1.12 CALCULATORS

In most texts, the calculator is not discussed in detail. Instead, students are left with the general exercise of choosing an appropriate calculator and learning to use it properly on their own. However, some discussion about the use of the calculator is needed to eliminate some of the impossible results obtained (and often strongly defended by the user—because the calculator says so) through a correct understanding of the process by which a calculator performs the various tasks. Time and space do not permit a detailed explanation of all the possible operations, but the following discussion explains why it is important to understand how a calculator proceeds with a calculation and that the unit cannot accept data in any form and still generate the correct answer.

When choosing a scientific calculator, be absolutely certain that it can operate on complex numbers and determinants, needed for the concepts introduced in this text. The simplest way to determine this is to look up the terms in the index of the operator's manual. Next, be aware that some calculators perform the required operations in a minimum number of steps while others require a lengthy and complex series of steps. Speak to your instructor if you are unsure about your purchase.

The calculator examples in this text have used the Texas Instruments TI-89 (see Fig.1.5). (For those students who still have the Texas Instruments TI-86, Appendix B was developed to provide the same coverage as offered in the text for the TI-89 calculator.)

When using any calculator for the first time, the unit must be set up to provide the answers in a desired format. Following are the steps needed to use a calculator correctly.

FIG. 1.5
Texas Instruments TI-89 calculator.
(Courtesy of Texas Instruments, Inc.)

Initial Settings

In the following sequences, the arrows within the square indicate the direction of the scrolling required to reach the desired location. The shape of the keys is a relatively close match of the actual keys on the TI-89.

Notation

The first sequence sets the **engineering notation** as the choice for all answers. It is particularly important to take note that you must select the ENTER key twice to ensure the process is set in memory.

ON HOME MODE ↓ Exponential Format → ↓

ENGINEERING ENTER ENTER

Accuracy Level Next, the accuracy level can be set to two places as follows:

MODE ↓ Display Digits → ↓ 3:FIX 2 ENTER ENTER

Approximate Mode For all solutions, the solution should be in decimal form to second-place accuracy. If this is not set, some answers will appear in fractional form to ensure the answer is EXACT (another option). This selection is made with the following sequence:

MODE **F2** ↓ Exact/Approx → ↓ 3: APPROXIMATE **ENTER** **ENTER**

Clear Screen To clear the screen of all entries and results, use the following sequence:

F1 ↓ 8: Clear Home **ENTER**

Clear Current Entries To delete the sequence of current entries at the bottom of the screen, select the **CLEAR** key.

Order of Operations

Although setting the correct format and accurate input is important, improper results occur primarily because users fail to realize that no matter how simple or complex an equation, the calculator performs the required operations in a specific order.

For instance, the operation

$$\frac{8}{3+1}$$

is often entered as

8 **÷** **3** **+** **1** **ENTER** $= \frac{8}{3} + 1 = 2.67 + 1 = \mathbf{3.67}$

which is totally incorrect (2 is the answer).

The calculator *will not* perform the addition first and then the division. In fact, addition and subtraction are the last operations to be performed in any equation. It is therefore very important that you carefully study and thoroughly understand the next few paragraphs in order to use the calculator properly.

1. ***The first operations to be performed by a calculator can be set using parentheses ( ). It does not matter which operations are within the parentheses. The parentheses simply dictate that this part of the equation is to be determined first. There is no limit to the number of parentheses in each equation—all operations within parentheses will be performed first. For instance, for the example above, if parentheses are added as shown below, the addition will be performed first and the correct answer obtained:***

$\frac{\mathbf{8}}{(\mathbf{3}+\mathbf{1})}$ = **8** **÷** **(** **3** **+** **1** **)** **ENTER** = **2.00**

2. ***Next, powers and roots are performed, such as x^2, $\sqrt{x}$, and so on.***
3. ***Negation (applying a negative sign to a quantity) and single-key operations such as sin, $\tan^{-1}$, and so on, are performed.***
4. ***Multiplication and division are then performed.***
5. ***Addition and subtraction are performed last.***

It may take a few moments and some repetition to remember the order, but at least you are now aware that there is an order to the operations and that ignoring them can result in meaningless results.

EXAMPLE 1.23 Determine

$$\sqrt{\frac{9}{3}}$$

Solution:

2ND √‾ 9 ÷ 3) ENTER $= \mathbf{1.73}$

In this case, the left bracket is automatically entered after the square root sign. The right bracket must then be entered before performing the calculation.

For all calculator operations, the number of right brackets must always equal the number of left brackets.

EXAMPLE 1.24 Find

$$\frac{3 + 9}{4}$$

Solution: If the problem is entered as it appears, the *incorrect answer* of 5.25 will result.

3 + 9 ÷ 4 ENTER $= 3 + \frac{9}{4} = 5.25$

Using brackets to ensure that the addition takes place before the division will result in the correct answer as shown below:

(3 + 9) ÷ 4 ENTER

$$= \frac{(3 + 9)}{4} = \frac{12}{4} = \mathbf{3.00}$$

EXAMPLE 1.25 Determine

$$\frac{1}{4} + \frac{1}{6} + \frac{2}{3}$$

Solution: Since the division will occur first, the correct result will be obtained by simply performing the operations as indicated. That is,

1 ÷ 4 + 1 ÷ 6 + 2 ÷

3 ENTER $= \frac{1}{4} + \frac{1}{6} + \frac{2}{3} = \mathbf{1.08}$

Powers of Ten

The EE key is used to set the power of ten of a number. Setting up the number $2200 = 2.2 \times 10^3$ requires the following keypad selections:

2 • 2 EE 3 ENTER = **2.20E3**

Setting up the number 8.2×10^{-6} requires the negative sign (−) from the *numerical keypad. Do not* use the negative sign from the mathematical listing of ÷, ×, −, and +. That is,

[8] [.] [2] [EE] [(−)] [6] [ENTER] = **8.20E−6**

EXAMPLE 1.26 Perform the addition $6.3 \times 10^3 + 75 \times 10^3$ and compare your answer with the longhand solution of Example 1.8(a).

Solution:

[6] [.] [3] [EE] [3] [+] [7] [5] [EE] [3]

[ENTER] = **81.30E3**

which confirms the results of Example 1.8(a).

EXAMPLE 1.27 Perform the division $(69 \times 10^4)/(13 \times 10^{-8})$ and compare your answer with the longhand solution of Example 1.10(b).

Solution:

[6] [9] [EE] [4] [÷] [1] [3] [EE] [(−)] [8]

[ENTER] = **5.31E12**

which confirms the results of Example 1.10(b).

EXAMPLE 1.28 Using the provided format of each number, perform the following calculation in one series of keypad entries:

$$\frac{(0.004)(6 \times 10^{-4})}{(2 \times 10^{-3})^2} = ?$$

Solution:

[(] [(] [0] [.] [0] [0] [4] [)] [×] [(]

[6] [EE] [(−)] [4] [)] [)] [÷] [2] [EE] [(−)]

[3] [∧] [2] [ENTER] = **600.00E−3** = **0.6**

Brackets were used to ensure that the calculations were performed in the correct order. Note also that the number of left brackets equals the number of right brackets.

1.13 COMPUTER ANALYSIS

The use of computers in the educational process has grown exponentially in the past decade. Very few texts at this introductory level fail to include some discussion of current popular computer techniques. In fact, the very accreditation of a technology program may be a function of the depth to which computer methods are incorporated in the program.

There is no question that a basic knowledge of computer methods is something that the graduating student must learn in a two-year or four-year program. Industry now requires students to be proficient in the use of a computer.

Two general directions can be taken to develop the necessary computer skills: the study of computer languages or the use of software packages.

Languages

There are several languages that provide a direct line of communication with the computer and the operations it can perform. A **language** is a set of symbols, letters, words, or statements that the user can enter into the computer. The computer system will "understand" these entries and will perform them in the order established by a series of commands called a **program.** The program tells the computer what to do on a sequential, line-by-line basis in the same order a student would perform the calculations in longhand. The computer can respond only to the commands entered by the user. This requires that the programmer understand fully the sequence of operations and calculations required to obtain a particular solution. A lengthy analysis can result in a program having hundreds or thousands of lines. Once written, the program must be checked carefully to ensure that the results have meaning and are valid for an expected range of input variables. Some of the popular languages applied in the electrical-electronics field today include C++, QBASIC, Pascal, and FORTRAN. Each has its own set of commands and statements to communicate with the computer, but each can be used to perform the same type of analysis.

Software Packages

The second approach to computer analysis—**software packages**—avoids the need to know a particular language; in fact, the user may not be aware of which language was used to write the programs within the package. All that is required is a knowledge of how to input the network parameters, define the operations to be performed, and extract the results; the package will do the rest. However, there is a problem with using packaged programs without understanding the basic steps the program uses. You can obtain solution without the faintest idea of either how the solution was obtained or whether the results are valid or way off base. It is imperative that you realize that the computer should be used as a tool to assist the user—it must not be allowed to control the scope and potential of the user! Therefore, as we progress through the chapters of the text, be sure that you clearly understand the concepts before turning to the computer for support and efficiency.

Each software package has a **menu,** which defines the range of application of the package. Once the software is entered into the computer, the system will perform all the functions appearing in the menu, as it was preprogrammed to do. Be aware, however, that if a particular type of analysis is requested that is not on the menu, the software package cannot provide the desired results. The package is limited solely to those maneuvers developed by the team of programmers who developed the software package. In such situations the user must turn to another software package or write a program using one of the languages listed above.

In broad terms, if a software package is available to perform a particular analysis, then that package should be used rather than developing new routines. Most popular software packages are the result of many hours of effort by teams of programmers with years of experience. However, if the results are not in the desired format, or if the software package does not provide all the desired results, then the user's innovative talents should be put to use to develop a software package. As noted above, any program the user writes that passes the tests of range and accuracy can be considered a software package of his or her authorship for future use.

Three software packages are used throughout this text: Cadence's OrCAD's PSpice Release 10, Electronics Workbench Multisim Version 8, and MathSoft's Mathcad 12. Although both PSpice and Multisim are designed to analyze electric circuits, there are sufficient differences between the two to warrant covering each approach. The growing use of some form of mathematical support in the educational and industrial environments supports the introduction and use of Mathcad throughout the text. However, you are not required to obtain all three programs in order to proceed with the content of this text. The primary reason for including these programs is simply to introduce each and demonstrate how each can support the learning process. In most cases, sufficient detail has been provided to actually use the software package to perform the examples provided, although it would certainly be helpful to have someone to turn to if questions arise. In addition, the literature supporting all three packages has improved dramatically in recent years and should be available through your bookstore or a major publisher. Appendix C lists all the system requirements, including how to get in touch with each company.

PROBLEMS

Note: More difficult problems are denoted by an asterisk (*) throughout the text.

SECTION 1.2 A Brief History

1. Visit your local library (at school or home) and describe the extent to which it provides literature and computer support for the technologies—in particular, electricity, electronics, electromagnetics, and computers.
2. Choose an area of particular interest in this field and write a very brief report on the history of the subject.
3. Choose an individual of particular importance in this field and write a very brief review of his or her life and important contributions.

SECTION 1.3 Units of Measurement

4. What is the velocity of a rocket in mph if it travels 20,000 ft in 10 s?

5. In a recent Tour de France time trial, Lance Armstrong traveled 31 miles in a time trial in 1 hour and 4 minutes. What was his average speed in mph?

* 6. A pitcher has the ability to throw a baseball at 95 mph.
   a. How fast is the speed in ft/s?
   b. How long does the hitter have to make a decision about swinging at the ball if the plate and the mound are separated by 60 feet?
   c. If the batter wanted a full second to make a decision, what would the speed in mph have to be?

SECTION 1.4 Systems of Units

7. Are there any relative advantages associated with the metric system compared to the English system with respect to length, mass, force, and temperature? If so, explain.

8. Which of the four systems of units appearing in Table 1.1 has the smallest units for length, mass, and force? When would this system be used most effectively?

* 9. Which system of Table 1.1 is closest in definition to the SI system? How are the two systems different? Why do you think the units of measurement for the SI system were chosen as listed in Table 1.1? Give the best reasons you can without referencing additional literature.

10. What is room temperature (68°F) in the MKS, CGS, and SI systems?

11. How many foot-pounds of energy are associated with 1000 J?

12. How many centimeters are there in 1/2 yd?

SECTIONS 1.6 and 1.7 Powers of Ten and Notation

13. Express the following numbers as powers of ten:
   a. 10,000 **b.** 1,000,000
   c. 1000 **d.** 0.001
   e. 1 **f.** 0.1

14. Using only those powers of ten listed in Table 1.2, express the following numbers in what seems to you the most logical form for future calculations:
   a. 15,000 **b.** 0.030
   c. 2,400,000 **d.** 150,000
   e. 0.00040200 **f.** 0.0000000002

15. Perform the following operations and express your answer as a power of ten using scientific notation:
   a. $4200 + 48{,}000$
   b. $9 \times 10^4 + 3.6 \times 10^5$
   c. $0.5 \times 10^{-3} - 6 \times 10^{-5}$
   d. $1.2 \times 10^3 + 50{,}000 \times 10^{-3} - 0.6 \times 10^3$

16. Perform the following operations and express your answer as a power of ten using engineering notation:
   a. (100) (1000) **b.** (0.01) (1000)
   c. $(10^3)(10^6)$ **d.** (100) (0.00001)
   e. $(10^{-6})(10{,}000{,}000)$ **f.** $(10{,}000)(10^{-8})(10^{28})$

17. Perform the following operations and express your answer in scientific notation:
   a. (50,000) (0.0003)
   b. 2200×0.002
   c. (0.000082) (2,800,000)
   d. $(30 \times 10^{-4})(0.004)(7 \times 10^8)$

18. Perform the following operations and express your answer in engineering notation:
   a. $\dfrac{100}{10{,}000}$ **b.** $\dfrac{0.010}{1000}$
   c. $\dfrac{10{,}000}{0.001}$ **d.** $\dfrac{0.0000001}{100}$
   e. $\dfrac{10^{38}}{0.000100}$ **f.** $\dfrac{(100)^{1/2}}{0.01}$

19. Perform the following operations and express your answer in scientific notation:
   a. $\dfrac{2000}{0.00008}$ **b.** $\dfrac{0.004}{60{,}000}$
   c. $\dfrac{0.000220}{0.00005}$ **d.** $\dfrac{78 \times 10^{18}}{4 \times 10^{-6}}$

20. Perform the following operations and express your answer in engineering notation:
   a. $(100)^3$ **b.** $(0.0001)^{1/2}$
   c. $(10{,}000)^8$ **d.** $(0.00000010)^9$

21. Perform the following operations and express your answer in scientific notation:
   a. $(400)^2$
   b. $(0.006)^3$
   c. $(0.004)(6 \times 10^2)^2$
   d. $((2 \times 10^{-3})(0.8 \times 10^4)(0.003 \times 10^5))^3$

22. Perform the following operations and express your answer in scientific notation:
   a. $(-0.001)^2$ **b.** $\dfrac{(100)(10^{-4})}{1000}$
   c. $\dfrac{(0.001)^2(100)}{10{,}000}$ **d.** $\dfrac{(10^3)(10{,}000)}{1 \times 10^{-4}}$
   e. $\dfrac{(0.0001)^3(100)}{1 \times 10^6}$ ***f.** $\dfrac{[(100)(0.01)]^{-3}}{[(100)^2][0.001]}$

23. Perform the following operations and express your answer in engineering notation:
   a. $\dfrac{(300)^2(100)}{3 \times 10^4}$ **b.** $[(40{,}000)^2]\,[(20)^{-3}]$
   c. $\dfrac{(60{,}000)^2}{(0.02)^2}$ **d.** $\dfrac{(0.000027)^{1/3}}{200{,}000}$
   e. $\dfrac{[(4000)^2][300]}{2 \times 10^{-4}}$
   f. $[(0.000016)^{1/2}]\,[(100{,}000)^5]\,[0.02]$
   ***g.** $\dfrac{[(0.003)^3][0.00007]^{-2}[(160)^2]}{[(200)(0.0008)]^{-1/2}}$ (a challenge)

SECTION 1.8 Conversion between Levels of Powers of Ten

24. Fill in the blanks of the following conversions:
   a. $6 \times 10^3 =$ ______ $\times 10^6$
   b. $4 \times 10^{-3} =$ ______ $\times 10^{-6}$

c. $50 \times 10^5 =$ ______ $\times 10^3 =$ ______ $\times 10^6$
$=$ ______ $\times 10^9$

d. $30 \times 10^{-8} =$ ______ $\times 10^{-3} =$ ______ $\times 10^{-6}$
$=$ ______ $\times 10^{-9}$

25. Perform the following conversions:
a. 0.05 s to milliseconds
b. 2000 μs to milliseconds
c. 0.04 ms to microseconds
d. 8400 ps to microseconds
e. 4×10^{-3} km to millimeters
f. 260×10^3 mm to kilometers

SECTION 1.9 Conversion within and between Systems of Units

26. Perform the following conversions:
a. 1.5 min to seconds
b. 0.04 h to seconds
c. 0.05 s to microseconds
d. 0.16 m to millimeters
e. 0.00000012 s to nanoseconds
f. 3,620,000 s to days

27. Perform the following conversions:
a. 0.1 μF to picofarads
b. 80 mm to centimeters
c. 60 cm to kilometers
d. 3.2 h to milliseconds
e. 0.016 mm to micrometers
f. 60 sq cm (cm^2) to square meters (m^2)

28. Perform the following conversions:
a. 100 in. to meters
b. 4 ft to meters
c. 6 lb to newtons
d. 60,000 dyn to pounds
e. 150,000 cm to feet
f. 0.002 mi to meters (5280 ft = 1 mi)

29. What is a mile in feet, yards, meters, and kilometers?

30. Calculate the speed of light in miles per hour using the speed defined in Section 1.4.

31. How long in seconds will it take a car traveling at 60 mph to travel the length of a football field (100 yd)?

32. Convert 30 mph to meters per second.

33. If an athlete can row at a rate of 50 yd/min, how many days would it take to cross the Atlantic ($\cong$ 3000 mi)?

34. How long would it take a runner to complete a 10 km race if a pace of 6.5 min/mi were maintained?

35. Quarters are about 1 in. in diameter. How many would be required to stretch from one end of a football field to the other (100 yd)?

36. Compare the total time required to drive 100 miles at an average speed of 60 mph versus an average speed of 75 mph. Is the time saved for such a long trip worth the added risk of the higher speed?

***37.** Find the distance in meters that a mass traveling at 600 cm/s will cover in 0.016 h.

***38.** Each spring there is a race up 86 floors of the 102 story Empire State Building in New York City. If you were able to climb 2 steps/second, how long would it take in minutes to reach the 86th floor if each floor is 14 ft high and each step is about 9 in.?

***39.** The record for the race in Problem 38 is 10 minutes, 47 seconds. What was the racer's speed in min/mi for the race?

***40.** If the race of Problem 38 were a horizontal distance, how long would it take a runner who can run 5 min miles to cover the distance? Compare this with the record speed of Problem 39. Gravity is certainly a factor to be reckoned with!

SECTION 1.11 Conversion Tables

41. Using Appendix A, determine the number of
a. Btu in 5 J of energy.
b. cubic meters in 24 oz of a liquid.
c. seconds in 1.4 days.
d. pints in 1 m^3 of a liquid.

SECTION 1.12 Calculators

Perform the following operations using a single sequence of calculator keys:

42. $6\,(4 + 8) =$

43. $\dfrac{20 + 32}{4} =$

44. $\sqrt{8^2 + 12^2} =$

45. $\cos 50° =$

46. $\tan^{-1} \dfrac{3}{4} =$

47. $\sqrt{\dfrac{400}{6^2 + 10}} =$

48. $\dfrac{8.2 \times 10^{-3}}{0.04 \times 10^3}$ (in engineering notation) $=$

***49.** $\dfrac{(0.06 \times 10^5)(20 \times 10^3)}{(0.01)^2}$ (in engineering notation) $=$

***50.** $\dfrac{4 \times 10^4}{2 \times 10^{-3} + 400 \times 10^{-5}} + \dfrac{1}{2 \times 10^{-6}}$
(in engineering notation) $=$

SECTION 1.13 Computer Analysis

51. Investigate the availability of computer courses and computer time in your curriculum. Which languages are commonly used, and which software packages are popular?

52. Develop a list of three popular computer languages, including a few characteristics of each. Why do you think some languages are better for the analysis of electric circuits than others?

GLOSSARY

Cathode-ray tube (CRT) A glass enclosure with a relatively flat face (screen) and a vacuum inside that will display the light generated from the bombardment of the screen by electrons.

CGS system The system of units employing the *C*entimeter, *G*ram, and *S*econd as its fundamental units of measure.

Difference engine One of the first mechanical calculators.

Edison effect Establishing a flow of charge between two elements in an evacuated tube.

Electromagnetism The relationship between magnetic and electrical effects.

Engineering notation A method of notation that specifies that all powers of ten used to define a number be multiples of 3 with a mantissa greater than or equal to 1 but less than 1000.

ENIAC The first totally electronic computer.

Fixed-point notation Notation using a decimal point in a particular location to define the magnitude of a number.

Fleming's valve The first of the electronic devices, the diode.

Floating-point notation Notation that allows the magnitude of a number to define where the decimal point should be placed.

Integrated circuit (IC) A subminiature structure containing a vast number of electronic devices designed to perform a particular set of functions.

Joule (J) A unit of measurement for energy in the SI or MKS system. Equal to 0.7378 foot-pound in the English system and 10^7 ergs in the CGS system.

Kelvin (K) A unit of measurement for temperature in the SI system. Equal to 273.15 + °C in the MKS and CGS systems.

Kilogram (kg) A unit of measure for mass in the SI and MKS systems. Equal to 1000 grams in the CGS system.

Language A communication link between user and computer to define the operations to be performed and the results to be displayed or printed.

Leyden jar One of the first charge-storage devices.

Menu A computer-generated list of choices for the user to determine the next operation to be performed.

Meter (m) A unit of measure for length in the SI and MKS systems. Equal to 1.094 yards in the English system and 100 centimeters in the CGS system.

MKS system The system of units employing the *M*eter, *K*ilogram, and *S*econd as its fundamental units of measure.

Nanotechnology The production of integrated circuits in which the nanometer is the typical unit of measurement.

Newton (N) A unit of measurement for force in the SI and MKS systems. Equal to 100,000 dynes in the CGS system.

Pound (lb) A unit of measurement for force in the English system. Equal to 4.45 newtons in the SI or MKS system.

Program A sequential list of commands, instructions, and so on, to perform a specified task using a computer.

Scientific notation A method for describing very large and very small numbers through the use of powers of ten, which requires that the multiplier be a number between 1 and 10.

Second (s) A unit of measurement for time in the SI, MKS, English, and CGS systems.

SI system The system of units adopted by the IEEE in 1965 and the USASI in 1967 as the International System of Units (*S*ystème *I*nternational d'Unités).

Slug A unit of measure for mass in the English system. Equal to 14.6 kilograms in the SI or MKS system.

Software package A computer program designed to perform specific analysis and design operations or generate results in a particular format.

Static electricity Stationary charge in a state of equilibrium.

Transistor The first semiconductor amplifier.

Voltaic cell A storage device that converts chemical to electrical energy.