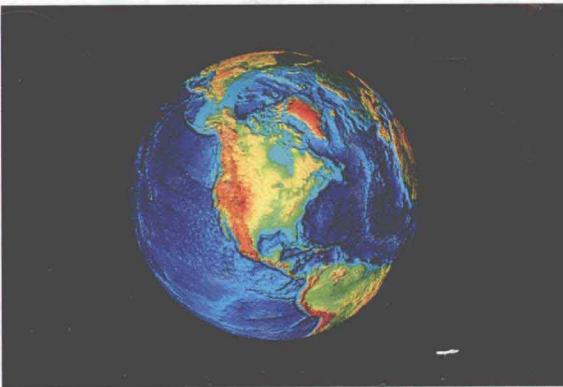
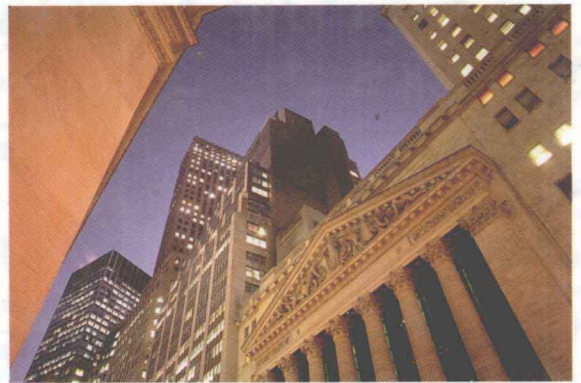


# *Mathematics*

## *in Life, Society, & the World*

*Second Edition*



*Harold Parks*  
*Gary Musser*  
*Robert Burton*  
*William Siebler*

*Second Edition*

# *Mathematics in Life, Society, & the World*

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# Preface

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Traditionally, much of the effort in teaching mathematics in colleges and universities has been devoted to teaching calculus and to calculus preparation. This was especially true for the first two years of study, when college algebra was the standard freshman level entry course and many other courses had algebra as a prerequisite.

Mathematics has often been referred to as “the queen and servant of the sciences”, and the primary mission of college-level mathematics was providing quantitative and logical tools for the study and practice of science and engineering. Much of this emphasis coming from the 1950’s and 60’s was a result of the Cold War and Space Race. Science and engineering became priority areas in educational planning and funding. The needs of students who were not in mathematics, science, or engineering were too often overlooked. Many of them would end up passing college algebra to fulfill graduation requirements, but failing to see how mathematics had relevance to their studies or their lives.

Beginning in the mid-1980’s, a renewed commitment was made to students not majoring in science or engineering. First, there was a recognition that mathematics was becoming essential in an increasing number of professional fields. A new type of competence, “quantitative literacy”, was also seen as essential in day-to-day functioning and communication. As a result, new mathematics courses have been developed that focus on “nontraditional” topics and applications of mathematics in the real world. This book is designed to be the textbook in such a course. In writing this book, we have kept certain goals before us.

**Relevance.** The title of the book “**Mathematics in Life, Society, & the World**” sums it up. We cover topics that play an important role in every day life (for example, Chapter 6—*Consumer Mathematics*), in civil life (for example, Chapter 9—*Voting and Apportionment*), or in their general appreciation of the world (for example, Chapter 12—*Geometry*). As we teach the material in this book, we continue to notice that students pick up on the relevance of the material.

**Accessibility.** In writing the text, we continue to make the material accessible by developing topics in a logical manner. This involves isolating the truly important points and presenting them without needless technical complication. We have avoided writing any impressively complicated derivations, and have tried to make it possible to solve everything with an inexpensive calculator, some graph paper, and a working knowledge of high school algebra.

**Pedagogy.** All the material in this book has been class tested many times. The book contains more exercises and problems than most texts of its kind. The exercises and problems, including the applied problems, have a wide range of difficulty so instructors can tailor their assessments to their classroom needs.

## OUTLINE

This book is organized into four major Parts (13 Chapters). Topics in geometry are included near the end of the book for students who need a brief refresher (self-study).

**Part I: The Language of Mathematics.** The material in Chapter 1, *Mathematical Structures and Methods*, includes an introduction to sets, and a review of the structure and operations in our number system. The concept of “function” is also introduced, and the properties and graphs of several elementary functions are explored. The material in this chapter is considered as prerequisites for the rest of the book. The other chapters are relatively independent, and may be studied in almost any order.

**Part II: Mathematics in Life.** These chapters consist of the mathematics a student will encounter on a regular basis. Chapter 2, *Descriptive Statistics*, is a very rich chapter which contains graphical information that students will see daily in newspapers, newsmagazines, or on the internet. Chapters 3 *Collecting and Interpreting Data*, shows how the data for Chapter 2 may be collected and Chapter 4, *Inferential Statistics*, shows how inferences may be drawn from such data. Chapter 5, *Probability*, shows how experiments can be used to predict the likelihood that certain events may occur. Finally, Chapter 6, *Consumer Mathematics*, contains most of the mathematics that students will typically use in their personal financial dealings.

**Part III: Mathematics in Society.** This part is composed of three modern topics whose mathematics underlies much of the social structure and interactions around us. Chapter 7, *Game Theory*, shows how games of a social nature can be analyzed and how optimal winning strategies can be developed. Chapter 8, *Management Mathematics*, provides many interesting applications where the techniques involving linear programming and networks can be used to solve problems, especially in the business world. Chapter 9, *Voting and Apportionment*, contains an analysis of a variety of strategies that may be used by politicians to bring fairness (or unfairness) to our democratic system.

**Part IV: Mathematics in the World.** These four chapters are varied in nature and can be covered anytime in a course. Chapter 10, *Critical Thinking*, is most useful in analyzing arguments for validity as well as to learn useful problem solving techniques. Chapter 11, *Elementary Number Theory*, provides insight into our Hindu-Arabic numeration system. In addition, it shows how simple mathematics can be used to develop interesting codes that have been used throughout history. Chapter 12, *Geometry*, contains many of the rich visual ideas contained in tilings as well as a study of conic sections, which have deep historical roots in mathematics. Finally Chapter 13, *Growth and Scaling*, provides many applications which illustrate the importance that growth and decay have in our world.

Throughout the book, we have sought to be faithful to recommendations of our professional organizations such as the MAA, the AMATYC, and the NCTM.

## CHANGES TO THE SECOND EDITION

Several changes have been made to reflect the suggestions of reviewers and new recommendations by professional groups in several states. These are

- Chapter 1, *Mathematical Structures and Methods*, has been substantially rewritten to include all material prerequisite to the rest of the book.



- Sections 1.1 and 1.8, *Sets and Solving Equations*, were revised and moved from the Topics sections into Chapter 1.
- Sections 1.6 and 1.7, *The Concept of Function and Functions and Their Graphs* were added to Chapter 1.
- Chapter 4, in the First Edition, was replaced by Chapters 3 and 4, *Collecting and Interpreting Data and Inferential Statistics*, to enhance understanding.
- Section 5.4, *Systematic Counting*, was added to Chapter 5 to allow for the solution of problems that involved more complex counting arguments.
- Section 9.3, *Weighted Voting Systems*, was added since many instructors consider it an important extension of the ideas of the preceding sections.
- Chapter 11, *Elementary Number Theory*, was added since many instructors like to cover this topic because of its rich historical material as well as its usefulness in solving interesting problems about numbers.

## CONTINUING CONTENT

- Chapter 6, *Consumer Mathematics*, contains most of the important day-to-day mathematics for the informed consumer.
- Chapters 7 and 8, *Game Theory and Management Mathematics*, contain many interesting business applications.
- Chapter 9, *Voting and Apportionment*, is particularly interesting to social scientists.
- Chapter 10, *Critical Thinking*, is rich in its coverage of logical thinking and problem solving. This chapter can be covered early in a course to provide a problem solving emphasis.
- Chapter 12, *Geometry*, contains several topics of historical significance. Also, Topics 1–3, may be covered for a more in-depth coverage of geometry.
- Chapter 13, *Growth and Scaling*, contains many fascinating ideas relating to growth and decay.

## ACKNOWLEDGMENTS

A leading force in the development of the type of course for which this textbook is intended has been the Consortium for Mathematics and Its Applications, and we acknowledge their valuable pioneering efforts. We have benefited from student feedback as we have tested these materials, and we thank those students for their help and advice. Our colleagues at Oregon State University, Burton Fein, Mary Flahive, and Lea Murphy, have also provided helpful advice, and we thank them.

We thank Ann Heath and Sally Yagan, our editors, for their continued support, and Bayani DeLeon, our production editor, for his excellent work and diligence in shepherding this book to completion. We again thank the following reviewers for their input on our first edition:

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# Text Preview

## 4



## *Inferential Statistics*

### *P&G to Cut Spending on Local Television Advertising*

Procter & Gamble Co. is dissatisfied with the “poor quality” of Nielsen Media Research’s TV diaries. Because of this dissatisfaction, the company is slashing its spending for local TV, or “spot,” advertising. For example, in October 1997, the company spent \$16 million in spot TV, but in October 1998, the company spent only \$10 million, a 37.5% decrease.

Nielsen Media Research uses diaries to measure

TV ratings in most of the nation’s local television markets. Diaries are the only way the company gathers demographic data for those markets. In April 1998, a high-ranking Procter & Gamble executive warned the annual convention of the Television Bureau of Advertising that people meters were needed in local markets, or spot television advertising would decrease. Those warnings were not heeded.



## CHAPTER GOALS

1. Graph data using various types of graphs to display and compare data.
2. Graph two or more sets of data using comparison graphs.
3. Identify graphs that have been distorted and explain how to correct the distortions.
4. Show the relationship between two variables using scatterplots and regression lines.

Page 91

**Chapter Goals:** The major concepts students should master in the chapter are presented up front.

Page 157

**Chapter Review - revisit chapter goals:** At chapter end, the key ideas are reviewed and the corresponding pages are referenced.

Chapter 2 Review 157

## Chapter 2 Review

### Key Ideas and Questions

The following questions review the main ideas of this chapter. Write your answers to the questions and then refer to the pages listed by number to make certain that you have mastered these ideas.

1. What are the six main types of graphs in this chapter, and what are the strengths and weaknesses of each of these

types? 94–103 How can these graphs be used to compare different, but related, data sets? 110–117

2. Describe four ways that graphs may be altered to influence perception of the viewer. 125–139
3. How does a scatterplot with a strong correlation allow you to make confident predictions? 148–149 Does a strong correlation allow you to infer that one variable is the cause of the other? 149

Section 3.1 Populations, Samples, and Data 165

### INITIAL PROBLEM

## 3.1 POPULATIONS, SAMPLES, AND DATA



As office manager for a radio station you have three tickets for a vacation in Tahiti. There are 29 workers, all equally deserving of extra recognition. How can you choose 3 of these 29 workers in a way that is fair to all of them?

Page 165

**Initial Problem:** Each section begins with an applied problem to introduce students to the skills that are the subject of the section.

Page 172

**Initial Problem - Solution:** At the end of the section, the problem is repeated and the solution is worked out fully for the student.

172 Chapter 3 Collecting and Interpreting Data

### INITIAL PROBLEM SOLUTION

As office manager for a radio station you have three tickets for a vacation in Tahiti. There are 29 workers, all equally deserving of extra recognition. How can you choose 3 of these 29 workers in a way that is fair to all of them?

### SOLUTION

Choose a simple random sample. Assign each of the 29 workers the numbers 00, 01, ..., 28 in order. Looking at the first two digits down the last column of Table 3.1, we see 99, 20, 04, 33, 49, 39, 29, 44, 77, 41, 54, 90, 70, 16, 07, .... The first three numbers that are 28 or less are 20, 04, 16. The workers that have been assigned the numbers 04, 16, and 20 go to Tahiti.

## History

The notation  $a^m$  was introduced by René Descartes in his work *La Géométrie* published in 1637.



Page 44

**History:** Interesting commentary on how mathematics developed and was used throughout the ages is placed along side relevant text.

## Tidbit

Because of the complex way ownership of real estate is determined, it is necessary to purchase insurance against the possibility that someone else actually owns the house you bought and paid for! This is called title insurance.

Page 320

**Tidbit:** These marginal notes call out “fun facts” and information that relate the mathematics being presented to various aspects of real life.

## THE HUMAN SIDE OF MATHEMATICS



Srinivasa Ramanujan

Srinivasa Ramanujan (1887–1920), whose full name was Srinivasa Ramanujan Ayengar, developed a passion for mathematics when he was a young man in India. Working from numerical examples, he arrived at astounding results in number theory. Yet, he had little formal training beyond high school. He obtained a scholarship from the University of Madras, but after his marriage in 1909, he worked as a clerk instead. In 1913, Ramanujan sent some of his results to the English mathematician George Hardy, who recognized the genius of the work. Hardy, who was at Cambridge University, was able to arrange for Ramanujan to come to England, where Hardy became his mentor and teacher. Ramanujan was elected a fellow of the Royal Society in 1918 and a fellow of Trinity College, Cambridge, later the same year. Unfortunately, Ramanujan became ill in 1917. In 1919, he returned to India, where he resumed his mathematical work, but he died in April 1920. On one occasion when Ramanujan was ill and confined to bed, Hardy went to visit, arriving in taxicab number 1729. He remarked to Ramanujan that the number seemed rather dull, and he hoped it wasn't a bad omen. “No,” said Ramanujan, “it is a very interesting number; it is the smallest number expressible as a sum of cubes in two different ways.” (Note that  $1729 = 1000 + 729 = 10^3 + 9^3$  and  $1729 = 1728 + 1 = 12^3 + 1^3$ .)



Andrew Wiles

Andrew Wiles (1953–) was born and educated in England. As a boy of age 10, he became fascinated with the conjecture known as Fermat's last “theorem.” Fermat claimed that there are no nonzero whole numbers  $a$ ,  $b$ ,  $c$ , where  $a^n + b^n = c^n$ , for  $n$  a whole number greater than 2. (This is a generalization of the Pythagorean theorem concerning right triangles with whole number lengths. That is,  $a^2 + b^2 = c^2$ , where  $a$  and  $b$  are the lengths of the sides and  $c$  is the length of the hypotenuse. For example,  $3^2 + 4^2 = 5^2$  and  $5^2 + 12^2 = 13^2$  are two such triples of numbers.) Fermat made the assertion in the margin of a book he was studying. He further claimed to have a “truly marvelous” proof of this result, which he would have written down, except that the margin was too narrow. No one any longer believes that Fermat had the proof he claimed, and for 350 years, the result eluded proof.

Wiles earned his Ph.D. from Cambridge University in 1980 and began a successful career in mathematics, specializing in number theory. Through the 1980s he held positions at various prestigious institutions in Europe and the United States, including Harvard, Princeton, and Oxford. In 1986, Wiles realized that recent work of Kenneth Ribet, in turn based on work of Jean-Pierre Serre and Barry Mazur, gave an avenue that might lead to a proof of Fermat's last theorem. Wiles began a seven-year, secret, obsessive quest to complete the proof of Fermat's last theorem. Finally, in June 1993, Wiles

Page 550

**The Human Side of Mathematics:** These short biographical sketches introduce students to the real people who helped develop the mathematical ideas presented in the chapter.

### Problem Set 2.3

1. The history of the world record times for the mile run is as follows:

1950	4:01.4 (4 min 1.4 sec)
1955	3:58.0
1960	3:54.5
1965	3:53.6
1970	3:51.1
1975	3:49.4
1980	3:48.8
1985	3:46.3
1990	3:46.3
1995	3:44.4
1999	3:43.1

Source: USA Track & Field.

- (a) Draw a line graph of this data using 3:30.0 as the baseline for the graph.  
 (b) What effect does having 3:30.0 as the baseline have on the impression made by the graph?
2. Harness Racing Records for the Mile

Trotters		Pacers	
1921	1:57.8	1904	1:56
1922	1:57	1938	1:55
1922	1:56.8	1955	1:54.8
1937	1:56.6	1960	1:54.6
1937	1:56	1966	1:54
1938	1:55.2	1966	1:53.6
1969	1:54.8	1971	1:52
1980	1:54.6	1980	1:49.2
1982	1:54	1989	1:48.4
1987	1:52.2	1993	1:46.2

Source: 1995 Information Please almanac.

- (a) Draw a line graph of the data on Trotters using 1:40.0 as the baseline for the graph.  
 (b) What effect does having 1:40.0 as the baseline have on the impression made by the graph?

3. Since  
Unit  
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the d

#### 542 Chapter 10 Critical Thinking, Logical Reasoning, and Problem Solving

### Extended Problems

55. The **Fibonacci sequence** is 1, 1, 2, 3, 5, 8, 13, 21, . . . , where each successive number is the sum of the preceding two. For example,  $13 = 5 + 8$ ,  $21 = 8 + 13$ , and so on. Observe the following pattern.

$$\begin{aligned}1^2 + 1^2 &= 1 \times 2 \\1^2 + 1^2 + 2^2 &= 2 \times 3 \\1^2 + 1^2 + 2^2 + 3^2 &= 3 \times 5\end{aligned}$$

Write out six more terms of the Fibonacci sequence and use the sequence to predict what  $1^2 + 1^2 + 2^2 + 3^2 + \dots + 14^2$  is without computing the sum. Then use your calculator to check your prediction.

56. Write out 16 terms of the Fibonacci sequence and observe the following pattern.

$$\begin{aligned}1 + 2 &= 3 \\1 + 2 + 5 &= 8 \\1 + 2 + 5 + 13 &= 21\end{aligned}$$

Use the pattern you observed to predict the sum

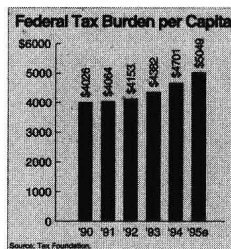
$$1 + 2 + 5 + 13 + \dots + 610$$

- (a) Draw a bar graph for this data using the same distance between each of the bars.  
 (b) Draw a line graph for the data having the years as the baseline with the usual spacing.  
 (c) Which graphing approach do you prefer? Why?
4. Redraw the bar graph from Figure 2.28 with horizontal bars, but this time reverse the order of the bars from how they appear in Figure 2.29.
- (a) What is the visual impression regarding profits in this graph?  
 (b) Which graph would you use? Why?
5. Draw a horizontal bar graph for the data in Problem 3. Draw the bar graph in such a way that it can give the impression that the death rate is increasing.

#### Problems 6 through 8

Use the following data and graph.

The Federal Tax Burden per Capita, Fiscal Year 1990–1995						
1990	1991	1992	1993	1994	1995	
\$4,026	\$4,064	\$4,153	\$4,382	\$4,701	\$5,049	



#### Page 141

**Exercises:** Each section offers an extensive set of exercises and problems covering all of the topics developed in the section. Odd and even numbered problems are matched, with the even problems being slightly more difficult. Students are frequently asked to interpret the results and write about their conclusions. Answers are provided for all odd problems.

#### Page 542

**Extended Problems:** Each section problem set ends with a selection of more challenging exercises. Some of the extended problems introduce additional topics that an instructor may wish to cover, while others offer the opportunity to do open-ended projects or group work.

without actually computing the sum. Then use your calculator to check your result.

57. Observe the following pattern based on the Fibonacci sequence.

$$\begin{aligned}1 + 1 &= 3 - 1 \\1 + 1 + 2 &= 5 - 1 \\1 + 1 + 2 + 3 &= 8 - 1 \\1 + 1 + 2 + 3 + 5 &= 13 - 1\end{aligned}$$

Write out six more terms of the Fibonacci sequence and use the sequence to predict the answer to

$$1 + 1 + 2 + 3 + 5 + \dots + 144$$

without actually computing the sum. Then use your calculator to check your result.

58. Write out the first 16 terms of the Fibonacci sequence.  
 (a) Notice that the fourth term in the sequence (called  $F_4$ ) is odd:  $F_4 = 3$ . The sixth term in the sequence ( $F_6$ ) is even:  $F_6 = 8$ . Look for a pattern in the terms of the sequence and describe which terms are even and which are odd.

## Chapter 6 Problem

You are buying a car for \$10,000 from a dealer who will give you a loan for five years at 10% interest. As an extra incentive he offers either \$1200 cash back on the 10% loan or a 6% interest rate (which is a rate that you could expect to get if you deposited funds in a bank or money market account). Which deal should you choose?

### SOLUTION

One approach to making a rational decision is to compare the total amount you would pay under each option. That means you have to first find the amount of the monthly payments for each choice. From this information, you can compute the total for *all* payments.

Since the interest rate is a whole percent, we can use a table rather than computing the monthly payment from a formula. Table 6.5 can be used for this purpose. The part of the table we are interested in is the following:

Amount per \$1000	
Percent	5 Years
6	19.332802
10	21.247045

We see that if the interest were 10% on a five-year loan, then the monthly payments would be \$21.247045 for a \$1000 loan. Multiplying by 10 gives payments of \$212.48 for a \$10,000 loan. (Note that we rounded up.) The total of the 60 monthly payments is  $60 \times 212.48 = \$12,748.80$ .

If the interest rate were 6%, then the monthly payments would be \$19.332802 for a \$1000 loan, which turns into \$193.34 for a \$10,000 loan. The total of the 60 monthly payments is  $60 \times 193.34 = \$11,600.40$ . (Note that the difference between the monthly payments is \$19.14.)

One way to look at the problem is that you have a choice either to have \$1200 now or have an extra \$19.14 a month for the next 60 months. The total amount of money that you will keep by going with the lower interest is  $\$19.14 \times 60 = \$1148$ . Thus you should take the \$1200 rather than the lower interest rate since you will have \$1200 to spend now or to invest during the entire 60 months. If you can invest the \$1200 at 6% compounded monthly for the next five years, it would be worth \$1618. The net amount you would pay for the car would be  $60 \times 212.48 - 1618 = \$11,130.80$  compared to the \$11,600.40 you would pay for the car with the lower rate.

Page 331

**Chapter Problem:** Each chapter ends with a solved problem to illustrate how the material learned in the chapter is used in the real world.

Page 493

### Chapter Review - Vocabulary:

Important vocabulary and notation presented in the chapter are listed by section and annotated with the page reference to facilitate study.

Chapter 9 Review 493

#### Vocabulary

Following is a list of key vocabulary for this chapter. Mentally review each of these items, write down the meaning of each term, and use it in a sentence. Then refer to the pages listed by number, and restudy any material that you are unsure of before solving the Chapter Nine Review Problems.

Voter with Veto Power 465  
Critical Voter 466  
Banzhaf Power 466

Total Banzhaf Power 466  
Banzhaf Power Index 466

#### Section 9.1

Plurality Method 435  
Borda Count Method 436  
Plurality with Elimination Method 438  
Run-Off Election 438  
Preference Table 438  
Pairwise Comparison Method 440

#### Section 9.4

Apportionment Problem 473  
Hamilton's Method of Apportionment 474  
Standard Divisor 474  
Standard Quota 474  
Jefferson's Method 476  
Modified Quota 476  
Webster's Method 478

## Chapter 9 Review Problems

### Problems 1 through 3

Use the following information.

Suppose that Anne, Brad and Claire are running for class groundskeeper. The following table tells the number of first, second, and third place votes cast for each.

	First	Second	Third
Anne	6	2	4
Brad	4	7	1
Claire	2	3	7

- Who is the winner using the plurality method?
- Who is the winner using the Borda count method?
- Is it possible to decide who would win using the plurality with elimination method from the information above? Explain.

### Problems 4 through 8

Use the following information

The following is a complete preference table for an election.

- What is the largest value possible for  $q$ ?
  - What is the smallest value possible for  $q$ ?
  - What is the smallest value possible for  $q$  if the first voter is not a dictator?
  - How many coalitions does this weighted voting system have?
10. For each of the following weighted voting systems, identify any voters who
- are dictators
  - are dummies
  - have veto power
- Justify your reasoning.
- $[8|5, 5, 2]$
  - $[25|25, 10, 8, 6]$
  - $[10|5, 5, 5, 2, 2]$
11. Find the Banzhaf power index for each voter in the following weighted voter system.

$[51|43, 41, 10, 6]$

12. Find the Banzhaf power index for each voter in the following weighted voter system.

$[18|10, 9, 8, 5, 3]$

Page 494

**Chapter Review - Problems:** Each chapter ends with a set of problems which cover the most important topics in the chapter.



# Supplements

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### **Instructors Resource Manual**

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*Mathematics  
in Life, Society,  
& the World*

# 1



## *Mathematical Structures and Methods*

### *Don't Trust Those Lying Lie Detectors*

Many powerful arguments have been made against the use of the lie detector. Here is another compelling objection.

Lie detectors make mistakes with both liars and truth-tellers. Let us assume that a lie detector has an accuracy rate of 80% (a generous estimate) and that no subject knows how to beat the lie detector (also questionable). Let us further assume that 900 out of 1000 people are telling the truth. Of the 900 truth-tellers, the lie detector will identify 720 (80% of

900) as truth-tellers but will incorrectly identify 180 (20% of 900) as liars. Of the 100 liars, the lie detector will identify 80 as liars (80% of 100) but will incorrectly identify 20 (20% of 100) as truth-tellers.

Thus, of the 260 people (180 + 80) the lie detector identifies as "liars," 180 are telling the truth. In other words, the lie detector is incorrect 70% of the time when it brands someone a liar.