

SULLIVAN




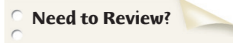
COLLEGE ALGEBRA

ELEVENTH EDITION



This page intentionally left blank


Prepare for Class “Read the Book”

Feature	Description	Benefit	Page
Every Chapter Opener begins with . . .			
Chapter-Opening Topic & Project	Each chapter begins with a discussion of a topic of current interest and ends with a related project.	The Project lets you apply what you learned to solve a problem related to the topic.	414
 Internet-Based Projects	The projects allow for the integration of spreadsheet technology that you will need to be a productive member of the workforce.	The projects give you an opportunity to collaborate and use mathematics to deal with issues of current interest.	516
Every Section begins with . . .			
LEARNING OBJECTIVES 	Each section begins with a list of objectives. Objectives also appear in the text where the objective is covered.	These focus your study by emphasizing what’s most important and where to find it.	435
Sections contain . . .			
PREPARING FOR THIS SECTION	Most sections begin with a list of key concepts to review with page numbers.	Ever forget what you’ve learned? This feature highlights previously learned material to be used in this section. Review it, and you’ll always be prepared to move forward.	435
Now Work the ‘Are You Prepared?’ Problems	Problems that assess whether you have the prerequisite knowledge for the upcoming section.	Not sure you need the Preparing for This Section review? Work the ‘Are You Prepared?’ problems. If you get one wrong, you’ll know exactly what you need to review and where to review it!	435, 446
 Now Work PROBLEMS	These follow most examples and direct you to a related exercise.	We learn best by doing. You’ll solidify your understanding of examples if you try a similar problem right away, to be sure you understand what you’ve just read.	442, 447
WARNING	Warnings are provided in the text.	These point out common mistakes and help you to avoid them.	469
Exploration and Seeing the Concept	These graphing utility activities foreshadow a concept or solidify a concept just presented.	You will obtain a deeper and more intuitive understanding of theorems and definitions.	430, 455
In Words	These provide alternative descriptions of select definitions and theorems.	Does math ever look foreign to you? This feature translates math into plain English.	452
 Calculus	These appear next to information essential for the study of calculus.	Pay attention—if you spend extra time now, you’ll do better later!	210, 419, 442
SHOWCASE EXAMPLES	These examples provide “how-to” instruction by offering a guided, step-by-step approach to solving a problem.	With each step presented on the left and the mathematics displayed on the right, you can immediately see how each step is used.	381
 Model It! Examples and Problems	These examples and problems require you to build a mathematical model from either a verbal description or data. The homework Model It! problems are marked by purple headings.	It is rare for a problem to come in the form “ <i>Solve the following equation.</i> ” Rather, the equation must be developed based on an explanation of the problem. These problems require you to develop models to find a solution to the problem.	459, 488
NEW!  Need to Review?	These margin notes provide a just-in-time reminder of a concept needed now, but covered in an earlier section of the book. Each note is back-referenced to the chapter, section and page where the concept was originally discussed.	Sometimes as you read, you encounter a word or concept you know you’ve seen before, but don’t remember exactly what it means. This feature will point you to where you first learned the word or concept. A quick review now will help you see the connection to what you are learning for the first time and make remembering easier the next time.	428

Practice “Work the Problems”

Feature	Description	Benefit	Page
‘Are You Prepared?’ Problems	These assess your retention of the prerequisite material you’ll need. Answers are given at the end of the section exercises. This feature is related to the Preparing for This Section feature.	Do you always remember what you’ve learned? Working these problems is the best way to find out. If you get one wrong, you’ll know exactly what you need to review and where to review it!	452, 460
Concepts and Vocabulary	These short-answer questions, mainly Fill-in-the-Blank, Multiple-Choice and True/False items, assess your understanding of key definitions and concepts in the current section.	It is difficult to learn math without knowing the language of mathematics. These problems test your understanding of the formulas and vocabulary.	446
Skill Building	Correlated with section examples, these problems provide straightforward practice.	It’s important to dig in and develop your skills. These problems provide you with ample opportunity to do so.	446–448
Applications and Extensions	These problems allow you to apply your skills to real-world problems. They also allow you to extend concepts learned in the section.	You will see that the material learned within the section has many uses in everyday life.	449–451
NEW! Challenge Problems	These problems have been added in most sections and appear at the end of the Application and Extensions exercises. They are intended to be thought-provoking, requiring some ingenuity to solve.	Challenge problems can be used for group work or to challenge your students. Solutions to Challenge Problems are in the Annotated Instructor’s Edition or in the Instructor’s Solution Manual (online).	451
Explaining Concepts: Discussion and Writing	“Discussion and Writing” problems are colored red. They support class discussion, verbalization of mathematical ideas, and writing and research projects.	To verbalize an idea, or to describe it clearly in writing, shows real understanding. These problems nurture that understanding. Many are challenging, but you’ll get out what you put in.	451
Retain Your Knowledge	These problems allow you to practice content learned earlier in the course.	Remembering how to solve all the different kinds of problems that you encounter throughout the course is difficult. This practice helps you remember.	451
Now Work PROBLEMS	Many examples refer you to a related homework problem. These related problems are marked by a pencil and orange numbers.	If you get stuck while working problems, look for the closest Now Work problem, and refer to the related example to see if it helps.	444, 447, 448
Review Exercises	Every chapter concludes with a comprehensive list of exercises to practice. Use the list of objectives to determine the objective and examples that correspond to the problems.	Work these problems to ensure that you understand all the skills and concepts of the chapter. Think of it as a comprehensive review of the chapter.	511–514

Review “Study for Quizzes and Tests”

Feature	Description	Benefit	Page
The Chapter Review at the end of each chapter contains . . .			
Things to Know	A detailed list of important theorems, formulas, and definitions from the chapter.	Review these and you’ll know the most important material in the chapter!	509–510
You Should Be Able to . . .	Contains a complete list of objectives by section, examples that illustrate the objective, and practice exercises that test your understanding of the objective.	Do the recommended exercises and you’ll have mastered the key material. If you get something wrong, go back and work through the objective listed and try again.	510–511
Review Exercises	These provide comprehensive review and practice of key skills, matched to the Learning Objectives for each section.	Practice makes perfect. These problems combine exercises from all sections, giving you a comprehensive review in one place.	511–514
Chapter Test	About 15–20 problems that can be taken as a Chapter Test. Be sure to take the Chapter Test under test conditions—no notes!	Be prepared. Take the sample practice test under test conditions. This will get you ready for your instructor’s test. If you get a problem wrong, you can watch the Chapter Test Prep Video.	514
Cumulative Review	These problem sets appear at the end of each chapter, beginning with Chapter 2. They combine problems from previous chapters, providing an ongoing cumulative review. When you use them in conjunction with the Retain Your Knowledge problems, you will be ready for the final exam.	These problem sets are really important. Completing them will ensure that you are not forgetting anything as you go. This will go a long way toward keeping you primed for the final exam.	515
Chapter Projects	The Chapter Projects apply to what you’ve learned in the chapter. Additional projects are available on the Instructor’s Resource Center (IRC).	The Chapter Projects give you an opportunity to use what you’ve learned in the chapter to the opening topic. If your instructor allows, these make excellent opportunities to work in a group, which is often the best way to learn math.	516
 Internet-Based Projects	In selected chapters, a Web-based project is given.	These projects give you an opportunity to collaborate and use mathematics to deal with issues of current interest by using the Internet to research and collect data.	516

Dedicated to the memory of Mary

College Algebra

Eleventh Edition

Michael Sullivan

Chicago State University



Director, Portfolio Management: *Anne Kelly*
Senior Portfolio Management Analyst: *Dawn Murrin*
Portfolio Management Administrator: *Joseph Colella*
Manager, Courseware QA: *Mary Durnwald*
VP, Production & Digital Studio: *Ruth Berry*
Manager Producer: *Vicki Dreyfus*
Associate Producer: *Stacey Miller*
Manager, Content Development: *Kristina Evans*
Senior Content Developer: *Megan M. Burns*
Managing Producer: *Scott Disanno*
Content Producer: *Peggy McMahon*
Product Marketing Director: *Erin Kelly*

Product Marketer for Precalculus: *Stacey Sveum*
Product Marketing Assistant: *Shannon McCormack*
Field Marketing Manager: *Peggy Lucas*
Senior Publishing Services Analyst, Author Support: *Joe Vetere*
Manager, Rights/ Permissions: *Gina Cheselka*
Manager Design: *Blair Brown*
Manufacturing Buyer: *Carol Melville, LSC Communications*
Cover Illustration: *Tamara Newnam*
Cover Design: *Jerilyn Bockorick, Pearson CSC*
Full Service Vendor: *Pearson, CSC*
Full Service Project Management: *Pearson CSC, Rose Kernan*
Composition: *Pearson CSC*

Copyright © 2020, 2016, 2012 by Pearson Education, Inc. 221 River Street, Hoboken, NJ 07030.

All Rights Reserved. Printed in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms and the appropriate contacts within the Pearson Education Global Rights & Permissions department, please visit www.pearsoned.com/permissions/.

Attributions of third party content appear on page C-1, which constitutes an extension of this copyright page.

MICROSOFT® AND WINDOWS® ARE REGISTERED TRADEMARKS OF THE MICROSOFT CORPORATION IN THE U.S.A. AND OTHER COUNTRIES. SCREEN SHOTS AND ICONS REPRINTED WITH PERMISSION FROM THE MICROSOFT CORPORATION. THIS BOOK IS NOT SPONSORED OR ENDORSED BY OR AFFILIATED WITH THE MICROSOFT CORPORATION.

MICROSOFT AND/OR ITS RESPECTIVE SUPPLIERS MAKE NO REPRESENTATIONS ABOUT THE SUITABILITY OF THE INFORMATION CONTAINED IN THE DOCUMENTS AND RELATED GRAPHICS PUBLISHED AS PART OF THE SERVICES FOR ANY PURPOSE. ALL SUCH DOCUMENTS AND RELATED GRAPHICS ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND. MICROSOFT AND/OR ITS RESPECTIVE SUPPLIERS HEREBY DISCLAIM ALL WARRANTIES AND CONDITIONS WITH REGARD TO THIS INFORMATION, INCLUDING ALL WARRANTIES AND CONDITIONS OF MERCHANTABILITY, WHETHER EXPRESS, IMPLIED OR STATUTORY, FITNESS FOR A PARTICULAR PURPOSE, TITLE AND NON-INFRINGEMENT. IN NO EVENT SHALL MICROSOFT AND/OR ITS RESPECTIVE SUPPLIERS BE LIABLE FOR ANY SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF INFORMATION AVAILABLE FROM THE SERVICES. THE DOCUMENTS AND RELATED GRAPHICS CONTAINED HEREIN COULD INCLUDE TECHNICAL INACCURACIES OR TYPOGRAPHICAL ERRORS. CHANGES ARE PERIODICALLY ADDED TO THE INFORMATION HEREIN. MICROSOFT AND/OR ITS RESPECTIVE SUPPLIERS MAY MAKE IMPROVEMENTS AND/OR CHANGES IN THE PRODUCT(S) AND/OR THE PROGRAM(S) DESCRIBED HEREIN AT ANY TIME. PARTIAL SCREEN SHOTS MAY BE VIEWED IN FULL WITHIN THE SOFTWARE VERSION SPECIFIED.

PEARSON, ALWAYS LEARNING, and MYLAB™MATH are exclusive trademarks owned by Pearson Education, Inc. or its affiliates in the U.S. and/or other countries.

Unless otherwise indicated herein, any third-party trademarks that may appear in this work are the property of their respective owners and any references to third-party trademarks, logos or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson's products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc. or its affiliates, authors, licensees or distributors.

**The student edition of this book has been cataloged by the Library of Congress as follows:
Library of Congress Cataloging-in-Publication Data**

Names: Sullivan, Michael, 1942- author.
Title: College algebra / Michael Sullivan (Chicago State University).
Description: Eleventh edition. | Hoboken, NJ : Pearson, [2020] | Includes index.
Identifiers: LCCN 2018060244 | ISBN 9780135163047
Subjects: LCSH: Algebra--Textbooks. | Algebra--Study and teaching (Higher)
Classification: LCC QA154.3 .S763 2020 | DDC 512.9--dc23 LC record available at <https://lccn.loc.gov/2018060244>

About the Cover:

The image on this book's cover was inspired by a talk given by Michael Sullivan III: *Is Mathematical Talent Overrated?*

The answer is yes. In mathematics, innate talent plays a much smaller role than grit and motivation as you work toward your goal. If you put in the time and hard work, you can succeed in your math course—just as an athlete must work to medal in their sport.

Contents

Three Distinct Series	xiv
The Flagship Series	xv
Preface to the Instructor	xvi
Get the Most Out of MyLab Math	xxi
Resources for Success	xxii
Applications Index	xxiv

R Review 1

R.1 Real Numbers	2
Work with Sets • Classify Numbers • Evaluate Numerical Expressions • Work with Properties of Real Numbers	
R.2 Algebra Essentials	17
Graph Inequalities • Find Distance on the Real Number Line • Evaluate Algebraic Expressions • Determine the Domain of a Variable • Use the Laws of Exponents • Evaluate Square Roots • Use a Calculator to Evaluate Exponents • Use Scientific Notation	
R.3 Geometry Essentials	30
Use the Pythagorean Theorem and Its Converse • Know Geometry Formulas • Understand Congruent Triangles and Similar Triangles	
R.4 Polynomials	39
Recognize Monomials • Recognize Polynomials • Add and Subtract Polynomials • Multiply Polynomials • Know Formulas for Special Products • Divide Polynomials Using Long Division • Work with Polynomials in Two Variables	
R.5 Factoring Polynomials	49
Factor the Difference of Two Squares and the Sum and Difference of Two Cubes • Factor Perfect Squares • Factor a Second-Degree Polynomial: $x^2 + Bx + C$ • Factor by Grouping • Factor a Second-Degree Polynomial: $Ax^2 + Bx + C, A \neq 1$ • Complete the Square	
R.6 Synthetic Division	57
Divide Polynomials Using Synthetic Division	
R.7 Rational Expressions	61
Reduce a Rational Expression to Lowest Terms • Multiply and Divide Rational Expressions • Add and Subtract Rational Expressions • Use the Least Common Multiple Method • Simplify Complex Rational Expressions	
R.8 nth Roots; Rational Exponents	72
Work with n th Roots • Simplify Radicals • Rationalize Denominators and Numerators • Simplify Expressions with Rational Exponents	

1 Equations and Inequalities 81

1.1 Linear Equations	82
Solve a Linear Equation • Solve Equations That Lead to Linear Equations • Solve Problems That Can Be Modeled by Linear Equations	
1.2 Quadratic Equations	92
Solve a Quadratic Equation by Factoring • Solve a Quadratic Equation Using the Square Root Method • Solve a Quadratic Equation by Completing the Square • Solve a Quadratic Equation Using the Quadratic Formula • Solve Problems That Can Be Modeled by Quadratic Equations	

1.3 Complex Numbers; Quadratic Equations in the Complex Number System	104
Add, Subtract, Multiply, and Divide Complex Numbers • Solve Quadratic Equations in the Complex Number System	
1.4 Radical Equations; Equations Quadratic in Form; Factorable Equations	113
Solve Radical Equations • Solve Equations Quadratic in Form • Solve Equations by Factoring	
1.5 Solving Inequalities	119
Use Interval Notation • Use Properties of Inequalities • Solve Inequalities • Solve Combined Inequalities	
1.6 Equations and Inequalities Involving Absolute Value	130
Solve Equations Involving Absolute Value • Solve Inequalities Involving Absolute Value	
1.7 Problem Solving: Interest, Mixture, Uniform Motion, Constant Rate Job Applications	134
Translate Verbal Descriptions into Mathematical Expressions • Solve Interest Problems • Solve Mixture Problems • Solve Uniform Motion Problems • Solve Constant Rate Job Problems	
Chapter Review	144
Chapter Test	147
Chapter Projects	147

2 Graphs **149**

2.1 The Distance and Midpoint Formulas	150
Use the Distance Formula • Use the Midpoint Formula	
2.2 Graphs of Equations in Two Variables; Intercepts; Symmetry	158
Graph Equations by Plotting Points • Find Intercepts from a Graph • Find Intercepts from an Equation • Test an Equation for Symmetry with Respect to the x -Axis, the y -Axis, and the Origin • Know How to Graph Key Equations	
2.3 Lines	169
Calculate and Interpret the Slope of a Line • Graph Lines Given a Point and the Slope • Find the Equation of a Vertical Line • Use the Point-Slope Form of a Line; Identify Horizontal Lines • Use the Slope-Intercept Form of a Line • Find an Equation of a Line Given Two Points • Graph Lines Written in General Form Using Intercepts • Find Equations of Parallel Lines • Find Equations of Perpendicular Lines	
2.4 Circles	185
Write the Standard Form of the Equation of a Circle • Graph a Circle • Work with the General Form of the Equation of a Circle	
2.5 Variation	191
Construct a Model Using Direct Variation • Construct a Model Using Inverse Variation • Construct a Model Using Joint Variation	
Chapter Review	197
Chapter Test	200
Cumulative Review	200
Chapter Project	201

3	Functions and Their Graphs	202
	3.1 Functions	203
	Describe a Relation • Determine Whether a Relation Represents a Function • Use Function Notation; Find the Value of a Function • Find the Difference Quotient of a Function • Find the Domain of a Function Defined by an Equation • Form the Sum, Difference, Product, and Quotient of Two Functions	
	3.2 The Graph of a Function	219
	Identify the Graph of a Function • Obtain Information from or about the Graph of a Function	
	3.3 Properties of Functions	229
	Identify Even and Odd Functions from a Graph • Identify Even and Odd Functions from an Equation • Use a Graph to Determine Where a Function Is Increasing, Decreasing, or Constant • Use a Graph to Locate Local Maxima and Local Minima • Use a Graph to Locate the Absolute Maximum and the Absolute Minimum • Use a Graphing Utility to Approximate Local Maxima and Local Minima and to Determine Where a Function Is Increasing or Decreasing • Find the Average Rate of Change of a Function	
	3.4 Library of Functions; Piecewise-defined Functions	242
	Graph the Functions Listed in the Library of Functions • Analyze a Piecewise-defined Function	
	3.5 Graphing Techniques: Transformations	254
	Graph Functions Using Vertical and Horizontal Shifts • Graph Functions Using Compressions and Stretches • Graph Functions Using Reflections about the x -Axis and the y -Axis	
	3.6 Mathematical Models: Building Functions	267
	Build and Analyze Functions	
	Chapter Review	273
	Chapter Test	277
	Cumulative Review	278
	Chapter Projects	278
4	Linear and Quadratic Functions	280
	4.1 Properties of Linear Functions and Linear Models	281
	Graph Linear Functions • Use Average Rate of Change to Identify Linear Functions • Determine Whether a Linear Function Is Increasing, Decreasing, or Constant • Build Linear Models from Verbal Descriptions	
	4.2 Building Linear Models from Data	291
	Draw and Interpret Scatter Plots • Distinguish between Linear and Nonlinear Relations • Use a Graphing Utility to Find the Line of Best Fit	
	4.3 Quadratic Functions and Their Properties	299
	Graph a Quadratic Function Using Transformations • Identify the Vertex and Axis of Symmetry of a Parabola • Graph a Quadratic Function Using Its Vertex, Axis, and Intercepts • Find a Quadratic Function Given Its Vertex and One Other Point • Find the Maximum or Minimum Value of a Quadratic Function	
	4.4 Building Quadratic Models from Verbal Descriptions and from Data	312
	Build Quadratic Models from Verbal Descriptions • Build Quadratic Models from Data	

4.5	Inequalities Involving Quadratic Functions	321
	Solve Inequalities Involving a Quadratic Function	
	Chapter Review	325
	Chapter Test	327
	Cumulative Review	328
	Chapter Projects	329
5	Polynomial and Rational Functions	330
5.1	Polynomial Functions	331
	Identify Polynomial Functions and Their Degree • Graph Polynomial Functions Using Transformations • Identify the Real Zeros of a Polynomial Function and Their Multiplicity	
5.2	Graphing Polynomial Functions; Models	346
	Graph a Polynomial Function • Graph a Polynomial Function Using a Graphing Utility • Build Cubic Models from Data	
5.3	Properties of Rational Functions	354
	Find the Domain of a Rational Function • Find the Vertical Asymptotes of a Rational Function • Find a Horizontal or an Oblique Asymptote of a Rational Function	
5.4	The Graph of a Rational Function	365
	Graph a Rational Function • Solve Applied Problems Involving Rational Functions	
5.5	Polynomial and Rational Inequalities	380
	Solve Polynomial Inequalities • Solve Rational Inequalities	
5.6	The Real Zeros of a Polynomial Function	387
	Use the Remainder and Factor Theorems • Use Descartes' Rule of Signs to Determine the Number of Positive and the Number of Negative Real Zeros of a Polynomial Function • Use the Rational Zeros Theorem to List the Potential Rational Zeros of a Polynomial Function • Find the Real Zeros of a Polynomial Function • Solve Polynomial Equations • Use the Theorem for Bounds on Zeros • Use the Intermediate Value of Theorem	
5.7	Complex Zeros; Fundamental Theorem of Algebra	401
	Use the Conjugate Pairs Theorem • Find a Polynomial Function with Specified Zeros • Find the Complex Zeros of a Polynomial Function	
	Chapter Review	408
	Chapter Test	411
	Cumulative Review	412
	Chapter Projects	413
6	Exponential and Logarithmic Functions	414
6.1	Composite Functions	415
	Form a Composite Function • Find the Domain of a Composite Function	
6.2	One-to-One Functions; Inverse Functions	423
	Determine Whether a Function Is One-to-One • Obtain the Graph of the Inverse Function from the Graph of a One-to-One Function • Verify an Inverse Function • Find the Inverse of a Function Defined by an Equation	
6.3	Exponential Functions	435
	Evaluate Exponential Functions • Graph Exponential Functions • Define the Number e • Solve Exponential Equations	

6.4	Logarithmic Functions	452
	Change Exponential Statements to Logarithmic Statements and Logarithmic Statements to Exponential Statements • Evaluate Logarithmic Expressions • Determine the Domain of a Logarithmic Function • Graph Logarithmic Functions • Solve Logarithmic Equations	
6.5	Properties of Logarithms	465
	Work with the Properties of Logarithms • Write a Logarithmic Expression as a Sum or Difference of Logarithms • Write a Logarithmic Expression as a Single Logarithm • Evaluate Logarithms Whose Base Is Neither 10 Nor e	
6.6	Logarithmic and Exponential Equations	474
	Solve Logarithmic Equations • Solve Exponential Equations • Solve Logarithmic and Exponential Equations Using a Graphing Utility	
6.7	Financial Models	481
	Determine the Future Value of a Lump Sum of Money • Calculate Effective Rates of Return • Determine the Present Value of a Lump Sum of Money • Determine the Rate of Interest or the Time Required to Double a Lump Sum of Money	
6.8	Exponential Growth and Decay Models; Newton's Law; Logistic Growth and Decay Models	491
	Model Populations That Obey the Law of Uninhibited Growth • Model Populations That Obey the Law of Uninhibited Decay • Use Newton's Law of Cooling • Use Logistic Models	
6.9	Building Exponential, Logarithmic, and Logistic Models from Data	502
	Build an Exponential Model from Data • Build a Logarithmic Model from Data • Build a Logistic Model from Data	
	Chapter Review	509
	Chapter Test	514
	Cumulative Review	515
	Chapter Projects	516

7 Analytic Geometry **517**

7.1	Conics	518
	Know the Names of the Conics	
7.2	The Parabola	519
	Analyze Parabolas with Vertex at the Origin • Analyze Parabolas with Vertex at (h, k) • Solve Applied Problems Involving Parabolas	
7.3	The Ellipse	528
	Analyze Ellipses with Center at the Origin • Analyze Ellipses with Center at (h, k) • Solve Applied Problems Involving Ellipses	
7.4	The Hyperbola	538
	Analyze Hyperbolas with Center at the Origin • Find the Asymptotes of a Hyperbola • Analyze Hyperbolas with Center at (h, k) • Solve Applied Problems Involving Hyperbolas	
	Chapter Review	551
	Chapter Test	552
	Cumulative Review	553
	Chapter Projects	553

8	Systems of Equations and Inequalities	555
8.1	Systems of Linear Equations: Substitution and Elimination	556
	Solve Systems of Equations by Substitution • Solve Systems of Equations by Elimination • Identify Inconsistent Systems of Equations Containing Two Variables • Express the Solution of a System of Dependent Equations Containing Two Variables • Solve Systems of Three Equations Containing Three Variables • Identify Inconsistent Systems of Equations Containing Three Variables • Express the Solution of a System of Dependent Equations Containing Three Variables	
8.2	Systems of Linear Equations: Matrices	570
	Write the Augmented Matrix of a System of Linear Equations • Write the System of Equations from the Augmented Matrix • Perform Row Operations on a Matrix • Solve a System of Linear Equations Using Matrices	
8.3	Systems of Linear Equations: Determinants	584
	Evaluate 2 by 2 Determinants • Use Cramer's Rule to Solve a System of Two Equations Containing Two Variables • Evaluate 3 by 3 Determinants • Use Cramer's Rule to Solve a System of Three Equations Containing Three Variables • Know Properties of Determinants	
8.4	Matrix Algebra	595
	Find the Sum and Difference of Two Matrices • Find Scalar Multiples of a Matrix • Find the Product of Two Matrices • Find the Inverse of a Matrix • Solve a System of Linear Equations Using an Inverse Matrix	
8.5	Partial Fraction Decomposition	612
	Decompose $\frac{P}{Q}$ Where Q Has Only Nonrepeated Linear Factors	
	• Decompose $\frac{P}{Q}$ Where Q Has Repeated Linear Factors • Decompose $\frac{P}{Q}$ Where Q Has a Nonrepeated Irreducible Quadratic Factor • Decompose $\frac{P}{Q}$ Where Q Has a Repeated Irreducible Quadratic Factor	
8.6	Systems of Nonlinear Equations	621
	Solve a System of Nonlinear Equations Using Substitution • Solve a System of Nonlinear Equations Using Elimination	
8.7	Systems of Inequalities	630
	Graph an Inequality • Graph a System of Inequalities	
8.8	Linear Programming	637
	Set Up a Linear Programming Problem • Solve a Linear Programming Problem	
	Chapter Review	645
	Chapter Test	648
	Cumulative Review	649
	Chapter Projects	650
9	Sequences; Induction; the Binomial Theorem	651
9.1	Sequences	652
	List the First Several Terms of a Sequence • List the Terms of a Sequence Defined by a Recursive Formula • Use Summation Notation • Find the Sum of a Sequence	
9.2	Arithmetic Sequences	662
	Determine Whether a Sequence Is Arithmetic • Find a Formula for an Arithmetic Sequence • Find the Sum of an Arithmetic Sequence	

9.3 Geometric Sequences; Geometric Series	669
Determine Whether a Sequence Is Geometric • Find a Formula for a Geometric Sequence • Find the Sum of a Geometric Sequence • Determine Whether a Geometric Series Converges or Diverges • Solve Annuity Problems	
9.4 Mathematical Induction	681
Prove Statements Using Mathematical Induction	
9.5 The Binomial Theorem	685
Evaluate $\binom{n}{j}$ • Use the Binomial Theorem	
Chapter Review	691
Chapter Test	694
Cumulative Review	694
Chapter Projects	695
10 Counting and Probability	696
10.1 Counting	697
Find All the Subsets of a Set • Count the Number of Elements in a Set • Solve Counting Problems Using the Multiplication Principle	
10.2 Permutations and Combinations	702
Solve Counting Problems Using Permutations Involving n Distinct Objects • Solve Counting Problems Using Combinations • Solve Counting Problems Using Permutations Involving n Nondistinct Objects	
10.3 Probability	711
Construct Probability Models • Compute Probabilities of Equally Likely Outcomes • Find Probabilities of the Union of Two Events • Use the Complement Rule to Find Probabilities	
Chapter Review	721
Chapter Test	723
Cumulative Review	724
Chapter Projects	724
Appendix Graphing Utilities	A1
A.1 The Viewing Rectangle	A1
A.2 Using a Graphing Utility to Graph Equations	A3
A.3 Using a Graphing Utility to Locate Intercepts and Check for Symmetry	A5
A.4 Using a Graphing Utility to Solve Equations	A6
A.5 Square Screens	A8
A.6 Using a Graphing Utility to Graph Inequalities	A9
A.7 Using a Graphing Utility to Solve Systems of Linear Equations	A9
Answers	AN1
Photo Credits	C1
Subject Index	I1

Three Distinct Series

Students have different goals, learning styles, and levels of preparation. Instructors have different teaching philosophies, styles, and techniques. Rather than write one series to fit all, the Sullivans have written three distinct series. All share the same goal—to develop a high level of mathematical understanding and an appreciation for the way mathematics can describe the world around us. The manner of reaching that goal, however, differs from series to series.

Flagship Series, Eleventh Edition

The Flagship Series is the most traditional in approach yet modern in its treatment of precalculus mathematics. In each text, needed review material is included, and is referenced when it is used. Graphing utility coverage is optional and can be included or excluded at the discretion of the instructor: *College Algebra*, *Algebra & Trigonometry*, *Trigonometry: A Unit Circle Approach*, *Precalculus*.

Enhanced with Graphing Utilities Series, Seventh Edition

This series provides a thorough integration of graphing utilities into topics, allowing students to explore mathematical concepts and encounter ideas usually studied in later courses. Many examples show solutions using algebra side-by-side with graphing techniques. Using technology, the approach to solving certain problems differs from the Flagship Series, while the emphasis on understanding concepts and building strong skills is maintained: *College Algebra*, *Algebra & Trigonometry*, *Precalculus*.

Concepts through Functions Series, Fourth Edition

This series differs from the others, utilizing a functions approach that serves as the organizing principle tying concepts together. Functions are introduced early in various formats. The approach supports the Rule of Four, which states that functions can be represented symbolically, numerically, graphically, and verbally. Each chapter introduces a new type of function and then develops all concepts pertaining to that particular function. The solutions of equations and inequalities, instead of being developed as stand-alone topics, are developed in the context of the underlying functions. Graphing utility coverage is optional and can be included or excluded at the discretion of the instructor: *College Algebra*; *Precalculus, with a Unit Circle Approach to Trigonometry*; *Precalculus, with a Right Triangle Approach to Trigonometry*.

The Flagship Series

College Algebra, Eleventh Edition

This text provides a contemporary approach to college algebra, with three chapters of review material preceding the chapters on functions. Graphing calculator usage is provided, but is optional. After completing this book, a student will be adequately prepared for trigonometry, finite mathematics, and business calculus.

Algebra & Trigonometry, Eleventh Edition

This text contains all the material in *College Algebra*, but also develops the trigonometric functions using a right triangle approach and shows how it relates to the unit circle approach. Graphing techniques are emphasized, including a thorough discussion of polar coordinates, parametric equations, and conics using polar coordinates. Vectors in the plane, sequences, induction, and the binomial theorem are also presented. Graphing calculator usage is provided, but is optional. After completing this book, a student will be adequately prepared for finite mathematics, business calculus, and engineering calculus.

Precalculus, Eleventh Edition

This text contains one review chapter before covering the traditional precalculus topics of polynomial, rational, exponential, and logarithmic functions and their graphs. The trigonometric functions are introduced using a unit circle approach and showing how it relates to the right triangle approach. Graphing techniques are emphasized, including a thorough discussion of polar coordinates, parametric equations, and conics using polar coordinates. Vectors in the plane and in space, including the dot and cross products, sequences, induction, and the binomial theorem are also presented. Graphing calculator usage is provided, but is optional. The final chapter provides an introduction to calculus, with a discussion of the limit, the derivative, and the integral of a function. After completing this book, a student will be adequately prepared for finite mathematics, business calculus, and engineering calculus.

Trigonometry: a Unit Circle Approach, Eleventh Edition

This text, designed for stand-alone courses in trigonometry, develops the trigonometric functions using a unit circle approach and shows how it relates to the right triangle approach. Vectors in the plane and in space, including the dot and cross products, are presented. Graphing techniques are emphasized, including a thorough discussion of polar coordinates, parametric equations, and conics using polar coordinates. Graphing calculator usage is provided, but is optional. After completing this book, a student will be adequately prepared for finite mathematics, business calculus, and engineering calculus.

Preface to the Instructor

As a professor of mathematics at an urban public university for 35 years, I understand the varied needs of college algebra students. Students range from being underprepared with little mathematical background and a fear of mathematics, to being highly prepared and motivated. For some, this is their final course in mathematics. For others, it is preparation for future mathematics courses. I have written this text with both groups in mind.

A tremendous benefit of authoring a successful series is the broad-based feedback I receive from instructors and students who have used previous editions. I am sincerely grateful for their support. Virtually every change to this edition is the result of their thoughtful comments and suggestions. I hope that I have been able to take their ideas and, building upon a successful foundation of the tenth edition, make this series an even better learning and teaching tool for students and instructors.

Features in the Eleventh Edition

A descriptive list of the many special features of *College Algebra* can be found on the endpapers in the front of this text. This list places the features in their proper context, as building blocks of an overall learning system that has been carefully crafted over the years to help students get the most out of the time they put into studying. Please take the time to review it and to discuss it with your students at the beginning of your course. My experience has been that when students use these features, they are more successful in the course.

- **Updated! Retain Your Knowledge Problems** These problems, which were new to the previous edition, are based on the article “*To Retain New Learning, Do the Math,*” published in the *Educati Review*. In this article, Kevin Washburn suggests that “the more students are required to recall new content or skills, the better their memory will be.” The Retain Your Knowledge problems were so well received that they have been expanded in this edition. Moreover, while the focus remains to help students maintain their skills, in most sections, problems were chosen that preview skills required to succeed in subsequent sections or in calculus. These are easily identified by the calculus icon (\int). All answers to Retain Your Knowledge problems are given in the back of the text and all are assignable in MyLab Math.
- **Guided Lecture Notes** Ideal for online, emporium/redesign courses, inverted classrooms, or traditional lecture classrooms. These lecture notes help students take thorough, organized, and understandable notes as they watch the Author in Action videos. They ask students to complete definitions, procedures, and examples based on the content of the videos and text. In addition, experience suggests that students learn by doing and understanding the why/how of the concept or property. Therefore, many

sections will have an exploration activity to motivate student learning. These explorations introduce the topic and/or connect it to either a real-world application or a previous section. For example, when the vertical-line test is discussed in Section 3.2, after the theorem statement, the notes ask the students to explain why the vertical-line test works by using the definition of a function. This challenge helps students process the information at a higher level of understanding.

- **Illustrations** Many of the figures have captions to help connect the illustrations to the explanations in the body of the text.
- **Graphing Utility Screen Captures** In several instances we have added Desmos screen captures along with the TI-84 Plus C screen captures. These updated screen captures provide alternate ways of visualizing concepts and making connections between equations, data and graphs in full color.
- **Chapter Projects**, which apply the concepts of each chapter to a real-world situation, have been enhanced to give students an up-to-the-minute experience. Many of these projects are new requiring the student to research information online in order to solve problems.
- **Exercise Sets** The exercises in the text have been reviewed and analyzed some have been removed, and new ones have been added. All time-sensitive problems have been updated to the most recent information available. The problem sets remain classified according to purpose.

The “*Are You Prepared?*” problems have been improved to better serve their purpose as a just-in-time review of concepts that the student will need to apply in the upcoming section.

The **Concepts and Vocabulary** problems have been expanded to cover each objective of the section. These multiple-choice, fill-in-the-blank, and True/False exercises have been written to also serve as reading quizzes.

Skill Building problems develop the student’s computational skills with a large selection of exercises that are directly related to the objectives of the section. **Mixed Practice** problems offer a comprehensive assessment of skills that relate to more than one objective. Often these require skills learned earlier in the course.

Applications and Extensions problems have been updated. Further, many new application-type exercises have been added, especially ones involving information and data drawn from sources the student will recognize, to improve relevance and timeliness.

At the end of Applications and Extensions, we have a collection of one or more **Challenge Problems**. These problems, as the title suggests, are intended to be thought-provoking, requiring some ingenuity to solve. They can be used for group work or to challenge students. At the end of the Annotated Instructor’s

Edition and in the online Instructor's Solutions Manual, we have provided solutions to all these problems.

The **Explaining Concepts: Discussion and Writing** exercises provide opportunity for classroom discussion and group projects.

Updated! Retain Your Knowledge has been improved and expanded. The problems are based on material learned earlier in the course. They serve to keep information that has already been learned “fresh” in the mind of the student. Answers to all these problems appear in the Student Edition.

Need to Review? These margin notes provide a just-in-time reminder of a concept needed now, but covered in an earlier section of the book. Each note includes a reference to the chapter, section and page where the concept was originally discussed.

Content Changes to the 11th edition

- **Challenge Problems** have been added in most sections at the end of the Application and Extensions exercises. Challenge Problems are intended to be thought-provoking problems that require some ingenuity to solve. They can be used to challenge students or for group work. Solutions to Challenge Problems are available in the Annotated Instructor's Edition and the online Instructors Solutions Manual.
- **Need to Review?** These margin notes provide a just-in-time review for a concept needed now, but covered in an earlier section of the book. Each note is back-referenced to the chapter, section and page where the concept was originally discussed.
- Additional **Retain Your Knowledge** exercises, whose purpose is to keep learned material fresh in a student's mind, have been added to each section. Many of these new problems preview skills required for calculus or for concepts needed in subsequent sections.
- **Desmos** screen captures have been added throughout the text. This is done to recognize that graphing technology expands beyond graphing calculators.
- Examples and exercises throughout the text have been augmented to reflect a broader selection of STEM applications.
- Concepts and Vocabulary exercises have been expanded to cover each objective of a section.
- Skill building exercises have been expanded to assess a wider range of difficulty.
- Applied problems and those based on real data have been updated where appropriate.

Chapter R

- Section R.8 Objective 3 now includes rationalizing the numerator
 - NEW Example 6 Rationalizing Numerators
 - Problems 69-76 provide practice.
- Section R.8 Exercises now include more practice in simplifying radicals

Chapter 1

- NEW Section 1.2 Objective 2 Solve a Quadratic Equation Using the Square Root Method.

Chapter 2

- NEW Section 2.2 Example 9 Testing an Equation for Symmetry
- Section 2.3 has been reorganized to treat the slope-intercept form of the equation of a line before finding an equation of a line using two points.

Chapter 3

- NEW Section 3.1 Objective 1 Describe a Relation
- NEW Section 3.2 Example 4 Expending Energy
- NEW Section 3.4 Example 4 Analyzing a Piecewise-defined Function
- NEW Example 1 Describing a Relation demonstrates using the Rule of Four to express a relation numerically, as a mapping, and graphically given a verbal description.

Chapter 4

- Section 4.3 introduces the concept of concavity for a quadratic function
- NEW Section 4.3 Example 3 Graphing a Quadratic Function Using Its Vertex, Axis, and Intercepts
- Section 4.3 Example 8 Analyzing the Motion of a Projectile (formerly in Section 4.4)
- NEW Section 4.4 Example 4 Fitting a Quadratic Function to Data

Chapter 5

- Section 5.1 has been revised and split into two sections:
 - 5.1 Polynomial Functions
 - 5.2 Graphing Polynomial Functions; Models
- NEW Section 5.2 Example 2 Graphing a Polynomial Function (a 4th degree polynomial function)

Chapter 6

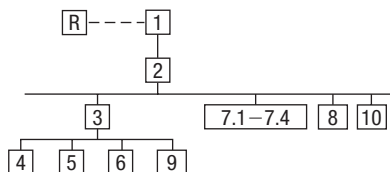
- Section 6.2 now finds and verifies inverse functions analytically and graphically

Chapter 8

- NEW Section 8.5 Example 1 Identifying Proper and Improper Rational Expressions

Using the Eleventh Edition Effectively with Your Syllabus

To meet the varied needs of diverse syllabi, this text contains more content than is likely to be covered in an *College Algebra* course. As the chart illustrates, this text has been organized with flexibility of use in mind. Within a given chapter, certain sections are optional (see the details that follow the figure below) and can be omitted without loss of continuity.



Chapter R Review

This chapter consists of review material. It may be used as the first part of the course or later as a just-in-time review when the content is required. Specific references to this chapter occur throughout the text to assist in the review process.

Chapter 1 Equations and Inequalities

Primarily a review of Intermediate Algebra topics, this material is a prerequisite for later topics. The coverage of complex numbers and quadratic equations with a negative discriminant is optional and may be postponed or skipped entirely without loss of continuity.

Acknowledgments

Textbooks are written by authors, but evolve from an idea to final form through the efforts of many people. It was Don Dellen who first suggested this text and series to me. Don is remembered for his extensive contributions to publishing and mathematics.

Thanks are due to the following people for their assistance and encouragement to the preparation of this edition:

- From Pearson Education: Anne Kelly for her substantial contributions, ideas, and enthusiasm; Dawn Murrin, for her unmatched talent at getting the details right; Joseph Colella for always getting the reviews and pages to me on time; Peggy McMahon for directing the always difficult production process; Rose Kernan for handling liaison between the compositor and author; Peggy Lucas and

Chapter 2 Graphs

This chapter lays the foundation for functions. Section 2.5 is optional.

Chapter 3 Functions and Their Graphs

Perhaps the most important chapter. Section 3.6 is optional.

Chapter 4 Linear and Quadratic Functions

Topic selection depends on your syllabus. Sections 4.2 and 4.4 may be omitted without loss of continuity.

Chapter 5 Polynomial and Rational Functions

Topic selection depends on your syllabus.

Chapter 6 Exponential and Logarithmic Functions

Sections 6.1–6.6 follow in sequence. Sections 6.7, 6.8, and 6.9 are optional.

Chapter 7 Analytic Geometry

Sections 7.1–7.4 follow in sequence.

Chapter 8 Systems of Equations and Inequalities

Sections 8.2–8.7 may be covered in any order, but each requires Section 8.1. Section 8.8 requires Section 8.7.

Chapter 9 Sequences; Induction; The Binomial Theorem

There are three independent parts: Sections 9.1–9.3; Section 9.4; and Section 9.5.

Chapter 10 Counting and Probability

The sections follow in sequence.

Stacey Sveum for their genuine interest in marketing this text. Marcia Horton for her continued support and genuine interest; Paul Corey for his leadership and commitment to excellence; and the Pearson Sales team, for their continued confidence and personal support of Sullivan texts.

- Accuracy checkers: C. Brad Davis who read the entire manuscript and accuracy checked answers. His attention to detail is amazing; Timothy Britt, for creating the Solutions Manuals; and Kathleen Miranda and Pamela Trim for accuracy checking answers.

Finally, I offer my grateful thanks to the dedicated users and reviewers of my texts, whose collective insights form the backbone of each textbook revision.

James Africh, College of DuPage
 Steve Agronsky, Cal Poly State University
 Gerardo Aladro, Florida International University
 Grant Alexander, Joliet Junior College
 Dave Anderson, South Suburban College
 Wes Anderson, Northwest Vista College
 Richard Andrews, Florida A&M University
 Joby Milo Anthony, University of Central Florida
 James E. Arnold, University of Wisconsin-Milwaukee

Adel Arshaghi, Center for Educational Merit
 Carolyn Atray, University of West Georgia
 Agnes Azzolino, Middlesex County College
 Wilson P. Banks, Illinois State University
 Sudeshna Basu, Howard University
 Timothy Bayer, Virginia Western CC
 Dale R. Bedgood, East Texas State University
 Beth Beno, South Suburban College
 Carolyn Bernath, Tallahassee Community College
 Rebecca Berthiaume, Edison State College
 William H. Beyer, University of Akron

Annette Blackwelder, Florida State University
 Richelle Blair, Lakeland Community College
 Kevin Bodden, Lewis and Clark College
 Jeffrey Boerner, University of Wisconsin-Stout
 Connie Booker, Owensboro Community and Technical College
 Barry Booten, Florida Atlantic University
 Laurie Boudreaux, Nicholls State University
 Larry Bouldin, Roane State Community College
 Bob Bradshaw, Ohlone College
 Trudy Bratten, Grossmont College

- Tim Bremer, Broome Community College
 Tim Britt, Jackson State Community College
 Holly Broesamle, Oakland CC-Auburn Hills
 Michael Brook, University of Delaware
 Timothy Brown, Central Washington University
 Joanne Brunner, Joliet Junior College
 Warren Burch, Brevard Community College
 Mary Butler, Lincoln Public Schools
 Melanie Butler, West Virginia University
 Jim Butterbach, Joliet Junior College
 Roberto Cabezas, Miami Dade College
 William J. Cable, University of Wisconsin-Stevens Point
 Lois Calamia, Brookdale Community College
 Jim Campbell, Lincoln Public Schools
 Roger Carlsen, Moraine Valley Community College
 Elena Catoiu, Joliet Junior College
 Mathews Chakkanakuzhi, Palomar College
 Tim Chappell, Penn Valley Community College
 John Collado, South Suburban College
 Amy Collins, Northwest Vista College
 Alicia Collins, Mesa Community College
 Nelson Collins, Joliet Junior College
 Rebecca Connell, Troy University
 Jim Cooper, Joliet Junior College
 Denise Corbett, East Carolina University
 Carlos C. Corona, San Antonio College
 Theodore C. Coskey, South Seattle Community College
 Rebecca Connell, Troy University
 Donna Costello, Plano Senior High School
 Rebecca Courter, Pasadena City College
 Garrett Cox, The University of Texas at San Antonio
 Paul Crittenden, University of Nebraska at Lincoln
 John Davenport, East Texas State University
 Faye Dang, Joliet Junior College
 Antonio David, Del Mar College
 Stephanie Deacon, Liberty University
 Duane E. Deal, Ball State University
 Jerry DeGroot, Purdue North Central
 Timothy Deis, University of Wisconsin-Platteville
 Joanna DelMonaco, Middlesex Community College
 Vivian Dennis, Eastfield College
 Deborah Dillon, R. L. Turner High School
 Guesna Dohrman, Tallahassee Community College
 Cheryl Doolittle, Iowa State University
 Karen R. Dougan, University of Florida
 Jerrett Dumouchel, Florida Community College at Jacksonville
 Louise Dyson, Clark College
 Paul D. East, Lexington Community College
 Don Edmondson, University of Texas-Austin
 Erica Egizio, Joliet Junior College
 Jason Eltrevoog, Joliet Junior College
 Christopher Ennis, University of Minnesota
 Kathy Eppler, Salt Lake Community College
 Ralph Esparza, Jr., Richland College
 Garret J. Etgen, University of Houston
 Scott Fallstrom, Shoreline Community College
 Pete Falzone, Pensacola Junior College
 Arash Farahmand, Skyline College
 Said Fariabli, San Antonio College
 W.A. Ferguson, University of Illinois-Urbana/Champaign
 Iris B. Fetta, Clemson University
 Mason Flake, student at Edison Community College
 Timothy W. Flood, Pittsburg State University
 Robert Frank, Westmoreland County Community College
 Merle Friel, Humboldt State University
 Richard A. Fritz, Moraine Valley Community College
 Dewey Furness, Ricks College
 Mary Jule Gabiou, North Idaho College
 Randy Gallaher, Lewis and Clark College
 Tina Garn, University of Arizona
 Dawit Getachew, Chicago State University
 Wayne Gibson, Rancho Santiago College
 Lorán W. Gierhart, University of Texas at San Antonio and Palo Alto College
 Robert Gill, University of Minnesota Duluth
 Nina Girard, University of Pittsburgh at Johnstown
 Sudhir Kumar Goel, Valdosta State University
 Adrienne Goldstein, Miami Dade College, Kendall Campus
 Joan Goliday, Sante Fe Community College
 Lourdes Gonzalez, Miami Dade College, Kendall Campus
 Frederic Gooding, Goucher College
 Donald Goral, Northern Virginia Community College
 Sue Graupner, Lincoln Public Schools
 Mary Beth Grayson, Liberty University
 Jennifer L. Grimsley, University of Charleston
 Ken Gurganus, University of North Carolina
 Igor Halfin, University of Texas-San Antonio
 James E. Hall, University of Wisconsin-Madison
 Judy Hall, West Virginia University
 Edward R. Hancock, DeVry Institute of Technology
 Julia Hassett, DeVry Institute, Dupage
 Christopher Hay-Jahans, University of South Dakota
 Michah Heibel, Lincoln Public Schools
 LaRae Helliwell, San Jose City College
 Celeste Hernandez, Richland College
 Gloria P. Hernandez, Louisiana State University at Eunice
 Brother Herron, Brother Rice High School
 Robert Hoberg, Western Connecticut State University
 Lynda Hollingsworth, Northwest Missouri State University
 Deltrey Holt, Augusta State University
 Charla Holzbog, Denison High School
 Lee Hruby, Naperville North High School
 Miles Hubbard, St. Cloud State University
 Kim Hughes, California State College-San Bernardino
 Stanislav Jabuka, University of Nevada, Reno
 Ron Jamison, Brigham Young University
 Richard A. Jensen, Manatee Community College
 Glenn Johnson, Middlesex Community College
 Sandra G. Johnson, St. Cloud State University
 Tuesday Johnson, New Mexico State University
 Susitha Karunaratne, Purdue University North Central
 Moana H. Karsteter, Tallahassee Community College
 Donna Katula, Joliet Junior College
 Arthur Kaufman, College of Staten Island
 Thomas Kearns, North Kentucky University
 Jack Keating, Massasoit Community College
 Shelia Kellenbarger, Lincoln Public Schools
 Rachael Kenney, North Carolina State University
 Penelope Kirby, Florida State University
 John B. Klassen, North Idaho College
 Debra Kopcsó, Louisiana State University
 Lynne Kowski, Raritan Valley Community College
 Yelena Kravchuk, University of Alabama at Birmingham
 Ray S. Kuan, Skyline College
 Keith Kuchar, Manatee Community College
 Tor Kwembe, Chicago State University
 Linda J. Kyle, Tarrant Country Jr. College
 H.E. Lacey, Texas A & M University
 Darren Lacoste, Valencia College-West Campus
 Harriet Lamm, Coastal Bend College
 James Lapp, Fort Lewis College
 Matt Larson, Lincoln Public Schools
 Christopher Lattin, Oakton Community College
 Julia Ledet, Louisiana State University
 Wayne Lee, St. Phillips CC
 Adele LeGere, Oakton Community College
 Kevin Leith, University of Houston
 JoAnn Lewin, Edison College
 Jeff Lewis, Johnson County Community College
 Janice C. Lyon, Tallahassee Community College
 Jean McArthur, Joliet Junior College
 Virginia McCarthy, Iowa State University
 Karla McCavit, Albion College
 Michael McClendon, University of Central Oklahoma
 Tom McCollow, DeVry Institute of Technology
 Marilyn McCollum, North Carolina State University
 Jill McGowan, Howard University
 Will McGowant, Howard University
 Angela McNulty, Joliet Junior College
 Lisa Meads, College of the Albemarle
 Laurence Maher, North Texas State University
 Jay A. Malmstrom, Oklahoma City Community College
 Rebecca Mann, Apollo High School
 Lynn Marecek, Santa Ana College
 Sherry Martina, Naperville North High School
 Ruby Martinez, San Antonio College
 Alec Matheson, Lamar University
 Nancy Matthews, University of Oklahoma
 James Maxwell, Oklahoma State University-Stillwater
 Marsha May, Midwestern State University
 James McLaughlin, West Chester University
 Judy Meckley, Joliet Junior College
 David Meel, Bowling Green State University
 Carolyn Meitler, Concordia University
 Samia Metwali, Erie Community College
 Rich Meyers, Joliet Junior College
 Eldon Miller, University of Mississippi
 James Miller, West Virginia University
 Michael Miller, Iowa State University
 Kathleen Miranda, SUNY at Old Westbury
 Chris Mirbaha, The Community College of Baltimore County
 Val Mohanakumar, Hillsborough Community College
 Thomas Monaghan, Naperville North High School
 Miguel Montanez, Miami Dade College, Wolfson Campus
 Maria Montoya, Our Lady of the Lake University
 Susan Moosai, Florida Atlantic University
 Craig Morse, Naperville North High School
 Samad Mortabit, Metropolitan State University
 Pat Mower, Washburn University
 Tammy Muhs, University of Central Florida
 A. Muhundan, Manatee Community College
 Jane Murphy, Middlesex Community College
 Richard Nadel, Florida International University
 Gabriel Nagy, Kansas State University
 Bill Naegele, South Suburban College
 Karla Neal, Louisiana State University
 Lawrence E. Newman, Holyoke Community College

XX Preface

- Dwight Newsome, Pasco-Hernando
Community College
- Denise Nunley, Maricopa Community Colleges
- James Nymann, University of Texas-El Paso
- Mark Omodt, Anoka-Ramsey Community
College
- Seth F. Oppenheimer, Mississippi State
University
- Leticia Oropesa, University of Miami
- Linda Padilla, Joliet Junior College
- Sanja Pantic, University of Illinois at Chicago
- E. James Peake, Iowa State University
- Kelly Pearson, Murray State University
- Dashamir Petrela, Florida Atlantic University
- Philip Pina, Florida Atlantic University
- Charlotte Pisors, Baylor University
- Michael Prophet, University of Northern Iowa
- Laura Pyzdrowski, West Virginia University
- Carrie Quesnell, Weber State University
- Neal C. Raber, University of Akron
- Thomas Radin, San Joaquin Delta College
- Aibeng Serene Radulovic, Florida Atlantic
University
- Ken A. Rager, Metropolitan State College
- Traci Reed, St. Johns River State College
- Kenneth D. Reeves, San Antonio College
- Elsi Reinhardt, Truckee Meadows Community
College
- Jose Remesar, Miami Dade College, Wolfson
Campus
- Jane Ringwald, Iowa State University
- Douglas F. Robertson, University of
Minnesota, MPLS
- Stephen Rodi, Austin Community College
- William Rogge, Lincoln Northeast High School
- Howard L. Rolf, Baylor University
- Mike Rosenthal, Florida International University
- Phoebe Rouse, Louisiana State University
- Edward Rozema, University of Tennessee at
Chattanooga
- Dennis C. Runde, Manatee Community College
- Paul Runnion, Missouri University of Science
and Technology
- Amit Saini, University of Nevada-Reno
- Laura Salazar, Northwest Vista College
- Alan Saleski, Loyola University of Chicago
- Susan Sandmeyer, Jamestown Community
College
- Brenda Santistevan, Salt Lake Community
College
- Linda Schmidt, Greenville Technical College
- Ingrid Scott, Montgomery College
- A.K. Shamma, University of West Florida
- Zachery Sharon, University of Texas at San
Antonio
- Joshua Shelor, Virginia Western CC
- Martin Sherry, Lower Columbia College
- Carmen Shershin, Florida International
University
- Tatiana Shubin, San Jose State University
- Anita Sikes, Delgado Community College
- Timothy Sipka, Alma College
- Charlotte Smedberg, University of Tampa
- Lori Smellegar, Manatee Community College
- Gayle Smith, Loyola Blakefield
- Cindy Soderstrom, Salt Lake Community
College
- Leslie Soltis, Mercyhurst College
- John Spellman, Southwest Texas State
University
- Karen Spike, University of North Carolina
- Rajalakshmi Sriram, Okaloosa-Walton
Community College
- Katrina Staley, North Carolina Agricultural
and Technical State University
- Becky Stamper, Western Kentucky University
- Judy Staver, Florida Community
College-South
- Robin Steinberg, Pima Community College
- Neil Stephens, Hinsdale South High School
- Sonya Stephens, Florida A&M University
- Patrick Stevens, Joliet Junior College
- John Sumner, University of Tampa
- Matthew TenHuisen, University of North
Carolina, Wilmington
- Christopher Terry, Augusta State University
- Diane Tesar, South Suburban College
- Tommy Thompson, Brookhaven College
- Martha K. Tietze, Shawnee Mission Northwest
High School
- Richard J. Tondra, Iowa State University
- Florentina Tone, University of West Florida
- Suzanne Topp, Salt Lake Community College
- Marilyn Toscano, University of Wisconsin,
Superior
- Marvel Townsend, University of Florida
- Jim Trudnowski, Carroll College
- David Tseng, Miami Dade College, Kendall
Campus
- Robert Tuskey, Joliet Junior College
- Mihaela Vajiac, Chapman University-Orange
- Julia Varbalow, Thomas Nelson Community
College-Leesville
- Richard G. Vinson, University of South
Alabama
- Jorge Viola-Prioli, Florida Atlantic University
- Mary Voxman, University of Idaho
- Jennifer Walsh, Daytona Beach Community
College
- Donna Wandke, Naperville North High School
- Timothy L. Warkentin, Cloud County
Community College
- Melissa J. Watts, Virginia State University
- Hayat Weiss, Middlesex Community College
- Kathryn Wetzel, Amarillo College
- Darlene Whitkenack, Northern Illinois
University
- Suzanne Williams, Central Piedmont
Community College
- Larissa Williamson, University of Florida
- Christine Wilson, West Virginia University
- Brad Wind, Florida International University
- Anna Wiodarczyk, Florida International
University
- Mary Wolyniak, Broome Community
College
- Canton Woods, Auburn University
- Tamara S. Worner, Wayne State College
- Terri Wright, New Hampshire Community
Technical College, Manchester
- Rob Wylie, Carl Albert State College
- Aletheia Zambesi, University of West Florida
- George Zazi, Chicago State University
- Loris Zucca, Lone Star College-Kingwood
- Steve Zuro, Joliet Junior College

Michael Sullivan







Get the Most Out of MyLab Math

Math courses are continuously evolving to help today’s students succeed. It’s more challenging than ever to support students with a wide range of backgrounds, learner styles, and math anxieties. The flexibility to build a course that fits instructors’ individual course formats—with a variety of content options and multimedia resources all in one place—has made MyLab Math the market-leading solution for teaching and learning mathematics since its inception.

Preparedness

One of the biggest challenges in College Algebra, Trigonometry, and Precalculus is making sure students are adequately prepared with prerequisite knowledge. For a student, having the essential algebra skills upfront in this course can dramatically increase success.

- **MyLab Math with Integrated Review** can be used in corequisite courses, or simply to help students who enter without a full understanding of prerequisite skills and concepts. **Integrated Review** provides videos on review topics with a corresponding worksheet, along with premade, assignable skills-check quizzes and personalized review homework assignments. **Integrated Review** is now available within all Sullivan 11th Edition MyLab Math courses.

Assignments	
10/18/19 11:59pm	 Chapter 4 Skills Check
10/18/19 11:59pm	 Chapter 4 Skills Review Homework
04/01/20 11:59pm	 Chapter 5 Skills Check
04/01/20 11:59pm	 Chapter 5 Skills Review Homework
09/14/20 11:59pm	 Chapter 6 Skills Check
09/14/20 11:59pm	 Chapter 6 Skills Review Homework

Resources for Success

MyLab Math Online Course for College Algebra, 11th Edition by Michael Sullivan (access code required)

MyLab™ Math is tightly integrated with each author's style, offering a range of author-created multimedia resources, so your students have a consistent experience.

Video Program and Resources

Author in Action Videos are actual classroom lectures by Michael Sullivan III with fully worked-out examples.

- **Video assessment** questions are available to assign in MyLab Math for key videos.
- **Updated!** The corresponding **Guided Lecture Notes** assist students in taking thorough, organized, and understandable notes while watching Author in Action videos.

EXAMPLE

Finding the Exact Value of a Logarithmic Expression

(a) $\log_3 81 = 4$ (b) $\log_2 \frac{1}{8}$

$y = \log_a x$ means $a^y = x$

(b) $y = \log_2 \frac{1}{8}$

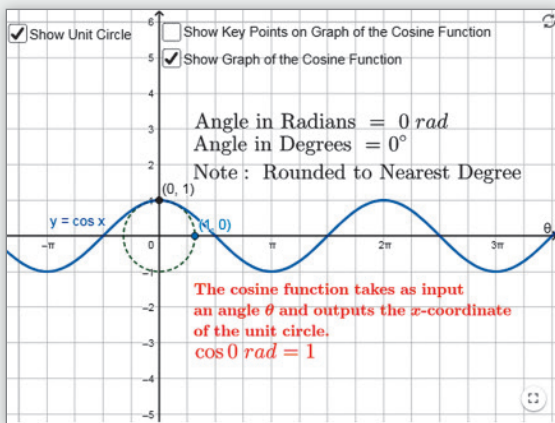
$2^y = \frac{1}{8}$

$2^y = 2^{-3}$

$y = -3$

$2^y = 2$

03:27 / 04:07



Guided Visualizations

New! Guided Visualizations, created in GeoGebra by Michael Sullivan III, bring mathematical concepts to life, helping students visualize the concept through directed exploration and purposeful manipulation. Assignable in MyLab Math with assessment questions to check students' conceptual understanding.

Retain Your Knowledge Exercises

Updated! Retain Your Knowledge Exercises, assignable in MyLab Math, improve students' recall of concepts learned earlier in the course. New for the 11th Edition, additional exercises will be included that will have an emphasis on content that students will build upon in the immediate upcoming section.

Retain Your Knowledge

Problems 154–162 are based on material learned earlier in the course. The purpose of these problems is to keep the material fresh in your mind so that you are better prepared for the final exam.

154. Simplify $\left(\frac{x^2y^{-3}}{x^2y}\right)^{-2}$. Assume $x \neq 0$ and $y \neq 0$. Express the answer so that all exponents are positive. x^4y^{16}

155. The lengths of the legs of a right triangle are $a = 8$ and $b = 15$. Find the hypotenuse. **17**

156. Solve the equation: $(x - 3)^2 + 25 = 49$
 $\{3 - 2\sqrt{6}, 3 + 2\sqrt{6}\}$

157. Solve $|2x - 5| + 7 < 10$. Express the answer using set notation or interval notation. Graph the solution set.

158. Determine the domain of the variable x in the expression:
 $\sqrt{8 - \frac{2}{3}x} \quad (-\infty, 12]$

159. Determine what number should be added to complete the square:
 $x^2 + \frac{3}{4}x$ **$\frac{9}{64}$**

160. Multiply and simplify the result.
 $\frac{x^2 - 16}{x^2 + 6x + 8} \cdot \frac{x + 2}{16 - 4x}$ **$-\frac{1}{4}$**

161. Rationalize the denominator:
 $\frac{\sqrt{x+1} + \sqrt{x}}{\sqrt{x+1} - \sqrt{x}}$ **$2x + 1 + 2\sqrt{x(x+1)}$**

162. Solve: $x - 5\sqrt{x} + 6 = 0$ **$\{4, 9\}$**

Resources for Success

Instructor Resources

Online resources can be downloaded from www.pearson.com, or hardcopy resources can be ordered from your sales representative.

Annotated Instructor's Edition

College Algebra, 11th Edition

ISBN – 013516320X / 9780135163207

Shorter answers are on the page beside the exercises. Longer answers are in the back of the text.

Instructor's Solutions Manual

ISBN – 0135163722 / 9780135163726

Includes fully worked solutions to all exercises in the text.

Learning Catalytics Question Library

Questions written by Michael Sullivan III are available within MyLab Math to deliver through Learning Catalytics to engage students in your course.

Powerpoint® Lecture Slides

Fully editable slides correlate to the textbook.

Mini Lecture Notes

Includes additional examples and helpful teaching tips, by section.

Testgen®

TestGen (www.pearsoned.com/testgen) enables instructors to build, edit, print, and administer tests using a computerized bank of questions developed to cover all the objectives of the text.

Online Chapter Projects

Additional projects that give students an opportunity to apply what they learned in the chapter.

Student Resources

Additional resources to enhance student success.

Lecture Video

Author in Action videos are actual classroom lectures with fully worked out examples presented by Michael Sullivan, III. All video is assignable within MyLab Math.

Chapter Test Prep Videos

Students can watch instructors work through step-by-step solutions to all chapter test exercises from the text. These are available in MyLab Math and on YouTube.

Student's Solutions Manual

ISBN - 013516317X / 9780135163177

Provides detailed worked-out solutions to odd-numbered exercises.

Guided Lecture Notes

ISBN – 0135163188 / 9780135163184

These lecture notes assist students in taking thorough, organized, and understandable notes while watching Author in Action videos. Students actively participate in learning the how/why of important concepts through explorations and activities. The Guided Lecture Notes are available as PDF's and customizable Word files in MyLab Math. They can also be packaged with the text and the MyLab Math access code.

Algebra Review

ISBN: 0131480065 / 9780131480063

Four printed chapters of Intermediate Algebra review available. Perfect for a corequisite course or for individual review.

Applications Index



Calculus

absolute maximum/minimum in, 233, 551
area under a curve, 267, 612
average rate of change in, 236, 353, 473, 528, 570, 662
composite functions in, 419
concavity test, 311, 644
critical numbers, 662
difference quotient in, 210, 217, 267, 324, 346, 451, 473, 490, 538, 629
discontinuous functions, 379
 e^x in, 443, 661
expression as single quotient in, 77
expressions with rational exponents in, 77
factoring in, 53, 57, 80, 465, 570, 644
functions approximated by polynomial functions in, 353
increasing/decreasing functions in, 231, 311, 346, 637
Intermediate Value Theorem, 396, 637
inverse functions, 551
local maxima/minima in, 233, 291, 501
partial fraction decomposition, 668, 685, 702, 711
perpendicular lines, 595, 620
quadratic equations in, 99–100
rationalizing numerators, 595
reducing expression to lowest terms in, 71
secant line in, 236, 291, 490
second derivative, 702
Simpson's rule, 320
trigonometric expressions and functions, 685

Acoustics

amplifying sound, 512
loudness of sound, 463, 514
whispering galleries, 536

Aeronautics

sonic boom, 550

Agriculture

farm management, 643
farm workers in U.S., 500
field enclosure, 628
milk production, 507
minimizing cost, 643
watering a field, 102

Air travel

distance between two planes, 269
parking at O'Hare International Airport, 251

Archaeology

age of ancient tools, 493–494
age of fossil, 499
age of tree, 499
date of prehistoric man's death, 513

Architecture

brick staircase, 668, 693
Burj Khalifa building, 31
floor design, 666, 693
football stadium seating, 667
mosaic design, 668, 693
Norman window, 37, 318
parabolic arch, 318
racetrack design, 537
special window, 318, 326
stadium construction, 668
vertically circular building, 190
window design, 318
window dimensions, 102

Art

framing a painting, 146

Astronomy

distance from Earth to its moon, 29
distances of planets from Sun, 661
light-year, 29
planetary orbits, 537

Aviation

orbital launches, 567

Biology

alcohol and driving, 459, 464
bacterial growth, 492–493, 506
E-coli, 240, 282
blood types, 701
bone length, 326–327
cricket chirp rate and temperature, 319
healing of wounds, 449, 463
maternal age versus Down syndrome, 297
yeast biomass as function of time, 505

Business

advertising, 183, 298, 327
automobile production, 421, 583
blending coffee, 141
candy bar size, 103
checkout lines, 720
clothing store, 723
commissions, 326
cookie orders, 648
copying machines, 146
cost
of can, 375, 378
of commodity, 421
of manufacturing, 29, 141, 386, 636
marginal, 311, 326
minimizing, 326, 643, 648
of printing, 350–351
of production, 240, 421, 610, 648
of transporting goods, 252
cost equation, 182, 195
cost function, 290
customer wait times, 377
demand
for candy, 196
demand equation, 326, 412
depreciation, 414, 464
discount pricing, 91, 92, 422
drive-thru rate
at Burger King, 445
at Citibank, 449, 463
at McDonald's, 449–450
equipment depreciation, 678
expense computation, 142
farm workers in U.S., 500
inventory management, 272
Jiffy Lube's car arrival rate, 449, 463
managing a meat market, 643
milk production, 507
mixing candy, 141
mixing nuts, 141
orange juice production, 583
precision ball bearings, 29
presale orders, 568
price markup, 91
product design, 644
production scheduling, 643
product promotion, 183
profit, 610
maximizing, 641–642, 643–644
profit function, 218
rate of return on, 488
restaurant management, 568
revenue, 141, 311, 324, 327, 506
advertising, 508
airline, 644
of clothing store, 600
daily, 311
from digital music, 266
from football seating, 679
maximizing, 311, 317–318
monthly, 311
theater, 569
revenue equation, 195
RV rental, 327
salary, 422, 668
gross, 217
increases in, 678, 693
sales
commission on, 128
of movie theater ticket, 556, 561, 567
net, 157
salvage value, 513
straight-line depreciation, 285–286, 289
supply and demand, 286–287, 289
tax, 386
theater attendance, 92
toy truck manufacturing, 636
transporting goods, 637
truck rentals, 182
unemployment, 723

wages
 of car salesperson, 182
 hourly, 89, 91

Carpentry. *See also* **Construction**

pitch, 184

Chemistry, 91

alpha particles, 550
 decomposition reactions, 500
 drug concentration, 377
 gas laws, 196
 mixing acids, 146
 pH, 462
 purity of gold, 142
 radioactive decay, 499, 506–507, 513, 514, 644
 radioactivity from Chernobyl, 500
 salt solutions, 142, 143, 146
 self-catalytic chemical reaction, 311
 sugar molecules, 142
 volume of gas, 128

Combinatorics

airport codes, 703
 binary codes, 723
 birthday permutations, 705, 710, 717, 721, 723
 blouses and skirts combinations, 701
 book arrangements, 710
 box stacking, 709
 code formation, 709
 combination locks, 710
 committee formation, 707, 709, 710, 723
 Senate committees, 710
 flag arrangement, 708, 723
 gender composition of children in
 family, 714
 letter codes, 703–704
 license plate possibilities, 710, 723
 lining up people, 704, 709
 number formation, 701, 709, 710, 723
 objects selection, 710
 passwords, 710
 seating arrangements, 723
 shirts and ties combinations, 701
 telephone numbers, 723
 two-symbol codewords, 700
 word formation, 708, 710, 723

Communications

data plan, 202, 227, 278–279
 fake news, 133
 installing cable TV, 271
 phone charges, 289
 satellite dish, 396, 527
 social networking, 501, 507
 spreading of rumors, 449, 463
 tablet service, 251
 texting speed, 378

Computers and computing

comparing tablets, 103
 graphics, 611
 households owning computers, 500
 Internet searches, 112

laser printers, 142
 three-click rule, 611
 website design, 611
 website map, 611
 Word users, 500

Construction

of border around a garden, 103
 of border around a pool, 103
 of box, 99–100, 102–103, 628
 closed, 276
 open, 272
 of brick staircase, 693
 of can, 411
 of coffee can, 143
 of cylindrical tube, 628
 of enclosures
 around garden, 142
 around pond, 142
 maximizing area of, 314–315, 318, 326
 of fencing, 314–315, 318, 326, 628
 minimum cost for, 377
 of flashlight, 527
 of headlight, 527
 installing cable TV, 271
 patio dimensions, 103
 of rain gutter, 318
 of ramp
 access ramp, 183
 of rectangular field enclosure, 318
 of stadium, 318, 668
 of steel drum, 378
 of swimming pool, 37, 38
 TV dish, 527
 vent pipe installation, 537

Cryptography

matrices in, 611

Decorating

Christmas tree, 32

Demographics

birth rate
 age of mother and, 320
 of unmarried women, 311
 diversity index, 462
 living at home, 103
 marital status, 702
 mosquito colony growth, 499
 population. *See* Population
 rabbit colony growth, 660

Design

of box with minimum surface area, 378

Direction

of fireworks display, 549
 of lightning strikes, 549

Distance

Bermuda Triangle, 38
 bicycle riding, 228
 of explosion, 550

height

of bouncing ball, 678, 693
 of Great Pyramid of Cheops, 38
 of Mt. Everest, 29
 oil tank, 38
 from home, 228
 of hot-air balloon
 from intersection, 156
 from intersection, 271
 limiting magnitude of telescope, 512
 pendulum swings, 674, 678
 pool depth, 253
 range of airplane, 143
 of search and rescue, 146
 sound to measure, 118–119
 stopping, 218, 311, 433
 of storm, 146
 traveled by wheel, 37
 between two moving vehicles, 156
 toward intersection, 271
 between two planes, 269
 visibility of Gibb's Hill Lighthouse beam, 38
 visual, 38
 walking, 228

Economics

Consumer Price Index (CPI), 490
 demand equations, 412
 inflation, 489
 IS-LM model in, 568
 marginal propensity to consume, 679
 multiplier, 679
 national debt, 240
 participation rate, 218
 per capita federal debt, 489
 poverty rates, 352
 poverty threshold, 157
 relative income of child, 611
 unemployment, 723

Education

age distribution of community college, 724
 college costs, 489, 678
 college tuition and fees, 513, 610
 computing grades, 129
 degrees awarded, 699
 doctorates, 720
 faculty composition, 721
 fraternity purchase, 103
 funding a college education, 513
 GPA and work relationship, 103
 grades, 91
 learning curve, 450, 463
 maximum level achieved, 650
 median earnings and level of, 103
 multiple-choice test, 710
 spring break, 643
 student loan
 interest on, 610
 true/false test, 709
 video games and grade-point average, 297

Electricity, 91

cost of, 249
 current in *RC* circuit, 450

current in *RL* circuit, 450, 463
 impedance, 112
 Kirchhoff's Rules, 569, 583
 Ohm's law, 126
 parallel circuits, 112
 resistance in, 363
 rates for, 129, 182
 resistance, 69, 72, 196, 200, 363
 voltage
 foreign, 29
 U.S., 29

Electronics. *See also* Computers and computing

microphones, 167

Energy

expended while walking, 222–223
 nuclear power plant, 549
 solar, 168, 527
 thermostat control, 266

Engineering

bridges
 Golden Gate, 315–316
 parabolic arch, 326, 526–527
 semielliptical arch, 536–537, 552
 suspension, 318, 526
 crushing load, 119
 Gateway Arch (St. Louis), 527
 grade
 of mountain trail, 629
 of road, 184
 horsepower, 196
 maximum weight supportable by pine, 193
 safe load for a beam, 196
 searchlight, 527, 552
 tolerance, 133
 whispering galleries, 406

Entertainment

Demon Roller Coaster customer rate, 450
 theater revenues, 569

Environment

endangered species, 449
 invasive species, 501
 lake pollution control laws, 660
 oil leakage, 421

Exercise, 129

heartbeats during, 283–284

Finance, 91. *See also* Investment(s)

balancing a checkbook, 29
 bank balance comparison, 489
 bills in wallet, 723
 clothes shopping, 649
 college costs, 489, 678
 computer system purchase, 488
 consumer expenditures annually by age, 316–317
 cost
 of car, 91, 182
 of car rental, 252

of electricity, 249
 of fast food, 568
 minimizing, 326, 377
 of natural gas, 182, 252
 of pizza, 92
 of printing, 350–351
 of towing car, 288
 of transatlantic travel, 218, 226
 cost equation, 195
 cost function, 290
 cost minimization, 311
 credit cards
 balance on, 620
 debt, 660
 interest on, 488
 payment, 253, 660
 depreciation, 449
 of car, 464, 480, 516
 discounts, 422
 division of money, 88, 91
 effective rate of interest, 485
 electricity rates, 182
 financial planning, 136–137, 568, 579–580, 583
 foreign exchange, 422
 fraternity purchase, 103
 funding a college education, 513
 future value of money, 352
 gross salary, 217
 income
 discretionary, 103
 inheritance, 146
 life cycle hypothesis, 319
 loans, 141
 car, 660
 interest on, 81, 136, 146, 147–148, 610
 repayment of, 488
 student, 146, 610
 median earnings and level of education, 103
 mortgages, 489
 fees, 252
 interest rates on, 489
 payments, 192, 195, 199
 second, 489
 price appreciation of homes, 488
 prices of fast food, 569
 refunds, 568
 revenue equation, 195
 revenue maximization, 311, 313–314, 317–318
 rich man's promise, 679
 salary options, 680
 sales commission, 128
 saving
 for a car, 488
 for a home, 678
 savings accounts interest, 488
 selling price of a home, 201
 sewer bills, 129
 sinking fund, 678
 taxes, 289
 competitive balance, 289
 federal income, 252, 422, 434
 truck rentals, 241
 used-car purchase, 488

Food and nutrition

animal, 644
 calories, 92
 candy, 296
 color mix of candy, 723
 cooler contents, 724
 cooling time of pizza, 499
 fast food, 568, 569
 fat content, 129
 Girl Scout cookies, 720
 hospital diet, 569, 582
 ice cream, 643
 number of possible meals, 699–700
 soda and hot dogs buying
 combinations, 290
 sodium content, 129
 warming time of beer stein, 500

Forensic science

tibia length and height relationship, 465

Forestry

wood product classification, 498

Games

coin toss, 713
 die rolling, 713, 714–715, 724
 grains of wheat on a chess board, 679
 lottery, 724–725

Gardens and gardening. *See also* Landscaping

border around, 103
 enclosure for, 142

Geology

earthquakes, 464
 geysers, 668

Geometry

balloon volume, 421
 circle
 area of, 141, 191
 center of, 190, 191
 circumference of, 28, 141, 191
 equation of, 594
 inscribed in square, 270
 radius of, 92, 191, 627
 collinear points, 594
 cone volume, 196, 422
 cube
 length of edge of, 400
 surface area of, 29
 volume of, 29
 cylinder
 inscribing in cone, 271
 inscribing in sphere, 271
 volume of, 196, 422
 Descartes's method of equal roots, 628
 equation of line, 594
 Pascal figures, 691
 polygon
 area of, 594
 diagonals of, 104

Pythagorean Theorem, 102
 rectangle
 area of, 28, 217, 268–269, 276, 537
 dimensions of, 92, 102, 146, 627
 inscribed in circle, 270
 inscribed in semicircle, 270
 perimeter of, 28
 semicircle inscribed in, 271
 sphere
 surface area of, 28
 volume of, 28
 square
 area of, 37, 141
 diagonals of, 156, 157
 perimeter of, 141
 shading, 679
 surface area
 of balloon, 421
 of cube, 29
 of sphere, 28
 tetrahedron, volume of, 594
 triangle
 area of, 28, 594
 equilateral, 28, 156, 157
 inscribed in circle, 271
 isosceles, 217, 627
 Koch's snowflake, 679
 medians of, 156
 Pascal's, 660
 perimeter of, 28
 wire into geometric shapes, 270–271

Government

federal debt, 240
 per capita, 489
 federal income tax, 218, 252, 422, 434
 federal tax withholding, 129
 first-class mail, 253

Health. *See also* Exercise; Medicine

age versus total cholesterol, 508
 elliptical trainer, 537
 expenditures on, 218
 ideal body weight, 433
 life cycle hypothesis, 319
 life expectancy, 128

Home improvement. *See also* Construction

painting a house, 569

Housing

apartment rental, 319
 price appreciation of homes, 488

Investment(s), 88, 91, 141, 146

401(k), 678, 693
 annuity, 675–676, 678
 in bonds, 644
 Treasuries, 583, 634, 636, 638
 zero-coupon, 486, 489
 in CDs, 485, 644
 compound interest on, 481–482, 483, 484,
 485, 488–489, 514
 diversified, 569

dividing, 254
 doubling of, 486, 489
 effective rate of interest, 485
 finance charges, 488
 in fixed-income securities, 489, 644
 growth rate for, 488–489
 IRA, 489, 675–676, 678
 mutual fund growth over time, 502–503
 return on, 488, 643, 644
 savings account, 481–482
 in stock
 analyzing, 329
 appreciation, 488
 beta, 280, 329
 NASDAQ stocks, 709
 NYSE stocks, 709
 portfolios of, 702
 price of, 679
 time to reach goal, 488, 490
 tripling of, 487, 489

Landscaping. *See also* Gardens and gardening

pond enclosure, 326
 project completion time, 143
 rectangular pond border, 326
 tree planting, 583

Law and law enforcement

motor vehicle thefts, 720
 violent crimes, 218

Leisure and recreation

cable TV, 271
 community skating rink, 277
 Ferris wheel, 190
 video games and grade-point average, 297

Mechanics, 91. *See also* Physics

Medicine. *See also* Health

age versus total cholesterol, 508
 cancer
 breast, 506
 pancreatic, 449
 drug concentration, 240, 377
 drug medication, 449, 463
 healing of wounds, 449, 463
 lithotripsy, 537
 spreading of disease, 513–514

Meteorology

weather balloon height and atmospheric
 pressure, 504

Miscellaneous

banquet seating, 643
 bending wire, 628
 citrus ladders, 668
 coffee container, 516
 cross-sectional area of beam, 218, 226
 curve fitting, 568, 582, 647
 diameter of wire, 29
 drafting error, 156
 Droste Effect, 661

motor, 29
 paper creases, 684
 pet ownership, 720
 surface area of balloon, 421
 volume of balloon, 421
 wire enclosure area, 270–271

Mixtures. *See also* Chemistry

blending coffees, 137–138, 141, 147, 636, 648
 blending teas, 141
 cement, 143
 mixed nuts, 141, 567, 637, 648
 mixing candy, 141
 solutions, 568
 water and antifreeze, 142, 191

Motion. *See also* Physics

of golf ball, 226
 revolutions of circular disk, 37
 tortoise and the hare race, 627
 uniform, 138–139, 141

Motor vehicles

alcohol and driving, 459, 464
 automobile production, 421, 583
 average car speed, 143
 brake repair with tune-up, 723
 depreciation, 414
 depreciation of, 464, 480, 516
 with Global Positioning System (GPS), 513
 loans for, 660
 runaway car, 324
 stopping distance, 218, 311, 433
 theft of, 720
 towing cost for car, 288
 used-car purchase, 488

Music

revenues from, 266

Optics

intensity of light, 196
 lamp shadow, 550
 lensmaker's equation, 72
 light obliterated through glass, 449
 mirrors, 550, 661
 reflecting telescope, 527

Pediatrics

height vs. head circumference, 433

Pharmacy

vitamin intake, 568, 583

Physics, 91

bouncing balls, 693
 diameter of atom, 29
 Doppler effect, 378
 effect of elevation on weight, 226
 falling objects, 195
 force, 141
 of attraction between two bodies, 195
 of wind on a window, 194, 196
 gravity, 363, 386
 on Earth, 217, 434
 on Jupiter, 218

heat loss, 193, 199
 Hooke's Law, 290
 horsepower, 196
 intensity of light, 146, 196
 kinetic energy, 141, 196
 maximum weight supportable by
 pine, 193
 missile trajectory, 329
 Newton's law, 195
 Ohm's law, 126
 pendulum motion, 119, 674
 period, 266, 434
 simple pendulum, 195
 pressure, 141, 196
 projectile motion, 103, 267, 307, 310–311
 artillery, 324
 safe load for a beam, 196
 sound to measure distance, 118–119
 speed of sound, 133
 stress of materials, 196
 stretching a spring, 195
 tension, 685
 thrown object, 146
 ball, 319, 324
 uniform motion, 141, 143, 271
 velocity down inclined planes, 80
 vertically propelled object, 324
 vibrating string, 195
 wavelength of visible light, 29
 weight, 196, 199
 work, 141

Population. *See also* Demographics

bacteria, 451, 499, 506
 decline in, 499
 E-coli growth, 240, 282
 of endangered species, 500–501
 of fruit fly, 497
 as function of age, 218
 growth in, 499, 501
 insect, 363, 499, 501
 of trout, 660
 of United States, 479, 507, 695
 of world, 479, 507–508, 513, 651

Probability

of ball not being chosen, 377
 of birthday shared by people in a
 room, 500
 checkout lines, 720
 classroom composition, 720
 exponential, 445, 449, 463
 of finding ideal mate, 464
 household annual income, 720
 Poisson, 449–450
 “Price is Right” games, 720
 standard normal density function, 267
 of winning a lottery, 721

Psychometrics

IQ tests, 129

Pyrotechnics

fireworks display, 549

Rate. *See also* Speed

current of stream, 568
 of emptying
 fuel tanks, 146
 oil tankers, 143
 a pool, 143
 of filling
 a conical tank, 272
 a tub, 143
 speed
 average, 143
 of current, 141
 of cyclist, 143
 of motorboat, 141
 of moving walkways, 141–142
 of plane, 143
 of sound, 133
 of water use, 267

Real estate

commission, 128
 housing prices, 411
 mortgage loans, 489

Recreation

bungee jumping, 386
Demon Roller Coaster customer rate, 450
 gambling, 720

Seismology

calibrating instruments, 552

Sequences. *See also* Combinatorics

ceramic tile floor design, 666
 Drury Lane Theater, 667
 football stadium seating, 667
 seats in amphitheater, 667

Speed

of current, 648
 as function of time, 228, 271
 wind, 568

Sports

baseball, 710, 723
 diamond, 156
 Little League, 156
 on-base percentage, 291–292
 World Series, 710
 basketball, 710
 free throws, 225–226
 granny shots, 225
 biathlon, 143
 bungee jumping, 386
 exacta betting, 723
 football, 142, 537
 defensive squad, 710
 field design, 103
 seating revenue, 679
 golf, 226, 508
 Olympic heroes, 143
 races, 142, 146, 625, 627
 relay runners, 723
 tennis, 142, 353, 378

Statistics. *See* Probability Surveys

of appliance purchases, 701
 data analysis, 698, 701
 stock portfolios, 702
 of summer session attendance, 701
 of TV sets in a house, 720

Temperature

of air parcel, 668
 body, 29, 133
 conversion of, 290, 422, 434
 cooling time of pizza, 499
 cricket chirp rate and, 319
 Fahrenheit from Celsius conversion, 87
 measuring, 183
 after midnight, 352
 relationship between scales, 266
 shelf life and, 241
 of skillet, 513
 warming time of beer stein, 500
 wind chill factor, 513

Time

for beer stein to warm, 500
 to go from an island to a town, 272
 hours of daylight, 413
 for pizza to cool, 499
 for rescue at sea, 146

Travel. *See also* Air travel

drivers stopped by the police, 515
 driving to school, 196
 parking at O'Hare International
 Airport, 251

Volume

of gasoline in tank, 80
 of ice in skating rink, 277
 of water in cone, 272

Weapons

artillery, 324
 cannons, 329

Weather

atmospheric pressure, 449, 463
 cooling air, 668
 hurricanes, 297, 352
 lightning and thunder, 146, 416–417,
 419, 549
 probability of rain, 716
 relative humidity, 450
 tornadoes, 296
 wind chill, 253, 513

Work

constant rate jobs, 648
 GPA and, 103
 working together, 140, 142, 146

To the Student

As you begin, you may feel anxious about the number of theorems, definitions, procedures, and equations. You may wonder if you can learn it all in time. Don't worry—your concerns are normal. This textbook was written with you in mind. If you attend class, work hard, and read and study this text, you will build the knowledge and skills you need to be successful. Here's how you can use the text to your benefit.

Read Carefully

When you get busy, it's easy to skip reading and go right to the problems. Don't ... the text has a large number of examples and clear explanations to help you break down the mathematics into easy-to-understand steps. Reading will provide you with a clearer understanding, beyond simple memorization. Read before class (not after) so you can ask questions about anything you didn't understand. You'll be amazed at how much more you'll get out of class if you do this.

Use the Features

I use many different methods in the classroom to communicate. Those methods, when incorporated into the text, are called "features." The features serve many purposes, from providing timely review of material you learned before (just when you need it) to providing organized review sessions to help you prepare for quizzes and tests. Take advantage of the features and you will master the material.

To make this easier, we've provided a brief guide to getting the most from this text. Refer to "Prepare for Class," "Practice," and "Review" at the front of the text. Spend fifteen minutes reviewing the guide and familiarizing yourself with the features by flipping to the page numbers provided. Then, as you read, use them. This is the best way to make the most of your text.

Please do not hesitate to contact me through Pearson Education, with any questions, comments, or suggestions for improving this text. I look forward to hearing from you, and good luck with all of your studies.

Best Wishes!

Michael Sullivan

This page intentionally left blank

Review

R



A Look Ahead →

Chapter R, as the title states, contains review material. Your instructor may choose to cover all or part of it as a regular chapter at the beginning of your course or later as a just-in-time review when the content is required. Regardless, when information in this chapter is needed, a specific reference to this chapter will be made so you can review.

Outline

- R.1** Real Numbers
- R.2** Algebra Essentials
- R.3** Geometry Essentials
- R.4** Polynomials
- R.5** Factoring Polynomials
- R.6** Synthetic Division
- R.7** Rational Expressions
- R.8** n th Roots; Rational Exponents

R.1 Real Numbers

PREPARING FOR THIS TEXT Before getting started, read “To the Student” at the front of this text.

- OBJECTIVES**
- 1 Work with Sets (p. 2)
 - 2 Classify Numbers (p. 4)
 - 3 Evaluate Numerical Expressions (p. 8)
 - 4 Work with Properties of Real Numbers (p. 9)

1 Work with Sets

A **set** is a well-defined collection of distinct objects. The objects of a set are called its **elements**. By **well-defined**, we mean that there is a rule that enables us to determine whether a given object is an element of the set. If a set has no elements, it is called the **empty set**, or **null set**, and is denoted by the symbol \emptyset .

For example, the set of **digits** consists of the collection of numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. If we use the symbol D to denote the set of digits, then we can write

$$D = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$$

In this notation, the braces $\{ \}$ are used to enclose the objects, or **elements**, in the set. This method of denoting a set is called the **roster method**. A second way to denote a set is to use **set-builder notation**, where the set D of digits is written as

$$D = \{ x \mid x \text{ is a digit} \}$$

Read as “ D is the set of all x such that x is a digit.”

EXAMPLE 1

Using Set-builder Notation and the Roster Method

- (a) $E = \{x \mid x \text{ is an even digit}\} = \{0, 2, 4, 6, 8\}$
- (b) $O = \{x \mid x \text{ is an odd digit}\} = \{1, 3, 5, 7, 9\}$

Because the elements of a set are distinct, we never repeat elements. For example, we would never write $\{1, 2, 3, 2\}$; the correct listing is $\{1, 2, 3\}$. Because a set is a collection, the order in which the elements are listed is immaterial. $\{1, 2, 3\}$, $\{1, 3, 2\}$, $\{2, 1, 3\}$, and so on, all represent the same set.

If every element of a set A is also an element of a set B , then A is a **subset** of B , which is denoted $A \subseteq B$. If two sets A and B have the same elements, then A **equals** B , which is denoted $A = B$.

For example, $\{1, 2, 3\} \subseteq \{1, 2, 3, 4, 5\}$ and $\{1, 2, 3\} = \{2, 3, 1\}$.

DEFINITION Intersection and Union of Two Sets

If A and B are sets, the **intersection** of A with B , denoted $A \cap B$, is the set consisting of elements that belong to both A and B . The **union** of A with B , denoted $A \cup B$, is the set consisting of elements that belong to either A or B , or both.

EXAMPLE 2

Finding the Intersection and Union of Sets

Let $A = \{1, 3, 5, 8\}$, $B = \{3, 5, 7\}$, and $C = \{2, 4, 6, 8\}$. Find:

- (a) $A \cap B$
- (b) $A \cup B$
- (c) $B \cap (A \cup C)$

- Solution**
- (a) $A \cap B = \{1, 3, 5, 8\} \cap \{3, 5, 7\} = \{3, 5\}$
- (b) $A \cup B = \{1, 3, 5, 8\} \cup \{3, 5, 7\} = \{1, 3, 5, 7, 8\}$
- (c) $B \cap (A \cup C) = \{3, 5, 7\} \cap [\{1, 3, 5, 8\} \cup \{2, 4, 6, 8\}]$
 $= \{3, 5, 7\} \cap \{1, 2, 3, 4, 5, 6, 8\} = \{3, 5\}$

 **Now Work** PROBLEM 15

Usually, in working with sets, we designate a **universal set** U , the set consisting of all the elements that we wish to consider. Once a universal set has been designated, we can consider elements of the universal set not found in a given set.

DEFINITION Complement of a Set

If A is a set, the **complement** of A , denoted \bar{A} , is the set consisting of all the elements in the universal set that are not in A .*

EXAMPLE 3

Finding the Complement of a Set

If the universal set is $U = \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$ and if $A = \{1, 3, 5, 7, 9\}$, then $\bar{A} = \{2, 4, 6, 8\}$.

It follows from the definition of complement that $A \cup \bar{A} = U$ and $A \cap \bar{A} = \emptyset$. Do you see why?

 **Now Work** PROBLEM 19

It is often helpful to draw pictures of sets. Such pictures, called **Venn diagrams**, represent sets as circles enclosed in a rectangle, which represents the universal set. Such diagrams often help us to visualize various relationships among sets. See Figure 1.

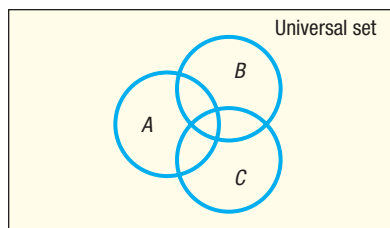


Figure 1 Venn diagram

If we know that $A \subseteq B$, we might use the Venn diagram in Figure 2(a). If we know that A and B have no elements in common—that is, if $A \cap B = \emptyset$ —we might use the Venn diagram in Figure 2(b). The sets A and B in Figure 2(b) are said to be **disjoint**.

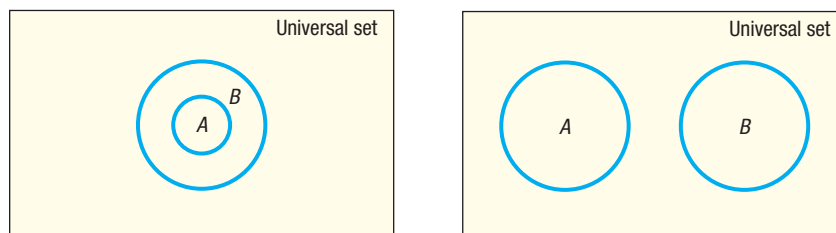


Figure 2

(a) $A \subseteq B$
subset

(b) $A \cap B = \emptyset$
disjoint sets

Figures 3(a), 3(b), and 3(c) use Venn diagrams to illustrate intersection, union, and complement, respectively.

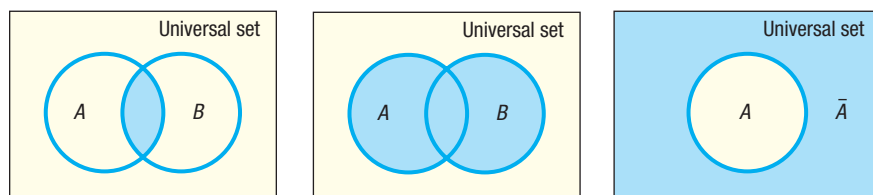


Figure 3

(a) $A \cap B$
intersection

(b) $A \cup B$
union

(c) \bar{A}
complement

*Some texts use the notation A' or A^c for the complement of A .

2 Classify Numbers

It is helpful to classify the various kinds of numbers that we deal with as sets. The **counting numbers**, or **natural numbers**, are the numbers in the set $\{1, 2, 3, 4, \dots\}$. (The three dots, called an **ellipsis**, indicate that the pattern continues indefinitely.) As their name implies, these numbers are often used to count things. For example, there are 26 letters in our alphabet; there are 100 cents in a dollar. The **whole numbers** are the numbers in the set $\{0, 1, 2, 3, \dots\}$ —that is, the counting numbers together with 0. The set of counting numbers is a subset of the set of whole numbers.

DEFINITION Integers

The **integers** are the set of numbers $\{\dots, -3, -2, -1, 0, 1, 2, 3, \dots\}$.

These numbers are useful in many situations. For example, if your checking account has \$10 in it and you write a check for \$15, you can represent the current balance as $-\$5$.

Each time we expand a number system, such as from the whole numbers to the integers, we do so in order to be able to handle new, and usually more complicated, problems. The integers enable us to solve problems requiring both positive and negative counting numbers, such as profit/loss, height above/below sea level, temperature above/below 0°F , and so on.

But integers alone are not sufficient for *all* problems. For example, they do not answer the question “What part of a dollar is 38 cents?” To answer such a question, we enlarge our number system to include *rational numbers*. For example, $\frac{38}{100}$ answers the question “What part of a dollar is 38 cents?”

DEFINITION Rational Number

A **rational number** is a number that can be expressed as a quotient $\frac{a}{b}$ of two integers. The integer a is called the **numerator**, and the integer b , which cannot be 0, is called the **denominator**. The rational numbers are the numbers in the set $\left\{x \mid x = \frac{a}{b}, \text{ where } a, b \text{ are integers and } b \neq 0\right\}$.

Examples of rational numbers are $\frac{3}{4}$, $\frac{5}{2}$, $\frac{0}{4}$, $-\frac{2}{3}$, and $\frac{100}{3}$. Since $\frac{a}{1} = a$ for any integer a , it follows that the set of integers is a subset of the set of rational numbers.

Rational numbers may be represented as **decimals**. For example, the rational numbers $\frac{3}{4}$, $\frac{5}{2}$, $-\frac{2}{3}$, and $\frac{7}{66}$ may be represented as decimals by merely carrying out the indicated division:

$$\frac{3}{4} = 0.75 \quad \frac{5}{2} = 2.5 \quad -\frac{2}{3} = -0.666\dots = -0.\overline{6} \quad \frac{7}{66} = 0.106060\dots = 0.1\overline{06}$$

Notice that the decimal representations of $\frac{3}{4}$ and $\frac{5}{2}$ terminate, or end. The decimal representations of $-\frac{2}{3}$ and $\frac{7}{66}$ do not terminate, but they do exhibit a pattern of repetition. For $-\frac{2}{3}$, the 6 repeats indefinitely, as indicated by the bar over the 6; for $\frac{7}{66}$, the block 06 repeats indefinitely, as indicated by the bar over the 06. It can be shown that every rational number may be represented by a decimal that either terminates or is nonterminating with a repeating block of digits, and vice versa.

On the other hand, some decimals do not fit into either of these categories. Such decimals represent **irrational numbers**. Every irrational number may be represented by a decimal that neither repeats nor terminates. In other words, irrational numbers cannot be written in the form $\frac{a}{b}$, where a, b are integers and $b \neq 0$.

Irrational numbers occur naturally. For example, consider the isosceles right triangle whose legs are each of length 1. See Figure 4. The length of the hypotenuse is $\sqrt{2}$, an irrational number.

Also, the number that equals the ratio of the circumference C to the diameter d of any circle, denoted by the symbol π (the Greek letter pi), is an irrational number. See Figure 5.

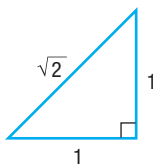
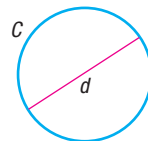


Figure 4

Figure 5 $\pi = \frac{C}{d}$

DEFINITION Real Numbers

The set of **real numbers** is the union of the set of rational numbers with the set of irrational numbers.

Figure 6 shows the relationship of various types of numbers.*

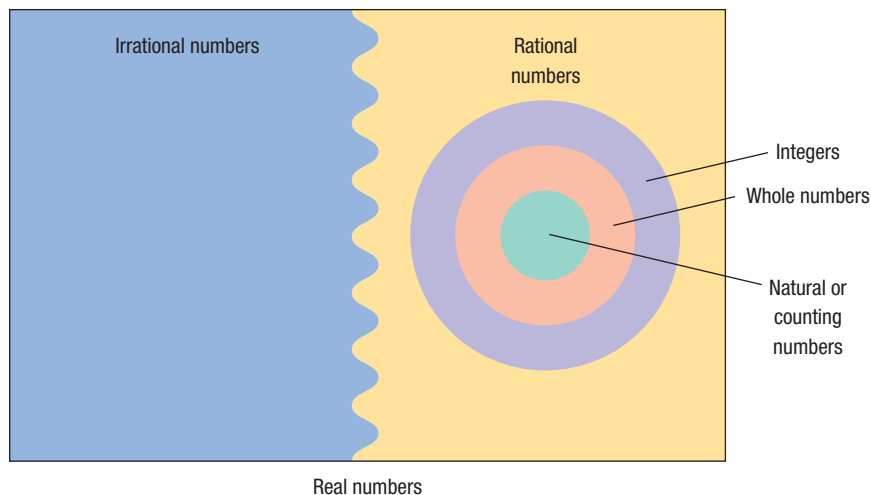


Figure 6

EXAMPLE 4

Classifying the Numbers in a Set

List the numbers in the set

$$\left\{ -3, \frac{4}{3}, 0.12, \sqrt{2}, \pi, 10, 2.151515 \dots \text{ (where the block 15 repeats)} \right\}$$

that are

- (a) Natural numbers (b) Integers (c) Rational numbers
 (d) Irrational numbers (e) Real numbers

Solution

- (a) 10 is the only natural number.
 (b) -3 and 10 are integers.
 (c) -3 , 10, $\frac{4}{3}$, 0.12, and 2.151515... are rational numbers.
 (d) $\sqrt{2}$ and π are irrational numbers.
 (e) All the numbers listed are real numbers.

Now Work PROBLEM 25

*The set of real numbers is a subset of the set of complex numbers. We discuss complex numbers in Chapter 1, Section 1.3.

Approximations

Every decimal may be represented by a real number (either rational or irrational), and every real number may be represented by a decimal.

In practice, the decimal representation of an irrational number is given as an approximation. For example, using the symbol \approx (read as “approximately equal to”), we can write

$$\sqrt{2} \approx 1.4142 \quad \pi \approx 3.1416$$

In approximating decimals, we either *round* or *truncate* to a given number of decimal places.* The number of places establishes the location of the *final digit* in the decimal approximation.

Truncation: Drop all of the digits that follow the specified final digit in the decimal.

Rounding: Identify the specified final digit in the decimal. If the next digit is 5 or more, add 1 to the final digit; if the next digit is 4 or less, leave the final digit as it is. Then truncate following the final digit.

EXAMPLE 5

Approximating a Decimal to Two Places

Approximate 20.98752 to two decimal places by

- Truncating
- Rounding

Solution

For 20.98752, the final digit is 8, since it is two decimal places from the decimal point.

- To truncate, we remove all digits following the final digit 8. The truncation of 20.98752 to two decimal places is 20.98.
- The digit following the final digit 8 is the digit 7. Since 7 is 5 or more, we add 1 to the final digit 8 and truncate. The rounded form of 20.98752 to two decimal places is 20.99.

EXAMPLE 6

Approximating a Decimal to Two and Four Places

Number	Rounded to Two Decimal Places	Rounded to Four Decimal Places	Truncated to Two Decimal Places	Truncated to Four Decimal Places
(a) 3.14159	3.14	3.1416	3.14	3.1415
(b) 0.056128	0.06	0.0561	0.05	0.0561
(c) 893.46125	893.46	893.4613	893.46	893.4612

Now Work PROBLEM 29



Calculators and Graphing Utilities

Calculators are incapable of displaying decimals that contain a large number of digits. For example, some calculators are capable of displaying only eight digits. When a number requires more than eight digits, the calculator either truncates or rounds.

*Sometimes we say “correct to a given number of decimal places” instead of “truncate.”

To see how your calculator handles decimals, divide 2 by 3. How many digits do you see? Is the last digit a 6 or a 7? If it is a 6, your calculator truncates; if it is a 7, your calculator rounds.

There are different kinds of calculators. An **arithmetic** calculator can only add, subtract, multiply, and divide numbers; therefore, this type is not adequate for this course. **Scientific** calculators have all the capabilities of arithmetic calculators and also contain **function keys** labeled \ln , \log , \sin , \cos , \tan , x^y , inv , and so on. As you proceed through this text, you will discover how to use many of the function keys. **Graphing** calculators have all the capabilities of scientific calculators and contain a screen on which graphs can be displayed. We use the term **graphing utilities** to refer generically to all graphing calculators and computer software graphing packages.

For those who have access to a graphing utility, we have included comments, examples, and exercises marked with a , indicating that a graphing utility is required. We have also included an appendix that explains some of the capabilities of graphing utilities. The  comments, examples, and exercises may be omitted without loss of continuity, if so desired.

Operations

In algebra, we use letters such as x , y , a , b , and c to represent numbers. The symbols used in algebra for the operations of addition, subtraction, multiplication, and division are $+$, $-$, \cdot , and $/$. The words used to describe the results of these operations are **sum**, **difference**, **product**, and **quotient**. Table 1 summarizes these ideas.

Table 1

Operation	Symbol	Words
Addition	$a + b$	Sum: a plus b
Subtraction	$a - b$	Difference: a minus b
Multiplication	$a \cdot b$, $(a) \cdot b$, $a \cdot (b)$, $(a) \cdot (b)$, ab , $(a)b$, $a(b)$, $(a)(b)$	Product: a times b
Division	a/b or $\frac{a}{b}$	Quotient: a divided by b

In algebra, we generally avoid using the multiplication sign \times and the division sign \div so familiar in arithmetic. Notice also that when two expressions are placed next to each other without an operation symbol, as in ab , or in parentheses, as in $(a)(b)$, it is understood that the expressions, called **factors**, are to be multiplied.

We also prefer not to use mixed numbers in algebra. When mixed numbers are used, addition is understood; for example, $2\frac{3}{4}$ means $2 + \frac{3}{4}$. In algebra, use of a mixed number may be confusing because the absence of an operation symbol between two terms is generally taken to mean multiplication. The expression $2\frac{3}{4}$ is therefore written instead as 2.75 or as $\frac{11}{4}$.

The symbol $=$, called an **equal sign** and read as “equals” or “is,” is used to express the idea that the number or expression on the left of the equal sign is equivalent to the number or expression on the right.

EXAMPLE 7

Writing Statements Using Symbols

- (a) The sum of 2 and 7 equals 9. In symbols, this statement is written as $2 + 7 = 9$.
 (b) The product of 3 and 5 is 15. In symbols, this statement is written as $3 \cdot 5 = 15$.

3 Evaluate Numerical Expressions

Consider the expression $2 + 3 \cdot 6$. It is not clear whether we should add 2 and 3 to get 5, and then multiply by 6 to get 30; or first multiply 3 and 6 to get 18, and then add 2 to get 20. To avoid this ambiguity, we have the following agreement.

In Words

Multiply first, then add.

We agree that whenever the two operations of addition and multiplication separate three numbers, the multiplication operation is always performed first, followed by the addition operation.

For $2 + 3 \cdot 6$, then, we have

$$2 + 3 \cdot 6 = 2 + 18 = 20$$

EXAMPLE 8

Finding the Value of an Expression

Evaluate each expression.

(a) $3 + 4 \cdot 5$

(b) $8 \cdot 2 + 1$

(c) $2 + 2 \cdot 2$

Solution

(a) $3 + 4 \cdot 5 = 3 + 20 = 23$

(b) $8 \cdot 2 + 1 = 16 + 1 = 17$

↑
Multiply first.

↑
Multiply first.

(c) $2 + 2 \cdot 2 = 2 + 4 = 6$

Now Work PROBLEM 53

When we want to indicate adding 3 and 4 and then multiplying the result by 5, we use parentheses and write $(3 + 4) \cdot 5$. Whenever parentheses appear in an expression, it means “perform the operations within the parentheses first!”

EXAMPLE 9

Finding the Value of an Expression

(a) $(5 + 3) \cdot 4 = 8 \cdot 4 = 32$

(b) $(4 + 5) \cdot (8 - 2) = 9 \cdot 6 = 54$

When we divide two expressions, as in

$$\frac{2 + 3}{4 + 8}$$

it is understood that the division bar acts like parentheses; that is,

$$\frac{2 + 3}{4 + 8} = \frac{(2 + 3)}{(4 + 8)}$$

Rules for the Order of Operations

1. Begin with the innermost parentheses and work outward. Remember that in dividing two expressions, we treat the numerator and denominator as if they were enclosed in parentheses.
2. Perform multiplications and divisions, working from left to right.
3. Perform additions and subtractions, working from left to right.

EXAMPLE 10

Finding the Value of an Expression

Evaluate each expression.

(a) $8 \cdot 2 + 3$

(b) $5 \cdot (3 + 4) + 2$

(c) $\frac{2 + 5}{2 + 4 \cdot 7}$

(d) $2 + [4 + 2 \cdot (10 + 6)]$

Solution

(a) $8 \cdot 2 + 3 = 16 + 3 = 19$



Multiply first.

(b) $5 \cdot (3 + 4) + 2 = 5 \cdot 7 + 2 = 35 + 2 = 37$



Parentheses first



Multiply before adding.

(c) $\frac{2 + 5}{2 + 4 \cdot 7} = \frac{2 + 5}{2 + 28} = \frac{7}{30}$

(d) $2 + [4 + 2 \cdot (10 + 6)] = 2 + [4 + 2 \cdot (16)]$

$$= 2 + [4 + 32] = 2 + [36] = 38$$

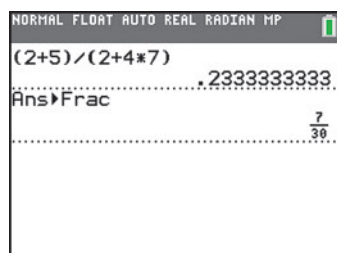


Figure 7

Be careful if you use a calculator. For Example 10(c), you need to use parentheses. See Figure 7.* If you don't, the calculator will compute the expression

$$2 + \frac{5}{2} + 4 \cdot 7 = 2 + 2.5 + 28 = 32.5$$

giving a wrong answer.

 **Now Work** PROBLEMS 59 AND 67

4 Work with Properties of Real Numbers

An equal sign is used to mean that one expression is equivalent to another. Four important properties of equality are listed next. In this list, a , b , and c represent real numbers.

- The **reflexive property** states that a number equals itself; that is, $a = a$.
- The **symmetric property** states that if $a = b$, then $b = a$.
- The **transitive property** states that if $a = b$ and $b = c$, then $a = c$.
- The **principle of substitution** states that if $a = b$, then we may substitute b for a in any expression containing a .

Now, let's consider some other properties of real numbers.

EXAMPLE 11

Commutative Properties

(a) $3 + 5 = 8$

$5 + 3 = 8$

$3 + 5 = 5 + 3$

(b) $2 \cdot 3 = 6$

$3 \cdot 2 = 6$

$2 \cdot 3 = 3 \cdot 2$

This example illustrates the *commutative property* of real numbers, which states that the order in which addition or multiplication takes place does not affect the final result.

*Notice that we converted the decimal to its fraction form. Another option, when using a TI-84 Plus C, is to use the fraction template under the MATH button to enter the expression as it appears in Example 10(c). Consult your manual to see how to enter such expressions on your calculator.