PROBLEMS WITH COMPUTER SOLUTIONS USING STANDARD FORTRAN

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The Chinese University Press
Hong Kong

International Standard Book Number: 962-201-267-1

First edition 1982
Second printing 1983

The Chinese University Press
The Chinese University of Hong Kong
SHATIN, N.T., HONG KONG

Printing by Don Bosco Printing Company

Preface

This book is written for those who need to solve problems by computers with Fortran. It is written in connection with the text 'A Course on Programming in Fortran' published by The Chinese University Press. The book is organized around a set of solved problems. It is divided into eleven chapters. The first two chapters contain problems and solutions concerning the basic knowledge of computers and computer programming. The later chapters consist of problems and solutions dealing with Standard Fortran Programming. We adhered strictly to the presentation of standard ANSI Fortran, because Fortran is a programming language with many dialects. By learning ANSI Fortran we can eliminate all the wasted hours spent converting a program for use on different computers. There are altogether 349 problems in this book. Every effort has been made to include those which will contribute to a better understanding of Fortran programming. Topics covered in each chapter are mentioned in the table of contents. Except Chapters 1 and 2, the problems are classified into two types. The first type consists of drill exercises intended to reinforce the readers' knowledge of individual Fortran statements and their use. Problems of the second type are programming exercises. They lead to the development of complete Fortran programs and their execution printouts. Writing, executing and debugging these programs is, of course, the best means of exercising, reinforcing, and applying one's knowledge in specific problem solving situations. This extensive collection of solved problems is particularly suited as a supplement to any standard text book in Fortran programming. It will also be valuable for independent study. No special mathematics is required beyond what is normally learned in the secondary school.

The readers are urged to work each of these problems carefully and thoroughly since it has been found that the only way to grasp command of programming is to practise the newly acquired knowledge as it is presented. These problems of wide varieties will assist greatly in securing the needed mastery of the subject.

In each chapter, solutions to problems are given after the questions. The readers are suggested not to turn to the answer until they have made a genuine effort to solve the problem by themselves, or unless they really do not have time to work that particular problem. After getting their own solution or giving the problem a decent try, they may find the answers instructive and helpful. It is quite possible that the readers may have a better answer than the one published here, or they may have found errors of one sort or another in the published solutions; in such a case, the authors will be pleased and grateful to know the details, so that corrections may be made as soon as possible in the second edition.

We wish to express our gratitude to the staff members of the Department of Computer Science at The Chinese University of Hong Kong and particularly to Lena Sham, Richard Fong, Mathew Lam, W.B. Ngai and W. K. Kan for checking the correctness of all the solutions in the book.

November, 1981

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Chapter 1 Introduction to Computers

PROBLEMS

1. What was the contribution to computers made by:
   (a) Blaise Pascal
   (b) Charles Babbage
   (c) George Boole
   (d) Herman Hollerith
   (e) Howard Aiken
   (f) J. Presper Eckert
   (g) John W. Mauchly
   (h) John von Neumann

2. What were the important features of
   (a) MARK I
   (b) ENIAC
   (c) EDVAC
   (d) UNIVAC I

3. What characterizes the first, second, third and fourth generation computers?

4. What are the essential differences between a desk calculator and an electronic computer?

5. (a) How many microseconds are there in two seconds?
   (b) How many microseconds are there in 500 nanoseconds?
   (c) How many nanoseconds are there in 3 milliseconds?
   (d) Which is the greatest period of time: 5 milliseconds, 800 microseconds, or 10,000 nanoseconds?
   (e) Which is the shortest period of time: 300 nanoseconds, 0.2 microsecond or 0.1 millisecond?

6. Discuss the various ways in which computers may be classified.

7. What are the characteristics of a processing problem that is suitable and economically justified for computer processing?

8. Name the five major components of a computer and draw a schematic diagram of these components.

9. "The memory of a computer is used for four purposes." What are these four purposes?

10. What are the functions of the arithmetic and logic unit of a computer?

11. What are the functions of the control unit of a computer?

12. Name some of the media used with computer systems and the devices used to input or output them.

13. List some of the principal secondary storage devices and the method of access for each of them..

14. What do the following abbreviations or acronyms stand for?

(a) ENIAC
(b) EDSAC
(c) CPU
(d) BIT
(e) I/O
(f) CRT
(g) MICR
(h) LSI

15. Define the following terms:

Automatic
Binary number system
Main frame
Address
Word length
Byte-addressable
Nonvolatile
K
Half word
Destructive read-in
Keypunch
Access
Operating systems
Utility programs
Stored-program
Hybrid computer
Location
Word
Byte
Access time
Generator
Application packages

16. What is the difference between the following:

(a) Analog computer and digital computer
(b) Special purpose computer and general purpose computer
(c) Word-addressable and character-addressable
(d) Online and offline
(e) Hardware and software
(f) Direct access and serial access

SOLUTIONS

1. (a) In 1642 Blaise Pascal developed the world's first mechanical adding machine. In his machine, gears with each tooth representing one of the digits from 0 through 9, were connected in a series. When a gear was rotated past the tooth representing the digit 9, the next gear to the left was automatically rotated one tooth (or digit). In other words, the first gear exchanged ten teeth for one tooth on the next gear. This was the first counting machine capable of carrying a group of ten to the next position. Since the gears could be rotated in either direction, the machine could, in principle, be used to substract as well as to add. The work of Pascal illustrates the first great idea in the history of automatic digital computation: the recognition that arithmetic operations can be mechanized.

(b) Charles Babbage dreamed of a machine to compute and print mathematical tables and with support from the British government, he began the construction of his difference engine in 1830. By 1834, Babbage had abandoned plans for his difference engine and began devoting energy to his analytic machine. The machine had a store for retaining numbers; a mill that served as a central arithmetic unit for calculating; and an operator to direct the operation of the machine. The sequencing of operations was to be controlled by punched cards. Results would be output on copper plates, and answers could be automatically fed back into the machine so that additional calculations could be performed without further action by the operator. The concept of branching was included in the design simply by advancing or backing up a certain number of cards. Numbers were to be accurate to fifty places, while the machine's memory unit would hold 50,000 digits. The speed of the machine was indicated by the specification that addition could be performed in one second, and a 50-by-50 digit product would take approximately one minute. Unfortunately, the machine was never completed, because his idea was beyond the technical capabilities of that time. Nevertheless, Babbage deserves credit for introducing the idea of data storage, sequential control through programming, and automatic readout --- principles that are basic to modern computers.

(c) In 1854 George Boole developed a system for representing logical statement in term of mathematical symbols. Using the symbols and some rules one could determine whether a statement was logically true or false. This method was not widely accepted, and it was not until the next century that his ideas were applied in the design of computers.

(d) In 1886 Herman Hollerith developed a system for representing data on punched cards. The machines that Hollerith developed for these cards used electricity to sense the holes in a card and in this manner data could be counted

(e) Beginning in 1937, Harvard professor Howard Aiken set out to build an automatic calculating machine that would combine established technology with the punched cards. With the help of graduate students and IBM engineers, the project was completed in 1944. The completed device was known as the Mark I digital computer, an electromechanical machine which was the immediate predecessor of automatic electronic computers.

(f) & (g) J. Presper Eckert and John W. Mauchly designed the Electronic Numerical Integrator And Calculator (ENIAC) which used 18,000 vacuum tubes and is often identified as the first electronic computer.

(h) In 1945, John Von Neumann was a well known mathematician who suggested that (i) binary numbering system be used in building computers and (ii) computer instructions as well as the data being manipulated could be stored internally in the machine. His suggestions then became a basic part of the philosophy of computer design.

2. (a)
- Internal operations were controlled automatically with electromagnetic relays ; arithmetic counters were mechanical.
- Capable of a precision factor of twenty-three places.
- In addition to performing the four basic arithmetic operations, it could reference tables containing previously computed results.
- Speed of performing addition and subtraction, multiplication and division were 0.3 sec, 4 sec and 16 sec, respectively.

(b)
- Vacuum tubes were used instead of electromagnetic relays.
- Could process 300 multiplications per second.
- Did not have internal storage -- a very serious limitation.

(c) . Stored-program computer, i.e. instructions were stored internally and were referred to as a program.

(d) . Stored-program computer
. Was the first electronic computer available commercially and was used for nonscientific data processing as well.
. It used magnetic tape for input and output.

3.

	FIRST GENERATION (1951-58)	SECOND GENERATION (1959-63)	THIRD GENERATION (1964-69)	FOURTH GENERATION (1970-PRESENT)
Technology	Relays, vacuum tubes. Magnetic cores and drums. Card and paper tape readers and line printers.	Diodes and transistors. Magnetic discs. Faster I/O devices.	Integrated circuits. Improved storage devices. Variety of I/O devices.	LSI circuits and semiconductor memories. New data entry devices.
Internal Operating Speed In	Milliseconds (10^{-3} sec)	Microseconds (10^{-6} sec)	Nanoseconds (10^{-9} sec)	Picoseconds (10^{-12} sec)
Software Features (Programming Capability)	Stored programs. Machine language and assembly language.	Symbolic languages and high-level languages. Subroutine libraries. Batch monitor.	Virtual memory. Operating systems. Multiprogramming. Multiprocessing.	Microprocessor and teleprocessing software.
Brief Notes	Computers were bulky, relatively slow, used great amounts of power, generated a great deal of heat, unreliable and very expensive. Mainly for scientific uses.	Computers were smaller (but still large), faster in operation, consumed less power, much more reliable, but still expensive. Separate scientific and business machines.	Computers were smaller, greater in capability and faster, used much less power and more reliable. More powerful general purpose machines were developed and also minicomputers. The overall increased efficiency resulted in great reduced computing cost.	Yet more powerful, faster and versatile computers and computing systems, smaller and less expensive. More minicomputers and the coming of microcomputers and microprocessors. Advanced in storage and data communication techniques.

4. The essential differences are :

   . A computer achieves its results through the movement of electronic impulses rather than the physical movement of internal parts of a mechanical calculator.
   . An electronic computer can hold data and instructions in an electronic reprsentation in an internal memory unit (stored-program).
   . In a computer, data is processed according to instructions which can be arithmetic, logical and input/output. Both the data and instructions must be in the storage during processing.
   . The computer is an automatic electronic machine in the sense that the stored program will direct the performance of a sequence of operations without human intervention. While the desk calculator is operated manually.

5. (a) 2×10^6 microseconds (b) 0.5 microseconds

   (c) 3×10^6 nanoseconds
   (d) 5 milliseconds is the greatest period of time among the three.
   (e) 0.2 microsecond is the shortest period of time among the three.

6. Classification by the type of data they are capable of handling:

   . Digital computer
   It operates directly on numbers expressed as digits in the familiar decimal system or some other numbering systems. It takes input and gives output in the form of numbers, letters, and special characters represented by holes in punched cards, spots on magnetic tapes, printing on paper, and so on. Digital computers can achieve a high degree of precision. They are generally used for both business data processing and scientific purposes. Most modern computers are digital computers, and it is usually digital computers that are referred to when the word "computer" is used.
   . Analog computer
   It measures continuous physical magnitudes (e.g. pressure, temperature, voltage, current, shaft rotation, length), which represent, or are analogous to, the numbers under consideration. Analog computers are used for scientific, engineering, and process control purposes. For instance, an analog computer may adjust a valve to control the flow of fluid through a pipe, or it may adjust a temperature

setting to control the temperature in an oven. A digital computer possesses greater accuracy than an analog computer, but the analog computer can process data faster than a digital computer.

Classification by the purpose for which they are designed:

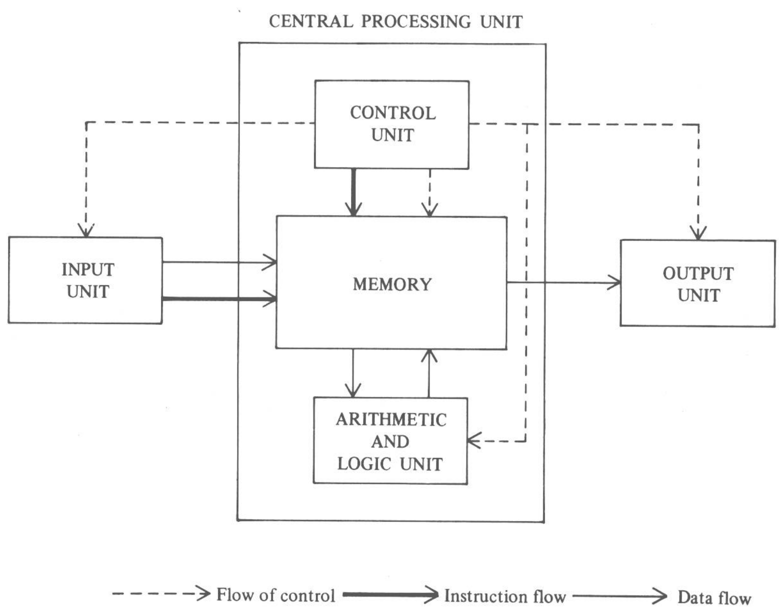
- Special purpose computer
  A special purpose computer, as the name implies, is designed to perform a special task. The program of instructions is built into the machine. This "specializing" of the machine leads to efficient, effective performance of specific task. A disadvantage however, is that the machine lacks versatility, it is inflexible and cannot be used to perform other operations. For example, the special purpose computers designed for the sole purpose of controlling a petroleum refinery cannot be used for other purpose without major changes.
- General purpose computer
  A general purpose computer, as the name implies is designed to perform a variety of tasks. This capability is a result of its ability to store different programs of instructions in its internal storage. In short, the stored program concept makes the machine a general purpose device -- one that has the versatility to make possible the processing of a payroll one minute and an inventory control application the next. Unfortunately, the ability to perform a variety of tasks is often achieved at the expense of certain aspect of speed and efficiency of performance. In most situations, the computer's flexibility, with respect to its being able to perform a variety of tasks, makes this compromise an acceptable one.

7. Experience has shown that operations most suitable for computer applications are those that have one or more of the following characteristics:
   - Large volume of input
     The greater the volume of data that must be processed, the more economical computer processing becomes relative to other possible methods.
   - Repetition of work
     Much time, effort, and cost are involved in preparing a task for computer processing, it is frequently most economical to use the computer for repetitive projects.
   - Desired and necessary greater speed in processing

The greater the need for immediate access to information or for rapid turnaround (processing input to produce output), the greater will be the value of a computer relative to slower methods.
Desired and necessary greater accuracy
Computer processing will achieve a high degree of accuracy, if the task to be performed has been properly prepared. Complex calculation: in some situations calculations of great complexity are involved, there is no alternative to the computer.

8. The five major components of a computer are
   - The control unit: the central controller for the entire system.
   - The memory: the storage area for programs and data being processed.
   - The arithmetic and logic unit : the component in which arithmetic and logical operations are carried out.
   - The input unit: the part of the computer that accepts information, both instruction and data, and stored it in the memory.
   - The output unit: the part of the computer that receives results from the memory and presents them to the user.

The control unit, the memory and the arithmetic and logic unit are grouped together to form the main frame of the computer system called the central processing unit or CPU.



Major Components of a Computer

9. The memory is used for four purposes, three of which related to the data being processed.

- Data is transferred from the input unit to the memory where it is held until ready to be processed.
- A working storage area within the memory is used to hold both the data being processed and the intermediate results of such processing.
- The memory retains the results of the processing of the data until it can be transferred to the output unit.
- In addition to the three data-related purposes just mentioned, the memory retains the program transferred from the input unit or a secondary storage medium to process the data.

10. All arithmetic calculations are performed and all logical comparisons are made in the arithmetic and logic unit. Under the supervision of the control unit, data are transferred as needed from the memory to the arithmetic and logic unit, manipulated, and returned to the memory. No manipulation is performed in the memory. Data may be transferred back and forth between the two units several times before manipulation is completed. When the manipulation of the data is completed, the results are transferred from the memory to the output unit.

11. The basic function of the control unit is to supervise the operation of all the other components and to control the flow of information to and fro from them. The control unit is told what to do by the program stored in the computer memory. It selects one program instruction at a time from the memory; it interprets the instruction and sends the appropriate electronic control signal to cause other units to carry out the instruction. Within the system, data flow is (i) from input through control to memory, (ii) from memory through control to the arithmetic and logic unit and back to memory through control, and (iii) from memory through control to output. The control unit, therefore acts as the central nervous system for the entire computer system, but performs no actual processing operations on the data.

12.

MEDIA	DEVICE	INPUT	OUTPUT
Punched cards	Card reader	X	
	Card punch		X
Paper tape	Paper tape reader	X	
	Paper tape punch		X
Paper	Optical scanner	X	
	Line printer		X
	Teletypewriter	X	X
	Graph plotter		X
Cathode ray tube (CRT)	Visual display unit (VDU)	X	X
Magnetic tape	Magnetic tape drive	X	X
Magnetic disc	Magnetic disc drive	X	X
Sound	Voice response unit	X	X
Magnetic ink	Magnetic ink character reader (MICR)	X	
Microfilm	Recorder		X

13. Secondary storage usually consists of magnetic storage media such as magnetic tape, magnetic drum or magnetic disc storage. They have the advantage of large capacity and low cost, and are used to store information in bulk.

- Magnetic tape is at present the most widely used form of secondary storage since it is relatively cheap and has a large capacity. Data is read serially from the tape, and so if one particular item of data is required, the tape must be physically moved through the reading mechanism until the required item is reached. This method of accessing data is known as serial access.

  Magnetic discs and magnetic drums are direct accesss devices; on these devices any item of data can be accessed directly and transferred to main storage without regard to the data preceding it. Thus direct access devices have the advantage of speed in accessing items of data over magnetic tape. Of course, data can be accesssed serially on direct access devices, and on jobs in which serial access is used there may be no great advantage in using direct access devices rather than magnetic tape. However, where complete files of data or complete programs are being transferred between main storage and secondary storage, direct access devices have a transfer rate advantage over that of magnetic tapes.

14. (a) Electronic Numerical Integrator And Calculator
(b) Electronic Delay-Storage Automatic Computer
(c) Central Processing Unit
(d) BInary digiT
(e) Input/Output
(f) Cathode Ray Tube
(g) Magnetic Ink Character Reader
(h) Large Scale Integration

15. . Automatic
Pertaining to a process or device that, under specified conditions, functions without intervention by a human operator.
. Access
The process of obtaining data from a peripheral unit or retrieving it from a storage device; the process involved in obtaining an instruction from memory.
. Binary number system
A number system having a base of two. Absolute values are 1 or 0, the positional values are power of 2.
. Operating system
Software that controls the execution of computer programs, and that may provide scheduling, debugging, input/output control, internal accounting, compilation, storage assignment, data management, and related services.
. Main frame
That part of a computer which contains the arithmetic and logic unit, control unit and memory. Also known as the central processing unit.
. Utility programs
Utility programs are part of the software of a system, devised to perform operating and testing functions frequently used in the operations of a particular computer. Examples are trace program, load program, and program to sort data.
. Address
That part of an instruction which specifies the location of operand; the identification of the position of a location in store; to indicate a specific location.
. Stored-program
A program which is wholly contained in store, and which is capable of being altered in store.
. Word length
A measure of the size of a word, usually specified in units such as characters or binary digits.