# INTERMEDIATE
## Algebra
### FIFTH EDITION

CONCEPTS

AND

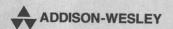APPLICATIONS

Bittinger

Ellenbogen

# INTERMEDIATE
# Algebra
## CONCEPTS AND APPLICATIONS

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## FIFTH EDITION
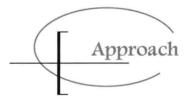
To Monroe and Zachary

# Preface

Appropriate for a one-term course in intermediate algebra, this text is intended for those students who have completed a first course in algebra. It is the second of three texts in an algebra series that also includes *Elementary Algebra: Concepts and Applications*, Fifth Edition, by Bittinger/Ellenbogen and *Elementary and Intermediate Algebra: Concepts and Applications, A Combined Approach*, Second Edition, by Bittinger/Ellenbogen/Johnson. *Intermediate Algebra: Concepts and Applications*, Fifth Edition, is a significant revision of the Fourth Edition with respect to design, contents, pedagogy, and an expanded supplements package. This series is designed to prepare students for any mathematics course at the college algebra level.

## Approach

Our approach is designed to help today's students both learn and retain mathematical concepts. The goal of this revision was to address the major challenges for teachers of developmental mathematics courses that we have seen emerging during the 1990s. The first challenge is to prepare students of developmental mathematics for the transition from "skills-oriented" elementary and intermediate algebra courses to more "concept-oriented" college-level mathematics courses. The second is to teach these same students critical thinking skills: to reason mathematically, to communicate mathematically, and to solve mathematical problems. The third challenge is to reduce the amount of content overlap between elementary algebra and intermediate algebra texts.

Following are some aspects of the approach that we have used in this revision to help meet the challenges we all face teaching developmental mathematics.

### Problem Solving

One distinguishing feature of our approach is our treatment of and emphasis on problem solving. We use problem solving and applications to motivate the material wherever possible, and we include real-life applications and problem-solving techniques throughout the text. Problem solving not only encourages

students to think about how mathematics can be used, it helps to prepare them for more advanced material in later courses.

- In Chapter 1, we introduce the five-step process for solving problems: (1) Familiarize, (2) Translate, (3) Carry out, (4) Check, and (5) State the answer. These steps are introduced in Chapter 1 and used consistently throughout the text whenever we encounter a problem-solving situation. Repeated use of this problem-solving strategy gives students a sense that they have a starting point for any type of problem they encounter, and frees them to focus on the mathematics necessary to successfully translate the problem situation. In this edition (see pages 29–31 and 153), estimation has been used more consistently to help with the Familiarize and Check steps.

### Functions and Graphing

To retain skills and to apply them at a more conceptual level in later courses, students must have an intuitive understanding of the material. A visual interpretation of mathematical concepts can provide this type of understanding to those students with a visual, rather than symbolic, orientation.

- We introduce functions and graphing in Chapter 2, substantially earlier than in many intermediate algebra texts. Functions and graphs then appear throughout the text to enrich the coverage of other topics. For instance, examples of polynomial and rational functions are introduced along with polynomial and rational expressions and equations in Chapters 5 and 6. (See pages 250 and 341.) Increased familiarity and practice with functions and graphing techniques make students more comfortable with these important topics when they move on to later courses.
- We have more than doubled the number of Technology Connections in the Fifth Edition. This optional feature allows students to use a graphing calculator or computer to help visualize concepts, and provides additional opportunities for students to see the usefulness of functions and graphing. (See pages 71, 89, and 137.)

### Applications

Interesting applications of mathematics help motivate both students and instructors. Solving applied problems gives students the opportunity to see their conceptual understanding put to use in a real way. In the Fifth Edition of *Intermediate Algebra: Concepts and Applications*, not only have we increased the number of applications by more than 60 percent, but we have also included a wide variety of real-data applications throughout the text. Over 80 percent of our applications are new. Art has also been integrated into the applications and exercises to aid the student in visualizing the mathematics. (See pages 34, 97, and 347.)

### Content

Many intermediate algebra texts contain a substantial review of elementary algebra topics. This can lull students into complacency and prevent instruc-

tors from covering the intermediate algebra topics required in later courses.

- By introducing graphing and functions in Chapter 2, we present students with "intermediate algebra" topics almost immediately. These topics reappear throughout the text to give students familiarity and practice with concepts that will be critical in later courses.
- Systems of equations are introduced in Chapter 3 to provide students with a valuable problem-solving tool. Students can then translate problem situations into systems of equations throughout the remainder of the text. This approach provides a useful alternative to always translating problems into equations in which only one variable is used.

## Pedagogy

**Skill Maintenance Exercises.** Retention of skills is critical to the future success of our students. To this end, nearly every exercise set includes carefully chosen exercises that review skills and concepts from preceding chapters of the text, often in preparation for the next section. In this edition, we have increased the number of skill maintenance exercises by about 50%.

**Cumulative Review.** After every three chapters, and at the end of the text, we have also included a Cumulative Review, which reviews skills and concepts from all preceding chapters of the text. (See pages 195, 373, 574, and 653.)

**Synthesis Exercises.** Each exercise set ends with a set of synthesis exercises. These problems can offer opportunities for students to synthesize skills and concepts from earlier sections with the present material, or they can provide students with deeper insights into the current topic. Synthesis exercises are generally more challenging than those in the main body of the exercise set. We have increased the number of synthesis exercises by 10% for the Fifth Edition. (See pages 10, 148, 168, and 226.)

**Writing Exercises.** Nearly every set of synthesis exercises begins with four writing exercises, which nearly doubles the number found in the Fourth Edition. All writing exercises are marked with a maze icon ( ◆ ). These exercises are usually not as difficult as other synthesis exercises, but require written answers that aid in student comprehension, critical thinking, and conceptualization. Because some instructors may collect answers to writing exercises, and because more than one answer may be correct, answers to writing exercises are not listed at the back of the text. (See pages 86, 108, and 234.)

## What's New in the Fifth Edition?

We have rewritten many key topics in response to user and reviewer feedback and have made significant improvements in design, art, and pedagogy. Detailed information about the content changes is available in the form of a

Conversion Guide. Please ask your local Addison Wesley Longman sales consultant for more information. Following is a list of the major changes in this revision.

### New Design

- The new design is more open and readable. We have increased the type size in many features to emphasize key topics. Pedagogical use of color has been increased to make it easier to see how examples unfold.
- The entire art program is new for this edition. We have ensured the accuracy of the graphical art through the use of computer-generated graphs. Color in the graphical art is used pedagogically and precisely to help the student visualize the mathematics. (See pages 103 and 455.)

### Technology Connections

- The optional Technology Connections, which appear throughout the text (see pages 71, 89, and 137), integrate technology, increase the understanding of concepts through visualization, encourage exploration, and motivate discovery learning. Due to user demand, we have more than doubled the number of Technology Connections in the Fifth Edition. Optional Technology Connection exercises appear in many exercise sets and are marked with a grapher icon ( ). (See pages 74, 100, and 337.)

### Collaborative Corners

- In today's professional world, teamwork is essential. We have included optional Collaborative Corner features throughout the text to allow students to work in groups to solve problems. There is an average of three Collaborative Corner activities per chapter, each one appearing after the appropriate section's exercise set. (See pages 36, 149, and 485.) Additional Collaborative Corner activities and suggestions for directing collaborative learning appear in the *Printed Test Bank/Instructor's Resource Guide*.

### World Wide Web Integration

- The World Wide Web is a powerful resource that reaches more and more people every day. In an effort to get students more involved in using this resource, we have enhanced every chapter opener to include a World Wide Web address **http://hepg.awl.com/be/inter_5**. Students can go to this page on the World Wide Web to further explore the subject matter of the chapter opening application. Selected exercise sets also have additional practice-problem worksheets that can be downloaded over the Internet. These exercise sets are listed opposite the inside front cover.

### Content Changes

A variety of content changes have been made throughout the text. Some of the more significant changes are listed below.

- In Chapter 1, Section 1.1 now includes order of operations to facilitate work in Section 1.2 and beyond. Sections 1.5 and 1.6 have been reorganized for better flow.

- In Chapter 2, Section 2.2 now includes more discussion of visualizing domain and range on a graph. Section 2.3 now includes reading solutions from graphs, and the definition of slope now precedes slope–intercept equations and is covered in more detail. Both of these changes encourage students to use their visualization skills and to read and interpret graphs.
- In Chapter 4, Section 4.2 now includes more material on domains of functions in order to better prepare students for Chapters 6 and 7. Section 4.3 now includes more graphing, for increased visualization. This change will also aid students in relating inequalities to equations.
- In Chapter 5, Section 5.8, we make greater use of function notation and provide more work with domain. This will better prepare students for Chapters 6 and 7 and for college algebra.
- Chapter 6 has many changes. Sections 6.1 and 6.2 have been reorganized to clarify simplifying rational expressions and more work with domain has been added. The reorganization of this traditional problem area for students should improve comprehension. Sections 6.4 and 6.6 make greater use of function notation and graphs. This is a more visual approach to the material and better prepares students for college algebra.
- Chapter 7 has been extensively revised. Section 7.1 now has more function notation and more work with domains of radical functions. Sections 7.3–7.6 include additional discussion of functions and represent a streamlining of Sections 7.3–7.7 of the Fourth Edition.
- In Chapter 8, Section 8.1, we have included more work with quadratic functions and more exercises with imaginary solutions to better prepare students for college algebra. Section 8.4 now includes more on writing equations from solutions to build mathematical understanding. Section 8.10 has been streamlined for increased clarity.
- In Chapter 10, Section 10.2 now includes ellipses not centered on the origin and Section 10.3 is dedicated to hyperbolas. These changes give the student a more complete picture and will better prepare them for college algebra.

## Supplements for the Instructor

### Instructor's Edition

The *Instructor's Edition* is a specially bound version of the student text with worked-out solutions to the even-numbered exercises and answers to the odd-numbered exercises at the back of the text.

### Instructor's Solutions Manual

The *Instructor's Solutions Manual* contains worked-out solutions to all exercises in the exercise sets.

### Printed Test Bank/Instructor's Resource Guide
### by Donna DeSpain

This supplement contains the following:

- Extra practice problems with more sections covered than in the Fourth Edition
- Black-line masters of grids and number lines for transparency masters or test preparation
- A videotape index and section cross references to the tutorial software packages available with this text
- Additional collaborative learning activities and suggestions
- A syllabus conversion guide from the Fourth Edition to the Fifth Edition

The test bank portion contains the following:

- Six alternative free-response test forms for each chapter
- Two multiple-choice versions of each chapter test
- Eight final examinations: three with questions organized by chapter, three with questions organized by type, and two with multiple-choice questions

All test forms have been completely rewritten.

### TestGen—EQ

TestGen—EQ is a computerized test generator that allows instructors to select test questions manually or randomly from selected topics. The test questions are algorithm-driven so that regenerated number values maintain problem types and provide a large number of test items in both multiple-choice and open-ended formats for one or more test forms. Test items can be viewed on screen, and the built-in question editor lets instructors modify existing questions or add new questions that include pictures, graphs, math symbols, and variable text and numbers. Instructors can also customize both the look and content of test banks and tests. Test questions are easily transferred from the test bank to a test and can be sorted, searched, and displayed in various ways. Available in both Windows and Macintosh versions, TestGen—EQ is free to qualifying adopters.

### QuizMaster—EQ

QuizMaster—EQ enables instructors to create and save tests and quizzes using TestGen—EQ so students can take them on a computer network. Instructors can set preferences for how and when tests are administered. QuizMaster—EQ automatically grades the exams and allows the instructor to view or print a variety of reports for individual students, classes, or courses. This software is available for both Windows and Macintosh and is fully networkable. QuizMaster—EQ is free to qualifying adopters.

### InterAct Math Plus

This software, available for both Windows and Macintosh, combines course management and on-line testing with the features of InterAct Math Tutorial Software (see *InterAct Math Tutorial* under Supplements for the Student) to create an invaluable teaching resource. Contact your local Addison Wesley Longman sales consultant for a demonstration.

# Supplements for the Student

### Student's Solutions Manual by Judith A. Penna

This manual contains completely worked-out solutions with step-by-step annotations for all the odd-numbered exercises in the exercise sets. Solution processes match those illustrated in the text. The manual also contains answers for all the even-numbered exercises in the text.

### Videotapes

Developed especially for the Bittinger/Ellenbogen texts, these videotapes feature an engaging team of lecturers presenting material from every section of the text in an interactive format. The lecturers' presentations support an approach that emphasizes visualization and problem solving. The videotapes are free to qualifying adopters.

### Video Manual by Janina Udrys

Designed to be used with the Bittinger/Ellenbogen videotapes in distance-learning situations, this manual includes many examples and art pieces from the video series. The manual also includes additional problems specifically developed for distant learners.

### InterAct Math Tutorial Software

*InterAct Math Tutorial Software* includes exercises that are linked one-to-one with the odd-numbered exercises in the textbook. Every exercise is accompanied by an example and an interactive guided solution designed to involve students in the solution process and to help them identify precisely where they are having trouble. In addition, the software recognizes common student errors and provides students with appropriate customized feedback. Available for both Windows or Macintosh and fully networkable, Interact Math Tutorial Software is free to qualifying adopters.

### World Wide Web Supplement http://hepg.awl.com/be/inter_5

This on-line supplement contains links to web sites related to the chapter openers in the text. It also contains extra practice-problem worksheets for selected text sections. Students can download these worksheets and use them for practice, as needed. Text sections that correlate with on-line worksheets are listed opposite the inside front cover.

## Acknowledgments

Antonio Ciro, *University of Delaware*
David Demic, *Tyler Junior College*
Barbara Duncan, *Hillsborough Community College*
Carol Lawrence, *North Carolina State University*
Patty Schwarzkopf, *University of Delaware*
Rick Serpone, *Mesa Community College*
Mahendra Singhal, *University of Wisconsin—Parkside*
Lois Speg, *Delaware Technical Community College*
Carl Thomas, *Napa Valley College*
Gerry Tolimante, *Mesa Community College*
William Waters, *North Carolina State University*
Larry Watson, *North Carolina State University*

**Manuscript Reviewers**
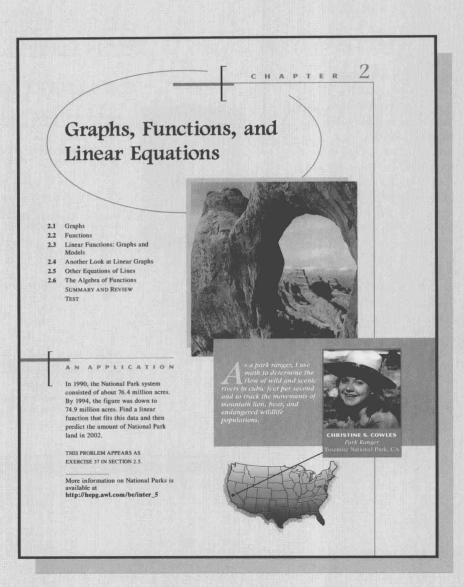
Diane Blansett, *Delta State University*
Connie Buller, *Metropolitan Community College*
Joseph Conrad, *Solano Community College*
Sally Copeland, *Johnson County Community College*
Ben Cornelius, *Oregon Institute of Technology*
Linda Crabtree, *Metropolitan Community College*
Sharon Hamsa, *Longview Community College*
Lonnie Hass, *North Dakota State University*
Robert Hickey, *Kishwaukee College*
Louise Hoover, *Clark College*
Judy Kasabian, *El Camino College*
Marie Long, *Pennsylvania State University—DuBois*
Jann McInness, *Florida Community College at Jacksonville*
Jane Murphy, *Middlesex Community College*
Paul O'Heron, *Broome Community College*
Mark Omodt, *Anoka Ramsey Community College*
Mark Parker, *Shoreline Community College*
Marjorie Stinespring, *Chicago State University*
June Strohm, *Pennsylvania State University—DuBois*
Sharon Testone, *Onondaga Community College*
Kathy Tomsich, *Anoka Ramsey Community College*
Marilyn Treder, *Rochester Community College*
Bettie Truitt, *Black Hawk Community College*
Terry Wyberg, *University of Minnesota*

Finally, a special thank you to all those who so generously agreed to discuss their professional uses for mathematics in our chapter openers. These dedicated people, none of whom we knew prior to writing this text, all share a desire to make math more meaningful to students. We cannot imagine a finer set of role models.

M.L.B.
D.J.E.

# Feature Walkthrough

The following six pages show you how to use *Intermediate Algebra* to maximize understanding while making studying easier.

- **Chapter Opener:** Each chapter opens with a list of the sections covered and a real-life application that helps show how mathematics is needed when solving real problems. Real data is often used in these applications, as well as in many other exercises and examples. For those students with access to the internet, the authors have equipped every chapter opener with a World Wide Web address, **http://hepg.awl.com/be/inter_5**. At this site, students can further explore the subject matter of the chapter opening application.

## Graphs, Functions, and Linear Equations

**AN APPLICATION**

In 1990, the National Park system consisted of about 76.4 million acres. By 1994, the figure was down to 74.9 million acres. Find a linear function that fits this data and then predict the amount of National Park land in 2002.

THIS PROBLEM APPEARS AS
EXERCISE 37 IN SECTION 2.5.

More information on National Parks is available at
**http://hepg.awl.com/be/inter_5**

*As a park ranger, I use math to determine the flow of wild and scenic rivers in cubic feet per second and to track the movements of mountain lion, bear, and endangered wildlife populations.*

**CHRISTINE S. COWLES**
*Park Ranger*
Yosemite National Park, CA

- One distinguishing feature of the authors' approach is their **Five-Step Process for Solving Problems:** 1) Familiarize, 2) Translate, 3) Carry Out, 4) Check, and 5) State the Answer. These steps are used throughout the text whenever a problem-solving situation arises. Use of this problem-solving process gives students a sense that they have a starting point for any problem they encounter, and helps them focus on the mathematics necessary to translate the problem situation.

## Problem Solving

At this point, our study of algebra is just beginning. Thus we have few algebraic tools with which to work problems. As the number of tools in our algebraic "toolbox" increases, so will the difficulty of the problems being solved. For now our problems may seem simple; however, to gain practice with the problem-solving process, you should try to use all five steps. Later some steps may be shortened or combined.

EXAMPLE 3



*Purchasing.*   Elka pays $1187.20 for a computer. If the price paid includes a 6% sales tax, what is the price of the computer itself?

SOLUTION

1. **Familiarize.**   Familiarize yourself with the problem. Note that tax is calculated from, and then added to, the computer's price. We let

   $C$ = the computer's price.

   Let's guess that the computer's price is $1000. To check the guess, we calculate the amount of tax, $(0.06)(\$1000) = \$60$, and add it to $1000:

   $$(0.06)(\$1000) + \$1000 = \$60 + \$1000$$
   $$= \$1060. \quad \$1060 \neq \$1187.20$$

   Our guess was wrong, but it was useful. The manner in which we checked the guess will guide us in the next step.

2. **Translate.**   Translate the problem to mathematical language. Our guess leads us to the following translation:

   | 6% of the computer's price | plus | the computer's price | is | the price with sales tax. |
   |:---:|:---:|:---:|:---:|:---:|
   | ↓ | ↓ | ↓ | ↓ | ↓ |
   | $(0.06)C$ | $+$ | $C$ | $=$ | $\$1187.20$ |

3. **Carry out.**   Carry out some mathematical manipulation:

   $$0.06C + 1C = 1187.20$$
   $$1.06C = 1187.20 \quad \text{Combining like terms}$$
   $$\frac{1}{1.06} \cdot 1.06C = \frac{1}{1.06} \cdot 1187.20 \quad \text{Using the multiplication principle}$$
   $$C = 1120.$$

4. **Check.**   Check the answer in the original problem. To do this, note that the tax on a computer costing $1120 would be $(0.06)(\$1120) = \$67.20$. When this is added to $1120, we have

   $$\$67.20 + \$1120, \text{ or } \$1187.20.$$

   We see that $1120 checks in the original problem.

5. **State.**   State the answer clearly. The computer itself costs $1120.

- **Applications:** In this edition the authors have increased the number of applications and have also included real data applications that come from a wide variety of disciplines and fields, such as natural and social sciences, business and economics, and health care. Over 80% of the applications are new. Art has also been integrated to aid the student in visualizing the many applications that appear in the examples and exercises.

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earth's distance from the sun, and $L$ is some fixed distance, is used in calculating when lunar eclipses occur. Solve for $D$.

SOLUTION    We first clear fractions by multiplying by the LCD, which is $D - d$:

$$(D - d)L = (D - d)\frac{dR}{D - d}$$

$$(D - d)L = dR.$$

We do *not* multiply the factors on the left since we wish to get $D$ all alone. Instead we multiply both sides by $1/L$ and then add $d$:

$$D - d = \frac{dR}{L} \qquad \text{Multiplying on both sides by } \frac{1}{L}$$

$$D = \frac{dR}{L} + d. \qquad \text{Adding } d \text{ on both sides}$$

We now have $D$ all alone on one side of the equation. Since $D$ does not appear on the other side, we have solved the formula for $D$.

EXAMPLE 3    *Acoustics (the Doppler Effect).*    The formula

$$f = \frac{sg}{s + v}$$

is used to determine the frequency $f$ of a sound that is moving at velocity $v$ toward a listener who hears the sound as frequency $g$. Here $s$ is the speed of sound in a particular medium. Solve for $s$.

SOLUTION    We first clear fractions by multiplying by the LCD, $s + v$:

$$f \cdot (s + v) = \frac{sg}{s + v}(s + v)$$

$$fs + fv = sg. \qquad \text{Here, because } s \text{ does appear on both sides, we do distribute on the left side.}$$

---

EXAMPLE 3    Arrange in descendi

SOLUTION

$$y^4 + 2 - 5x^2 + 3x$$

### Polynomial Fu

A polynomial functi

$$P(x) = 5x^7 + 3$$

where the expressio ate a polynomial fun In this text, we cond

EXAMPLE 4    For the polynomial
(a) $P(2)$; (b) $P(10)$;

SOLUTION

a) $P(2) = -2^2 + 4$
$\quad = -4 + 8$

b) $P(10) = -10^2 + 4(10)$
$\quad = -100 + 40 - 1 = -61$

c) $P(-10) = -(-10)^2 + 4(-10) - 1$
$\quad = -100 - 40 - 1 = -141$
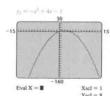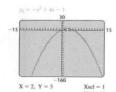
TECHNOLOGY CONNECTION 5.1A

A visual way to evaluate a polynomial function is to enter and graph the function as $y_1$. If a CALC menu exists, selecting VALUE allows us to enter the value of $x$ in which we are interested. The corresponding $y$-value and point on the graph then appear.

1. Use this approach to check Examples 4(b) and 4(c).
2. What advantage(s) does this approach offer over use of the TRACE feature?

$y_1 = -x^2 + 4x - 1$

Eval X = ■     Xscl = 1     Yscl = 8

$y_1 = -x^2 + 4x - 1$

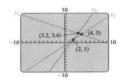X = 2, Y = 3     Xscl = 1     Yscl = 8

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- **Technology Connection Features:** Due to user demand the authors have more than doubled the number of Technology Connection features in this edition. Optional Technology Connection exercises also appear in many exercise sets and are marked with a grapher icon ( ▱ ).

- **New Design:** The new design is more open and readable. With an entirely new art program for this edition, generous amounts of color-coded technical and situational art appear throughout the text to enhance student understanding of an example or exercise and to aid in the visualization of mathematical concepts.

**b)** The domain of the function is the set of all *x*-values that are in the graph. These extend from −5 to 3 and can be viewed as the curve's shadow, or *projection*, on the *x*-axis. Thus the domain is $\{x| -5 \le x \le 3\}$.

**c)** To determine what member of the domain is paired with 1, we locate 1 on the vertical axis. (See the graph on the left below.) From there we look left and right to the graph of *f* to find any points for which 1 is the second coordinate. One such point exists, (−4, 1). We observe that −4 is the only element of the domain paired with 1.

**d)** The range of the function is the set of all *y*-values that are in the graph. (See the graph on the right above.) These extend from −1 to 4 and can be viewed as the curve's projection on the *y*-axis. Thus the range is $\{y| -1 \le y \le 4\}$.

**87.** Assume that the graphs of $y_1 = -\frac{1}{2}x + 5$, $y_2 = x - 1$, and $y_3 = 2x - 3$ are as shown below. Solve each inequality, referring only to the figure.

(3.2, 3.4)  (4, 3)  (2, 1)

**COLLABORATIVE C·O·R·N·E·R**

*Focus:* Inequalities and problem solving

*Time:* 10–15 minutes

*Group size:* 2

In the United States, the amount of solid waste being recycled is slowly catching up to the amount being generated. In 1991, each person generated, on average, 4.3 lb of solid waste every day, of which 0.8 lb was recycled. In 1994, each person generated, on average, 4.4 lb of solid waste, of which 1.0 lb was recycled. (*Source:* Characterization of Municipal Solid Waste in the United States: 1995 Update, Executive Summary, United States Environmental Protection Agency, March 1996.)
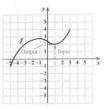
**ACTIVITY**

Assume that the amount of solid waste being generated and the amount being recycled are both increasing linearly. One group member should find a linear function *w* for which $w(t)$ represents the number of pounds of waste generated per person per day *t* years after 1991. The other group member should find a linear function *r* for which $r(t)$ represents the number of pounds recycled per person per day *t* years after 1991. Finally, working together, the group should determine those years for which the amount recycled will meet or exceed the amount generated.
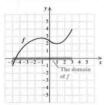
## 4.2 Intersections, Unions, and Compound Inequalities

Intersections of Sets and Conjunctions of Sentences • Unions of Sets and Disjunctions of Sentences • More on Domains of Functions
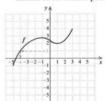
We now consider **compound inequalities**—that is, sentences formed by two or more inequalities, joined by the word *and* or the word *or*.

- **Collaborative Corner Features:** The authors now include optional Collaborative Corner features throughout the text that allow students to work in groups to solve problems or to perform specially designed activities. There is an average of three Collaborative Corners per chapter, each one appearing after the appropriate exercise set.