

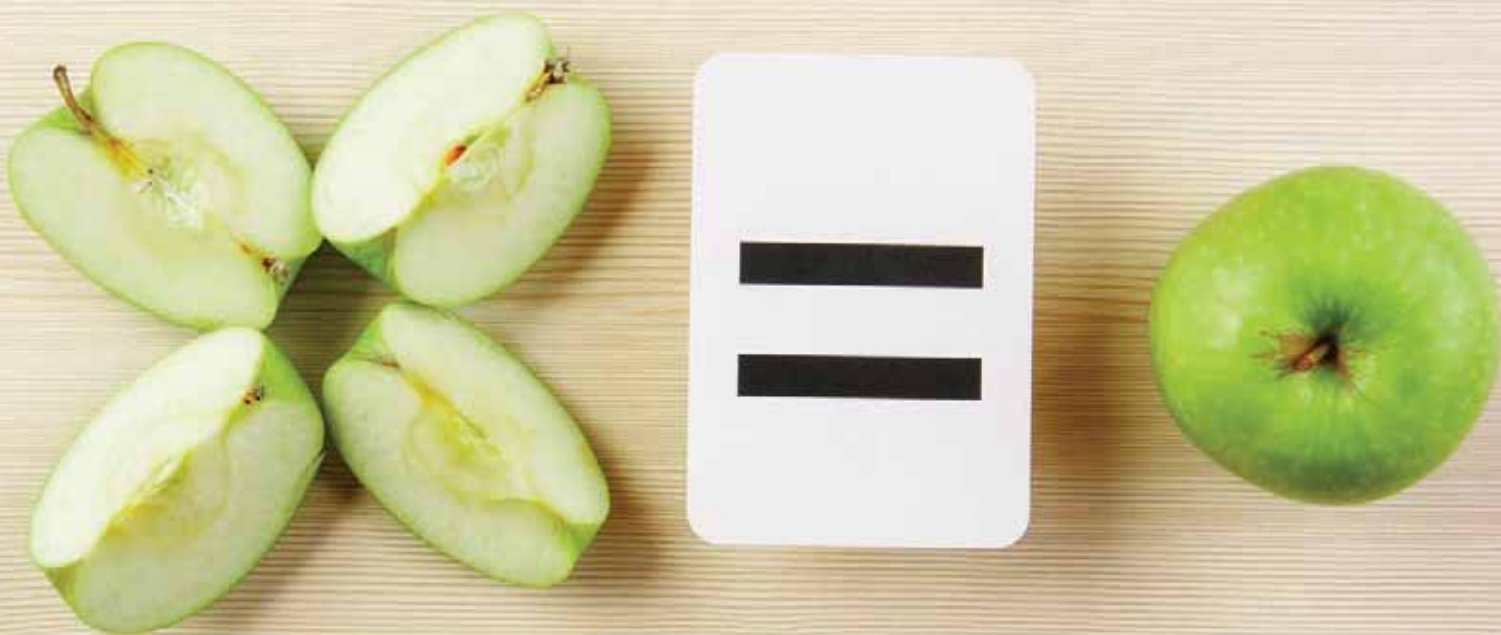
GLOBAL
EDITION



Precalculus

Concepts Through Functions
A Unit Circle Approach to Trigonometry

THIRD EDITION



Michael Sullivan • Michael Sullivan III

Precalculus

Concepts Through Functions

A Unit Circle Approach To Trigonometry

Third Edition

Global Edition

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Shannon, Patrick, and Ryan (Murphy)

Maeve, Sean, and Nolan (Sullivan)

Kaleigh, Billy, and Timmy (O'Hara)

The Next Generation



Contents

To the Student	15
Preface to the Instructor	17
Prepare for Class “Read the Book”	21
Practice “Work the Problems”	22
Review “Study for Quizzes and Tests”	23
Resources for Success	24
Applications Index	25

F Foundations: A Prelude to Functions 33

F.1 The Distance and Midpoint Formulas	34
Use the Distance Formula • Use the Midpoint Formula	
F.2 Graphs of Equations in Two Variables; Intercepts; Symmetry	41
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	51
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	66
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	73

1 Functions and Their Graphs 74

1.1 Functions	75
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	88
Identify the Graph of a Function • Obtain Information from or about the Graph of a Function	
1.3 Properties of Functions	98
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	110
	Graph the Functions Listed in the Library of Functions • Graph Piecewise-defined Functions	
1.5	Graphing Techniques: Transformations	121
	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	133
	Build and Analyze Functions	
1.7	Building Mathematical Models Using Variation	138
	Construct a Model Using Direct Variation • Construct a Model Using Inverse Variation • Construct a Model Using Joint or Combined Variation	
	Chapter Review	143
	Chapter Test	147
	Chapter Projects	148

2 Linear and Quadratic Functions 150

2.1	Properties of Linear Functions and Linear Models	151
	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	162
	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	169
	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	180
	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	192
	Solve Inequalities Involving a Quadratic Function	
2.6	Building Quadratic Models from Verbal Descriptions and from Data	196
	Build Quadratic Models from Verbal Descriptions • Build Quadratic Models from Data	
2.7	Complex Zeros of a Quadratic Function	207
	Find the Complex Zeros of a Quadratic Function	
2.8	Equations and Inequalities Involving the Absolute Value Function	210
	Solve Absolute Value Equations • Solve Absolute Value Inequalities	
	Chapter Review	216
	Chapter Test	219

Cumulative Review	220
--------------------------	------------

Chapter Projects	221
-------------------------	------------

3 Polynomial and Rational Functions 223

3.1 Polynomial Functions and Models	224
--	------------

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	244
--	------------

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	258
--	------------

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	264
---	------------

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	275
---	------------

Analyze the Graph of a Rational Function • Solve Applied Problems Involving Rational Functions

3.6 Polynomial and Rational Inequalities	290
---	------------

Solve Polynomial Inequalities • Solve Rational Inequalities

Chapter Review	298
-----------------------	------------

Chapter Test	302
---------------------	------------

Cumulative Review	302
--------------------------	------------

Chapter Projects	303
-------------------------	------------

4 Exponential and Logarithmic Functions 305

4.1 Composite Functions	306
--------------------------------	------------

Form a Composite Function • Find the Domain of a Composite Function

4.2 One-to-One Functions; Inverse Functions	314
--	------------

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	326
----------------------------------	------------

Evaluate Exponential Functions • Graph Exponential Functions • Define the Number e • Solve Exponential Equations

4.4 Logarithmic Functions	343
----------------------------------	------------

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	356
	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	365
	Solve Logarithmic Equations • Solve Exponential Equations • Solve Logarithmic and Exponential Equations Using a Graphing Utility	
4.7	Financial Models	371
	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	381
	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	391
	Build an Exponential Model from Data • Build a Logarithmic Model from Data • Build a Logistic Model from Data	
	Chapter Review	399
	Chapter Test	404
	Cumulative Review	405
	Chapter Projects	406

5 **Trigonometric Functions** **407**

5.1	Angles and Their Measures	408
	Convert between Decimals and Degrees, Minutes, Seconds Measures for Angles • Find the Length of 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	Trigonometric Functions: Unit Circle Approach	422
	Find the Exact Values of the Trigonometric Functions Using a Point on the Unit Circle • Find the Exact Values of the Trigonometric Functions of Quadrantal Angles • Find the Exact Values of the Trigonometric Functions of $\pi/4 = 45^\circ$ • Find the Exact Values of the Trigonometric Functions of $\pi/6 = 30^\circ$ and $\pi/3 = 60^\circ$ • Find the Exact Values of the Trigonometric Functions for Integer Multiples of $\pi/6 = 30^\circ$, $\pi/4 = 45^\circ$, and $\pi/3 = 60^\circ$ • Use a Calculator to Approximate the Value of a Trigonometric Function • Use a Circle of Radius r to Evaluate the Trigonometric Functions	
5.3	Properties of the Trigonometric Functions	439
	Determine the Domain and the Range of the Trigonometric Functions • Determine the Period of the Trigonometric Functions • Determine the Signs of the Trigonometric Functions in a Given Quadrant • Find the Values of the Trigonometric Functions Using Fundamental Identities • Find the Exact Values of the Trigonometric Functions of an Angle Given One of the Functions and the Quadrant of the Angle • Use Even-Odd Properties to Find the Exact Values of the Trigonometric Functions	
5.4	Graphs of the Sine and Cosine Functions	452
	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

5.5	Graphs of the Tangent, Cotangent, Cosecant, and Secant Functions	467
	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 $y = A \sec(\omega x) + B$	
5.6	Phase Shift; Sinusoidal Curve Fitting	475
	Graph Sinusoidal Functions of the Form $y = A \sin(\omega x - \phi) + B$ • Build Sinusoidal Models from Data	
	Chapter Review	486
	Chapter Test	492
	Cumulative Review	492
	Chapter Projects	493

6 Analytic Trigonometry 495

6.1	The Inverse Sine, Cosine, and Tangent Functions	496
	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)	508
	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	514
	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	523
	Use Algebra to Simplify Trigonometric Expressions • Establish Identities	
6.5	Sum and Difference Formulas	531
	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	543
	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	553
	Express Products as Sums • Express Sums as Products	
	Chapter Review	557
	Chapter Test	561
	Cumulative Review	561
	Chapter Projects	562

7	Applications of Trigonometric Functions	563
7.1	Right Triangle Trigonometry; Applications Find the Value of Trigonometric Functions of Acute Angles Using Right Triangles • Use the Complementary Angle Theorem • Solve Right Triangles • Solve Applied Problems	564
7.2	The Law of Sines Solve SAA or ASA Triangles • Solve SSA Triangles • Solve Applied Problems	576
7.3	The Law of Cosines Solve SAS Triangles • Solve SSS Triangles • Solve Applied Problems	587
7.4	Area of a Triangle Find the Area of SAS Triangles • Find the Area of SSS Triangles	593
7.5	Simple Harmonic Motion; Damped Motion; Combining Waves 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	600
	Chapter Review	609
	Chapter Test	612
	Cumulative Review	613
	Chapter Projects	613
8	Polar Coordinates; Vectors	615
8.1	Polar Coordinates 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	616
8.2	Polar Equations and Graphs Identify and Graph Polar Equations by Converting to Rectangular Equations • Test Polar Equations for Symmetry • Graph Polar Equations by Plotting Points	625
8.3	The Complex Plane; De Moivre's Theorem 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	640
8.4	Vectors 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	648
8.5	The Dot Product 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	662
8.6	Vectors in Space 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	670

8.7 The Cross Product	679
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	685
Chapter Test	688
Cumulative Review	689
Chapter Projects	689

9 Analytic Geometry 691

9.1 Conics	692
Know the Names of the Conics	
9.2 The Parabola	693
Analyze Parabolas with Vertex at the Origin • Analyze Parabolas with Vertex at (h, k) • Solve Applied Problems Involving Parabolas	
9.3 The Ellipse	701
Analyze Ellipses with Center at the Origin • Analyze Ellipses with Center at (h, k) • Solve Applied Problems Involving Ellipses	
9.4 The Hyperbola	711
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	724
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	731
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	737
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	749
Chapter Test	752
Cumulative Review	752
Chapter Projects	753

10 Systems of Equations and Inequalities 754

10.1 Systems of Linear Equations: Substitution and Elimination	755
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	770
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	784
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	794
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	813
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	821
Solve a System of Nonlinear Equations Using Substitution • Solve a System of Nonlinear Equations Using Elimination	
10.7 Systems of Inequalities	830
Graph an Inequality • Graph a System of Inequalities	
10.8 Linear Programming	838
Set up a Linear Programming Problem • Solve a Linear Programming Problem	
Chapter Review	845
Chapter Test	848
Cumulative Review	849
Chapter Projects	850
11 Sequences; Induction; the Binomial Theorem	851
11.1 Sequences	852
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	862
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	868
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	879
Prove Statements Using Mathematical Induction	
11.5 The Binomial Theorem	883
Evaluate $\binom{n}{j}$ • Use the Binomial Theorem	
Chapter Review	890
Chapter Test	892
Cumulative Review	892
Chapter Projects	893

12	Counting and Probability	894
	12.1 Counting	895
	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	900
	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	909
	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	919
	Chapter Test	921
	Cumulative Review	922
	Chapter Projects	922
13	A Preview of Calculus: The Limit, Derivative, and Integral of a Function	923
	13.1 Finding Limits Using Tables and Graphs	924
	Find a Limit Using a Table • Find a Limit Using a Graph	
	13.2 Algebra Techniques for Finding Limits	929
	Find the Limit of a Sum, a Difference, and a Product • Find the Limit of a Polynomial • Find the Limit of a Power or a Root • Find the Limit of a Quotient • Find the Limit of an Average Rate of Change	
	13.3 One-sided Limits; Continuous Functions	936
	Find the One-sided Limits of a Function • Determine Whether a Function Is Continuous	
	13.4 The Tangent Problem; The Derivative	943
	Find an Equation of the Tangent Line to Graph a Function • Find the Derivative of a Function • Find Instantaneous Rates of Change • Find the Instantaneous Speed of a Particle	
	13.5 The Area Problem; The Integral	950
	Approximate the Area Under the Graph of a Function • Approximate Integrals Using a Graphing Utility	
	Chapter Review	956
	Chapter Test	959
	Chapter Projects	960
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.

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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 21–23. 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*

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 21–23.

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 21–23 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.
- **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.
- **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.
- 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 downloaded from the Instructor’s Resource Center.

Changes in the Third Edition

• CONTENT

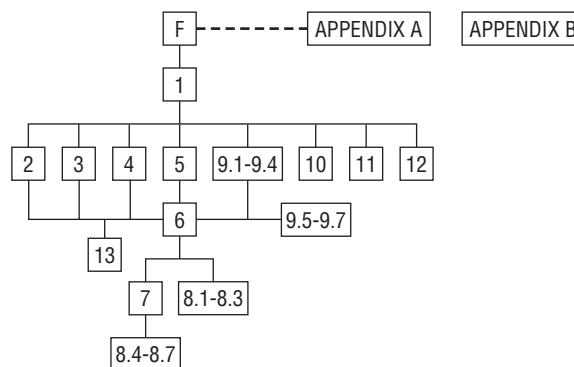
- **Chapter 2, Section 4** A new objective “Find a quadratic function given its vertex and one point” has been added.
- **Chapter 2, Section 5** A new example was added to illustrate that quadratic inequalities may have the empty set or all real numbers as a solution.
- **Chapter 3, Sections 1 and 4** 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 5.6 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.

Chapter 13 A Preview of Calculus: The Limit, Derivative, and Integral of a Function

If time permits, coverage of this chapter will provide your students with a beneficial head-start in calculus. 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

Third Edition

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.

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

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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.	305, 406
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.	305, 406
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.	326
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.	326
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!	326, 337
 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.	333, 338
WARNING	Warnings are provided in the text.	These point out common mistakes and help you to avoid them.	360
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.	232, 347
 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.	343
 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!	102, 334
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.	236
 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.	351, 379

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!	326, 337
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.	337
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.	337–339
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.	339–340
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.	340–342
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.	342
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.	342
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.	336, 339
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.	401–404

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!	399–400
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.	401
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.	401–404
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.	404–405
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.	405
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.	406
 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.	406



Resources for Success

Instructor Resources

Additional resources can be downloaded from www.pearsonglobaleditions.com/sullivan.

TestGen®

TestGen® (www.pearsonglobaleditions.com/sullivan) 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.

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:

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 on YouTube.



Algebra Review

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



Applications Index

Acoustics

amplifying sound, 403
loudness of sound, 355, 405
loudspeaker, 607
tuning fork, 607
whispering galleries, 708

Aerodynamics

modeling aircraft motion, 689–90

Aeronautics

Challenger disaster, 390

Agriculture

farm management, 843
farm workers in U.S., 390–91
field enclosure, 828
grazing area for cow, 598
minimizing cost, 843
removing stump, 661

Air travel

bearing of aircraft, 571, 574
flight time and ticket price, 167
frequent flyer miles, 584–85
holding pattern, 521
intersection point of two planes, 134–35
parking at O'Hare International
 Airport, 118
revising a flight plan, 592
speed and direction of aircraft, 656, 660

Archaeology

age of ancient tools, 384
age of fossil, 388, 389
age of tree, 389
date of prehistoric man's death, 403

Architecture

brick staircase, 867, 891
Burj Khalifa building, A14–A15
floor design, 865–66, 891
football stadium seating, 867
mosaic design, 867, 891
Norman window, 204, A20
parabolic arch, 204
racetrack design, 710
special window, 204
stadium construction, 867
window design, 204

Area. *See also* Geometry

of Bermuda Triangle, 598
under a curve, 507
of isosceles triangle, 552
of sector of circle, 415–16, 419
of segment of circle, 610

Art

fine decorative pieces, 437

Astronomy

angle of elevation of Sun, 573
distances of planets from Sun, 861
planetary orbits, 707–08, 711
 Earth, 710
 Jupiter, 710
 Mars, 710
 Mercury, 737
 Pluto, 711
radius of the Moon, 437

Aviation

modeling aircraft motion, 689–90
orbital launches, 767

Biology

age versus total cholesterol, 398
alcohol and driving, 351, 356
bacterial growth, 382–83, 395
 E-coli, 109, 152–53
blood pressure, 521
blood types, 899
bone length, 219
cricket chirping, 206
gestation period, 215
healing of wounds, 340, 355
maternal age versus Down syndrome,
 168
muscle force, 661
yeast biomass as function of time, 394–95

Business

advertising, 167, 219
automobile production, 312, 783
blending coffee, A78
car rentals, 159
checkout lines, 918
clothing store, 920
cookie orders, 848
cost
 of can, 286–87, 289
 of commodity, 313
 of manufacturing, 243, 297, 837,
 A13, A78
 marginal, 191, 218
 minimizing, 218, 843, 848
 of production, 108, 313, 810–11, 848
 of theater ticket per student, 297
 of transporting goods, 119
 weekly, 239
cost equation, 63, 142
cost function, 160
 average, 92
demand
 for candy, 142
 for jeans, 167
 for PCs, 396
demand equation, 218, 303
discounts, 313

drive-thru rate

 at Burger King, 336
 at Citibank, 340, 355
earnings of young adults, 754
equipment depreciation, 877
ethanol production, 395
expense computation, A79
Jiffy Lube's car arrival rate, 340–41, 355
managing a meat market, 844
milk production, 396
mixing candy, A78
mixing nuts, A78
new-car markup, A88
orange juice production, 783
personal computer price and demand,
 396
precision ball bearings, A13
presale order, 767
product design, 844
production scheduling, 843
product promotion, 64
profit, 811
 cigar company, 132
 maximizing, 841–42, 843–44
profit function, 88, 191–92
rate of return on, 379
restaurant management, 767
revenue, 191, 195–64, A78
 advertising and, 167
 airline, 844
 from calculator sales, 181
 of clothing store, 799–800
 daily, 192
 from digital music, 132
 instantaneous rate of change of, 950,
 958
 maximizing, 191–92, 203
 monthly, 191–92
 from seating, 878
 theater, 768
revenue equation, 142
salary, 867
 gross, 87
 increases in, 877, 891
sales
 commission on, A88
 of movie theater ticket,
 755, 759–60, 767
 net, 40
salvage value, 403
straight-line depreciation, 156–57, 160
supply and demand, 157–58, 160
tax, 297
toy truck manufacturing, 837
transporting goods, 837
truck rentals, 63, 161
unemployment, 921
wages
 of car salesperson, 63

Calculus

area under a curve, 507
 carrying a ladder around a corner, 522
 maximizing rain gutter construction, 552
 projectile motion, 522
 Simpson's rule, 204

Carpentry. *See also* **Construction**

pitch, 65

Chemistry

alpha particles, 723
 decomposition reactions, 389
 drug concentration, 288
 gas laws, 142
 pH, 354
 purity of gold, A79
 radioactive decay, 388, 389, 396, 404
 radioactivity from Chernobyl, 389
 reactions, 204
 salt solutions, A79
 sugar molecules, A80
 volume of gas, A88

Combinatorics

airport codes, 901
 binary codes, 920
 birthday permutations, 903, 907, 914–15,
 918, 920
 blouses and skirts combinations, 899
 book arrangements, 907
 box stacking, 907
 code formation, 907
 combination locks, 908
 committee formation,
 905, 907, 908, 920
 Senate committees, 908
 flag arrangement, 906, 920
 letter codes, 901, 921
 letter combinations, 920
 license plate possibilities,
 907, 920, 921
 lining people up, 902, 907
 number formation, 899, 907, 908, 921
 objects selection, 908
 seating arrangements, 920
 shirts and ties combinations, 899
 telephone numbers, 920
 two-symbol codewords, 898
 word formation, 905–06, 907, 921

Communications

cell phone plan, 74
 cell phone service, 118, 148, 161
 cell phone towers, 397
 installing cable TV, 137
 long distance
 comparing phone companies, 218
 international call plan, 161
 phone charges, 160
 satellite dish, 698, 700
 spreading of rumors, 340, 355
 Touch-Tone phones, 556–57, 608

Computers and computing

Dell PCs, 396
 graphics, 659, 812–13
 households without personal computers,
 390
 JPEG image compression, 812
 laser printers, A79
 LCD monitors, 218
 social media, 812
 three-click rule for web design, 812
 website map, 811
 Word users, 390

Construction

of box, 828
 closed, 147
 open, 137
 of brick staircase, 891
 of can, 301
 of coffee can, A80
 of cylindrical tube, 828
 of enclosures
 around garden, A79
 around pond, A79
 maximizing area of, 198–99, 203
 of fencing, 198–99, 203, 828
 minimum cost for, 289
 of flashlight, 700
 of headlight, 700
 of highway, 574, 585, 611
 installing cable TV, 137
 of open box, 179
 pitch of roof, 575
 of rain gutter, 204, 430, 552, 565–66
 of ramp, 584
 access ramp, 64
 of rectangular field enclosure, 203
 sidewalk area, 438
 of stadium, 204, 867
 of steel drum, 289
 of swimming pool, A21
 of swing set, 593
 of tent, 597
 TV dish, 700
 vent pipe installation, 710

Crime

income and, 398

Cryptography

matrices in, 811

Decorating

Christmas tree, A15–A16

Demographics

birth rate
 mother's age and, 206
 of unmarried women, 191
 diversity index, 354–55
 life expectancy, A88
 marital status, 900
 mosquito colony growth, 388–89

population. *See* Population
 rabbit colony growth, 860

Design

of awning, 585–86
 of box with minimum surface area, 289
 of fine decorative pieces, 437
 of Little League Field, 421
 of water sprinkler, 419

Direction

of aircraft, 660
 compass heading, 660
 for crossing a river, 660, 661
 of fireworks display, 722
 of lightning strikes, 722
 of motorboat, 660
 of swimmer, 688

Distance

Bermuda Triangle, A21
 bicycle riding, 97
 from Chicago to Honolulu, 508
 circumference of Earth, 421
 between cities, 414–15, 419
 between Earth and Mercury, 586
 between Earth and Venus, 586
 from Earth to a star, 573–74
 of explosion, 723
 height
 of aircraft, 584, 586
 of bouncing ball, 877, 891
 of bridge, 584
 of building, 574, 575, 576
 of cloud, 569
 of Eiffel Tower, 573
 of embankment, 574
 of Ferris Wheel rider, 521
 of Great Pyramid of Cheops, 586, A21
 of helicopter, 582, 611
 of hot-air balloon, 574
 of Lincoln's caricature on Mt. Rushmore,
 574
 of monument, 574
 of mountain, 581, 584
 of statue on building, 569–70
 of tree, 437
 of Willis Tower, 574
 from home, 97
 from Honolulu to Melbourne, Australia,
 508
 of hot-air balloon
 to airport, 612
 from intersection, 40
 from intersection, 40, 136
 length
 of guy wire, 592
 of mountain trail, 574
 of ski lift, 584
 limiting magnitude of telescope, 403
 to the Moon, 584
 nautical miles, 420
 pendulum swings, 873, 877
 to plateau, 573

across pond, 573
 range of airplane, A80
 reach of ladder, 573
 of rotating beacon, 474–75
 at sea, 581–82, 585
 of ship from shore, 573
 to shore, 585, 610
 between skyscrapers, 575
 sound to measure, A71
 to tower, 586
 traveled by wheel, A20
 between two moving vehicles, 40
 toward intersection, 136
 between two objects, 574
 viewing, 437
 visibility of Gibb's Hill Lighthouse beam,
 570–71, 576, A22
 visual, A21
 walking, 97
 of water tower to building, 900
 width
 of gorge, 572
 of Mississippi River, 575
 of river, 568, 610

Economics

Consumer Price Index (CPI), 380
 demand equations, 303
 earnings of young adults, 754
 federal deficit, 379, 403
 income versus crime rate, 398
 inflation, 379–80
 IS-LM model in, 768
 marginal propensity to consume, 878
 multiplier, 878
 participation rate, 88
 personal computer price and demand,
 396
 poverty rates, 301
 poverty threshold, 40
 relative income of child, 811
 unemployment, 921

Education

admission probabilities, 921
 age distribution of community college,
 921
 college costs, 379, 877
 college tuition and fees, 810
 degrees awarded, 897
 doctoral degrees awarded, 918
 faculty composition, 918
 funding a college education, 403
 grade computation, A88
 grade-point average and video games,
 167
 IQ tests, A88
 learning curve, 341, 355
 maximum level achieved, 850
 multiple-choice test, 907
 Spring break, 843
 student loan, 148
 interest on, 810
 true/false test, 907

Electricity

alternating current (ac), 491, 542
 alternating current (ac) circuits, 466, 484
 alternating current (ac) generators, 466
 charging a capacitor, 608
 cost of, 116–17
 current in RC circuit, 341
 current in RL circuit, 341, 355
 impedance, A95
 Kirchhoff's Rules, 768, 783
 parallel circuits, A95
 resistance in, 274
 rates for, 63–64, A88
 resistance, 142, 143, 274, A52, A54
 due to a conductor, 148
 voltage
 foreign, A13
 U.S., A13

Electronics

loudspeakers, 607
 microphones, 50
 sawtooth curve, 552, 608

Energy

ethanol production, 395
 heat loss
 through wall, 140
 through window, 147
 nuclear power plant, 722–23
 solar, 50, 668, 700
 thermostat control, 131–32

Engineering

bridges
 clearance, 466
 Golden Gate, 200–01
 parabolic arch, 218, 700–01
 semielliptical arch, 710, 751
 suspension, 204, 700
 crushing load, A71
 drive wheel, 611
 Gateway Arch (St. Louis), 701
 grade of road, 65
 horsepower, 142
 lean of Leaning Tower of Pisa, 585
 maximum weight supportable by pine,
 139
 moment of inertia, 557
 piston engines, 436–37
 product of inertia, 552
 road system, 624
 robotic arm, 678
 rods and pistons, 593
 rod tolerance, 215
 safe load for a beam, 143
 searchlight, 530, 700, 751
 whispering galleries, 710

Entertainment

banquet hall rental, 843
 cable subscribers, 398
Demon Roller Coaster customer rate, 341

movie theater, 507
 theater revenues, 768

Environment

endangered species population, 340
 lake pollution control laws, 860
 oil leakage, 312

Exercise and fitness. *See also Sports*

heartbeats during exercise, 153–54
 for weight loss, A88

Finance. *See also Investment(s)*

balancing a checkbook, A13
 bills in wallet, 921
 calculator sales revenue, 181
 clothes shopping, 849
 college costs, 379, 877
 computer system purchase, 379
 cost
 of car rental, 119
 of driving a car, 63
 of electricity, 116–17
 of fast food, 767
 minimizing, 218, 289
 of natural gas, 118–19
 of RV rental, 220
 of tattoo, 685
 of trans-Atlantic travel, 87, 95–96
 of triangular lot, 597
 cost equation, 142
 cost function, 160
 cost minimization, 191
 credit cards
 balance on, 820
 debt, 860
 interest on, 379
 minimum payments for, 119–20
 payment, 860
 demand equation, 203, 220
 depreciation, 340, 399
 of car, 371, 406
 division of money, A73–A74, A78
 electricity rates, 63–64
 federal income tax, A88
 financial planning, 767, 780, 783–84,
 834–35, 836, 838, 844, A73–A74, A78
 foreign exchange, 313
 future value of money, 243
 gross salary, 87
 international call plan, 161
 life cycle hypothesis, 205
 loans, A78
 car, 860
 interest on, 148, 810, A73
 repayment of, 379
 student, 810
 mortgages
 fees, 119
 interest rates on, 379
 payments, 138, 141, 147
 second, 379
 national debt, 108–09
 price appreciation of homes, 379

prices

- demand vs., 218
- of fast food, 769
- for soda and hot dog combinations, 161
- refunds, 767
- rents and square footage, 205
- revenue equation, 142
- revenue maximization, 191, 197–98
- rich man's promise, 878
- salary calculation, 313
- salary options, 878–79
- saving
 - for a car, 379
 - for a home, 877
- savings accounts interest, 379
- sinking fund, 877
- taxes, 160
 - e-filing returns, 119
 - federal income, 119, 325
 - luxury, 160
- used-car purchase, 379
- water bills, A88

Food and nutrition

- animal, 844
- calories in fast foods, 76–77
- candy, 166
- colored candies, 909–10, 921
- cooler contents, 921
- cooling time of pizza, 389
- fast food, 767, 769
- Girl Scout cookies, 918
- hospital diet, 768, 783
- “light” foods, A88
- milk production, 396
- number of possible meals, 897–98
- pig roasts, 390
- raisins, 166
- warming time of Beer stein, 389

Forestry

- wood product classification, 388

Games

- die rolling, 910–11, 912, 921
- grains of wheat on a chess board, 878
- Powerball, 921

Gardens and gardening. *See also* Landscaping

- enclosure for, A79

Geography

- area of Bermuda Triangle, 598
- area of lake, 597, 611
- grade of a mountain trail, 829
- inclination of hill, 669
- inclination of mountain trail, 568–69, 610
- width of a river, 568

Geology

- earthquakes, 355–56

Geometry

- angle between two lines, 542
- balloon volume, 312
- circle
 - area of, 597, A78
 - area of sector of, 415–16, 419
 - circumference of, A7, A12, A78
 - equation of, 794
 - inscribed, 135–36, 599
 - length of chord of, 593
 - radius of, 827
- collinear points, 793
- cone volume, 142, 313
- cube
 - length of edge of, 257
 - surface area of, A13
 - volume of, A13
- cylinder
 - inscribing in cone, 137
 - inscribing in sphere, 136
 - volume of, 142, 313
- Descartes's method of equal roots, 828
- equation of line, 793
- ladder angle, 612
- polygon
 - area of, 794
 - number of sides of, 179
- quadrilateral area, 612
- rectangle
 - area of, 87, 134, 218, 420, 711, A12
 - dimensions of, 218, 827
 - inscribed in semicircle, 136, 553
 - perimeter of, A12
 - semicircle inscribed in, 136
- semicircle area, 597, 612
- sphere
 - surface area of, A12
 - volume of, A12
- square
 - area of, A20, A78
 - perimeter of, A78
- surface area
 - of balloon, 312
 - of cube, A13
 - of sphere, A12
- triangle
 - area of, 597, 612, 794, A12
 - circumscribing, 587
 - equilateral, A12
 - inscribed in circle, 136
 - isosceles, 87, 827, 828
 - Pascal's, 860
 - perimeter of, A12
 - right, 572
 - sides of, 613
 - volume of parallelepiped, 684

Government

- federal deficit, 403
- federal income tax, 88, 119, 325, A88
- first-class mail charge, 120
- national debt, 108–09
- stimulus package (2009), 379

Health. *See also* Medicine

- breast cancer survival rate, 396
- cigarette use among teens, 64
- expenditures on, 88
- ideal body weight, 325
- life cycle hypothesis, 205
- pancreatic cancer survival rate, 340

Home improvement. *See also* Construction

- painting a house, 769
- painting a room, 475

Investment(s)

- annuity, 874–75, 877
- in bonds, 844
 - EE Series, 379
 - Treasuries, 783, 784, 834–35, 836, 838
 - Treasury notes vs. Treasury bonds, 780
 - zero-coupon, 376, 380
- in CDs, 375, 844
- compound interest on, 372–75, 379, 467, 929
- diversified, 768–69
- division among instruments, A78
- doubling of, 377, 380
- in fixed-income securities, 844
- 433(K), 877, 891
- growth rate for, 379
- IRA, 379, 874–75, 877
- in mutual fund, 392–93
- return on, 379, 843, 844
- in stock
 - appreciation, 379
 - beta, 150, 221–22
 - NASDAQ stocks, 907
 - NYSE stocks, 907
 - portfolios of, 900
 - price of, 878
 - time to reach goal, 379, 380
 - tripling of, 377, 380

Landscaping. *See also* Gardens and gardening

- pond enclosure, 218
- removing stump, 661
- tree cutting, 584, 783
- watering lawn, 419

Law and law enforcement

- motor vehicle thefts, 918
- violent crimes, 88

Leisure and recreation

- cable TV, 137
- centrifugal force ride, 419
- community skating rink, 148
- Ferris wheel, 71, 420, 521, 586, 607
- gondola, 419
- swing displacement, 613
- video games and grade-point average, 167

Marketing. *See* **Business****Measurement**

optical methods of, 530
of rainfall, 668

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

blood pressure, 521
breast cancer survival rate, 396
drug concentration, 108, 288
drug medication, 340, 355
healing of wounds, 340, 355
pancreatic cancer, 340
spreading of disease, 404

Meteorology

weather balloon height and atmospheric pressure, 393–94

Miscellaneous

bending wire, 828
biorhythms, 466
carrying a ladder around a corner, 474, 522
citrus ladders, 867
cross-sectional area of beam, 87–88, 95
curve fitting, 768, 782, 847
drafting error, 40
pet ownership, 918
rescue at sea, 581–82
rooms in housing units, 87
surface area of balloon, 312
surveillance satellites, 575–76
volume of balloon, 312
window dimensions, 179
wire enclosure area, 136

Mixtures. *See also* **Chemistry**

blending coffees, 837, 848,
A74–A75, A78
blending teas, A78
cement, A80
mixed nuts, 767, 837, 848, A78
mixing candy, A78
solution, 767
water and antifreeze, A79

Motion. *See also* **Physics**

catching a train, 752
on a circle, 419
of Ferris Wheel rider, 521
of golf ball, 95, 522
minute hand of clock, 418
objects approaching
intersection, 748
of pendulum, 608
revolutions of circular disk, A20
simulating, 742–43
tortoise and the hare race, 827
uniform, 136, 748, A75–A77,
A78–A79

Motor vehicles

alcohol and driving, 351, 356
approaching intersection, 748
automobile production, 312, 783
automobile theft, 918
average car speed, A80
brake repair with tune-up, 921
braking load, 669, 688
crankshafts, 585
depreciation of, 305, 371, 399, 406
distance between, 437
with Global Positioning System (GPS),
403
loans for, 860
miles per gallon, 205–06
new-car markup, A88
RV rental cost, 220
spin balancing tires, 420
stopping distance, 88, 191, 325
used-car purchase, 379
windshield wiper, 419

Music

iPod storage capacity for, 161
revenues from, 132

Navigation

avoiding a tropical storm, 592
bearing, 571, 591
of aircraft, 571, 574
of ship, 574, 611
charting a course, 661
commercial, 584–85
compass heading, 660
correct direction for crossing river, 660
error in
correcting, 589–90, 611
time lost due to, 585
rescue at sea, 581–82, 584
revising a flight plan, 592

Oceanography

tides, 485

Optics

angle of incidence, 522–23
angle of refraction, 522–23
bending light, 523
index of refraction, 522–23
intensity of light, 142
laser beam, 573
laser projection, 552
lensmaker's equation, A54
light obliterated through
glass, 340
magnitude of telescope, 403
measurements using, 530
mirrors, 723
reflecting telescope, 700

Pediatrics

height vs. head circumference,
196, 325

Pets

dog roaming area, 420

Pharmacy

vitamin intake, 768, 784

Photography

camera distance for full-body shot, 574

Physics

angle of elevation of Sun, 573
bouncing balls, 891
braking load, 669, 688
damped motion, 603–04
direction of aircraft, 660
Doppler effect, 289
falling objects, 141
force, 659, A78
muscle, 661
resultant, 659
of wind on a window, 140, 142
gravity, 274, 297
on Earth, 87, 325
on Jupiter, 87
harmonic motion, 602, 607, 611
heat loss through a wall, 140
heat transfer, 522
horsepower, 142
inclination of mountain trail, 568–69
inclination of ramp, 661
intensity of light, 142
kinetic energy, 143, A78
maximum weight supportable by pine, 139
moment of inertia, 557
motion of object, 602, 744
Newton's law, 141
pendulum motion, 419, 607, 608, 873,
A62, A71
period, 132, 326
simple pendulum, 141
pressure, 142, A78
product of inertia, 552
projectile motion, 181, 199–200, 203–04,
436, 437–38, 522, 547, 552, 557,
741–42, 747, 748, 749, 752
artillery, 513
hit object, 748
thrown object, 747
rate of change
average, 960
instantaneous, 946, 949
safe load for a beam, 143
simulating motion, 742–43
sound to measure distance, A71
static equilibrium, 657, 660, 661, 688, 689
static friction, 661
stopping distance, 191
stress of materials, 143
stretching a spring, 142
tension, 657, 660, 688, 689, 883
thrown object, 195, 205,
655, 947–48, 949
truck pulls, 660

uniform motion, 136, 748, 752, A75–A77, A78–A79
 velocity down inclined planes, A62
 vertically propelled object, 179, 195
 vibrating string, 142
 weight, 142, 147, 656, 660
 effect of elevation on, 96
 work, 678, A78

Play

wagon pulling, 659, 666, 667

Population. *See also* Demographics

bacterial, 388, 389, 390, 395
 decline in, 389
 of divorced people, 201–02
 E-coli growth, 109, 152–53
 of endangered species, 340, 390
 of fruit fly, 387
 as function of age, 87
 growth in, 388, 389
 insect, 274, 388
 of rabbit colony, 860
 of trout, 860
 of United States, 370, 396–97, 893
 of world, 371, 397, 403, 851
 future of, 960

Probability

checkout lines, 918
 classroom composition, 918
 “Deal or No Deal” TV show, 894
 exponential, 336, 340, 355
 gender composition of 35-child family, 912
 household annual income, 918
 Monty Hall Game, 922
 Poisson, 341
 “Price is Right” games, 918
 of shared birthdays in room of n people, 391
 tossing a fair coin, 909, 911
 of winning a lottery, 919

Psychometrics

IQ tests, 215

Pyrotechnics

fireworks display, 722

Rate. *See also* Speed

of car, 419
 catching a bus, 747–48
 catching a train, 747
 current of stream, 768
 of emptying
 oil tankers, A80
 a pool, A80
 a tub, A80
 to keep up with the Sun, 420
 miles per gallon, 205–06
 revolutions per minute
 of bicycle wheels, 419
 of pulleys, 421

speed
 average, A80
 of current, A78–A79
 of motorboat, A78–A79
 of moving walkways, A79
 of plane, A80

Real estate

commission schedule, A88
 cost of triangular lot, 597
 ground area covered by building, 597–98
 price appreciation of homes, 379
 rents and square footage, 205
 valuing a home, 33, 73

Recreation

bungee jumping, 297
Demon Roller Coaster customer rate, 341
 online gambling, 918

Security

security cameras, 573

Seismology

calibrating instruments, 751

Sequences. *See also* Combinatorics

ceramic tile floor design, 865–66
 Drury Lane Theater, 867
 Fibonacci, 860
 football stadium seating, 867
 seats in amphitheater, 867

Speed

of aircraft, 660
 angular, 419, 491
 of current, 420, 848
 of cyclists moving in opposite directions, A80
 as function of time, 97, 136
 of glider, 610
 ground, 660
 instantaneous
 of ball, 947–48, 949, 958
 on the Moon, 949–50
 linear, 416–17
 on Earth, 419, 420
 of Moon, 420
 of motorboat, 660, A76–A77
 revolutions per minute of pulley, 420
 of rotation of lighthouse beacons, 491
 of swimmer, 688
 of truck, 573
 of wheel pulling cable cars, 420
 wind, 767

Sports

baseball, 748–49, 908, 920
 diamond, 39
 dimensions of home plate, 597
 field, 592
 Little League, 40, 421
 on-base percentage, 162–63
 stadium, 592
 World Series, 908

basketball, 908
 free throws, 95, 575
 granny shots, 95
 biathlon, A80
 bungee jumping, 297
 exacta betting, 921
 football, 710, 752, 908, A79
 golf, 918
 distance to the green, 591
 putts, 398–99
 sand bunkers, 513
 hammer throw, 492
 Olympic heroes, A80
 pool shots, 576
 races, 825, 827–28, A80
 relay runners, 920
 swimming, 613, 688
 tennis, A79

Statistics. *See* Probability

Surveys

of appliance purchases, 899
 data analysis, 896, 899
 stock portfolios, 899
 of summer session attendance, 899
 of TV sets in a house, 918

Technology. *See also* Computers and computing

Blu-ray drive, 419
 DVD drive, 419
 iPod storage capacity for music, 161

Temperature

of air parcel, 867
 body, A13
 conversion of, 313, 325
 cooling time of pizza, 389
 cricket chirping and, 206
 measuring, 64, 132
 after midnight, 243
 monthly, 484–85, 491
 of portable heater, 403
 relationship between scales, 132
 sinusoidal function from, 480–81
 of skillet, 403
 warming time of Beer stein, 389
 wind chill factor, 404

Tests and testing

IQ, A88

Time

for Beer stein to warm, 389
 for block to slide down inclined plane, 436
 Ferris Wheel rider height as function of, 521
 to go from an island to a town, 137
 hours of daylight, 482–83, 485–86, 506–07
 for pizza to cool, 389
 of sunrise, 420, 507
 of trip, 437, 451