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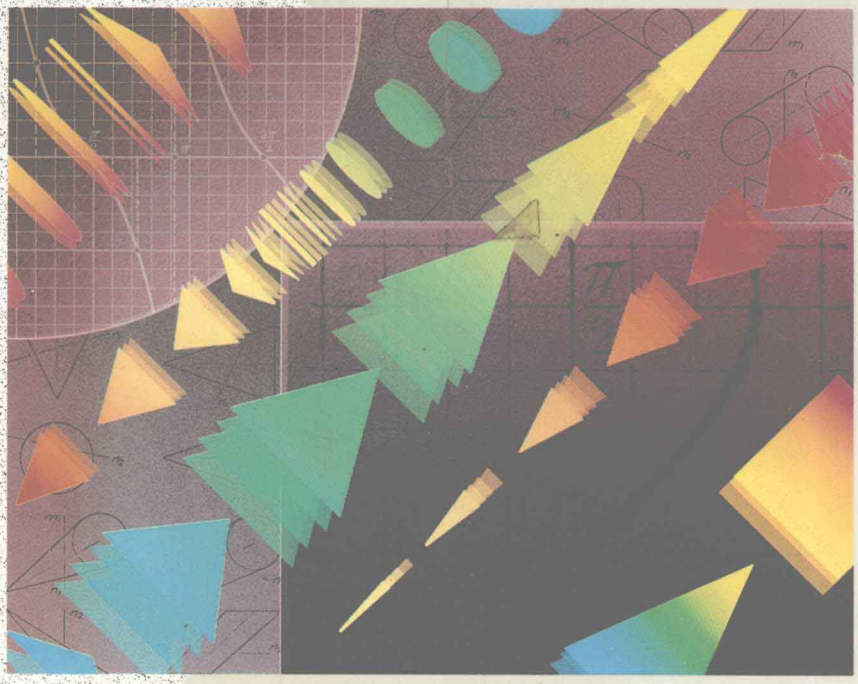

Fundamentals of TRIGONOMETRY

Includes
POCKET REFERENCE CARD

EIGHTH EDITION

FUNDAMENTALS OF TRIGONOMETRY

EARL W. SWOKOWSKI

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DEDICATION

This Eighth Edition of *Fundamentals of Trigonometry* is dedicated to the memory of Earl W. Swokowski.

I am grateful for having been given the opportunity to work with a great mentor.

A NOTE FROM THE PUBLISHER

Earl W. Swokowski died on June 2, 1992. We at PWS-KENT are grateful to have been associated with one of the premier mathematics authors of the last twenty-five years, and we will miss him.

Earl has left us a rich legacy of extraordinary work and a tradition of excellence. Jeffery A. Cole has worked with Earl over the course of several editions of this precalculus series, and we are confident that he will carry on this tradition of uncompromising quality.

PREFACE

One of our main goals in preparing the eighth edition of *Fundamentals of Trigonometry* was to enhance the clarity of the discussions. We wanted to enable the student to more easily understand the concepts presented, but we did not want to sacrifice the mathematical soundness that has been paramount to the success of this text. By improving the explanations of the more difficult concepts and including step-by-step comments on the solutions of the examples, we have furthered our goal of helping the student while maintaining mathematical rigor.

Treatment of various topics has been updated to include the use of a graphics calculator. Graphics calculator exercises and examples are found throughout the text, wherever they are appropriate to the material being presented.

Suggestions provided by reviewers and instructors for improvements in the arrangement of topics and the writing have resulted in a great deal of reorganization for this edition. The principal changes made to each chapter are highlighted below.

CHANGES FOR THE EIGHTH EDITION

Chapter 1 Graphics calculator examples and exercises first appear in Section 1.2. The topic of horizontally stretching or compressing graphs has been added to Section 1.4, providing a sound foundation for the study of periods of trigonometric functions. A brief survey of exponential and logarithmic functions has been added as Section 1.5 to acquaint the student with these functions, which will be used in some of the new calculator exercises in Chapters 2–4. A thorough treatment of these functions appears in Chapter 5.

Chapter 2 The formula for the area of a circular sector has been added to Section 2.1. In Section 2.2, the discussion of calculator solutions for equations requiring inverse trigonometric functions has been enhanced. Verification of simple trigonometric identities has been added to Sections 2.2 and 2.3.

Chapters 3 and 4 The inclusion of calculator usage and exercises has strengthened these chapters, and general rewriting has made all sections easier to understand. Topics dealing with complex numbers are now included in Chapter 4.

Chapter 5 Two new theorems highlight the fact that exponential and logarithmic functions are one-to-one. Greater emphasis has been placed on changing exponential forms to equivalent logarithmic forms (and vice versa) in the solving of exponential and logarithmic equations.

Chapter 6 A new relationship for finding the distance from the vertex of a parabola to its focus is emphasized in Section 6.2. The graphing of half-parabolas, half-ellipses, and portions of a hyperbola has been added to this chapter, as have exercises dealing with properties of paraboloids and ellipsoids. The orientation of parametrized curves is thoroughly discussed in Section 6.8.

FEATURES

Illustrations Brief demonstrations of the use of definitions, laws, and theorems are provided in the form of illustrations.

Examples All examples, well structured and graded by difficulty, have been titled for this edition. Many examples contain graphs, charts, or tables to help the student understand procedures and solutions.

Step-by-Step Explanations In order to help students follow them more easily, step-by-step explanations have been added to the solutions in examples.

Checks The solutions to some examples are explicitly checked, to remind students to verify that their solutions satisfy the conditions of the problems.

Calculator Examples Wherever appropriate, examples requiring the use of a graphics calculator have been added to the text. These are designated by a green graphics calculator icon and illustrated with a figure reproduced from a graphics calculator screen.

Calculator Exercises Exercises specifically designed to be solved with a graphics calculator or computer software have been included in appropriate sections. Over 100 of these exercises, designated with a C, have been added to this edition.

Exercise Applications Applications in the exercise sets are identified with titles that show students how the problems are related to practical situations.

Exercise Sets After beginning with drill problems, exercise sets progress to more challenging problems. Many exercises containing graphs have been added.

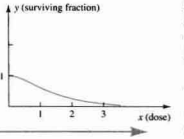
Warnings Interspersed throughout the text are warnings to alert students to common mistakes.

Text Art Each figure has been redrawn and relabeled, and graphs have been computer-generated for accuracy, using the latest technology. Additional colors are used to distinguish between different parts of figures. For example,

Examples, well structured and graded by difficulty, have been titled for this edition.

Examples requiring the use of a graphics calculator have been added to the text wherever appropriate. These are designated by an icon and illustrated with a figure reproduced from a graphics calculator screen.

FIGURE 16
Surviving fraction of tumor cells after a radiation treatment



A complete analysis of the graph of f requires calculus. The graph is sketched in Figure 16. The *shoulder* on the curve near the point (0, 1) represents the threshold nature of the treatment—that is, a small dose results in very little tumor cell elimination. Note that for a large x, an increase in dosage has little effect on the surviving fraction. To determine the ideal dose to administer to a patient, specialists in radiation therapy must also take into account the number of healthy cells that are killed during a treatment.

Problems of the type illustrated in the next example occur in the study of calculus.

EXAMPLE 4 ***Finding zeros of a function involving exponentials***
If $f(x) = x^2(-2e^{-2x}) + 2xe^{-2x}$, find the zeros of f.

SOLUTION We may factor $f(x)$ as follows:

$$f(x) = 2xe^{-2x} - 2x^2e^{-2x}$$
$$= 2xe^{-2x}(1 - x)$$

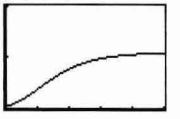
To find the zeros of f, we solve the equation $f(x) = 0$. Since $e^{-2x} > 0$ for every x, we see that $f(x) = 0$ if and only if $x = 0$ or $1 - x = 0$. Thus, the zeros of f are 0 and 1.

EXAMPLE 5 ***Sketching a Gompertz growth curve***
In biology, the **Gompertz growth function** G given by

$$G(t) = ke^{(-Ae^{-Bt})},$$

where k, A, and B are positive constants, is used to estimate the size of certain quantities at time t. The graph of G is called a **Gompertz growth curve**. The function is always positive and increasing, and as t increases without bound, $G(t)$ levels off and approaches the value k. Graph G on the interval $[0, 5]$ for $k = 1.1$, $A = 3.2$, and $B = 1.1$, and estimate the time t at which $G(t) = 1$.

FIGURE 17
[0, 5] by [0, 2]



SOLUTION We begin by assigning

$$1.1e^{(-3.2e^{-1.1x})}$$

to Y_1. Since we wish to graph G on the interval $[0, 5]$, we choose Xmin = 0 and Xmax = 5. Because $G(t)$ is always positive and does not exceed $k = 1.1$, we choose Ymin = 0 and Ymax = 2. Hence, the viewing rectangle dimensions are $[0, 5]$ by $[0, 2]$. Graphing G gives us a display similar to Figure 17. The end point values of the graph are approximately (0, 0.045) and (5, 1.086).

To determine the time when $y = G(t) = 1$, we use the tracing and zoom-in features and obtain $x = t \approx 3.194$.

ILLUSTRATION
Exponential Functions Are One-to-One
If $7^{3x} = 7^{2x+5}$, then $3x = 2x + 5$, or $x = 5$.

In the following example we solve a simple *exponential equation*—that is, an equation in which the variable appears in an exponent.

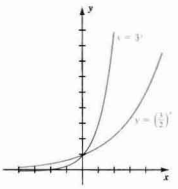
EXAMPLE 1 ***Solving an exponential equation***
Solve the equation $3^{5x-8} = 9^{x+2}$.

SOLUTION

$3^{5x-8} = 9^{x+2}$	given
$3^{5x-8} = (3^2)^{x+2}$	express both sides with the same base
$3^{5x-8} = 3^{2x+4}$	law of exponents
$5x - 8 = 2x + 4$	exponential functions are one-to-one
$3x = 12$	subtract $2x$ and add 8
$x = 4$	divide by 3

In the next two examples we sketch the graphs of several different exponential functions.

FIGURE 3



EXAMPLE 2 ***Sketching graphs of exponential functions***
If $f(x) = (\frac{1}{3})^x$ and $g(x) = 3^x$, sketch the graphs of f and g on the same coordinate plane.

SOLUTION Since $\frac{1}{3} > 1$ and $3 > 1$, each graph *rises* as x increases. The following table displays coordinates for several points on the graphs.

x	-2	-1	0	1	2	3	4
$y = (\frac{1}{3})^x$	$\frac{9}{1} \approx 0.4$	$\frac{3}{1} \approx 0.7$	1	$\frac{1}{3}$	$\frac{1}{9} \approx 2.3$	$\frac{1}{27} \approx 3.4$	$\frac{1}{81} \approx 5.1$
$y = 3^x$	$\frac{1}{9} \approx 0.1$	$\frac{1}{3} \approx 0.3$	1	3	9	27	81

Plotting points and being familiar with the general graph of $y = a^x$ leads to the graphs in Figure 3.

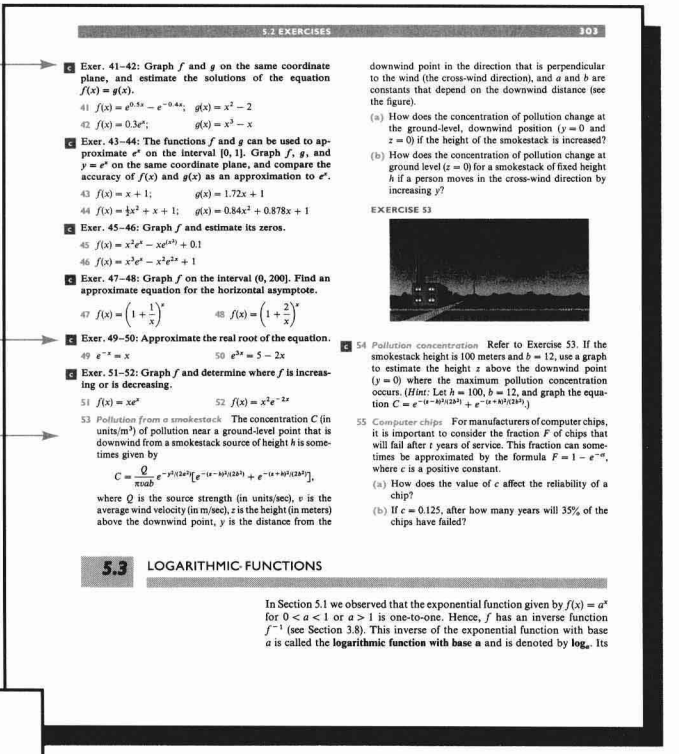
Illustrations provide brief demonstrations of the use of definitions, laws, and theorems.

Many examples contain graphs, charts, or tables to help the student understand procedures and solutions.

Exercise sets begin with drill problems and progress to more challenging problems.

Graphics calculator exercises, designated by a C, are included in many sections. Over 100 of these exercises have been added to this edition.

Exercise applications are identified to show students how the problems are related to current real-life situations.



5.2 EXERCISES 303

C **Exer. 41–42: Graph f and g on the same coordinate plane, and estimate the solutions of the equation $f(x) = g(x)$.**

41 $f(x) = e^{0.5x} - e^{-0.4x}$; $g(x) = x^2 - 2$

42 $f(x) = 0.3e^x$; $g(x) = x^3 - x$

C **Exer. 43–44: The functions f and g can be used to approximate e^x on the interval [0, 1]. Graph f, g, and $y = e^x$ on the same coordinate plane, and compare the accuracy of $f(x)$ and $g(x)$ as an approximation to e^x.**

43 $f(x) = x + 1$; $g(x) = 1.72x + 1$

44 $f(x) = \frac{1}{2}x^2 + x + 1$; $g(x) = 0.84x^2 + 0.878x + 1$

C **Exer. 45–46: Graph f and estimate its zeros.**

45 $f(x) = x^2e^x - xe^{(x^2)} + 0.1$

46 $f(x) = x^3e^x - x^2e^{2x} + 1$

C **Exer. 47–48: Graph f on the interval [0, 200]. Find an approximate equation for the horizontal asymptote.**

47 $f(x) = \left(1 + \frac{1}{x}\right)^x$ 48 $f(x) = \left(1 + \frac{2}{x}\right)^x$

C **Exer. 49–50: Approximate the real root of the equation.**

49 $e^{-x} = x$ 50 $e^{3x} = 5 - 2x$

C **Exer. 51–52: Graph f and determine where f is increasing or is decreasing.**

51 $f(x) = xe^x$ 52 $f(x) = x^2e^{-2x}$

53 *Pollution from a smokestack* The concentration C (in units/m³) of pollution near a ground-level point that is downwind from a smokestack source of height h is sometimes given by

$$C = \frac{Q}{\pi vab} e^{-y^2/(2a^2)}\left[e^{-(z-h)^2/(2b^2)} + e^{-(z+h)^2/(2b^2)}\right],$$

where Q is the source strength (in units/sec), v is the average wind velocity (in m/sec), z is the height (in meters) above the downwind point, y is the distance from the downwind point in the direction that is perpendicular to the wind (the cross-wind direction), and a and b are constants that depend on the downwind distance (see the figure).

(a) How does the concentration of pollution change at the ground-level, downwind position ($y = 0$ and $z = 0$) if the height of the smokestack is increased?

(b) How does the concentration of pollution change at ground level ($z = 0$) for a smokestack of fixed height h if a person moves in the cross-wind direction by increasing y?

EXERCISE 53

C 54 *Pollution concentration* Refer to Exercise 53. If the smokestack height is 100 meters and $b = 12$, use a graph to estimate the height z above the downwind point ($y = 0$) where the maximum pollution concentration occurs. (*Hint:* Let $h = 100$, $b = 12$, and graph the equation $C = e^{-(x-h)^2/(2b^2)} + e^{-(x+h)^2/(2b^2)}$.)

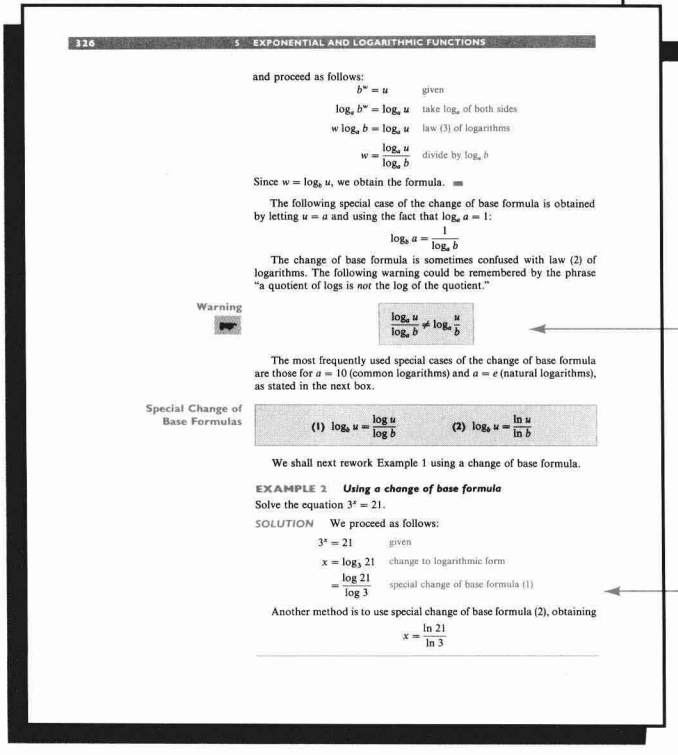
55 *Computer chips* For manufacturers of computer chips, it is important to consider the fraction F of chips that will fail after t years of service. This fraction can sometimes be approximated by the formula $F = 1 - e^{-ct}$, where c is a positive constant.

(a) How does the value of c affect the reliability of a chip?

(b) If $c = 0.125$, after how many years will 35% of the chips have failed?

5.3 LOGARITHMIC FUNCTIONS

In Section 5.1 we observed that the exponential function given by $f(x) = a^x$ for $0 < a < 1$ or $a > 1$ is one-to-one. Hence, f has an inverse function f^{-1} (see Section 3.8). This inverse of the exponential function with base a is called the **logarithmic function with base a** and is denoted by $\log_a$. Its



326 5 EXPONENTIAL AND LOGARITHMIC FUNCTIONS

and proceed as follows:

$b^w = u$ given

$\log_a b^w = \log_a u$ take $\log_a$ of both sides

$w \log_a b = \log_a u$ law (3) of logarithms

$w = \frac{\log_a u}{\log_a b}$ divide by $\log_a b$

Since $w = \log_b u$, we obtain the formula. ■

The following special case of the change of base formula is obtained by letting $u = a$ and using the fact that $\log_a a = 1$:

$$\log_b a = \frac{1}{\log_a b}$$

The change of base formula is sometimes confused with law (2) of logarithms. The following warning could be remembered by the phrase "a quotient of logs is *not* the log of the quotient."

Warning

$$\frac{\log_a u}{\log_a b} \neq \log_a \frac{u}{b}$$

The most frequently used special cases of the change of base formula are those for $a = 10$ (common logarithms) and $a = e$ (natural logarithms), as stated in the next box.

Special Change of Base Formulas

(1) $\log_b u = \frac{\log u}{\log b}$ (2) $\log_b u = \frac{\ln u}{\ln b}$

We shall next rework Example 1 using a change of base formula.

EXAMPLE 2 ***Using a change of base formula***

Solve the equation $3^x = 21$.

SOLUTION We proceed as follows:

$3^x = 21$ given

$x = \log_3 21$ change to logarithmic form

$= \frac{\log 21}{\log 3}$ special change of base formula (1)

Another method is to use special change of base formula (2), obtaining

$$x = \frac{\ln 21}{\ln 3}$$

Warnings are interspersed throughout the text to alert students to common mistakes.

Step-by-step explanations have been added to examples to help students more easily follow the solutions.

the graph of one function may be shown in blue and that of a second function in red. Labels are the same color as the parts of the figure they identify.

Text Design The text has been completely redesigned to ensure that discussions are easy to follow and important concepts are highlighted. Color is employed pedagogically to clarify complex graphs and to help students visualize applied problems.

Answer Section The answer section at the end of the text provides answers for most of the odd-numbered exercises, as well as answers for all chapter review exercises. Considerable thought and effort were devoted to making this section a learning device for the student. For instance, verifications are given of trigonometric identities, and numerical answers for many exercises are stated in both exact and approximate form. Graphs, proofs, and hints are included wherever appropriate.

Flexibility Syllabi from schools using previous editions attest to the flexibility of this text. Sections and chapters can be arranged in many different ways, depending on objectives and the length of the course.

TEACHING TOOLS FOR THE INSTRUCTOR

Instructor's Solutions Manual Included in the *Instructor's Solutions Manual* are answers to all exercises and reasonably detailed solutions to most exercises. The manual has been thoroughly reviewed for accuracy.

EXPTest This computerized test bank for IBM and compatibles contains over 700 problems, many new to this edition. Questions are multiple choice, true-false, and open-ended. Instructors can interact with the program by adding to existing questions and producing individual tests.

EXPTest Sampler with Demonstration Disk The sampler demonstrates the computerized test bank's capabilities and contains sample tests.

ExamBuilder This computerized test bank for the Macintosh has features and questions similar to those of EXPTest, described above. A demo is available.

Test Bank with Chapter Tests All the questions found in EXPTest (and ExamBuilder), along with their answers, appear in print form in the *Test Bank*. Two sample tests are also included for each chapter.

Transparencies Full-color acetates provide enlarged versions of illustrations found in the text. This teaching tool is available to adopters only.

LEARNING TOOLS FOR THE STUDENT

Quick Reference Card Packaged with this edition of the text is a new tool for solving exercises—a formula card. This perforated card, found in the back of the book, will aid students in mastering the key formulas, equations, and graphs in the course. By serving as a quick reference and minimizing the need for page turning, the formula card will reduce the time spent on tedious tasks so that the student can focus on the central concepts and principles of the course.

Student's Solutions Manual (*Cole*) Solutions are given for approximately one-third of the exercises, as well as strategies for solving additional exercises. Many helpful hints and warnings are also included.

INVESTIGATE This text-specific tutorial software package for the Macintosh, IBM, and compatibles helps students review material as needed.

College Algebra: In Simplest Terms A series of videotapes, produced by the Annenberg/CPB Collection, is available to qualified adopters. This lively series shows college algebra at work in everyday situations. Symbols, charts, pictures, and state-of-the-art computer graphics illustrate basic algebraic techniques.

Precalculus in Context: Functioning in the Real World (*Davis/Moran/Murphy*) This lab manual consists of 12 projects that encourage students to explore precalculus concepts. Graphics calculators and computer graphing software are used to solve each experiment and its corresponding exercises.

College Algebra Activities for the TI-81 Graphics Calculator (*Huff/Peterson*) Designed to supplement any college algebra course, this manual offers concise instructions for using the TI-81 graphics calculator, provides examples of how to apply the instructions, and demonstrates techniques for using the calculator as a problem-solving tool. Exercises provide students with additional experience.

TrueBasic for College Algebra (*Kemeny/Kurtz*) This graphing software package is ideal for classroom demonstrations, individual study, and problem-solving.

Student Edition of Theorist This Macintosh-compatible software combines powerful algebra and graphics capabilities with an intuitive, user-friendly interface.

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Special thanks go to Gary Rockswold, of Mankato State University, for supplying most of the fine assortment of new applied problems and calculator exercises. We also wish to thank Thomas Vanden Eynden, of Thomas More College, for doing a detailed accuracy check of the exercises; Joan Cole, for additional proofreading of the page proofs; and George Morris, of Scientific Illustrators, for creating the mathematically precise art package.

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