ANNOTATED INSTRUCTOR'S EDITION

Intermediate Algebra

through Modeling and Visualization

Rockswold

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INTERMEDIATE ALGEBRA

through Modeling and Visualization

Gary Rockswold

Minnesota State University, Mankato

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To my daughter, Jessica

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PREFACE

Intermediate Algebra through Modeling and Visualization offers an innovative approach to the intermediate algebra curriculum that allows students to gain both skills and understanding. This text not only demonstrates the relevance of mathematics but it also prepares students for future courses. The early introduction of functions and graphs allows the instructor to use applications and visualization to present mathematical topics. Real data, graphs, and tables play an important role in the course, giving meaning to the numbers and equations that students encounter. This approach increases student interest, motivation, and the likelihood for success.

Approach

A comprehensive curriculum is presented with a *balanced* and *flexible* approach that is essential for today's intermediate algebra courses. Instructors have the flexibility to strike their own balance with regard to emphasis on skills, rule of four, applications, modeling, and graphing calculator technology. With this approach to the rule of four (verbal, graphical, numerical, and symbolic methods), instructors can easily emphasize one rule more than another to meet their students' needs. This flexibility also extends to modeling, applications, and graphing calculator use. The text contains numerous practical applications, including modeling of real-world data with functions and word problems. Instructors have the freedom to fully integrate graphing calculators throughout the course. However, regular graphing calculator use is not a requirement of the text.

In *Intermediate Algebra through Modeling and Visualization* mathematical concepts are introduced by moving from the concrete to the abstract. Relevant applications underscore mathematical concepts. This text includes a diverse collection of unique, up-to-date applications that answer the commonly asked question: "When will I ever use this?" Modeling, visualization, and the rule of four allow greater access to mathematics for students with different learning styles. However, the primary purpose of this text is to teach mathematical concepts and skills. Standard mathematical definitions, theorems, symbolism, and rigor are maintained.

Organization

This text consists of 11 chapters and 50 sections. Most sections represent one class day.

Chapter 1: Real Numbers and Algebra
This chapter reviews several topics from beginning algebra, including numbers, operations on numbers, and integer exponents. Formulas are introduced as a way to describe data, and the xy-plane is used to plot and visualize data.

Chapter 2: Linear Functions and Models
Basic concepts about functions, along with their verbal, symbolic, graphical, and numerical representations, are discussed in this chapter. It features linear functions, linear models, slope, and lines. The applications presented make the concepts more concrete and relevant to students.

Chapter 3: Linear Equations and Inequalities
This chapter covers solving linear equations and inequalities. Symbolic, graphical, and numerical techniques for solving equations are presented. Many of the concepts presented in this chapter are used to solve equations and inequalities in subsequent chapters. Real-world applications and models promote student learning and understanding. Compound inequalities and absolute value inequalities are included.

Chapter 4: Systems of Linear Equations
The concepts presented in Chapter 3 are extended to systems of linear equations and inequalities. Emphasis is given to systems involving two equations in two variables. Matrix methods and determinants are included at the end of the chapter.

Chapter 5: Polynomial Expressions and Functions
Polynomials and polynomial functions are introduced, and a discussion about factoring is included. This chapter extends many of the techniques introduced in Chapters 2 and 3 to polynomials. Functions, applications, and real-world data continue to motivate many of the discussions.

Chapter 6: Quadratic Functions and Equations
Building on material from Chapter 5, this chapter discusses quadratic equations and functions. Quadratic functions and their graphs are used to model nonlinear data. Quadratic equations are solved with standard symbolic techniques, along with graphical and numerical methods.

Chapter 7: Rational Expressions and Functions
Rational expressions and functions are introduced in this chapter. Arithmetic operations on rational expressions are included. Applications occur throughout, along with a special section on proportions and variation.

Chapter 8: Radical Expressions and Functions
Radical notation and some basic functions, such as the square root and cube root functions, are discussed. Presentation of properties of rational exponents was delayed until this chapter so that students can immediately apply them. The chapter concludes with a section on complex numbers.

Chapter 9: Conic Sections
This chapter introduces parabolas, circles, ellipses, and hyperbolas and includes applications. The chapter concludes with a section on solving nonlinear equations and inequalities.

Chapter 10: Exponential and Logarithmic Functions
Logarithms, properties of logarithms, exponential and logarithmic functions, and exponential and logarithmic equations are covered in this chapter. Linear growth and exponential growth are compared so that students grasp the fundamental difference be-

tween the two types of growth. The chapter contains many real-world applications and models.

Chapter 11: Sequences and Series
This chapter introduces the basic concepts of both sequences and series, concentrating on arithmetic and geometric sequences and series. Both graphical and symbolic representations of sequences are discussed, along with applications and models. The chapter concludes with the binomial theorem.

Features

Applications and Models
Interesting, straightforward applications are a strength of this textbook, helping students become more effective problem solvers. Applications are intuitive and not overly technical so that they can be introduced in a minimum of class time. Current data are utilized to create meaningful mathematical models, exposing students to a wealth of real-world uses of mathematics. A unique feature of this text is that the applications and models are woven into both the discussions and the exercises. Students can more easily learn how to solve applications if they are discussed within the text. (See pages 94, 108, and 290.)

Graphing Calculator Technology
The use of a graphing calculator with this text is optional, but for instructors who want to fully integrate graphing technology into their courses, this text integrates the graphing calculator thoroughly and seamlessly, without sacrificing development of traditional algebraic skills. Students are encouraged to solve problems with multiple methods, learning to evaluate graphing calculator techniques against other problem-solving methods. An  icon next to selected examples refers students to the *Graphing Calculator Lab Manual* that accompanies the text, in which the examples from the book are used to further instruct students in how to use the graphing calculator. (See pages 82, 144, and 350.)

Putting It All Together
This helpful feature occurs at the end of each section and summarizes techniques and reinforces the mathematical concepts presented in the section. It is given in an easy-to-follow grid format. (See pages 37, 218, and 311.)

Section Exercise Sets
The exercise sets are at the heart of any mathematics text, and this text includes a wide variety of exercises that are instructive for student learning. Each exercise set contains exercises involving basic concepts, skill-building, and applications. In addition, many exercises ask students to read and interpret graphs. Writing About Mathematics exercises are also included at the end of every exercise set. The exercise sets are carefully graded and categorized by topic, making it easier for an instructor to select an appropriate assignment. Each exercise set concludes with an assortment of appealing applications. (See pages 97, 126, and 151.)

Checking Basic Concepts
Provided after every two sections, this feature presents a brief set of exercises that students can use for review purposes or group activities. These exercises require 10–20

minutes to complete and can be used during class if time permits. (See pages 130, 296, and 449.)

Group Activities: Working with Real Data
This feature occurs after selected sections (1 or 2 per chapter) and provides an opportunity for students to work collaboratively on a problem that involves real-world data. Most activities can be completed with limited use of class time. (See pages 115, 322, and 496.)

Chapter and Section Introductions
Many intermediate algebra students have little or no understanding of what mathematics is about. Chapter and section introductions present and explain some of the reasons for studying mathematics. They provide insights into the relevance of mathematics to many aspects of real life. (See pages 50, 72, and 274.)

Chapter Summaries
Chapter summaries are presented in an easy-to-read grid format for students to use in reviewing the important topics in the chapter. (See pages 132, 330, and 389.)

Chapter Review Exercises
Chapter Review Exercises contain both skill-building exercises, which are keyed to the appropriate sections within the chapter, and application exercises, which stress the relevance of mathematical concepts to the real world. The Chapter Review Exercises stress different techniques for solving problems and provide students with the review necessary to successfully pass a chapter test. (See pages 134, 190, and 391.)

Chapter Tests
A test is provided in the end-of-chapter review material so that students can practice their knowledge and skills. (See pages 70, 138, and 195.)

Extended and Discovery Exercises
These exercises occur at the end of each chapter and are usually more complex than the Review Exercises, requiring extension or discovery of a topic presented in the chapter. They can be utilized for either collaborative learning or extra homework assignments. (See pages 71, 140, and 336.)

Making Connections
This feature occurs throughout the text and helps students see how previously learned concepts are related to new concepts. (See pages 93, 171, and 172.)

Critical Thinking
At least one Critical Thinking exercise is included in most sections and poses a question that can be used for either classroom discussion or a homework assignment. These exercises typically ask students to extend a mathematical concept beyond what has already been discussed. (See pages 27, 173, and 346.)

Technology Notes
Occurring throughout the text, Technology Notes offer students guidance, suggestions, and cautions on the use of the graphing calculator. (See pages 124, 147, and 474.)

Sources
For the numerous real-world applications that appear throughout the text, genuine sources are cited to help establish the practical applications of mathematics in real life. (See pages 100, 349, and 403.) In addition, a comprehensive bibliography appears at the end of the text.

Supplements for the Student

***Graphing Calculator Lab Manual* (0-201-72619-X)**
Written specifically by mathematics instructor Joe May to accompany *Intermediate Algebra through Modeling and Visualization*, the *Graphing Calculator Lab Manual* is organized in a just-in-time format, with new keystrokes and skills introduced as needed in the text. The manual is divided into two parts, with the first half covering the TI–83 Plus and the second half covering the TI–86. Extra emphasis is placed on illustrating the uses and skills associated with setting a window. An icon 

is placed in the text next to every example that appears in the manual, so students immediately know when they can reference the manual for extra help. There is a list at the end of this text of all the topics covered in the manual.

***Student's Solutions Manual* (0-201-72616-5)**
This manual, written by mathematics instructor Terry Krieger, contains solutions to the odd-numbered exercises for each section (excluding Writing About Mathematics and Group Activity exercises) and solutions to all Checking Basic Concepts exercises, Chapter Review Exercises, and Chapter Test questions.

InterAct Math® Tutorial Software (0-201-72620-3)
Available on a dual-platform, Windows/Macintosh CD-ROM, this interactive tutorial software provides algorithmically generated practice exercises that are correlated at the objective level to the content of the text. Every exercise in the program is accompanied by an example and a guided solution designed to involve students in the solution process. For Windows users, selected problems also include a video clip to provide additional instruction and help students visualize concepts. The software recognizes common student errors and provides appropriate feedback, and it also tracks student activity and scores and can generate printed summaries of students' progress. Instructors can use the InterAct Math® Plus course-management software to create, administer, and track tests and monitor student performance during practice sessions (see the description on page xvii).

InterAct MathXL: www.mathxl.com
InterAct MathXL is a Web-based tutorial system that helps students prepare for tests by allowing them to take practice tests and receive personalized study plans based on their results. Practice tests are correlated directly to the section objectives in the text, and once a student has taken an on-line practice test, the software scores the test and generates a study plan that identifies strengths, pinpoints topics where more review is needed, and links directly to the appropriate section(s) of the InterAct Math® tutorial software for additional practice and review. A course-management feature allows instructors to create and administer tests, view students' test results, study plans, and practice work. Students gain access to the InterAct MathXL Web site through a password-protected subscription; subscriptions can either be bundled free with new copies of the text or purchased separately with a used book.

Videotapes (0-201-70487-0)
Created specifically to accompany *Intermediate Algebra through Modeling and Visualization*, these videotapes cover every section of every chapter, and the lecturers present examples that are taken directly from the text. Each video segment includes a "stop the tape" feature that encourages students to pause the video, work through the example presented on their own, and then resume play to watch the video instructor go over the solution.

Digital Video Tutor (0-201-72618–1)
This supplement provides the entire set of videotapes for this text in digital format on CD-ROM, making it easy and convenient for students to watch video segments displayed on a computer, either at home or on campus. Available for student purchase with the text at minimal cost, the Digital Video Tutor is ideal for distance learning and supplemental instruction.

Addison-Wesley Math Tutor Center
The Addison-Wesley Math Tutor Center is staffed by qualified mathematics instructors who provide students with tutoring on examples and odd-numbered exercises from their textbooks. Tutoring is provided via toll-free telephone, fax, or e-mail, and White Board technology allows tutors and students to actually see problems being worked while they "talk" in real time over the Internet during their tutoring sessions. The Math Tutor Center is accessed through a registration number that may be bundled free with a new textbook or purchased separately with a used book.

Web Site: www.MyMathLab.com
Ideal for lecture-based, lab-based, and on-line courses, this state-of-the-art Web site provides students with a centralized point of access to the wide variety of on-line resources available with this text. The pages of the actual book are loaded into MyMathLab.com, and as students work through a section of the on-line text, they can link directly from the pages to supplementary resources (e.g., tutorial software, interactive animations, and audio and video clips) that provide instruction, exploration, and practice beyond that offered in the printed book. MyMathLab.com generates personalized study plans for students and allows instructors to track all student work on tutorials, quizzes, and tests. Complete course-management capabilities, including a host of communication tools for course participants, are provided to create a user-friendly and interactive on-line learning environment.

Supplements for the Instructor

***Annotated Instructor's Edition* (0-201-71967-3)**
The Annotated Instructor's Edition contains Teaching Tips and provides answers to every exercise in the text except the Writing About Mathematics exercises. Answers that do not fit on the same page as the exercises themselves are supplied in the Instructor's Answers section at the back of the text.

***Instructor's Solutions Manual* (0-201-72615-7)**
This manual provides solutions to all section-level exercises (excluding Writing About Mathematics exercises), Critical Thinking exercises, Checking Basic Concepts exercises, Chapter Review Exercises, Extended and Discovery Exercises, Group Activity exercises, and Chapter Test questions.

***Printed Test Bank and Instructor's Resource Guide* (0-201-72622-X)**
The Printed Test Bank portion of this manual contains

- three free-response test forms per chapter, one of which (Form C) places stronger emphasis on applications and graphing calculator technology than the other test forms;
- one multiple-choice test form per chapter; and
- one free-response and one multiple-choice final exam.

The Instructor's Resource Guide portion of the manual contains

- four sets of cumulative review exercises that cover Chapters 1–3, 1–6, 1–9, and 1–11;
- transparency masters consisting of tables, figures, and examples from the text;
- teaching notes designed to assist instructors with presenting graphing calculator topics in class; and
- supplemental graphing calculator activities.

TestGen-EQ with QuizMaster-EQ (0-201-72623-8)
Available on a dual-platform, Windows/Macintosh CD-ROM, this fully networkable software enables instructors to create, edit, and administer tests by using a computerized test bank of questions organized according to the chapter content of the text. Six question formats are available, and a built-in question editor allows the instructor to create graphs, import graphics, and insert mathematical symbols and templates, variable numbers, or text. An Export to HTML feature allows practice tests to be posted to the Internet, and instructors can use QuizMaster-EQ to post quizzes to a local computer network so that students can take them on-line. QuizMaster-EQ automatically grades the quizzes, stores results, and lets the instructor view or print a variety of reports for individual students or for an entire class or section.

InterAct Math® Plus (0-201-72140-6)
This networkable software provides course-management capabilities and network-based test administration for Addison-Wesley's InterAct Math® Tutorial Software (see the description on page xv). InterAct Math® Plus enables instructors to create and administer on-line tests, summarize students' results, and monitor students' progress with the tutorial software, providing an invaluable teaching and tracking resource.

Web Site: www.MyMathLab.com
In addition to providing a wealth of resources for lecture-based courses, this state-of-the-art Web site gives instructors a quick and easy way to create a complete on-line course based on *Intermediate Algebra through Modeling and Visualization*. Hosted nationally at no cost to instructors, students, or schools, MyMathLab.com provides access to an interactive learning environment wherein all content is keyed directly to the text. A customized version of Blackboard, Inc.™ provides the course-management platform. MyMathLab.com lets instructors administer pre-existing tests and quizzes or create their own, provides detailed tracking of all student work, and offers a wide array of communication tools for course participants. Within MyMathLab.com, students link directly from on-line pages of their text to supplementary resources such as tutorial software, interactive animations, and audio and video clips. Instructors can access on-line versions of the *Printed Test Bank and Instructor's Resource Guide*, which includes PowerPoint slides. MyMathLab.com is accessed through a registration number that may be bundled free with a new textbook or purchased separately with a used book.

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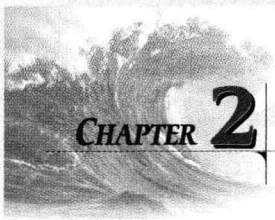
Gary Rockswold

WALKTHROUGH



CHAPTER 2 LINEAR FUNCTIONS AND MODELS

Mathematics is a unique subject. Although mathematics is not dependent on people making observations about the real world, it is frequently used to describe the real world. Mathematics has become an invaluable tool for modeling phenomena occurring in everyday life. For example, sunbathing is a popular pastime. Ultraviolet light from the sun is responsible for both tanning and burning exposed skin. With mathematics, we can use numbers to describe the intensity of ultraviolet light. The following table shows the maximum ultraviolet intensity measured in milliwatts per square meter for various latitudes and dates.

Latitude	Mar. 21	June 21	Sept. 21	Dec. 21
0° N	325	254	325	272
10° N	311	275	280	220
20° N	249	292	256	143
30° N	179	248	182	80
40° N	99	199	127	34
50° N	57	143	75	13

If a student from Chicago, Illinois, located at a latitude of 42° N, spends spring break in Hawaii at a latitude of 20° N, the sun's ultraviolet rays in Hawaii will be approximately $\frac{249}{99}$, or 2.5, times more intense than in Chicago. Suppose that you travel to the equator for spring break. How much more intense will the sun be than where you presently live?

Education is not the filling of a pail, but the lighting of a fire.
—William Butler Yeats

Source: J. Williams, *The USA Today Weather Almanac 1995.*

Chapter Openers

Each chapter opener describes an applied, real-life example to motivate students by giving them insight into the relevance of that chapter's central mathematical concepts.

Rule of Four

Throughout the text, concepts are consistently presented through verbal, graphical, numerical, and symbolic representations to support multiple learning styles and methods of problem solving. Many sections are divided into sub-sections that present, in turn, graphical, numerical, and symbolic solutions to the same types of examples. This structure provides a flexible approach to the rule of four that lets instructors easily emphasize whichever method(s) they prefer.

REPRESENTATIONS OF A FUNCTION

A function f forms a relation between inputs x and outputs y that can be represented verbally, numerically, symbolically, and graphically. Functions can also be represented with diagrams. We begin by considering a function f that converts yards to feet.

VERBAL REPRESENTATION (WORDS). To convert x yards to y feet we must multiply x by 3. Therefore, if function f computes the number of feet in x yards, a **verbal representation** of f is given by "Multiply the input x in yards by 3 to obtain the output y in feet."

NUMERICAL REPRESENTATION (TABLE OF VALUES). A function f that converts yards to feet is shown in Table 2.1, where $y = f(x)$.

TABLE 2.1

x (yards)	1	2	3	4	5	6	7
y (feet)	3	6	9	12	15	18	21

A *table of values* is called a **numerical representation** of a function. Many times it is impossible to list all possible inputs x in a table. On the one hand, if a table does not contain every x-input, it is a *partial* numerical representation. On the other hand, a *complete* numerical representation includes all possible inputs. Table 2.1 is a partial numerical representation of f because many valid inputs, such as $x = 10$ or $x = 5.3$, are not shown in it.

SYMBOLIC REPRESENTATION (FORMULA). A *formula* provides a **symbolic representation** of a function. The computation performed by f to convert x yards to y feet is expressed by $y = 3x$. A formula for f is $f(x) = 3x$, where $y = f(x)$. We say that function f is *represented by or given by* $f(x) = 3x$.

GRAPHICAL REPRESENTATION (GRAPH). A **graphical representation,** or graph, visually associates an x-input with a y-output. The ordered pairs

$$(1, 3), (2, 6), (3, 9), (4, 12), (5, 15), (6, 18), \text{and } (7, 21)$$

from Table 2.1 are plotted in Figure 2.1. This scatterplot suggests a line for the graph f. If we restrict inputs to $x \geq 0$ and plot all ordered pairs (x, y) satisfying $y = 3x$, a line with no breaks appears and represents a graph of f, as shown in Figure 2.2.

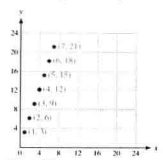


Figure 2.1

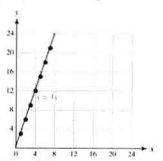
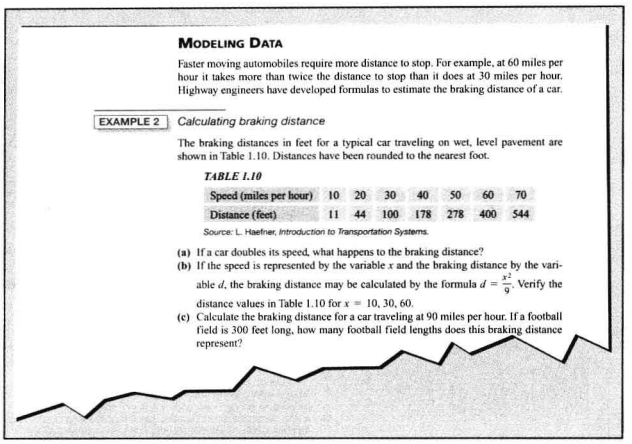


Figure 2.2

Applications and Models

Both the exposition and exercises contain unique applications that truly model real-world data. Examples often begin with concrete applications that are used to derive the abstract mathematical concepts—an approach that motivates students by illustrating the relevance of the math from the very start. Application headings in the exercise sets call out the real-world topics presented, and sources for data are cited throughout.



MODELING DATA

Faster moving automobiles require more distance to stop. For example, at 60 miles per hour it takes more than twice the distance to stop than it does at 30 miles per hour. Highway engineers have developed formulas to estimate the braking distance of a car.

EXAMPLE 2 *Calculating braking distance*

The braking distances in feet for a typical car traveling on wet, level pavement are shown in Table 1.10. Distances have been rounded to the nearest foot.

TABLE 1.10

Speed (miles per hour)	10	20	30	40	50	60	70
Distance (feet)	11	44	100	178	278	400	544

Source: L. Haefner, *Introduction to Transportation Systems.*

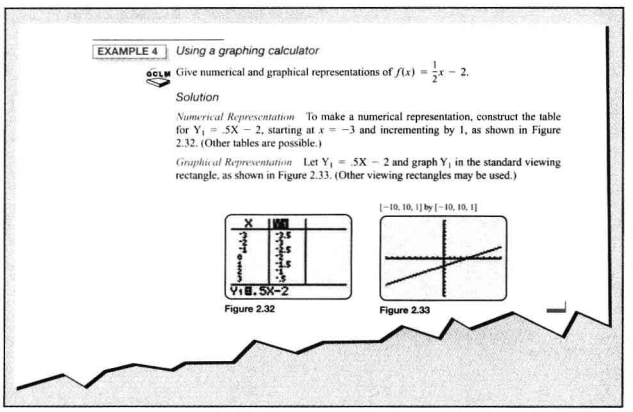
(a) If a car doubles its speed, what happens to the braking distance?

(b) If the speed is represented by the variable x and the braking distance by the variable d, the braking distance may be calculated by the formula $d = \frac{x^2}{9}$. Verify the distance values in Table 1.10 for $x = 10, 30, 60$.

(c) Calculate the braking distance for a car traveling at 90 miles per hour. If a football field is 300 feet long, how many football field lengths does this braking distance represent?

Graphing Calculator Technology

Graphing calculator use is optional, but for instructors who wish to fully integrate graphing calculators, this text thoroughly and seamlessly integrates graphing technology without sacrificing traditional algebraic skills. Students are encouraged to solve problems with multiple methods, learning to evaluate graphing calculator techniques against other problem-solving methods. An icon next to selected examples refers students to the *Graphing Calculator Lab Manual* that accompanies the text, where they find that same example used to further instruct them in the use of the graphing calculator.



EXAMPLE 4 *Using a graphing calculator*

GCLM Give numerical and graphical representations of $f(x) = \frac{1}{2}x - 2$.

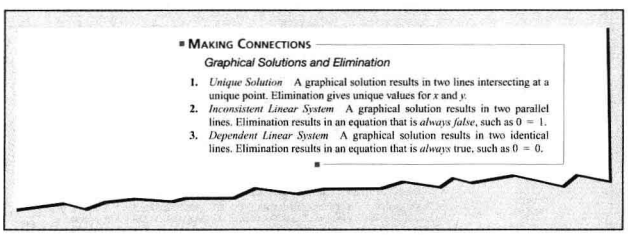
Solution

Numerical Representation To make a numerical representation, construct the table for $Y_1 = .5X - 2$, starting at $x = -3$ and incrementing by 1, as shown in Figure 2.32. (Other tables are possible.)

Graphical Representation Let $Y_1 = .5X - 2$ and graph Y_1 in the standard viewing rectangle, as shown in Figure 2.33. (Other viewing rectangles may be used.)

Figure 2.32

Figure 2.33



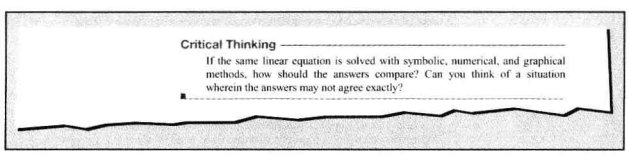
MAKING CONNECTIONS

Graphical Solutions and Elimination

1. *Unique Solution* A graphical solution results in two lines intersecting at a unique point. Elimination gives unique values for x and y.
2. *Inconsistent Linear System* A graphical solution results in two parallel lines. Elimination results in an equation that is *always false*, such as $0 = 1$.
3. *Dependent Linear System* A graphical solution results in two identical lines. Elimination results in an equation that is *always* true, such as $0 = 0$.

Making Connections

This feature occurs throughout the text and helps students see how topics are interrelated. It also helps motivate students by calling out connections between mathematics and the real world.

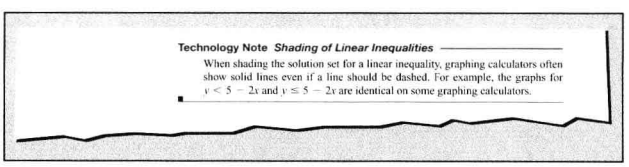


Critical Thinking

If the same linear equation is solved with symbolic, numerical, and graphical methods, how should the answers compare? Can you think of a situation wherein the answers may not agree exactly?

Critical Thinking

The *Critical Thinking* feature appears in most sections and poses a question that can be used for either classroom discussion or homework. Critical Thinking questions typically ask students to extend a mathematical concept beyond what has already been discussed in the text.



Technology Note *Shading of Linear Inequalities*

When shading the solution set for a linear inequality, graphing calculators often show solid lines even if a line should be dashed. For example, the graphs for $y < 5 - 2x$ and $y \le 5 - 2x$ are identical on some graphing calculators.

Technology Notes

Occurring throughout the text, *Technology Notes* offer students guidance and suggestions for using the graphing calculator to solve problems and explore concepts.