



Precalculus

Concepts Through Functions

A Right Triangle Approach to Trigonometry

3

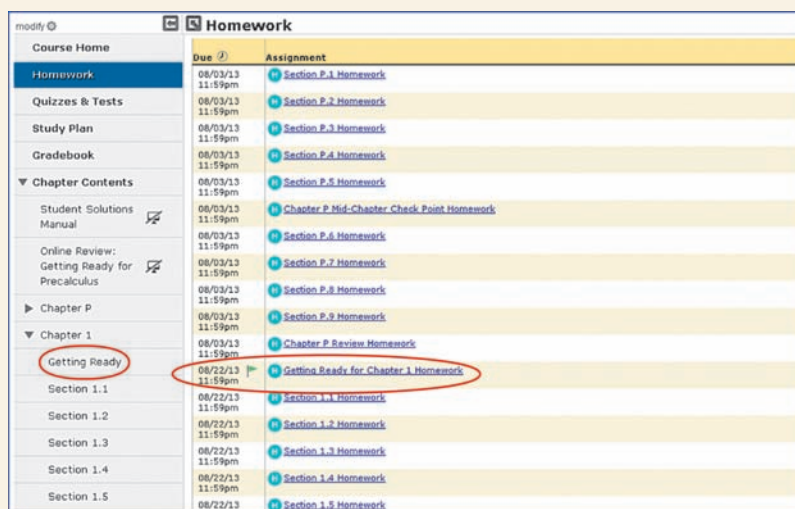
Sullivan
Sullivan

Getting Ready

Are you frustrated when you know you learned a math concept in the past, but you can't quite remember the skill when it's time to use it? Don't worry!

The authors have included Getting Ready material so you can brush up on forgotten material efficiently by taking a quick skill review quiz to pinpoint the areas where you need help.

Then, a personalized homework assignment provides additional practice on those forgotten concepts, right when you need it.



Due	Assignment
08/03/13 11:59pm	Section P.1 Homework
08/03/13 11:59pm	Section P.2 Homework
08/03/13 11:59pm	Section P.3 Homework
08/03/13 11:59pm	Section P.4 Homework
08/03/13 11:59pm	Section P.5 Homework
08/03/13 11:59pm	Chapter P Mid-Chapter Check Point Homework
08/03/13 11:59pm	Section P.6 Homework
08/03/13 11:59pm	Section P.7 Homework
08/03/13 11:59pm	Section P.8 Homework
08/03/13 11:59pm	Section P.9 Homework
08/03/13 11:59pm	Chapter P Review Homework
08/22/13 11:59pm	Getting Ready for Chapter 1 Homework
08/22/13 11:59pm	Section 1.1 Homework
08/22/13 11:59pm	Section 1.2 Homework
08/22/13 11:59pm	Section 1.3 Homework
08/22/13 11:59pm	Section 1.4 Homework
08/22/13 11:59pm	Section 1.5 Homework



Retain Your Knowledge

As you work through your math course, these MyMathLab® exercises support ongoing review to help you maintain essential skills.

The ability to recall important math concepts as you continually acquire new mathematical skills will help you be successful in this math course and in your future math courses.



Scan the code or visit www.mymathlab.com/success-stories to learn how students across the country have used MyMathLab to achieve their potential and be successful in their math courses.

Achieve Your Potential

The authors, Michael Sullivan and Michael Sullivan, III, have developed specific content in MyMathLab® to ensure you have many resources to help you achieve success in mathematics - and beyond!

The MyMathLab features described here will help you:

- **Brush up** on math skills and concepts you may have forgotten
- **Retain** new concepts as you move through your math course
- **Develop** skills that will help with your transition to college to your profession

Adaptive Study Plan

The Study Plan will help you study more efficiently and effectively.

Your performance and activity are assessed continually in real time, providing a personalized experience based on your individual needs.



Skills for Success

The Skills for Success Module supports your continued success in college.

This module provides tutorials and guidance on a variety of topics, including transitioning to college, online learning, time management and more.

Additional content is provided to help with the development of professional skills such as resume writing or creation and interview preparation.

Precalculus

Concepts Through Functions

A Right Triangle Approach To Trigonometry

Third Edition

Michael Sullivan

Chicago State University

Michael Sullivan, III

Joliet Junior College

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editor in Chief: *Anne Kelly*
Acquisitions Editor: *Dawn Murrin*
Assistant Editor: *Joseph Colella*
Senior Managing Editor: *Karen Wernholm*
Associate Managing Editor: *Tamela Ambush*
Senior Production Project Manager: *Peggy McMahan*
Digital Assets Manager: *Marianne Groth*
Associate Media Producer: *Marielle Guiney*
Project Manager, MyMathLab: *Kristina Evans*
QA Manager, Assessment Content: *Marty Wright*
Senior Marketing Manager: *Michelle Cook*
Marketing Manager: *Peggy Sue Lucas*
Marketing Assistant: *Justine Goulart*
Senior Author Support/Technology Specialist: *Joe Vetere*

Procurement Manager: *Vincent Scelta*
Procurement Specialist: *Debbie Rossi*
Text Design: *Tamara Newnam*
Production Coordination,
Composition, Illustrations: *Cenveo® Publisher Services*
Associate Director of Design,
USHE EMSS/HSC/EDU: *Andrea Nix*
Image Manager: *Rachel Youdelman*
Photo Research: *Integra, Inc.*
Text Permissions Liaison Manager: *Joseph Croscup*
Art Director: *Heather Scott*
Cover Design: *Tamara Newnam*
Cover Photo: *Kurhan/Shutterstock*

For permission to use copyrighted material, grateful acknowledgment has been made to the copyright holders listed on page C1, which is hereby made part of the copyright page.

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and Pearson Publisher was aware of a trademark claim, the designations have been printed in initial caps or all caps.

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.

The student edition of this text has been cataloged as follows:

Library of Congress Cataloging-in-Publication Data

Sullivan, Michael, 1942- author.

Precalculus: concepts through functions, a right triangle approach to trigonometry / Michael Sullivan, Chicago State University, Michael Sullivan, III, Joliet Junior College.—3/e.

pages cm

Includes bibliographical references and index.

ISBN 0-321-93105-X (alk. paper)

1. Functions—Textbooks. 2. Trigonometry—Textbooks.

I. Sullivan, Michael, III, 1967- author. II. Title.

QA331.3.S9238 2014

515—dc23

2013029570

Copyright © 2015, 2011, 2007 Pearson Education, Inc. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher. Printed in the United States of America. To obtain permission(s) to use material from this work, please submit a written request to Pearson Education, Inc., Permissions Department, One Lake Street, Upper Saddle River, New Jersey 07458, or you may fax your request to 201-236-3290.

1 2 3 4 5 6 7 8 9 10—CRK—16 15 14 13

PEARSON

www.pearsonhighered.com

ISBN-10: 0-321-93105-X

ISBN-13: 978-0-321-93105-4

For Michael S., Kevin, and Marissa (Sullivan)

Shannon, Patrick, and Ryan (Murphy)

Maeve, Sean, and Nolan (Sullivan)

Kaleigh, Billy, and Timmy (O'Hara)

The Next Generation



Contents

To the Student	xiv
Three Distinct Series	xv
Preface to the Instructor	xvi
Prepare for Class “Read the Book”	xxi
Practice “Work the Problems”	xxii
Review “Study for Quizzes and Tests”	xxiii
Resources for Success	xxiv
Applications Index	xxvi
F Foundations: A Prelude to Functions	1
F.1 The Distance and Midpoint Formulas	2
Use the Distance Formula • Use the Midpoint Formula	
F.2 Graphs of Equations in Two Variables; Intercepts; Symmetry	9
Graph Equations by Plotting Points • Find Intercepts from a Graph • Find Intercepts from an Equation • Test an Equation for Symmetry • Know How to Graph Key Equations	
F.3 Lines	19
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 • Find the Equation of a Line Given Two Points • Write the Equation of a Line in Slope-Intercept Form • Identify the Slope and y -Intercept of a Line from Its Equation • Graph Lines Written in General Form Using Intercepts • Find Equations of Parallel Lines • Find Equations of Perpendicular Lines	
F.4 Circles	34
Write the Standard Form of the Equation of a Circle • Graph a Circle • Work with the General Form of the Equation of a Circle	
Chapter Project	41
1 Functions and Their Graphs	42
1.1 Functions	43
Determine Whether a Relation Represents a Function • Find the Value of a Function • Find the Domain of a Function Defined by an Equation • Form the Sum, Difference, Product, and Quotient of Two Functions	
1.2 The Graph of a Function	56
Identify the Graph of a Function • Obtain Information from or about the Graph of a Function	
1.3 Properties of Functions	66
Determine Even and Odd Functions from a Graph • Identify Even and Odd Functions from the 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	

1.4 Library of Functions; Piecewise-defined Functions	78
Graph the Functions Listed in the Library of Functions • Graph Piecewise-defined Functions	
1.5 Graphing Techniques: Transformations	89
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	
1.6 Mathematical Models: Building Functions	101
Build and Analyze Functions	
1.7 Building Mathematical Models Using Variation	106
Construct a Model Using Direct Variation • Construct a Model Using Inverse Variation • Construct a Model Using Joint or Combined Variation	
Chapter Review	111
Chapter Test	115
Chapter Projects	116

2 Linear and Quadratic Functions **118**

2.1 Properties of Linear Functions and Linear Models	119
Graph Linear Functions • Use Average Rate of Change to Identify Linear Functions • Determine Whether a Linear Function Is Increasing, Decreasing or Constant • Find the Zero of a Linear Function • Build Linear Models from Verbal Descriptions	
2.2 Building Linear Models from Data	130
Draw and Interpret Scatter Diagrams • Distinguish between Linear and Nonlinear Relations • Use a Graphing Utility to Find the Line of Best Fit	
2.3 Quadratic Functions and Their Zeros	137
Find the Zeros of a Quadratic Function by Factoring • Find the Zeros of a Quadratic Function Using the Square Root Method • Find the Zeros of a Quadratic Function by Completing the Square • Find the Zeros of a Quadratic Function Using the Quadratic Formula • Find the Point of Intersection of Two Functions • Solve Equations That Are Quadratic in Form	
2.4 Properties of Quadratic Functions	148
Graph a Quadratic Function Using Transformations • Identify the Vertex and Axis of Symmetry of a Quadratic Function • 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	
2.5 Inequalities Involving Quadratic Functions	160
Solve Inequalities Involving a Quadratic Function	
2.6 Building Quadratic Models from Verbal Descriptions and from Data	164
Build Quadratic Models from Verbal Descriptions • Build Quadratic Models from Data	
2.7 Complex Zeros of a Quadratic Function	175
Find the Complex Zeros of a Quadratic Function	
2.8 Equations and Inequalities Involving the Absolute Value Function	178
Solve Absolute Value Equations • Solve Absolute Value Inequalities	
Chapter Review	184
Chapter Test	187

	Cumulative Review	188
	Chapter Projects	189
3	Polynomial and Rational Functions	191
3.1	Polynomial Functions and Models	192
	Identify Polynomial Functions and Their Degree • Graph Polynomial Functions Using Transformations • Identify the Real Zeros of a Polynomial Function and Their Multiplicity • Analyze the Graph of a Polynomial Function • Build Cubic Models from Data	
3.2	The Real Zeros of a Polynomial Function	212
	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 Theorem	
3.3	Complex Zeros; Fundamental Theorem of Algebra	226
	Use the Conjugate Pairs Theorem • Find a Polynomial Function with Specified Zeros • Find the Complex Zeros of a Polynomial Function	
3.4	Properties of Rational Functions	232
	Find the Domain of a Rational Function • Find the Vertical Asymptotes of a Rational Function • Find the Horizontal or Oblique Asymptote of a Rational Function	
3.5	The Graph of a Rational Function	243
	Analyze the Graph of a Rational Function • Solve Applied Problems Involving Rational Functions	
3.6	Polynomial and Rational Inequalities	258
	Solve Polynomial Inequalities • Solve Rational Inequalities	
	Chapter Review	266
	Chapter Test	270
	Cumulative Review	270
	Chapter Projects	271
4	Exponential and Logarithmic Functions	273
4.1	Composite Functions	274
	Form a Composite Function • Find the Domain of a Composite Function	
4.2	One-to-One Functions; Inverse Functions	282
	Determine Whether a Function Is One-to-One • Determine the Inverse of a Function Defined by a Map or a Set of Ordered Pairs • Obtain the Graph of the Inverse Function from the Graph of the Function • Find the Inverse of a Function Defined by an Equation	
4.3	Exponential Functions	294
	Evaluate Exponential Functions • Graph Exponential Functions • Define the Number e • Solve Exponential Equations	
4.4	Logarithmic Functions	311
	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	

4.5	Properties of Logarithms	324
	Work with Properties of Logarithms • Write a Logarithmic Expression as a Sum or Difference of Logarithms • Write a Logarithmic Expression as a Single Logarithm • Evaluate a Logarithm Whose Base Is Neither 10 Nor e • Graph a Logarithmic Function Whose Base Is Neither 10 Nor e	
4.6	Logarithmic and Exponential Equations	333
	Solve Logarithmic Equations • Solve Exponential Equations • Solve Logarithmic and Exponential Equations Using a Graphing Utility	
4.7	Financial Models	339
	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	
4.8	Exponential Growth and Decay Models; Newton's Law; Logistic Growth and Decay Models	349
	Find Equations of Populations That Obey the Law of Uninhibited Growth • Find Equations of Populations That Obey the Law of Decay • Use Newton's Law of Cooling • Use Logistic Models	
4.9	Building Exponential, Logarithmic, and Logistic Models from Data	359
	Build an Exponential Model from Data • Build a Logarithmic Model from Data • Build a Logistic Model from Data	
	Chapter Review	367
	Chapter Test	372
	Cumulative Review	373
	Chapter Projects	374

5 **Trigonometric Functions** **375**

5.1	Angles and Their Measures	376
	Convert between Decimals and Degrees, Minutes, Seconds Measures for Angles • Find the Length if an Arc of a Circle • Convert from Degrees to Radians and from Radians to Degrees • Find the Area of a Sector of a Circle • Find the Linear Speed of an Object Traveling in Circular Motion	
5.2	Right Triangle Trigonometry	390
	Find the Values of Trigonometric Functions of Acute Angles • Use the Fundamental Identities • Find the Values of the Remaining Trigonometric Functions, Given the Value of One of Them • Use the Complementary Angle Theorem	
5.3	Computing the Values of Trigonometric Functions of Acute Angles	402
	Find the Exact Values of the Trigonometric Functions of $\frac{\pi}{4} = 45^\circ$ • Find the Exact Values of the Trigonometric Functions of $\frac{\pi}{6} = 30^\circ$ and $\frac{\pi}{3} = 60^\circ$ • Use a Calculator to Approximate the Values of the Trigonometric Functions of Acute Angles • Model and Solve Applied Problems Involving Right Triangles	
5.4	Trigonometric Functions of any Angle	413
	Find the Exact Values of the Trigonometric Functions for Any Angle • Use Coterminal Angles to Find the Exact Value of a Trigonometric Function • Determine the Signs of the Trigonometric Functions of an Angle in a Given Quadrant • Find the Reference Angle of an Angle • Use a Reference Angle to Find the Exact Value of a Trigonometric Function • Find the Exact Values of Trigonometric Functions of an Angle, Given Information about the Functions	

5.5	Unit Circle Approach; Properties of the Trigonometric Functions	423
	Find the Exact Values of the Trigonometric Functions Using the Unit Circle • Know the Domain and Range of the Trigonometric Functions • Use the Periodic Properties to Find the Exact Values of the Trigonometric Functions • Use Even–Odd Properties to Find the Exact Values of the Trigonometric Functions	
5.6	Graphs of the Sine and Cosine Functions	434
	Graph Functions of the Form $y = A \sin(\omega x)$ Using Transformations • Graph Functions of the Form $y = A \cos(\omega x)$ Using Transformations • Determine the Amplitude and Period of Sinusoidal Functions • Graph Sinusoidal Functions Using Key Points • Find an Equation for a Sinusoidal Graph	
5.7	Graphs of the Tangent, Cotangent, Cosecant, and Secant Functions	449
	Graph Functions of the Form $y = A \tan(\omega x) + B$ and $y = A \cot(\omega x) + B$ • Graph Functions of the Form $y = A \csc(\omega x) + B$ and $y = A \sec(\omega x) + B$	
5.8	Phase Shift; Sinusoidal Curve Fitting	457
	Graph Sinusoidal Functions of the Form $y = A \sin(\omega x - \phi) + B$ • Build Sinusoidal Models from Data	
	Chapter Review	468
	Chapter Test	473
	Cumulative Review	474
	Chapter Projects	475
6	Analytic Trigonometry	477
6.1	The Inverse Sine, Cosine, and Tangent Functions	478
	Find the Exact Value of an Inverse Sine Function • Find an Approximate Value of an Inverse Sine Function • Use Properties of Inverse Functions to Find Exact Values of Certain Composite Functions • Find the Inverse Function of a Trigonometric Function • Solve Equations Involving Inverse Trigonometric Functions	
6.2	The Inverse Trigonometric Functions (Continued)	490
	Find the Exact Value of Expressions Involving the Inverse Sine, Cosine, and Tangent Functions • Define the Inverse Secant, Cosecant, and Cotangent Functions • Use a Calculator to Evaluate $\sec^{-1} x$, $\csc^{-1} x$, and $\cot^{-1} x$ • Write a Trigonometric Expression as an Algebraic Expression	
6.3	Trigonometric Equations	496
	Solve Equations Involving a Single Trigonometric Function • Solve Trigonometric Equations Using a Calculator • Solve Trigonometric Equations Quadratic in Form • Solve Trigonometric Equations Using Fundamental Identities • Solve Trigonometric Equations Using a Graphing Utility	
6.4	Trigonometric Identities	505
	Use Algebra to Simplify Trigonometric Expressions • Establish Identities	
6.5	Sum and Difference Formulas	513
	Use Sum and Difference Formulas to Find Exact Values • Use Sum and Difference Formulas to Establish Identities • Use Sum and Difference Formulas Involving Inverse Trigonometric Functions • Solve Trigonometric Equations Linear in Sine and Cosine	
6.6	Double-angle and Half-angle Formulas	525
	Use Double-angle Formulas to Find Exact Values • Use Double-angle Formulas to Establish Identities • Use Half-angle Formulas to Find Exact Values	

6.7	Product-to-Sum and Sum-to-Product Formulas	535
	Express Products as Sums • Express Sums as Products	
	Chapter Review	539
	Chapter Test	543
	Cumulative Review	543
	Chapter Projects	544

7 Applications of Trigonometric Functions 545

7.1	Applications Involving Right Triangles	546
	Solve Right Triangles • Solve Applied Problems	
7.2	The Law of Sines	551
	Solve SAA or ASA Triangles • Solve SSA Triangles • Solve Applied Problems	
7.3	The Law of Cosines	562
	Solve SAS Triangles • Solve SSS Triangles • Solve Applied Problems	
7.4	Area of a Triangle	568
	Find the Area of SAS Triangles • Find the Area of SSS Triangles	
7.5	Simple Harmonic Motion; Damped Motion; Combining Waves	575
	Build a Model for an Object in Simple Harmonic Motion • Analyze Simple Harmonic Motion • Analyze an Object in Damped Motion • Graph the Sum of Two Functions	
	Chapter Review	584
	Chapter Test	586
	Cumulative Review	587
	Chapter Projects	588

8 Polar Coordinates; Vectors 589

8.1	Polar Coordinates	590
	Plot Points Using Polar Coordinates • Convert from Polar Coordinates to Rectangular Coordinates • Convert from Rectangular Coordinates to Polar Coordinates • Transform Equations between Polar and Rectangular Forms	
8.2	Polar Equations and Graphs	599
	Identify and Graph Polar Equations by Converting to Rectangular Equations • Test Polar Equations for Symmetry • Graph Polar Equations by Plotting Points	
8.3	The Complex Plane; De Moivre's Theorem	614
	Plot Points in the Complex Plane • Convert a Complex Number between Rectangular Form and Polar Form • Find Products and Quotients of Complex Numbers in Polar Form • Use De Moivre's Theorem • Find Complex Roots	
8.4	Vectors	622
	Graph Vectors • Find a Position Vector • Add and Subtract Vectors Algebraically • Find a Scalar Multiple and the Magnitude of a Vector • Find a Unit Vector • Find a Vector from Its Direction and Magnitude • Model with Vectors	
8.5	The Dot Product	636
	Find the Dot Product of Two Vectors • Find the Angle between Two Vectors • Determine Whether Two Vectors Are Parallel • Determine Whether Two Vectors Are Orthogonal • Decompose a Vector into Two Orthogonal Vectors • Compute Work	

8.6	Vectors in Space	644
	Find the Distance between Two Points in Space • Find Position Vectors in Space • Perform Operations on Vectors • Find the Dot Product • Find the Angle between Two Vectors • Find the Direction Angles of a Vector	
8.7	The Cross Product	653
	Find the Cross Product of Two Vectors • Know Algebraic Properties of the Cross Product • Know Geometric Properties of the Cross Product • Find a Vector Orthogonal to Two Given Vectors • Find the Area of a Parallelogram	
	Chapter Review	659
	Chapter Test	662
	Cumulative Review	663
	Chapter Projects	663

9 Analytic Geometry **665**

9.1	Conics	666
	Know the Names of the Conics	
9.2	The Parabola	667
	Analyze Parabolas with Vertex at the Origin • Analyze Parabolas with Vertex at (h, k) • Solve Applied Problems Involving Parabolas	
9.3	The Ellipse	675
	Analyze Ellipses with Center at the Origin • Analyze Ellipses with Center at (h, k) • Solve Applied Problems Involving Ellipses	
9.4	The Hyperbola	685
	Analyze Hyperbolas with Center at the Origin • Find Asymptotes of Hyperbola • Analyze Hyperbolas with Center at (h, k) • Solve Applied Problems Involving Hyperbolas	
9.5	Rotation of Axes; General Form of a Conic	698
	Identify a Conic • Use a Rotation of Axes to Transform Equations • Analyze an Equation Using Rotation of Axes • Identify Conics without a Rotation of Axes	
9.6	Polar Equations of Conics	705
	Analyze and Graph Polar Equations of Conics • Convert the Polar Equation of a Conic to a Rectangular Equation	
9.7	Plane Curves and Parametric Equations	711
	Graph Parametric Equations • Find a Rectangular Equation for a Curve Defined Parametrically • Use Time as a Parameter in Parametric Equations • Find Parametric Equations for Curves Defined by Rectangular Equations	
	Chapter Review	723
	Chapter Test	726
	Cumulative Review	726
	Chapter Projects	727

10 Systems of Equations and Inequalities **728**

10.1	Systems of Linear Equations: Substitution and Elimination	729
	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

10.2 Systems of Linear Equations: Matrices	744
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	
10.3 Systems of Linear Equations: Determinants	758
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	
10.4 Matrix Algebra	768
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	
10.5 Partial Fraction Decomposition	787
Decompose P/Q , Where Q Has Only Nonrepeated Linear Factors • Decompose P/Q , Where Q Has Repeated Linear Factors • Decompose P/Q , Where Q Has a Nonrepeated Irreducible Quadratic Factor • Decompose P/Q , Where Q Has a Repeated Irreducible Quadratic Factor	
10.6 Systems of Nonlinear Equations	795
Solve a System of Nonlinear Equations Using Substitution • Solve a System of Nonlinear Equations Using Elimination	
10.7 Systems of Inequalities	804
Graph an Inequality • Graph a System of Inequalities	
10.8 Linear Programming	812
Set up a Linear Programming Problem • Solve a Linear Programming Problem	
Chapter Review	819
Chapter Test	822
Cumulative Review	823
Chapter Projects	824

11**Sequences; Induction; the Binomial Theorem 825**

11.1 Sequences	826
Write the First Several Terms of a Sequence • Write the Terms of a Sequence Defined by a Recursive Formula • Use Summation Notation • Find the Sum of a Sequence	
11.2 Arithmetic Sequences	836
Determine Whether a Sequence Is Arithmetic • Find a Formula for an Arithmetic Sequence • Find the Sum of an Arithmetic Sequence	
11.3 Geometric Sequences; Geometric Series	842
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	
11.4 Mathematical Induction	853
Prove Statements Using Mathematical Induction	

11.5	The Binomial Theorem	857
	Evaluate $\binom{n}{j}$ • Use the Binomial Theorem	
	Chapter Review	864
	Chapter Test	866
	Cumulative Review	866
	Chapter Projects	867
12	Counting and Probability	868
12.1	Counting	869
	Find All the Subsets of a Set • Count the Number of Elements in a Set • Solve Counting Problems Using the Multiplication Principle	
12.2	Permutations and Combinations	874
	Solve Counting Problems Using Permutations Involving n Distinct Objects • Solve Counting Problems Using Combinations • Solve Counting Problems Using Permutations Involving n Nondistinct Objects	
12.3	Probability	883
	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	893
	Chapter Test	895
	Cumulative Review	896
	Chapter Projects	896
A	Review	A1
A.1	Algebra Essentials	A1
	Work with Sets • 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	
A.2	Geometry Essentials	A13
	Use the Pythagorean Theorem and Its Converse • Know Geometry Formulas • Understand Congruent Triangles and Similar Triangles	
A.3	Polynomials	A22
	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	
A.4	Factoring Polynomials	A32
	Factoring 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	
A.5	Synthetic Division	A41
	Divide Polynomials Using Synthetic Division	
A.6	Rational Expressions	A45
	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	

A.7	<i>n</i>th Roots; Rational Exponents	A55
	Work with <i>n</i> th Roots • Simplify Radicals • Rationalize Denominators • Simplify Expressions with Rational Exponents	
A.8	Solving Equations	A63
	Solve Linear Equations • Solve Rational Equations • Solve Equations by Factoring • Solve Radical Equations	
A.9	Problem Solving: Interest, Mixture, Uniform Motion, Constant Rate Job Applications	A72
	Translate Verbal Descriptions into Mathematical Expressions • Solve Interest Problems • Solve Mixture Problems • Solve Uniform Motion Problems • Solve Constant Rate Job Problems	
A.10	Interval Notation; Solving Inequalities	A81
	Use Interval Notation • Use Properties of Inequalities • Solve Inequalities • Solve Combined Inequalities	
A.11	Complex Numbers	A89
	Add, Subtract, Multiply, and Divide Complex Numbers	

B **Graphing Utilities** **B1**

B.1	The Viewing Rectangle	B1
B.2	Using a Graphing Utility to Graph Equations	B3
B.3	Using a Graphing Utility to Locate Intercepts and Check for Symmetry	B5
B.4	Using a Graphing Utility to Solve Equations	B6
B.5	Square Screens	B8
B.6	Using a Graphing Utility to Graph Inequalities	B9
B.7	Using a Graphing Utility to Solve Systems of Linear Equations	B9
B.8	Using a Graphing Utility to Graph a Polar Equation	B11
B.9	Using a Graphing Utility to Graph Parametric Equations	B11
	Answers	AN1
	Photo Credits	C1
	Index	I1

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 book, you will build the knowledge and skills you need to be successful. Here's how you can use the book to your benefit.

Read Carefully

When you get busy, it's easy to skip reading and go right to the problems. Don't . . . the book 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

We use many different methods in the classroom to communicate. Those methods, when incorporated into the book, 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 book. Refer to the "Prepare for Class," "Practice," and "Review" on pages xxi–xxiii. 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 textbook.

Please do not hesitate to contact us, through Pearson Education, with any questions, suggestions, or comments that would improve this text. We look forward to hearing from you, and good luck with all of your studies.

Best Wishes!

*Michael Sullivan
Michael Sullivan, III*

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.

Concepts through Functions Series, Third 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. This approach supports the Rule of Four, which states that functions are 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*.

Contemporary Series, Ninth Edition

The Contemporary Series is the most traditional in approach yet modern in its treatment of precalculus mathematics. Graphing utility coverage is optional and can be included or excluded at the discretion of the instructor: *College Algebra*, *Algebra & Trigonometry*, *Trigonometry*, *Precalculus*.

Enhanced with Graphing Utilities Series, Sixth Edition

This series provides a thorough integration of graphing utilities into topics, allowing students to explore mathematical concepts and foreshadow ideas usually studied in later courses. Using technology, the approach to solving certain problems differs from the Concepts or Contemporary Series, while the emphasis on understanding concepts and building strong skills does not: *College Algebra*, *Algebra & Trigonometry*, *Precalculus*.

Preface to the Instructor

As professors at both an urban university and a community college, Michael Sullivan and Michael Sullivan, III, are aware of the varied needs of Precalculus students, ranging from those who have little mathematical background and a fear of mathematics courses, to those having a strong mathematical education and a high level of motivation. For some of your students, this will be their last course in mathematics, whereas others will further their mathematical education. This text is written for both groups.

As a teacher, and as an author of precalculus, engineering calculus, finite mathematics, and business calculus texts, Michael Sullivan understands what students must know if they are to be focused and successful in upper-level math courses. However, as a father of four, he also understands the realities of college life. As an author of a developmental mathematics series, Michael's co-author and son, Michael Sullivan, III, understands the trepidations and skills students bring to the Precalculus course. Michael, III also believes in the value of technology as a tool for learning that enhances understanding without sacrificing math skills. Together, both authors have taken great pains to ensure that the text contains solid, student-friendly examples and problems, as well as a clear and seamless writing style.

A tremendous benefit of authoring a successful series is the broad-based feedback we receive from teachers and students. We are sincerely grateful for their support. Virtually every change in this edition is the result of their thoughtful comments and suggestions. We are sincerely grateful for this support and hope that we have been able to take these ideas and, building upon a successful first edition, make this series an even better tool for learning and teaching. We continue to encourage you to share with us your experiences teaching from this text.

About This Book

This book utilizes a functions approach to Precalculus. Functions are introduced early (Chapter 1) in various formats: maps, tables, sets of ordered pairs, equations, and graphs. Our approach to functions illustrates the symbolic, numeric, graphic, and verbal representations of functions. This allows students to make connections between the visual representation of a function and its algebraic representation.

It is our belief that students need to “hit the ground running” so that they do not become complacent in their studies. After all, it is highly likely that students have been exposed to solving equations and inequalities prior to entering this class. By spending precious time reviewing these concepts, students are likely to think of the course as a re-hash of material learned in other courses and say to themselves, “I know this material, so I don't have to study.” This may result in the students developing poor study habits for

this course. By introducing functions early in the course, students are less likely to develop bad habits.

Another advantage of the early introduction of functions is that the discussion of equations and inequalities can focus around the concept of a function. For example, rather than asking students to solve an equation such as $2x^2 + 5x + 2 = 0$, we ask students to find the zeros of $f(x) = 2x^2 + 5x + 2$ or solve $f(x) = 0$ when $f(x) = 2x^2 + 5x + 2$. While the technique used to solve this type of problem is the same, the fact that the problem looks different to the student means the student is less apt to say, “Oh, I already have seen this problem before, and I know how to solve it.” In addition, in Calculus students are going to be asked to solve equations such as $f'(x) = 0$, so solving $f(x) = 0$ is a logical prerequisite skill to practice in Precalculus. Another advantage to solving equations through the eyes of a function is that the properties of functions can be included in the solution. For example, the linear function $f(x) = 2x - 3$ has one real zero because the function f is increasing on its domain.

Features in the Third Edition

Rather than provide a list of new features here, that information can be found on pages xxi–xxiii.

This places the new 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 the features listed on pages xxi–xxiii and to discuss them with your students at the beginning of your course. Our experience has been that when students utilize these features, they are more successful in the course.

New to the Third Edition

- **Retain Your Knowledge** This new category of problems in the exercise set are based on the article “To Retain New Learning, Do the Math” published in the *Educati Review* in which author Kevin Washburn suggests that “the more students are required to recall new content or skills, the better their memory will be.” It is frustrating when students cannot recall skills learned earlier in the course. To alleviate this recall problem, we have created “Retain Your Knowledge” problems. These are problems considered to be “final exam material” that students must complete to maintain their skills. All the answers to these problems appear in the back of the book and all are programmed in MyMathLab.
- **Guided Lecture Notes** Ideal for online, emporium/re-design courses, inverted classrooms or traditional lecture classrooms. These lecture notes assist students in taking thorough, organized, and understandable notes as they watch the Author in Action videos by asking students to complete definitions, procedures, and examples based

on the content of the videos and book. 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 will introduce the topic and/or connect it somehow to either a real world application or previous section. For example, when teaching about the vertical line test in Section 1.2, 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 helps students process the information at a higher level of understanding.

- **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 projects are new and Internet-based, requiring the student to research information online in order to solve problems.
- **Author Solves It MathXL Video Clips**—author Michael Sullivan, III solves MathXL exercises typically requested by his students for more explanation or tutoring. These videos are a result of Sullivan’s experiences in the classroom and experiences in teaching online.
- **Exercise Sets** at the end of each section remain classified according to purpose. The “*Are You Prepared?*” exercises have been expanded to better serve the student who needs a just-in-time review of concepts utilized in the section. The *Concepts and Vocabulary* exercises have been updated. These fill-in-the-blank and True/False problems have been written to serve as reading quizzes. *Skill Building* exercises develop the student’s computational skills and are often grouped by objective. *Mixed Practice* exercises have been added where appropriate. These problems offer a comprehensive assessment of the skills learned in the section by asking problems that relate to more than one objective. Sometimes these require information from previous sections so students must utilize skills learned throughout the course. *Applications and Extension* problems have been updated and many new problems involving sourced information and data have been added to bring relevance and timeliness to the exercises. The *Explaining Concepts: Discussion and Writing* exercises have been updated and reworded to stimulate discussion of concepts in online discussion forums. These can also be used to spark classroom discussion. Finally, in the **Annotated Instructor’s Edition**, we have preselected problems that can serve as sample homework assignments. These are indicated by a blue underline, and they are assignable in MyMathLab[®] as part of a “Ready-to-Go” course, if desired.
- The **Chapter Review** now includes answers to all the problems. We have created a separate review worksheet for each chapter to help students review and practice key skills to prepare for exams. The worksheets can be found within MyMathLab[®] or downloaded from the Instructor’s Resource Center.

Changes in the Third Edition

• CONTENT

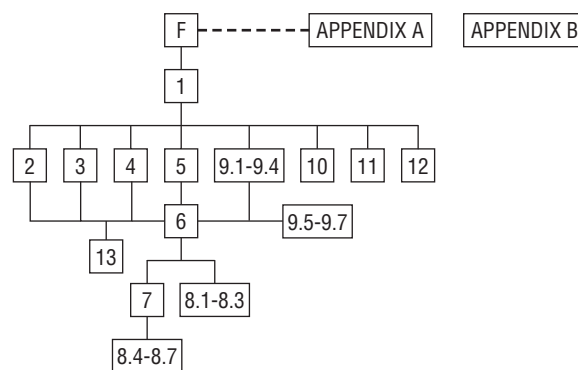
- **Chapter 2, Section 4** A new objective “Find a quadratic function given its vertex and one point” has been added.
- **Chapter 2, Section 5** A new example was added to illustrate that quadratic inequalities may have the empty set or all real numbers as a solution.
- **Chapter 3, Sections 1 and 4** The content related to describing the behavior of the graph of a polynomial or rational function near a zero has been removed.
- **Chapter 3, Section 4** Content has been added that discusses the role of multiplicity and behavior of the graph of rational function as the graph approaches a vertical asymptote.

• ORGANIZATION

- **Chapter 3, Sections 5 and 6** Section 5, *The Real Zeros of a Polynomial Function* and Section 6, *Complex Zeros, Fundamental Theorem of Algebra* have been moved to Sections 2 and 3, respectively. This was done in response to reviewer requests that “everything involving polynomials” be located sequentially. Skipping the new Sections 2 and 3 and proceeding to Section 4 *Properties of Rational Functions* can be done without loss of continuity.

Using this Book Effectively and Efficiently with Your Syllabus

To meet the varied needs of diverse syllabi, this book contains more content than is likely to be covered in a typical Precalculus course. As the chart illustrates, this book has been organized with flexibility of use in mind. Even within a given chapter, certain sections are optional and can be omitted without loss of continuity. See the detail following the flow chart.



Foundations A Prelude to Functions

Quick coverage of this chapter, which is mainly review material, will enable you to get to Chapter 1, *Functions and Their Graphs*, earlier.

Chapter 1 Functions and Their Graphs

Perhaps the most important chapter. Sections 1.6 and 1.7 are optional.

Chapter 2 Linear and Quadratic Functions

Topic selection depends on your syllabus. Sections 2.2, 2.6, and 2.7 may be omitted without a loss of continuity.

Chapter 3 Polynomial and Rational Functions

Topic selection depends on your syllabus. Section 3.6 is optional.

Chapter 4 Exponential and Logarithmic Functions

Sections 4.1–4.6 follow in sequence. Sections 4.7–4.9 are optional.

Chapter 5 Trigonometric Functions

The sections follow in sequence. Section 5.8 is optional.

Chapter 6 Analytic Trigonometry

Sections 6.2 and 6.7 may be omitted in a brief course.

Chapter 7 Applications of Trigonometric Functions

Sections 7.4 and 7.5 may be omitted in a brief course.

Chapter 8 Polar Coordinates; Vectors

Sections 8.1–8.3 and Sections 8.4–8.7 are independent and may be covered separately.

Chapter 9 Analytic Geometry

Sections 9.1–9.4 follow in sequence. Sections 9.5, 9.6, and 9.7, are independent of each other, but each requires Sections 9.1–9.4.

Chapter 10 Systems of Equations and Inequalities

Sections 10.2–10.7 may be covered in any order. Section 10.8 requires Section 10.7.

Chapter 11 Sequences; Induction; the Binomial Theorem

There are three independent parts: Sections 11.1–11.3, Section 11.4, and Section 11.5.

Chapter 12 Counting and Probability

The sections follow in sequence.

Appendix A Review

This review material may be covered at the start of a course or used as a just-in-time review. Specific references to this

material occur throughout the text to assist in the review process.

Appendix B Graphing Utilities

Reference is made to these sections at the appropriate place in the text.

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 book and series. 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; Peggy Lucas, who is a huge fan and works tirelessly to get the word out; Dawn Murrin, for her unmatched talent at getting the details right; Peggy McMahon for her organizational skills and leadership in overseeing production; Chris Hoag for her continued support and genuine interest; Greg Tobin for his leadership and commitment to excellence; and the Pearson Math and Science Sales team, for their continued confidence and personal support of our books.
- Bob Walters, Production Manager, who passed away after a long and valiant battle fighting lung disease. He was an old and dear friend—a true professional in every sense of the word.
- 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 accuracy checking answers.
- Michael Sullivan, III would like to thank his colleagues at Joliet Junior College for their support and feedback.

Finally, we offer our grateful thanks to the dedicated users and reviewers of our books, whose collective insights form the backbone of each textbook revision.

Our list of indebtedness just grows and grows. And, if we've forgotten anyone, please accept our apology. Thank you all.

James Africh—College of DuPage
 Steve Agronsky—Cal Poly State University
 Grant Alexander—Joliet Junior College
 Gary Amara—South Maine Community College
 Dave Anderson—South Suburban College
 Richard Andrews—Florida A&M University
 Joby Milo Anthony—University of Central Florida
 Jay Araas—Sheridan College
 James E. Arnold—University of Wisconsin-Milwaukee
 Adel Arshaghi—Center for Educational Merit
 Carolyn Autray—University of West Georgia

Agnes Azzolino—Middlesex County College
 Wilson P. Banks—Illinois State University
 Sudeshna Basu—Howard University
 Dale R. Bedgood—East Texas State University
 Beth Beno—South Suburban College
 Jessica Bernards—Portland Community college
 Carolyn Bernath—Tallahassee Community College
 Rebecca Berthiaume—Edison State College
 William H. Beyer—University of Akron
 John Bialas—Joliet Junior College
 Annette Blackwelder—Florida State University
 Richelle Blair—Lakeland Community College

Linda Blanco—Joliet Junior College
 Kevin Boddin—Lewis and Clark College
 Rebecca Bonk—Joliet Junior College
 Barry Booten—Florida Atlantic University
 Larry Bouldin—Roane State Community College
 Susan Bradley—Angelina College
 Bob Bradshaw—Ohlone College
 Trudy Bratten—Grossmont College
 Tim Bremer—Broome Community College
 Tim Britt—Jackson State Community College
 Michael Brook—University of Delaware
 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
 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
 Christine Cole—Moorpark College
 John Collado—South Suburban College
 Alicia Collins—Mesa Community College and Technical State University
 Nelson Collins—Joliet Junior College
 Jim Cooper—Joliet Junior College
 Denise Corbett—East Carolina University
 Carlos C. Corona—San Antonio College
 Theodore C. Coskey—South Seattle Community College
 Rebecca Cosner—Spokane Community College
 Donna Costello—Plano Senior High School
 Paul Crittenden—University of Nebraska at Lincoln
 Faye Dang—Joliet Junior College
 John Davenport—East Texas State University
 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—Lewis University
 Laura Egner—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
 W.A. Ferguson—University of Illinois-Urbana/Champaign
 Iris B. Fetta—Clemson University
 Vaden Fitton—North Virginia Community College
 Mason Flake—student at Edison Community College
 Timothy W. Flood—Pittsburgh State University
 Robert Frank—Westmoreland County Community College
 Merle Friel—Humboldt State University
 Richard A. Fritz—Moraine Valley Community College
 Dewey Furness—Ricke College
 Randy Gallaher—Lewis and Clark College
 Tina Garn—University of Arizona
 Dawit Getachew—Chicago State University
 Carrie Rose Gibson—North Idaho College
 Wayne Gibson—Rancho Santiago 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
 Scott Greenleaf—South Maine Community College
 Jennifer L. Grimsley—University of Charleston
 Ken Gurganus—University of North Carolina
 James E. Hall—University of Wisconsin-Madison
 Judy Hall—West Virginia University
 Edward R. Hancock—DeVry Institute of Technology
 Donna Harbin—University of Hawaii-Maui
 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 Hoburg—Western Connecticut State University
 Lynda Hollingsworth—Northwest Missouri 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
 Ron Jamison—Brigham Young University
 Richard A. Jensen—Manatee Community College
 Maritza Jimenez-Zeljak—Los Angeles Harbor College
 Glenn Johnson—Middlesex Community College
 Sandra G. Johnson—St. Cloud State University
 Tuesday Johnson—New Mexico State University
 Moana H. Karsteter—Tallahassee Community College
 Susitha Karunaratne—Purdue University North Central
 Donna Katula—Joliet Junior College
 Arthur Kaufman—College of Staten Island Baltimore County
 Thomas Kearns—North Kentucky University
 Jack Keating—Massasoit Community College
 Shelia Kellenbarger—Lincoln Public Schools
 Rachael Kenney—North Carolina State University
 Debra Kopco—Louisiana State University
 Lynne Kowski—Raritan Valley Community College
 Yelena Kravchuk—University of Alabama at Birmingham
 Mary Krohn—Butler University
 Keith Kuchar—Manatee Community College
 Tor Kwembe—Chicago State University
 Linda J. Kyle—Tarrant Country Jr. College
 H.E. Lacey—Texas A & M University
 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
 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
 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
 Alec Matheson—Lamar University
 Nancy Matthews—University of Oklahoma
 James Maxwell—Oklahoma State University-Stillwater
 Marsha May—Midwestern State University
 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
 David McGuire—Joliet Junior College
 James McLaughlin—West Chester University
 Angela McNulty—Joliet Junior College
 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
 A. Muhundan—Manatee Community College
 Jane Murphy—Middlesex Community College
 Brigitte M. Myers—Stanly Community College
 Richard Nadel—Florida International University
 Bill Naegele—South Suburban College
 Gabriel Nagy—Kansas State University
 Karla Neal—Louisiana State University
 Lawrence E. Newman—Holyoke Community College
 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
 E. James Peake—Iowa State University
 Kelly Pearson—Murray State University
 Dashamir Petrela—Florida Atlantic University
 Philip Pina—Florida Atlantic University
 Michael Prophet—University of Northern Iowa
 Laura Pyzdrowski—West Virginia 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
 Kenneth D. Reeves—San Antonio College
 Elsi Reinhardt—Truckee Meadows Community College
 Jose Remesar—Miami Dade College, Wolfson Campus
 Jane Ringwald—Iowa State University
 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
 David Ruffatto—Joliet Junior College
 Dennis C. Runde—Manatee Community College
 Alan Saleski—Loyola University of Chicago
 Susan Sandmeyer—Jamestown Community College
- Brenda Santistevan—Salt Lake Community College
 Catherine Sausville—George Mason University
 Linda Schmidt—Greenville Technical College
 Ingrid Scott—Montgomery College
 A.K. Shamma—University of West Florida
 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
 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
 Becky Stamper—Western Kentucky University
 Judy Staver—Florida Community College-South
 Neil Stephens—Hinsdale South High School
 Sonya Stephens—Florida A&M University
 Patrick Stevens—Joliet Junior College
 John Sumner—University of Tampa
 Steve Szabo—Eastern Kentucky University
 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
 Suzanne Topp—Salt Lake Community College
 Marilyn Toscano—University of Wisconsin, Superior
 Marvel Townsend—University of Florida
 Jim Trudnowski—Carroll College
 Robert Tuskey—Joliet Junior College
 Mihaela Vajiac—Chapman University-Orange
 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
 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
 George Zazi—Chicago State University
 Sharyn Zias—Jamestown Community College
 Steve Zuro—Joliet Junior College

Michael Sullivan
Chicago State University

Michael Sullivan, III
Joliet Junior College


Prepare for Class “Read the Book”

Feature	Description	Benefit	Page
Every Chapter Opener begins with...			
Chapter Opening Article & Project	Each chapter begins with a current article and ends with a related project. The article describes a real situation.	The Article describes a real situation. The Project lets you apply what you learned to solve a related problem.	273, 374
NEW! Internet Based Projects	The projects allow for the integration of spreadsheet technology that students will need to be a productive member of the workforce.	The projects allow the opportunity for students to collaborate and use mathematics to deal with issues that come up in their lives.	273, 374
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 studying by emphasizing what’s most important and where to find it.	294
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.	294
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!	294, 305
 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.	301, 306
WARNING	Warnings are provided in the text.	These point out common mistakes and help you to avoid them.	328
Exploration and Seeing the Concept	These represent graphing utility activities to foreshadow a concept or solidify a concept just presented.	You will obtain a deeper and more intuitive understanding of theorems and definition.	200, 315
 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.	311
 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!	70, 302
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, students can immediately see how each step is employed.	204
 Model It! Examples and Problems	These are examples and problems that 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, “Solve the following equation”. Rather, the equation must be developed based on an explanation of the problem. These problems require you to develop models that will allow you to describe the problem mathematically and suggest a solution to the problem.	319, 347

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!	294, 305
Concepts and Vocabulary	These short-answer questions, mainly Fill-in-the-Blank 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.	305
Skill Building	Correlated to section examples, these problems provide straightforward practice.	It’s important to dig in and develop your skills. These problems provide you with ample practice to do so.	305–307
Mixed Practice	These problems offer comprehensive assessment of the skills learned in the section by asking problems that relate to more than one concept or objective. These problems may also require you to utilize skills learned in previous sections.	Learning mathematics is a building process. Many concepts are interrelated. These problems help you see how mathematics builds on itself and also see how the concepts tie together.	307–308
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.	308–310
Discussion and Writing	“Discussion and Writing” problems are colored red. These 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.	310
NEW! Retain Your Knowledge	These problems allow you to practice content learned earlier in the course.	The ability to remember how to solve all the different problems learned throughout the course is difficult. These help you remember.	310
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 back to the related example to see if it helps.	304, 307
Chapter Review Problems	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 verify you understand all the skills and concepts of the chapter. Think of it as a comprehensive review of the chapter.	369–372

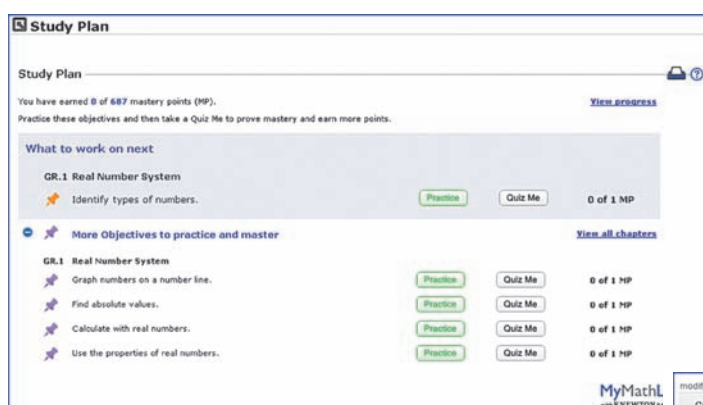
Review “Study for Quizzes and Tests”

Feature	Description	Benefit	Page
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!	367–368
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 mastery over the key material. If you get something wrong, review the suggested page numbers and try again.	369
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.	369–372
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.	372–373
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.	These are really important. They will ensure that you are not forgetting anything as you go. These will go a long way toward keeping you primed for the final exam.	373
Chapter Project	The Chapter Project applies to what you’ve learned in the chapter. Additional projects are available on the Instructor’s Resource Center (IRC).	The Project gives you an opportunity to apply what you’ve learned in the chapter to the opening article. If your instructor allows, these make excellent opportunities to work in a group, which is often the best way of learning math.	374
 NEW! Internet Based Projects	In selected chapters, a web-based project is given.	The projects allow the opportunity for students to collaborate and use mathematics to deal with issues that come up in their lives.	374

Resources for Success

MyMathLab® Online Course (access code required)

MyMathLab delivers **proven results** in helping individual students succeed. It provides **engaging experiences** that personalize, stimulate, and measure learning for each student. And, it comes from an **experienced partner** with educational expertise and an eye on the future. MyMathLab helps prepare students and gets them thinking more conceptually and visually through the following features:

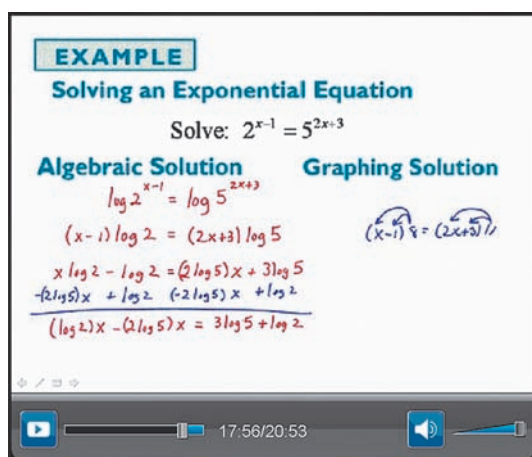
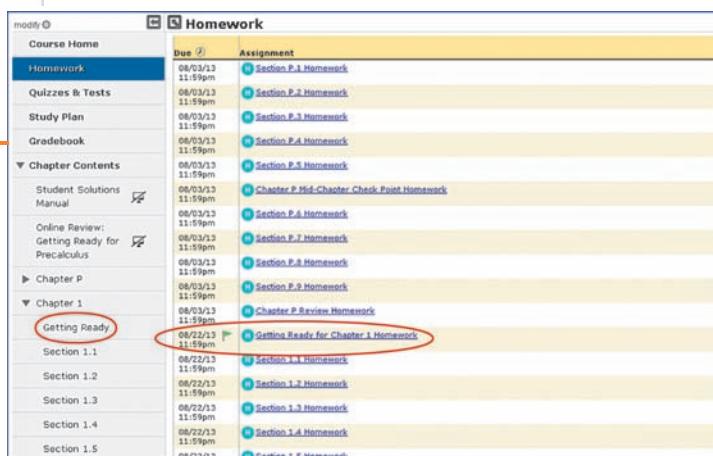


Adaptive Study Plan

The Study Plan makes studying more efficient and effective for every student. Performance and activity are assessed continually in real time. The data and analytics are used to provide personalized content-reinforcing concepts that target each student's strengths and weaknesses.

Getting Ready

Students refresh prerequisite topics through assignable skill review quizzes and personalized homework integrated in MyMathLab.

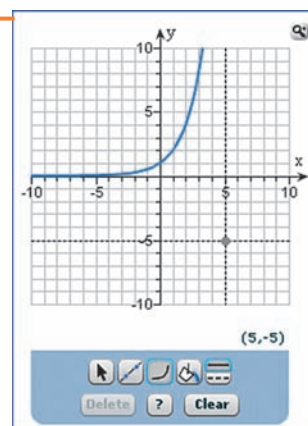


Video Assessment

Video assessment is tied to key Author in Action videos to check student's conceptual understanding of important math concepts.

Enhanced Graphing Functionality

New functionality within the graphing utility allows graphing of 3-point quadratic functions, 4-point cubic graphs, and transformations in exercises.



Skills for Success Modules are integrated within MyMathLab course to help students succeed in collegiate courses and prepare for future professions.

Retain Your Knowledge These new exercises support ongoing review at the course level and help students maintain essential skills.

Instructor Resources

Additional resources can be downloaded from www.pearsonhighered.com or hardcopy resources can be ordered from your sales representative.

Ready to Go MyMathLab® Course

Now it is even easier to get started with MyMathLab. The Ready to Go MyMathLab course option includes author-chosen preassigned homework, integrated review, and more.

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.

PowerPoint® Lecture Slides

Fully editable slides that correlate to the textbook.

Annotated Instructor's Edition

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

Instructor Solutions Manual

Includes fully worked solutions to all textbook exercises.

Mini Lecture Notes

Includes additional examples and helpful teaching tips, by section.

Online Chapter Projects

Additional projects that let students apply what was learned in the chapter.

Student Resources

Additional resources to help 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 MyMathlab.

Chapter Test Prep Videos

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



Student Solutions Manual

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

Guided Lecture Notes

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 MyMathLab. They can also be packaged with the textbook and MyMathLab access code.

Algebra Review

Four Chapters of Intermediate Algebra review. Perfect for a slower-paced course or for individual review.



Applications Index

Acoustics

amplifying sound, 371
loudness of sound, 323, 373
loudspeaker, 582
tuning fork, 582
whispering galleries, 682

Aerodynamics

modeling aircraft motion, 663–664

Aeronautics

Challenger disaster, 358

Agriculture

farm management, 817
farm workers in U.S., 358–359
field enclosure, 802
grazing area for cow, 573
minimizing cost, 817
removing stump, 635

Air travel

bearing of aircraft, 548, 550
flight time and ticket price, 135
frequent flyer miles, 559–560
intersection point of two planes,
102–103
parking at O'Hare International Airport,
86
revising a flight plan, 567
speed and direction of aircraft,
630, 634

Archaeology

age of ancient tools, 352
age of fossil, 356, 357
age of tree, 357
date of prehistoric man's death, 371

Architecture

brick staircase, 841, 865
floor design, 839–840, 865
football stadium seating, 841
mosaic design, 841, 865
Norman window, 172
One World Trade Center, 412
parabolic arch, 172
racetrack design, 684
special window, 172
stadium construction, 841
window design, 172

Area. *See also* Geometry

of Bermuda Triangle, 573
of sector of circle, 387
of segment of circle, 585

Art

fine decorative pieces, 410

xxvi

Astronomy

angle of elevation of Sun, 549
distances of planets from Sun, 835
planetary orbits, 681–682, 685
Earth, 684
Jupiter, 684
Mars, 684
Mercury, 711
Pluto, 685

Aviation

modeling aircraft motion, 663–664
orbital launches, 741

Biology

age versus total cholesterol, 366
alcohol and driving, 319, 324
bacterial growth, 350–351, 363
E-coli, 77, 120–121
blood types, 873
bone length, 187
cricket chirping, 174
gestation period, 183
healing of wounds, 308, 323
maternal age versus Down syndrome,
136
muscle force, 635
yeast biomass as function of time,
362–363

Business

advertising, 135, 187
automobile production, 280, 757
car rentals, 127
checkout lines, 892
clothing store, 894
cookie orders, 822
cost
of can, 254–255, 257
of commodity, 281
of manufacturing, 211, 265, 811
marginal, 159, 186
minimizing, 186, 817, 822
of production, 76, 281, 784–785, 822
of theater ticket per student, 265
of transporting goods, 87
weekly, 207
cost equation, 31, 110
cost function, 128
average, 60
demand
for candy, 110
for jeans, 135
for PCs, 364
demand equation, 186, 271
discounts, 281
drive-thru rate
at Burger King, 304
at Citibank, 308, 323

earnings of young adults, 728
equipment depreciation, 851
ethanol production, 363
Jiffy Lube's car arrival rate, 308–309, 323
managing a meat market, 818
milk production, 364
orange juice production, 757
personal computer price and demand,
364
presale order, 741
product design, 818
production scheduling, 817
product promotion, 32
profit, 785
cigar company, 100
maximizing, 815–816, 817–818
profit function, 56, 159–160
rate of return on, 347
restaurant management, 741
revenue, 159, 163–164
advertising and, 135
airline, 818
from calculator sales, 149
of clothing store, 773–774
daily, 160
from digital music, 100
maximizing, 159–160, 171
monthly, 159–160
from seating, 852
theater, 742
revenue equation, 110
salary, 841
gross, 55
increases in, 851, 865
sales
of movie theater ticket, 729, 733–734,
741
net, 8
salvage value, 371
straight-line depreciation, 124–125, 128
supply and demand, 125–126, 128
tax, 265
toy truck manufacturing, 811
transporting goods, 811
truck rentals, 31, 129
unemployment, 895
wages
of car salesperson, 31

Calculus

Simpson's rule, 172

Carpentry. *See also* Construction

pitch, 33

Chemistry

alpha particles, 697
decomposition reactions, 357
drug concentration, 256

gas laws, 110
 pH, 322
 radioactive decay, 356, 357, 364, 372
 radioactivity from Chernobyl, 357
 reactions, 172

Combinatorics

airport codes, 875
 binary codes, 894
 birthday permutations, 877, 881, 888–889,
 892, 894
 blouses and skirts combinations, 873
 book arrangements, 881
 box stacking, 881
 code formation, 881
 combination locks, 882
 committee formation, 879, 881, 882, 894
 Senate committees, 882
 flag arrangement, 880, 894
 letter codes, 875, 895
 letter combinations, 894
 license plate possibilities, 881, 894, 895
 lining people up, 876, 881
 number formation, 873, 881, 882, 895
 objects selection, 882
 seating arrangements, 894
 shirts and ties combinations, 873
 telephone numbers, 894
 two-symbol codewords, 872
 word formation, 879–880, 881, 895

Communications

cell phone plan, 42
 cell phone service, 86, 116, 129
 cell phone towers, 365
 installing cable TV, 105
 long distance
 comparing phone companies, 186
 international call plan, 129
 phone charges, 128
 satellite dish, 672, 674
 spreading of rumors, 308, 323
 Touch-Tone phones, 583

Computers and computing

Dell PCs, 364
 graphics, 633, 786–787
 households without personal computers,
 358
 JPEG image compression, 786
 LCD monitors, 186
 social media, 786
 three-click rule for web design,
 786
 website map, 785
 Word users, 358

Construction

of box, 802
 closed, 115
 open, 105
 of brick staircase, 865
 of can, 269
 of cylindrical tube, 802

of enclosures
 maximizing area of, 166–167, 171
 of fencing, 166–167, 171, 802
 minimum cost for, 257
 of flashlight, 674
 of headlight, 674
 of highway, 412, 560, 585
 installing cable TV, 105
 of open box, 147
 pitch of roof, 550
 of rain gutter, 172, 405–406
 of ramp, 559
 access ramp, 32
 of rectangular field enclosure, 171
 of stadium, 172, 841
 of steel drum, 257
 of swing set, 568
 of tent, 572
 TV dish, 674
 vent pipe installation, 684

Crime

income and, 366

Cryptography

matrices in, 785

Demographics

birth rate
 mother's age and, 174
 of unmarried women, 159
 diversity index, 322–323
 marital status, 874
 mosquito colony growth, 356–357
 population. *See* Population
 rabbit colony growth, 834

Design

of awning, 560
 of box with minimum surface area, 257
 of fine decorative pieces, 410
 of Little League Field, 389
 of water sprinkler, 387

Direction

of aircraft, 634
 compass heading, 634
 for crossing a river, 634, 635
 of fireworks display, 696
 of lightning strikes, 696
 of motorboat, 634
 of swimmer, 662

Distance

bicycle riding, 65
 circumference of Earth, 389
 between cities, 382–383, 387
 between Earth and Mercury, 561
 between Earth and Venus, 561
 from Earth to a star, 550
 of explosion, 697
 height
 of aircraft, 559, 561
 of bouncing ball, 851, 865

of bridge, 559
 of building, 550
 of cloud, 407–408
 of CN Tower, 411
 of Eiffel Tower, 411
 of embankment, 550
 of Great Pyramid of Cheops, 561
 of helicopter, 557, 585
 of hot-air balloon, 411
 of Lincoln's caricature on Mt. Rush-
 more, 411
 of mountain, 556, 559
 of One World Trade Center, 412
 of statue on a building, 408
 of tower, 411
 of Washington Monument, 411
 of Willis Tower, 550
 from home, 65
 of hot-air balloon
 to airport, 586
 from intersection, 8
 from intersection, 8, 104
 length
 of guy wire, 411, 413, 567
 of lake, 472
 of mountain trail, 411
 of ski lift, 559
 limiting magnitude of telescope, 371
 to the Moon, 559
 nautical mile in terms of statute miles,
 388
 pendulum swings, 847, 851
 to plateau, 411
 across a pond, 411
 reach of ladder, 411
 of rotating beacon, 456–457
 at sea, 556–557, 560
 to shore, 411, 472, 560
 between skyscrapers, 550
 to tower, 561
 between two moving vehicles, 8
 toward intersection, 104
 between two objects, 411
 visibility of Gibb's Hill Lighthouse beam,
 547–548, 551
 walking, 65
 of water tower to building, 874
 width
 of gorge, 410
 of Mississippi River, 550
 of river, 406–407, 472

Economics

Consumer Price Index (CPI), 348
 demand equations, 271
 earnings of young adults, 728
 federal deficit, 347, 371
 income versus crime rate, 366
 inflation, 347–348
 IS-LM model in, 742
 marginal propensity to consume, 852
 multiplier, 852
 participation rate, 56
 personal computer price and demand, 364

poverty rates, 269
 poverty threshold, 8
 relative income of child, 785
 unemployment, 895

Education

admission probabilities, 895
 age distribution of community college, 895
 college costs, 347, 851
 college tuition and fees, 784
 degrees awarded, 871
 doctoral degrees awarded, 892
 faculty composition, 892
 funding a college education, 371
 grade-point average and video games, 135
 learning curve, 309, 323
 maximum level achieved, 824
 multiple-choice test, 881
 Spring break, 817
 student loan, 116
 interest on, 784
 true/false test, 881

Electricity

alternating current (ac), 473
 alternating current (ac) circuits, 448, 466
 alternating current (ac) generators, 448
 charging a capacitor, 583
 cost of, 84–85
 current in *RC* circuit, 309
 current in *RL* circuit, 309, 323
 Kirchhoff's Rules, 742, 757
 parallel circuits
 resistance in, 242
 rates for, 31–32
 resistance, 110, 111, 242
 due to a conductor, 116

Electronics

Blu-ray drive, 387
 DVD drive, 387
 loudspeakers, 582
 microphones, 18
 sawtooth curve, 583

Energy

ethanol production, 363
 heat loss
 through wall, 108
 through window, 115
 nuclear power plant, 696–697
 solar, 18, 642, 674
 thermostat control, 99–100

Engineering

bridges
 clearance, 448
 Golden Gate, 168–169
 parabolic arch, 186, 674–675
 semielliptical arch, 684, 725
 suspension, 172, 674

drive wheel, 585–586
 electrical, 400
 Gateway Arch (St. Louis), 675
 grade of road, 33
 horsepower, 110
 lean of Leaning Tower of Pisa, 560
 maximum weight supportable by pine, 107
 piston engines, 410
 road system, 598
 robotic arm, 652
 rods and pistons, 568
 rod tolerance, 183
 safe load for a beam, 111
 searchlight, 674, 725
 whispering galleries, 684

Entertainment

banquet hall rental, 817
 cable subscribers, 366
Demon Roller Coaster customer rate, 309
 theater revenues, 742

Environment

endangered species population, 308
 lake pollution control laws, 834
 oil leakage, 280

Exercise and fitness. *See also Sports*

heartbeats during exercise, 121–122

Finance. *See also Investment(s)*

bills in wallet, 895
 calculator sales revenue, 149
 clothes shopping, 823
 college costs, 347, 851
 computer system purchase, 347
 cost
 of car rental, 87
 of driving a car, 31
 of electricity, 84–85
 of fast food, 741
 minimizing, 186, 257
 of natural gas, 86–87
 of RV rental, 188
 of tattoo, 659
 of trans-Atlantic travel, 55, 63–64
 of triangular lot, 572
 cost equation, 110
 cost function, 128
 cost minimization, 159
 credit cards
 balance on, 794
 debt, 834
 interest on, 347
 minimum payments for, 87–88
 payment, 834
 demand equation, 171, 188
 depreciation, 308, 367
 of car, 339, 374
 electricity rates, 31–32
 financial planning, 741, 754, 757–758, 808–809, 810, 812, 818

foreign exchange, 281
 future value of money, 211
 gross salary, 55
 international call plan, 129
 life cycle hypothesis, 173
 loans
 car, 834
 interest on, 116, 784
 repayment of, 347
 student, 784
 mortgages
 fees, 87
 interest rates on, 347
 payments, 106, 109, 115
 second, 347
 national debt, 76–77
 price appreciation of homes, 347
 prices
 demand vs., 186
 of fast food, 743
 for soda and hot dog combinations, 129
 refunds, 741
 rents and square footage, 173
 revenue equation, 110
 revenue maximization, 159, 165–166
 rich man's promise, 852
 salary calculation, 281
 salary options, 852–853
 saving
 for a car, 347
 for a home, 851
 savings accounts interest, 347
 sinking fund, 851
 taxes, 128
 e-filing returns, 87
 federal income, 87, 293
 luxury, 128
 used-car purchase, 347

Food and nutrition

animal, 818
 calories in fast foods, 44–45
 candy, 134
 colored candies, 883–884, 895
 cooler contents, 895
 cooling time of pizza, 357
 fast food, 741, 743
 Girl Scout cookies, 892
 hospital diet, 742, 757
 milk production, 364
 number of possible meals, 871–872
 pig roasts, 358
 raisins, 134
 warming time of Beer stein, 357

Forestry

wood product classification, 356

Games

die rolling, 884–885, 886, 895
 grains of wheat on a chess board, 852
 Powerball, 895

Gardens and gardening. *See also Landscaping***Geography**

area of Bermuda Triangle, 573
 area of lake, 572, 585
 grade of a mountain trail, 803
 inclination of hill, 643
 inclination of mountain trail, 547, 585

Geology

earthquakes, 323–324

Geometry

balloon volume, 280
 circle
 area of, 572
 equation of, 768
 inscribed, 103–104, 574
 length of chord of, 568
 radius of, 801
 collinear points, 767
 cone volume, 110, 281
 cube
 length of edge of, 225
 cylinder
 inscribing in cone, 105
 inscribing in sphere, 104
 volume of, 110, 281
 Descartes's method of equal roots, 802
 equation of line, 767
 ladder angle, 586
 polygon
 area of, 768
 number of sides of, 147
 quadrilateral area, 587
 rectangle
 area of, 55, 102, 186, 685
 dimensions of, 186, 801
 inscribed in semicircle, 104
 semicircle inscribed in, 104
 semicircle area, 572, 587
 surface area
 of balloon, 280
 triangle
 area of, 572, 586–587, 768
 circumscribing, 562
 inscribed in circle, 104
 isosceles, 55, 801, 802
 Pascal's, 834
 right, 410, 549
 sides of, 587
 volume of parallelepiped, 658

Government

federal deficit, 371
 federal income tax, 56, 87, 293
 first-class mail charge, 88
 national debt, 76–77
 stimulus package (2009), 347

Health. *See also Medicine*

breast cancer survival rate, 364
 cigarette use among teens, 32

expenditures on, 56
 ideal body weight, 293
 life cycle hypothesis, 173
 pancreatic cancer survival rate, 308

Home improvement. *See also Construction*

painting a house, 743

Investment(s)

annuity, 848–849, 851
 in bonds, 818
 EE Series, 347
 Treasuries, 757, 758, 808–809, 810, 812
 Treasury notes vs. Treasury bonds, 754
 zero-coupon, 344, 348
 in CDs, 343, 818
 compound interest on, 340–343, 347
 diversified, 742–743
 doubling of, 345, 348
 in fixed-income securities, 818
 401(K), 851, 865
 growth rate for, 347
 IRA, 347, 848–849, 851
 in mutual fund, 360–361
 return on, 347, 817, 818
 in stock
 appreciation, 347
 beta, 118, 189–190
 NASDAQ stocks, 881
 NYSE stocks, 881
 portfolios of, 874
 price of, 852
 time to reach goal, 347, 348
 tripling of, 345, 348

Landscaping. *See also Gardens and gardening*

pond enclosure, 186
 removing stump, 635
 tree cutting, 559, 757
 watering lawn, 387

Law and law enforcement

motor vehicle thefts, 892
 violent crimes, 56

Leisure and recreation

amusement park ride, 387
 cable TV, 105
 community skating rink, 116
 Ferris wheel, 39, 388, 561, 582
 swing displacement, 587
 video games and grade-point average, 135

Marketing. *See Business***Measurement**

of rainfall, 642

Mechanics. *See Physics***Medicine.** *See also Health*

breast cancer survival rate, 364
 drug concentration, 76, 256
 drug medication, 308, 323
 healing of wounds, 308, 323
 pancreatic cancer, 308
 spreading of disease, 372

Meteorology

weather balloon height and atmospheric pressure, 361–362

Miscellaneous

bending wire, 802
 biorhythms, 448
 carrying a ladder around a corner, 400, 456
 citrus ladders, 841
 cross-sectional area of beam, 55–56, 63
 curve fitting, 742, 756, 821
 drafting error, 8
 pet ownership, 892
 rescue at sea, 556–557
 rooms in housing units, 55
 surface area of balloon, 280
 surveillance satellites, 551
 volume of balloon, 280
 window dimensions, 147
 wire enclosure area, 104

Mixtures. *See also Chemistry*

blending coffees, 811, 822
 mixed nuts, 741, 811, 822
 solution, 741

Motion. *See also Physics*

catching a train, 726
 on a circle, 387
 of golf ball, 63
 minute hand of clock, 386, 472
 objects approaching intersection, 722
 of pendulum, 583
 simulating, 716–717
 tortoise and the hare race, 801
 uniform, 104, 722

Motor vehicles

alcohol and driving, 319, 324
 approaching intersection, 722
 automobile production, 280, 757
 automobile theft, 892
 brake repair with tune-up, 895
 braking load, 643, 662
 crankshafts, 560
 depreciation of, 273, 339, 367, 374
 with Global Positioning System (GPS), 371
 loans for, 834
 miles per gallon, 173–174
 RV rental cost, 188
 spin balancing tires, 388
 stopping distance, 56, 159, 293
 used-car purchase, 347
 windshield wiper area coverage, 387

Music

iPod storage capacity for, 129
revenues from, 100

Navigation

avoiding a tropical storm, 567
bearing, 548, 566
 of aircraft, 548
 of ship, 550, 585
charting a course, 635
commercial, 559–560
compass heading, 634
correct direction for crossing river, 634
error in
 correcting, 564–565, 585
 time lost due to, 560
rescue at sea, 556–557, 559
revising a flight plan, 567

Oceanography

tides, 467

Optics

intensity of light, 110
laser beam, 549
light obliterated through glass, 308
magnitude of telescope, 371
mirrors, 697
reflecting telescope, 674

Pediatrics

height vs. head circumference,
 164, 293

Pet(s)

dog's roaming area, 388

Pharmacy

vitamin intake, 742, 758

Photography

camera distance, 412

Physics

angle of elevation of Sun, 549
bouncing balls, 865
braking load, 643, 662
damped motion, 578–579
direction of aircraft, 634
Doppler effect, 257
falling objects, 109
force, 633
 muscle, 635
 resultant, 633
 of wind on a window, 108, 110
gravity, 242, 265
 on Earth, 55, 293
 on Jupiter, 55
harmonic motion, 577, 582, 586
heat loss through a wall, 108
horsepower, 110
inclination of mountain trail, 547
inclination of ramp, 635
intensity of light, 110

kinetic energy, 111
maximum weight supportable by pine,
 107
motion of object, 577, 718
Newton's law, 109
pendulum motion, 387, 582, 583, 847
 period, 100, 294
 simple pendulum, 109
pressure, 110
projectile motion, 149, 167–168, 171–172,
 409, 423, 715–716, 721, 722, 723, 726
 hit object, 722
 thrown object, 721
safe load for a beam, 111
simulating motion, 716–717
static equilibrium, 631, 634, 635,
 662, 663
static friction, 635
stopping distance, 159
stress of materials, 111
stretching a spring, 110
tension, 631, 634, 662, 663, 857
thrown object, 163, 173, 629
truck pulls, 634
uniform motion, 104, 722, 726
vertically propelled object, 147, 163
vibrating string, 110
weight, 110, 115, 630, 634
 effect of elevation on, 64
work, 652

Play

wagon pulling, 633, 640, 641

Population. *See also* Demographics

bacterial, 356, 357, 358, 363
decline in, 357
of divorced people, 169–170
E-coli growth, 77, 120–121
of endangered species, 308, 358
of fruit fly, 355
as function of age, 55
growth in, 356, 357
insect, 242, 356
of rabbit colony, 834
of trout, 834
of United States, 338, 364–365, 867
of world, 339, 365, 371, 825

Probability

checkout lines, 892
classroom composition, 892
"Deal or No Deal" TV show, 868
exponential, 304, 308, 323
gender composition of 3-child family,
 886
household annual income, 892
Monty Hall Game, 896
Poisson, 309
"Price is Right" games, 892
of shared birthdays in room of n people,
 359
tossing a fair coin, 883, 885
of winning a lottery, 893

Psychometrics

IQ tests, 183

Pyrotechnics

fireworks display, 696

Rate. *See also* Speed

of car, 387
catching a bus, 721–722
catching a train, 721
current of stream, 742
to keep up with the Sun, 388
miles per gallon, 173–174
revolutions per minute
 of bicycle wheels, 387
 of pulleys, 389

Real estate

cost of triangular lot, 572
ground area covered by building, 572–573
price appreciation of homes, 347
rents and square footage, 173
valuing a home, 1, 41

Recreation

bungee jumping, 265
Demon Roller Coaster customer rate, 309
online gambling, 892

Security

security cameras, 549

Seismology

calibrating instruments, 725

Sequences. *See also* Combinatorics

ceramic tile floor design, 839–840
Drury Lane Theater, 841
Fibonacci, 834
football stadium seating, 841
seats in amphitheater, 841

Speed

of aircraft, 634
angular, 387, 472
of current, 388, 822
as function of time, 65, 104
ground, 634
linear, 384–385
 on Earth, 387
of Moon, 388
of motorboat, 634
revolutions per minute of pulley, 388
of rotation of lighthouse beacons, 472
of swimmer, 662
of truck, 549
of wheel pulling cable cars, 388
wind, 741

Sports

baseball, 722–723, 882, 894
diamond, 7
dimensions of home plate, 572
field, 567

Little League, 8, 389
 on-base percentage, 130–131
 stadium, 567
 World Series, 882
 basketball, 882
 free throws, 63, 550–551
 granny shots, 63
 bungee jumping, 265
 calculating pool shots, 412
 exacta betting, 895
 football, 684, 726, 882
 golf, 892
 distance to the green, 566
 putts, 366–367
 hammer throw, 473–474
 races, 799, 801–802
 relay runners, 894
 swimming, 587, 662

Statistics. *See* **Probability**

Surveys

of appliance purchases, 873
 data analysis, 870, 873
 stock portfolios, 873
 of summer session attendance, 873
 of TV sets in a house, 892

Technology. *See also* **Computers and computing**

iPod storage capacity for music, 129

Temperature

of air parcel, 841
 conversion of, 281, 293
 cooling time of pizza, 357
 cricket chirping and, 174
 measuring, 32, 100
 after midnight, 211
 monthly, 466–467, 473
 of portable heater, 371
 relationship between scales,
 100
 sinusoidal function from, 462–463
 of skillet, 371
 warming time of Beer stein, 357
 wind chill factor, 372

Time

for Beer stein to warm, 357
 for block to slide down inclined plane,
 409–410
 to go from an island to a town, 105
 hours of daylight, 375, 464–465, 467–468,
 475
 for pizza to cool, 357
 of sunrise, 388
 of trip, 400, 410

Transportation. *See also* **Air travel; Motor vehicles**

Falls Incline Railway, 550

Travel. *See also* **Air travel; Navigation**

bearing, 585
 drivers stopped by the police, 373
 driving to school, 110
 parking at O'Hare International Airport,
 86

Volume

of box, 643
 of water in cone, 105

Weather

atmospheric pressure,
 308, 323
 avoiding a tropical storm, 567
 cooling air, 841
 hurricanes, 210, 466
 lightning strikes, 693–694, 696
 rainfall measurement, 642
 relative humidity, 309
 weather satellites, 39
 wind chill, 88, 372

Work, 641, 652

computing, 641, 642, 662
 constant rate jobs, 822
 pulling a wagon, 640, 641
 ramp angle, 643
 wheel barrow push, 633

This page intentionally left blank

Foundations: A Prelude to Functions

F

How to Value a House

Two things to consider in valuing a home are, first, how does it compare to similar homes that have sold recently? Is the asking price fair? And second, what value do you place on the advertised features and amenities? Yes, other people might value them highly, but do you?

Zestimate home valuation, RealEstateABC.com, and Reply.com are among the many algorithmic (generated by a computer model) starting points in figuring out the value of a home. They show you how the home is priced relative to other homes in the area, but you need to add in all the things that only someone who has seen the house knows. You can do that using My Estimator, and then you create your own estimate and see how it stacks up against the asking price.

Looking at “Comps”

Knowing whether an asking price is fair will be important when you're ready to make an offer on a house. It will be even more important when your mortgage lender hires an appraiser to determine whether the house is worth the loan you're after.

Check with your agent, Zillow.com, propertyshark.com, or other websites to see recent sales of homes in the area that are similar, or comparable, to what you're looking for. Print them out and keep these “comps” in a three-ring binder; you'll be referring to them quite a bit.

Note that “recent sales” usually means within the last six months. A sales price from a year ago may bear little or no relation to what is going on in your area right now. In fact, some lenders will not accept comps older than three months.

Market activity also determines how easy or difficult it is to find accurate comps. In a “hot” or busy market, with sales happening all the time, you're likely to have lots of comps to choose from. In a less active market, finding reasonable comps becomes harder. And if the home you're looking at has special design features, finding a comparable property is harder still. It's also necessary to know what's going on in a given sub-segment. Maybe large, high-end homes are selling like hotcakes, but owners of smaller houses are staying put, or vice versa.

Source: http://realestate.yahoo.com/Homevalues/How_to_Value_a_House.html

 — See the Internet-based Chapter Project —



<A Look Back

Appendix A reviews skills from Intermediate Algebra.

A Look Ahead>

Here we connect algebra and geometry using the rectangular coordinate system. In the 1600s, algebra had developed to the point that René Descartes (1596–1650) and Pierre de Fermat (1601–1665) were able to use rectangular coordinates to translate geometry problems into algebra problems, and vice versa. This allowed both geometers and algebraists to gain new insights into their subjects, which had been thought to be separate but now were seen as connected.

Outline

- F.1 The Distance and Midpoint Formulas
 - F.2 Graphs of Equations in Two Variables;
Intercepts; Symmetry
 - F.3 Lines
 - F.4 Circles
- Chapter Project

F.1 The Distance and Midpoint Formulas

PREPARING FOR THIS SECTION Before getting started, review the following:

- Algebra Essentials (Appendix A, Section A.1, pp. A1–A10)
- Geometry Essentials (Appendix A, Section A.2, pp. A13–A19)

 **Now Work** the 'Are You Prepared?' problems on page 6.

- OBJECTIVES**
- 1 Use the Distance Formula (p. 3)
 - 2 Use the Midpoint Formula (p. 5)

Rectangular Coordinates

A point on the real number line is located by a single real number called the *coordinate of the point*. For work in a two-dimensional plane, points are located by using two numbers.

Begin with two real number lines located in the same plane: one horizontal and the other vertical. The horizontal line is called the ***x*-axis**, the vertical line the ***y*-axis**, and the point of intersection the **origin *O***. See Figure 1. Assign coordinates to every point on these number lines using a convenient scale. Recall that the scale of a number line is the distance between 0 and 1. In mathematics, we usually use the same scale on each axis, but in applications, a different scale is often used.

The origin *O* has a value of 0 on both the *x*-axis and the *y*-axis. Points on the *x*-axis to the right of *O* are associated with positive real numbers, and those to the left of *O* are associated with negative real numbers. Points on the *y*-axis above *O* are associated with positive real numbers, and those below *O* are associated with negative real numbers. In Figure 1, the *x*-axis and *y*-axis are labeled as *x* and *y*, respectively, and an arrow at the end of each axis is used to denote the positive direction.

The coordinate system described here is called a **rectangular** or **Cartesian*** **coordinate system**. The plane formed by the *x*-axis and *y*-axis is sometimes called the ***xy*-plane**, and the *x*-axis and *y*-axis are referred to as the **coordinate axes**.

Any point *P* in the *xy*-plane can be located by using an **ordered pair** (*x*, *y*) of real numbers. Let *x* denote the signed distance of *P* from the *y*-axis (*signed* means that, if *P* is to the right of the *y*-axis, then $x > 0$, and if *P* is to the left of the *y*-axis, then $x < 0$); and let *y* denote the signed distance of *P* from the *x*-axis. The ordered pair (*x*, *y*), also called the **coordinates** of *P*, then gives us enough information to locate the point *P* in the plane.

For example, to locate the point whose coordinates are $(-3, 1)$, go 3 units along the *x*-axis to the left of *O* and then go straight up 1 unit. We **plot** this point by placing a dot at this location. See Figure 2, in which the points with coordinates $(-3, 1)$, $(-2, -3)$, $(3, -2)$, and $(3, 2)$ are plotted.

The origin has coordinates $(0, 0)$. Any point on the *x*-axis has coordinates of the form $(x, 0)$, and any point on the *y*-axis has coordinates of the form $(0, y)$.

If (*x*, *y*) are the coordinates of a point *P*, then *x* is called the ***x*-coordinate**, or **abscissa**, of *P* and *y* is the ***y*-coordinate**, or **ordinate**, of *P*. We identify the point *P* by its coordinates (*x*, *y*) by writing $P = (x, y)$. Usually, we will simply say, “the point (*x*, *y*)” rather than “the point whose coordinates are (*x*, *y*).”

The coordinate axes divide the *xy*-plane into four sections called **quadrants**, as shown in Figure 3. In quadrant I, both the *x*-coordinate and the *y*-coordinate of all points are positive; in quadrant II, *x* is negative and *y* is positive; in quadrant III, both *x* and *y* are negative; and in quadrant IV, *x* is positive and *y* is negative. Points on the coordinate axes belong to no quadrant.

Figure 1

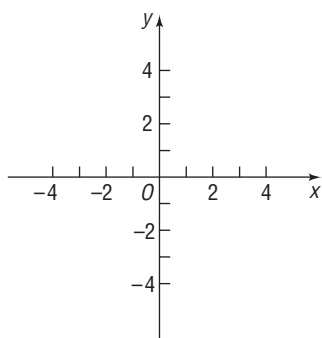


Figure 2

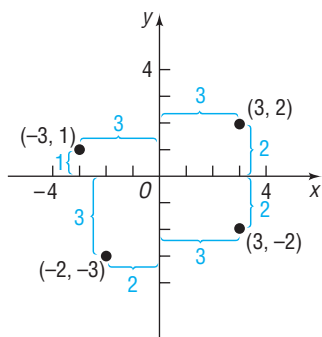
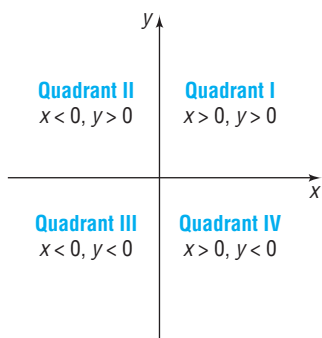


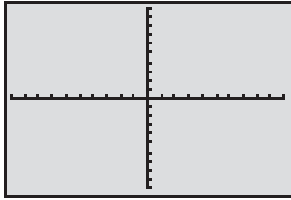
Figure 3



 **Now Work** PROBLEM 11

*Named after René Descartes (1596–1650), a French mathematician, philosopher, and theologian.

Figure 4



COMMENT On a graphing calculator, you can set the scale on each axis. Once this has been done, you obtain the **viewing rectangle**. See Figure 4 for a typical viewing rectangle. You should now read Section B.1, *The Viewing Rectangle*, in Appendix B. ■

1 Use the Distance Formula

If the same units of measurement (such as inches, centimeters, and so on) are used for both the x -axis and y -axis, then all distances in the xy -plane can be measured using this unit of measurement.

EXAMPLE 1

Finding the Distance between Two Points

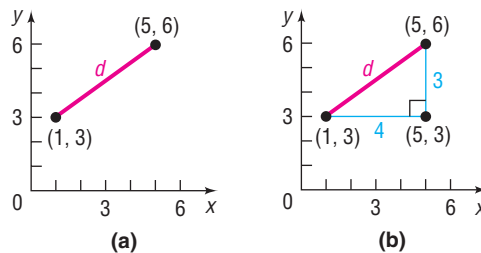
Find the distance d between the points $(1, 3)$ and $(5, 6)$.

Solution

First plot the points $(1, 3)$ and $(5, 6)$ and connect them with a straight line. See Figure 5(a). To find the length d , begin by drawing a horizontal line from $(1, 3)$ to $(5, 3)$ and a vertical line from $(5, 3)$ to $(5, 6)$, forming a right triangle, as shown in Figure 5(b). One leg of the triangle is of length 4 (since $|5 - 1| = 4$), and the other is of length 3 (since $|6 - 3| = 3$). By the Pythagorean Theorem, the square of the distance d that we seek is

$$\begin{aligned} d^2 &= 4^2 + 3^2 = 16 + 9 = 25 \\ d &= \sqrt{25} = 5 \end{aligned}$$

Figure 5



The **distance formula** provides a straightforward method for computing the distance between two points.

THEOREM

Distance Formula

The distance between two points $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$, denoted by $d(P_1, P_2)$, is

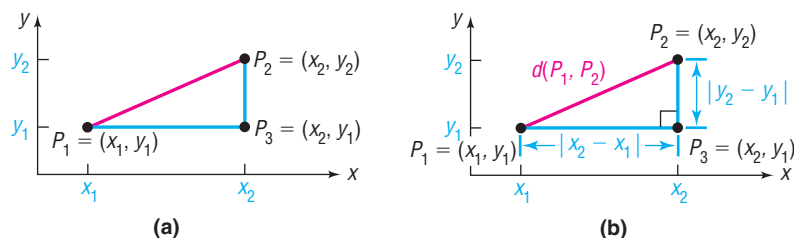
$$d(P_1, P_2) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

In Words

To compute the distance between two points, find the difference of the x -coordinates, square it, and add this to the square of the difference of the y -coordinates. The square root of this sum is the distance.

Proof of the Distance Formula Let (x_1, y_1) denote the coordinates of point P_1 and let (x_2, y_2) denote the coordinates of point P_2 . Assume that the line joining P_1 and P_2 is neither horizontal nor vertical. Refer to Figure 6(a). The coordinates of P_3 are (x_2, y_1) . The horizontal distance from P_1 to P_3 is the absolute value of the difference of the x -coordinates, $|x_2 - x_1|$. The vertical distance from P_3 to P_2 is the

Figure 6



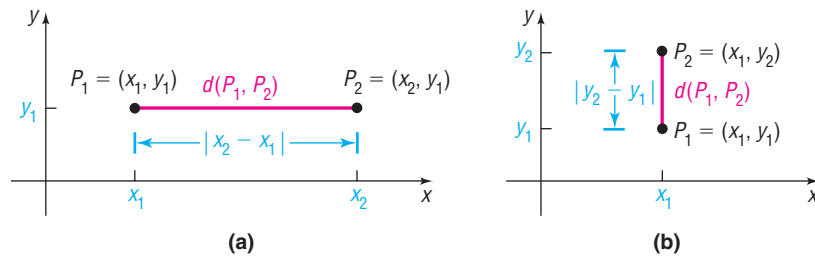
absolute value of the difference of the y -coordinates, $|y_2 - y_1|$. See Figure 6(b). The distance $d(P_1, P_2)$ that we seek is the length of the hypotenuse of the right triangle, so, by the Pythagorean Theorem, it follows that

$$\begin{aligned} [d(P_1, P_2)]^2 &= |x_2 - x_1|^2 + |y_2 - y_1|^2 \\ &= (x_2 - x_1)^2 + (y_2 - y_1)^2 \\ d(P_1, P_2) &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \end{aligned}$$

Now, if the line joining P_1 and P_2 is horizontal, then the y -coordinate of P_1 equals the y -coordinate of P_2 ; that is, $y_1 = y_2$. Refer to Figure 7(a). In this case, the distance formula (1) still works, because, for $y_1 = y_2$, it reduces to

$$d(P_1, P_2) = \sqrt{(x_2 - x_1)^2 + 0^2} = \sqrt{(x_2 - x_1)^2} = |x_2 - x_1|$$

Figure 7



A similar argument holds if the line joining P_1 and P_2 is vertical. See Figure 7(b). ■

EXAMPLE 2 Using the Distance Formula

Find the distance d between the points $(-3, 5)$ and $(3, 2)$.

Solution

Use the distance formula, equation (1), with $P_1 = (x_1, y_1) = (-3, 5)$ and $P_2 = (x_2, y_2) = (3, 2)$. Then

$$\begin{aligned} d &= \sqrt{[3 - (-3)]^2 + (2 - 5)^2} = \sqrt{6^2 + (-3)^2} \\ &= \sqrt{36 + 9} \\ &= \sqrt{45} \\ &= 3\sqrt{5} \approx 6.71 \end{aligned}$$

Now Work PROBLEMS 15 AND 19

The distance between two points $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$ is never a negative number. Furthermore, the distance between two points is 0 only when the points are identical—that is, when $x_1 = x_2$ and $y_1 = y_2$. Also, because $(x_2 - x_1)^2 = (x_1 - x_2)^2$ and $(y_2 - y_1)^2 = (y_1 - y_2)^2$, it makes no difference whether the distance is computed from P_1 to P_2 or from P_2 to P_1 ; that is, $d(P_1, P_2) = d(P_2, P_1)$.

The introduction to this chapter mentioned that rectangular coordinates enable us to translate geometry problems into algebra problems, and vice versa. The next example shows how algebra (the distance formula) can be used to solve geometry problems.

EXAMPLE 3 Using Algebra to Solve Geometry Problems

Consider the three points $A = (-2, 1)$, $B = (2, 3)$, and $C = (3, 1)$.

- Plot each point and form the triangle ABC .
- Find the length of each side of the triangle.
- Verify that the triangle is a right triangle.
- Find the area of the triangle.

Solution

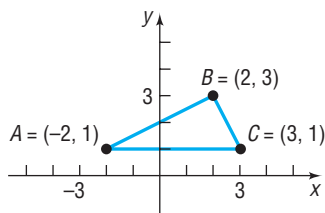
- (a) Figure 8 shows the points A, B, C and the triangle ABC .
 (b) To find the length of each side of the triangle, use the distance formula, equation (1).

$$d(A, B) = \sqrt{[2 - (-2)]^2 + (3 - 1)^2} = \sqrt{16 + 4} = \sqrt{20} = 2\sqrt{5}$$

$$d(B, C) = \sqrt{(3 - 2)^2 + (1 - 3)^2} = \sqrt{1 + 4} = \sqrt{5}$$

$$d(A, C) = \sqrt{[3 - (-2)]^2 + (1 - 1)^2} = \sqrt{25 + 0} = 5$$

Figure 8



- (c) If the triangle is a right triangle, then the sum of the squares of the lengths of two of the sides will equal the square of the length of the third side. (Why is this sufficient?) Looking at Figure 8, it seems reasonable to conjecture that the right angle is at vertex B . We shall check to see whether

$$[d(A, B)]^2 + [d(B, C)]^2 = [d(A, C)]^2$$

Using the results from part (b) yields

$$\begin{aligned} [d(A, B)]^2 + [d(B, C)]^2 &= (2\sqrt{5})^2 + (\sqrt{5})^2 \\ &= 20 + 5 = 25 = [d(A, C)]^2 \end{aligned}$$

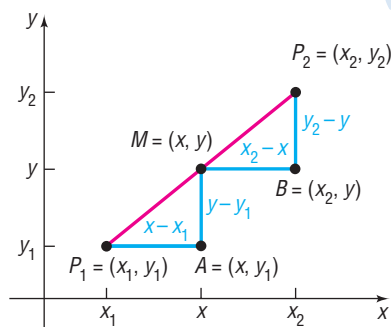
It follows from the converse of the Pythagorean Theorem that triangle ABC is a right triangle.

- (d) Because the right angle is at vertex B , the sides AB and BC form the base and height of the triangle. Its area is

$$\text{Area} = \frac{1}{2}(\text{Base})(\text{Height}) = \frac{1}{2}(2\sqrt{5})(\sqrt{5}) = 5 \text{ square units}$$

 **Now Work** PROBLEM 29

Figure 9



2 Use the Midpoint Formula

We now derive a formula for the coordinates of the **midpoint of a line segment**. Let $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$ be the endpoints of a line segment, and let $M = (x, y)$ be the point on the line segment that is the same distance from P_1 as it is from P_2 . See Figure 9. The triangles P_1AM and MBP_2 are congruent. [Do you see why? Angle $AP_1M =$ angle BMP_2 ,* angle $P_1MA =$ angle MP_2B , and $d(P_1, M) = d(M, P_2)$ is given. Thus we have angle–side–angle.] Hence, corresponding sides are equal in length. That is,

$$\begin{aligned} x - x_1 &= x_2 - x & \text{and} & & y - y_1 &= y_2 - y \\ 2x &= x_1 + x_2 & & & 2y &= y_1 + y_2 \\ x &= \frac{x_1 + x_2}{2} & & & y &= \frac{y_1 + y_2}{2} \end{aligned}$$

THEOREM

Midpoint Formula

The midpoint $M = (x, y)$ of the line segment from $P_1 = (x_1, y_1)$ to $P_2 = (x_2, y_2)$ is

$$M = (x, y) = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right) \quad (2)$$

In Words

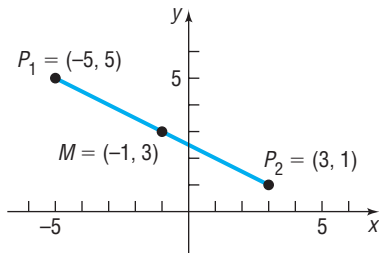
To find the midpoint of a line segment, average the x -coordinates of the endpoints, and average the y -coordinates of the endpoints.

*A postulate from geometry states that the transversal $\overline{P_1P_2}$ forms congruent corresponding angles with the parallel line segments $\overline{P_1A}$ and \overline{MB} .

EXAMPLE 4 Finding the Midpoint of a Line Segment

Find the midpoint of the line segment from $P_1 = (-5, 5)$ to $P_2 = (3, 1)$. Plot the points P_1 and P_2 and the midpoint.

Figure 10



Solution

Apply the midpoint formula (2) using $x_1 = -5$, $y_1 = 5$, $x_2 = 3$, and $y_2 = 1$. Then the coordinates (x, y) of the midpoint M are

$$x = \frac{x_1 + x_2}{2} = \frac{-5 + 3}{2} = -1 \quad \text{and} \quad y = \frac{y_1 + y_2}{2} = \frac{5 + 1}{2} = 3$$

That is, $M = (-1, 3)$. See Figure 10.

 **Now Work** PROBLEM 35

F.1 Assess Your Understanding

'Are You Prepared?' Answers are given at the end of these exercises. If you get a wrong answer, read the pages listed in red.

- On the real number line the origin is assigned the number _____. (p. A4)
- If -3 and 5 are the coordinates of two points on the real number line, the distance between these points is _____. (p. A6)
- If 3 and 4 are the legs of a right triangle, the hypotenuse is _____. (pp. A13–A14)
- Use the converse of the Pythagorean Theorem to show that a triangle whose sides are of lengths 11 , 60 , and 61 is a right triangle. (p. A14)
- State the formula for the area A of a triangle whose base is b and whose altitude is h . (p. A15)
- State the three cases for which two triangles are congruent. (p. A16)

Concepts and Vocabulary

- If (x, y) are the coordinates of a point P in the xy -plane, then x is called the _____ of P , and y is the _____ of P .
- The coordinate axes divide the xy -plane into four sections called _____.
- The distance d between two points $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$ is $d =$ _____.
- If three distinct points P , Q , and R all lie on a line, and if $d(P, Q) = d(Q, R)$, then Q is called the _____ of the line segment from P to R .


Skill Building

In Problems 11 and 12, plot each point in the xy -plane. Tell in which quadrant or on what coordinate axis each point lies.

- | | | | |
|--|-------------------|----------------------|-------------------|
|  11. (a) $A = (-3, 2)$ | (d) $D = (6, 5)$ | 12. (a) $A = (1, 4)$ | (d) $D = (4, 1)$ |
| (b) $B = (6, 0)$ | (e) $E = (0, -3)$ | (b) $B = (-3, -4)$ | (e) $E = (0, 1)$ |
| (c) $C = (-2, -2)$ | (f) $F = (6, -3)$ | (c) $C = (-3, 4)$ | (f) $F = (-3, 0)$ |

- Plot the points $(2, 0)$, $(2, -3)$, $(2, 4)$, $(2, 1)$, and $(2, -1)$. Describe the set of all points of the form $(2, y)$, where y is a real number.
- Plot the points $(0, 3)$, $(1, 3)$, $(-2, 3)$, $(5, 3)$, and $(-4, 3)$. Describe the set of all points of the form $(x, 3)$, where x is a real number.

In Problems 15–28, find the distance $d(P_1, P_2)$ between the points P_1 and P_2 .

- | | | | |
|--|-----|-----|-----|
|  15. | 16. | 17. | 18. |
|--|-----|-----|-----|

19. $P_1 = (3, -4)$; $P_2 = (5, 4)$
 21. $P_1 = (-3, 2)$; $P_2 = (6, 0)$
 23. $P_1 = (4, -2)$; $P_2 = (-2, -5)$
 25. $P_1 = (-0.2, 0.3)$; $P_2 = (2.3, 1.1)$
 27. $P_1 = (a, b)$; $P_2 = (0, 0)$

In Problems 29–34, plot each point and form the triangle ABC . Verify that the triangle is a right triangle. Find its area.

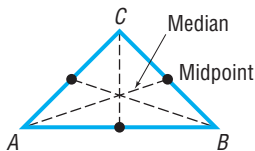
29. $A = (-2, 5)$; $B = (1, 3)$; $C = (-1, 0)$
 31. $A = (-5, 3)$; $B = (6, 0)$; $C = (5, 5)$
 33. $A = (4, -3)$; $B = (0, -3)$; $C = (4, 2)$
 30. $A = (-2, 5)$; $B = (12, 3)$; $C = (10, -11)$
 32. $A = (-6, 3)$; $B = (3, -5)$; $C = (-1, 5)$
 34. $A = (4, -3)$; $B = (4, 1)$; $C = (2, 1)$

In Problems 35–44, find the midpoint of the line segment joining the points P_1 and P_2 .

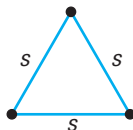
35. $P_1 = (3, -4)$; $P_2 = (5, 4)$
 37. $P_1 = (-3, 2)$; $P_2 = (6, 0)$
 39. $P_1 = (4, -2)$; $P_2 = (-2, -5)$
 41. $P_1 = (-0.2, 0.3)$; $P_2 = (2.3, 1.1)$
 43. $P_1 = (a, b)$; $P_2 = (0, 0)$
 36. $P_1 = (-2, 0)$; $P_2 = (2, 4)$
 38. $P_1 = (2, -3)$; $P_2 = (4, 2)$
 40. $P_1 = (-4, -3)$; $P_2 = (2, 2)$
 42. $P_1 = (1.2, 2.3)$; $P_2 = (-0.3, 1.1)$
 44. $P_1 = (a, a)$; $P_2 = (0, 0)$

Applications and Extensions

45. Find all points having an x -coordinate of 2 whose distance from the point $(-2, -1)$ is 5.
 46. Find all points having a y -coordinate of -3 whose distance from the point $(1, 2)$ is 13.
 47. Find all points on the x -axis that are 5 units from the point $(4, -3)$.
 48. Find all points on the y -axis that are 5 units from the point $(4, 4)$.
 49. **Geometry** The **medians** of a triangle are the line segments from each vertex to the midpoint of the opposite side (see the figure). Find the lengths of the medians of the triangle with vertices at $A = (0, 0)$, $B = (6, 0)$, and $C = (4, 4)$.



50. **Geometry** An **equilateral triangle** is one in which all three sides are of equal length. If two vertices of an equilateral triangle are $(0, 4)$ and $(0, 0)$, find the third vertex. How many of these triangles are possible?



51. **Geometry** Find the midpoint of each diagonal of a square with side of length s . Draw the conclusion that the diagonals of a square intersect at their midpoints. [Hint: Use $(0, 0)$, $(0, s)$, $(s, 0)$, and (s, s) as the vertices of the square.]

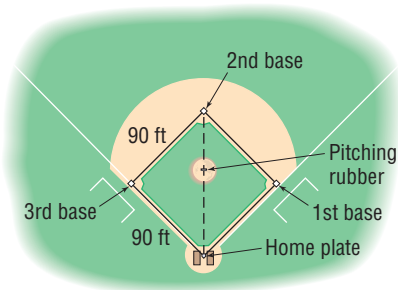
20. $P_1 = (-1, 0)$; $P_2 = (2, 4)$
 22. $P_1 = (2, -3)$; $P_2 = (4, 2)$
 24. $P_1 = (-4, -3)$; $P_2 = (6, 2)$
 26. $P_1 = (1.2, 2.3)$; $P_2 = (-0.3, 1.1)$
 28. $P_1 = (a, a)$; $P_2 = (0, 0)$

52. **Geometry** Verify that the points $(0, 0)$, $(a, 0)$, and $(\frac{a}{2}, \frac{\sqrt{3}a}{2})$ are the vertices of an equilateral triangle. Then show that the midpoints of the three sides are the vertices of a second equilateral triangle (refer to Problem 50).

In Problems 53–56, find the length of each side of the triangle determined by the three points P_1 , P_2 , and P_3 . State whether the triangle is an isosceles triangle, a right triangle, neither of these, or both. (An **isosceles triangle** is one in which at least two of the sides are of equal length.)

53. $P_1 = (2, 1)$; $P_2 = (-4, 1)$; $P_3 = (-4, -3)$
 54. $P_1 = (-1, 4)$; $P_2 = (6, 2)$; $P_3 = (4, -5)$
 55. $P_1 = (-2, -1)$; $P_2 = (0, 7)$; $P_3 = (3, 2)$
 56. $P_1 = (7, 2)$; $P_2 = (-4, 0)$; $P_3 = (4, 6)$

57. **Baseball** A major league baseball “diamond” is actually a square 90 feet on a side (see the figure). What is the distance directly from home plate to second base (the diagonal of the square)?



58. Little League Baseball The layout of a Little League playing field is a square 60 feet on a side. How far is it directly from home plate to second base (the diagonal of the square)?

Source: Little League Baseball, *Official Regulations and Playing Rules, 2012.*

59. Baseball Refer to Problem 57. Overlay a rectangular coordinate system on a major league baseball diamond so that the origin is at home plate, the positive x -axis lies in the direction from home plate to first base, and the positive y -axis lies in the direction from home plate to third base.

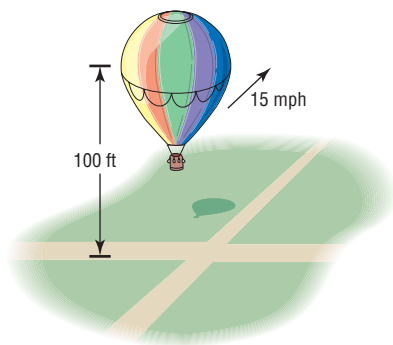
- (a) What are the coordinates of first base, second base, and third base? Use feet as the unit of measurement.
- (b) If the right fielder is located at $(310, 15)$, how far is it from there to second base?
- (c) If the center fielder is located at $(300, 300)$, how far is it from there to third base?

60. Little League Baseball Refer to Problem 58. Overlay a rectangular coordinate system on a Little League baseball diamond so that the origin is at home plate, the positive x -axis lies in the direction from home plate to first base, and the positive y -axis lies in the direction from home plate to third base.

- (a) What are the coordinates of first base, second base, and third base? Use feet as the unit of measurement.
- (b) If the right fielder is located at $(180, 20)$, how far is it from there to second base?
- (c) If the center fielder is located at $(220, 220)$, how far is it from there to third base?

61. Distance between Moving Objects A Ford Focus and a Mack truck leave an intersection at the same time. The Focus heads east at an average speed of 30 miles per hour, while the truck heads south at an average speed of 40 miles per hour. Find an expression for their distance apart d (in miles) at the end of t hours.

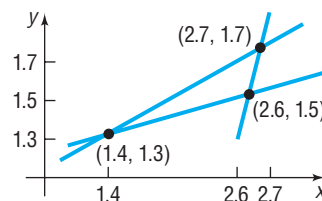
62. Distance of a Moving Object from a Fixed Point A hot-air balloon, headed due east at an average speed of 15 miles per hour and at a constant altitude of 100 feet, passes over an intersection (see the figure). Find an expression for the distance d (measured in feet) from the balloon to the intersection t seconds later.



63. Drafting Error When a draftsman draws three lines that are to intersect at one point, the lines may not intersect as intended and subsequently will form an **error triangle**. If this error triangle is long and thin, one estimate for the location of the desired point is the midpoint of the shortest side. The figure shows one such error triangle.

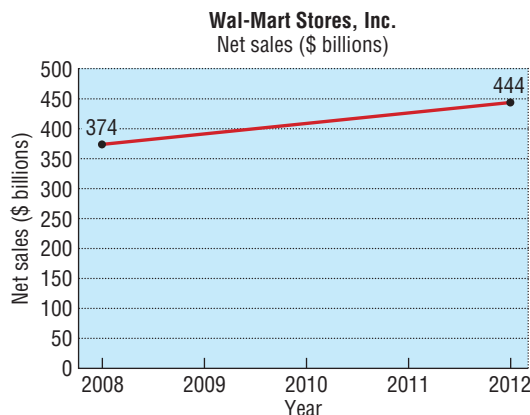
- (a) Find an estimate for the desired intersection point.
- (b) Find the length of the median for the midpoint found in part (a). See Problem 49.

Source: www.uwgb.edu/DutchS/structge/s100.htm



64. Net Sales The figure illustrates how net sales of Wal-Mart Stores, Inc., grew from 2008 through 2012. Use the midpoint formula to estimate the net sales of Wal-Mart Stores, Inc., in 2010. How does your result compare to the reported value of \$405 billion?

Source: Wal-Mart Stores, Inc., 2012 Annual Report



65. Poverty Threshold Poverty thresholds are determined by the U.S. Census Bureau. A poverty threshold represents the minimum annual household income for a family not to be considered poor. In 2004, the poverty threshold for a family of four with two children under the age of 18 years was \$19,157. In 2012, the poverty threshold for a family of four with two children under the age of 18 years was \$23,283. Assuming poverty thresholds increase in a straight-line fashion, use the midpoint formula to estimate the poverty threshold of a family of four with two children under the age of 18 in 2008. How does your result compare to the actual poverty threshold in 2008 of \$21,834?

Source: U.S. Census Bureau

66. Horizontal and Vertical Shifts Suppose that $A = (2, 5)$ are the coordinates of a point in the xy -plane.

- (a) Find the coordinates of the point if A is shifted 3 units to the right and 2 units down.
- (b) Find the coordinates of the point if A is shifted 2 units to the left and 8 units up.

67. Completing a Line Segment Plot the points $A = (-1, 8)$ and $M = (2, 3)$ in the xy -plane. If M is the midpoint of a line segment AB , find the coordinates of B .

