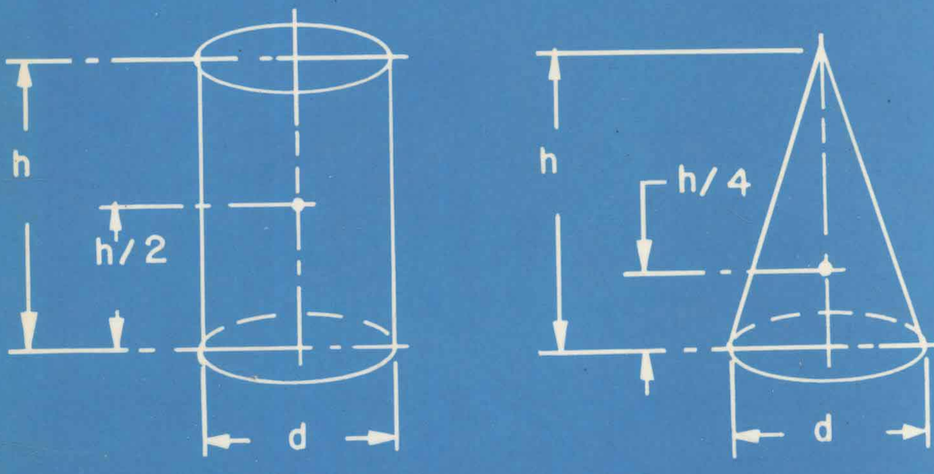
ENGINEERING TECHNOLOGY PROBLEM SOLVING

TECHNIQUES USING ELECTRONIC CALCULATORS

HOUSTON N. IRVINE



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Engineering Technology Problem Solving

ENGINEERING TECHNOLOGY

A Series of Textbooks

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Other Volumes in Preparation

PREFACE

This text is designed for a technical problems course for beginning engineering students or as a supplementary text and handbook for such students where there is no separate technical problems course. Our purpose is to introduce the engineering approach to practical problem solving. Students will learn practical applications of mathematics and problem-solving techniques that will be used in other technical courses.

Formerly, such a course involved instruction in the use of the slide rule. Now, however, the electronic calculator, which has greatly facilitated the solution of technical problems, is used. This text is intended to instruct students in the use of this instrument.

As students learn the basic operation of the calculator, they are given practical problems to solve. Because they will probably be taking other technical courses concurrently, they are given problems from these disciplines for calculator solution. Numerous examples of problems they will encounter in the various engineering technologies are also included.

After the first three chapters, which present the basic principles, the remaining chapters may be covered in any order desired.

Houston N. Irvine

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chapter 1

INTRODUCTION TO PROBLEM SOLVING

I. Problem-Solving Format

The wonders of modern civilization would not have been possible without the efforts of the engineering profession. Designing and creating the structures and machinery for modern living involves a great deal of problem solving. Engineers must be able to design equipment which is safe and reliable. They must also be able to design for cost effectiveness so that their projects are affordable and competitive. The technician, as an engineering assistant, is responsible for much of the problem solving involved.

The solution of technical problems requires developing habits of neatness and organization. While this may at first seem tedious, it should soon become apparent that the extra effort is well justified. All problem-solving work is to be lettered. Special care should be taken to ensure that all figures are formed accurately, so that there is no chance of their being misread. Lettering should be done with a well-sharpened pencil, preferably H or 2H. When erasures are necessary, the student should use a clean drafting eraser. Erasures should be clean. No smudges or smears are tolerated. All decimal points must be distinct.

Where geometrical relationships are involved, a carefully drawn sketch should be provided, with all pertinent dimensions and other information clearly shown. As more experience is gained in this procedure, the student will find that a well-prepared sketch is a valuable aid in the solution of a problem.

Next is the statement of the problem. What information is given and what is required? If a formula is involved, state the formula, followed by the substitution of the given data in the formula. Make sure that the proper units are used. When the problem has been solved, underline the answer so that it stands out clearly. Make sure that the proper units are part of the answer. A sample problem solution sheet is shown in Fig. 1.1.

Observe and follow this format carefully. Among the reasons for taking this care in setting up technical problems are the following:

1. Accuracy. Mistakes can be expensive.
2. Ease in interpretation. In technical and engineering work, other people will have occasion to check your calculations from time to time.

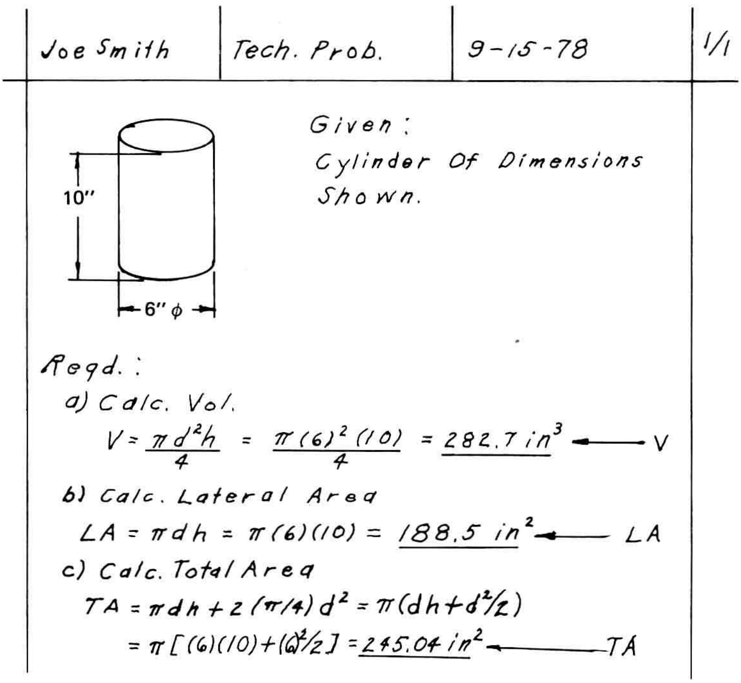

FIG. 1.1 Sample problem solution sheet.

3. As problems become more lengthy and complex, you can easily lose track of what you are doing if your problem solution is not well organized.

Your problem solution should be clear enough that you can look at it a year from now and easily understand what you did.

Before learning to depend on the calculator for answers, you should train yourself to approximate answers by mental arithmetic. Improper entries of numbers can lead to answers that are greatly in error. If the calculator answer agrees fairly closely with the approximate answer, you can be confident you have solved the problem correctly. To explain methods of approximation we will start with fairly small numbers. Consider the calculation of volume for the sample problem:

$$v = \frac{\pi d^2 h}{4} = \frac{\pi(6)^2(10)}{4}$$

We know that the value of π is slightly more than 3. Approximating:

$$v = \frac{(3)(6)^2(10)}{4} = 270$$

As we can see, this is fairly close to the correct answer. A general rule to follow is to round off all numbers to whole numbers of one or two digits and apply them in the equation. When the figure beyond the last place to be retained is less than 5, the figure in the last place retained is left unchanged. When the figure beyond the last place to be retained is greater than 5, the figure in the last place retained is increased by 1. Following are some examples of calculator solutions compared with approximate solutions:

EXAMPLE 1. $\frac{6.5 \times 7.3}{2.9} = 16.362$

Approximating: $\frac{7 \times 7}{3} = 16.3$

EXAMPLE 2. $\frac{(5.65)(3.75 + 9.05)}{17.6} = 4.109$

or approximately,

$$\frac{(5.6)(3.7 + 9)}{18} \cong \frac{(6)(13)}{18} \cong \frac{78}{18} \cong 4.3$$

EXAMPLE 3. $\frac{(15.6 + 3.8)}{(5.3 + 2.9)} = 2.366$

or approximately,

$$\frac{(16 + 4)}{(5 + 3)} = \frac{20}{8} = 2.5$$

EXAMPLE 4. $\frac{(17.9 + 5.3)(4.7 + 1.2)}{2.9} = 47.2$

or approximately,

$$\frac{(18 + 5)(5 + 1)}{3} = \frac{(23)(\cancel{6})^{2}}{\cancel{3}} = 46$$

Methods for dealing with more complex numbers will be taken up in Section 1.6.

II. Basic Functions and Operations

The electronic calculator you will be using is a marvel of design. Only a few years ago the bulky desk-top calculators available were capable of doing only a fraction of the operations this instrument can accomplish. The compactness and complexity of the pocket calculator has been made possible by the development of integrated circuits by the electronics industry. As this instrument is fairly complex, there is a great deal to learn about its use.

The functions described below are common to most calculators of the scientific type. As there are differences in operating procedure, we have chosen two generally equivalent scientific calculators typical of the two basic types of logic used. These are the Texas Instruments TI-55 and the Hewlett-Packard 33E (HP-33E). These calculators contain a number of special functions in addition to the standard ones mentioned below. They deal with such subjects as statistics, linear regression, metric conversions, and programming. Because of the number of functions covered in the limited space available, it is necessary to place more than one function on a key.

On the TI-55 the number or function appearing on the face of the key is activated unless the 2nd key is pressed. For functions appearing above the keys, it is necessary to press the 2nd key before pressing the key for the function desired. For example, to convert degrees, minutes, and seconds to decimal degrees it is necessary to press 2nd followed by DMS-DD. On the TI-55 the inverse key INV is used to obtain the inverse of a function. For example, to convert decimal degrees to degrees, minutes, and seconds the key sequence is INV 2nd DMS-DD.

On the HP-33E there are three functions per key. The number or function appearing on the top face of the key is activated unless one of the shift keys is pressed. For functions appearing above the keys in gold letters, it is necessary to first press the gold shift key marked f. For example, to find the square root of 36 the key sequence is 36 f $\sqrt{x}$. For functions appearing on the front face of the key in blue letters, it is necessary to first press the blue shift key marked g. For example, to obtain the value of π, the sequence is g π.

Following is a description of the basic functions you will find on the keyboard:

1. The basic four functions, addition, subtraction, multiplication, and division
2. The reciprocal function 1/x
3. The square root function $\sqrt{x}$
4. The x^2 function
5. The Y^x function, which allows you to raise a number to any power
6. The $\sqrt[x]{y}$ function, which enables you to take any root of a number
7. The trigonometry functions, sin, cos, tan
8. The common logarithm function, log x
9. The natural logarithm function, ln x
10. The scientific notation key, EE
11. The storage key STO, which enables you to store a number

12. The recall key RCL, which enables you to recall a number from storage
13. The change sign key +/-
14. The π key, which enters the value of π directly
15. The exchange key x↘y, which enables you to exchange registers
16. The clear key, generally with three levels of clearing available: the "clear entry" which allows you to clear a mistaken entry, the "clear display" which clears whatever is in the display, and the "clear all" which clears everything including all the memory registers

In this book we progress a step at a time from the simpler to the more complex functions. Practical applications in problem solving are presented as each function is explained.

III. Algebraic and Reverse Polish Logic

Electronic pocket calculators fall into two categories: those using algebraic logic and those using Lukasciewicz (reverse Polish) logic. Typical calculators using algebraic logic are those made by Texas Instruments and Rockwell. These calculators have an = key on the keyboard. Entry of a problem is in regular algebraic order:

2 + 3 = 5
6 - 4 = 2
5 × 4 = 20
55 ÷ 11 = 5

Calculators using reverse Polish logic have an ENTER key, but no = key. Examples of key operation follow (Hewlett-Packard, 1978a):

2 ENTER, 3 +, 5
6 ENTER, 4 -, 2
5 ENTER, 4 ×, 20
55 ENTER, 11 ÷, 5

At first this may seem awkward, but as you learn to work with more complex problems, certain advantages become apparent. Typical of calculators using reverse Polish notation are those made by Hewlett-Packard and the National Semiconductor Corporation.

Other differences between the two basic types of logic will be explained as we take up functions other than the basic ones of addition, subtraction, multiplication, and division.

IV. Hierarchy of Operations - Algebraic Logic

Calculator hierarchy determines the order of completion of each calculator function. When functions are used individually, hierarchy is of little consequence. However, when functions are used collectively in the solution of an algebraic equation, the order of completion is important. The complete list of priorities for algebraic hierarchy follows (Texas Instruments, 1977a).

1. Special functions (trigonometric, logarithmic, square, square root, factorial, e^x, 10^x, percent reciprocal, and conversions) immediately replace the displayed value with its functional value.
2. Percent change (Δ%) has only the ability to complete other percent change operations.
3. Exponentiation (Y^x) and roots ($\sqrt[x]{y}$) are performed as soon as special functions and percent change are completed.
4. Multiplication and division are performed after the above operations and other multiplication and division are completed.
5. Addition and subtraction are performed only after completing all operations through multiplication and division as well as other addition and subtraction.
6. Equals completes all operations.

The solution of problems involving the four basic functions has already been explained for both types of logic. One of the most convenient features of the calculator is its ability to handle problems involving chain multiplication and division. It is only necessary to enter the numbers in succession:

$$\frac{7.5 \times 83}{0.57} = 1092.1052$$

For algebraic logic the procedure is as follows:

Enter	Press	Display
7.5	×	
83	÷	
0.57	=	1092.1052

For reverse Polish logic the procedure is as follows:

Press	Display
7.5 ENTER	
83 ×	622.5
0.57 ÷	1092.105

For the algebraic operating system parentheses are used to enter complex equations in straightforward order. If an expression is enclosed in parentheses, it is evaluated without pressing the = sign. For example, press (5 × 9) and 45 will be displayed. Parentheses can be used in this manner to enter more complex expressions.

EXAMPLE 5. $\frac{4 \times (5 + 9)}{(7 - 4)} = 18.667$

For algebraic logic, using parentheses:

Enter	Press	Display
4	× (	4
5	+	5
9	)	14
	÷	56
	(	
7	-	7
4	)	3
	=	18.667

Remember to close parentheses at the proper places.

For reverse Polish notation the procedure is simpler and uses fewer strokes: