APPLIED MATHEMATICS

FOR THE PETROLEUM AND OTHER INDUSTRIES

5th Edition

The University of Texas at Austin
Petroleum Extension (PETEX®)
Cockrell School of Engineering

Applied Mathematics
for the Petroleum and Other Industries

Fifth Edition

by

Will L. McNair, P. E.

published by

THE UNIVERSITY OF TEXAS AT AUSTIN

Cockrell School of Engineering

PETROLEUM EXTENSION (PETEX®)

2019

Library of Congress Cataloging-in-Publication Data

Names: McNair, Will L., author. | University of Texas at Austin. Petroleum Extension Service.
Title: Applied mathematics for the petroleum and other industries / by Will L. McNair, P.E.
Other titles: Applied mathematics in the petroleum and other industries
Description: Fifth edition. | Austin, Texas : The University of Texas at Austin, Cockrell School of Engineering, Petroleum Extension [Service], 2019.
Identifiers: LCCN 2019019553 | ISBN 9780886982843 (alk. paper)
Subjects: LCSH: Mathematics--Problems, exercises, etc. | Petroleum engineering--Mathematics--Problems, exercises, etc.
Classification: LCC QA39.3.M466 2019 | DDC 510--dc23 LC record available at https://lccn.loc.gov/2019019553

Disclaimer

Although all reasonable care has been taken in preparing this publication, the authors, the Petroleum Extension (PETEX®) of The University of Texas at Austin, and any other individuals and their affiliated groups involved in preparing this content, assume no responsibility for the consequences of its use. Each recipient should ensure he or she is properly trained and informed about the unique policies and practices regarding application of the information contained herein. Any recommendations, descriptions, and methods in this book are presented solely for educational purposes.

First Edition Published 1948. Second Edition 1961
Third Edition 1985, Revised 1996
Fourth Edition 2004
Printed in the United States of America

Catalog No. 1.60050
ISBN 0-88698-284-7
978-0-88698-284-3

Contents

FIGURES v

TABLES ix

FOREWORD xi

ACKNOWLEDGMENTS xiii

CHAPTER 1—THE NUMBER SYSTEM 1

- Objectives 1
- Introduction 1
- Whole Numbers 4
- Common Fractions 14
- Mixed Numbers 21
- Decimal Fractions 24
- Roots and Powers 32
- Self-Test 36

CHAPTER 2—THE CALCULATOR 39

- Objectives 39
- Introduction 39
- Choosing a Calculator 40
- Understanding Calculator Functions 45
- Operating a Calculator 49
- Self-Test 57

CHAPTER 3—NUMBER RELATIONS 59

- Objectives 59
- Introduction 59
- Percentage 59
- Ratio and Proportion 63
- Mean (Average), Median, and Mode 67
- Tables and Graphs 70
- Self-Test 78

CHAPTER 4—PRINCIPLES OF ALGEBRA 83

- Objectives 83
- Introduction 83
- Algebraic Expressions 83
- Equations 90
- Formulas 93
- Self-Test 104

CHAPTER 5—SOME PHYSICAL QUANTITIES AND THEIR MEASUREMENT 109

- Objectives 109
- Introduction 109

Length, Area, and Volume 112
Time and Temperature 122
Mass and Related Derived Quantities 127
Work and Power 134
Electricity 136
Self-Test 143

CHAPTER 6—PRACTICAL GEOMETRY 147
Objectives 147
Introduction 147
Plane Figures 148
Tables for Conversions and Formulas 155
Solid Figures 159
Tables for Volumes and Surface Areas 166
Geometric Constructions 170
Self-Test 182

CHAPTER 7—TRIGONOMETRY 187
Objectives 187
Introduction 187
Right Triangle Trigonometry 188
Oblique Triangle Calculations 197
Self-Test 202

CHAPTER 8—ADVANCED MATH CONCEPTS 207
Objectives 207
Introduction 207
Binary Arithmetic 208
Special Binary Codes 214
Boolean Concepts 217
Self-Test 222

CHAPTER 9—ADVANCED OIL INDUSTRY APPLICATIONS 225
Objectives 225
Introduction 225
Electrical Power and Power Factor Equations 226
Mathematics in Drilling Operations 237
Mathematics in Production Operations 257
Mathematics in Pipeline Operations 267
Mathematics in Refining Operations 273
Self-Test 277

APPENDICES 281
A. Commonly Used Formulas 281
B. Reference Tables 285
C. Conversion Factors 291

GLOSSARY 297

ANSWER KEY 303
Answers to Practice Problems 303
Answers to Self-Tests 307

Figures

2.1	Typical calculator keyboards	41
2.2	Entries and displays on arithmetic logic calculator	42
2.3	Entries and displays on algebraic notation calculator	42
2.4	Entries, displays, and memory in RPN calculator	43
2.5	Entries and displays in graphing calculator	43
2.6	Arithmetic calculator	49
2.7	Entries and displays on arithmetic calculator using memory key	50
2.8	Algebraic logic scientific calculator	52
2.9	Entries and displays on algebraic logic calculator	53
2.10	RPN calculator	54
2.11	Stack memory of RPN calculator	55
3.1	Percent relations	60
3.2	Direct proportion	64
3.3	Inverse proportion	64
3.4	Pulley arrangement	65
3.5	Gear arrangement	65
3.6	Simple table	70
3.7	Simple graph	70
3.8	Reference table	71
3.9	Parts of table	72
3.10	Table data	72
3.11	Pair of reference axes	72
3.12	Information arranged in tabular form	73
3.13	Points plotted for graph	73
3.14	Bar graph showing tabular data given in figure 3.12	73
3.15	Line graph showing tabular data given in figure 3.12	74
3.16	Broken-line graph	74
3.17	Curved-line graph	74
3.18	Curved graph showing general relationship	74
3.19	Circle graph or pie chart	75
5.1	Micrometer caliper	113
5.2	Section of conventional ruler, divided into sixteenths	113
5.3	Section of metric ruler, divided into tenths	114
5.4	Equal-sided square and cube	115
5.5	Rectangle and rectangular solid	115
5.6	Several forms of triangles	116
5.7	Area of triangle	116
5.8	Comparison of various temperature scales	124
5.9	Ohm's law wheel	137
5.10	Electrical symbols	137
5.11	Series circuit	138
5.12	Parallel circuit	138
5.13	Parallel circuit with total current	138

5.14	Series circuit with three resistors	138
5.15	Parallel circuit with four branch resistors	139
5.16	Series-parallel circuit arrangement	139
5.17	Power law wheel	140
6.1	Right angle	148
6.2	Circle	148
6.3	Acute angle	148
6.4	Obtuse angle	148
6.5	Parallel lines	148
6.6	Parallelogram	149
6.7	Rectangle	149
6.8	Square	149
6.9	Area and perimeter of rectangle	149
6.10	Trapezoid	150
6.11	Right triangle	150
6.12	Equilateral triangle	150
6.13	Isosceles triangle	150
6.14	Scalene triangle	150
6.15	Parallelogram has two identical triangles	151
6.16	Dimensioned triangle	151
6.17	Diagram showing side relationships	151
6.18	Triangle problem	151
6.19	Triangle solution	151
6.20	Regular six-sided polygon (hexagon)	152
6.21	Octagon	152
6.22	Irregular five-sided polygon (pentagon)	152
6.23	Parts of circle	153
6.24	Concentric circles	153
6.25	Semicircle	153
6.26	Dimensioned circle	154
6.27	Ellipse	154
6.28	Dimensioned ellipse	155
6.29	Cube	159
6.30	Rectangular solid	159
6.31	Cylinder	160
6.32	Elliptical solid	161
6.33	Cone	162
6.34	Lateral area of cone or conical surface	162
6.35	Dimensioned cone	162
6.36	Pyramids	163
6.37	Dimensioned pyramid	163
6.38	Lateral area of pyramid	163
6.39	Frustum of cone	164
6.40	Frustum of pyramid	164
6.41	Frustum cone calculations	164
6.42	Frustum pyramid calculations	165
6.43	Sphere	165
6.44	Compass drawing	171
6.45	Bisecting line	171
6.46	Bisecting line	171

6.47	Bisecting line	171
6.48	Bisecting line	171
6.49	Bisecting arc	171
6.50	Bisecting angle	172
6.51	Bisecting angle	172
6.52	Bisecting angle	172
6.53	Constructing circle	172
6.54	Constructing circle	172
6.55	Constructing angle	172
6.56	Constructing angle	172
6.57	Constructing angle	173
6.58	Constructing angle	173
6.59	Constructing parallel line	173
6.60	Constructing parallel line	173
6.61	Constructing parallel line	173
6.62	Constructing parallel line	173
6.63	Constructing perpendicular line	174
6.64	Constructing perpendicular line	174
6.65	Constructing perpendicular line	174
6.66	Constructing perpendicular line	174
6.67	Constructing perpendicular line	174
6.68	Constructing perpendicular line	174
6.69	Constructing perpendicular line	175
6.70	Constructing perpendicular line	175
6.71	Constructing perpendicular line	175
6.72	Constructing perpendicular line	175
6.73	Dividing line into parts	175
6.74	Dividing line into parts	175
6.75	Dividing circle into equal parts	175
6.76	Dividing acircle into equal parts	175
6.77	Constructing tangents to circle	176
6.78	Constructing tangent to circle	176
6.79	Constructing tangent to circle	176
6.80	Constructing sphere to plane	176
6.81	Constructing sphere to plane	176
6.82	Constructing sphere to plane	177
6.83	Constructing sphere to plane	177
6.84	Constructing sphere to plane	177
6.85	Constructing sphere to nonparallel lines	177
6.86	Constructing sphere to nonparallel lines	177
6.87	Drawing triangles	178
6.88	Proper drawing strokes	178
6.89	Using drawing triangle	178
6.90	Using drawing triangle	178
6.91	Drawing line perpendicular to another line	179
6.92	Drawing line perpendicular to another line	179
6.93	Dividing circle into equal parts	179
7.1	Triangle ratios	187
7.2	Sides of triangle	188
7.3	Angles of triangle	189

7.4	Dimensioned triangle	191
7.5	Triangle side ratios	192
7.6	Triangle angle definitions	192
7.7	Triangle angle definitions	192
7.8	Dimensioned triangle	192
7.9	Dimensioned triangle	194
7.10	Dimensioned triangle	194
7.11	Dimensioned triangle	195
7.12	Oblique triangle	197
7.13	Dimensioned oblique triangle	197
7.14	Dimensioned oblique triangle	197
7.15	Area of triangle	198
9.1	Power triangle	226
9.2	Diagram of simple circuit	228
9.3	Diagram of three-phase system	229
9.4	Diagram of 480-VAC facility and load	231
9.5	Power triangles: (A) system values and (B) calculated values	232
9.6	Diagram of modified system	232
9.7	Diagram of example system	234
9.8	A/D converter in PLC	235
9.9	A/D converter example	236
9.10	Diagram demonstrating engine torque	237
9.11	Engine producing mechanical power, which alternator converts to electrical power	239
9.12	Power loading example	240
9.13	Effective weight of pipe in drilling mud	252
9.14	Effective weight of drill collars in drilling mud	253
9.15	Standard specifications for meter runs	262
9.16	Block diagram of electronic transmitter	264
9.17	Gas measurement chart (linear)	266
9.18	Flow of crude petroleum to pipelines	271
9.19	Profile method of calculating pipeline pump station spacing	272
9.20	Material balance bottoms process	275

Tables

1.1	Arabic Numerals and Roman Equivalents	2
1.2	Number Value and Placement	3
1.3	Decimal System of Numbers	4
1.4	Multiplication Table	9
1.5	Decimal Equivalents	30
5.1	Conventional and Metric (SI) Units of Measurement for Some Physical Quantities	110
5.2	SI Metric Prefixes	111
5.3	Units of Length Measurement	114
5.4	Units of Area Measurement	119
5.5	Units of Volume Measurement	119
5.6	Common Units of Time	122
5.7	Temperature Scales	125
5.8	Units of Weight, Mass, and Force Measurement	128
5.9	Densities of Some Solids, Liquids, and Gases	129
5.10	Specific Gravity Based on Air	131
5.11	Basic Electrical Units of Measure	136
6.1	Common Units of Area Measurement	149
6.2	Formulas for Finding Areas of Plane Figures	155
6.3	Common Units of Volume Measurement	160
6.4	Formulas for Finding Volumes	166
6.5	Formulas for Finding Lateral or Total Surface Areas of Solid Figures	167
7.1	Natural Trigonometric Functions	190
7.2	Reciprocal Functions	193
8.1	Base Ten Numbers	208
8.2	Decimal Equivalents	209
8.3	BCD Code and Binary and Decimal Equivalents	214
8.4	ASCII Characters and the Equivalent Binary Numbers	215
8.5	Gray Code Numbers with Equivalent Binary Numbers	215
8.6	Binary Number in Groups of Three and Decimal Equivalents	216
8.7	Hexadecimal and Binary Equivalent Numbers and Letters	217
8.8	Truth Table for C = AB	220
8.9	Truth Table for D = ABC	221
8.10	Truth Table for D = A + B + C	221
9.1	Scale of Values	237
9.2	Lightening and Weighting Drilling Mud	243
9.3	Converting Bottle Test Results to Chemical Pump Rates	260
9.4	Minimum Length Requirements for Meter Runs	263
9.5	Negative Pipe Buoyancy	268
9.6	Fuel Gas Data	273

Foreword

Employees, students, and others who are involved in the petroleum and other industries are discovering that operation of their facilities includes equipment, products, and systems requiring knowledge of mathematics. From the simplest valve to the automated operation of sophisticated production systems, mathematics is an integral part of understanding how they function. To quote Lord Kelvin from an earlier era,

> *When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.*

The original intent of this work was to provide a basic reference for field employees in the oil and gas industry who had little or no mathematical background. It has now grown to the point that personnel in many industries require knowledge of math as a means of understanding system operation as well as designing, maintaining, and troubleshooting equipment.

This new edition is designed to provide both a text and reference source in one book that covers basic mathematics as well as advanced technology. Handheld calculators are available with basic mathematic functions as well as specialized functions (such as exponents, logic functions, trigonometric functions, etc.), and use of these is suggested as the book is studied.

When used as a refresher course in elementary mathematics, it is assumed that the user will refer to those chapters where review is needed. Practice problems and self-tests are provided to assist the learners in testing their skills in the appropriate areas.

When used as a technical reference, the book gives basic guidelines and examples in a number of mechanical, hydraulic, and electrical areas that are commonly found in the field.

PETEX encourages those studying this book to communicate to us any suggestions or improvements you may find for consideration to be included in future revisions.

Will L. McNair, P. E.

Acknowledgments

This work is the result of the efforts of many people who have contributed to *Applied Mathematics* in previous editions. Since the early 1930s, the American Petroleum Institute (API) sponsored the first oilfield mathematics books and sponsored subsequent publications by PETEX by providing resources and contributors.

Among these earlier contributors are:

Dois D. Dallas, Tanana Valley Community College

Bruce Whalen, PETEX Consultant

Tommy Bicknell, Sedco, Inc.

R. G. Carson, Exxon Co.

Charlie Smith, Conoco, Inc.

Howard Swaim, Conoco, Inc.

Lejeune Wilson, Sedco, Inc.

Jeanette Maddox, TRAINCO

Contributors to this current work include Maureen Watson, Fletcher Technical Community College, and PETEX staff members Mary Lin, Virginia Dosher, and Deborah Caples.

1

The Number System

OBJECTIVES

Upon completion of chapter 1, the student, without using a calculator, will be able to—

1. Convert numbers that are written out into digits in their proper places.
2. Convert numbers from one unit into another given unit.
3. Add and subtract whole numbers.
4. Multiply and divide whole numbers.
5. Determine whether a word problem requires addition, subtraction, multiplication, or division.
6. Find the lowest common denominator of a group of fractions.
7. Reduce a common fraction to its lowest terms.
8. Add and subtract common fractions.
9. Multiply and divide common fractions.
10. Add and subtract mixed numbers.
11. Multiply and divide mixed numbers.
12. Add and subtract decimal fractions.
13. Multiply and divide decimal fractions.
14. Convert common fractions into decimal fractions and decimal fractions into common fractions.
15. Find the square root of a number.
16. Calculate the quantity of a number squared or raised to another power.

INTRODUCTION

Imagine that you are a lone hunter for your tribe on the plains of Africa, thousands of years ago. You have spotted a herd of gazelles that will, if you can successfully bring a few of them down, provide food for your family and your tribe for several days. Since you cannot effectively hunt the gazelles alone, you need to find your fellow hunters and get their help. You realize that your friends will want to know how many gazelles are in the herd, so you begin counting them. You count to ten using ten fingers; then, you start over and count to ten again. Finally, you count three more on your fingers. You can now tell your fellow hunters that the herd is made up of two tens and three gazelles, which is large enough to bring them running to help.

This very short story illustrates that early humans could easily count to ten using ten fingers. Then, they could start over and count to ten again. And, when they counted to ten, ten times, they had counted to one hundred. Besides remembering the count, they could also scratch straight lines into the dirt or onto the wall of a shelter to record a count. But, as time passed and humans became more sophisticated, they found that they had to keep track of large numbers. Indeed, these numbers were so large that using fingers and scratching straight lines was not adequate. So, they came up with special symbols, or figures, to represent numbers. A group of people who lived in the Middle East—the Arabs—cleverly invented symbols to represent the numbers from one to nine and for zero. Having a figure for zero was a great step forward, as you will see in a moment. Because the Arabs were the first to create symbols for numbers, everyone began calling the symbols *Arabic numerals*.

Later, the Romans also developed a system of symbols, which, logically enough, were called Roman numerals. Today, we mostly use Arabic numerals; however, we sometimes use Roman numerals for such items as chapter headings in books, hours on clocks, and copyright dates for movies.

The Arabic figures are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Letters of the alphabet stand for Roman numerals. For example, the Roman numeral I represents the Arabic numeral 1. Similarly, the Roman V is equivalent to the Arabic 5, X is 10, L is 50, C is 100, D is 500, and M is 1,000. Table 1.1 lists several Arabic numerals and their Roman equivalents.

TABLE 1.1
Arabic Numerals and Roman Equivalents

Arabic	Roman
1	I
2	II
3	III
4	IV
5	V
9	IX
10	X
19	XIX
20	XX
40	XL
44	XLIV
45	XLV
49	XLIX
50	L
90	XC
100	C
500	D
700	DCC
900	CM
999	CMIX
1,000	M
1,500	MD

Notice that the Roman numeral system sometimes places a symbol of lower value before the symbol for the next higher value. This placement indicates that you should subtract the lower value from the higher value. For example, the Roman numeral for 4 is IV, instead of IIII. The I before the V means to subtract 1 from 5. Similarly, the Roman numeral for 9 is IX and the Roman numeral for 49 is XLIX. For the equivalent of 9, the I before the X means subtract 1 from ten. For 49, the X before the L means to subtract 10 from 50, which is L, and the I means subtract 1 from 10, which is 9. Therefore, Arabic 49 is Roman XLIX. Notice, too, that the Roman system does not have a symbol for zero.

Suppose a movie was copyrighted in 1969. The Roman numeral equivalent is MCMLXIX. M equals 1,000; C (100) less M (1,000) is 900; LX is 60; and IX is 9. On the other hand, the Roman numeral equivalent for a movie copyrighted in 2000 is simply MM.

Because the Arabic system contains the figures 0 through 9, it certainly saves time in writing—that is, Arabic 3 is easier to write than Roman III. But this advantage is only a minor part of the system's usefulness. The truly revolutionary aspect of the Arabic system is that the placement of each symbol determines its value. That is, Arabic numerals are written one after the other on a single line and their place in that line indicates the number's value.

Take, for example, the number 692. Because we read from left to right, six starts the number, nine follows it, and two follows the nine. The number's position, or place, in the line determines the value of that number. In this case, the position of the six represents 600, or six hundreds; the nine represents 90, or ten nines; and the two represents two ones. Consequently, we read it as six hundred ninety-two—that is, the number contains six hundreds, nine tens, and two ones.

Another feature of Arabic numbers is that we can put different numbers in columns and manipulate them in many ways. For example, as you will soon learn, several numbers can be added together, subtracted from each other, multiplied by each other, and divided by each other.

Table 1.2 shows four Arabic numerals arranged in columns. The numbers are 5, 50, 500, and 5,000. Reading from left to right and starting in the table's first row, the table displays these numbers as 0005, 0050, 0500, and 5,000 to show

2
The Calculator

OBJECTIVES

Upon completing chapter 2, the student will be able to—

1. Choose a calculator that matches calculation needs with calculator design.
2. Explain the differences and similarities of the three types of notation commonly used in calculators.
3. Describe the functions of commonly used keys on a calculator.
4. Solve addition, subtraction, multiplication, and division problems on a calculator.
5. Solve square root and percentage problems using a calculator.
6. Perform chain calculations using the memory function of a calculator.

INTRODUCTION

Calculators represent a major technological advancement. However, calculators are so common that few people realize just how technologically advanced they are.

The earliest calculators offered four basic functions: addition, subtraction, multiplication, and division. Later, manufacturers added percentage and square-root functions. Today's sophisticated models not only include trigonometric, logarithmic, and graphing functions, but also include preprogrammed scientific operations, which rapidly calculate problems that would require many steps on a four-function calculator.

A calculator eliminates the tedious aspects of carrying out calculations. For example, you may recall that working the square-root problem in chapter 1 was a long, drawn-out process. But, to obtain the root on a calculator with a square-root function, merely enter the number you wish to find the square root of and press the square-root function key. The calculator displays the square root in a fraction of the time required to work it out on paper.

Calculators are valuable tools for solving mathematical problems related to many industrial operations. For example, in oilwell drilling operations, high-pressure fluids from a formation—a *kick*—may enter the wellbore. Crewmembers must quickly recognize and control a kick to prevent the well from blowing out. Supervisory personnel on rigs can use calculators to quickly determine actions needed to control the well. For example, they can calculate the new mud weight required to contain the pressure, determine pump circulating pressures, and find the number of strokes of the mud pump required to get the mud from the surface to the bit, all of which are vital to controlling the well.

Pipeline construction workers may use calculators to figure pipe buoyancy, while refinery employees may use them to determine heat transfer and material balance. Electricians may use a calculator to determine total load amperes, voltage drops in wiring, or power consumption. In virtually every industry, personnel use calculators for estimating the cost of materials and labor for a job.

CHOOSING A CALCULATOR

Calculators are available in a wide variety of capabilities and prices. The least expensive models not only perform addition, subtraction, multiplication, and division, but also percentages and square roots. Most also have a memory. The user can store a set of numbers in the calculator's memory and retrieve it later without having to reenter the numbers.

For example, suppose you need to convert several measurements in feet to metres. To convert feet to metres, you multiply the number of feet by 0.3048. By entering 0.3048 into the calculator's memory, you may recall this conversion factor by pressing a single key rather than entering 0.3048 each time you wish to make the conversion. Also, when solving complicated equations, you can store part of the solved equation in the calculator's memory. Then, you can retrieve the partial solution later when it is required to solve the entire problem. Later, this chapter covers both these uses of a calculator's memory.

More expensive models offer trigonometric and logarithmic functions, among other things. Also, advanced models are equipped with more than one level of memory. That is, you can store parts of a calculation in more than one place. Although this chapter does not cover it because programming is beyond the scope of this manual, some calculators are programmable: you can load special mathematical operations into the calculator, which allow it to perform advanced functions.

Calculator Features

When choosing a calculator, it is important to match your calculation needs with the calculator's capabilities. If you anticipate solving involved calculations, then consider buying a sophisticated model. On the other hand, if most calculations are little more than solving addition, subtraction, multiplication, and division problems, then a simple, inexpensive model is adequate.

Most of today's handheld calculators are battery operated or have a power cell that operates the calculator when it is struck by light. Manufacturers often call such calculators solar powered, but sunlight is not needed to operate them. Ordinary indoor or outdoor light is adequate. If batteries operate the calculator, it may come with an AC adapter-charger, which not only powers the calculator, but also charges the batteries when the calculator is plugged in. Desktop calculators may plug into a normal electrical outlet.

Keyboards have the usual operational symbols of +, –, ×, ÷, and =. Advanced models contain other symbols, such as %, √, x^2, y^x, log, and sin. (This chapter discusses these keys shortly.) The keyboard also has a period key (.), which is a decimal point. The number of symbols and characters vary with the complexity and price of the calculator. The manufacturer may print the numbers and symbols directly on the keys, on the case near the keys, or on both. In this chapter, reference to a key is by its symbol regardless of its printed location. Figure 2.1 shows typical calculator keyboards.

Small calculators display numbers and other entries in a window usually located at the top of the calculator. Light emitting diodes (LEDs) or liquid crystal displays (LCDs) show the numbers and symbols in the window. (Some desktop calculators also print out characters on a paper tape.) The display should be easy to read—that is, the size, color, intensity, and visibility of the symbols and numbers should be readable in sunlight as well as in artificial light.

3

Number Relations

OBJECTIVES

Upon completion of chapter 3, the student will be able to—

1. Discuss the relation of percent to the whole, and calculate a given percent of a given number.
2. Change percent to hundredths and hundredths to percent.
3. Solve for base, rate, or percentage in percent problems.
4. Read, write, and determine ratios of one quantity to another.
5. Solve problems involving direct proportion.
6. Solve problems involving inverse proportion, including pulley and gear ratio problems.
7. Find the average, or mean, of a set of statistics.
8. Find the median and mode in a body of data.
9. Use reference tables for extracting information.
10. Interpolate additional numerical data from information given in a table.
11. Name the parts of a table and construct a table from given data.
12. Extract approximate statistics from a graph, noting trends.
13. Determine the best method for depicting numerical information.
14. Plot and draw a bar graph, a line graph, and a circle graph.

INTRODUCTION

Number relationships, charts, graphs, and tables can help in making calculations and decisions. Charts, graphs, and the like can show trends, illustrate deductions, and help make decisions based on numerical facts. Common relationships are percentage, ratio, proportion, average, mean, median, and mode. Graphs, tables, and charts are often used to depict relationships.

PERCENTAGE

Percent expresses a proportion of an amount in hundredths. Percent means for or out of each hundred. The symbol for percent is % and it expresses quantity in relation to a whole. It is only used specifically and always with a number. For example:

$$26 \text{ percent} = {}^{26}\!/_{100} = 26\% = 0.26.$$
$$14\tfrac{1}{2} \text{ percent} = {}^{145}\!/_{1,000} = 14.5\% = 0.145.$$

To change from percent to hundredths, shift the decimal point two places to the left and drop the percent symbol. For example, to change 32% to hundredths, drop the % symbol and move the decimal point two places to the left, which yields 0.32. In other words, 32% = 0.32. To change a decimal fraction to percent, move the decimal point two places to the right and add the percent symbol; for example, 0.64 becomes 64%.

Example Problem: Find 14% of 430.

Solution:

14% = 0.14
$0.14 \times 430 = 60.2$.

Thus, 14% of 430 is 60.2.

If you have a calculator with a % key, all you do is enter:

$$430 \times 14\% = 60.2.$$

Example Problem: Find 4½% of 85.

Solution:

$0.045 \times 85 = 3.825$,

or, using the calculator,

$85 \times 4.5\% = 3.825$.

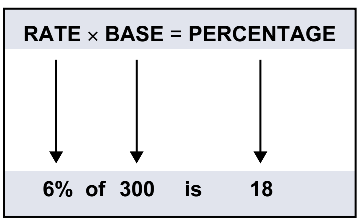


Figure 3.1 Percent relations

Base, Rate, and Percentage

Base, rate, and percentage are terms used in percentage problems. *Base* is the quantity of which a percentage is desired. *Rate* is a desired percentage of the base. *Percentage* is the product of the rate times the base. For example, figure 3.1 shows that 6% of 300 is 18. In this case, 6% is the rate, 300 is the base, and 18 is the percentage. The relationship of base, rate, and percentage can be expressed as

$$\textit{percentage} = \textit{rate} \times \textit{base}.$$

Three types of percentage problems involve finding one of these elements when the other two are known. First, when the base and rate are known, percentage is found by multiplying the base times the rate.

Example Problem: How much is 8% of $625?

Solution: In this example, 8% is the rate and $625 is the base. So, rate times base is

$625 × 0.08 = $50.00.
Eight percent of $625 is $50.00.

Example Problem: If a woman earns $120 and saves 12½% of it, what percentage of her earnings did she save?

Solution:

12½% = 12.5% = 0.125
$120 × 0.125 = $15.00.
The percentage saved is $15.00.

4
Principles of Algebra

OBJECTIVES

Upon completion of chapter 4, the student will be able to—

1. Use variables to represent an unknown quantity.
2. Solve an equation for an unknown quantity.
3. Convert a written problem into an equation and solve the equation.
4. Simplify an expression by removing the grouping symbols.
5. Add two or more algebraic expressions.
6. Add algebraic expressions containing a negative quantity.
7. Subtract one algebraic expression from another.
8. List the rules for multiplying algebraic expressions.
9. Multiply algebraic expressions containing exponents.
10. Divide one algebraic expression by another.
11. Transpose an equation to solve for a variable.
12. Use formulas to solve for quantities often used in industrial applications.

INTRODUCTION

In general, to calculate problems in simple arithmetic, only the numbers 0 through 9 (alone and in combination) and the signs +, −, ×, and ÷ are used. *Algebra* goes a step further because it not only employs numbers and signs, but also letters and symbols. For example, algebra uses the letters *a* through *z* and symbols such as γ, α, and β.

The letters and symbols in algebra represent variables. A *variable* is an unspecified or unknown quantity—a quantity that varies with a problem. A variable may denote different values in different problems, but it always represents the same value in a given problem. For instance, *x* may stand for gallons in one problem and for feet in another, but, if it is selected to stand for gallons in a problem, it must represent gallons throughout that problem.

Algebraic expressions—combinations of symbols, letters, and signs—are used in formulas and equations. A *formula* is a symbolic expression of a general fact, rule, or principle and is often stated as an equation. An *equation* is an expression of equality between two quantities.

ALGEBRAIC EXPRESSIONS

An algebraic expression is a combination of algebraic symbols and signs. For example, $2a + 3ab - 4c$ is an algebraic expression. The letters *a*, *b*, and *c* stand for unknown quantities. Also, *a* and *b* are used together (*ab*, which means $a \times b$) to form another unknown. These unknowns are *terms*. The terms of the expression are the combinations of symbols that a sign does not separate—for example, $2a$, $3ab$, and $4c$ are the terms of the expression $2a + 3ab - 4c$. The plus (+) and minus (–) are operational signs—they tell you to add or subtract. Also, $2a$, $3ab$, and $4c$ indicate multiplication in that $2a = 2 \times a$, $3ab = 3 \times a \times b$, and $4c = 4 \times c$. Thus, algebraic expressions may be added, subtracted, multiplied, and divided.

Example Problem: If $a = 6$, $b = 4$, and $c = 3$, find the value of $2a + 3b + 5c$.

Solution: Substitute numerical values for letters:

$$(2 \times 6) + (3 \times 4) + (5 \times 3) = 12 + 12 + 15 = 39.$$

Grouping Terms

Another important aspect of algebraic expressions is that the terms within them may be grouped. Grouping terms indicates the order in which these operations should be carried out. Parentheses (), brackets [], and braces {} may be used for grouping terms. These symbols indicate that you should keep certain terms together; they also indicate the order in which you should perform the various operations in the expression. These grouping symbols must be removed before addition or subtraction can be performed. Removing parentheses, brackets, and braces means performing the operation indicated inside them before working the rest of the expression. A few rules govern grouping symbols.

Rule 1. When an expression within the parentheses is preceded by the plus sign, the parentheses are removed without changing the signs within the parentheses.

Rule 2. When an expression within the parentheses is preceded by the minus sign, the parentheses are removed by changing the signs within the parentheses.

Rule 3. A number or symbol before the parentheses indicates that each term within the parentheses is to be multiplied by that number or symbol.

Example Problem: Simplify the expression, $3(a - b) + 4(b + c)$.

Solution: First remove the parentheses. Perform this calculation by understanding exactly what the expression states. In this case, the expression says to multiply a – b by 3, then add the result to 4 times b + c. So, to remove the parentheses:

$3 \times a$ and $3 \times b = 3a$ and $3b$; in the same way, $4 \times b = 4b$ and $4 \times c = 4c$. The result is

$$3a - 3b + 4b + 4c.$$

Then, combine like terms by performing the subtraction and addition:

$$3a + b + 4c.$$

Notice that only one part of the entire expression has like terms, which are $+4b$ and $-3b$. Subtracting $3b$ from $4b$ leaves $1b$, or simply b. Like terms are terms whose letters or symbols are the same. Just as you cannot add or subtract apples from oranges—they are unlike terms—you cannot add or subtract a from b, b from c, and so on. You can, of course, add or subtract like terms—apples and apples or oranges and oranges, as it were. In the case of the previous problem, subtract $3b$ from $4b$ to get b.

5

Some Physical Quantities and Their Measurement

OBJECTIVES

Upon completion of chapter 5, the student will be able to—

1. Describe the difference between fundamental quantities and derived quantities.
2. Convert measurements from U.S. conventional units to SI metric units and from SI metric units to conventional units.
3. Convert units of measurement to equivalent units in order to solve problems.
4. Use and read proper symbols and abbreviations for common measurement units.
5. Measure distance using a ruler or scale.
6. Solve problems using length, area, and volume measurements.
7. Convert temperatures from one scale of measurement to another.
8. Work in all increments of time measurement.
9. Solve problems involving measurements of weight, mass, force, work, power, pressure, density, and specific gravity.
10. Read simple electrical circuits and solve problems involving voltage, current, and resistance.
11. Solve for kilowatt-hours and other electrical power measurements.

INTRODUCTION

Quantity has many definitions. As used here, a *physical quantity* is something that has dimensions and can be measured, such as length, mass (weight), and time. These three physical quantities are *fundamental quantities*. A fundamental quantity cannot normally be divided into other quantities. Seven major fundamental quantities exist: (1) length, (2) mass, (3) time, (4) electricity, (5) luminous intensity, (6) temperature, and (7) the amount of a substance.

Another term for a fundamental quantity is *dimension*. Dimensions include distance (length), time, and mass (weight). So, we can say, for example, that the dimension of a room is 12 feet wide by 14 feet long by 8 feet high. We can also say that it takes two hours to complete a journey, and that a car weighs 3,250 pounds.

Scientists derived several nonfundamental quantities from the seven fundamental quantities. Consequently, they called nonfundamental quantities *derived quantities*. For example, velocity is a derived physical quantity because it is composed of distance (length) and time. So, when we speak of velocity, we speak of it in terms of miles per hour, feet per second, and so forth. Another example of a derived quantity is pressure. It is a measure of a force on a given area—for example, pounds per square inch.

TABLE 5.1
Conventional and Metric (SI) Units of Measurement for Some Physical Quantities

	Conventional		Metric (SI)	
Quantity	**Unit**	**Symbol**	**Unit**	**Symbol**
Fundamental Quantities				
Length	foot	ft	metre	m
Mass	pound	lb	kilogram	kg
Time	second	sec	second	s
Temperature	degree Fahrenheit degree Rankine	°F °R	degree Celsius Kelvin	°C K
Electrical current	ampere	A	ampere	A
Amount of substance	mole	mol	mole	mol
Luminous intensity	candela	cd	candela	cd
Derived Quantities				
Acceleration	feet per second per second	ft/sec^2	metre per second per second	m/s^2
Area	square feet	ft^2	square metre	m^2
Density	pound per cubic foot	lb/ft^3	kilogram per cubic metre	kg/m^3
Electrical potential	volt	V	volt	V
Electrical resistance	ohm	Ω	ohm	Ω
Electrical capacitance	farad	F	farad	F
Energy	kilowatt-hour	kWh	kilowatt-hour	kWh
Force	pound-force	lb_f	newton	N
Frequency	hertz	Hz	hertz	Hz
Power	foot-pound per second horsepower watt	ft-lb/sec hp W	joule per second watt	J/s W
Pressure	pound-force per square inch	psi	pascal	Pa
Velocity	foot per second	ft/sec	metre per second	m/s
Volume	cubic foot gallon barrel	ft^3 gal bbl	cubic metre	m^3
Work	foot-pound	ft-lb	joule newton-metre	J N•m

6
Practical Geometry

OBJECTIVES

Upon completion of chapter 6, the student will be able to—

1. Find the perimeters of rectangles and other parallelograms, trapezoids, triangles, and polygons.
2. Find the circumferences of circles and ellipses.
3. Find the length of a triangle's side with the dimensions of two sides given.
4. Find the areas of parallelograms, trapezoids, triangles, regular polygons, circles, and ellipses.
5. Solve problems involving plane figures by using geometrical formulas.
6. Find the volumes of rectangular solids, cylinders, elliptical solids, cones, pyramids, frustums of cones and pyramids, and spheres.
7. Find the lateral and total surface areas of some solid figures.
8. Solve problems involving solid figures by using geometrical formulas.
9. Construct geometric figures by using only a compass and a straightedge.
10. Use triangles and a T-square properly for drawing geometric figures.

INTRODUCTION

Geometry deals with the measurements, properties, and relationships of points, lines, angles, surfaces, and solids. Plane geometry is concerned with plane, or two-dimensional, figures, such as squares, rectangles, triangles, and circles. Solid geometry deals with solid, or three-dimensional, objects, such as cubes, pyramids, cones, and spheres.

To solve advanced geometry problems, you must use deductive reasoning—that is, you must apply logical thinking along with special statements, which are called theorems, to solve problems. A *theorem* is a proposition or a formula that can be solved, or proved, by using basic assumptions and declarations called axioms.

An *axiom* is a statement or an idea that is accepted as true. For example, a mathematician may say that a statement or formula is axiomatic. By axiomatic, the mathematician means that the statement cannot be proven but that it is nevertheless accepted as true. An axiomatic equation, for instance, is 2 + 2 = 4. It is axiomatic because the equation assumes that everyone agrees that figures we call numbers exist, that we agree what the numbers stand for, and that if we add two and two, we get four.

To solve complex geometry problems, you must clearly understand the terms, comprehend the theorems and their related formulas, and be able to draw conclusions based on given facts. Students of pure geometry spend a great deal of time proving theorems. That is, a theorem is proposed as true and, using axioms, students prove whether it is or is not true. This chapter, however, does not prove theorems. Rather, it covers practical geometry problems that you may encounter in the shop or field.

Geometric construction—that is, drawing accurate geometric figures—aids in visualizing a problem and its solution. So, you should also learn to use a geometric compass, straightedge, and basic drawing tools. (A geometric compass, unlike the direction finding instrument, is a V-shaped device for drawing circles or circular arcs.)

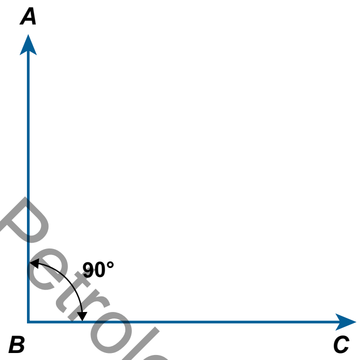


Figure 6.1 Right angle

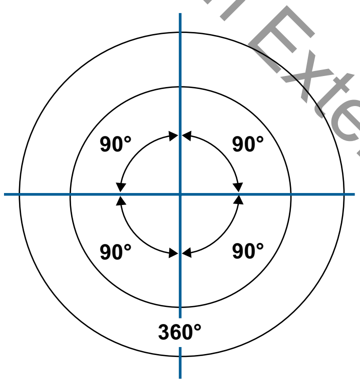


Figure 6.2 Circle

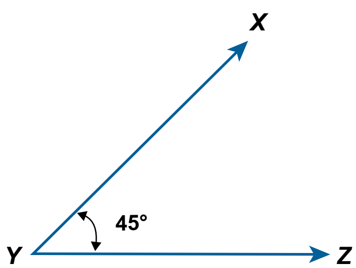


Figure 6.3 Acute angle

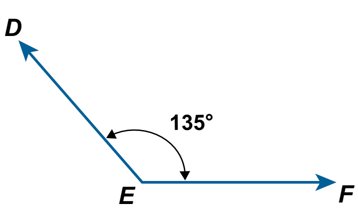


Figure 6.4 Obtuse angle

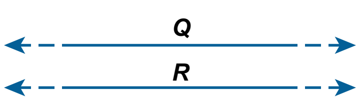


Figure 6.5 Parallel lines

PLANE FIGURES

Lines and angles are the basic elements that make up plane geometric figures. Examples of plane geometrical figures and a polygon or a circle. A polygon is any closed figure of three or more straight sides on the same plane. A polygon has length and width, but no depth. The most common mathematical problems involving plane figures are determining their perimeters and their areas. The *perimeter* of a polygon is the total distance of all its sides. The area of a polygon is the amount of space that it encloses.

Measurements of length and width (or base and altitude, or height) and angles determine the area and perimeter of a polygon. Polygons include squares, rectangles, multisided figures such as hexagons and octagons, trapezoids, parallelograms, and triangles. A circle is a closed plane curve, all points of which are equally distant from a point within called the center. Circle measurements include circumference, radius, diameter, and area.

Angles and Lines

An angle is formed when two straight lines, called sides, meet at a point, called the vertex. For example, in figure 6.1 sides *AB* and *BC* meet at point *B*, forming the angle *ABC*. The vertex of the angle is at *B*. The size of an angle is measured in degrees (°). One degree is a unit of measurement that is equal to 1/360 of a circle. The angle in figure 6.1 contains 90° and is called a right angle. If a circle is divided into four equal parts, it contains four right angles of 90° each, or 360° (fig. 6.2). So, a circle contains 360°.

An angle that measures less than 90° is an acute angle (fig. 6.3), and an angle that measures more than 90° is an obtuse angle (fig. 6.4). The acute angle in figure 6.3 is a 45° angle. The obtuse angle in figure 6.4 is a 135° angle.

Lines may be straight or curved. Mathematically speaking, lines have length but not width and generally lie between two points. Parallel lines are straight lines in the same plane that do not meet, or intersect, however far extended. Lines *Q* and *R* in figure 6.5 are parallel lines; they are equidistant from all points on the lines.

Perpendicular lines meet at right angles to each other, like the lines *AB* and *BC* in figure 6.1. Put another way, line *AB* is perpendicular to line *BC*.

Parallelograms

A parallelogram is a closed figure whose opposite sides are parallel (fig. 6.6). If the sides do not meet at right angles, as in figure 6.6, then the figure is a parallelogram. If, however, the sides meet at right angles—that is, if they are perpendicular to each other—then the parallelogram is a rectangle (fig. 6.7).

7
Trigonometry

OBJECTIVES

Upon completion of chapter 7, the student will be able to—

1. Explain the principles of right triangle trigonometry.
2. Define the three most common trigonometric functions, or ratios: sine, cosine, and tangent.
3. Use trigonometric functions to find the unknown measurement of one side of a right triangle when the other two sides or one acute angle and one side are known.
4. Use a table of trigonometric functions or a scientific calculator to quickly solve for missing values in triangles.
5. Name the reciprocals of the sine, cosine, and tangent.
6. Determine which trigonometric function to use when solving problems involving triangles.
7. Solve for unknown measurements of oblique triangles by using trigonometric formulas.
8. Find the area of triangles by using trigonometric functions.
9. Apply trigonometric formulas to everyday situations by constructing triangles to represent the situations.
10. Solve problems requiring the use of inverse functions.

INTRODUCTION

Trigonometry is the study of triangles and their use in solving problems. Indeed, the word trigonometry derives from the Greek words for triangle measurement. All triangles have sides and angles, and trigonometry deals with the relationship these sides and angles have to each other. Using trigonometry, unknown data can be found from given, or known, data. For example, surveyors can compute a distance that they cannot physically measure by determining angles and lengths with their surveying instruments. Then, using these known values and trigonometric ratios, they can find the unknown measurement.

To understand the basis for trigonometry, consider the two triangles in figure 7.1. Although triangle $A'B'C'$ is larger than triangle ABC, the angles are the same—90, 60, and 30 degrees in this case. Because the angles are the same, the ratios of the sides of the triangles are the same. That is, the length of the sides of both triangles is proportional to each other because the angles are the same. The principles of trigonometry come from these ratios.

The *right triangle* (a triangle with a right, or 90-degree, angle) is the basis for all trigonometry calculations. The relationships between a right triangle's angles and sides are simple and well known. Even so, trigonometric formulas can also solve problems with *oblique triangles*, which are triangles without right angles, as you will learn later in this chapter.

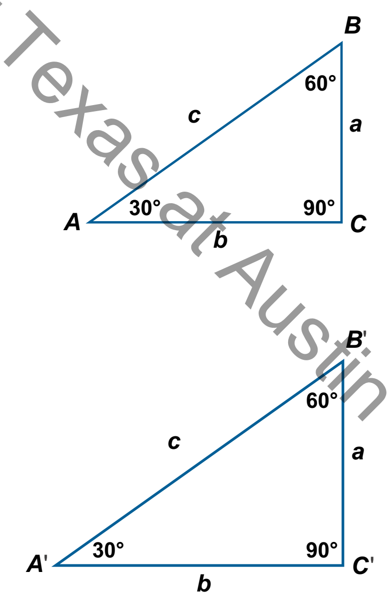


Figure 7.1 Triangle ratios

RIGHT TRIANGLE TRIGONOMETRY

Right triangle trigonometry allows you to solve problems involving triangles that have a right angle. When you know the values of two of the sides of a right triangle, or the value of one angle and one side of a right triangle, you can indirectly calculate the values of the remaining angles and sides.

Angles are measured from an arbitrary radial line of a circle. A *radial line* is a straight line that begins at the center of the circle and runs, or radiates, outward from the center. Draw several radial lines inside a circle and the spaces between the lines are angles. Angles are measured in degrees, minutes, and seconds. A circle has 360 degrees (360°). Each degree is made up of 60 minutes (60') and each minute is made up of sixty seconds (60"). Thus, a 360° circle contains 21,600' and 1,296,000".

A *quadrant* is one-fourth of a circle, or 90°, and a 90° angle is a right angle. A right triangle has one right angle (a 90° angle) and two acute angles, which are angles of less than 90°. Regardless of the size of each of the two acute angles, their sum is 90°. Therefore, the sum of all three angles in a right triangle is 180°. This fact can be helpful when determining the value of the acute angles in a right triangle. For example, if you know that a right triangle has one acute angle of 60°, you also know that the other acute angle is 30° because 180 – 90 – 60 = 30° and 90 + 60 + 30 = 180°.

Trigonometric Functions

A trigonometric function expresses the relationship between the angles and sides of a right triangle. Trigonometric functions, or ratios, involve two sides and an acute angle of a right triangle. One side of a right triangle is the hypotenuse. The other two sides of a right triangle are generally referred to as being opposite or adjacent to an angle.

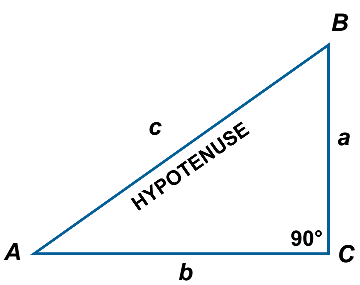


Figure 7.2 Sides of triangle

Figure 7.2 shows the sides of a right triangle. Side *c* is the hypotenuse and is opposite right angle *C*. Side *a* is opposite angle *A*, and side *b* is opposite angle *B*. Side *a* is also adjacent to angle *B*, and side *b* is adjacent to angle *A*. Although side *c* is also adjacent to angles *A* and *B*, the side opposite the right angle is always the hypotenuse. Understanding this terminology is important because trigonometric functions are defined in terms of these sides. The three most commonly used trigonometric functions are *sine* (sin), *cosine* (cos), and *tangent* (tan).

Sine

The sine of an acute angle in a right triangle is a trigonometric function equal to the length of the side opposite the angle divided by the hypotenuse. Put another way, sine is found by dividing the side opposite the acute angle by the hypotenuse:

$$\text{sine} = \frac{\text{opposite side}}{\text{hypotenuse}}\,.$$

As mentioned earlier, figure 7.2 shows a right triangle with angles *A*, *B*, and *C* and sides *a*, *b*, and *c*. Angles *A* and *B* are acute angles. Side *a* is opposite angle *A* and side *b* is opposite angle *B*. Angle *C* is 90°. Side *c* is opposite angle *C* and is the hypotenuse. The sine of angle *A* (referred to as sin *A*) is

$$\text{sine } A = \frac{a}{c}$$

8

Advanced Math Concepts

OBJECTIVES

Upon completing chapter 8, the student will be able to—

1. Identify binary devices that have only two states.
2. Write numbers with value in binary format.
3. Compare various number systems with specific base numbers.
4. Add, subtract, multiply, and divide logic numbers.
5. Create octal numbers from binary numbers.
6. Create hexadecimal numbers from binary numbers.
7. Prepare numbers in ASCII format.
8. Write numbers in BCD and Gray code format.

INTRODUCTION

The first chapter of this manual pointed out that our numbering system is based on the ten fingers on our hands. Because we have ten fingers and it is easy to count on them, it is logical that we base our numbering system on 10. Later, Arabic-speaking scholars developed this primitive system into what we now term the base 10, or decimal, numbering system. In the base 10 system, characters begin at 0 and end at 9. To count above 9, we create the double-digit number of 10. In the number 10, 1 represents the value ten and the 0 represents the value one. Put another way, the number 10 represents zero ones and one ten. We commonly refer to this number as representing the quantity ten. When we say the number, we normally don't say, "one ten and zero ones"; instead, we abbreviate it simply to ten.

Now, consider the number 203. In this case, 2 is in the hundreds column, 0 is in the tens column, and 3 is in the ones column. So, the number 203 represents 2 hundreds, 0 tens, and 3 ones. However, we simply say that this number is two hundred-three. Notice that the place of the numbers in the base 10, or decimal, numbering system shows their relative value.

Thus, the ones are in the right-most column. Then, moving one column at a time from right to left, come the tens, the hundreds, the thousands, the ten thousands, and so on. For example, the number 34,895 has 5 ones, 9 tens, 8 hundreds, 4 thousands, and 3 ten thousands. Notice that each succeeding column is a multiple of 10—that is, 10 is ten ones, 100 is 10 tens, 1,000 is 10 hundreds, and so on. Since the base number in the decimal system is 10, number values can be shown in columns (table 8.1).

The example decimal number is written as 3,634,209 and is read as three million, six hundred thirty-four thousand, two hundred nine. In reality, this number results from adding seven numbers: 3,000,000 + 600,000 + 30,000 + 4,000 + 200 + 00 + 9. The placement of the numbers signifies their relative value in this system. When saying or writing a complete number, we abbreviate it.

TABLE 8.1
Base Ten Numbers

Base number with exponent	10^6	10^5	10^4	10^3	10^2	10^1	10^0
Equivalent decimal value	1,000,000	100,000	10,000	1,000	100	10	1
Example decimal number	3,	6	3	4,	2	0	9

BINARY ARITHMETIC

Most people take the decimal number system for granted because the numbers are easy to see, speak, and write. However, computers are a big part of most people's lives, and a digital computer does not have the ability to see, speak, or write decimal numbers. Decimal numbers are characters or symbols of varying shapes that the core of a computer system cannot recognize directly. Special programs must be written before a computer can deal with the numbers that are so familiar to us. On the other hand, computers easily recognize the presence or absence of an electrical signal. That is, a computer can recognize a signal that has two states: either present or absent. A two-state signal is referred to as a binary signal. You can think of a computer as having only one finger that is either present or absent depending on which of the two states is occurring.

Binary logic is the study of statements, devices, or symbols that can be represented in two distinct states or conditions. Examples of binary conditions are on/off, true/false, yes/no, black/white, and high/low. An example of a device that exhibits two states is a light switch because it is either on or off. Many devices exhibit a two-state condition and are referred to as binary devices. No contradiction exists between these two states and they are considered to be absolute, but opposite, conditions. Just as the decimal system is termed the base-ten system, the binary system is termed a base-two system.

The binary numbering system uses the symbols 1 and 0 to represent the only two numbers in the system. Keep in mind that 1 and 0 do not have numerical value, although they resemble the decimal system's 1 and 0; 1 and 0 are only symbols that represent one of two binary states.

The binary number system has several characteristics, which include—

1. It is a base 2 numbering system.
2. It uses 1 and 0 as symbols to make discrete decisions or to show states of devices.
3. The largest valued symbol is 1. The lowest valued symbol is 0.
4. The decimal number 0 is a valid number when converting binary numbers to decimal.

A binary number can be converted to decimal and decimal to binary by using table 8.2. Table 8.2 counts through 4 binary digits. Incidentally, the term *binary digit* is often shortened to *bit*; so, 4 binary digits can also be called 4 bits. The table shows the binary digits, or bits, as 2 raised to the exponents 0, 1, 2, and 3. Larger binary numbers can be achieved by adding more columns with values such as 2^4, 2^5, 2^6, 2^7, and 2^8.

To use the table to convert binary numbers to decimal numbers, be aware that any 0 in the columns of binary numbers is not valid. On the other hand, a 1 in the columns of binary numbers indicates the value is valid, or, as a mathematician might

9
Advanced Oil Industry Applications

OBJECTIVES

Upon completion of chapter 9, the student will be able to—

1. Perform an electrical loading analysis of drilling, production, pipeline, and refining facilities.
2. Calculate electrical power factor of a system.
3. Analyze PLC applications using logic numbering systems.
4. Understand how electrical power influences diesel engine power loading.
5. Calculate mud control problems involving mud in the system, mud weighting, cycle time, and annular volume and velocity of mud.
6. Solve well-control problems dealing with hydrostatic pressure, circulating pressure, bottomhole pressure, shut-in drill pipe pressure, maximum allowable surface pressure, and gradients of mud and influx.
7. Determine the ton-miles of service required by a drilling line while making a round trip, making hole, coring, and setting casing.
8. Determine the amount of emulsion-treating chemical needed to use on a lease.
9. Calculate the hourly gas flow through an orifice meter.
10. Determine how to calibrate electronic instruments using basic math principles.
11. Calculate negative buoyancy involved in pipeline construction under water.
12. Convert hydrostatic head to pressure and vice versa in dealing with pumps.
13. Find the pump horsepower needed for an oil pipeline.
14. Determine the locations of pipeline pumping stations and plot a profile of ground elevations along a pipeline route.
15. Find the amount of heat required to raise the temperature of a volume of liquid.
16. Calculate the amount of product from a particular refining process using known data on feeds and other products.

INTRODUCTION

This chapter gives several equations that are useful to those who work in the petroleum industry. However, those who work in other industries may also find them helpful. Furthermore, be aware that Appendix A lists other industry-related formulas that are used in this text.

For more detailed explanations of electrical power and the power factors, see the Petroleum Extension (PETEX) publication entitled *Basic Electronics for the Petroleum Industry*, fourth edition. Other PETEX publications that readers should find helpful concerning the subjects covered in the chapter include *Basic Instrumentation,* fourth edition; *Diesel Engines and Electric Power,* third edition, revised; *Drilling Fluids, Mud Pumps, and Conditioning Equipment*; *Practical Well Control,* fourth edition; *The Blocks and Drilling Line*, third edition, revised; *Treating Oilfield Emulsions*, fourth edition; and *Gas and Liquid Measurement*.

ELECTRICAL POWER AND POWER FACTOR EQUATIONS

In alternating current (AC) electrical systems, the equipment being powered influences the form of power a transformer or generator delivers to the equipment. Also, whether the system is single-phase or three-phase influences wire and equipment sizing.

Three forms of electrical power exist in AC systems. They include—

1. apparent power, in kilovolt-amperes (kVA);
2. real power, in kilowatts (kW); and
3. reactive power, in kilovolt-amperes-reactive (kVARs).

Apparent power is the vector sum of the power in watts plus the reactive power in volt-amperes reactive (VAR) in a circuit.

Real power is the component of apparent power that represents true work. Real power is expressed in watts and equals volt-amperes multiplied by the power factor.

Reactive power is the value of the power in an electric circuit obtained by multiplying the effective value of the current in amperes, the effective value of the voltage in volts, and the sine of the angular phase difference between current and voltage.

In addition, a ratio of real power to apparent power is a measure of how power is being delivered and used. This ratio is referred to as the *power factor* and is expressed in equation form as:

$$pf = \frac{kW}{kVA} = \frac{W}{VA}$$

where

pf = power factor
kW = kilowatts
kVA = kilovolt-amperes
W = watts
VA = volt-amperes.

Apparent power is the result of multiplying voltage by current. Apparent power is also considered to be the total power. On the other hand, the capacitors and inductors in the load determine reactive power. Therefore, the power actually doing work is the real power, in kW, which is subtracted from the apparent power by the amount of reactive power.

A right triangle—a power triangle—shows the three forms of power (fig. 9.1). Side *a* of the triangle represents the amount of kW, side *b* represents the amount of kVARs, and the hypotenuse (side *c*) represents total power, or kVA.

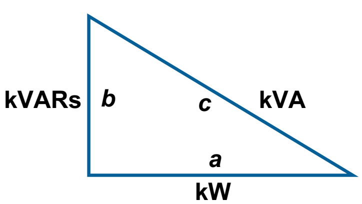


Figure 9.1 Power triangle

Appendix A
COMMONLY USED FORMULAS

A-1. PROPORTION AND RATIO

Direct proportion:

$$a:b = c:d, \text{ or } ad = bc$$

Inverse proportion:

$$a:d = b:c, \text{ or } ac = bd$$

where

a = small, or first term
b = small, or second term
c = large, or third term
d = large, or fourth term.

Pulley ratio:

$$S_A/S_B = d_B/d_A$$

where

S_A = speed of pulley A
S_B = speed of pulley B
d_A = diameter of pulley A
d_B = diameter of pulley B.

Gear ratio:

$$S_A \times T_A = S_B \times T_B$$

where

S_A = speed of gear A
T_A = number of teeth in gear A
S_B = speed of gear B
T_B = number of teeth in gear B.

A-2. LENGTH, AREA, AND VOLUME

Board feet:

$$bd\,ft = \frac{t \times w \times l}{12}$$

where

$bd\,ft$ = board feet in lumber
t = thickness of board, in inches
w = width of board, in inches
l = length of board, in feet.

Circle:

$$C = \pi d$$
$$C = \pi 2r$$
$$d = C/\pi$$
$$d = 2r$$
$$A = \pi r^2$$
$$r = \sqrt{A/\pi}$$

where

C = circumference
d = diameter
r = radius
π = 3.1416
A = area.

Cone, right circular:

$$L = \tfrac{1}{2}sC$$
$$V = \tfrac{1}{3}(BH)$$
$$V = \tfrac{1}{3}(\pi r^2 h)$$

where

L = lateral surface
s = slant height
V = volume
B = area of base
r = radius of base
h = height, or altitude
π = 3.1416
C = circumference of base.

Cube:

$$V = l^3$$

where

V = volume
l = length of one side.

Cylinder, right:

$$L = 2\pi rh$$
$$L = hC$$
$$T = 2\pi r(r + h)$$
$$V = Bh$$
$$V = \pi r^2 h$$

where

L = lateral surface
T = total surface area
r = radius of base
h = altitude
C = circumference of base
π = 3.1416
V = volume
B = area of base.

Appendix B
REFERENCE TABLES

B-1. DECIMAL EQUIVALENTS

Fraction	Decimal Equivalent	Fraction	Decimal Equivalent
1/64	0.015625	33/64	0.515625
1/32	0.03125	17/32	0.53125
3/64	0.046875	35/64	0.546875
1/16	0.0625	9/16	0.5625
5/64	0.078125	37/64	0.578125
3/32	0.09375	19/32	0.59375
7/64	0.109375	39/64	0.609375
1/8	**0.125**	**5/8**	**0.625**
9/64	0.140625	41/64	0.640625
5/32	0.15625	21/32	0.65625
11/64	0.171875	43/64	0.671875
3/17	0.1875	11/16	0.6875
13/64	0.203125	45/64	0.703125
7/32	0.21875	23/32	0.71875
15/64	0.234375	47/64	0.734375
1/4	**0.25**	**3/4**	**0.75**
17/64	0.265625	49/64	0.765625
9/32	0.28125	25/32	0.78125
19/64	0.296875	51/64	0.796875
5/16	0.3125	13/16	0.8125
21/64	0.328125	53/64	0.828125
11/32	0.34375	27/32	0.84375
23/64	0.359375	55/64	0.857375
3/8	**0.375**	**7/8**	**0.875**
25/64	0.390625	57/64	0.890625
13/32	0.40625	29/32	0.90625
27/64	0.421875	59/64	0.921875
7/16	0.4375	15/16	0.9375
29/64	0.453125	61/64	0.953125
15/32	0.46875	31/32	0.96875
31/64	0.484375	63/64	0.984375
1/2	**0.5**	**1**	**1**

Appendix C
CONVERSION FACTORS

C-1. CONVERSION FACTORS FOR CONVENTIONAL AND METRIC (SI) MEASUREMENTS

To use this table, multiply the number of known units of measure (in the left-hand column) by the conversion factor for the desired unit of measure; for example, to convert 50 barrels to gallons, multiply: 50 × 42 = 2,100 gallons.

Unit of Measure	Conventional Units		Metric Units	
To convert:	*to:*	*multiply by:*	*to:*	*multiply by:*
acre	square foot	43,560	square metre	4,046.875
	square yard	4,840	square kilometre	0.004046875
	square rod	160		
	square mile	0.0015625		
	section	0.0015625		
acre-foot	cubic foot	43,560	cubic metre	1,233.48766
bar	inch of water @ 60°F	407.229	millimetre of water @ 60°F	10,343.6
	inch of mercury @ 32°F	29.5282	millimetre of mercury @ 0°C	750.0187
barrel, U.S. petroleum (bbl)	cubic foot	5.6146	cubic metre	0.1589873
	gallon	42	litre	158.9873
British thermal unit @ 60°F (Btu)	foot-pound	777.97265	joule	1,054.68
	kilowatt-hour	0.00029283	kilowatt-hour	0.00029283
	calorie	251.98		
	horsepower-hour	0.0003927		
calorie (cal)	British thermal unit	0.003968	joule	4.1868
centimetre (cm)	mil	393.70	millimetre	10
	inch	0.3937	metre	0.01
	foot	0.032808		
centipoise (cp)	poise	100	pascal-second	0.001
cubic centimetre (cm^3)	cubic inch	0.061023	cubic millimetre	1,000
	cubic foot	0.000035314	millilitre	1
	gallon	0.00026417		
cubic foot	cubic inch	1,729.98829	cubic centimetre	28,317
	cubic yard	0.037036	cubic metre	0.028317
	gallon	7.48050		
	barrel	0.17811		
cubic foot of water (ft^3 of H_2O)	pound of water	62.3		
cubic foot/second (ft^3/sec)	gallon/minute	488.883		
cubic inch ($in.^3$)	cubic foot	0.0005787	cubic centimetre	16.38716
	cubic yard	0.000021434	litre	0.016387
	gallon	0.0043290	millilitre	16.38716

Glossary

abscissa *n:* the horizontal coordinate of a point in a plane obtained by measuring parallel to the x-axis. Compare *ordinate*.

addend *n*: one of a collection of numbers to be added.

algebra *n*: the part of mathematics in which letters and other general symbols are used to represent numbers and quantities in formulae and equations.

algebraic expression *n*: a mathematical expression consisting of a combination of numbers, symbols, letters, and signs.

ampere (A) *n*: the fundamental unit of electrical current; 1 ampere = 6.28×10^{18} electrons passing through the circuit per second. One ampere delivers 1 coulomb in 1 second.

antilogarithm *n*: the number of which a given number is the logarithm for a given base. See *logarithm*.

apparent power *n*: the vector sum of the power in watts plus the reactive power in volt-ampere-reactive (VAR) in a circuit. See *reactive power*.

Arabic numeral *n*: any of the symbols first invented by the Arabs to represent the numbers from one through nine and for zero.

area *n*: the extent of a surface enclosed within a boundary, found by obtaining the product of two lengths; the extent of the surface of all or part of a solid. For two-dimensional plane surfaces, area is usually stated in square units. For example, a rectangle 2 feet long on one side and 3 feet long on the other side has an area of 2 × 3 feet, which equals 6 square feet (ft^2). Thus, the area of the rectangle is 6 ft^2.

augend *n*: the quantity or number to which another quantity or number is added.

average *n*: approximately or resembling an arithmetic mean, specifically, about midway between extremes.

axiom *n*: a statement or idea that is generally accepted as true.

bar graph *n*: a type of graph that represents data with rectangular bars of differing heights or lengths, which is a good way to present data that represents a series of observations made at periodic intervals.

base *n*: in mathematics, the quantity of which a percentage is desired; in geometry, the side of a polygon that is oriented perpendicular to the direction in which height is measured or that is generally considered the bottom of the polygon.

binary digit *n*: a basic unit of information in a computer with a single binary value of either 0 or 1.

bit *n*: a shortening and portmanteau of the term "binary digit." See *binary digit*.

blowout *n:* an uncontrolled flow of gas, oil, or other well fluids into the atmosphere or into an underground formation. A blowout may occur when formation pressure exceeds the pressure applied to it by the column of drilling fluid and rig crew members fail to take steps to contain the pressure. Before a well blows out, it kicks; thus a kick precedes a blowout. See *kick*.

board foot *n*: a variation of volume measurement commonly used for lumber, consisting of 144 cubic inches of wood.

body *n*: the part of the table that presents the desired statistics.

Boolean logic *n*: a system of symbolic logic based on algebraic symbols representing such logical operations as AND, OR, and NOR.

boxhead *n*: the primary set of variables in a table. They also need units of measure to quantify them, such as percent, dollars, inches, and so on.

calibration *n*: the process of establishing the lowest process variable to be measured, along with the highest process variable to be measured through mechanical or electronic adjustment; sometimes called reranging. See *process variable*.

Celsius scale *n*: the metric scale of temperature measurement used universally by scientists. On this scale, 0° represents the freezing point of water and 100° its boiling point at a barometric pressure of 760 mm.

circle graph *n*: a type of graph in which a circle is divided into sectors that represent a proportion of the whole, often used to compare various parts of a whole to each other and to the whole.

common denominator *n*: a shared denominator in a series of fractions to be added or subtracted.

cosecant (cs) *n*: in a right triangle, the ratio of the hypotenuse to the side opposite a given angle, also known as the reciprocal of the sine function. See *sine.*

cosine (cos) *n*: in a right triangle, the ratio of the side adjacent to a given angle to the hypotenuse.

cotangent (cot) *n:* in a right triangle, the ratio of the side next to a given angle to the side opposite the given angle, also known as the reciprocal of the tangent function. See *tangent*.

current *n*: the flow of electric charge or the rate of such flow, measured in amperes.

current output *n*: the range of electrical current, measured in milliamperes (mA), which the electronic instrument produces during operation.

decimal key *n*: the key on a computer or calculator that allows the user to enter a decimal point into the display. See *decimal point*.

decimal point *n*: a period (.) placed to the left of the first digit in the decimal fraction.

decimal system *n*: the standard base ten number system.

denominator *n*: in a mathematical fraction, the term or number that divides the other term or number (called the numerator) and is written below the line.

density *n*: the mass or weight of a substance per unit volume.

derived quantity *n*: a non-fundamental quantity that scientists derived from the seven fundamental quantities. See *fundamental quantity.*

difference *n*: See *remainder.*

dimension *n*: another term for a fundamental quantity. See *fundamental quantity*.

dividend *n*: the number to be divided in a division problem.

divisor *n*: the number that does the dividing in a division problem.

electromotive force (emf) *n*: 1. the force that drives electrons and thus produces an electric current. 2. the voltage or electric pressure that causes an electric current to flow along a conductor. 3. a difference of potential, or electrical, flow through a circuit against a resistance.

ephemeris second *n*: an astronomical term based on the amount of time it takes for the Earth to orbit around the sun, rather than the time it takes the Earth to make one axial rotation.

equals key *n*: the key on a computer or calculator that allows the user to enter an equal sign into the display.

equation *n*: in mathematics, a statement that each of two expressions is the same as (is equal to) the other. For example, $a = b$ is an equation, as is $2 + 5 = 3 + 4$.

exponent *n*: in mathematics, a number or symbol, such as the 3 in x^3, placed to the right of and above another number, symbol, or expression, denoting the power to which that number, symbol, or expression is raised to. Also called power.

extremes *n*: the first and fourth terms of a proportion.

foot *n*: a unit of distance equal to 12 inches or 30.48 cm.

formula *n*: a symbolic expression of a general mathematical or scientific fact, rule, or principle, often stated as an equation.

fundamental quantity *n*: a quantity that cannot normally be divided into other quantities. The seven fundamental quantities are length, mass, time, electricity, luminous intensity, temperature, and amount of a substance.

gauge pressure (psig) *n*: 1. the amount of pressure exerted on the interior walls of a vessel by the fluid contained in it (as indicated by a pressure gauge). It is expressed in pounds per square inch gauge or in kilopascals. Gauge pressure plus atmospheric pressure equals absolute pressure. 2. pressure measured relative to atmospheric pressure considered as zero.

graph *n*: a diagram that indicates relationships between two or more variables.

hypotenuse *n*: the side of a right triangle that is the longest and located opposite the right angle.

ideal gas law *n*: the equation of the state of an ideal gas, showing a close approximation to real gases at sufficiently high temperature and low pressures. Combining Boyle's law with Charles' law, it states that the volume of a quantity of gas varies inversely as the absolute pressure and directly as the absolute temperature.

improper fraction *n*: a fraction in which the numerator is larger than the denominator.

inch *n*: a unit of distance equal to one-twelfth of a foot or 2.54 cm.

inertia *n*: the tendency of a stationary object to remain stationary or of a moving object to continue moving in a straight line, unless acted upon by an outside force.

interpolate *v*: to insert or estimate values between two known values.

joule (J) *n*: the unit of work and energy in the SI system, also known as the newton-metre (N•m).

Kelvin scale *n*: the absolute temperature scale for metric measurements, in which 0 indicates absolute zero temperature.

kick *n*: an entry of water, gas, oil, or other formation fluid into the wellbore during drilling, workover, or other operations. It occurs because the pressure exerted by the column of drilling or other fluid in the wellbore is not great enough to overcome the pressure exerted by the fluids in a formation exposed to the wellbore. If prompt action is not taken to control the kick, or kill the well, a blowout may occur. See *blowout*.

kilogram *n*: the metric unit of mass equal to 1,000 grams.

kilograms per square centimeter (kg/cm^2) *n*: a measure of pressure that falls outside the definition of force per unit area but may still be encountered where people employ the old metric system rather than using SI units. One kg/cm^2 is equal to about 98 kPA or 14.2 psi.

kilowatt (kW) *n*: a metric unit of power equal to approximately 1.34 horsepower; 1,000 watts. See *watt*.

leap year *n*: a year occurring every four years that contains 366 days by adding a 29th day to February in order to keep synchronized with the astronomical or seasonal year.

light year *n*: a measure of distance indicating the distance that light would travel in one year, equivalent to 9.4607 × 10^{12} km or 5.88 trillion miles.

line graph *n*: a type of graph in which data is represented by points connected by one or more lines to show trends and patterns in the data.

liquid measure *n:* a unit or series of units for measuring the volume of liquids.

log *abbr*: logarithm.

logarithm *n*: the exponent that indicates the power to which a number is raised to produce a given number. For example, the logarithm of 100 to the base 10 is 2.

lower range value (LRV) *n*: the lowest value of the process variable to be measured and calibrated.

lowest common denominator (LCD) *n*: the smallest number that all the denominators in a series of fractions will divide into evenly.

mass *n*: the quantity of matter a substance contains, independent of such external conditions as the buoyancy of the atmosphere or the acceleration caused by gravity.

mean *n*: the average of two or more observed values.

means *n*: the second and third terms of a proportion.

measured depth (MD) *n*: the total length of the wellbore, measured in feet along its actual course through the Earth. Measured depth can differ from true vertical depth, especially in directionally drilled wellbores. See *true vertical depth*.

median *n*: a statistical measure of the midmost value, such that half the values in a set are greater and half are less than the median.

metre *n*: the SI base unit of distance equal to 100 centimetres or about 3.28 feet.

mile *n*: a conventional unit of distance equal to 5,280 feet or 1,760 yards and approximately 1,609 metres.

minuend *n*: the number from which another number is to be subtracted.

mode *n*: the value that occurs most frequently in a set of data.

multiplicand *n*: the number that is to be multiplied or increased in multiples.

multiplier *n*: the number of times that the multiplicand is added to itself.

natural logarithm *n*: a logarithm to the base of *e*, which equals approximately 2.718. This type of logarithm comes about naturally in a mathematical process.

Newton per square metre (N/m^2) *n*: the SI unit of pressure, also known as a pascal (Pa).

number key *n*: a key on a computer or calculator that allows the user to enter a numeral into the display.

numerator *n*: in a mathematical fraction, the number or term that is written above the line and is to be divided by the denominator.

oblique triangle *n*: any triangle without right angles.

ohm (Ω) *n*: the SI unit for electrical resistance.

Ohm's law *n*: a basic law of electrical behavior, which states that the strength or intensity of an unvarying electrical current is directly proportional to the voltage and inversely proportional to the resistance of the current. The formula for Ohm's law is: $V = IR$, where V stands for voltage, I stands for current, and R stands for resistance.

operation key *n*: a key on a computer or calculator that allows the user to enter a mathematical operator (such as a plus sign, minus sign, multiplication sign, division sign, or other signs) into the display.

ordinate *n*: the vertical coordinate of a point in a plane obtained by measuring parallel to the y-axis. Compare *abscissa.*

orifice *n*: in gas measurement, a precisely drilled hole of a given size in a flat metal plate.

pascal (Pa) *n*: the SI unit for measuring pressure, equal to 1 N/m^2.

percent *n*: a proportion of an amount in hundredths. The symbol for percent is % and expresses quantity in relation to a whole.

percentage *n*: the product of the rate times the base when calculating percent.

perimeter *n*: the total distance of all the sides of a polygon.

physical quantity *n*: a quantity that has dimensions and can be measured, such as length, mass (weight), and time.

pie chart *n*: See *circle graph*.

plane figure *n*: a figure that only has two dimensions.

potential *n*: See *electromotive force* and *voltage.*

potential difference *n*: See *electromotive force* and *voltage.*

pound per square inch (psi) *n:* in the English system of measurement, the most often used unit of pressure.

pound per square inch absolute (psia) *n*: in the English system of measurement, the unit of pressure for absolute pressure, which signifies the total pressure measured from an absolute vacuum. Absolute pressure equals the sum of the gauge pressure and the atmospheric pressure, because the Earth's atmosphere exerts a pressure of about 14.7 psi at sea level.

power *n*: 1. for exponents, the number of times a root number is multiplied by itself. 2. the rate of time of doing work, expressed in foot-pounds per unit of time.

power factor (pf) *n*: the ratio of real power to apparent power. This ratio measures how effectively power is being delivered and used.

process variable (PV) *n*: the quantity of the process under consideration; this variable may be pressure, temperature, level, flow, density, or other characteristics of the process that can be measured.

product *n*: the result obtained by multiplying one number by another.

proportion *n*: a relation of equality between two ratios.

quadrant *n*: one-fourth of a circle, or 90° of a circle.

quantity *n*: a property that can exist in a range of magnitudes and multitudes.

quotient *n*: the result obtained by division.

radial line *n*: a straight line that begins at the center of the circle and radiates outward from the center.

rate *n*: in percentage problems, the desired percentage of the base.

ratio *n*: a proportional relationship between two numbers or quantities.

reactive power *n*: the value of the power in an electric circuit obtained by multiplying the effective value of the current in amperes, the effective value of the voltage in volts, and the sine of the angular phase difference between current and voltage.

real power *n*: the component of apparent power that represents true work. It is represented in watts and equals volt-amperes multiplied by the power factor.

reciprocal *n*: a number related to another number by the fact that the product of the two numbers is 1.

remainder *n*: the number that represents the results or answer to a subtraction problem.

resistance (R) *n*: opposition to the flow of direct current caused by a particular material or device. Resistance is equal to the voltage drop across the circuit divided by the current through the circuit.

right triangle *n*: a triangle that contains one 90° angle.

root *n*: one of the equal factors that, when multiplied together, produce a given number or quantity.

secant (sec) *n*: in a right triangle, the ratio of the hypotenuse to the side adjacent to a given angle, also known as the reciprocal of the cosine function. See *cosine.*

second *n*: the fundamental SI unit for time equal to $1/60$ of a minute.

sine (sin) *n*: in a right triangle, the ratio of the hypotenuse to the side opposite a given angle.

specific gravity (sp gr) *n*: the ratio between the weight of a given volume of a substance and the weight of an equal volume of pure water at 39°F.

square *n*: the product of a number multiplied by itself.

square root *n*: a number that produces a specified quantity when multiplied by itself.

straight average *n*: the average in a set of numbers obtained by adding all the quantities together and dividing by the number of quantities involved.

stub *n*: the second set of variables down the left side of a table.

subtrahend *n*: the number that is subtracted from the minuend in a subtraction problem.

sum *n*: the result obtained by addition.

table *n*: a set of data or information systematically organized and displayed in columns and rows.

tangent (tan) *n*: in a right triangle, the ratio of the side opposite a given angle over the side adjacent to the given angle.

term *n*: a combination of symbols in a mathematical expression that a sign does not separate.

theorem *n*: a proposition or formula that can be solved or proved by using basic assumptions and axioms.

times *n*: the sign used for multiplication.

title *n*: in a table, the name that describes the table and affects the amount of information that each boxhead must present.

transpose *v*: to move to a different place or cause two or more things to exchange places.

trigonometry *n*: the study of triangles and their use in solving problems.

true vertical depth *n*: the depth of a well measured from the surface straight down to the bottom of the well. The true vertical depth of a well may be quite different from its actual measured depth, because wells are very seldom drilled exactly vertical.

unit *n*: a quantity chosen as a standard of measurement in terms of which other quantities may be expressed.

upper range value (URV) *n*: the maximum value of the process variable to be measured and calibrated; sometimes referred to as span when adjusting the transmitter.

vapor density *n*: the density of a vapor or gas in relation to the density of hydrogen at the same pressure and temperature. Compare *specific gravity*.

volt (V) *n*: the SI unit for voltage or electromotive force.

voltage *n*: an electromotive force or electrical potential difference expressed in volts. See *electromotive force*.

volume *n*: the amount of a substance that occupies a particular space, obtained by taking the product of three lengths.

watt (W) *n*: the SI unit of power, equal to 1 J/s.

weighted average *n*: an average obtained by multiplying each number in the set by a factor reflecting its importance.

work *n*: the acting of a force through distance, or the overcoming of a resistance to motion. No work is done unless motion is produced. Mathematically, work is force times distance.

yard *n*: a conventional unit of distance equal to three feet.

Answer Key

Problems involving decimals may have discrepancies in their answers—for example, the problem involving the number of fans needed to change the air every 3 minutes in a given area. Possible answers are 4.053, 4.05, 4, or 5 fans, depending upon the practical application. Four fans will not quite do the job. Also, with 4 fans, there is no standby for emergency. The engineer would probably call for 5 fans. If the specification for a change of air each 3 minutes included a factor for safety, perhaps 4 fans would suffice. Obviously, it is not possible to install 4.053 fans, but that is the solution to the problem to three decimal places. At this point, judgment enters the picture.

Problems involving only whole numbers are precise in the results obtained. Many problems in fractions cannot be worked to a final answer. Rounding off fractions to whole numbers, to one place, to two places, and so forth will change the end result. For example, using pi on a calculator instead of 3.1416 will slightly alter an answer. Using rounded-off conversion factors as given in the chapter tables will result in answers different from those solved by using the exact conversion factors given in Appendix C. These answers may vary considerably if large quantities are involved.

As a user of this manual, you should compare your answer with that given, and if there is a difference, check your work. If it is not in error, then you might ask, "How can this difference be accounted for?" or "Is my answer satisfactory although perhaps not exact?" If it is satisfactory for the purpose you had in mind from the beginning, then it should be acceptable. However, you should always be able to explain how the difference arose.

ANSWERS TO PRACTICE PROBLEMS

1. THE NUMBER SYSTEM

Whole Numbers, pp. 13–14

1. a. 5,000
   b. 110
   c. 30
   d. 10
2. a. 42
   b. 361,000,000
   c. 27,051,289,000
   d. 20,400,502,000,000
3. a. four thousand, six hundred
   b. seventy-eight thousand
   c. eight million, six hundred thousand
   d. eighty billion, seven hundred forty million
4. a. 953
   b. 236
   c. 1,281,150
   d. 6,485,381
5. a. $3,520 per month
   $42,240 per year
   b. 17 hr
   c. 1,090 ft
   d. 4,811 ft

Common Fractions, pp. 19–20

1. a. $^{6}/_{64}$
   b. $^{12}/_{16}$
   c. $^{14}/_{16}$
   d. $^{7}/_{8}$
2. a. $^{4}/_{8}$, $^{1}/_{8}$, $^{6}/_{8}$
   b. $^{4}/_{32}$, $^{2}/_{32}$, $^{7}/_{32}$
   c. $^{56}/_{64}$, $^{19}/_{64}$, $^{22}/_{64}$, $^{17}/_{64}$, $^{4}/_{64}$, $^{62}/_{64}$
   d. $^{62}/_{64}$, $^{60}/_{64}$, $^{3}/_{64}$
3. a. $^{1}/_{2}$
   b. $^{7}/_{8}$
   c. $^{1}/_{8}$
   d. $^{5}/_{6}$
4. a. $1^{1}/_{2}$
   b. $3^{5}/_{16}$
   c. $^{7}/_{32}$
   d. $^{43}/_{64}$
5. a. $5^{5}/_{8}$
   b. $^{35}/_{160}$ or $^{7}/_{32}$
   c. $1^{1}/_{10}$
   d. $^{5}/_{18}$
6. 30 bbl
7. Jones: $28, 125
   Smith: $14,062.50
   White: $32,812.50
8. $^{5}/_{16}$"
9. $7'5^{9}/_{16}$"
10. $^{21}/_{64}$"

Mixed Numbers, pp. 23–24

1. 40 hr
2. $17^{15}/_{16}$"
3. $20^{29}/_{32}$"
4. $12^{1}/_{4}$ hr
5. $^{5}/_{32}$"
6. $45^{3}/_{8}$"
7. $764^{4}/_{13}$ bbl
8. 10
9. 21
10. 1,100 bbl

Decimal Fractions, pp. 31–32

1. a. three thousandths
   b. six hundred twenty-five thousandths
   c. one hundred twenty and four hundredths
   d. eight and three thousand, seven hundred, forty-five ten thousandths

2. a. 0.115; $^{115}/_{1,000}$
   b. 76.76; $76^{76}/_{100}$ or $76^{19}/_{25}$
   c. 5,000.6; $5000^{6}/_{10}$ or $5,000^{3}/_{5}$
   d. 3,125.8; $3,125^{8}/_{10}$ or $3,125^{4}/_{5}$
3. $196.16
4. $570.15
5. 3.21 gal
6. 42.48 hp
7. 53,400 lb
8. $23.03
9. 1.53 in.
10. 1.25 in.

Roots and Powers, p. 35

1. 28
2. 2,744
3. 36 mi^2
4. 3.2
5. 13,839

2. THE CALCULATOR, pp. 55–56

1. 117.8
2. 1,391.84
3. 5,035.24
4. 1,548.55
5. 1,872
6. 0.50
7. 548.17
8. 625
9. 408
10. 1,610,069.92
11. 59.45
12. 308 mi
13. $1.29
14. $14.70
15. 1,276.66

3. NUMBER RELATIONS

Percentage, pp. 61–62

1. $54.60
2. 17
3. $116.40
4. a. Tin—416.50 lb
   b. Copper—28 lb
   c. Antimony—55.50 lb
5. 200
6. $294.40
7. 15%
8. a. Lathe—53.70%
   b. Drill press—8.33%
   c. Shaper—25%
   d. Welding—12.96%
9. 1,282.05 bbl
10. a. 22
    b. $400/wk
    c. 58%
    d. $87^{1}/_{2}$%
    e. 50%

Ratio and Proportion, pp. 66–67

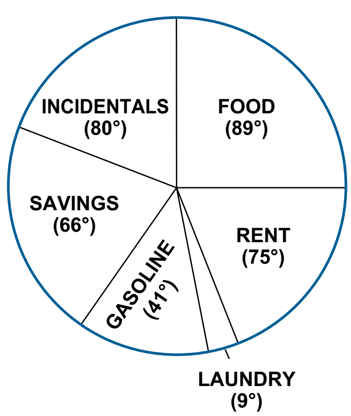
1. 25 to 1
2. 5 to 3
3. 1 to 14
4. 816 sacks
5. 40 ft
6. 50 men
7. 80 mph
8. 435 rpm
9. 200 rpm
10. 123.75 rpm

Mean (Average), Median, and Mode, p. 70

1. 110 rigs
2. 43.5¢ or 44¢/copy
3. 40.91
4. $1,860
5. 12", 1', or 30.48 cm

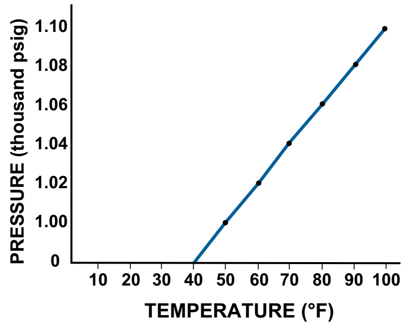
Tables and Graphs, pp. 75–77

1.



2. a. September, 1984
   b. Increased
   c. 8 million bbl/day
   d. 44 million bbl/day
   e. 1981

3.

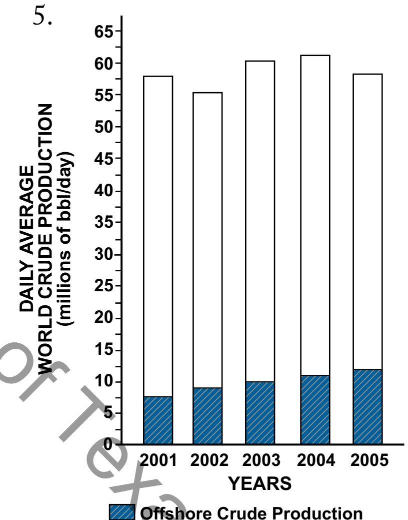


4.

GAS PIPE INSTALLED BY TYPE

Year	Plastic Pipe (mi)	Steel Pipe (mi)
2000	15,985	12,663
2001	11,640	9,718
2002	15,991	6,157
2003	14,576	7,212
2004	18,826	8,145
2005	18,912	8,334

5.



4. PRINCIPLES OF ALGEBRA

Algebraic Expressions, pp. 89–90

1. $3a - 3b$
2. $11a + 3b - bc + 6c$
3. $2a - 4ab + 26b - 2c$
4. $-3x + xy + y$
5. $15a - 8ab + 8b + 9c$
6. $a^2 - 4b + c$
7. $4x^2 - 6x - 6xy - 7y$
8. $-4a + 3ab - 15ac - 12b - 8c$
9. $5a^2 - 3ab - 14c^2$

10. $6x^2 - 10x - 4xy - 6y$
11. $4ax^2 + 8axy + 4ay^2$
12. $20a^2b + 30a^2b^2 + 15abc$
13. $3a^2 + ab - 4b^2$
14. $-4a^3 + 4a^2 - 8a^2b + 12ab - 4ab^2$
15. $x^2 + 2xy - 2x + 3y + y^2$
16. $-4a - 2b$
17. $9a^2 + 3a + 4b + 2b/a$
18. $m^2 - 3m + 14$
19. $x^2 - 2xy + y^2$
20. $m^2 - 4m + 8$

Equations, pp. 92–93

1. a. 36
   b. 22
   c. 10
2. 2
3. a. $a + c + b = e + a + b + d$
   b. $b + c + e = b + d + 2e$
   c. $c + a + d = c + e + b + d$
4. $71.50 per day
5. 7.43 lb
6. Greater number: 20
   Lesser number: 15
7. 1,225 ft^2
8. $147.69
9. 90
10. $5.00

Formulas, pp. 101–103

1. 0.4 darcys
2. a. 0.2364 in.
   b. 94.24 mi
   c. 6.56 yd
   d. 11.82 in.
   e. 6.56 ft
3. $130.00
4. 3.68 gal
5. a. $D = ST$
   b. $S = D/T$
   c. $T = D/S$
6. 55,063, or approx. 55,000 bbl
7. $sp\ gr = 141.5 \div (API + 131.5)$
8. 38.76 °API
9. $P_1 = P_2V_2 \div V_1$
   $V_1 = P_2V_2 \div P_1$
   $P_2 = P_1V_1 \div V_2$
   $V_2 = P_1V_1 \div P_2$
10. 1,651.26 ft^3

5. SOME PHYSICAL QUANTITIES AND THEIR MEASUREMENT

Length, Area, and Volume, pp. 120–122

1. a. 3/8 in.
   b. 5 3/4 in.
   c. 1 1/2 in.
   d. 3 1/16 in.
   e. 3 1/4 in.
2. a. 7.4 cm
   b. 3.8 cm
   c. 5.1 cm
   d. 1.2 cm
   e. 7.9 cm
3. 91.44 m
4. 30.48 cm
5. 51.49 km
6. 1.93 m
7. a. 2.40 m
   b. 2,400 mm
   c. 0.0024 km
   d. 2,400,000 mm
   e. 0.00000240 Mm
8. 1,196.17 yd^2
9. 14 hr
10. 10,857 $in.^3$
11. 144 $in.^3$
12. 4 bd ft
13. 1.48 yd^3
14. 0.00156 mi^2
15. 320
16. 1.323 yd^3
17. 158.928 litres
18. 7.0861 ft^3
19. 1,308.64 acres
20. 2.396 mi^2

Time and Temperature, pp. 126–127

1. a. 530 mph
   b. 8.833 mi/min
2. 21 min
3. 1,350 rpm
4. a. 161.6°F
   b. 68°F
   c. 32°F
   d. 22°F
   e. –108.4°F
5. a. –67.2°C
   b. 0°C
   c. 4°C
   d. –33.3°C
   e. –263°C
6. a. 51°C
   b. –70°C
   c. 20°C
   d. –23°C
   e. –224°C
7. a. 1,140°R
   b. 463°R
   c. 503°R
   d. 436°R
   e. 347°R
8. 12:47 P.M., Wed.
9. 99 min
10. 180.6 K

Mass and Related Derived Quantities, pp. 135–136

1. 907.185 kg
2. 53,400 daN; 534 kN
3. 631.579 ft
4. 11.023 lb
5. 1.8 lb/ft^3
6. 40.7669°API
7. 3,200 ft-lb
8. 51.6 psia
9. 15.93 lb
10. 6.928 psi

Electricity, pp. 141–142

1. 0.12 A
2. a. 60 V
   b. 3 A
   c. 12 V
   d. 3 A
3. 172.5 kWh
4. a. 1.96 Ω
   b. 0.385 A
   c. 0.25 A
   d. 19.2 V
   e. 148 Ω
5. 180 W
6. 240 Wh
7. 4 Ω
8. a. 7.5 A
   b. 225 W
9. 0.5 A
10. 500 W

6. PRACTICAL GEOMETRY

Plane Figures, pp. 156–159

1. 330 ft^2
2. 4.5 ft^2
3. 42 in.
4. 37.19 acres
5. 1,111.11 yd^2; 136.67 yd
6. 25 lb
7. ¾ of an acre
8. a. 11,200 ft^2
   b. 1,400 boards
9. 73.9, or 74 ft^2
10. a. 38.0431, or 38 ft^2
    b. 9 ft^2
    c. 65.96, or 66 in.^{2}
       b = 8.25"
11. 37.70 in.^{2}
12. 175.93, or 176
13. 0.0865 of an acre
14. 15 in.^{2}
15. a. 212.06 in.^{2}
    b. 805.82 in.^{2}

Solid Figures, pp. 167–170

1. 10,378.125 lb
2. 138.89 yd^3
3. 7.48 gal
4. 1,468.698, or 1,469 gal
5. 204.57 bbl
6. 7.83 gal
7. 24 lb
8. 10 ft^3
9. $3\frac{1}{9}$ yd^3
10. 12.101 ft^3
11. 11.13 lb
12. a. 18.96 ft^3
    b. 26.4 times/min
13. 4.14, or 5, fans
14. 20.23 lb
15. 59.6 ft^2

Geometric Constructions, pp. 179–181

Since these are construction exercises, no answers are given.

7. TRIGONOMETRY

Right Triangle Trigonometry, pp. 195–196

1. 75°
2. 8.49 in.
3. 42.43 ft
4. 8 in.
5. 6.93 in.
6. 20.42 in.
7. 17.54 ft
8. a. 22.29 ft
   b. 20.07 ft
9. 41°24'
10. 4.29°

Oblique Triangle Calculations, pp. 199–201

1. 81.91 ft
2. 9.25 in.
3. 58.40°
4. 5.63 in.
5. X = 0.88 in.
   Y = 1.52 in.
6. 2.39 in.
7. 15.06 ft^2
8. Approximately 300 ft^2
9. 13.5 ft
10. 3.53 in./side

9. ADVANCED OIL INDUSTRY APPLICATIONS

Mathematics in Drilling Operations, pp. 256–257

1. 1,201.08 sacks
2. 171.58 bbl
3. 444 hp
4. 299 ton-miles
5. 285 ton-miles
6. 4,212 psig
7. 11.7 ppg
8. 1,325 psi
9. 10.9 ppg
10. 0.52
11. 625 psi
12. 0.78

Mathematics in Production Operations, pp. 266–267

1. 0.74 bpd/psi
2. 14.06 hp
3. 4.03 pt
4. 38.59 Mcf/hr
5. 1.54 MMcf
6. 175°F

Mathematics in Pipeline Operations, pp. 272–273

1. 1,732 ft
2. 478.32 hp
3. 81.1 lb/ft
4. ½"
5. 8,805 ft

Mathematics in Refining Operations, p. 276

1. 0.813 Btu/lb/°F
2. 81%

ANSWERS TO SELF-TESTS

1. THE NUMBER SYSTEM, pp. 36–38

1. 2,242,000,000
2. $^{1}/_{4}$
3. $^{27}/_{32}$"
4. $4^{1}/_{8}$"
5. $^{27}/_{32}$"
6. Royalty owner: $19,880
   Operator: $139,160
7. 1,837.5 gal/hr
   44,100 gal/day
8. a. 0.5625
   b. 0.0938
   c. 0.4844
   d. $2^{21}/_{32}$
   e. $^{1}/_{16}$
9. 610.3 mi
10. 152.4 bbl
11. a. 266.4 lb
    b. 177.6 lb
12. $2.11
13. 64 pins
14. 4.7430 in.
15. a. $190,000
    b. 3,115 bbl
    c. 12,460 bbl
    d. $976
    e. 195 or 196 days
16. $533^{1}/_{3}$ bbl
17. a. 11
    b. 348
    c. 71,639,296
    d. 6.346
    e. 10,000
18. a. 0.109 in.
    b. 0.133 in.
    c. 0.154 in.
    d. 0.203 in.
    e. 0.216 in.
19. a. 11,250 gal
    b. 236,250 gal
    c. 337,500 gal
    d. $6,851.25
    e. $2,500,706.25
20. a. 3,063
    b. $8.50
    c. 2.75
    d. $88.27
    e. 6,400

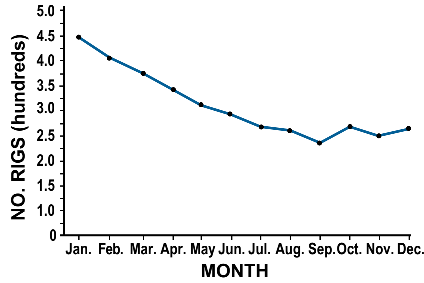
2. THE CALCULATOR, pp. 57–58

1. 45
2. 33.4411
3. 31.88
4. 8.33
5. 1
6. 365.6
7. 14,300
8. $2.00
9. 2,329.6
10. 1.12
11. 14.213986
12. 436.8
13. 2,496.7091
14. 3.898885
15. 59.16567
16. 12,016
17. 74.934007
18. 14.3175
19. $71.70
20. 2,303.818

3. NUMBER RELATIONS, pp. 78–81

1. 1 to 4
2. 312.5 ft
3. 1:3
4. 14.29 gal
5. $576.00
6. 3 hr 40 min.
7. 480 rpm
8. 294.55 rpm
9. 200 rpm
10. $40.71/bbl
11. 128 ft
12. Mean: 51.62°F
    Median: 52°F
    Mode: 52°F
13. $2.65/Mcf
14. 7.39¢/kWh
15. 39 qt

16.

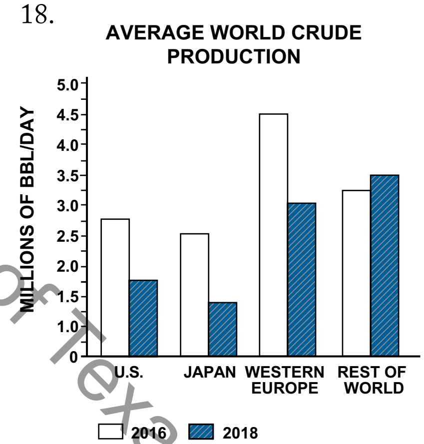


17.

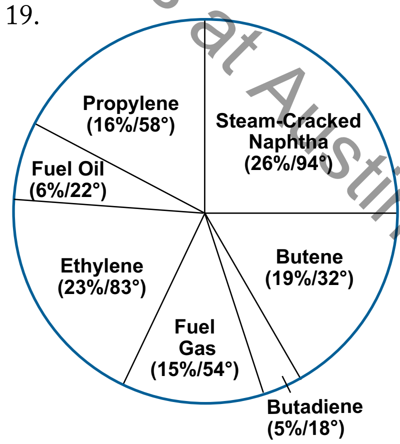
U.S. WHOLESALE PRODUCT PRICES ($/bbl)

	October 2011	November 2011	December 2011
Gasoline	$76.86	$63.34	$70.85
Kerosene	$42.20	$42.97	$36.88
Fuel oil	$52.30	$6166	$58.53
Residual fuel	$24.78	$26.06	$24.57

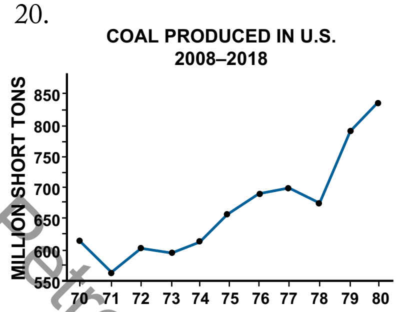
18.



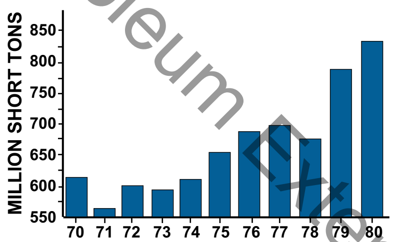
19.



20.



OR



4. PRINCIPLES OF ALGEBRA, pp. 104–108

1. a. $x = 4$
   b. $x = 9$
   c. $x = 30$
   d. $x = 20$
   e. $x = 13.07$
2. a. 45
   b. 66
   c. −78
   d. 54
   e. 107
3. 1,500 lb
4. a. $9x - 3y$
   b. $-x - 4y$
   c. $20x - 5y - 7z$
   d. $a + 5b + 8c + 21d$
   e. $x^2 + 11x^2y + 8xy^2$
5. a. $-a - 4c$
   b. $-3b - c$
   c. $x - y - 4z - 6$
   d. $3a^2 - 7a^2b + 2ab^2 + b^3$
   e. $8x^2z + 9z^3 + 2x^3 - xz^2$
6. a. $7a + 2b - 4$
   b. $2x^2 - 3x + 12$
   c. $3x - 12y$
   d. $9a - 7b + 6c$
   e. $-2y^2 + 4a^2$
7. a. $-5ab^2$
   b. $6x^5$
   c. $24x^8$
   d. $4x^3y + 8x^2y^2 + 4xy^3$
   e. $-x^5ay + 2x^4a^2y - x^3ay^3$
8. a. $8a$
   b. $-2x^3$
   c. $x/5$
   d. $1 - 2(a + x)^2 = 1 - 2a^2 - 4ax - 2x^2$
   e. $a^2 + 2ab - b^2$
9. 140 acres
10. 20 ohms
11. 150°F
12. a. $A = 118.30$
    b. $h = 16.77$
    c. $d = 0.5092$
    d. $A = 31.82$
    e. $P = 23.321$
13. Larger part: 36
    Smaller part: 19
14. 84 ft/sec
15. 57.25 mph
16. a. Plan A: 33¢; plan B: 25¢
    b. Plan A: 2,500; plan B: 3,750
    c. Plan A: 12,500; plan B: 26,250
    d. Plan A: $25,000; plan B: $52,500
    e. Plan B costs $2,000 less.
17. $°R = {}^9\!/\!_5 °C + 492$
18. $w = A/l$
19. 108 tiles
20. 8 ohms

5. SOME PHYSICAL QUANTITIES AND THEIR MEASUREMENT, pp. 143–145

1. 6.21 mi
2. 79.45 m^3
3. a fundamental quantity
4. a. mi
   b. lb/gal, or ppg
   c. ft^3
   d. m^2
   e. lb/in.^{2}, or psi
   f. g/cm^3, or g/cc
   g. lb_f
   h. Ω
   i. ft/sec
   j. rpm
   k. kWh
5. a. 10^3, or 1,000
   b. 10^{-1}, or 0.10
   c. 10^{-3}, or 0.001
   d. 10^{-6}, or 0.000001
   e. 10^6, or 1,000,000
6. a. 29.03 kg
   b. 3.5825 tn
   c. 17.976 lb_f
   d. 165.345 lb_m
   e. 2.222 oz
7. 26.2 lb/m
8. 268.56 MJ
9. a. 21.1°C
   b. 51°C
   c. −18.4°F
   d. 365.4°R
   e. 612°R
10. 7.52
11. 335,000 lb
12. 12.08 ft^3
13. 21,600 ft-lb
14. 279.75 kW
15. 10 A
16. $E_1 = 7.5$ V, $E_2 = 20$ V, $E_3 = 2.5$ V
17. 215.424 kPa
18. a. 570°R
    b. 296 K
    c. 53.7 psia
    d. 30.7 psia
    e. 1,760°R
19. 347.8°R or −112.2°F
20. 2.4 kW

6. PRACTICAL GEOMETRY, pp. 182–186

1. 12.5664 mm^2
2. 0.3314, or 0.33 in.^{2}
3. 1,368.84 gal
4. 150.8 in.^{2}
5. 1,436.76 in.^{3}
6. 1,034.47 bbl
7. 18 in.^{2}
8. 16.98 acres on right; 144.63 acres on left
9. 1.2, or $1\,{}^1\!/\!_5$ gal
10. 23,687.11 gal
11. 563.98 gal
12. a. 97.23 ft
    b. 7.57 ft
    c. 1.55 ft
    d. 11.66 mm
    e. 4.69 in., or $4\,{}^7\!/\!_{10}$ in.

13. 131.9472 + 1, or 132 bolts
14. 534.38 ft^2
15. 1.2, or $1^1/_5$ gal
16. 105 $in.^2$
17. 2.25 ft^3
18. 448.18 rpm
19. 37.70 $in.^2$
20. 4.97 $in.^3$

7. TRIGONOMETRY, pp. 202–206

1. 17.3 ft
2. a. 39.3 ft
   b. 22.6 ft
3. 46.7 ft
4. 5.6 in.
5. 12.1 ft
6. 591 ft
7. a. 385.5 ft
   b. 619.3 ft
   c. 143 ft
8. Angle *A*: 10°
   Angle *B*: 80°
   Angle *C*: 90°
9. 7.3 ft
10. 8.7 ft
11. 17.5 ft
12. Side *a*: 156.2 ft
    Side *c*: 294.8 ft
13. 22'3.5"
14. a. 1.2349
    b. 0.8098
15. 3 in./side
16. 2.3 in./side
17. 13.1 in.
18. 2.5 in.
19. 2.3 in.
20. 9.9 in.

8. ADVANCED MATH CONCEPTS, pp. 223–224

1. a. 11
   b. 55
   c. 14
   d. 731
   e. 255
2. a. 1010
   b. 1100100
   c. 1111101000
   d. 100110011000
   e. 100000000
3. a. 100110
   b. 1001100
   c. 101100101
4. a. 10011
   b. 001000
   c. 00010001
5. a. 10110000 (decimal equivalent = 176)
   b. 10110010100 (decimal equivalent = 1428)
   c. 111110000101110 (decimal equivalent = 31790)
6. a. 10 (decimal equivalent = 2)
   b. 100 (decimal equivalent = 4)
   c. 10100 (decimal equivalent = 20)
7. a. 103652_8
   b. 73414_8
   c. 12525_8
   d. 1306563_8
8. a. $87AA_{16}$
   b. $770C_{16}$
   c. 1555_{16}
   d. $58D73_{16}$
9. a. 1000001
   b. 1011001
   c. 1011100
   d. 1011110
   e. 0111111
   f. 0101111
   g. 0100110
10. a. A • B = C
    b. (A + B) + (C + D) = E
    c. (A • B) + C = D

9. ADVANCED OIL INDUSTRY APPLICATIONS, pp. 277–279

1. 11.2 ppg
2. 875 psi
3. 12.27 psig
4. 1,615.54 psi
5. 3.08 MMcf/d
6. 163,800 lb
7. 2 P.M. on Wednesday
8. 65 psi
9. 142 kW
10. 630 kW
11. 1,873 ft^3
12. 1,873,500 Btu/hr
13. 2,853.76 ft^3
14. 111001100110
15. 1000 hp
16. 166 kVA
17. 0.69
18. 238 kVARs capacitive
19. 250 ft-lbs
20. 12 mA

To obtain additional training materials, contact:

PETEX®
PETROLEUM EXTENSION
The University of Texas at Austin
J.J. Pickle Research Campus
10100 Burnet Road, Bldg. 2
Austin, TX 78758

Telephone: 512-471-5940
or 800-687-4132
FAX: 512-471-9410
or 800-687-7839
Visit our website: petex.utexas.edu

To obtain information about training courses, contact:

PETEX®
HOUSTON TRAINING CENTER
The University of Texas at Austin
4702 N. Sam Houston Parkway West, Suite 800
Houston, TX 77086

Telephone: 281-397-2440
or 800-687-7052
Visit our website: petex.utexas.edu/our_courses

ISBN 9780886982843
9 780886 982843

Catalog No. 1.60050
ISBN 0-88698-284-7
978-0-88698-284-3