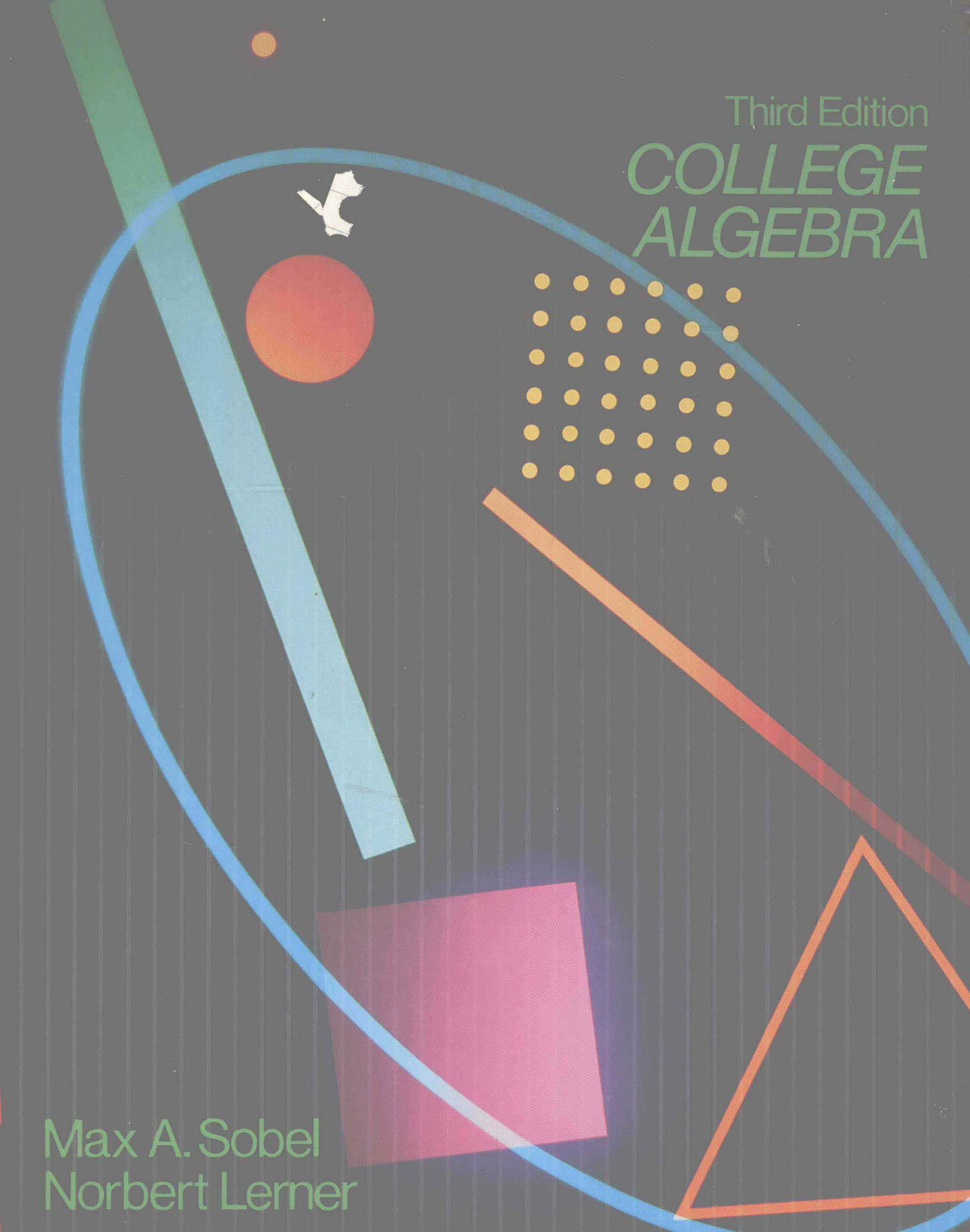
Third Edition

COLLEGE ALGEBRA



Max A. Sobel
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Third Edition

COLLEGE ALGEBRA

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COLLEGE ALGEBRA

PREFACE

College Algebra has been written to provide the essential concepts and skills of algebra and the study of functions, that are needed for further study in mathematics. Since calculus is a subject numerous students study after this course, a special emphasis is given to the preparation for the study of calculus. Thus, one of the *major objectives* of the book is *to help you make a comfortable transition from elementary mathematics to calculus*. (However, the objectives of your particular course may not require this special pre-calculus emphasis. You will find out from your instructor or from the course syllabus.)

A major difficulty that students have in future mathematics courses, especially in calculus, involves the lack of adequate algebraic skills. To help you overcome such deficiencies, an extensive review of the fundamentals of algebra has been included in Chapter 1. You are encouraged to refer to this chapter throughout the course if you encounter algebraic difficulties.

Of special interest are the numerous features in this book that have been designed to assist you in learning the subject matter of the course. These features are listed below, with descriptions of their purpose and suggested use.

Margin Notes

Throughout the text, notes appear in the margin to enhance the exposition, raise questions, point out interesting facts, explain why some things are done as they are, show alternate procedures, give references and reminders, and caution you to avoid errors.

Test Your Understanding

These are short sets of exercises (in addition to the end-of-section exercises) that are found within most sections of the text. These encourage you to *think carefully* and to test your knowledge of new material just developed, prior to attempting to solve the exercises at the end of each section. Answers to all of these are given at the end of

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each chapter and thus provide an excellent means of self-study. For example, note the following set of exercises which appears on page 37:

TEST YOUR UNDERSTANDING
Think Carefully

Write each of the following using fractional exponents.

1. $\sqrt{7}$ **2.** $\sqrt[3]{-10}$ **3.** $\sqrt[4]{7}$ **4.** $\sqrt[3]{7^2}$ **5.** $(\sqrt[4]{5})^3$

Evaluate.

6. $25^{1/2}$ **7.** $64^{1/3}$ **8.** $(\frac{1}{36})^{1/2}$ **9.** $49^{-1/2}$ **10.** $(-\frac{1}{27})^{-1/3}$

11. $4^{3/2}$ **12.** $4^{-3/2}$ **13.** $(\frac{81}{16})^{3/4}$ **14.** $(-8)^{2/3}$ **15.** $(-8)^{-2/3}$

(Answers: Page 75)

Caution Items

Where appropriate, these items appear in the margin notes or in the text and alert you to the typical kinds of errors that you should avoid. Frequently the caution, as shown on page 60, will show the errors and the corrections side by side.

CAUTION: Learn to Avoid These Mistakes

WRONG	RIGHT
$\frac{2}{3}+\frac{x}{5}=\frac{2+x}{3+5}$	$\frac{2}{3}+\frac{x}{5}=\frac{2\cdot 5+3\cdot x}{3\cdot 5}=\frac{10+3x}{15}$
$\frac{1}{a}+\frac{1}{b}=\frac{1}{a+b}$	$\frac{1}{a}+\frac{1}{b}=\frac{b+a}{ab}$
$\frac{2x+5}{4}=\frac{x+5}{2}$	$\frac{2x+5}{4}=\frac{2x}{4}+\frac{5}{4}=\frac{x}{2}+\frac{5}{4}$
$2+\frac{x}{y}=\frac{2+x}{y}$	$2+\frac{x}{y}=\frac{2y+x}{y}$
$3\left(\frac{x+1}{x-1}\right)=\frac{3(x+1)}{3(x+1)}$	$3\left(\frac{x+1}{x-1}\right)=\frac{3(x+1)}{x-1}$
$a\div\frac{b}{c}=\frac{1}{a}\cdot\frac{b}{c}$	$a\div\frac{b}{c}=a\cdot\frac{c}{b}=\frac{ac}{b}$
$\frac{1}{a^{-1}+b^{-1}}=a+b$	$\frac{1}{a^{-1}+b^{-1}}=\frac{1}{\frac{1}{a}+\frac{1}{b}}=\frac{ab}{b+a}$
$\frac{x^2+4x+6}{x+2}=\frac{x^2+4x+\cancel{6}^{\,3}}{x+\cancel{2}_{\,1}}=\frac{x^2+4x+3}{x+1}$	$\frac{x^2+4x+6}{x+2}$ is in simplest form.

Illustrative Examples and Exercises

The text contains numerous illustrative examples with detailed solutions, designed to help you to understand new concepts and learn new skills. You should study these examples, and carefully follow each step with paper and pencil in hand. If this is done, you will be well prepared for the exercises at the end of each section.

Written Assignments

It is generally agreed that students need to be able to practice writing skills in their mathematics courses. Therefore, throughout the book, written assignments will be found that ask you to write an explanation or description rather than just to solve a problem. These are designated in the text by this symbol: ✎ Here is a selection from Chapter 4.

✎ **Written Assignment:** Use specific examples of your own to describe the conditions for the graph of a rational function to have vertical and horizontal asymptotes.

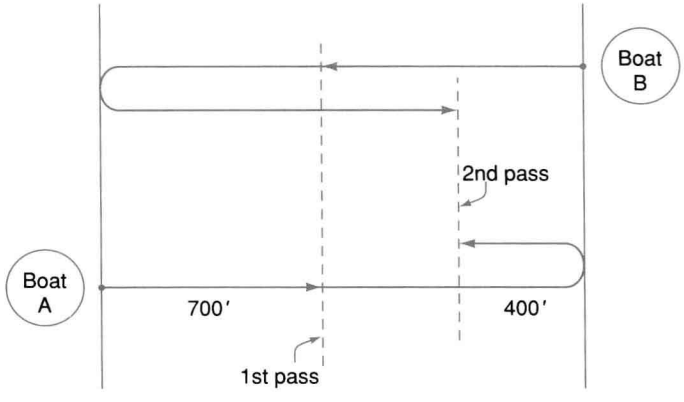
Challenges

At several places in each chapter you will be challenged to *think creatively* and attempt to solve a problem that is more difficult than others, or that has an unusual twist to it. For example, consider the challenge that appears on page 13:

CHALLENGE
Think Creatively

Two boats begin their journeys back and forth across a river at the same time, but from opposite sides of the river. The first time that they pass each other, they are 700 feet from one of the shores of the river. After they each make one turn, they pass each other once again at a distance of 400 feet from the other shore. Assuming that each boat goes at a constant speed and that there is no loss of time making the turn, how wide is the river?

To solve this problem, you might consider the problem-solving strategy of drawing a diagram and then using it to find the solution, as follows:



Explorations

Within each chapter there are sets of exercises that encourage you to *think critically*. These demand higher-order thinking skills and do not depend alone on the routine

application of skills. For example, consider this set of Explorations which appear on page 156:

EXPLORATIONS
Think Critically

1. How can you determine the maximum or minimum value of a function given by $f(x) = ax^2 + bx + c$?
2. Suppose that a function if increasing on one side of a point P with coordinates (a, b) and decreasing on the other side of this point. What can be said about the point P? Explain.
3. Consider the graph of $y = (x + 2)^2 - 1$. *How can you use this to determine the graph of* $x = (y + 2)^2 - 1$?
4. Describe the graph of $y = a(x - h)^2 + k$ for various values of a, h, and k. For example, consider $a > 0$, $h < 0$, and $k > 0$ as one case.
5. Sketch the graph of a function such that any horizontal line drawn through a range value will intersect the curve exactly once. Such functions are called *one-to-one functions*. If f is a one-to-one function, and if $f(x_1) = f(x_2)$, what can you say about x_1 and x_2?

Review Exercises

Each chapter has a set of review exercises that are exactly the same as the illustrative examples developed in the text. Thus you can use this as a self-study review of the chapter by comparing your results with the worked-out solutions that can be found in the body of the chapter. Following is a sample taken from Chapter 3.

REVIEW EXERCISES

The solutions to the following exercises can be found within the text of Chapter 3. Try to answer each question before referring to the text.

Section 3.1

Graph each of the following.

1. $y = x^2$
2. $y = x^2 + 2$
3. $y = x^2 - 2$
4. $y = (x + 2)^2$
5. $y = (x - 2)^2$
6. $y = -x^2$
7. $y = \frac{1}{2}x^2$
8. $y = 2x^2$
9. $y = -x^2 + 2$
10. $y = f(x) = -(x - 2)^2 + 1$
11. $y = f(x) = -2(x - 3)^2 + 4$
12. $x = y^2$
13. $x = (y + 2)^2 - 4$
14. $y \geq x^2$
15. $y + (x - 2)^2 \leq 5$

Section 3.2

Write in standard form.

16. $y = x^2 + 4x + 3$
17. $y = 2x^2 - 12x + 11$
18. $y = -\frac{1}{3}x^2 - 2x + 1$

Write in standard form, graph, and give the vertex and axis of symmetry.

19. $y = x^2 - 4x + 4$
20. $y = -2 - 4x + 3x^2$
21. Graph the function $y = f(x) = |x^2 - 4|$ and find the range.
22. State the conditions on the values a and k so that the parabola $y = a(x - h)^2 + k$ opens downward and intersects the x-axis in two points. What are the domain and range of this function?

Key Terms

At the end of each chapter a list of key terms will be found, such as the following for Chapter 6. These allow you to test your knowledge of new items found in that particular chapter and provide for yet another means of self-study.

KEY TERMS

Review these ***key terms*** *so that you are able to define or describe them. A clear understanding of these terms will be very helpful when reviewing the developments of this chapter.*

Exponential function • Properties of $y = b^x$ • Exponential equation • Logarithmic function • Properties of $y = \log_b x$ • Laws of logarithms • Logarithmic equation • The base e • The function $y = e^x$ and its properties • The natural logarithm function $y = \ln x$ and its properties • Exponential growth • Exponential decay • Radioactive carbon dating • Compound interest • Continuous compound interest • Scientific notation • Common logarithm • Characteristic • Mantissa

Chapter Tests

Each chapter concludes with two forms of a chapter test: standard answer and multiple choice. You should use these to test your knowledge of the work of the chapter, and check your answers with those provided at the back of the book. Following are sample test items from Chapter 4.

CHAPTER 4 TEST: STANDARD ANSWER

Use these questions to test your knowledge of the basic skills and concepts of Chapter 4. Then check your answers with those given at the back of the book.

Graph each function and write the equation of the asymptotes if there are any.

1. $f(x) = (x + 2)^3 - \frac{3}{2}$ 2. $y = f(x) = x^3$ 3. $y = f(x) = -\dfrac{1}{x - 2}$ 4. $y = f(x) = \dfrac{x - 1}{x^2 - x - 2}$

5. Graph: $y = x^3 - x^2 - 4x + 4$

6. Construct a table of signs for $f(x) = \dfrac{x^2 - 2x}{x + 3}$.

7. Graph: $y = f(x) = \dfrac{2}{x^2 + 2}$

8. Graph on a number line: $\dfrac{x + 2}{x - 1} \leq 0$

9. Solve for a: $S = \dfrac{n}{2}[2a + (n - 1)d]$

Solve for x.

10. $\dfrac{6}{x} = 2 + \dfrac{3}{x + 1}$ 11. $\dfrac{x}{2} - \dfrac{3x + 1}{3} > 2$ 12. $\dfrac{6}{x^2 - 9} - \dfrac{2}{x - 3} = \dfrac{1}{x + 3}$

CHAPTER 4 TEST: MULTIPLE CHOICE

1. Which of the following are true?

   I. The graph of $f(x) = x^2$ is symmetric about the y-axis.

   II. The graph of $f(x) = x^3$ is symmetric through the origin.

   III. The graph of $f(x) = \dfrac{1}{x}$ is symmetric about the x-axis.

   (a) Only I **(b)** Only II **(c)** Only III **(d)** Only I and II **(e)** None of the preceding

2. The equation of the horizontal asymptote for $f(x) = \dfrac{1}{x - 3}$ is

   (a) $x = 0$ **(b)** $y = 0$ **(c)** $x = 3$ **(d)** $x = -3$ **(e)** None of the preceding

3. For $h > 0$, the graph of $y = f(x - h)$ can be obtained by shifting the graph of $y = f(x)$

   (a) h units to the right **(b)** h units to the left **(c)** h units upward

   (d) h units downward **(e)** None of the preceding

Boxed Displays

Boxed displays for important results, definitions, formulas, and summaries appear throughout the text and serve to alert you to major concepts and results.

> **DEFINITION OF POSITIVE INTEGRAL EXPONENT**
>
> If n is a positive integer and b is any real number, then
>
> $$b^n = \underbrace{b \cdot b \cdot \cdots \cdot b}_{n \text{ factors}}$$
>
> The number b is called the **base** and n is called the **exponent.**

Inside Covers

The inside of the covers contain summaries of useful information. The front cover contains a collection of basic graphs; the back contains useful algebraic and geometric formulas.

Solutions Manual

There is a solutions manual accompanying this text that includes worked-out solutions to all the odd numbered section exercises, and for all of the questions in the chapter tests. You may wish to check with your instructor about this.

There are two other important features that are identified by special symbols:

This symbol indicates that an exercise or set of exercises would best be solved by use of a scientific calculator. It would be advantageous to have such a calculator, and the instructor of the course will probably indicate any limitations for its use. Although calculator displays appear in the text as part of the solution to some problems, the variety of different calculators in common usage is such that you are encouraged to refer to the manual that accompanies your calculator for specific instruction in its use.

△ This symbol identifies exercises that are *directly supportive* to topics in calculus. Also, when this symbol appears next to a section heading it means that the entire section and its exercises fall into this support category.

How does one succeed in a mathematics course? Unfortunately, there is no universal prescription guaranteed to work. However, our experience with many students suggests that the most important thing to do is to *get involved in the mathematical process*. Don't use this text only as a source for exercises. Rather, read the book, attend class regularly, study your class notes, and make use of the special features described earlier. Furthermore, keep up to date. Don't let yourself fall behind; it often leads to poor results. If difficulties arise and you begin to fall behind, then don't hesitate to get additional assistance from your instructor or from a classmate. Working together with a friend can often be beneficial, as long as individual efforts are also made.

Be positive! Don't give up! We are convinced that even if you have an initial negative attitude toward mathematics, an honest attempt to learn it properly will result not only in greater success, but will lead to a self-awareness that you have more ability and talent than you ever gave yourself credit for!

We hope that you will find this book enjoyable, and that you will learn the skills and concepts for future study of mathematics. We encourage you to write to us; your comments, criticisms, and suggestions might be useful for future editions. Also, despite all of our efforts, errors occasionally creep into a book. We would appreciate it if you would call any of these to our attention. We promise to respond with our letter of thanks.

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Norbert Lerner

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However, there are fractions that cannot be written as integers, such as $\frac{2}{3}$ and $-\frac{3}{4}$. The collection of all such integers and fractions is called the set of **rational numbers.**

For every integer a we have $a = \frac{a}{1}$. Therefore, every integer is a rational number.

A **rational number** is one that can be written in the form $\frac{a}{b}$, where a and b are integers, $b \neq 0$.

In Exercises 57 and 58 you will learn how to convert repeating decimals into the form a/b.

Every rational number a/b can be converted into decimal form by dividing b into a. The decimal form will either *terminate* as in $11/4 = 2.75$, or it will *repeat endlessly* as in

$$\frac{2}{3} = .666\ldots \qquad \frac{4}{11} = .363636\ldots$$

Decimals that neither terminate nor repeat are called **irrational numbers** such as

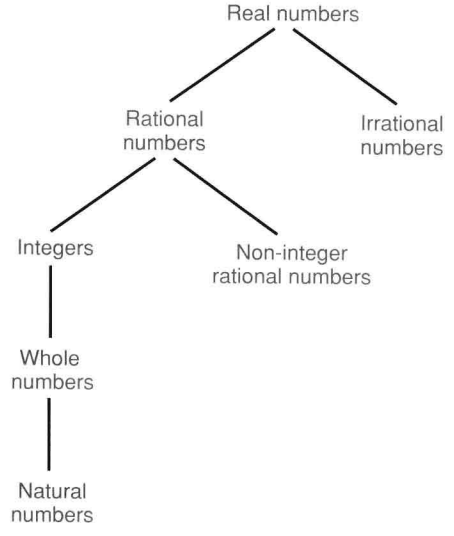
$$\sqrt{3} = 1.73205\ldots \qquad \pi = 3.14159\ldots$$

The irrational number Pi (π) is the ratio of the circumference of a circle to its diameter. Using a supercomputer, the decimal form of π has recently been calculated to more than one billion decimal places.

Irrational numbers *cannot* be expressed as the ratio of integers. Some other examples of irrational numbers are

$$\sqrt{5} \qquad \sqrt{12} \qquad \sqrt[3]{4} \qquad -\sqrt{17} \qquad \sqrt[4]{\frac{16}{9}}$$

The collection of rational numbers and irrational numbers comprises the set of **real numbers.** The relationships between these various sets of numbers can be shown by means of this *tree diagram*:



Reading upward, each set of numbers is a subset of the set of numbers listed above it.

EXAMPLE 1 To which subsets of the real numbers do each of the following numbers belong?

(a) 5 **(b)** $\frac{2}{3}$ **(c)** $\sqrt{7}$ **(d)** -14

Solution

(a) 5 is a natural number, a whole number, an integer, a rational number, and a real number.

(b) $\frac{2}{3}$ is a rational number and a real number.

(c) $\sqrt{7}$ is an irrational number and a real number.

(d) -14 is an integer, a rational number, and a real number. ■

EXAMPLE 2 Classify as true or false: Every whole number is a natural number.

Solution In order for a statement to be true, it must be true for all possible cases; otherwise it is false. Since 0 is a whole number but is *not* a natural number, the statement is false. ■

0 is the identity element for addition; 1 is the identity element for multiplication.

Throughout this course we shall be using various properties of the set of real numbers, most of which you have encountered before. Here is a summary of some of these important properties.

PROPERTIES OF THE REAL NUMBERS

For all real numbers a, b, and c:	Addition	Multiplication
Closure Properties	$a + b$ is a real number	$a \cdot b$ is a real number
Commutative Properties	$a + b = b + a$	$a \cdot b = b \cdot a$
Associative Properties	$(a + b) + c = a + (b + c)$	$(a \cdot b) \cdot c = a \cdot (b \cdot c)$
Distributive Property	$a(b + c) = ab + ac$	
Identity Properties	$0 + a = a + 0 = a$	$1 \cdot a = a \cdot 1 = a$
Inverse Properties	$a + (-a) = 0$	$a \cdot \frac{1}{a} = \frac{1}{a} \cdot a = 1, a \neq 0$
Multiplication Property of Zero		$0 \cdot a = a \cdot 0 = 0$
Zero-product Property	If $ab = 0$, then $a = 0$ or $b = 0$, or both $a = 0$ and $b = 0$.	

TEST YOUR UNDERSTANDING
Think Carefully

Throughout this book we shall occasionally pause for you to test your understanding of the ideas just presented. If you have difficulty with these brief sets of exercises, you should reread the material in the section before going ahead. Answers are given at the end of the chapter.

Name the property of real numbers being illustrated.

1. $3 + (\frac{1}{2} + 5) = (3 + \frac{1}{2}) + 5$

2. $3 + (\frac{1}{2} + 5) = (\frac{1}{2} + 5) + 3$

3. $6 + 4(2) = 4(2) + 6$

4. $8(-6 + \frac{2}{3}) = 8(-6) + 8(\frac{2}{3})$

5. $(17 \cdot 23)59 = (23 \cdot 17)59$

6. $(17 \cdot 23)59 = 17(23 \cdot 59)$

7. Does $3 - 5 = 5 - 3$? Is there a commutative property for subtraction?

8. Given a *counterexample* to show that the set of real numbers is not commutative with respect to division. (That is, use a specific example to show that $a \div b \neq b \div a$.)

9. Does $(8 - 5) - 2 = 8 - (5 - 2)$? Is there an associative property for subtraction?

10. Give a counterexample to show that the set of real numbers is not associative with respect to division.

(Answers: Page 74)

11. Are $3 + \sqrt{7}$ and $3\sqrt{7}$ real numbers? Explain.

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