & \text{or} & \quad m < -\frac{3}{7} \end{aligned}$$

The solution, all numbers in $(-\infty, -\frac{3}{7})$ or $(1, \infty)$, is graphed in Figure 1.21.

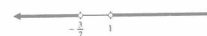


FIGURE 1.21

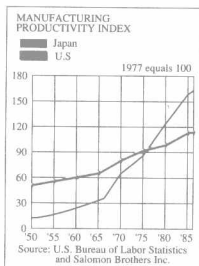
9.1 PERMUTATIONS AND COMBINATIONS

- How many area codes would be possible if all restrictions on the second digit were removed?
- A problem with the plan in Exercise 29 is that the second digit in the area code now tells the phone company equipment that a long-distance call is being made. To avoid changing all equipment, an alternative plan proposes a 4-digit area code and restricting the first and second digits as before. How many area codes would this plan provide?
- Still another alternative solution is to increase the local dialing sequence to 8 digits instead of 7. How many additional numbers would this plan create? (Assume the same restrictions.)
- Define permutation in your own words.
Use permutations to solve each of the following problems. (See Examples 5–7.)
- A baseball team has 20 players. How many 9-player batting orders are possible?
- In a game of musical chairs, 12 children will sit in 11 chairs arranged in a row (one will be left out). In how many ways can the 11 children find seats?
- From a carton of 12 cans of a soft drink, 2 are to be selected for testing. In how many ways can this be done?
- In an election with 3 candidates for one office and 5 candidates for another office, how many different ballots may be printed?
- From a pool of 7 secretaries, 3 are selected to be assigned to 3 managers. In how many ways can they be selected?
- A chapter of union Local 715 has 35 members. In how many different ways can the chapter select a president, a vice-president, a treasurer, and a secretary?
- The television schedule for a certain evening shows 8 choices from 8 to 9 P.M., 5 choices from 9 to 10 P.M., and 6 choices from 10 to 11 P.M. In how many different ways could a person schedule that evening of television viewing from 8 to 11 P.M.? (Assume each program that is selected is watched for an entire hour.)
- In a club with 15 members, how many ways can a slate of 3 officers consisting of president, vice-president, and secretary/treasurer be chosen?

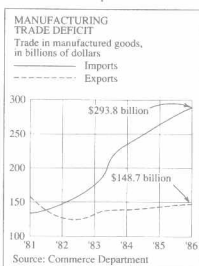
Use combinations to solve each of the following problems. (See Examples 8–9 and 12–13.)

- Management Five items are chosen from the first 50 items on an assembly line. How many different combinations can be chosen?
 - Social Science A group of 3 students is chosen from a group of 12 students to take a biology exam.
(a) In how many ways can this be done?
(b) In how many ways can the group be chosen?
 - Natural Science From a group of 16 smokers and 20 nonsmokers, a researcher wants to randomly select 8 smokers and 8 nonsmokers for a study. In how many ways can the study group be selected?
 - Five cards are drawn from an ordinary deck. In how many ways is it possible to draw
(a) all queens;
(b) all face cards (face cards are the Jack, Queen, and King);
(c) no face card;
(d) exactly 2 face cards;
(e) 1 heart, 2 diamonds, and 2 clubs.
- Exercises 45–64 are mixed problems that may require permutations, combinations, or the multiplication principle. (See Examples 10, 11, and 14.)*
- Use a tree diagram to find the number of ways 2 letters can be chosen from the set $\{L, M, N\}$ if order is important and
(a) if repetition is allowed;
(b) if no repeats are allowed.
(c) Find the number of combinations of 3 elements taken 2 at a time. Does this answer differ from (a) or (b)?
 - Repeat Exercise 45 using the set $\{L, M, N, P\}$.
 - Explain the difference between a permutation and a combination.
 - Padlocks with digit dials are often referred to as “combination locks.” According to the mathematical definition of combination, is this an accurate description? Explain.

Conceptual Exercises
Writing Exercises



34. **Management** The graph gives U.S. imports and exports in billions of dollars over a five-year period. Estimate the break-even point.



35. **Management** Canadian and Japanese investment in the United States in billions of dollars in 1980 and 1990 are shown in the chart.*

* Data reprinted with permission from *The World Almanac and Book of Facts*, 1992. Copyright © 1991. All rights reserved. The World Almanac is an imprint of Funk & Wagnalls Corporation.

	1980	1990
Canada	12.1	27.7
Japan	4.7	108.1

- (a) Assuming the change in investment in each case is linear, write an equation in function form giving the investment in year x for each country. Let x be the number of years since 1980.
- (b) Graph the functions from part (a) on the same coordinate axes.
- (c) Find the intersection point where the graphs in part (b) cross and interpret your answer.

36. **Social Science** The median family income (in thousands of dollars) for the white population in the United States is given by $f(x) = (4/3)x + 8$, where x is the number of years since 1973. The median family income (in thousands of dollars) for the black population in the United States is given by $f(x) = (2/3)x + 6$.
- (a) Graph both functions on the same coordinate axes.
- (b) Do the graphs intersect? If so, in what year was median family income the same for white and black populations?
- (c) What can you infer from the two graphs in part (a)?

Management Suppose that you are the manager of a firm. You are considering the manufacture of a new product, so you ask the accounting department to produce cost estimates and the sales department to produce sales estimates. After you receive the data, you must decide whether to go ahead with production of the new product. Analyze the following data (find a break-even point) and then decide what you would do. (See Example 7.)

37. $C(x) = 80x + 7000$; $R(x) = 95x$; no more than 400 units can be sold.

38. $C(x) = 65x + 9500$; $R(x) = 80x$; no more than 600 units can be sold.

39. $C(x) = 140x + 3000$; $R(x) = 125x$ (Hint: what does a negative value of x mean?)

40. $C(x) = 1750x + 95,000$; $R(x) = 1750x$

41. **Management** The revenue in millions of dollars from sales of x units at a home supplies outlet is given by $R(x) = 3x$. The profit in millions of dollars from sales of x units is given by $P(x) = 2x - .5$.

- (a) Find the cost function.
- (b) Find $C(7)$.
- (c) What is the marginal cost?

MATHEMATICS OF FINANCE

deposits \$10,000 at the beginning of years in an account paying 5% compounded quarterly so that he will have \$10,000 in 8 years.

He then puts the total amount on account paying 6% compounded annually for the entire 21-year period.

He should deposit at the end of each quarter so that he will have \$10,000 in 8 years.

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Connection Exercises

How many years would it take until the value of this investment would be greater than the amount the firm would have if it had simply invested its original \$7 million at the same rate (instead of buying lottery tickets)? (Hint: Experiment with different values of n , the number of years.)

- (b) How many years would it take in part (a) at an interest rate of 12%?

58. Diane Gray sells some land in Nevada. She will be paid a lump sum of \$60,000 in 7 yr. Until then, the buyer pays 8% simple interest quarterly.

- (a) Find the amount of each quarterly interest payment.

- (b) The buyer sets up a sinking fund so that enough money will be present to pay off the \$60,000. The buyer wants to make semiannual payments into the sinking fund; the account pays 6% compounded semiannually. Find the amount of each payment into the fund.

- (c) Prepare a table showing the amount in the sinking fund after each deposit.

59. Joe Seniwi bought a rare stamp for his collection. He agreed to pay a lump sum of \$4000 after 5 yr. Until then, he pays 6% simple interest semiannually.

- (a) Find the amount of each semiannual interest payment.

- (b) Seniwi sets up a sinking fund so that enough money will be present to pay off the \$4000. He wants to make annual payments into the fund. The account pays 8% compounded annually. Find the amount of each payment.

- (c) Prepare a table showing the amount in the sinking fund after each deposit.

5.4 PRESENT VALUE OF AN ANNUITY; AMORTIZATION

Suppose that at the end of each year, for the next 10 years, \$500 is deposited in a savings account paying 7% interest compounded annually. This is an example of an ordinary annuity. The **present value** of this annuity is the amount that would have to be deposited in one lump sum today (at the same compound interest rate) in order to produce exactly the same balance at the end of 10 years. We can find a formula for the present value of an annuity as follows.

COURSE FLEXIBILITY

The book can be used for a variety of courses, including the following:

Finite Mathematics and Calculus (one year or less) Use the entire book; cover topics from Chapters 1–4 as needed before proceeding to further topics.

Finite Mathematics (one semester or two quarters) Use as much of Chapters 1–4 as needed, and then go into the topics of Chapters 5–10 as time permits and local needs require.

Calculus (one semester or quarter) Use Chapters 1–4 as necessary and then use Chapters 11–14.

College Algebra with Applications (one semester or quarter) Use Chapters 1–8 with the topics of Chapters 7 and 8 being optional.

Chapter interdependence is as follows.

Chapter	Prerequisite
1 Fundamentals of Algebra	None
2 Functions and Graphs	None
3 Polynomial and Rational Functions	Chapter 2
4 Exponential and Logarithmic Functions	Chapter 2
5 Mathematics of Finance	Chapter 4
6 Systems of Linear Equations and Matrices	None
7 Linear Programming	Chapters 2, 6
8 Sets and Probability	None
9 Further Topics in Probability	Chapter 8
10 Introduction to Statistics	Chapter 8
11 Differential Calculus	Chapters 2–4
12 Applications of the Derivative	Chapter 11
13 Integral Calculus	Chapters 11–12
14 Multivariate Calculus	Chapters 11–13

SUPPLEMENTS

FOR THE INSTRUCTOR

Our extensive supplemental package includes an instructor's guide, answer manual, and software. A number of other related materials are available, and are also listed below.

Instructor's Guide with Tests and Solutions The *Instructor's Guide with Tests and Solutions* includes a lengthy set of test questions for each chapter, organized by section, plus answers to all of the test questions. It also includes one pretest, in a short-answer format. This manual also contains solutions to the even-numbered section exercises, which, with the *Student's Solution Manual* together provide detailed, worked-out solutions to each exercise in the book. Finally, this guide includes a list of all conceptual, writing, challenging, connection, and grapher exercises.

Instructor's Answer Manual This manual includes answers to every exercise in the book. This manual also includes a list of all conceptual, writing, challenging, connection, and grapher exercises.

Printed Test Forms This manual includes three different but equivalent tests for each chapter generated using the HarperCollins Test Generator/Editor for Mathematics (described below).

HarperCollins Test Generator/Editor for Mathematics with QuizMaster Available in IBM and Macintosh versions, the test generator is fully networkable. The test generator enables instructors to select questions by objective, section, or chapter, or to use a ready-made test for each chapter. The editor enables instructors to edit any preexisting data or to create their own questions. The software is algorithm driven, allowing the instructor to regenerate constants while maintaining problem type, providing a nearly unlimited number of available test or quiz items in multiple-choice and/or open-response formats for one or more test forms. The system features printed graphics and accurate mathematics symbols. **QuizMaster** enables instructors to create tests and quizzes using the Test Generator/Editor and save them to disk so students can take the test or quiz on a stand-alone computer or network. **QuizMaster** then grades the test or quiz and allows the instructor to create reports on individual students or entire classes.

Overhead Transparencies A set of two-color transparencies is available to help enhance lectures.

FOR THE STUDENT

Student's Solution Manual This book provides solutions to the odd-numbered section exercises, odd-numbered chapter review exercises, and all case study exercises. (ISBN 0-673-46944-1)

Topics in Finite Mathematics: An Introduction to the Electronic Spreadsheet, by Sam Spero, Cuyahoga Community College (ISBN 0-065-00300-4), is a user-friendly guide designed to introduce students to the various ways one can approach problem solving with spreadsheets. Knowledge of spreadsheets is not assumed, and the approach is adaptable to all spreadsheet programs.

The Electronic Spreadsheet and Elementary Calculus, by Sam Spero, Cuyahoga Community College (ISBN 0-673-46595-0), is a companion to *Topics in Finite Mathematics: An Introduction to the Electronic Spreadsheet*. This guide helps students get started with graphing and problem solving by means of the spreadsheet. As with the companion volume, knowledge of spreadsheets is not assumed, and the approach is adaptable to all spreadsheet programs.

Interactive Mathematics Tutorial Software with Management System This innovative package is available in IBM (both DOS and Windows formats) and Macintosh versions and is fully networkable. As with the Test Generator/Editor, this software is algorithm driven, which automatically regenerates constants so a student will not see the numbers repeat in a problem type if he or she revisits any particular section. The tutorial is objective-based,

self-paced, and provides unlimited opportunities to review lessons and to practice problem solving. If students give a wrong answer, they can request to see the problem worked out and get a textbook page reference. The program is menu-driven for ease of use, and on-screen help can be obtained at any time with a single keystroke. Students' scores are automatically recorded and can be printed for a permanent record. The optional **Management System** lets instructors record student scores on disk and print diagnostic reports for individual students or classes. This software may also be purchased by students for home use. (Macintosh version ISBN 0-673-55815-0; IBM version 0-673-55814-2)

GraphExplorer provides students and instructors with a comprehensive graphing utility, and is available in IBM and Macintosh formats.

StatExplorer (IBM and Macintosh), helps students enhance their understanding of statistics by exploring a wide range of statistical representations including graphs, centers and spreads, and transformations.

Explorations in Finite Mathematics (IBM format only), by David Schneider, University of Maryland (ISBN 0-673-46932-8), contains on one disk a wider selection of routines than in any similar software supplement. Included are utilities for Gaussian elimination, matrix operations, graphical and simplex methods for linear programming problems, probability, binomial distribution, simple and compound interest, loan and annuity analysis, finance table, difference equations, and more. Refined monitor display for fractions, color capabilities, choice of exact or approximate calculations with matrices, and refined printing capabilities further set this apart from other programs.

Visual Calculus (IBM format only), by David Schneider, University of Maryland, (ISBN 0-673-99015-X), is intended to enhance the visualization of the fundamental concepts of calculus. Although it has most of the computing power of standard calculus packages, it focuses on the teaching of concepts rather than on the calculations. The program can be run with a CGA, Hercules, MCGA, EGA, or VGA monitor, and can be used with or without a mouse.

Matrix with Linear Programming (IBM format only), by MaylinDittmore (ISBN 0-06-501266-6), is designed to assist the student in any course of study that involves the use of matrices. MATRIX was created not only to help the student with tedious calculations associated with matrices, but also to help them gain an understanding of and appreciation for real-world problems that can be analyzed and solved using matrices.

Developmental Mathematics: Graphing Calculator Investigations, Dennis C. Ebersole, Northampton County Area Community College (ISBN 0-06-501439-1)

College Algebra and Trigonometry: Graphing Calculator Investigations, Dennis C. Ebersole, Northampton County Area Community College (ISBN 0-06-500888-X)

These are intended to supplement a standard text by providing investigations that help students visualize key concepts, look for patterns, generalize and apply concepts.

RELATED BOOKS

Mathematics with Applications, Sixth Edition, is one text within the complete line of Lial/Miller mathematics for management offerings: *Finite Mathematics*, Fifth Edition, *Calculus with Applications*, Fifth Edition, *Calculus with Applications, Brief Version*, Fifth Edition, and *Finite Mathematics and Calculus with Applications*, Fourth Edition.

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Margaret L. Lial
 Thomas W. Hungerford

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To The Student

FEATURES TO AID YOUR UNDERSTANDING

There are many pedagogical features in this text which will enhance your understanding of the concepts.

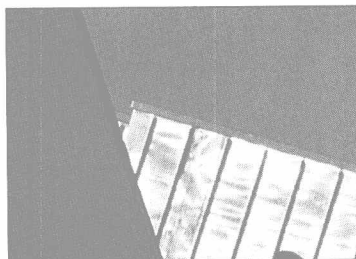
Side problems are one of these features that will help you to learn new concepts and reinforce your understanding. They are referred to in the text by numbers within colored squares: **1**. When you see that symbol, you should work the indicated problem at the side before going on.

One of the main reasons for learning mathematics is to be able to use it to solve practical problems. As its name implies, the purpose of this book is to show how to use mathematics to solve applied problems. However, for many students, learning how to use mathematical skills in real-world applications is the most difficult task they face. A common difficulty students have with applied problems is trying to do everything at once. It is usually best to attack the problem in stages as outlined below:

Solving Applied Problems

1. Decide on the unknown. Name it with some variable that you *write down*. Many students try to skip this step. They are eager to get on with the writing of the equation. But this is an important step. If you don't know what the variable represents, how can you write a meaningful equation or interpret a result?
2. Draw a sketch or make a chart, if appropriate, showing the information given in the problem.

3. Decide on a variable expression to represent any other unknowns in the problem. For example, if x represents the width of a rectangle, and you know that the length is one more than twice the width, then *write down* that the length is $1 + 2x$.
4. Using the results of Steps 1–3, write an equation that expresses a condition that must be satisfied
5. Solve the equation.
6. Check the solution in the words of the *original problem*, not just in the equation you have written.



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