

17

ORIENTATION OF COMPUTERS

17.1 INTRODUCTION TO COMPUTER

17.1.1 Computer. The *computer* is defined as an electronic device which is used to store and process data to solve different problems according to a set of instructions given to it. The word "computer" came from the word "compute" which means "to calculate".

17.1.2 Capabilities of Modern Computer. The following are the details of capabilities of a modern computer.

Speed. The speed of a computer is defined as the number of instructions processed in one second.

A computer can perform millions of instructions in one micro second. It performs one operation at a time. When a computer performs an operation, the clock of the processor generates electronic pulses at a fixed rate. It generates millions of pulses or signals in one second. The number of pulses generated in one second is called frequency. The unit of frequency is hertz (abbreviated Hz). Hertz is a measure of number of vibrations per second.

The speed of a computer is measured in megahertz (abbreviated MHz) and in gigahertz (abbreviated GHz). Modern personal computers may have the speed more than 2 GHz (1 GHz = 1024 MHz).

Data Storage. A computer can store a large amount of data. It stores the data in its memory and can retrieve it with a high speed. The ability of a computer to store the data and to retrieve it with a very high speed makes it suitable for modern data processing.

Data is defined as a combination of characters, numbers and symbols collected for a specified purpose.

Data Processing. Data processing consists of series of operations performed on the data to achieve the required results.

The main function of a computer is data processing. It includes the arithmetic and logical operations. It also includes the classification of data, arrangement of data and its transmission from one place to another. The results of data processing are called the output or the information.

Accuracy. The computers are very accurate in calculations.

A modern computer can perform millions of operations in one second without any error. The accuracy of calculations depends upon the input data and the program instructions. If the input data and the program instructions are correct, then we expect that the computer will produce accurate result.

Diligence. The computer has the ability to do work for long hours. It never tires. Working for long hours does not affect the accuracy of a computer.

17.2 HISTORY OF COMPUTER

The history of computer and calculator goes back to a very long way. For many centuries, people used their own brain-power to perform arithmetic calculations. The names of three great scientists who contributed in the invention of computer are

1. Abu Jaafar Muhammad Ibn Musa Al-Khwarizmi (780 — 850)
2. Alan Mathison Turing (1912 — 1954)
3. John von Neumann (1903 — 1957)

Blaise Pascal, a mathematician and scientist of France, developed the first mechanical adding machine called "Pascaline" in the 1642. Pascaline performed addition and subtraction. This machine was modified by Baron Gottfried Wilhelm von Leibnitz in 1671. He introduced "Multiplier Wheel" to perform all the basic arithmetic operations such as addition, subtraction, multiplication and division.

The designer of the first computer was Charles Babbage a mathematician of the United Kingdom. He designed a machine called "Analytical Engine" in 1833. Analytical Engine was the first programmable computer. It consisted of the following units.

- (i) A storage (to store data)
- (ii) A mill (to perform arithmetic operations)
- (iii) A control unit (to control all operations and to coordinate the Input/ Output units).

The program (instructions) was given to the Analytical Engine with the help of punched cards.

The Americans were also experimenting to develop a computer. An American scientist working at Harvard University, developed a computer between 1937 and 1943. It was the "Harvard Mark-I"

In 1943, American scientists, J. W. Mauchly and J. P. Eckert developed an electronic computer at Moor School of Engineering, U.S.A. The electronic computer was called Electronic Numerical Integrator and Calculator (ENIAC). Manufacturing of ENIAC was started in 1943 and finally completed in 1946. ENIAC differed in only one significant way from the computer of today that its programs were stored externally on tape. This means that programs could be executed sequentially.

In 1944 John von Neumann suggested that the computer program should actually be stored electronically inside the computer. This was the final breakthrough in computer design.

17.3 TYPES OF COMPUTERS

The computers are of three types:

- (i) Digital Computer
- (ii) Analog Computer
- (iii) Hybrid Computer

17.3.1 Digital Computer. A digital computer works with digits. It operates by counting numbers or digits and gives output in digital form. It works with only two signals, 0 and 1. The data and instructions are entered and stored in coded form of 0's and 1's.

These computers are manufactured in wide variety of sizes, speeds and capacities. The digital computers are commonly used in offices and educational institutions. Digital watches, digital thermometers, etc., are the examples of digital computers.

17.3.2 Analog Computer. An *analog computer* does not operate directly with digital signals. It receives input gives output in the form of an analog signal.

The analog computers measure physical quantities to give output on a scale. The output is in the form of graph or a reading on a scale. A dial clock, thermometer and weighing machine are all examples of analog computers. The results achieved are not accurate as compared to those achieved by digital computers.

17.3.3 Hybrid Computer. A *hybrid computer* have features of both analog and digital computers.

The hybrid computers get input and give output either in analog or digital form. Modem is an example of hybrid computer.

17.4 CLASSIFICATION OF COMPUTERS

The computers are manufactured in a wide variety of sizes, speeds and capacities. In computer terminology, size refers to the amount of data a computer can handle. Generally a computer with a high processing speed is called a big computer. Depending upon their speed and memory size, the computers are classified into the following different groups

- | | |
|----------------------|--------------------------|
| (i) Micro Computers | (ii) Mainframe Computers |
| (iii) Mini Computers | (iv) Super Computers |

17.4.1 Micro Computers. The *micro computers* or *personal computers* are designed to be used by one user at a time. These are commonly used in offices, at homes and in educational institutions. These computers have processing speed of the order of millions of instructions processed per second (MIPS). The peripherals used in these systems include keyboard, monitor, character or page printer and a mouse.

The micro computers are small in size and are mainly used in accounting, database, word processing and graphics, etc. Laptop and notebooks are micro computers.

17.4.2 Mainframe Computers. The *mainframe computers* are very large computers. The mainframe computers have very high processing speed. These computers are used by large business organizations like banks, insurance companies, scientific research institutes and weather forecasting bureaus. The largest IBM S/390 mainframe, for example, can support 50,000 users while executing more than 1,600,000,000 instructions per second.

17.4.3 Mini Computers. The *mini computers* released in 1960s got their name because of their small size compared to the other computers of the day. They are smaller version of the mainframe computers. Like the mainframes, mini computers can handle much more data than personal computers. These are used for maintaining details of a large business organization, to analyse the results of experiments or to control and maintain the production activity in factory.

The mini computers have large memory and faster input/output devices. They are more expensive and have more processing speed than micro computers. The most powerful mini computer can serve the input and output needs of hundreds of users at a time. The mini computers cost anywhere from \$ 18,000 to \$ 500,000 and are ideal for many organizations and companies that cannot afford or do not need mainframe systems.

17.4.4 Super Computers. The *super computers* are the most powerful computers made, and physically they are some of the largest. These systems are built to process huge amounts of data, and the fastest super computers can perform more than 1 trillion calculations per second.

Some super computers such as the Cray T90 system can house thousands of processor. This speed and power make super computers ideal for handling large and highly complex problems that require extreme calculating power. These computers are used by Nuclear scientists

to create and analyze models of nuclear fission and fusion, predicting the action and the reactions of millions of atoms as they interact. These computers are also being used to map the human genome, or DNA structure. The super computers can cost tens of millions of dollars and consume enough electricity to power dozens of homes.

17.5 HARDWARE AND SOFTWARE

17.5.1 Hardware. The physical parts of the computer are called *hardware*. It includes all physical devices or units that make up a computer. The examples of hardware are: CPU, monitor, mouse, keyboard, etc.

17.5.2 Software. The set of instructions given to the computer to solve a problem or to control the operation of the computer is called *software*. The software is prepared in computer programming languages. The examples of software are: Microsoft Word, Excel, Corel Draw, Photoshop, etc.

17.6 HARDWARE COMPONENTS OF A PERSONAL COMPUTER

The computer itself, the hardware, has many parts, but the critical components fall into one of four categories.

1. Central Processing Unit (CPU)
2. Main Memory
3. Input/Output Devices
4. Secondary Storage

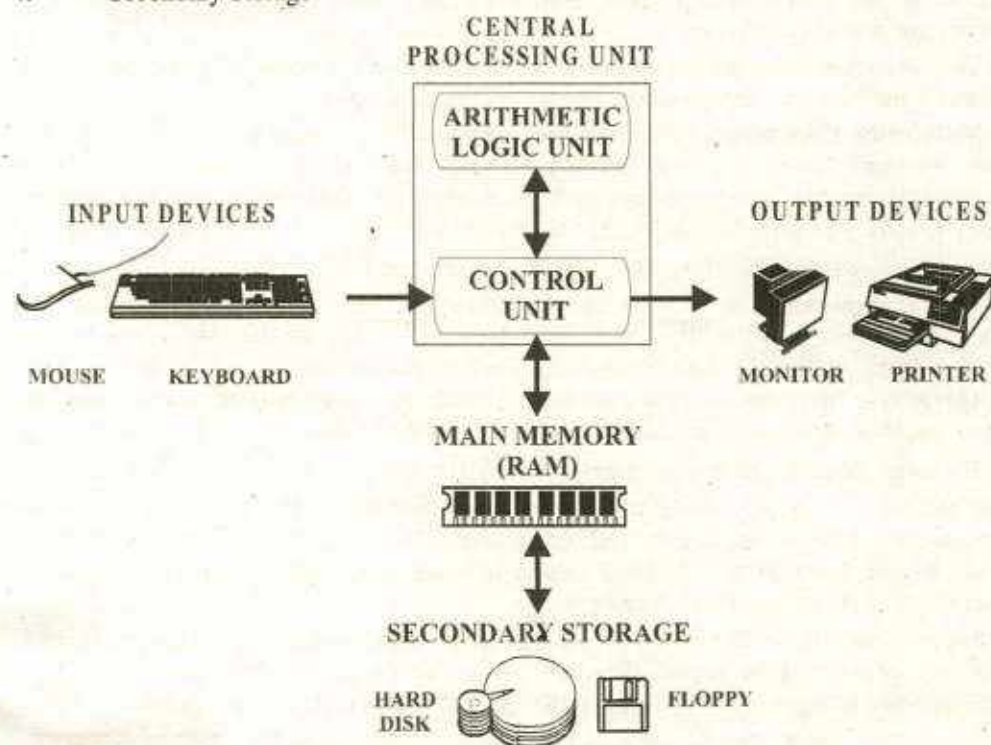


Fig. 17.1 Hardware Components of Personal Computers

17.6.1 Central Processing Unit (CPU). The *central processing unit* is the brain of the computer, the place where data is manipulated. In large computer systems, such as super computers and mainframe computers, processing tasks may be handled by multiple processing chips. (Some powerful computers systems use hundreds or even thousands of separate processing units). In average micro computer, the entire CPU is a single chip called a micro processor. The CPU has at least two basic parts:

- (i) Control Unit
- (ii) Arithmetic Logic Unit (ALU)

Control Unit. All the computer's resources are managed from the control unit. Think of the control unit as a traffic cop directing the flow of data through the CPU, and to the other devices. The control unit is the logical hub of the computer.

The CPU's instructions for carrying out commands are built into the control unit. The instructions, or instructions set is expressed in macrocode a series of basic direction tells CPU how to execute more complex operations.

Data will have to be first transferred from the input device or secondary storage to the main memory and taken from there to the ALU for processing. Instructions on what to do with the data must be given to the ALU. Then the results have to be transferred to the main memory and from there to the output device. For these and many more such tasks we need a sort of manager. It is the control unit which takes care of all these activities.

One of the most important function of the control unit is the handling of program steps. Each basic instruction such as 'add', 'subtract' or 'store' is in the form of code. Only the control unit understand each code and gets the instruction executed. In that process it may move data from an input device to the memory, from the memory to the ALU, from the ALU back to the memory, from memory to an output device and so on. The control unit is like the nervous system of the body and supervises all the operations of computer

Arithmetic Logic Unit (ALU). The arithmetic logic unit is a part of the processor in which all arithmetic and logical operations on the data are performed.

Arithmetic section of the ALU performs basic arithmetic operations such as addition, subtraction, multiplication and division.

A logical operation is one in which data is compared. For example, whether the *first number* is greater than the *second number*, or it is less than, equal to, not equal to, grater than or equal to, etc. The logic section of ALU performs logical operations.

Arithmetic Operations		Logical Operations	
+	add	=, ≠	equal to, not equal to
−	subtract	>, >	greater that, not greater than
×	multiply	<, <	less than, not less than
÷	divide	≥, ≥	greater than or equal to, not greater than or equal to
^	raised by a power	≤, ≤	less than or equal to, not less than or equal to

The ALU includes a group of registers high speed memory locations built directly into the CPU that are used to hold the data currently being processed. For example, the control unit might load two numbers from memory into the register in the ALU. Then it might tell the ALU to

divide the two numbers (an arithmetic operation) or to see whether the numbers are equal (a logical operation)

17.6.2 Main Memory. The main memory, also called RAM (Random Access Memory) or primary storage contained in the processor unit of the computer temporarily stores data and programme instructions when they are being processed.

The main memory has many storage locations. Each memory location has a Storage Address, like a Post Box number. The computer stores or retrieves data using the address. The computer always keeps a list of data items and corresponding addresses. This is, of course, done automatically and we need not worry about it.

When the computer retrieves data from a location, it merely reads what is stored and transfer them elsewhere. It does not destroy the stored data. On the other hand, when it stores new data in a location, the previous contents in that location are lost.

The most common measurement unit for describing a computer's memory is bytes, the amount of memory it takes to store a single character, such as a letter of the alphabet or numerical.

The measurement for Computer Memory and Storage				
Unit	Abbreviation	Pronounced	Approximate value (bytes)	Actual values (bytes)
Kilobyte	KB	KILL-uh-bite	1,000	1,024
Megabyte	MB	MEHG-uh-bite	1,000,000 (1 million)	1,048,576
Gigabyte	GB	GIG-uh-bite	1,000,000,000 (1 billion)	1,073,741,824
Terabyte	TB	TERR-uh-bite	1,000,000,000,000 (1 trillion)	1,099,511,627,776

Today's personal computers commonly have from 64 to 256 million bytes (or 64 to 256 MB) of memory. Some computers improve their processing efficiency by using a limited amount of high speed RAM memory between the CPU and main memory. High-speed memory used in this manner is called cache (pronounced cash) memory. Cache memory is used to store the most frequently used instructions and data. When the processor needs the next program instructions and data, it first check the cache memory. If the required instruction or data is present in cache (called a cache hit), the processor will execute faster than if the instructions or data has to retrieve from the slower main memory.

17.6.3 Input/ Output Devices. Computers would be useless if they did not provide interaction with users. They could not receive or deliver the results of their work. Input devices accept data and instructions from the user or from another computer system (such as a computer on the internet). Output devices return processed data back to the user or to another computer system.

Input Devices. Before processing unit can work, the data and programme must be entered into the computer memory, this is done by means of input devices. The most common input devices are keyboard, mouse, scanners and digital cameras.

Output Unit. There are various devices to present information in a particular manner or to deliver it at appropriate speed., e. g., video display units, line printer and COM (Computer Output Microfilm).

17.6.4 Secondary Storage. A computer can function with only processing unit, memory, input and output devices. To be really useful, however, it also need a place to keep programme files and related data when it is not using them. The purpose of storage is to hold data.

It is important to understand the difference between how a computer uses main memory and how it uses secondary storage. Main memory, also called primary storage or RAM, temporarily stores programmes and data being processed. *Secondary storage*, also called auxiliary storage, stores programmes and data when they are not being processed.

The physical components or materials on which data is stored are called storage media. The hardware components that write to, and read it from, storage media are called storage devices. Two main categories of storage technology used today are magnetic storage and optical storage. Although most storage devices and media employ one technology or other, some use both.

The primary types of magnetic storage are as follows;

- (i) Diskettes
- (ii) Hard disks (both fixed and removable)
- (iii) High-capacity floppy disks
- (iv) Disk cartridges
- (v) Magnetic tape

The primary types of optical storage are as follows;

- (i) Compact Disk Read-Only Memory (CD-ROM)
- (ii) Digital Video Disk Read-Only Memory (DVD-ROM)
- (iii) CD-Recordable (CD-R)
- (iv) CD-ReWritable (CD-RW)
- (v) Photo CD

The most common storage medium is the magnetic disk. A disk is a round, flat object that spins around its centre. Read/write heads, which are similar to the heads of tape recorder or VCR, are used to read data from the disk or write data onto the disk. Depending on the type of disk, read/write heads may float just above the disk's surface or may actually touch the disk.

17.7 INPUT DEVICES AND OUTPUT DEVICES

17.7.1 Input Devices. *Input devices* consist of hardware that translate data into a form the computer can process. The people readable form may be words like the ones in these sentences, but computer readable form consists of '0' and '1' or "off" and "on" electrical signals. Input hardware devices are categorized as three types

- (i) Keyboards
- (ii) Pointing devices
- (iii) Source data entry devices

17.7.2. Keyboard. Keyboard is a device that converts letters, numbers and other characters into electrical signals that are machine readable by the computer processor. The keyboard may look like a type writer keyboard to which some special keys have been added. Keyboard has 3 types of keys, namely

- (i) Alphabet keys (A, B, C, ..., Z, a, b, c, ..., z)
- (ii) Numeric keys (1, 2, 3, 4, 5, 6, 7, 8, 9, 0)
- (iii) Special keys (F1, F2, ..., F12, Alt, Ctrl, Shift, Tab, Capslock, Enter, ..., etc)

The standard keyboard has 101 buttons on it and now a days the keyboards with 104, 106, 110 buttons are available in the market.

17.7.3. Pointing Devices. *Pointing devices* control the position of the cursor or pointer on the screen. Pointing devices include.

- (i) Mouse
- (ii) Light pens, etc.

Mouse. A mouse is a device that is rolled about on a desktop and direct a pointer on the computer's display screen the mouse has a cable that is connected to the micro computer's system unit by being plugged into a special port or socket. It has two/three buttons, a wire or wireless. On the bottom side of the mouse is ball that translates the mouse movement into digital signals. Depending upon the software, many commands that you can execute with a mouse can also be performed through a keyboard. The following are the functions of a mouse.

- (i) **Point.** Move the pointer to the desired spot on the screen, such as over a particular word or object.
- (ii) **Click.** Press and quickly release, the left mouse button twice as quickly as possible.
- (iii) **Drag.** the pointer to another location
- (iv) **Drop.** Release the mouse button after dragging
- (v) **Right click.** To make a selection using the button on the right side of the mouse which usually brings up a pop up menu

Trackball. The trackball is movable, on top of a stationery device, that is rotated with fingers or palm of the hand. Trackballs are specially suited to portable computers, which are often used in confined places such as on airplane tray, tables. Trackballs may appear on the keyboard centred below the space bar.

Joystick. A joystick is a pointing device that consist of vertical handle like a gearshift lever mounted on a base with one or two buttons

Touch pad The touch pad is a small, flat surface over which you slide your finger, using the same movement mouse.

Light Pen. The light pen is a light sensitive stylus, or pen like device connected by a wire to the computer terminal the user brings the pen to a desired point on the display screen and presses the pen button, which identifies that screen location to the computer.

17.7.4 Output Devices. The devices that are used to receive data from the CPU in binary code and convert it into readable form are called *output devices*. The output devices enable CPU to transfer information to the user and other devices.

The output device receives data from CPU in computer code and converts it into a form that a user can understand or which is readable to the other devices. For example, the binary string 01000001 from CPU represents letter 'A' on the screen. The output is divided in two categories:

- (i) The output that is sent to the secondary storage, e. g., magnetic tape disk, etc. This output can be used by the CPU as input for further processing.
- (ii) The output that can be read and used by people. This output is further divided into:

- (a) **Softcopy Output.** It is the output that is temporary and is erased when the computer is switched off, e. g. display on the computer screen.
- (b) **Hardcopy Output.** It is the output that is permanent and is always available for use, e. g., print out on the paper.

Softcopy Output Devices. Softcopy output devices are used to display output on the screen. They are also called Visual Display Units (VDU). The most commonly used softcopy device are;

- (i) Monitors
- (ii) Pc Projectors
- (iii) Sound Systems

Hardcopy Output Devices. The computer user usually needs output printed on the paper for permanent record. The output received from the computer on the paper is called hardcopy. The devices used to produce a hardcopy are two types

- (i) Printer
- (ii) Plotter

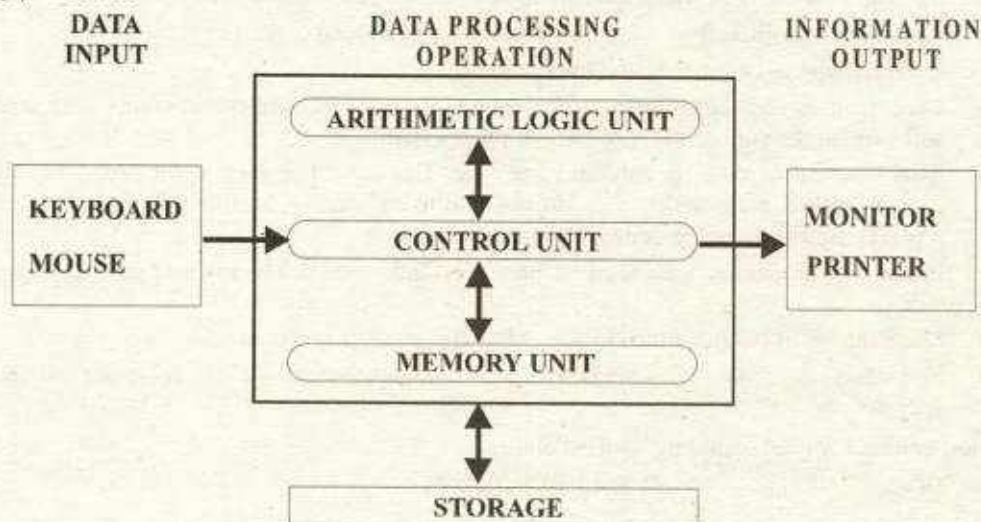


Fig. 17.2 Information Processing System

17.8 SYSTEM SOFTWARE

System software consists of all programs including the programs including the operating system that are to controlling the operations of the computer equipment. Some of the functions that system software perform include: starting up the computer; loading, executing, and storing application programs; storing and retrieving files; and performing a variety of functions such as formatting disks, sorting data files, and translating programs instructions into machine languages. System software can be classified into three major categories; operating systems, utilities, and language translators.

17.9 OPERATING SYSTEM

An operating system (OS) is an integrated set of programs that is used to manage the various hardware resources of computer system. Its prime objective is to improve the performance and efficiency of a computer system and increase facility, the ease with which a

system can be used. Each time a computer is turned on, or restarted the operating system is loaded into the computer and stored in the computer's main memory.

17.9.1 Functions of Operating Systems. The following are the functions of operating systems.

- (i) Processor management, that is, assignment of processors to different tasks being performed by the computer system
- (ii) Memory management, that is, allocation of main memory and other storage areas to system programs as well as user programs and data.
- (iii) Input/ Output management, that is, coordination and assignment of the different input and output devices while one or more programs are being executed.
- (iv) File management, that is, the storage of files on various storage devices and transfer of these files from one storage device to another. It also allows all files to be easily changed and modified through the use of text editors or some other file manipulation routines.
- (v) Establishment and enforcement of job priority system. That is, it determines and maintains the order in which jobs are to be executed in the computer system.
- (vi) Automatic transition from job to job as directed by special control statements.
- (vii) Interpretation of commands and instructions.
- (viii) Coordination and assignment of compilers, assemblers, utility programs and other software to the various users of the computer system.
- (ix) Establishment of data security and integrity. That is, it keeps different programs, and data in such a manner that they do not interfere with each other. Moreover, it also protects itself from being destroyed by any user.
- (x) Production of dumps, traces, errors messages and other debugging and error-detecting aids.
- (xi) Maintenance of internal time clock and log of system usage for all user.
- (xii) Facilitates easy communication between the computer system and the computer (human) operator

The most commonly used operating systems are:

- | | |
|------------|--------------|
| (i) DOS | (ii) WINDOWS |
| (iii) OS/2 | (iv) UNIX |
| (v) LINUX | |

17.9.2 DOS. DOS stands for *Disk Operating System*, the most widely used operating system on personal computers. Several slightly different but compatible versions of DOS exist. The two most widely used, MS-DOS and PC-DOS were both originally developed by Microsoft Corporation in 1981.

MS-DOS is the text driven user interface, that is, the user types a line of text as a command. The computer then executes the command. These commands can be used to format disk, copy, and surname, delete backup files and organize and manage files on disk. MS-DOS versions 2.0 and up incorporated a tree structured hierarchical file management scheme. In this scheme, files can be managed into groups, which are known as directories. MS-DOS version 4.0 and above added additional enhanced commands and support for network and added a user interface called DOS shell with pull down menus. A *shell* program usually provides a limited graphic interface and certain utility functions file maintenance

17.10 APPLICATION SOFTWARE

Application software consist of programs that tell a computer how to produce information. When you think of the different ways that people uses computer in their careers or in their personal lives, your are thinking of examples of application software. Business, scientific, and educational programs are the examples of application software. The most widely used personal computer application softwares are:

- (i) Word processing
- (ii) Desktop publishing
- (iii) Spreadsheet
- (iv) Database
- (v) Presentation graphics
- (vi) Communications
- (vii) Electronic mail
- (viii) Personal information management
- (ix) Project management

17.11 PROGRAMMING LANGUAGES

A programming language is a way of communication between the user and the computer. With the help of a programming language, programmer writes programs to solve problems with the computer.

Each programming language has its own rules for writing a computer program. The rules are called the *syntax* of the language. The process of writing a computer program is called *coding*.

17.11.1 Types of Programming Languages. Many computer programming languages are available. Some programming languages are close to human language and some programming languages are close to machine language. Therefore, programming languages are divided into two types:

- (i) Low level languages
- (ii) High level languages

Low Level Language. The programming language that are close to machine code are called Low Level Languages. The programs or instructions written in these languages are close to the machine language instructions. The mainly used low level languages are:

- (i) **Machine Language.** The instructions written in this language are in the form of binary strings of 0's and 1's. It is the fundamental language. The programs written in this language are executed directly by the computer.
- (ii) **Assembly Language.** It is similar to the machine language. In this language, symbolic codes are used instead of binary codes. The symbolic codes are also called mnemonic. The program written in this language is translated to machine code with the help of an assembler. This language is also known as *symbolic language*.

High Level Language. The programming languages that are close to human languages are called high level languages. The programs or instructions written in high level languages are close to English language. Each high level language has its own rules (syntax) and character set. Some of the commonly used high level languages are:

- ALGOL:** Algol stands for ALGOrithmic Language.
- BASIC:** Basic stands for Beginners All-purposes Symbolic Instruction Code.
- COBOL:** Cobol stands for Common Business Oriented Language.

- PASCAL:** This language is named in the honour of French mathematician Pascal, who invented the first mechanical calculator.
- FORTRAN:** Stands for **FOR**mula **TRAN**slation.
- C:** It is a general purpose language. It is widely used language in scientific and all other fields.

17.12 LANGUAGE PROCESSORS AND TRANSLATORS

The program that converts a source program, written in the programming, into the machine code, i. e., in the form of strings of 0's and 1's is called language processor or translator. There are three types of language processors or translators:

- (i) Assembler
- (ii) Interpreter
- (iii) Compiler

17.12.1 Assembler. An assembler translates a program written in an assembly language into machine code.



17.12.2 Interpreter. The language processors that execute a source program by translating and executing one instruction at a time are called interpreters.

17.12.3 Compiler. A compiler is a translator that converts a program written in a high-level language.



17.13 BASIC IDEA OF WRITING AND RUNNING A COMPUTER PROGRAM

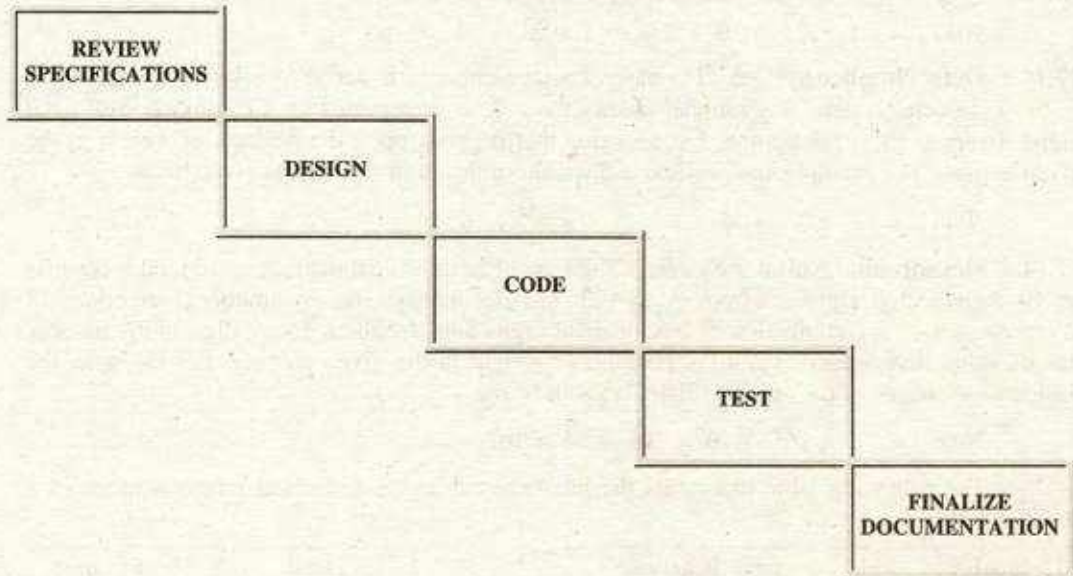
17.13.1 Computer Program. The *computer program* is a detailed set of instructions that directs a computer to perform the tasks necessary to process data into information. These instructions usually written by computer programmer, can be coded (written) in a variety of programming languages. A computer program is also known as software.

17.13.2 Computer Program Development. The program development is a process of producing one or more programs to perform specific tasks on a computer. The process of program development has evolved into a series of five steps most experts agree should take place when any program is developed

1. **Review specification.** The programmer reviews the specification created by system analyst during the system design phase.
2. **Design.** The programmer determines and documents the specific action the computer will take to accomplish the desired tasks.

3. **Code.** The programmer writes the actual program instructions.
4. **Test.** The written programs are tested to make sure they perform as intended.
5. **Finalize documentation.** Throughout the program development process, the programmer documents, or writes, explanatory information about program steps 1 through 4 is brought together and organized.

Five Steps of Program Development



17.14 NUMBER SYSTEM

A set of digits, symbols and rules used to express quantities for counting, comparing amount, performing calculations, making measurements, representing values, *etc.* is called number system. A number system is named after the base of the system. The total number of digits in a number system is called its base. The most commonly used number systems are:

1. Decimal Number System.
2. Binary Number System.
3. Octal Number System.
4. Hexadecimal Number System.

The most common number system is the decimal number system. It is used in normal every day life. High level computer language nowadays use only decimal number system. Earlier programming languages required writing of long strings of numeric digits. Different number systems were used as shortcut for writing these strings. These number systems are no longer in use. However, their knowledge is necessary for understanding data representation inside the computer.

17.14.1 Decimal Number System. The base of decimal number is 10 and it consists of 10 digits from 0 to 9. In decimal system, any number greater than 9 is represented by a combination of decimal digits. Every digit in the number has its value that depends upon the

position or weight in the given number. For example, the position and weight of the number 3046 is given below

$$3046 = 3 \times 10^3 + 0 \times 10^2 + 4 \times 10^1 + 6$$

17.14.2 Binary Number System. The base of decimal number is 2 and it consists of 2 digits 0 and 1. In binary system, any number greater than 1 is represented by a combination of binary digits. Every digit in the number has its value that depends upon the position or weight in the given number. For example, the position and weight of the number 1011 is given below

$$1011 = 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1$$

17.14.3 Octal Number System. The base of octal number is 8 and it consists of 8 digits from 0 to 7. In octal system, any number greater than 7 is represented by a combination of octal digits. Every digit in the number has its value that depends upon the position or weight in the given number. For example, the position and weight of the number 3046 is given below

$$3046 = 3 \times 8^3 + 0 \times 8^2 + 4 \times 8^1 + 6$$

17.14.4 Hexadecimal Number System. The base of hexadecimal number is 16 and it consists of 10 digits and 6 alphabets from A to F. In hexadecimal system, any number greater than 15 is represented by a combination of hexadecimal digits and alphabets. Every digit in the number has its value that depends upon the position or weight in the given number. For example, the position and weight of the number 3046 is given below

$$3046 = 3 \times 16^3 + 0 \times 16^2 + 4 \times 16^1 + 6$$

The following table represents the binary, octal and hexadecimal representations of a decimal number.

Decimal numbers	Binary representation	Octal representation	Hexadecimal representation
0	0000	00	0
1	0001	01	1
2	0010 one 2, no units	02	2
3	0011	03	3
4	0100	04	4
5	0101 one 4, no twos, one unit	05	5
6	0110	06	6
7	0111	07	7
8	1000	10	8
9	1001 one 8, no fours, no twos, one unit	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F
16	10000 one 16, no eight, no fours, no twos, no unit	20	10

17.15 HOW COMPUTERS REPRESENT DATA

To a computer, every thing is a number. Numbers are numbers; letter a punctuation marks are numbers; sounds and pictures are numbers. Even computer's own instructions are numbers. When you see letters of the alphabet on a computer screen, you are seeing just one of the computer's ways of representing numbers. For example, consider this sentence: *Here are some words.* It may look like a string of alphabet characters to you, but to a computer it look the string of ones and zeros shown in the following table

H	0100 1000
e	0110 0101
r	0111 0010
e	0110 0101
	0010 0000
a	0110 0001
r	0111 0010
e	0110 0101
	0010 0000
s	0111 0011
o	0110 1111
m	0110 1101
e	0110 0101
	0010 0000
w	0111 0111
o	0110 1111
r	0111 0010
d	0110 0100
s	0111 0011

17.16 BINARY SYSTEM AS A FOUNDATION OF COMPUTER PROGRAMMING

In computer, however, all the data is represented by the state of the computer's electrical switches. A switch has only two possible states "on" and "off" so it can represent only two numeric values. To a computer when a switch is off, it represents a 0; when a switch is on, it represents a 1. Because there are only two values, computer are said to function in base 2, which is also known as binary number system (*bi* means "2" in Latin). Why we go for binary numbers instead of decimal numbers? The reasons are as follows:

1. The first and foremost reason is that electronic and electrical components, by their very nature, operate in binary mode. Information is handled in the computer by electronic / electrical components such as transistors, semiconductors, wires, *etc.*, all of which can

only indicate two states or conditions on (1) or off (0). Transistors are either conducting (1) or non-conducting (0); magnetic materials are either magnetized (1) or non-magnetized (0) in one direction or in the opposite direction; a pulse or voltage is present (1) or not present (0) in wire. All information is represented within the computer by presence or absence of these various signals. The binary number system, which has only two digits (0 and 1), is the most suitable and conveniently used to express the two possible states.

2. The second reason is that computer circuits only have to handle two binary digits rather than ten decimal digits. The result is that the internal circuit design of computers is simplified to great extent. This ultimately results in less expensive and more reliable circuits for computers.
3. Finally, the binary number system is used because everything that can be done with base of 10 can also be done in binary.

The reason why the octal number system is used with computers is because it can represent binary values in a more compact form and because the conversion between the binary and the octal number system is very efficient.

The primary reason why the hexadecimal number systems is used with computers is because it can represent binary values in a more compact form and because the conversion between the binary and the hexadecimal number system is most efficient. An eight-digit binary number can be represented by a two-digit hexadecimal number

Exercise 17.1

1. (a) How are computers generally classified? What are the four major categories of computers?
(b) What is CPU? Why is it called the brain of the computer?
2. (a) Explain the working of Arithmetic Logical Unit (ALU).
(a) Explain the Control Unit.
(c) What is secondary storage? How it differ from a primary storage?
3. (a) Describe the various input and output devices with examples.
4. (a) What is computers software?
(b) What are the functions of a system software?
5. (a) What do you know about DOS?
(b) What does application software do and what are its generic types?
6. (a) What are computer languages and their types?
(b) What is an assembler?
(c) What is a compiler?
7. (a) What is Binary Number System? Why is it used in computer?.

Exercise 17.2
Objective Questions

1. Fill in the blanks.

- (i) _____ is commonly used input device. (keyboard)
- (ii) 1 MB equals _____ bytes. (1,048,576)
- (iii) Screen output is considered as a _____. (softcopy)
- (iv) CD-ROM is a type of _____. (Optical disk)
- (v) _____ is a set of electronic instructions. (Software)
- (vi) The most common type of computer memory is called _____. (RAM)
- (vii) A high speed memory that is built into the processor is called _____. (cache memory)
- (viii) RAM is called _____ storage. (primary)
- (xi) Arithmetic operations are carried out by _____ unit (ALU)
- (x) The _____ is the TV type screen that you view your programs on. (monitor)
- (xi) The _____ allow you to type information into the computer (keyboard)
- (xii) Keyboard, mouse, scanner are the _____ devices (input)

2. Mark off the following statements as true or false.

- (i) 1 Kb = 1000 bytes. (true)
- (ii) Plotter is an input device to draw the graphs of the output (false)
- (iii) A complete computer system has two parts: hardware and software. (true)
- (iv) The keyboard and monitor are examples of output devices. (false)
- (v) UNIX is a application software (false)
- (vi) The purpose of a storage device is to hold data (true)
- (vii) Base 2 is another name for the decimal number system (false)
- (viii) A CD-ROM is an example of a magnetic storage device (false)

- (ix) A hard disk may also be referred to as secondary storage device. (true)
- (x) The central processing unit (CPU) contains a Control Unit that performs arithmetic and logic operations. (false)
- (xi) All computers work on a binary number system (true)
- (xii) FORTRAN is a low-level language (false)

A

SAMPLING DISTRIBUTIONS FROM NORMAL POPULATIONS

A.1 Chi-square χ^2 Random Variable. If $Z_1, Z_2, \dots, Z_v$ be the v independent standard normal variables, then the sum of the squares of these v random variables

$$\chi_v^2 = \sum_{i=1}^v Z_i^2$$

follows a chi-square distribution with v degrees of freedom. Thus χ^2 is a continuous random variable with its range

$$R = \{ \chi^2 : 0 \leq \chi^2 < \infty \}$$

A.2 Degrees of Freedom. The term *degrees of freedom* is defined as the number of independent or "freely chosen" variables.

A.3 Shape of Chi-square Distribution. The chi-square distribution is positively skewed rather than symmetric as is the normal. The skewness decreases as the value of its parameter v increases. The chi-square distribution approaches to the normal distribution with $\mu = v$ and $\sigma^2 = 2v$ as the number of degrees of freedom tends to infinity.

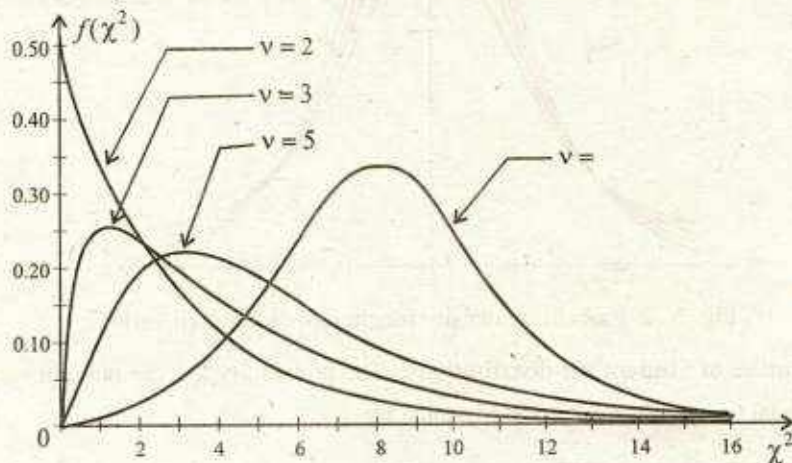


Fig. A.1 Probability density function of χ^2 random variable

A.4 Quantiles of Chi-square Distributions. The probability that the chi-square random variable χ_v^2 is less than or equal to a positive number $\chi_{v,p}^2$ is represented by

$$F(\chi_{v,p}^2) = P(\chi_v^2 \leq \chi_{v,p}^2) = p$$

This function has been tabulated, and the quantiles $\chi^2_{v;p}$ of the chi-square distributions can be found in Table 11. For example, if $v = 10$ and $p = 0.9$, then

$$P(\chi^2_{10} \leq \chi^2_{10;0.9}) = P(\chi^2_{10} \leq 15.99) = 0.9$$

A. 5 The T Random Variable. If the random variable Z has a standard normal distribution and another random variable χ^2 has a chi-square distribution with v degrees of freedom, and if Z and χ^2 are independent, then the random variable

$$T_v = \frac{Z}{\sqrt{\chi^2/v}}$$

follows a t -distribution with v degrees of freedom. Thus T is a continuous random variable with its range

$$R = \{t: -\infty < t < \infty\}$$

A. 6 Shape of t -distribution. The t -distribution is mound shaped, single humped, perfectly symmetric about the value $t = 0$. As the number of degrees of freedom v increases, the t -distribution approaches the standard normal distribution.

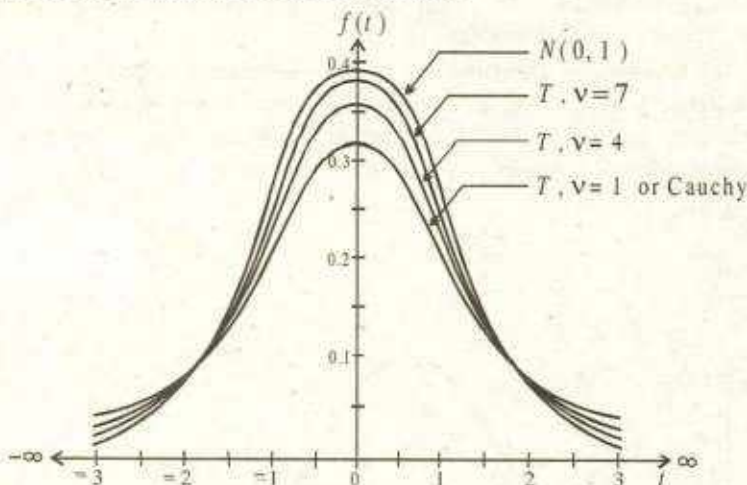


Fig. A. 2 Probability density function of T random variable

A. 7 Quantiles of Student's t -distributions. The probability that the random variable T_v is less than or equal to a number $t_{v;p}$ is represented by

$$F(t_{v;p}) = P(T_v \leq t_{v;p}) = p$$

This function has been tabulated and the quantiles $t_{v;p}$ of the Student's t -distributions can be found in Table 12. For example, if $v = 10$ and $p = 0.9$, then

$$P(T_{10} \leq t_{10;0.9}) = P(T_{10} < 1.372) = 0.9$$

Table 7

Ordinates of the Standard Normal Curve at $Z = z$

Tabulated Values: $\varphi(z) = \frac{1}{\sqrt{2\pi}} e^{-z^2/2}$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-4.9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
-4.8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
-4.7	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000
-4.6	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
-4.5	0.00002	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
-4.4	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
-4.3	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
-4.2	0.00006	0.00006	0.00005	0.00005	0.00005	0.00005	0.00005	0.00004	0.00004	0.00004
-4.1	0.00009	0.00009	0.00008	0.00008	0.00008	0.00007	0.00007	0.00007	0.00006	0.00006
-4.0	0.00013	0.00013	0.00012	0.00012	0.00011	0.00011	0.00011	0.00010	0.00010	0.00009
-3.9	0.00020	0.00019	0.00018	0.00018	0.00017	0.00016	0.00016	0.00015	0.00014	0.00014
-3.8	0.00029	0.00028	0.00027	0.00026	0.00025	0.00024	0.00023	0.00022	0.00021	0.00021
-3.7	0.00042	0.00041	0.00039	0.00038	0.00037	0.00035	0.00034	0.00033	0.00031	0.00030
-3.6	0.00061	0.00059	0.00057	0.00055	0.00053	0.00051	0.00049	0.00047	0.00046	0.00044
-3.5	0.00087	0.00084	0.00081	0.00079	0.00076	0.00073	0.00071	0.00068	0.00066	0.00063
-3.4	0.00123	0.00119	0.00115	0.00111	0.00107	0.00104	0.00100	0.00097	0.00094	0.00090
-3.3	0.00172	0.00167	0.00161	0.00156	0.00151	0.00146	0.00141	0.00136	0.00132	0.00127
-3.2	0.00238	0.00231	0.00224	0.00216	0.00210	0.00203	0.00196	0.00190	0.00184	0.00178
-3.1	0.00327	0.00317	0.00307	0.00298	0.00288	0.00279	0.00271	0.00262	0.00254	0.00246
-3.0	0.00443	0.00430	0.00417	0.00405	0.00393	0.00381	0.00370	0.00358	0.00348	0.00337
-2.9	0.00595	0.00578	0.00562	0.00545	0.00530	0.00514	0.00499	0.00485	0.00470	0.00457
-2.8	0.00792	0.00770	0.00748	0.00727	0.00707	0.00687	0.00668	0.00649	0.00631	0.00613
-2.7	0.01042	0.01014	0.00987	0.00961	0.00935	0.00909	0.00885	0.00861	0.00837	0.00814
-2.6	0.01358	0.01323	0.01289	0.01256	0.01223	0.01191	0.01160	0.01130	0.01100	0.01071
-2.5	0.01753	0.01709	0.01667	0.01625	0.01585	0.01545	0.01506	0.01468	0.01431	0.01394
-2.4	0.02239	0.02186	0.02134	0.02083	0.02033	0.01984	0.01936	0.01888	0.01842	0.01797
-2.3	0.02833	0.02768	0.02705	0.02643	0.02582	0.02522	0.02463	0.02406	0.02349	0.02294
-2.2	0.03547	0.03470	0.03394	0.03319	0.03246	0.03174	0.03103	0.03034	0.02965	0.02898
-2.1	0.04398	0.04307	0.04217	0.04128	0.04041	0.03955	0.03871	0.03788	0.03706	0.03626
-2.0	0.05399	0.05292	0.05186	0.05082	0.04980	0.04879	0.04780	0.04682	0.04586	0.04491

Table 7 (Continued)

<i>z</i>	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-1.9	0.06562	0.06438	0.06316	0.06195	0.06077	0.05959	0.05844	0.05730	0.05618	0.05508
-1.8	0.07895	0.07754	0.07614	0.07477	0.07341	0.07206	0.07074	0.06943	0.06814	0.06687
-1.7	0.09405	0.09246	0.09089	0.08933	0.08780	0.08628	0.08478	0.08329	0.08183	0.08038
-1.6	0.11092	0.10915	0.10741	0.10567	0.10396	0.10226	0.10059	0.09893	0.09728	0.09566
-1.5	0.12952	0.12758	0.12566	0.12376	0.12188	0.12001	0.11816	0.11632	0.11450	0.11270
-1.4	0.14973	0.14764	0.14556	0.14350	0.14146	0.13943	0.13742	0.13542	0.13344	0.13147
-1.3	0.17137	0.16915	0.16694	0.16474	0.16256	0.16038	0.15822	0.15608	0.15395	0.15183
-1.2	0.19419	0.19186	0.18954	0.18724	0.18494	0.18265	0.18037	0.17810	0.17585	0.17360
-1.1	0.21785	0.21546	0.21307	0.21069	0.20831	0.20594	0.20357	0.20121	0.19886	0.19652
-1.0	0.24197	0.23955	0.23713	0.23471	0.23230	0.22988	0.22747	0.22506	0.22265	0.22025
-0.9	0.26609	0.26369	0.26129	0.25888	0.25647	0.25406	0.25164	0.24923	0.24681	0.24439
-0.8	0.28969	0.28737	0.28504	0.28269	0.28034	0.27798	0.27562	0.27324	0.27086	0.26848
-0.7	0.31225	0.31006	0.30785	0.30563	0.30339	0.30114	0.29887	0.29659	0.29431	0.29200
-0.6	0.33322	0.33121	0.32918	0.32713	0.32506	0.32297	0.32086	0.31874	0.31659	0.31443
-0.5	0.35207	0.35029	0.34849	0.34667	0.34482	0.34294	0.34105	0.33912	0.33718	0.33521
-0.4	0.36827	0.36678	0.36526	0.36371	0.36213	0.36053	0.35889	0.35723	0.35553	0.35381
-0.3	0.38139	0.38023	0.37903	0.37780	0.37654	0.37524	0.37391	0.37255	0.37115	0.36973
-0.2	0.39104	0.39024	0.38940	0.38853	0.38762	0.38667	0.38568	0.38466	0.38361	0.38251
-0.1	0.39695	0.39654	0.39608	0.39559	0.39505	0.39448	0.39387	0.39322	0.39253	0.39181
-0.0	0.39894	0.39892	0.39886	0.39876	0.39862	0.39844	0.39822	0.39797	0.39767	0.39733
0.0	0.39894	0.39892	0.39886	0.39876	0.39862	0.39844	0.39822	0.39797	0.39767	0.39733
0.1	0.39695	0.39654	0.39608	0.39559	0.39505	0.39448	0.39387	0.39322	0.39253	0.39181
0.2	0.39104	0.39024	0.38940	0.38853	0.38762	0.38667	0.38568	0.38466	0.38361	0.38251
0.3	0.38139	0.38023	0.37903	0.37780	0.37654	0.37524	0.37391	0.37255	0.37115	0.36973
0.4	0.36827	0.36678	0.36526	0.36371	0.36213	0.36053	0.35889	0.35723	0.35553	0.35381
0.5	0.35207	0.35029	0.34849	0.34667	0.34482	0.34294	0.34105	0.33912	0.33718	0.33521
0.6	0.33322	0.33121	0.32918	0.32713	0.32506	0.32297	0.32086	0.31874	0.31659	0.31443
0.7	0.31225	0.31006	0.30785	0.30563	0.30339	0.30114	0.29887	0.29659	0.29431	0.29200
0.8	0.28969	0.28737	0.28504	0.28269	0.28034	0.27798	0.27562	0.27324	0.27086	0.26848
0.9	0.26609	0.26369	0.26129	0.25888	0.25647	0.25406	0.25164	0.24923	0.24681	0.24439
1.0	0.24197	0.23955	0.23713	0.23471	0.23230	0.22988	0.22747	0.22506	0.22265	0.22025
1.1	0.21785	0.21546	0.21307	0.21069	0.20831	0.20594	0.20357	0.20121	0.19886	0.19652
1.2	0.19419	0.19186	0.18954	0.18724	0.18494	0.18265	0.18037	0.17810	0.17585	0.17360
1.3	0.17137	0.16915	0.16694	0.16474	0.16256	0.16038	0.15822	0.15608	0.15395	0.15183
1.4	0.14973	0.14764	0.14556	0.14350	0.14146	0.13943	0.13742	0.13542	0.13344	0.13147

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[illegible]

Table 9

Values of the Standard Normal Cumulative Distribution Function

Tabulated Values: $\Phi(z) = P(Z \leq z) = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-4.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
-4.4	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
-4.3	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
-4.2	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
-4.1	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00001	0.00001
-4.0	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00002	0.00002	0.00002	0.00002
-3.9	0.00005	0.00005	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00003	0.00003
-3.8	0.00007	0.00007	0.00007	0.00006	0.00006	0.00006	0.00006	0.00005	0.00005	0.00005
-3.7	0.00011	0.00010	0.00010	0.00010	0.00009	0.00009	0.00008	0.00008	0.00008	0.00008
-3.6	0.00016	0.00015	0.00015	0.00014	0.00014	0.00013	0.00013	0.00012	0.00012	0.00011
-3.5	0.00023	0.00022	0.00022	0.00021	0.00020	0.00019	0.00019	0.00018	0.00017	0.00017
-3.4	0.00034	0.00032	0.00031	0.00030	0.00029	0.00028	0.00027	0.00026	0.00025	0.00024
-3.3	0.00048	0.00047	0.00045	0.00043	0.00042	0.00040	0.00039	0.00038	0.00036	0.00035
-3.2	0.00069	0.00066	0.00064	0.00062	0.00060	0.00058	0.00056	0.00054	0.00052	0.00050
-3.1	0.00097	0.00094	0.00090	0.00087	0.00084	0.00082	0.00079	0.00076	0.00074	0.00071
-3.0	0.00135	0.00131	0.00126	0.00122	0.00118	0.00114	0.00111	0.00107	0.00104	0.00100
-2.9	0.00187	0.00181	0.00175	0.00169	0.00164	0.00159	0.00154	0.00149	0.00144	0.00139
-2.8	0.00256	0.00248	0.00240	0.00233	0.00226	0.00219	0.00212	0.00205	0.00199	0.00193
-2.7	0.00347	0.00336	0.00326	0.00317	0.00307	0.00298	0.00289	0.00280	0.00272	0.00264
-2.6	0.00466	0.00453	0.00440	0.00427	0.00415	0.00402	0.00391	0.00379	0.00368	0.00357
-2.5	0.00621	0.00604	0.00587	0.00570	0.00554	0.00539	0.00523	0.00508	0.00494	0.00480
-2.4	0.00820	0.00798	0.00776	0.00755	0.00734	0.00714	0.00695	0.00676	0.00657	0.00639
-2.3	0.01072	0.01044	0.01017	0.00990	0.00964	0.00939	0.00914	0.00889	0.00866	0.00842
-2.2	0.01390	0.01355	0.01321	0.01287	0.01255	0.01222	0.01191	0.01160	0.01130	0.01101
-2.1	0.01786	0.01743	0.01700	0.01659	0.01618	0.01578	0.01539	0.01500	0.01463	0.01426
-2.0	0.02275	0.02222	0.02169	0.02118	0.02068	0.02018	0.01970	0.01923	0.01876	0.01831
-1.9	0.02872	0.02807	0.02743	0.02680	0.02619	0.02559	0.02500	0.02442	0.02385	0.02330
-1.8	0.03593	0.03515	0.03438	0.03362	0.03288	0.03216	0.03144	0.03074	0.03005	0.02938
-1.7	0.04457	0.04363	0.04272	0.04182	0.04093	0.04006	0.03920	0.03836	0.03754	0.03673
-1.6	0.05480	0.05370	0.05262	0.05155	0.05050	0.04947	0.04846	0.04746	0.04648	0.04551
-1.5	0.06681	0.06552	0.06426	0.06301	0.06178	0.06057	0.05938	0.05821	0.05705	0.05592

Table 9 (Continued)

<i>z</i>	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-1.4	0.08076	0.07927	0.07780	0.07636	0.07493	0.07353	0.07215	0.07078	0.06944	0.06811
-1.3	0.09680	0.09510	0.09342	0.09176	0.09012	0.08851	0.08692	0.08534	0.08379	0.08226
-1.2	0.11507	0.11314	0.11123	0.10935	0.10749	0.10565	0.10383	0.10204	0.10027	0.09853
-1.1	0.13567	0.13350	0.13136	0.12924	0.12714	0.12507	0.12302	0.12100	0.11900	0.11702
-1.0	0.15866	0.15625	0.15386	0.15151	0.14917	0.14686	0.14457	0.14231	0.14007	0.13786
-0.9	0.18406	0.18141	0.17879	0.17619	0.17361	0.17106	0.16853	0.16602	0.16354	0.16109
-0.8	0.21186	0.20897	0.20611	0.20327	0.20045	0.19766	0.19489	0.19215	0.18943	0.18673
-0.7	0.24196	0.23885	0.23576	0.23270	0.22965	0.22663	0.22363	0.22065	0.21770	0.21476
-0.6	0.27425	0.27093	0.26763	0.26435	0.26109	0.25785	0.25463	0.25143	0.24825	0.24510
-0.5	0.30854	0.30503	0.30153	0.29806	0.29460	0.29116	0.28774	0.28434	0.28096	0.27760
-0.4	0.34458	0.34090	0.33724	0.33360	0.32997	0.32636	0.32276	0.31918	0.31561	0.31207
-0.3	0.38209	0.37828	0.37448	0.37070	0.36693	0.36317	0.35942	0.35569	0.35197	0.34827
-0.2	0.42074	0.41683	0.41294	0.40905	0.40517	0.40129	0.39743	0.39358	0.38974	0.38591
-0.1	0.46017	0.45620	0.45224	0.44828	0.44433	0.44038	0.43644	0.43251	0.42858	0.42465
-0.0	0.50000	0.49601	0.49202	0.48803	0.48405	0.48006	0.47608	0.47210	0.46812	0.46414
0.0	0.50000	0.50399	0.50798	0.51197	0.51595	0.51994	0.52392	0.52790	0.53188	0.53586
0.1	0.53983	0.54380	0.54776	0.55172	0.55567	0.55962	0.56356	0.56749	0.57142	0.57535
0.2	0.57926	0.58317	0.58706	0.59095	0.59483	0.59871	0.60257	0.60642	0.61026	0.61409
0.3	0.61791	0.62172	0.62552	0.62930	0.63307	0.63683	0.64058	0.64431	0.64803	0.65173
0.4	0.65542	0.65910	0.66276	0.66640	0.67003	0.67364	0.67724	0.68082	0.68439	0.68793
0.5	0.69146	0.69497	0.69847	0.70194	0.70540	0.70884	0.71226	0.71566	0.71904	0.72240
0.6	0.72575	0.72907	0.73237	0.73565	0.73891	0.74215	0.74537	0.74857	0.75175	0.75490
0.7	0.75804	0.76115	0.76424	0.76730	0.77035	0.77337	0.77637	0.77935	0.78230	0.78524
0.8	0.78814	0.79103	0.79389	0.79673	0.79955	0.80234	0.80511	0.80785	0.81057	0.81327
0.9	0.81594	0.81859	0.82121	0.82381	0.82639	0.82894	0.83147	0.83398	0.83646	0.83891
1.0	0.84134	0.84375	0.84614	0.84849	0.85083	0.85314	0.85543	0.85769	0.85993	0.86214
1.1	0.86433	0.86650	0.86864	0.87076	0.87286	0.87493	0.87698	0.87900	0.88100	0.88298
1.2	0.88493	0.88686	0.88877	0.89065	0.89251	0.89435	0.89617	0.89796	0.89973	0.90147
1.3	0.90320	0.90490	0.90658	0.90824	0.90988	0.91149	0.91308	0.91466	0.91621	0.91774
1.4	0.91924	0.92073	0.92220	0.92364	0.92507	0.92647	0.92785	0.92922	0.93056	0.93189
1.5	0.93319	0.93448	0.93574	0.93699	0.93822	0.93943	0.94062	0.94179	0.94295	0.94408
1.6	0.94520	0.94630	0.94738	0.94845	0.94950	0.95053	0.95154	0.95254	0.95352	0.95449
1.7	0.95543	0.95637	0.95728	0.95818	0.95907	0.95994	0.96080	0.96164	0.96246	0.96327
1.8	0.96407	0.96485	0.96562	0.96638	0.96712	0.96784	0.96856	0.96926	0.96995	0.97062
1.9	0.97128	0.97193	0.97257	0.97320	0.97381	0.97441	0.97500	0.97558	0.97615	0.97670

[illegible]

Table 10 (a)

Quantiles of the Standard Normal Distribution

(Inverse Standard Normal Cumulative Distribution Function)

Tabulated Values:

$$z_p = \Phi^{-1}(p)$$

$$\Phi(z_p) = P(Z \leq z_p) = \int_{-\infty}^{z_p} \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz = p$$

p	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.00	$-\infty$	-3.0902	-2.8782	-2.7478	-2.6521	-2.5758	-2.5121	-2.4573	-2.4089	-2.3656
0.01	-2.3263	-2.2904	-2.2571	-2.2262	-2.1973	-2.1701	-2.1444	-2.1201	-2.0969	-2.0748
0.02	-2.0537	-2.0335	-2.0141	-1.9954	-1.9774	-1.9600	-1.9431	-1.9268	-1.9110	-1.8957
0.03	-1.8808	-1.8663	-1.8522	-1.8384	-1.8250	-1.8119	-1.7991	-1.7866	-1.7744	-1.7624
0.04	-1.7507	-1.7392	-1.7279	-1.7169	-1.7060	-1.6954	-1.6849	-1.6747	-1.6646	-1.6546
0.05	-1.6449	-1.6352	-1.6258	-1.6164	-1.6072	-1.5982	-1.5893	-1.5805	-1.5718	-1.5632
0.06	-1.5548	-1.5464	-1.5382	-1.5301	-1.5220	-1.5141	-1.5063	-1.4985	-1.4909	-1.4833
0.07	-1.4758	-1.4684	-1.4611	-1.4538	-1.4466	-1.4395	-1.4325	-1.4255	-1.4187	-1.4118
0.08	-1.4051	-1.3984	-1.3917	-1.3852	-1.3787	-1.3722	-1.3658	-1.3595	-1.3532	-1.3469
0.09	-1.3408	-1.3346	-1.3285	-1.3225	-1.3165	-1.3106	-1.3047	-1.2988	-1.2930	-1.2873
0.10	-1.2816	-1.2759	-1.2702	-1.2646	-1.2591	-1.2536	-1.2481	-1.2426	-1.2372	-1.2319
0.11	-1.2265	-1.2212	-1.2160	-1.2107	-1.2055	-1.2004	-1.1952	-1.1901	-1.1850	-1.1800
0.12	-1.1750	-1.1700	-1.1650	-1.1601	-1.1552	-1.1503	-1.1455	-1.1407	-1.1359	-1.1311
0.13	-1.1264	-1.1217	-1.1170	-1.1123	-1.1077	-1.1031	-1.0985	-1.0939	-1.0893	-1.0848
0.14	-1.0803	-1.0758	-1.0714	-1.0669	-1.0625	-1.0581	-1.0537	-1.0494	-1.0451	-1.0407
0.15	-1.0364	-1.0322	-1.0279	-1.0237	-1.0194	-1.0152	-1.0110	-1.0069	-1.0027	-0.9986
0.16	-0.9945	-0.9904	-0.9863	-0.9822	-0.9782	-0.9741	-0.9701	-0.9661	-0.9621	-0.9581
0.17	-0.9542	-0.9502	-0.9463	-0.9424	-0.9385	-0.9346	-0.9307	-0.9269	-0.9230	-0.9192
0.18	-0.9154	-0.9116	-0.9078	-0.9040	-0.9002	-0.8965	-0.8927	-0.8890	-0.8853	-0.8816
0.19	-0.8779	-0.8742	-0.8706	-0.8669	-0.8632	-0.8596	-0.8560	-0.8524	-0.8488	-0.8452
0.20	-0.8416	-0.8381	-0.8345	-0.8310	-0.8274	-0.8239	-0.8204	-0.8169	-0.8134	-0.8099
0.21	-0.8064	-0.8030	-0.7995	-0.7961	-0.7926	-0.7892	-0.7858	-0.7824	-0.7790	-0.7756
0.22	-0.7722	-0.7688	-0.7655	-0.7621	-0.7588	-0.7554	-0.7521	-0.7488	-0.7454	-0.7421
0.23	-0.7388	-0.7356	-0.7323	-0.7290	-0.7257	-0.7225	-0.7192	-0.7160	-0.7128	-0.7095
0.24	-0.7063	-0.7031	-0.6999	-0.6967	-0.6935	-0.6903	-0.6871	-0.6840	-0.6808	-0.6776
0.25	-0.6745	-0.6713	-0.6682	-0.6651	-0.6620	-0.6588	-0.6557	-0.6526	-0.6495	-0.6464
0.26	-0.6433	-0.6403	-0.6372	-0.6341	-0.6311	-0.6280	-0.6250	-0.6219	-0.6189	-0.6158
0.27	-0.6128	-0.6098	-0.6068	-0.6038	-0.6008	-0.5978	-0.5948	-0.5918	-0.5888	-0.5858
0.28	-0.5828	-0.5799	-0.5769	-0.5740	-0.5710	-0.5681	-0.5651	-0.5622	-0.5592	-0.5563
0.29	-0.5534	-0.5505	-0.5476	-0.5446	-0.5417	-0.5388	-0.5359	-0.5330	-0.5302	-0.5273
0.30	-0.5244	-0.5215	-0.5187	-0.5158	-0.5129	-0.5101	-0.5072	-0.5044	-0.5015	-0.4987
0.31	-0.4958	-0.4930	-0.4902	-0.4874	-0.4845	-0.4817	-0.4789	-0.4761	-0.4733	-0.4705
0.32	-0.4677	-0.4649	-0.4621	-0.4593	-0.4565	-0.4538	-0.4510	-0.4482	-0.4454	-0.4427
0.33	-0.4399	-0.4372	-0.4344	-0.4316	-0.4289	-0.4261	-0.4234	-0.4207	-0.4179	-0.4152
0.34	-0.4125	-0.4097	-0.4070	-0.4043	-0.4016	-0.3989	-0.3961	-0.3934	-0.3907	-0.3880

Table 10 (a) (Continued)

p	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.35	-0.3853	-0.3826	-0.3799	-0.3772	-0.3745	-0.3719	-0.3692	-0.3665	-0.3638	-0.3611
0.36	-0.3585	-0.3558	-0.3531	-0.3505	-0.3478	-0.3451	-0.3425	-0.3398	-0.3372	-0.3345
0.37	-0.3319	-0.3292	-0.3266	-0.3239	-0.3213	-0.3186	-0.3160	-0.3134	-0.3107	-0.3081
0.38	-0.3055	-0.3029	-0.3002	-0.2976	-0.2950	-0.2924	-0.2898	-0.2871	-0.2845	-0.2819
0.39	-0.2793	-0.2767	-0.2741	-0.2715	-0.2689	-0.2663	-0.2637	-0.2611	-0.2585	-0.2559
0.40	-0.2533	-0.2508	-0.2482	-0.2456	-0.2430	-0.2404	-0.2378	-0.2353	-0.2327	-0.2301
0.41	-0.2275	-0.2250	-0.2224	-0.2198	-0.2173	-0.2147	-0.2121	-0.2096	-0.2070	-0.2045
0.42	-0.2019	-0.1993	-0.1968	-0.1942	-0.1917	-0.1891	-0.1866	-0.1840	-0.1815	-0.1789
0.43	-0.1764	-0.1738	-0.1713	-0.1687	-0.1662	-0.1637	-0.1611	-0.1586	-0.1560	-0.1535
0.44	-0.1510	-0.1484	-0.1459	-0.1434	-0.1408	-0.1383	-0.1358	-0.1332	-0.1307	-0.1282
0.45	-0.1257	-0.1231	-0.1206	-0.1181	-0.1156	-0.1130	-0.1105	-0.1080	-0.1055	-0.1030
0.46	-0.1004	-0.0979	-0.0954	-0.0929	-0.0904	-0.0878	-0.0853	-0.0828	-0.0803	-0.0778
0.47	-0.0753	-0.0728	-0.0702	-0.0677	-0.0652	-0.0627	-0.0602	-0.0577	-0.0552	-0.0527
0.48	-0.0502	-0.0476	-0.0451	-0.0426	-0.0401	-0.0376	-0.0351	-0.0326	-0.0301	-0.0276
0.49	-0.0251	-0.0226	-0.0201	-0.0175	-0.0150	-0.0125	-0.0100	-0.0075	-0.0050	-0.0025
0.50	0.0000	0.0025	0.0050	0.0075	0.0100	0.0125	0.0150	0.0175	0.0201	0.0226
0.51	0.0251	0.0276	0.0301	0.0326	0.0351	0.0376	0.0401	0.0426	0.0451	0.0476
0.52	0.0502	0.0527	0.0552	0.0577	0.0602	0.0627	0.0652	0.0677	0.0702	0.0728
0.53	0.0753	0.0778	0.0803	0.0828	0.0853	0.0878	0.0904	0.0929	0.0954	0.0979
0.54	0.1004	0.1030	0.1055	0.1080	0.1105	0.1130	0.1156	0.1181	0.1206	0.1231
0.55	0.1257	0.1282	0.1307	0.1332	0.1358	0.1383	0.1408	0.1434	0.1459	0.1484
0.56	0.1510	0.1535	0.1560	0.1586	0.1611	0.1637	0.1662	0.1687	0.1713	0.1738
0.57	0.1764	0.1789	0.1815	0.1840	0.1866	0.1891	0.1917	0.1942	0.1968	0.1993
0.58	0.2019	0.2045	0.2070	0.2096	0.2121	0.2147	0.2173	0.2198	0.2224	0.2250
0.59	0.2275	0.2301	0.2327	0.2353	0.2378	0.2404	0.2430	0.2456	0.2482	0.2508
0.60	0.2533	0.2559	0.2585	0.2611	0.2637	0.2663	0.2689	0.2715	0.2741	0.2767
0.61	0.2793	0.2819	0.2845	0.2871	0.2898	0.2924	0.2950	0.2976	0.3002	0.3029
0.62	0.3055	0.3081	0.3107	0.3134	0.3160	0.3186	0.3213	0.3239	0.3266	0.3292
0.63	0.3319	0.3345	0.3372	0.3398	0.3425	0.3451	0.3478	0.3505	0.3531	0.3558
0.64	0.3585	0.3611	0.3638	0.3665	0.3692	0.3719	0.3745	0.3772	0.3799	0.3826
0.65	0.3853	0.3880	0.3907	0.3934	0.3961	0.3989	0.4016	0.4043	0.4070	0.4097
0.66	0.4125	0.4152	0.4179	0.4207	0.4234	0.4261	0.4289	0.4316	0.4344	0.4372
0.67	0.4399	0.4427	0.4454	0.4482	0.4510	0.4538	0.4565	0.4593	0.4621	0.4649
0.68	0.4677	0.4705	0.4733	0.4761	0.4789	0.4817	0.4845	0.4874	0.4902	0.4930
0.69	0.4958	0.4987	0.5015	0.5044	0.5072	0.5101	0.5129	0.5158	0.5187	0.5215
0.70	0.5244	0.5273	0.5302	0.5330	0.5359	0.5388	0.5417	0.5446	0.5476	0.5505
0.71	0.5534	0.5563	0.5592	0.5622	0.5651	0.5681	0.5710	0.5740	0.5769	0.5799
0.72	0.5828	0.5858	0.5888	0.5918	0.5948	0.5978	0.6008	0.6038	0.6068	0.6098
0.73	0.6128	0.6158	0.6189	0.6219	0.6250	0.6280	0.6311	0.6341	0.6372	0.6403
0.74	0.6433	0.6464	0.6495	0.6526	0.6557	0.6588	0.6620	0.6651	0.6682	0.6713

Table 10 (a) (Continued) and Table 10 (b)

p	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.75	0.6745	0.6776	0.6808	0.6840	0.6871	0.6903	0.6935	0.6967	0.6999	0.7031
0.76	0.7063	0.7095	0.7128	0.7160	0.7192	0.7225	0.7257	0.7290	0.7323	0.7356
0.77	0.7388	0.7421	0.7454	0.7488	0.7521	0.7554	0.7588	0.7621	0.7655	0.7688
0.78	0.7722	0.7756	0.7790	0.7824	0.7858	0.7892	0.7926	0.7961	0.7995	0.8030
0.79	0.8064	0.8099	0.8134	0.8169	0.8204	0.8239	0.8274	0.8310	0.8345	0.8381
0.80	0.8416	0.8452	0.8488	0.8524	0.8560	0.8596	0.8632	0.8669	0.8706	0.8742
0.81	0.8779	0.8816	0.8853	0.8890	0.8927	0.8965	0.9002	0.9040	0.9078	0.9116
0.82	0.9154	0.9192	0.9230	0.9269	0.9307	0.9346	0.9385	0.9424	0.9463	0.9502
0.83	0.9542	0.9581	0.9621	0.9661	0.9701	0.9741	0.9782	0.9822	0.9863	0.9904
0.84	0.9945	0.9986	1.0027	1.0069	1.0110	1.0152	1.0194	1.0237	1.0279	1.0322
0.85	1.0364	1.0407	1.0451	1.0494	1.0537	1.0581	1.0625	1.0669	1.0714	1.0758
0.86	1.0803	1.0848	1.0893	1.0939	1.0985	1.1031	1.1077	1.1123	1.1170	1.1217
0.87	1.1264	1.1311	1.1359	1.1407	1.1455	1.1503	1.1552	1.1601	1.1650	1.1700
0.88	1.1750	1.1800	1.1850	1.1901	1.1952	1.2004	1.2055	1.2107	1.2160	1.2212
0.89	1.2265	1.2319	1.2372	1.2426	1.2481	1.2536	1.2591	1.2646	1.2702	1.2759
0.90	1.2816	1.2873	1.2930	1.2988	1.3047	1.3106	1.3165	1.3225	1.3285	1.3346
0.91	1.3408	1.3469	1.3532	1.3595	1.3658	1.3722	1.3787	1.3852	1.3917	1.3984
0.92	1.4051	1.4118	1.4187	1.4255	1.4325	1.4395	1.4466	1.4538	1.4611	1.4684
0.93	1.4758	1.4833	1.4909	1.4985	1.5063	1.5141	1.5220	1.5301	1.5382	1.5464
0.94	1.5548	1.5632	1.5718	1.5805	1.5893	1.5982	1.6072	1.6164	1.6258	1.6352
0.95	1.6449	1.6546	1.6646	1.6747	1.6849	1.6954	1.7060	1.7169	1.7279	1.7392
0.96	1.7507	1.7624	1.7744	1.7866	1.7991	1.8119	1.8250	1.8384	1.8522	1.8663
0.97	1.8808	1.8957	1.9110	1.9268	1.9431	1.9600	1.9774	1.9954	2.0141	2.0335
0.98	2.0537	2.0748	2.0969	2.1201	2.1444	2.1701	2.1973	2.2262	2.2571	2.2904
0.99	2.3263	2.3656	2.4089	2.4573	2.5121	2.5758	2.6521	2.7478	2.8782	3.0902
1.00	∞									

Table 10 (b)

Specific Quantiles of the Standard Normal Distribution

Tabulated Values: $z_p = \Phi^{-1}(p)$

$$\Phi(z_p) = P(Z \leq z_p) = \int_{-\infty}^{z_p} \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz = p$$

p	0.0005	0.001	0.005	0.01	0.025	0.05	0.10	0.20	0.30	0.40
z_p	-3.291	-3.090	-2.576	-2.326	-1.960	-1.645	-1.282	-0.842	-0.524	-0.253
p	0.60	0.70	0.80	0.90	0.95	0.975	0.990	0.995	0.999	0.9995
z_p	0.253	0.524	0.842	1.282	1.645	1.960	2.326	2.576	3.090	3.291

Table 11

Quantiles of the Chi-square Distributions

Tabulated Values:

$$\chi^2_{v;p}$$

$$F(\chi^2_{v;p}) = P(\chi^2_v \leq \chi^2_{v;p}) = \int_0^{\chi^2_{v;p}} f(\chi^2) d\chi^2 = p$$

v	$\chi^2_{0.005}$	$\chi^2_{0.010}$	$\chi^2_{0.025}$	$\chi^2_{0.050}$	$\chi^2_{0.100}$	$\chi^2_{0.900}$	$\chi^2_{0.950}$	$\chi^2_{0.975}$	$\chi^2_{0.990}$	$\chi^2_{0.995}$
1	0.00	0.00	0.00	0.00	0.02	2.71	3.84	5.02	6.63	7.88
2	0.01	0.02	0.05	0.10	0.21	4.61	5.99	7.38	9.21	10.60
3	0.07	0.11	0.22	0.35	0.58	6.25	7.81	9.35	11.34	12.84
4	0.21	0.30	0.48	0.71	1.06	7.78	9.49	11.14	13.28	14.86
5	0.41	0.55	0.83	1.15	1.61	9.24	11.07	12.83	15.09	16.75
6	0.68	0.87	1.24	1.64	2.20	10.64	12.59	14.45	16.81	18.55
7	0.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48	20.28
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09	21.95
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67	23.59
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21	25.19
11	2.60	3.05	3.82	4.57	5.58	17.28	19.68	21.92	24.73	26.76
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22	28.30
13	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69	29.82
14	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14	31.32
15	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58	32.80
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00	34.27
17	5.70	6.41	7.56	8.67	10.09	24.77	27.59	30.19	33.41	35.72
18	6.26	7.01	8.23	9.39	10.86	25.99	28.87	31.53	34.81	37.16
19	6.84	7.63	8.91	10.12	11.65	27.20	30.14	32.85	36.19	38.58
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57	40.00
21	8.03	8.90	10.28	11.59	13.24	29.62	32.67	35.48	38.93	41.40
22	8.64	9.54	10.98	12.34	14.04	30.81	33.92	36.78	40.29	42.80
23	9.26	10.20	11.69	13.09	14.85	32.01	35.17	38.08	41.64	44.18
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98	45.56
25	10.52	11.52	13.12	14.61	16.47	34.38	37.65	40.65	44.31	46.93

Table 11 (Continued)

ν	$\chi^2_{0.005}$	$\chi^2_{0.010}$	$\chi^2_{0.025}$	$\chi^2_{0.050}$	$\chi^2_{0.100}$	$\chi^2_{0.900}$	$\chi^2_{0.950}$	$\chi^2_{0.975}$	$\chi^2_{0.990}$	$\chi^2_{0.995}$
26	11.16	12.20	13.84	15.38	17.29	35.56	38.89	41.92	45.64	48.29
27	11.81	12.88	14.57	16.15	18.11	36.74	40.11	43.19	46.96	49.65
28	12.46	13.56	15.31	16.93	18.94	37.92	41.34	44.46	48.28	50.99
29	13.12	14.26	16.05	17.71	19.77	39.09	42.56	45.72	49.59	52.34
30	13.79	14.95	16.79	18.49	20.60	40.26	43.77	46.98	50.89	53.67
31	14.46	15.66	17.54	19.28	21.43	41.42	44.99	48.23	52.19	55.00
32	15.13	16.36	18.29	20.07	22.27	42.58	46.19	49.48	53.49	56.33
33	15.82	17.07	19.05	20.87	23.11	43.75	47.40	50.73	54.78	57.65
34	16.50	17.79	19.81	21.66	23.95	44.90	48.60	51.97	56.06	58.96
35	17.19	18.51	20.57	22.47	24.80	46.06	49.80	53.20	57.34	60.27
36	17.89	19.23	21.34	23.27	25.64	47.21	51.00	54.44	58.62	61.58
37	18.59	19.96	22.11	24.07	26.49	48.36	52.19	55.67	59.89	62.88
38	19.29	20.69	22.88	24.88	27.34	49.51	53.38	56.90	61.16	64.18
39	20.00	21.43	23.65	25.70	28.20	50.66	54.57	58.12	62.43	65.48
40	20.71	22.16	24.43	26.51	29.05	51.81	55.76	59.34	63.69	66.77
45	24.31	25.90	28.37	30.61	33.35	57.51	61.66	65.41	69.96	73.17
50	27.99	29.71	32.36	34.76	37.69	63.17	67.50	71.42	76.15	79.49
55	31.73	33.57	36.40	38.96	42.06	68.80	73.31	77.38	82.29	85.75
60	35.53	37.48	40.48	43.19	46.46	74.40	79.08	83.30	88.38	91.95
65	39.38	41.44	44.60	47.45	50.88	79.97	84.82	89.18	94.42	98.10
70	43.28	45.44	48.76	51.74	55.33	85.53	90.53	95.02	100.43	104.21
75	47.21	49.48	52.94	56.05	59.79	91.06	96.22	100.84	106.39	110.29
80	51.17	53.54	57.15	60.39	64.28	96.58	101.88	106.63	112.33	116.32
85	55.17	57.63	61.39	64.75	68.78	102.08	107.52	112.39	118.24	122.32
90	59.20	61.75	65.65	69.13	73.29	107.57	113.15	118.14	124.12	128.30
95	63.25	65.90	69.92	73.52	77.82	113.04	118.75	123.86	129.97	134.25
100	67.33	70.06	74.22	77.93	82.36	118.50	124.34	129.56	135.81	140.17

For values of $\nu > 100$, the quantity $\sqrt{2\chi^2}$ may be taken normally distributed about mean $\sqrt{2\nu - 1}$ with unit variance.

Table 12

Quantils of the Student's t -DistributionsTabulated Values: $t_{v;p}$

$$F(t_{v;p}) = P(T_v \leq t_{v;p}) = \int_{-\infty}^{t_{v;p}} f(t) dt = p$$

V	$t_{0.0005}$	$t_{0.001}$	$t_{0.005}$	$t_{0.010}$	$t_{0.025}$	$t_{0.050}$	$t_{0.100}$	$t_{0.200}$
1	-636.58	-318.29	-63.656	-31.821	-12.706	-6.314	-3.078	-1.376
2	-31.600	-22.328	-9.925	-6.965	-4.303	-2.920	-1.886	-1.061
3	-12.924	-10.214	-5.841	-4.541	-3.182	-2.353	-1.638	-0.978
4	-8.610	-7.173	-4.604	-3.747	-2.776	-2.132	-1.533	-0.941
5	-6.869	-5.894	-4.032	-3.365	-2.571	-2.015	-1.476	-0.920
6	-5.959	-5.208	-3.707	-3.143	-2.447	-1.943	-1.440	-0.906
7	-5.408	-4.785	-3.499	-2.998	-2.365	-1.895	-1.415	-0.896
8	-5.041	-4.501	-3.355	-2.896	-2.306	-1.860	-1.397	-0.889
9	-4.781	-4.297	-3.250	-2.821	-2.262	-1.833	-1.383	-0.883
10	-4.587	-4.144	-3.169	-2.764	-2.228	-1.812	-1.372	-0.879
11	-4.437	-4.025	-3.106	-2.718	-2.201	-1.796	-1.363	-0.876
12	-4.318	-3.930	-3.055	-2.681	-2.179	-1.782	-1.356	-0.873
13	-4.221	-3.852	-3.012	-2.650	-2.160	-1.771	-1.350	-0.870
14	-4.140	-3.787	-2.977	-2.624	-2.145	-1.761	-1.345	-0.868
15	-4.073	-3.733	-2.947	-2.602	-2.131	-1.753	-1.341	-0.866
16	-4.015	-3.686	-2.921	-2.583	-2.120	-1.746	-1.337	-0.865
17	-3.965	-3.646	-2.898	-2.567	-2.110	-1.740	-1.333	-0.863
18	-3.922	-3.610	-2.878	-2.552	-2.101	-1.734	-1.330	-0.862
19	-3.883	-3.579	-2.861	-2.539	-2.093	-1.729	-1.328	-0.861
20	-3.850	-3.552	-2.845	-2.528	-2.086	-1.725	-1.325	-0.860
21	-3.819	-3.527	-2.831	-2.518	-2.080	-1.721	-1.323	-0.859
22	-3.792	-3.505	-2.819	-2.508	-2.074	-1.717	-1.321	-0.858
23	-3.768	-3.485	-2.807	-2.500	-2.069	-1.714	-1.319	-0.858
24	-3.745	-3.467	-2.797	-2.492	-2.064	-1.711	-1.318	-0.857
25	-3.725	-3.450	-2.787	-2.485	-2.060	-1.708	-1.316	-0.856
26	-3.707	-3.435	-2.779	-2.479	-2.056	-1.706	-1.315	-0.856
27	-3.689	-3.421	-2.771	-2.473	-2.052	-1.703	-1.314	-0.855
28	-3.674	-3.408	-2.763	-2.467	-2.048	-1.701	-1.313	-0.855
29	-3.660	-3.396	-2.756	-2.462	-2.045	-1.699	-1.311	-0.854
30	-3.646	-3.385	-2.750	-2.457	-2.042	-1.697	-1.310	-0.854
35	-3.591	-3.340	-2.724	-2.438	-2.030	-1.690	-1.306	-0.852
40	-3.551	-3.307	-2.704	-2.423	-2.021	-1.684	-1.303	-0.851
45	-3.520	-3.281	-2.690	-2.412	-2.014	-1.679	-1.301	-0.850
50	-3.496	-3.261	-2.678	-2.403	-2.009	-1.676	-1.299	-0.849
60	-3.460	-3.232	-2.660	-2.390	-2.000	-1.671	-1.296	-0.848
70	-3.435	-3.211	-2.648	-2.381	-1.994	-1.667	-1.294	-0.847
80	-3.416	-3.195	-2.639	-2.374	-1.990	-1.664	-1.292	-0.846
90	-3.402	-3.183	-2.632	-2.368	-1.987	-1.662	-1.291	-0.846
100	-3.390	-3.174	-2.626	-2.364	-1.984	-1.660	-1.290	-0.845
200	-3.340	-3.131	-2.601	-2.345	-1.972	-1.653	-1.286	-0.843
500	-3.310	-3.107	-2.586	-2.334	-1.965	-1.648	-1.283	-0.842
1000	-3.300	-3.098	-2.581	-2.330	-1.962	-1.646	-1.282	-0.842
∞	-3.290	-3.090	-2.576	-2.326	-1.960	-1.645	-1.282	-0.842

Table 15 (Continued)

Random Digits

64119	11674	34433	80653	25321	17230	77512	22717
99487	84735	18567	06167	25868	89254	44284	36531
33487	12940	81066	03932	22995	63819	93008	91036
59084	16322	61468	10892	45293	92002	61615	63042
28392	11748	93258	38469	66641	21238	89783	73263
18843	06459	38892	16345	52877	37816	64429	74941
16775	44189	86040	70478	08742	51497	72241	53739
37215	38833	35809	56718	88865	89718	64221	87313
70428	14106	67084	16900	57991	27293	24933	67225
75540	43367	66893	62172	52680	29871	43473	92425
55011	81643	83608	00358	67205	90420	21093	81661
45256	85777	49392	34030	01333	73306	37140	29328
27450	75061	90673	87307	61117	02154	45530	75927
83211	90459	11077	61617	45434	74188	74107	04174
01081	95300	45883	17135	20818	10232	27402	17652
43733	66312	89736	61899	71169	44481	02216	24818
95795	83057	55595	03599	84502	81021	05600	39627
88906	04170	86180	25240	22555	76362	77569	33507
01781	16820	81576	60679	92598	60516	24450	50498
86319	82730	96410	23505	89424	73665	06425	41488
15142	70090	66357	39584	27701	19869	91501	20927
47858	87100	82344	27498	62815	31773	71180	04575
50841	64632	02451	73548	87668	53544	54121	75902
72075	27307	77034	98096	39624	20637	45372	88899
53553	76957	65153	56256	70384	17137	48864	73643
29024	82572	64194	37612	12688	52138	38805	63458
16510	51461	58797	41945	54267	81621	92317	01977
55930	46033	07817	48020	63293	85080	17929	13394
93483	24150	20013	58713	85030	63067	68492	16757
81151	20032	06443	98872	85398	54162	46466	20674
69469	87910	96381	79558	27127	07147	41653	42271
83151	73238	34258	66251	25888	63555	30446	96100
64963	05580	18568	61200	61639	24896	06224	32626
22341	49421	88538	38456	16923	17510	91239	24956
76616	74956	71033	44945	89275	64612	01573	68408

Table 15 (Continued)

Random Digits

31531	48095	01630	57115	44739	26312	68345	68221
59292	16215	51040	99934	74608	96802	38402	73813
34172	04973	01793	67995	25390	83861	31324	22329
55867	54715	23927	80668	84573	36067	22915	95681
76360	72976	01760	44282	98731	83555	12183	09803
50418	36528	69287	59951	82973	27655	83915	11430
29733	41389	77388	35630	93351	77534	65027	35853
38103	95561	49260	82008	20327	25049	31321	14642
04223	99352	09073	84483	59064	76376	06764	66908
40722	28253	23527	57504	91017	88325	69274	66864
26099	76287	45241	45147	88001	28415	21056	88190
95426	82300	16743	18001	39763	98192	43383	95093
40001	45549	61549	91297	05432	92682	62538	80338
31005	19057	68167	89797	15253	97775	21658	45135
96511	88634	18992	86894	36575	10265	71836	44024
20508	44694	83129	85287	27277	86908	88233	06921
38727	33012	47645	30384	11018	20368	31151	38065
23972	68014	93315	88123	16285	86222	34871	09893
63236	19222	94061	92027	07163	28134	15994	70102
01115	38537	52434	18506	77530	79390	71266	70547
78952	21090	74575	92675	97835	36745	68946	29473
21570	11526	01095	54467	74764	79599	35026	51879
64788	76012	20007	16220	69643	17339	18589	43843
76881	06219	22328	18374	33474	77195	11584	20068
47005	54849	32483	71661	49193	80388	75115	77841
42034	83668	89405	40782	37789	58788	54635	27077
55862	47528	68543	45201	56625	11720	06488	21503
37581	03756	61884	23279	39380	05006	52357	90889
68477	70249	61999	98149	38343	48367	29498	70442
09070	04575	95717	90053	49422	19690	69543	09691
35665	61707	46988	87555	76487	33611	05324	72969
24142	31078	68713	95984	10349	92823	43623	26740
65680	88011	55416	41472	85925	23177	52339	58849
92463	28512	10051	56376	11857	62148	70168	10288
18327	35770	74715	66557	11527	21912	17073	06014

Table 15

Random Digits

(Blocked merely for convenience)

51111	60012	53169	63212	46285	57542	21616	74487
63523	40697	91282	68120	94872	73262	22126	93500
02991	62570	65237	61795	95791	43326	80040	72265
89738	36786	01206	59202	46772	99176	87792	79475
87774	17396	34160	57570	01756	60142	80909	01918
56926	46055	16021	85746	92962	71025	36479	99619
89382	91375	67039	94735	42556	31913	11235	39872
88580	42057	25479	50229	33192	50649	24974	02352
97687	24984	39260	43521	09995	88876	47985	07695
92602	28542	04512	94980	17919	37019	20743	50808
08978	70087	20563	97243	00593	33371	94475	20863
83206	86175	36552	47171	40389	17157	34321	55811
91653	10865	67832	48586	80390	36501	29560	17288
77158	87801	66190	83858	45838	24976	47020	95085
10635	61930	15186	68532	76689	97944	10970	42695
72693	93372	04634	18810	41336	82463	54823	98263
04689	64783	67992	33700	46813	84656	72103	41266
16625	91809	65745	82325	62054	17324	78129	34381
79042	24811	28281	35789	40755	33337	99974	85223
43350	35640	42482	67223	11246	78154	76075	37544
20939	29266	13007	20091	64197	16443	97779	14942
54980	68981	45638	90781	25282	96238	56215	29242
91642	99423	82242	10390	70643	44658	97192	23376
83634	32671	64868	80365	80733	64605	90427	32963
48621	89555	03308	74958	37645	40607	59152	64219
58239	31378	81652	03074	77526	91014	68936	60941
57648	69646	74784	66776	27930	04533	14589	09153
38550	65767	52579	25103	67376	60452	48108	80838
92158	97699	48018	89953	76630	23043	95199	06153
18829	30585	69139	67181	09902	09218	36717	20011
99255	09599	34793	81877	06984	19701	89401	74699
29474	79815	58182	91065	46339	45712	74215	37738
81283	42417	68463	70505	99724	67320	11375	60426
37412	11624	18164	05530	01983	36286	19312	07252
24643	29187	23665	01038	64170	50433	88716	47354

Table 12 (Continued)

V	$t_{0.800}$	$t_{0.900}$	$t_{0.950}$	$t_{0.975}$	$t_{0.990}$	$t_{0.995}$	$t_{0.999}$	$t_{0.9995}$
1	1.376	3.078	6.314	12.706	31.821	63.656	318.29	636.58
2	1.061	1.886	2.920	4.303	6.965	9.925	22.328	31.600
3	0.978	1.638	2.353	3.182	4.541	5.841	10.214	12.924
4	0.941	1.700	2.132	2.776	3.747	4.604	7.173	8.610
5	0.920	1.476	2.015	2.571	3.365	4.032	5.894	6.869
6	0.906	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.896	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.889	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.883	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.879	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.876	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.873	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.870	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.868	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.866	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.865	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.863	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.862	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.861	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.860	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.859	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.858	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.858	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.857	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.856	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.856	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.855	1.314	1.703	2.052	2.473	2.771	3.421	3.689
28	0.855	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.854	1.311	1.699	2.045	2.462	2.756	3.396	3.660
30	0.854	1.310	1.697	2.042	2.457	2.750	3.385	3.646
35	0.852	1.306	1.690	2.030	2.438	2.724	3.340	3.591
40	0.851	1.303	1.684	2.021	2.423	2.704	3.307	3.551
45	0.850	1.301	1.679	2.014	2.412	2.690	3.281	3.520
50	0.849	1.299	1.676	2.009	2.403	2.678	3.261	3.496
60	0.848	1.296	1.671	2.000	2.390	2.660	3.232	3.460
70	0.847	1.294	1.667	1.994	2.381	2.648	3.211	3.435
80	0.846	1.292	1.664	1.990	2.374	2.639	3.195	3.416
90	0.846	1.291	1.662	1.987	2.368	2.632	3.183	3.402
100	0.845	1.290	1.660	1.984	2.364	2.626	3.174	3.390
200	0.843	1.286	1.653	1.972	2.345	2.601	3.131	3.340
500	0.842	1.283	1.648	1.965	2.334	2.586	3.107	3.310
1000	0.842	1.282	1.646	1.962	2.330	2.581	3.098	3.300
∞	0.842	1.282	1.645	1.960	2.326	2.576	3.090	3.290

Table 15 (Continued)

Random Digits

40887	08843	04158	17766	62048	12460	67670	74160
39769	98382	42082	74472	65978	83223	15014	85530
19071	77964	57117	11438	43497	43734	92867	97585
11872	05718	35665	37597	16967	99887	17300	73206
18585	93417	38142	23635	33162	62992	40636	45108
08873	45777	86663	21681	27600	76307	21629	72281
86461	23620	76270	06756	86623	52599	19009	29505
39029	73019	40640	26037	48449	11424	84280	49349
80117	27669	53375	53797	22612	03658	91474	33821
63750	55853	99135	54259	06904	30371	60548	11847
07933	53878	47608	20735	95654	37742	78738	05297
90675	35073	95773	02817	93162	01159	07621	83393
53674	32002	85103	63110	06773	82875	56382	83653
85478	97431	16401	97445	79732	62706	52829	75290
36897	27107	94133	85891	81015	33897	10552	10327
98500	76027	25552	60626	43973	58516	11768	55230
37490	45221	23528	31596	76135	98432	36975	24477
21739	23468	28295	24608	16619	92676	60771	85960
26995	12579	33151	87529	05453	48051	58565	13699
47418	24554	98181	92334	77016	80723	76616	92913
40921	34239	08148	85563	10233	66315	02912	08024
75463	02620	43318	73497	74035	85246	03539	51573
03820	97524	70314	08956	66818	93279	27211	16494
48752	85933	57113	65075	99696	57472	69090	12551
75275	97488	50896	13800	08785	29256	18768	16758
32521	35461	01764	26246	39689	79662	39141	91204
32933	29941	78600	67557	84177	88316	04789	59504
36958	28914	51729	49889	72203	62534	38924	93945
32470	85046	67117	38300	09237	06639	63399	86652
62177	87069	80588	74671	03078	43562	03669	11672
28633	08504	02639	29316	44232	39546	86271	30435
80557	84859	47794	99929	37987	94291	77088	50814
45958	50321	14660	96664	91769	54657	26878	09854
41041	89788	80677	06772	58746	77404	08983	36131
30208	02012	95331	85327	13841	60117	57560	16089

Table 15 (Continued)

Random Digits

62849	00522	32055	29561	58517	19929	83971	70325
06811	91997	05203	86806	87265	20684	93421	49909
67843	71012	91317	11850	55739	89929	92120	99018
11790	61854	25065	68551	90495	52856	49097	23952
64049	55624	94564	31454	78018	30714	54557	31052
89196	92205	48557	25271	66936	46962	82498	01932
16921	39390	40432	57520	87502	51384	96731	42587
20268	78442	13053	72094	28927	17295	66070	71988
42626	67896	24331	40302	10069	60936	67698	15789
97655	11384	03388	21018	86708	02003	26908	56576
59851	19594	36606	04785	66944	95565	30956	15639
53223	97891	14874	26879	95552	99342	47143	88600
61374	55721	90149	22485	88938	86064	31176	74623
30394	63965	95392	82832	21216	38066	73824	97836
01788	53424	23319	89682	00349	74446	83068	46308
40999	74948	16189	29405	22474	64236	15007	80316
47470	51792	39382	60203	84439	67503	34787	58110
84513	28834	76355	83630	64225	92487	07184	24185
14877	08250	42031	54551	71282	82738	39716	09475
94907	32201	11546	49077	66448	28855	85997	82534
84030	59987	44352	44464	98518	31405	82173	31918
96852	67153	25335	33979	43567	45784	76893	54639
82112	87617	10760	71019	29265	16822	96916	59378
20200	92128	68970	37019	75253	99522	71039	32209
30793	14699	61780	41828	96823	37605	10730	69368
64221	27958	87404	01566	51826	40849	62722	92010
00229	98223	51879	76770	71732	04278	58647	43183
44690	06767	90785	53321	42019	91558	79286	61771
74392	33377	69104	88737	12941	79558	24274	38371
01635	19198	13051	16211	23520	39217	26965	97763
70808	52913	02908	37295	83282	86251	55547	27096
12068	06067	16117	64197	56341	99804	04531	73117
18341	69023	92785	97762	94819	43484	92195	08199
52050	26318	70204	09953	93959	19838	08642	71426
76422	73257	94285	95955	55890	27843	86208	70366



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