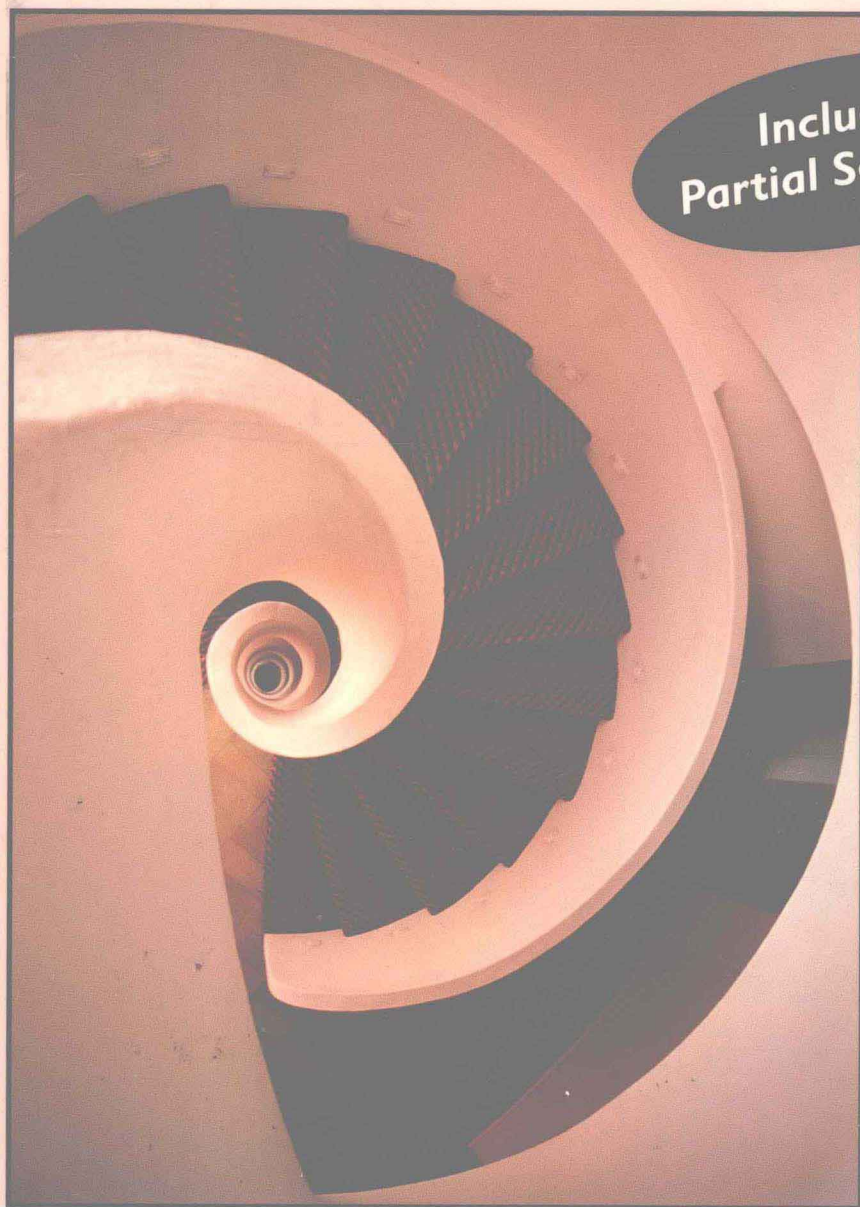


ESSENTIAL ALGEBRA

seventh edition



Includes
Partial Solutions

JOHNSTON • WILLIS • LAZARIS

ESSENTIAL ALGEBRA

seventh edition

C. L. JOHNSTON
ALDEN T. WILLIS
JEANNE LAZARIS



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***This book is dedicated to our students,
who inspired us to do our best
to produce a book worthy of their time.***



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PREFACE

ESSENTIAL ALGEBRA, Seventh Edition, can be used in a beginning algebra course in any community college or four-year college, either with a lecture format, in a learning laboratory setting, or for self-study. The main goal of this book is to prepare students for intermediate algebra and for any other course that requires knowledge of elementary algebra.

Changes in the Seventh Edition

This edition incorporates changes that resulted from many helpful comments from users of the first six editions, as well as from the authors' own classroom experience in teaching from the book. The major changes in the Seventh Edition include the following:




1. Writing Problems have been added throughout the book. We believe that writing about mathematics helps students develop a deeper understanding of the subject. Because communication is one of the essential goals of mathematics, we think that students should be encouraged to express mathematical concepts in writing.
2. Critical Thinking and Problem-Solving Exercises have been added at the end of each chapter. These exercises give the student an opportunity to try types of problems not often seen in elementary mathematics books. Techniques used for solving these problems include, but are not limited to, the following: using logic, looking for patterns or relationships, making organized lists, and guessing-and-checking. Some open-ended critical-thinking questions are asked in these exercises also. Many of the problems are suitable for small-group activities.
3. The objectives for every section are enumerated in an Objectives Checklist found in the printed Test Bank.
4. More material on calculator use has been added whenever appropriate.
5. In Chapter 1 (Real Numbers), factorization of integers is now discussed before finding roots of integers is covered; therefore, the student can find square roots of large numbers by using prime factorization. Simplifying square roots of natural numbers is now discussed in Chapter 1 also.
6. More explanation is provided about how to decide whether a number is rational, irrational, etc., and more instructions are given on graphing numbers on the real number line.
7. The beginning of Chapter 2 (Simplifying and Evaluating Algebraic Expressions) has been reorganized.
8. In solving equations, we now show horizontal addition as the primary method of using the addition property of equality, although vertical addition is still illustrated. (This change was at the request of many users and reviewers of the book.)

9. Section 3.3 (Solving Equations by Using the Multiplication and Division Properties of Equality) has been rewritten and reorganized, with more exercises added to exercise sets. In Section 3.6 (Graphing and Solving Inequalities in One Variable), concrete examples are now given before the rules for solving inequalities, and set-builder notation is introduced.
10. In Chapter 4 (Applications), we emphasize that when we set up an applied problem, “Let” means that we are making a choice and “Then” means that we no longer have a choice. Section 4.5 (Solving Ratio and Rate Problems) has been totally rewritten.
11. In Chapter 5 (Exponents), Section 5.5 has been divided into two parts; zero and negative exponents are introduced in Section 5.5A, and then Section 5.5B is concerned with using the properties of exponents on expressions that contain zero and negative exponents.
12. In Chapter 6 (Polynomials), old Section 6.3A, which was a review of a section from Chapter 5, has been deleted. A new format is used for showing the *FOIL* method for multiplying two binomials. Dividing a monomial by a monomial is now discussed in this chapter.
13. More applied problems have been added in the last section of Chapter 7 (Factoring).
14. Chapter 8 (Rational Expressions) includes a better discussion of what the GCF and LCM *are*. More problems have been added in which students need to reduce rational expressions, as well as problems involving rational expressions in which students have to follow the correct order of operations. At the suggestion of some of the reviewers, the discussion of excluded values has been postponed until solving rational equations is discussed (Section 8.8). A new section (Solving Variation Problems) has been added to Chapter 8.
15. A new section has been added to Chapter 10 (Quadratic Equations), in which we emphasize solving quadratic equations by completing the square. This section includes many examples and exercises that lend themselves particularly well to calculator use.
16. In Chapter 11 (Graphing), the section on writing equations has been rearranged and clarified. Included now are examples and exercises in which we graph a line when the slope of the line and one point on the line are given.
17. At the suggestion of several reviewers (who wanted radicals and the quadratic equation introduced earlier), the chapters at the end of the book have been rearranged. The new order is as follows: Radicals (Chapter 9), Quadratic Equations (Chapter 10), Graphing (Chapter 11), and Systems of Equations (Chapter 12).
18. Topics that are often seen on entry-level tests, exit exams, and so on, have been added whenever appropriate.

Features of This Book

The major features of this book include the following:

1. Over 180 Writing Problems in exercise sets throughout the book motivate students to think about mathematical concepts.
2. Over 60 Critical Thinking and Problem-Solving Exercises at the ends of the chapters stimulate creativity in problem solving.
3. Two or more approaches to the same problem are often discussed because we believe that students need to learn that there is no single correct method for solving a given problem, and that learning mathematics is more than memorizing a set of rules for solving each kind of problem.

4. For the most part, this book uses a one-step, one-concept-at-a-time approach. That is, major topics are divided into small sections, each with its own examples and often with its own exercises. This approach allows students to master each section before proceeding confidently to the next section.
5. Many concrete, annotated examples illustrate the general algebraic principles covered in each section.
6. In special “Word of Caution” screened boxes, students are warned against common algebraic errors.
7. Interspersed throughout the text and the examples are “Notes” that provide students with additional information regarding the topic or example under discussion. These notes are easily identified with the pointing-finger icon: 
8. Visual aids such as shading, color, and annotations guide students through the examples. This new edition makes use of a third color to better differentiate elements in figures and examples.
9. The solutions for many of the examples are explicitly checked in the text, and the importance of checking solutions is emphasized throughout the book.
10. The approach to solving applied problems includes a detailed method for translating English statements into algebraic equations or inequalities and a step-by-step outline of a procedure that can be used in solving many applied problems.
11. Important concepts and algorithms are enclosed in boxes for easy identification and reference.
12. Examples are given of the problem-solving techniques of making an organized list and of guessing-and-checking.
13. The numerous examples and exercises that lend themselves to the use of a scientific or graphics calculator are designated with the corresponding calculator icon:  for a scientific calculator and  for a graphics calculator.
14. The book contains approximately 7,500 exercises, over 25% of which are new to this series:

Set I Exercises All the answers for the Set I Exercises are included in the back of the book, along with **completely worked-out solutions** for nearly all the odd-numbered exercises. Most of the even-numbered Set I Exercises are matched to the odd-numbered exercises. Thus, students can use the solutions of the odd-numbered exercises as examples and study aids for doing the even-numbered Set I exercises.

Set II Exercises The answers for the Set II exercises are given in the *Annotated Instructor's Edition* and in the printed Test Bank. The odd-numbered exercises of Set II are usually matched to the odd-numbered exercises of Set I.

Set II Review Exercises The Set II Review Exercises allow space for working problems and for writing answers; the pages can be removed from the book for grading without interrupting the continuity of the text.

15. A Diagnostic Test at the end of each chapter can be used for study and review or as a pretest. There are also mid-chapter Diagnostic Tests in Chapters 1 and 8. Complete solutions to all the problems in these diagnostic tests, together with section references, appear in the answer section at the back of this book.
16. A set of Cumulative Review Exercises is included at the end of each chapter except Chapter 1; the answers are in the answer section at the back of this book.

Major topics are divided into small manageable sections, as part of the book's one-step, one-concept-at-a-time approach

Boxes enclose important concepts and algorithms, for easy identification and reference

"Notes" to students provide additional information or point out problem-solving hints

3.4B Solving Equations That Contain Grouping Symbols

When grouping symbols appear in an equation, first we remove them, and then we solve the resulting equation by the methods discussed in the previous sections. We suggest the following procedure for solving a first-degree equation (an equation in which the exponent on the variable is understood to be 1) in one variable:

Solving a first-degree equation in one variable

1. If there are any grouping symbols, remove them.
2. At each step, combine like terms (if there are any) on each side of the equation.
3. If the variable appears on both sides of the equation, rewrite the equation so that all terms containing the variable appear on only one side of the equation; do this by adding the additive inverse of one term that contains the variable to both sides of the equation or by subtracting that term from both sides. (If we add the *additive inverse* of the term with the smaller coefficient to both sides of the equation, the coefficient of the sum of the x -terms will be positive.)
4. Remove all the numbers that appear on the same side of the equation as the variable, as follows:
First, remove any numbers being added to (or subtracted from) the term containing the variable by using the addition (or subtraction) property of equality. *Next*, complete the solution by multiplying both sides of the equation by the reciprocal of the coefficient of the variable, or complete the solution by using the two-step method (clearing fractions and then dividing both sides of the equation by the coefficient of the variable).
5. Check the apparent solution in the *original* equation.

Note In step 4 in the box above, we suggest using the addition property first and then the multiplication or division property. It is possible to use the multiplication (or even the division) property first, but we believe that the order we recommend in step 4 normally makes solving an equation relatively easy.

EXAMPLE 4

Solve and check the equation $10x - 2(3 + 4x) = 7 - (x - 2)$, and graph its solution on the number line.

SOLUTION

$$\begin{array}{lcl}
 10x - 2(3 + 4x) = 7 - (x - 2) & & \text{Addition shown vertically} \\
 10x - 6 - 8x = 7 - x + 2 & \text{Removing the grouping symbols} & \\
 2x - 6 = -x + 9 & \text{Combining like terms; the smaller coefficient is } -1 & \begin{array}{r} 2x - 6 = -x + 9 \\ + x \quad + x \\ \hline 3x - 6 = -x + 9 \\ + 6 \quad + 6 \\ \hline 3x = -x + 15 \end{array} \\
 x + 2x - 6 = x + (-x) + 9 & \text{Adding } x \text{ to both sides to get the } x\text{-terms all on one side} & \\
 3x - 6 = 9 & & \text{We must now remove } -6 \text{ from the left side} \\
 3x - 6 + 6 = 9 + 6 & \text{Adding } +6 \text{ to both sides} & \\
 3x = 15 & \text{The coefficient of } x \text{ is } 3 & \\
 \frac{3x}{3} = \frac{15}{3} & \text{Dividing both sides by } 3 & \\
 x = 5 & \text{The apparent solution} &
 \end{array}$$

A Word of Caution Notice the difference between the equations (a) $2x = 10$ and (b) $2 + x = 10$. In (a), 2 and x are *factors*; that is, 2 is multiplied by x . We isolate x by dividing both sides of the equation by 2 (or by multiplying both sides of the equation by $\frac{1}{2}$). In (b), 2 and x are *terms*; that is, 2 is added to x . We isolate x by adding -2 to both sides of the equation (or by subtracting 2 from both sides of the equation).

EXAMPLE 2

Solve and check the equation $9x = -27$, and graph the solution on the number line.

SOLUTION

Using the division property

We isolate x by dividing both sides by 9, the coefficient of x .

$$\begin{array}{l}
 9x = -27 \\
 \frac{9x}{9} = \frac{-27}{9} \\
 x = -3
 \end{array}$$

Using the multiplication property

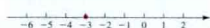
We isolate x by multiplying both sides by $\frac{1}{9}$, the reciprocal of 9.

$$\begin{array}{l}
 9x = -27 \\
 \left(\frac{1}{9}\right)(9x) = \left(\frac{1}{9}\right)(-27) \\
 x = -3
 \end{array}$$

Check $9x = -27$
 $9(-3) \stackrel{?}{=} -27$ Substituting -3 for x
 $-27 = -27$ A true statement

Therefore, the solution is -3 .

Graph



EXAMPLE 3

Solve and check the equation $-12x = 8$, and graph the solution on the number line.

SOLUTION

Using the division property

We isolate x by dividing both sides by -12 , the coefficient of x .

$$\begin{array}{l}
 -12x = 8 \\
 \frac{-12x}{-12} = \frac{8}{-12} \\
 x = -\frac{2}{3}
 \end{array}$$

Using the multiplication property

We isolate x by multiplying both sides by $-\frac{1}{12}$, the reciprocal of -12 .

$$\begin{array}{l}
 -12x = 8 \\
 \left(-\frac{1}{12}\right)(-12x) = \left(-\frac{1}{12}\right)(8) \\
 x = -\frac{2}{3}
 \end{array}$$

(You can verify that $\frac{-2}{3}$ and $(-\frac{2}{3})(8)$ both reduce to $-\frac{16}{3}$.)

In special screened boxes labeled "A Word of Caution," students are warned against common errors

The importance of checking solutions is reiterated throughout the book

Two or more approaches to solving a problem are often presented side by side

In Exercises 16–20, set up each problem algebraically, solve, and check. Be sure to state what your variables represent.

16. The sum of two consecutive integers is 33. What are the integers?
 17. The sum of two numbers is 5. Their product is -24. What are the numbers?
 18. A dealer makes up a 15-lb mixture of oranges. One kind costs 78¢ per pound, and the other costs 99¢ per pound. How many pounds of each kind must be used in order for the mixture to cost 85¢ per pound?

19. Manny has twenty coins with a total value of \$1.65. If the coins are all nickels and dimes, how many of each does he have?
 20. Ricardo drove at a certain rate for 4 hr. If he had been able to drive 11 mph faster, the trip would have taken 3 hr. How fast did he drive? How far did he drive?



Critical Thinking and Problem-Solving Exercises

1. One day recently, Tad, Ted, and Adam were eating apples. Tad and Adam each ate the same number of apples, and they each ate at least one apple. Ted ate the most apples, and he ate fewer than 10. The product of the numbers of apples eaten by all three people was 12. How many apples did each person eat?

2. Julia, Ned, Sean, and Tiffany met for breakfast. Each ordered a different item for breakfast, and each was in a different type of business. The items ordered were pancakes, Belgian waffles, eggs Benedict, and oatmeal. Using the following clues, determine who sat in which chair, what business each person was in, and what each person ordered for lunch.

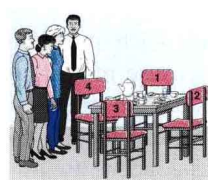
The dentist was not sitting in seat 2 or 3.
 The machinist sat opposite the sales associate, who ordered eggs Benedict.

Julia sat in seat 2.
 Tiffany sat in an odd-numbered seat, opposite the person who ordered pancakes.

The machinist sat in seat 4 and ate oatmeal.

Ned is a dentist.

One person is an optician.



3. Three friends were comparing notes about reading. They discovered that in the last four months, the total number of books that Victor and Nina had read was 16, the total number of books that Nina and Ryan had read was 20, and the total number of books that Victor and Ryan had read was 22. How many books had each person (individually) read?

4. Consider the following algebraic expressions: $x + y$, $x - y$, $y - x$, $y + x$, $-y + x$, $-x + y$, $-x - y$, and $-y - x$.

- a. Name (if there are any) the pairs that are equal to each other.

- b. Name all the expressions that are the additive inverses of $x + y$.

- c. Name all the expressions that are the additive inverses of $x - y$.

5. The solution of each of the following problems contains an error. Find and describe the error, and solve each problem correctly.

- a. Simplify $\frac{4}{x} + \frac{2}{x+2}$.
 LCD = $x(x+2)$

$$\frac{4}{x(x+2)} + \frac{2}{x(x+2)} = \frac{4x+2}{x(x+2)} = 4x+2$$

- b. Simplify $\frac{1 - \frac{1}{x^2}}{1 - \frac{1}{x}}$

$$\frac{1 - \frac{1}{x^2}}{1 - \frac{1}{x}} = \frac{\frac{x^2 - 1}{x^2}}{\frac{x - 1}{x}} = \frac{x^2 - 1}{x^2} \cdot \frac{x}{x - 1} = \frac{(x+1)(x-1)}{x^2} \cdot \frac{x}{x-1} = \frac{x+1}{x}$$

NEW!

“Critical Thinking and Problem-Solving Exercises” have been added at the end of every chapter

Large, screened cross-out marks indicate incorrect procedures and anticipate common stumbling blocks for students

All new artwork enhances students’ ability to visualize problems and examples

Fully worked out solutions are given, with careful one-step-at-a-time explanation provided and problem-solving points highlighted

Calculator icons designate examples and exercises appropriate for solving with a scientific or graphics calculator

NEW!

“Writing Problems” have been added throughout the text and are denoted by a pencil icon

EXAMPLE 5

Solve $3(2x - 5) = 2x + 4(x - 1)$, or identify the equation as either an identity or an equation with no solution.

SOLUTION

$$\begin{aligned} 3(2x - 5) &= 2x + 4(x - 1) \\ 6x - 15 &= 2x + 4x - 4 && \text{Removing parentheses} \\ 6x - 15 &= 6x - 4 && \text{Combining like terms} \\ -6x + 6x - 15 &= -6x + 6x - 4 && \text{Adding } -6x \text{ to both sides} \\ -15 &= -4 && \text{A false statement} \end{aligned}$$

When we tried to isolate x , all the x 's dropped out. Because the two sides of the equation reduced to different constants and we obtained a *false statement* ($-15 = -4$), the equation is an equation with no solution. (The solution set is the empty set, $\{\}$.)

Exercises 3.5

Set I

Find the solution of each conditional equation. Identify any equation that is *not* a conditional equation as either an identity or an equation with no solution.

- $x + 3 = 8$
- $x - 4 = 6$
- $2x + 5 = 7 + 2x$
- $10 - 5y = 8 - 5y$
- $6 + 4x = 4x + 6$
- $7x + 12 = 12 + 7x$
- $5x - 2(4 - x) = 6$
- $8x - 3(5 - x) = 7$
- $6x - 3(5 + 2x) = -15$
- $4x - 2(6 + 2x) = -12$
- $4x - 2(6 + 2x) = -15$

- $6x - 3(5 + 2x) = -12$
- $7(2 - 5x) - 32 = 10x - 3(6 + 15x)$
- $6(3 - 4x) + 10 = 8x - 3(2 - 3x)$
- $2(2x - 5) - 3(4 - x) = 7x - 20$
- $3(x - 4) - 5(6 - x) = 2(4x - 21)$
- $2(3 - 4(5 - x)) = 2(3x - 11)$
- $3(5 - 2(7 - x)) = 6(x - 7)$

In Exercises 19 and 20, if the equation is conditional, round off the solution to three decimal places.

- $460.2x - 23.6(19.5x - 51.4) = 1.21304$
- $46.2x - 23.6(19.5x - 51.4) = 213.04$



Writing Problems

Express the answers in your own words and in complete sentences.

- Explain why $x + 7 = 2$ is a conditional equation.
- Determine whether $3x + 2 = 3(x + 2)$ is a conditional equation, an equation with no solution, or an identity. Then explain why you reached that conclusion.

- Determine whether $5x + 60 = 5(x + 12)$ is a conditional equation, an equation with no solution, or an identity. Then explain why you reached that conclusion.

Using This Book

As mentioned earlier, *Essential Algebra*, Seventh Edition, can be used in three types of instructional programs: lecture, laboratory, and self-study.

The Conventional Lecture Course This book has been class-tested and used successfully in conventional lecture courses by the authors and by many other instructors. It is not a workbook, and therefore it contains enough material to stimulate classroom discussion. Examinations for each chapter are provided in the printed Test Bank, and two different kinds of computer software enable instructors to create their own tests. Tutorial software is available to help students who require extra assistance.

The Learning Laboratory Class This text has also been used successfully in many learning labs. The format of explanation, example, and exercises in each section of the book and the tutorial software make the book easy to use in laboratories. Students can use the diagnostic test at the end of each chapter as a pretest or for review and diagnostic purposes. Because several forms of each chapter test are available in the printed Test Bank and because test generators are available, a student who does not pass a test can review the material covered on that test and can then take a different form of the test.

Self-Study This book lends itself to self-study because each new topic is short enough for the student to master before continuing, and because more than 1,000 examples and over 1,900 completely solved exercises show students exactly how to proceed. Students can use the Diagnostic Test at the end of each chapter to determine which parts of that chapter they need to study and can thus concentrate on those areas in which they have weaknesses. The tutorial software extends the usefulness of the new edition in laboratory and self-study settings.

In addition to assigning the writing problems that appear in this text, instructors might also encourage students to keep a journal and/or to do other writing about their feelings about mathematics.

Please note that Chapter 4, the chapter on applied problems, need not be covered all at once. It is quite possible to cover one or two sections with Chapter 5, one or two sections with Chapter 6, one or two sections with Chapter 7, and so on.

Also note that the even-numbered problems of Set II can be especially challenging to students, since these problems are not necessarily matched to any other problems and sometimes include problems for which *no* examples are given. (Some instructors assign only these problems as homework to be collected and graded.)

Ancillaries

The following ancillaries are available with this text:

- **Annotated Instructor's Edition** includes the complete student text along with answers to most of the exercises printed adjacent to each exercise in a fourth color—purple. Also included are five teaching essays, written by leading mathematics educators, offering ideas to both new and experienced instructors on teaching developmental mathematics.
- **Test Bank with Answers to Set II Exercises** includes five different exams for each chapter, two forms for each of three unit exams, five forms of the midchapter exams for Chapters 1 and 8, and two forms of the final exam. All these exams, which can be easily removed and duplicated for class use, are prepared with adequate workspace; answer keys for these exams, with complete solutions, are provided in this printed manual. The Test Bank also contains the answers to the Set II Exercises and answers to many of the Critical Thinking and Problem-Solving Exercises. An Objectives Checklist is also included, which lists objectives for each section of the text.

- **Computerized Testing Programs** are available. **EXPTest** is available in both Windows and DOS versions for the IBM PC and compatibles; **ExamBuilder** is available for the Macintosh. Questions are multiple choice, true-false, and open-ended. Instructors can add to, delete, or change existing questions and produce individual tests. Demos are available.
- **MathQUEST™ Tutorial Software** is a text-specific, intuitive tutorial, which runs on Microsoft Windows and Macintosh platforms. It allows students to practice the skills taught in the textbook section by section. The tutorial provides hints at the first wrong answer and a detailed solution at the second wrong answer. Students can also view the detailed solution after working the problem. The format is mainly fill-in-the-blank, with some multiple choice. This diagnostic program keeps track of right and wrong responses and can report on the student's progress to the instructor. A demo is available.
- **Expert Algebra Tutor Tutorial Software** is a text-specific tutoring software system, available for IBM PC and compatibles with DOS. It uses an interactive format to tailor lessons to the specific learning problems of students. The multiple-choice questions help students master mathematical ideas and procedures. Demos are available.
- **Videotape Series** is a new text-specific series that teaches key topics in the text and features professional math instructors.

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FOREWORD

To the Student

Mathematics is not a spectator sport! Mathematics is learned by *doing*, not by watching. (The fact that you “understand everything the teacher does on the board” does not mean that you have learned the material!) No textbook can teach mathematics to you, and no instructor can teach mathematics to you; the best that both can do is to help *you* learn.

If you have not been successful in mathematics courses previously and if you really want to succeed now, we strongly recommend that you obtain and study *Mastering Mathematics: How to Be a Great Math Student*, Second Edition, by Richard Manning Smith (Belmont, CA: Wadsworth Publishing Company, 1994). This little book contains *many* fine suggestions for studying, a few of which are listed below:

- Attend all classes. Missing even one class can put you behind in the course by at least two classes. To quote Mr. Smith on this topic:

My experience provides irrefutable evidence that you are much more likely to be successful if you attend *all* classes, always arriving on time or a little early. If you are even a few minutes late, or if you miss a class entirely, you risk feeling lost in class when you finally do get there. Not only have you wasted the class time you missed, but you may spend most or all of the first class after your absence trying to catch up. (p. 46)

- Learn as much as you can during class time.
- Sit in the front of the classroom.
- Take complete class notes.
- Ask questions about class notes.
- Solve homework problems on time (*before* the next class).
- Ask questions that deal with course material.
- Organize your notebook.
- Read other textbooks.
- Don't make excuses.

Mastering Mathematics: How to Be a Great Math Student also gives specific suggestions about getting ready for a math course even before the course begins, preparing for tests (including the final exam), coping with a bad teacher, improving your attitude toward math, using class time effectively, avoiding “mental blocks,” and so forth.

Two Final Notes (1) If you see a word in this book with which you are not familiar, *look it up in the dictionary*. Learning to use a dictionary effectively is a major part of your education. (2) **It is impossible to overemphasize the value of doing homework!**

It is important for you to realize that, to a very great extent, you can take charge of and have control over your success in mathematics. We believe that studying from *Essential Algebra*, Seventh Edition, can help you be successful.

CONTENTS

Preface
Foreword to the Student

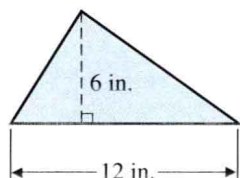
ix
xvii

Chapter 1 **Real Numbers**

- 1.1** Basic Definitions **2**
- 1.2** Negative Numbers and Rational Numbers **7**
- 1.3** Absolute Value; Adding Integers and Other Signed Numbers **11**
- 1.4** Subtracting Integers and Other Signed Numbers **20**
- 1.5** Multiplying Integers and Other Signed Numbers **24**
- 1.6** Dividing Integers and Other Signed Numbers **30**
- Sections 1.1–1.6 Review* **34**
- Sections 1.1–1.6 Diagnostic Test* **39**
- 1.7** The Commutative, Associative, and Distributive Properties of Real Numbers **39**
- 1.8** Finding Powers of Integers and Other Signed Numbers **47**
- 1.9** Factoring Integers **51**
- 1.10** Finding Roots of Integers and Other Signed Numbers **56**
- 1.11** Grouping Symbols; Order of Operations **74**
- 1.12** Preparing to Solve Applied Problems **83**
- Sections 1.7–1.12 Review* **84**
- Chapter 1 Diagnostic Test* **89**
- Critical Thinking and Problem-Solving Exercises* **90**

Chapter 2 **Simplifying and Evaluating Algebraic Expressions**

91



- 2.1** Basic Definitions **92**
- 2.2** Using the Distributive Property **98**
- 2.3** Evaluating Algebraic Expressions **111**
- 2.4** Using Formulas **114**

2.5	Solving Applied Problems by Using Formulas	118
	<i>Sections 2.1–2.5 Review</i>	120
	<i>Chapter 2 Diagnostic Test</i>	125
	<i>Chapters 1 and 2 Cumulative Review Exercises</i>	125
	<i>Critical Thinking and Problem-Solving Exercises</i>	126

Chapter 3

Solving Equations and Inequalities

127

3.1	Conditional Equations; Solutions and Solution Sets; Equivalent Equations	128
3.2	Solving Equations by Using the Addition and Subtraction Properties of Equality	130
3.3	Solving Equations by Using the Multiplication and Division Properties of Equality	135
3.4	Solving Equations in Which Simplification of Algebraic Expressions Is Necessary	149
3.5	Conditional Equations, Identities, and Equations with No Solution	156
3.6	Graphing and Solving Inequalities in One Variable	160
	<i>Sections 3.1–3.6 Review</i>	170
	<i>Chapter 3 Diagnostic Test</i>	175
	<i>Chapters 1–3 Cumulative Review Exercises</i>	175
	<i>Critical Thinking and Problem-Solving Exercises</i>	176

Chapter 4

Applications

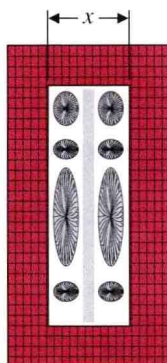
177



4.1	Problem Solving—Translating English Expressions into Algebraic Expressions	178
4.2	Translating Statements into Equations	186
4.3	Solving Applied Problems by Using Algebra	189
4.4	Solving Money Problems	196
4.5	Solving Ratio and Rate Problems	201
4.6	Solving Percent Problems	208
4.7	Solving Distance-Rate-Time Problems	213
4.8	Solving Mixture Problems	220
4.9	Solving Solution Mixture Problems	225
4.10	Miscellaneous Applications	230
	<i>Sections 4.1–4.10 Review</i>	231
	<i>Chapter 4 Diagnostic Test</i>	235
	<i>Chapters 1–4 Cumulative Review Exercises</i>	235
	<i>Critical Thinking and Problem-Solving Exercises</i>	236

Chapter 5**Exponents****237**

- 5.1** Multiplying Exponential Numbers 238
- 5.2** Simplifying Products of Factors 240
- 5.3** Using the Distributive Property; Simplifying Algebraic Expressions 242
- 5.4** More Properties of Exponents 245
- 5.5** Zero and Negative Exponents 251
- 5.6** Scientific Notation 261
- Sections 5.1–5.6 Review* 267
- Chapter 5 Diagnostic Test* 271
- Chapters 1–5 Cumulative Review Exercises* 271
- Critical Thinking and Problem-Solving Exercises* 272

Chapter 6**Polynomials****273**

- 6.1** Basic Definitions 274
- 6.2** Simplifying, Adding, and Subtracting Polynomials 278
- 6.3** Multiplying Polynomials 282
- 6.4** Special Products 293
- 6.5** Dividing Polynomials 297
- 6.6** Applied Problems and Polynomials 308
- Sections 6.1–6.6 Review* 309
- Chapter 6 Diagnostic Test* 315
- Chapters 1–6 Cumulative Review Exercises* 315
- Critical Thinking and Problem-Solving Exercises* 316

Chapter 7**Factoring****317**

- 7.1** Factoring Polynomials That Contain a Common Factor 318
- 7.2** Factoring the Difference of Two Squares 328
- 7.3** Factoring Trinomials 332
- Sections 7.1–7.3 Review* 346
- 7.4** Factoring by Grouping 349
- 7.5** The Master Product Method for Factoring Trinomials (Optional) 352
- 7.6** Factoring Completely; Selecting the Method of Factoring 354
- 7.7** Solving Equations by Factoring 357

7.8	Solving Applied Problems by Factoring	363
	<i>Sections 7.4–7.8 Review</i>	371
	<i>Chapter 7 Diagnostic Test</i>	375
	<i>Chapters 1–7 Cumulative Review Exercises</i>	375
	<i>Critical Thinking and Problem-Solving Exercises</i>	376

Chapter 8

Rational Expressions

377

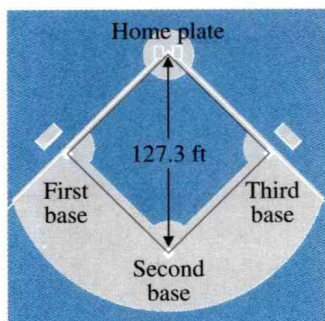
8.1	Basic Definitions	378
8.2	Reducing Rational Expressions to Lowest Terms	380
8.3	Multiplying and Dividing Rational Expressions	387
8.4	Adding and Subtracting Rational Expressions That Have the Same Denominator	396
8.5	The Least Common Multiple (LCM) and the Least Common Denominator (LCD)	400
8.6	Adding and Subtracting Rational Expressions That Have Different Denominators	404
8.7	Simplifying Complex Fractions	411
	<i>Sections 8.1–8.7 Review</i>	415
	<i>Sections 8.1–8.7 Diagnostic Test</i>	419
8.8	Solving Rational Equations	419
8.9	Solving Literal Equations	434
8.10	Solving Applied Problems That Involve Rational Expressions	438
8.11	Solving Variation Problems (Optional)	447
	<i>Sections 8.8–8.11 Review</i>	453
	<i>Chapter 8 Diagnostic Test</i>	457
	<i>Chapters 1–8 Cumulative Review Exercises</i>	457
	<i>Critical Thinking and Problem-Solving Exercises</i>	458

Chapter 9

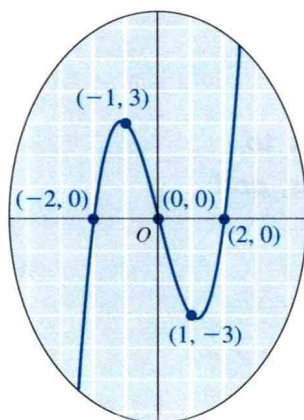
Radicals

459

9.1	Simplifying Square Roots	460
9.2	Multiplying and Dividing Square Roots	466
9.3	Adding and Subtracting Square Roots	471
9.4	Products and Quotients That Involve More Than One Term	476
9.5	Solving Radical Equations	480
	<i>Sections 9.1–9.5 Review</i>	486
	<i>Chapter 9 Diagnostic Test</i>	491
	<i>Chapters 1–9 Cumulative Review Exercises</i>	491
	<i>Critical Thinking and Problem-Solving Exercises</i>	492

Chapter 10**Quadratic Equations****493**

- 10.1** The General Form for Quadratic Equations **494**
- 10.2** Solving Quadratic Equations by Factoring **496**
- 10.3** Solving Incomplete Quadratic Equations **501**
- 10.4** Solving Quadratic Equations by Completing the Square **506**
- 10.5** Solving Quadratic Equations by Using the Quadratic Formula **511**
- 10.6** The Pythagorean Theorem **517**
- Sections 10.1–10.6 Review* **523**
- Chapter 10 Diagnostic Test* **527**
- Chapters 1–10 Cumulative Review Exercises* **527**
- Critical Thinking and Problem-Solving Exercises* **528**

Chapter 11**Graphing****529**

- 11.1** The Rectangular Coordinate System **530**
- 11.2** Solutions of Linear Equations in Two Variables **536**
- 11.3** Graphing Straight Lines **540**
- 11.4** The Slope of a Line **552**
- 11.5** Writing Equations of Straight Lines **561**
- 11.6** Graphing Curves **571**
- 11.7** Graphing Solution Sets of First-Degree Inequalities in Two Variables **577**
- Sections 11.1–11.7 Review* **584**
- Chapter 11 Diagnostic Test* **591**
- Chapters 1–11 Cumulative Review Exercises* **591**
- Critical Thinking and Problem-Solving Exercises* **592**

Chapter 12**Systems of Equations****593**

- 12.1** Basic Definitions **594**
- 12.2** The Graphical Method of Solving a System of Linear Equations **595**
- 12.3** The Elimination Method of Solving a System of Linear Equations **601**
- 12.4** The Substitution Method of Solving a System of Linear Equations **609**

12.5	Using Systems of Equations to Solve Applied Problems	615
	<i>Sections 12.1–12.5 Review</i>	620
	<i>Chapter 12 Diagnostic Test</i>	625
	<i>Chapters 1–12 Cumulative Review Exercises</i>	625
	<i>Critical Thinking and Problem-Solving Exercises</i>	626

Appendix A **Sets**

627

A.1	Basic Definitions	628
A.2	Subsets	631
A.3	Set Union and Set Intersection	632

Appendix B **Brief Review of Arithmetic**

635

Appendix C **Functions**

643

C.1	Definitions	644
C.2	Functional Notation	649

Answers to Set I Exercises (including Solutions to Odd-Numbered Exercises), Diagnostic Tests, and Cumulative Review Exercises	AI
Index	A94