ALAGAPPA UNIVERSITY

[Accredited with 'A+' Grade by NAAC (CGPA:3.64) in the Third Cycle and Graded as Category–I University by MHRD-UGC]

KARAIKUDI – 630 003

DIRECTORATE OF DISTANCE EDUCATION

B.Sc. [Computer Science]
130 13

PROGRAMMING IN C

I - Semester

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(A State University Established by the Government of Tamil Nadu)

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PROGRAMMING IN C

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SYLLABI-BOOK MAPPING TABLE

Programming in C

Syllabi	Mapping in Book
BLOCK 1: INTRODUCTION **Unit-1: Introduction and Features:** History of C, Importance of C, Basic Structure of C Program, Character set, Tokens, Keywords and Identifiers **Unit-2: Constants and Variables and Data Types:** Declaration of Variables, Defining Symbolic Constants, Declaring a Variable as a Constant **Unit-3: Operators and Expressions:** Arithmetic, Relational, Logical, Assignment Operators, Arithmetic Expression, Evaluation of Expressions, Precedence of Arithmetic Operators	**Unit-1:** Introduction and Features **(Pages 1-11);** **Unit-2:** Constants, Variables and Data Types **(Pages 12-34);** **Unit-3:** Operators and Expressions **(Pages 35-48)**
BLOCK 2 : I/O OPERATIONS AND DECISION MAKING **Unit-4: Managing I/O Operations:** Reading and Writing a Character, Formatted Input, Output **Unit-5: Decision Making and Branching:** IF Statement, If..else statement, nesting if else Statement, else if ladder, switch statement, goto statement, while statement, do statement, for statement **Unit-6: Arrays:** One-dimensional Arrays, Declaration, Initialization, Two Dimensional Arrays, Multi Dimensional Arrays, Dynamic Arrays **Unit-7: Strings :** Declaration, Initialization of String Variables, Reading and Writing Strings, String Handling Functions	**Unit-4:** Managing I/O Operations **(Pages 49-56);** **Unit-5:** Decision Making and Branching **(Pages 57-94);** **Unit-6:** Arrays **(Pages 95-120);** **Unit-7:** Strings **(Pages 121-133)**
BLOCK 3 : USER DEFINED FUNCTIONS **Unit-8: Functions Basics:** Elements of User Defined Functions, Definitions, Return Values and their Types, Function Calls, Declaration, Nesting of Functions, Recursion **Unit-9: Structures and Unions:** Defining a Structure, Declaring a Structure Variable, Accessing Structure Members, Array of Structures, Array within Structures, Structures within Structures, Structures and Functions	**Unit-8:** Functions Basics **(Pages 134-156);** **Unit-9:** Structure and Union **(Pages 157-176)**
BLOCK 4 : POINTERS **Unit-10: Pointers:** Basics, Declaring, Initialization of Pointer Variables, Address of Variable, Accessing a Variable through its Pointer **Unit-11: Pointer as Functions:** Chain of Pointers, Pointer Increments and Scale Factors **Unit-12: Strings with Pointer:** Pointers and Character Strings, Pointers and Structures	**Unit-10:** Pointers **(Pages 177-190);** **Unit-11:** Pointer as Functions **(Pages 191-204);** **Unit-12:** Strings with Pointer **(Pages 205-215)**
BLOCK 5 : FILES **Unit-13: Introduction:** Introduction, Defining, Opening and Closing Files, I/O Operations on Files **Unit-14: Error Handling Methods:** Error Handling During I/O Operations, Command Line Arguments	**Unit-13:** Introduction to Files **(Pages 216-230)** **Unit-14:** Error Handling Methods **(Pages 231-240)**

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INTRODUCTION

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C is a programming language and is substantially different from C++ and C#. Many operating systems are written using C, UNIX being the first. Later, Microsoft Windows, Mac OS X and GNU/Linux were written in C. Not only is C the language of operating systems, it is the precursor and inspiration for almost all the popular high-level languages available today. Perl, PHP, Python and Ruby are also written in C. In fact, one of the strengths of C is its universality and portability across various computer architectures. Therefore, C can be used for the development of different types of applications that include real-time systems and expert systems. C also provides flexibility to users for introducing new types of features in their programs, depending upon the requirement and definition of user-defined functions. The various features of C—algorithms, flow charts, decision-making statements, functions, arrays, structures and pointers—are useful for program developers. The goal of this book is to introduce you to C—a programming language that is ideally suited to modern computers and modern programming.

This book introduces you to the basic concepts under the following topics: Introduction to Programming Languages, Structured Programming Concept, Introduction to C Language, C Character Set, Identifiers and Keywords, Data Types, Operators and Expressions, Library Functions, Data Input and Output, Control Statements, Functions, Recursion, Program Structure, Arrays, Pointers, Dynamic Memory Allocation, Structures and Unions, Data Files, Binary Files, Low-Level Programming and Additional Features of C, such as Enumeration, and Command Line Parameters. Therefore, this book is meant for students and programmers who want to achieve proficiency in programming using the C language.

This book, *Programming in C*, follows the self-instruction mode or the SIM format wherein each unit begins with an 'Introduction' to the topic followed by an outline of the 'Objectives'. The content is presented in a simple and structured form interspersed with 'Check Your Progress' questions for better understanding. At the end of the each unit a list of 'Key Words' is provided along with a 'Summary' and a set of 'Self Assessment Questions and Exercises' for effective recapitulation.

BLOCK - I
INTRODUCTION

NOTES

UNIT 1 INTRODUCTION AND FEATURES

Structure

1.0 INTRODUCTION

In any programming language, writing even an elementary program requires the knowledge and clear understanding of various data types, variables, constants and operators provided by that language. All these constitute the most basic elements of a language which are combined to form an instruction. A set of these instructions constitute a program. Generally, the instructions are executed in the sequence in which they appear in the program. However, to make a program more flexible and efficient, the flow of execution can be altered using various control statements. This unit discusses the various basic concepts of C programming language, history of C language, advantages and basics of C.

1.1 OBJECTIVES

After going through this unit, you will be able to:

- Describe the history and advantages of the 'C' programming language
- Discuss the concept of structured programming

- Provide an overview of the basics of C, such as, character sets, tokens, data types and operators

NOTES

1.2 BASIC CONCEPTS OF PROGRAMMING IN C

Designed and developed by Brian Kernighan and Dennis Ritchie, at The Bell Research Labs in 1972, the 'C' programming language is one of the most popular computer languages in today's computer world. It was created so as to allow the programmer access to almost all of the machine's internals—registers, I/O slots and absolute addresses. In addition to this, 'C' allows for as much data handling and programmed text modularization as is needed to allow very complex multi-programmer projects to be constructed in an organized and timely fashion.

Although this language was originally intended to run under UNIX, there has been a great interest in running it under the MS-DOS operating system on the IBM PC and compatibles. It is an excellent language for this environment because of the simplicity of expression, the compactness of the code, and the wide range of applicability.

Also, due to the simplicity and ease of writing a C compiler, it is usually the first high level language available on any new computer, including microcomputers, minicomputers, and mainframes.

Programming in C can be a great help in the areas where you need to use Assembly Language but would prefer to keep it simple to write and easy to maintain the program. The time saved in coding of C can be quite rewarding in such cases.

Even though the C language has a good record when programs are transported from one implementation to another, there are differences in compilers that you will find anytime you try to use another compiler. You come to know of many differences when you use nonstandard extensions such as calls to the DOS BIOS when using MS-DOS. Nevertheless, these differences can be minimized by careful choice of programming constructs.

When the C programming language gained popularity among users, using a wide range of computers, representatives of the software sector met to propose a standard set of rules for the use of the C programming language. The group represented all sectors of the software industry and after many meetings, and many preliminary drafts, they finally wrote an acceptable standard for the C language. It has been accepted by the American National Standards Institute (ANSI), and by the International Standards Organization (ISO). Although implementation of the program is not compulsory, it would be the loss of the individual/organization not opting for it.

1.3 CONCEPT OF STRUCTURED PROGRAMMING

NOTES

which provided a structured way of writing programs. Structured programming (also known as procedural programming) was a powerful and an easy approach of writing complex programs. In **procedural programming**, programs are divided into different procedures (also known as functions, routines or subroutines) and each procedure contains a set of instructions that performs a specific task. This approach follows the top-down approach for designing the program. That is, first the entire program is divided into a number of subroutines. These subroutines are again divided into small subroutines and so on, until each subroutine becomes an indivisible unit (Figure 1.1).

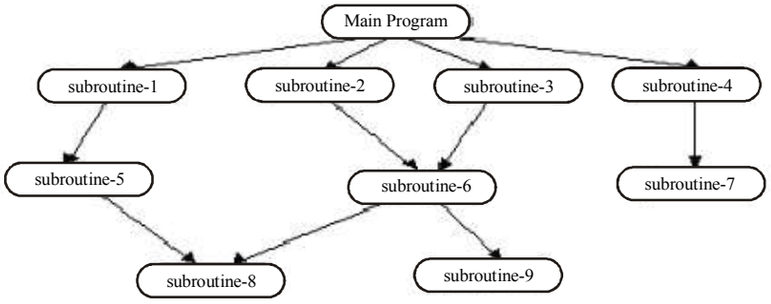

Fig 1.1 *Top-down Approach*

Programs in procedural programming consist of a controlling procedure known as the **main**, which controls the execution of other procedures. When a call to a procedure is made, the program control is passed to that procedure and all the instructions in that procedure are executed one after another. After executing all the instructions, the program control returns to the procedure, from where the call is made.

For example, to write a program that can add, modify, find and delete students' records from a database using the procedural programming, the entire program can be divided into four different procedures, namely, `add ()`, `find ()`, `delete ()` and `modify ()` (Figure 1.2). In addition to these procedures, the program consists of a main procedure. If a user wants to add a record of a student in a database, the control is passed from the main procedure to the *add* procedure. Once all the instructions are executed in *add* procedure, the control is transferred back to the main procedure. The same steps are followed while calling other procedures.

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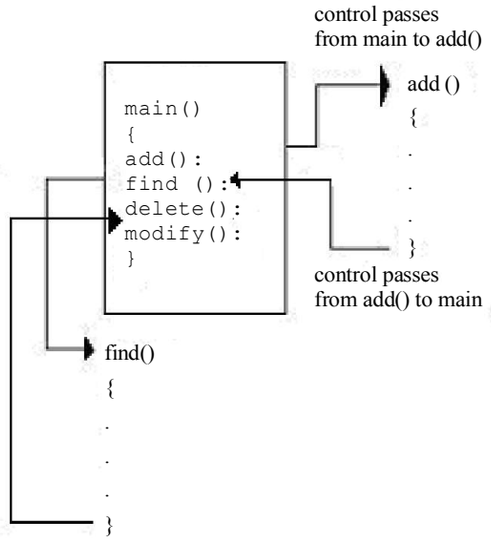

Fig 1.2 *Procedural Programming*

1.4 HISTORY OF C LANGUAGE

C is a general-purpose high-level programming language that was developed by Dennis Ritchie at the Bell Laboratories, USA in the early 70s. The language was named 'C' because it was the successor to a language named 'B', which was developed by Ken Thompson in 1969–70. Dennis Ritchie extended the features of B and turned-into C by adding some more features in it. C was developed as a high-level language that could be used to rewrite the UNIX operating system which was earlier written in assembly language. C was initially used to develop system software such as operating systems, compilers, interpreters, assemblers, databases, text editors, utilities, etc. One of the most interesting features of C language is that its compiler is written in C itself.

In 1978, Brian Kernighan and Dennis Ritchie wrote a book 'The C Programming Language'. Because of this book, the de facto standard for C programming language was known as K. & R. standard for many years. However, there were many changes made unofficially to the C language that were not present in the K. & R. standard. Due to this reason, a group of compiler vendors and software developers approached the American Standards Institute (ANSI) in 1983 to build a standard for the C language, and by the end of 1989 the committee approved the ANSI standard for C programming language.

1.5 BASICS OF C

This section discusses some basic concepts of C which lay the foundation for harnessing the features and capabilities of this language. First the basic elements

required to construct simple C statements will be discussed. This includes the C character set, followed by the various tokens in C (such as keywords, identifiers, constants, operators and punctuators). In addition, we will discuss the various data types in C and working with variables, operators and expressions.

NOTES

1.5.1 C Character Set

A character set can be defined as a set of characters that either individually or in combination, represents a meaning in a language. In C, a character set includes the upper case (A–Z) and lower case (a–z) letters, decimal digits (0–9), blank spaces (tabs, new line, space, etc.) and special characters (characters that perform a specific action based on the context in which they are used). The special characters are listed in Table 1.1.

Table 1.1 *Special Characters*

Special Characters				
+	>	/	[	\
!	;	“	]	{
<	*	.	%	}
:	^	,	~	#
-	(	=	_	|
?	)	‘	&	

Apart from the upper and lower case letters, decimal digits and special characters, C also uses a combination of characters. For example, the escape sequences such as ‘\b’, ‘\c’ and ‘\t’ are a combination of the special character ‘\’ and a letter (‘b’, ‘c’ and ‘t’).

1.5.2 C Tokens

A **token** is defined as the smallest unit of a program. When a program is compiled, the compiler scans the source code and parses it into tokens to find the syntax errors. C tokens are broadly classified into the following.

Keywords

The predefined words that have special significance in any language are known as **keywords**. Every keyword is reserved for a specific purpose and hence cannot be used as variable or function names. All the keywords of C are listed in Table 1.2.

Table 1.2 *C Keywords*

Keywords			
auto	double	int	struct
break	else	long	switch
case	enum	register	typedef
char	extern	return	union
const	float	short	unsigned
continue	for	signed	void
default	goto	sizeof	volatile
do	if	static	while

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Identifiers

The names given to uniquely identify various programming elements like *variables*, *arrays* and *functions* are known as **identifiers**. An identifier must be unique in a program. It must contain only upper case and lower case letters, underscore character (_) or digits 0 to 9 in any order, except that the first character cannot be a digit. Other special characters such as '*', ';' and white space characters (tabs, space and newline) are not allowed. Since C is a case-sensitive language, an identifier in the upper case is different from that in lower case.

Constants

Constants, also known as **literals**, are the values that a program cannot modify during its execution. For example, '391', 'Byron', '51.072' and 'p' are all constants. Based on the type of value (data), C constants are broadly classified into three categories, namely, numeric (or integer) constants, real constants and character constants.

Operators

The symbols which represent various computations (such as addition, subtraction, etc.) performed on various data items are known as **operators**. The data items on which the operators act are known as **operands**. Depending on the function they perform, C operators are classified into various categories. This includes *arithmetic operators*, *relational operators*, *logical operators*, *the conditional operator assignment operators, bitwise operators* and *other operator.*

Depending on the number of operands, C operators are broadly classified into three categories, namely, unary operators (work on only one operand), binary operators (work on two operators) and ternary operators (work on three operators).

Punctuators

Punctuators, also known as **separators**, are tokens that serve different purposes based on the context in which they are used. Some punctuators are used as operators, some are used to demarcate a portion of the program and so on. The various punctuators defined in C are asterisk '*', braces '{ }', brackets '[ ]', colon ':', comma ',', ellipsis '...', equal to '=', semicolon ';', parentheses '( )' and pound (hash) '#'.

1.5.3 The Structure of a C Program

Programs are a sequence of instructions or statements. These statements form the structure of a C program. To understand the structure of a program, consider Figure 1.3.

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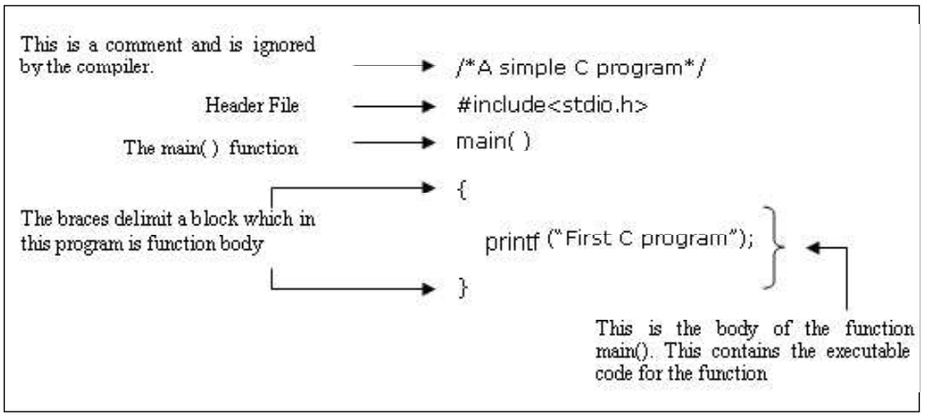

Fig 1.3 *Structure of a C Program*

The structure of a C program can be broadly classified into *header files* and the *main() function*. They can be described as follows:

- **Header files**: While writing programs, programmers use various programming elements defined in the Standard C Library. These pre-defined programming elements include library functions, variables, constants, etc. In order to use such pre-defined elements in a program, appropriate standard header files must be included in the program. The standard header files are files that contain the information (like the return type of library functions, data type of constants, etc.) required by C compilers in order to use the pre-defined elements. In other words, they contain declarations of library functions, type definitions and so on. As a result, programmers do not need to explicitly declare (or define) the programming elements. Standard header files are specified in a program through the preprocessor directive, `# include`

  In Figure 1.3, the `stdio.h` header file is used. When the compiler processes the instruction `#include <stdio.h>`, it includes the contents of `stdio.h` in the program. Once the contents of the `stdio.h` header file are included, programmers can work with the *standard input*, *output* and *file system* facilities. The name `stdio.h` file stands for standard input-output header file. The `stdio.h` file contains numerous prototypes and macros to perform input or output (I/O) operations for C program. The standard I/O functions defined in `stdio.h` are discussed here.

- **printf()**: It is the standard library function used to display any message or values on screen. It takes as arguments a format string and an optional list of variables or literals to output. The `printf()` takes the following form:

  ```
  printf("format-control-string",variable-list);
  ```

  The `format-control-string` controls the format of the output and it can consist of the following:

NOTES

1. Sequence of characters
2. Conversion specifications that always begin with a % sign and end with a conversion specifier
3. Escape sequences that always begin with a \ sign.

The `variable-list` (which is optional) consists of variable names separated by commas whose values are to be printed. This list should include a variable corresponding to each conversion specifier.

- **scanf()**: It is also a standard library function used to receive formatted input from keyboard. The `scanf()` takes the following form:

```
scanf("format-control-string", variable-address-
list);
```

The `format-control-string` describes the format of the data to be input. It can consist of conversion specifications and character literals. The `variable-address-list` is a list of addresses of the variables in which the input values are to be stored. This list should include an address for each conversion specification. The address of variable is obtained by using ampersand (`&`) followed by the variable name.

- **main()**: The first executable instruction in all C programs is the `main()` function. That is, programs begin their execution from this instruction. Once all the instructions in the `main()` function are executed, the control passes out of `main()`, terminating the entire program. Generally, large and complex programs are divided into smaller subprograms known as functions. Out of all the functions defined in a program, the `main()` function is one of the most important functions.

  In Figure 1.3, `main()` is the beginning of its function definition. The word `main` refers to the name of function and the following '`()`' indicates that it is a function. The opening and closing curly braces '`{}`' enclose the `main()` *function's body*. All C statements that need to be executed are written within the `main()` function's body. The statement `printf("First C Program";` written within the `main()` function's body, displays the message `First C Program` with the help of the `printf( )` function.

Note: *Every C program must have one and only one* `main()` *function.*

1.5.4 Advantages of C

Some of the advantages of C language are as follows.

- **Readability**: It is easier to learn and understand because it is very close to human languages.
- **Machine independent**: Programs written in C language are portable as codes. Once written they can be used on different platforms (machines) also.

NOTES

- **Easy debugging**: Programs written in this language are easy for debugging. Debugging means to rectify the errors in a program. High-level languages require an interpreter or a compiler to detect error(s) and helps programmers to correct errors.
- **Easy maintenance**: Programs written in C are modified easily as they are similar to human languages.
- **Reusability**: C codes are reusable, that is, once the programs are loaded into a library they can be used by other applications also.
- **Structured programming**: Code written in C can be broken down into several functional programs. This can be developed independently and then combined into a single program.
- **Low development cost**: Programs written in C language increase programmers' productivity (number of lines of code generated per hour).
- **Easy documentation**: Programs written in C provide easy documentation for future maintenance.

Check Your Progress

1. What do you understand by a character set?
2. Define keywords.
3. What is a program?

1.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. A character set can be defined as a set of characters that either individually or in combination, represents a meaning in a language.
2. The predefined words that have special significance in any language are known as keywords.
3. Programs are a sequence of instructions or statements.

1.7 SUMMARY

- Programming in C can be a great help in the areas where you need to use Assembly Language but would prefer to keep it simple to write and easy to maintain the program.
- Structured programming (also known as procedural programming) was a powerful and an easy approach of writing complex programs. In **procedural programming**, programs are divided into different procedures (also known as functions, routines or subroutines) and each procedure contains a set of

NOTES

instructions that performs a specific task. This approach follows the top-down approach for designing the program.

- C is a general-purpose high-level programming language that was developed by Dennis Ritchie at the Bell Laboratories, USA in the early 70s. The language was named 'C' because it was the successor to a language named 'B', which was developed by Ken Thompson in 1969–70. Dennis Ritchie extended the features of B and turned-into C by adding some more features in it. C was developed as a high-level language that could be used to rewrite the UNIX operating system which was earlier written in assembly language.
- A character set can be defined as a set of characters that either individually or in combination, represents a meaning in a language. In C, a character set includes the upper case (A–Z) and lower case (a–z) letters, decimal digits (0–9), blank spaces (tabs, new line, space, etc.) and special characters (characters that perform a specific action based on the context in which they are used).
- The predefined words that have special significance in any language are known as **keywords**. Every keyword is reserved for a specific purpose and hence cannot be used as variable or function names.
- Constants, also known as **literals**, are the values that a program cannot modify during its execution.
- The symbols which represent various computations (such as addition, subtraction, etc.) performed on various data items are known as **operators**.
- Punctuators, also known as **separators**, are tokens that serve different purposes based on the context in which they are used.
- The structure of a C program can be broadly classified into *header files* and the *main () function*.
- The first executable instruction in all C programs is the main() function. That is, programs begin their execution from this instruction.

1.8 KEY WORDS

- **C language:** It is a general-purpose, high-level programming language.
- **Token:** It is the smallest unit of a program.
- **Keywords:** These are pre-defined words that have a special significance in any language.
- **Program:** It is a sequence of instructions or statements.

1.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

NOTES

Short Answer Questions

1. Write a note on the following.
   (i) Character set
   (ii) Token
   (iii) Keywords
   (iv) Identifiers
2. What are the advantages of C language?

Long Answer Questions

1. Discuss the concept of structured programming.
2. Discuss the evolution of C language.
3. Explain the structure of a simple C program.

1.10 FURTHER READINGS

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UNIT 2 CONSTANTS, VARIABLES AND DATA TYPES

NOTES

Structure

2.0 INTRODUCTION

In this unit, you will learn about the data types, variables and constants. In C, data types refer to the system used for declaring constants and variables of different types. The type of data determines how much space it occupies in the memory of the computer system and how the bit pattern stored is interpreted. Variables are identifiers which refer to the data items stored at particular memory locations. Constants are the programming elements whose values are fixed during the execution of a program.

2.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the elementary data types
- Define and declare variables
- Explain the different types of variables and constants

2.2 ELEMENTARY DATA TYPES

NOTES

Data is used in a program to get information. In a program used to find out the greater of two numbers, the numbers are data, and the output which says which number is greater, is information. C is a versatile language and handles many different types of data in an elegant manner.

Bit stands for binary digit, i.e., 0 or 1. Each byte is a collection of 8 bits, i.e., 8 consecutive bits of '0' or '1'. Data is handled in a computer generally in terms of bytes and therefore, will be in the form of multiples of 8 bits. Each ASCII character is represented by one byte.

2.2.1 Fundamental Data Types

An item that holds data is also called an object. An object has a name or an identifier associated with it. Each object can hold a specific type of data. There are five basic data types in C, as follows:

(i) Character

(ii) Integer

(iii) Real numbers

(iv) Void

(v) Enum

You have to first understand how a computer works. Assume that two numbers a and b are to be multiplied. First, the two numbers have to be stored in the memory. Then the required calculation has to be performed. The result has also to be stored in memory. Each number is of a specific data type; for instance, all three of them can be declared to be integers. Each data type occupies a specific size in the memory. What does one mean by size? It is the amount of storage space required; each bit needs one storage space. One byte needs eight storage spaces. If a number is of type integer declared as int, it is stored in 2 bytes. The number depending on its type gets stored in different forms. If a number is of float type, it takes 4 bytes to store it. All characters can be represented according to the ASCII table and hence, 1 byte, i.e., 8 bits are good enough to store a character, which is represented as char.

These sizes may vary from computer to computer. The header files `<limits.h>` and `<float.h>` contain information about the sizes of the data types.

Real numbers can be expressed with single precision or double precision. Double precision means that real numbers can be expressed more precisely. Double precision also means more digits in mantissa. The type `'float'` means single precision and `'double'` means a double precision real number. Table 2.1 indicates the size of various data types.

NOTES

Table 2.1 Size of Data Types

Data Type	Size
`char`	1 byte
`int`	2 bytes
`float`	4 bytes
`double`	8 bytes

2.2.2 Maximum and Minimum Magnitudes

The maximum and minimum values of data types are not limitless. For example, `<limits.h>` specifies the minimum and maximum magnitudes for integers and characters. Since `char` is stored in a byte, it is as good as a short integer. `char` can be stored as an unsigned character, which means all the 8 bits can be used to store it. The maximum value of an 8-bit number is 255 when all bits are 1. If it is a `signed char`, the first bit will be reserved for storing the sign. The sign bit will be 0 for a positive number and 1 for a negative number. The integer values of `signed` and `unsigned chars` are given below:

CHAR-BIT		8	bits in a `char`
SCHAR	MAX + `char`	127	maximum value of `signed`
SCHAR	MIN –	127	minimum value of `signed char`
UCHAR	MAX	255	maximum value of `unsigned char`

Now, let us look at the maximum and minimum magnitudes for the integer data type. They are:

INT	MAX +	32767	maximum value of `int`
INT	MIN –	32767	minimum value of `int`

Integer means signed integer. The data type integer occupies 2 bytes or 16 bits. The most significant bit is reserved for sign. It will be '0' for a positive number and '1' for a negative number. Therefore, you can easily calculate how the limits for the integer data types have been arrived at.

The standard has also provided for another type of integer called short int with the same maximum and minimum values.

2.3 VARIABLE DECLARATIONS

The names of variables and constants are identifiers. The names are made up of alphabets, digits and underscore, but the first character of an identifier must be an alphabet. C allows up to 31 characters for the identifier (names) and therefore, the naming of the variables should be carried out in an easily understandable manner. For example, in the program for the calculation of,

```
Simple interest I = pnr/100,
```

you can declare them with actual names,

```
p = principal, r = rate_of_interest, n = number_of_
years
```

Naturally, programmers may not like typing long names for fear of making mistakes elsewhere in the program apart from being reluctant to increase their typing workload. Meaningful names can, however, be assigned to data types even with few letters. For example,

```
p = princ; r = intrate; n = years
```

Some compilers may allow names with up to 31 (thirty-one) characters, but may consider the first eight characters for all purposes. Hence, a programmer could coin shorter yet meaningful names, instead of using single alphabets for variable names. One should, however, be careful not to use the reserved words, such as the 32 keywords, for variable names as they have a specific meaning to the compiler. If they are used as variable names, then the compiler will get confused. Be careful not to use the reserved words as identifiers.

A program to find out the square of integer 5 is given as follows:

```
/*Example 2.1*/

/*program to find square of 5*/

#include <stdio.h>

int main()

{

printf("square of %d= %d", 5, 5*5);

}
```

Result of the program

```
square of 5= 25
```

You have now achieved the objective of finding the square of 5. Later on, you may want to find out the square of another number, say 7, for example. We would have to write the same program again replacing 5 by 7 and then compile and run it. This would waste a lot of time. To save time, we can, therefore, write a general-purpose program as shown in Example 2.2.

```
/*Example 2.2*/

/*program to find square of any given number*/

#include <stdio.h>

int main()

{

int num;

printf("Enter the integer whose square is to be found\n");

scanf("%d", &num);
```

```
printf("square of %d= %d", num, num*num);
}
```

NOTES

Here, we define `num` as an integer variable. When '`&`' precedes `num`, it indicates the memory address of `num`.

At the first `printf`, the message appears as it is and the cursor goes to the next line because of the new line character `\n` at the end of the message, but before the closing quotation mark. The next statement is new to you. It is used to receive an integer typed on the console. You can type in any integer number, and the number typed will be stored in the memory at the memory location named '`num`'. The purpose of the statement is, therefore, to get the integer (because of the appearance of `%d` within quotes) and it is stored at the memory address '`num`'.

The next statement prints the number typed and its square.

When you execute the program, the following message appears on the monitor:

Enter the integer whose square is to be found.

Since we want to find out the square of 25 type:

```
25
```

Promptly, the reply will be as shown as follows:

```
square of 25 = 625
```

The next time you may want to find out the square of another number, say 121. Then simply run the program and when prompted, type 121 to get the answer.

Here the number whose square has to be found out has been declared as a variable. The variable has a name and is stored at the location pointed to by the variable name. Therefore, the execution of the program for finding out the square of any number is easy with the above modification.

Variables and constants are fundamental data types. A **variable** can be assigned only one value at a time, but can change value during program execution. A constant, as the name indicates, cannot be assigned a different value during program execution. For example, `PI`, if declared as a constant, cannot have its value varied in a given program. If `PI` has been declared as a constant = 3.14, it cannot be reassigned any other value in the program. Programs may declare a number of constants. Variables are similarly useful for any programming language. If `PI` has been declared as a variable, then it can be changed in the program to any value. This is one difference between a variable and a constant. Whether an identifier is constant or variable depends on how it is declared. Both variables and constants belong to one of the data types like `int, float`, etc. The convention in 'C' is to indicate the names of constants by the upper case letters.

```
PI
SIGMA
```

Variable names are, on the other hand, indicated by the lower case letters.

```
int a
float xy
```

Size of Variables

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The C programmer should understand how much memory storage each variable type occupies in the IDE used by him. The following example will help us to find the size of each variable type. The result will be in terms of bytes occupied by the variable type. A new keyword `sizeof` is used to find out the size. The syntax for using the keyword is as follows:

```
sizeof (<data type>)
```

or

```
sizeof (<expression>)
```

Consider the following example:

```
/*Example 2.3*/
/*program to find out the sizes of various types of
integers*/
#include<stdio.h>
int main()
{
printf("size of char =%d\n", sizeof(char));
printf("size of short=%d\n", sizeof(short));
printf("size of int =%d\n", sizeof(int));
printf("size of unsigned int=%d\n", sizeof(unsigned));
printf("size of long int=%d\n", sizeof(long));
printf("size of unsigned long int=%d\n", sizeof(unsigned
long));
printf("size of float =%d\n", sizeof(float));
printf("size of double=%d\n", sizeof(double));
printf("size of long double%d\n", sizeof(long double));
}
```

Result of the program

```
size of char = 1
size of short = 2
size of int = 2
size of unsigned int = 2
size of long int = 4
size of unsigned long int = 4
size of float = 4
size of double = 8
size of long double = 10
```

NOTES

Therefore, it is obvious that a long double occupies 10 bytes and stores long floating-point numbers with double precision.

Note that the size of `short int` will be either equal to or less than the size of an integer variable.

Variables, which require more than 1 byte for storage, will be stored consecutively in the memory.

2.4 SYNTAX AND SEMANTICS

You have learnt in the previous sections about variables, constants, tokens, identifiers, keywords and elementary data types. For syntax and semantics, the storage specifiers in C are `auto`, `static`, `extern`, `register` and `typedef` and the storage modifiers are `const` and `volatile`. The storage specifiers and modifiers might appear before or after the type name in a declaration but by convention they come before the type name. The semantics of each keyword is specified at the time of declaration. Table 2.2 summarizes the storage specifiers and their functions:

Table 2.2 *Semantics of Storage Specifiers*

Storage Specifiers	Function
`auto`	This keyword makes a variable automatic and is essential for variables with block scope. It is rarely used because of its default property.
`static`	This storage specifier is applied to declarations within and outside the function. Within a function it causes the variables to have fixed duration instead of default automatic duration. For outside of the function, it provides the variable file scope instead of default programming scope.
`extern`	This storage specifier is used for declarations both within and outside a function except for function arguments. It signifies global allusion within a function and outside a function, it provides global scope.
`register`	The `register` storage specifier tells the compiler to store the variable being declared in a CPU register. It is especially used with `for` loop control variables.
`typedef`	The purpose of `typedef` is to declare the variables of the various data types, such as `int, char`. It allows you to introduce the synonyms for C data types which could have been declared in the program.

The syntax for storage keywords and functions is flexible which supports declaration part only. A variable can be declared using `register` and `volatile`, but

NOTES

the compiling part depends on a compiler which decides how to interpret it as per the set rules.

The `typedef` specifier can be declared in the following way:

```
typedef int aa, bb;

aa int_val1;

bb int_val2;
```

Table 2.3 shows the semantics of storage specifiers.

Table 2.3 *Semantics of Storage Class Specifiers*

Storage Class Specifer/Place Where Declared	Outside a Function	Within a Function	Function Arguments
`auto` or `register`	Not Allowed	`scope: block duration: automatic`	`scope: block duration: automatic`
`static`	`scope: file duration: fixed`	`scope: file duration: fixed`	Not Allowed
`extern`	`scope: program duration: fixed`	`scope: block duration: fixed`	Not Allowed
No Storage Class Specifier Present	`scope: program duration: fixed`	`scope: block duration: dynamic`	`scope: block duration: dynamic`

Now, let us discuss about storage modifiers, i.e., `const` and `volatile`. A type qualifier is used to refine the declaration of a variable, a function and parameters by specifying if:

- The value of a variable can be changed.
- The value of a variable must always be read from memory rather than from a register.

Standard C language recognizes the following two qualifiers:

- `const`
- `volatile`

Any type can be qualified by the type qualifiers `const` or `volatile`. In C code, `const` keyword is frequently used but `volatile` is used often. The `const` value is one you can not to modify. The compiler may therefore be able to make certain optimizations, such as placing a `const`qualified variable in read

NOTES

only memory. However, a `const`qualified variable is not a true constant, i.e., it does not qualify as a *constant expression* which C requires in certain situations, such as in array declaration, `case` labels and initializers for variables with static duration `global` and `static` variables. A `volatile` value is one that might change unexpectedly. This situation only arises when you are directly accessing special hardware registers, usually at the time of writing the software files for device drivers. The compiler should not assume that a `volatile` qualified variable which contains the last value that was written to it. The compiler should therefore avoid making any optimizations which would suppress the `volatile` qualified variable. Examples of `volatile` locations would be a clock register or a device control and status register which causes the specified peripheral devices to perform an action each time the register was written to.

Const Qualifier: The `const` qualifier is used to tell C that the variable value cannot change after initialization and is declared in the following way:

```
const float pi=3.14159;
```

Now, `pi` cannot be changed at a later time within the program. Another way to define a constant is using the `#define` preprocessor which has the advantage that it does not use any storage. In simple declarations, the type qualifier is simply another keyword in the type name along with the basic type and the storage class. For example, the following code involves all declarations of type qualifiers.

```
const int i;
const float f;
extern volatile unsigned long int ul;
```

Volatile Qualifier: The **volatile qualifier** declares a data type that can have its value changed in ways outside the control or detection of the compiler, such as a variable updated by the system clock or by another program. This prevents the compiler from optimizing code referring to the object by storing the object's value in a register and re-reading it from there rather than from memory where it may have changed.

Check Your Progress

1. What are the five basic data types in C?
2. What is the difference between variables and constants?

2.5 RESERVED WORDS

The **reserved words** have special meaning within the language and are predefined in the language's formal specifications. Typically, reserved words include labels for primitive data types in languages that support a type system and identify programming constructs, such as data types, loops, blocks, conditionals and

NOTES

branches. The list of reserved words in a language are defined when a language is developed. Reserved words may not be redefined by the programmer, unlike predefined functions, methods or subroutines, which can often be overridden in some capacity.

The syntax rules or grammar of C defines certain symbols and keywords to have a unique meaning within a C program. These symbols and keywords are known as reserved words and must not be used for declaring data and variables. This is because most of the facilities which C offers are in libraries that are included in programs. Once a library has been included in a program, its functions are defined and you cannot use these reserved words as user-defined keywords, for example variables. As per C syntax specifications, all of these reserved words must be in lower case. Each is considered to be a single word like the special keywords. The word symbols cannot be redefined within the C program, i.e., they cannot be used for anything other than their predefined and intended use. The C language uses a number of keywords such as `int`, `char` and `while`. A keyword has a special meaning in the context of a C program and can be used for that specific purpose only, for example `int` can be used only to specify that the data type is integer. All keywords are written in lowercase letters only. Thus, `int` is a keyword but `Int` and `INT` are not. Keywords are the reserved words. It means you cannot use them as identifiers. Table 2.4 shows the list of reserved words, which are not used in declaring variables:

Table 2.4 *Reserved Words in C*

auto	break	case	char	const
continue	default	do	double	float
else	enum	extern	if	goto
int	long	register	for	include
return	short	signed	sizeof	static
void	volatile	while	exit	main
struct	switch	typedef	union	unsigned
short	asm	system	getc	putchar

2.6 CONSTANTS

The following are the types of constants:

- Integer constant
- Character constant
- Float constant
- Enumeration constant
- String constant
- Symbolic constant

All these types are explained below.

NOTES

2.6.1 Integer Constants

The following are the types of integers:

```
int
unsigned int
long
unsigned long
```

Variations in integer types

We can use the sign bit also for holding the value. In such cases, the variable will be called `unsigned int`. The maximum value of an `unsigned int` will be equal to 65535 because we are using the Most Significant Bit (MSB) also for storing the value. The minimum value will obviously be 0.

A long integer is represented as `long int` or simply `long`. The maximum and minimum values of long are given below:

LONG	MAX	+	2147483647
LONG	MIN	–	2147483647

Unless otherwise specified, integers or long integers will be signed, i.e., the first bit will be reserved for the sign. The `long int` obviously uses 4 bytes or 32 bits.

The magnitudes of `long` can also be doubled by using an unsigned long integer denoted as `unsigned long`.

However, integers are not suitable for very low values and very large values. This can be overcome by floating point or real numbers.

An integer constant may be suffixed by the letter `u` or `U` to specify that it is an `unsigned integer`. Similarly, if the integer is suffixed with `l` or `L`, it signifies a `long integer`. If we specify `unsigned long integer` we suffix the constant with `ul` or `UL`.

The following are the examples of valid and invalid integers:

Valid integers

```
+345      /* integer */
 345      /* integer */
-345      /* integer */
729u      /* unsigned integer */
729U      /* unsigned integer */
-112345L  /* Long integer */
112345UL  /* Unsigned Long integer */
+112345l  /* Long integer */
112345l   /* Long integer - if no sign precedes, it is a
positive number */
```

NOTES

Invalid integers

```
345.0        /* decimal point not allowed */
112, 345L    /* no comma allowed */
112 345UL    /* = blank not allowed */
112890345L   /* exceeds the maximum */
+112 345UL   /* unsigned cannot have + */
(345l        /* ( not allowed */
–345s        /* illegal characters */
```

We have so far considered only decimal numbers. The C language, however, entertains other type of numbers as well. The octal numbers will be preceded by 0 (zero).

The following are examples of valid and invalid octal numbers:

Valid octal number

```
0346
0547
0120
```

Invalid octal number

```
0394         /* 8 or 9 are not allowed in an octal number
*/
0 x 345      /* prefix has to be zero only */
```

The C language also supports hexadecimal numbers. Here, since the base is 16, we use alphabets also in the numbers as given in Table 2.5.

Table 2.5

a	or	A	for	10
b	or	B	for	11
c	or	C	for	12
d	or	D	for	13
e	or	E	for	14
f	or	F	for	15

Additionally, hexadecimal numbers will be preceded by `0X` or `ox`, i.e., zero followed by `x`.

The following are examples of valid and invalid hexadecimal numbers:

Valid hexadecimal numbers

```
0x345
0xA132
0x100
0x20B
```

Invalid hexadecimal numbers

```
0x, 123   /* no comma */
0x        /* cannot be empty */
0A00      /* x is missing */
```

NOTES

2.6.2 Character Constants

A **character constant** is a single character enclosed in single quotes as in `'x'`. Characters can be alphabets, digits or special symbols.

The following are examples of valid and invalid character constants:

Valid character constants

```
'A'
'Z'
'C'
'c'
```

Invalid character constants

```
'\n'
'\t'
'\u'
'\b'
AA
'AA'
"AA"
'1a'
```

A character constant represents its integer value as defined in the character set of the machine. Therefore, you can add 2 characters. For example, the ASCII values of digit 1 = 49 and C = 67. When we add these values we get code 116 whose equivalent character is `t`.

Let us verify this with the following example:

```
/* Example 2.4
demonstrates that chars can be treated like integers*/
#include <stdio.h>
int main()
{
const char ALPHA1='1';
char alpha2='C';
char alpha3;
alpha3=ALPHA1+alpha2;
putchar(alpha3);
}
```

NOTES

Result of the program

```
t
```

Therefore, characters can be treated like integers as well, although they are declared as character variables and constants. Since characters are of type `int`, we could add them. Characters can also be defined as integers as given in Example 2.5.

```
/* Example 2.5
Demonstrates that a char can also be declared as int*/
#include <stdio.h>
int main()
{
int x;
x='1'+'C';
printf("x as integer=%d\n", x);/*x printed as integer*/
printf("x as character=%c\n", x);/*x printed as character*/
}
```

Result of the program

```
x as integer=116
x as character=t
```

2.6.3 Floating Point or Real Numbers

Let us enumerate the difference between floating point and integer numbers.

- Integers are whole numbers without decimal points but a float has always a decimal point. Even if the number is a whole number, it is written with a decimal point. For instance, 42 is an integer, while 42.0 is floating-point number.
- Floating-point numbers occupy more space for storage as we have already seen.

A real number in the simple form consists of a whole number followed by the decimal point and also one or more decimal numbers following the decimal point, which makes the fractional part. This form of representation is known as fractional form. It must have a decimal point. It could be either positive or negative. As usual the default sign is positive. No commas or blanks or special characters are allowed in between.

The following are the examples of valid and invalid float types:

Valid floats

```
144.00
226.012
```

Invalid floats

```
+144   /* no decimal point  */
1,44.0 /* comma not allowed */
```

NOTES

Scientific notation: Floating-point numbers can also be expressed in scientific notation. For example, `3.0 E2` is a floating-point number. The value of the number will be equal to $3.0 \times 10^2 = 300.0$.

Instead of the upper case `E`, the lower case `e` can be used as in
`0.453 e + 05`, which will be equal to `0.453 × 10⁵ = 45300`

There are two parts in the scientific notation of a real number, which are as follows:

(i) Mantissa (before E)

(ii) Exponent (after E)

In the scientific form the following rules are to be observed:

- The mantissa part can be positive or negative.
- The exponent must have at least one digit, which can be a positive or negative integer. Remember the exponent cannot be a floating-point number.

`type float` is a single precision number occupying a storage space of 4 bytes.

`type double` represents floating-point numbers of double precision and hence occupies 8 bytes.

If you look at the file `<float.h>` you will find the maximum and minimum floating-point numbers as given below.

FLT – MAX	1E	+ 37	maximum floating point number
FLT – MIN	1E	– 37	minimum floating point number

Floating-point constants The constants are suffixed as given below:

`F` or `f`	–	`float`
no suffix	–	`double`
`L` or `l`	–	`long double`

If an integer is suffixed with `L` or `l`, then it is a `long integer`.

If a float is suffixed with `L` or `l`, then it is a `long double` floating-point number.

Examples

Valid floating-point constants

```
1.0 e 5
123.0 f          /* float          */
11123.05         /* double         */
23467.34 e 5 l   /* long double    */
```

Invalid real constants

```
245.0        /* invalid float, but valid double     */
456          /* It is an integer                    */
1.0 e 5.0    /* exponent cannot be a real number    */
```

NOTES

When they are declared as variables, they can be declared as follows:

```
float  a = 3.12;
float  a, b, c;
float val1;
float val2;
long double val3;
```

The values of constants cannot be altered in programs. They can be defined as follows:

```
const int PRINC = 1000;
const float INT_RATE = 0.12 f;
```

The values of PRINC and INT_RATE cannot be changed in the program even by introducing another assignment statement when they are declared as constants using const. Example 2.6 verifies this statement:

```
/*Example 2.6
Demonstrates that constants cannot be changed
even with assignment statements. To verify, include
statements 7, 8 & 9 in the program by removing
the comment specifiers at the beginning of the program
statement 7 and the end of statement 9*/
#include<stdio.h>
main()
{
const int PRINC =1000;
const float INTST=0.12f;
printf("PRINCIPAL=%d INTEREST=%f\n", PRINC, INTST);
/*PRINC =2000;
INTST=0.24f;
printf("PRINCIPAL=%d INTEREST=%f\n", PRINC, INTST);*/
}
```

Key in the example and execute the program. After successful compilation, you will get the result as follows:

Result of the program

```
PRINCIPAL = 1000; INTEREST = 0.1200
```

Now include the second part of the program by removing /* and */ at statements 7 and 9, respectively. Earlier this was treated as a comment. Now this part will get included in the program. Now compile it. You will get a compilation error. This is due to your attempt to redefine the constants PRINC and INTST, which is not allowed. Incidentally, the technique of including or excluding a program segment at will using /* and */ is a convenient method for program development.

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2.6.4 Enumeration Constant

The keyword for this data type is `enum`. We can define *guardian* as follows:

```
enum guardian
{
   father,
   husband,
   guardian
};
```

Note that there are no semicolons, but only a comma after the members except the last member. There is not even a comma after the last member. There is no conflict between both guardians. The top one is `enum` and the bottom one is a member of `enum` guardian. See the similarity between `structure`, `union` and `enum`. The `enum` variables can be declared as follows:

```
enum guardian          emp1, emp2, emp3;
```

This is similar to structures and unions. The first part is the declaration of the data type. The second part is the declaration of the variable.

The initial values can be assigned in a simpler manner as given below:

```
emp1 = husband;
emp2 = guardian;
emp3 = father;
```

We have to assign only those declared as part of the `enum` declaration. Assigning constants not declared will cause error. The compiler treats the enumerators given within the braces as constants. The first enumerator father will be treated as 0, the husband as 1 and the guardian as 2. Therefore it is strictly as per the natural order starting from 0.

The enumerated data type is never used alone. It is used in conjunction with other data types. We can write a program using `enum` and `struct` as shown in Example 2.7.

```
/*Example 2.7
enum within structure*/
#include <stdio.h>
main()
{
    enum guardian
    {
       father,
       husband,
       relative
    };
```

NOTES

```
    struct employee
    {
       char *name;
       float basic;
       char *birthdate;
       enum guardian guard;
    }emp[2];
    int i;
    emp[0].name="RAM";
    emp[0].basic= 20000.00;
    emp[0].birthdate= "19/11/1948";
    emp[0].guard= father;
    emp[1].name="SITA";
    emp[1].basic= 12000.00;
    emp[1].birthdate= "19/11/1958";
    emp[1].guard=husband;
    for(i=0;i<2;i++)
       {
          if( emp[i].basic ==12000)
          {
             printf("Name:%s\nbirthdate:%s\nguardian:
%d\n",
             emp[i].name,  emp[i].  birthdate,
emp[i].guard);
          }
       }
}
```

Result of the program

```
Name:SITA
birthdate:19/11/1958
guardian: 1
```

The program clearly assigns the relationships between the `employee` and the `guardian`. `enum guardian` is the data type, and `guard` is a variable of this type.

However, when you are printing `emp [i]. guard`, you are printing an integer. Hence 0, 1 or 2 will only be printed for the status, and this is a limitation. This can be overcome by modifying the program. The program modified with a switch statement is given in Example 2.8.

```
/*Example 2.8 expanding enum*/
#include <stdio.h>
```

NOTES

```
main()
{   enum guardian
    {  father,
       husband,
       relative };
    struct employee
    {
       char *name;
       float basic;
       char *birthdate;
       enum guardian guard;
    }emp[2];
    int i;
    emp[0].name=”RAM”;
    emp[0].basic= 20000.00;
    emp[0].birthdate= “19/11/1948”;
    emp[0].guard= father;
    emp[1].name=”SITA”;
    emp[1].basic= 12000.00;
    emp[1].birthdate= “19/11/1958”;
    emp[1].guard=husband;
    for(i=0;i<2;i++)
    {
       if( emp[i].basic ==12000)
          {printf(“Name:%s\nbirthdate:%s\nguardian:”,
          emp[i].name, emp[i]. birthdate);
          switch(emp[i].guard)
          {  case 0:printf(“father\n”);
                break;
             case 1:printf(“husband\n”);
                break;
             case 2:printf(“relative\n”);
                break;
          }
       }
    }
}
```

Result of the program

```
Name:SITA
birthdate:19/11/1958
guardian:husband
```

NOTES

Even though the conversion of an integer to actual name is additional work, enum is an useful construct since it improves readability in addition to number of other advantages.

For example, we can define boolean as follows:

```
enum boolean      {
          false,
          true
        };
```

Here 'false' will contain an integer value 0 and true 1. This can be used to assign values for 'found' in our sorting programs. We can define found as follows after declaring boolean.

```
enum boolean found;
```

We have allowed the system to assign integer values to the members of enum, but we can also assign specific values to the various members of enum. When values are assigned, then it takes precedence over what the system assigns.

We can define boolean as:

```
enum boolean
{  yes = 1,
   no = 0
};
```

This is similar to defining using #define. The #define equivalent for this will be:

```
#define yes 1
#define no 0
```

Although #define and enum provide a way to associate symbolic names such as boolean with constants, there are difference between them. The differences are:

(i) enum can generate values itself unlike #define where you have to specify the replacement constant.

(ii) The compilers need not check the validity of what is stored in the enum variable, but the #define replacement constant will be checked for valildity.

(iii) It is possible to print out the values of enum variables in symbolic form, but this is not possible with # define. Anyway, either of them can be used depending on the context.

2.6.5 String Constants

A character constant is a single character enclosed within single quotes. A string constant is a number of characters, arranged consecutively and enclosed within double quotes.

NOTES

Examples of valid strings:

```
"God"
"is within me"
" "
```

You may be surprised about the third string constant, which has no character. This is called a NULL or empty string and is allowed in C.

The string constant can contain blanks, special characters, quotation marks, etc. within the string. In order to distinguish the end of a string constant, the compiler places a null character `\0` (back slash followed by zero) at the end of each string before the quotation mark. The null character is not visible when the string appears on the screen. The programmer does not include the null character either. It is the compiler which automatically inserts the null character at the end of every string.

Invalid string:

```
'Yoga'    /* should be enclosed in double quotes */
```

2.6.6 Symbolic Constants

The format for symbolic constant is as follows:

```
# define name constant
```

For example, we can define:

```
# define INITIAL 1
```

Which defines INITIAL as 1.

The `INITIAL` type of definition is called symbolic constants. They are not variables and hence, they are not defined as part of the declarations of variables. They are specified on top of the program before the main function. The symbolic constants are to be written in capital or upper case letters. Wherever the symbolic constant names appear in the program, the compiler will replace them with the corresponding replacement constants defined in the `# define` statement. In this case, 1 will be substituted wherever `INITIAL` appears in the program. Note that there is no semicolon at the end of the `# define` statement.

Check Your Progress

3. What is the maximum value of an `unsigned int`?
4. What are character and string constants?

2.7 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. There are five basic data types in C, as follows:
   (i) Character
   (ii) Integer

(iii) Real numbers

(iv) Void

(v) Enum

NOTES

2. Variables and constants are fundamental data types. A **variable** can be assigned only one value at a time, but can change value during program execution. A constant, as the name indicates, cannot be assigned a different value during program execution.
3. The maximum value of an `unsigned int` will be equal to 65535 because we are using the Most Significant Bit (MSB) also for storing the value.
4. A character constant is a single character enclosed within single quotes. A string constant is a number of characters, arranged consecutively and enclosed within double quotes.

2.8 SUMMARY

- An item that holds data is also called an object. An object has a name or an identifier associated with it. Each object can hold a specific type of data. There are five basic data types in C, as follows: Character, Integer, Real numbers, Void and Enum.
- The sizes of data type may vary from computer to computer. The header files `<limits.h>` and `<float.h>` contain information about the sizes of the data types.
- The names of variables and constants are identifiers. The names are made up of alphabets, digits and underscore, but the first character of an identifier must be an alphabet.
- Variables and constants are fundamental data types. A **variable** can be assigned only one value at a time, but can change value during program execution. A constant, as the name indicates, cannot be assigned a different value during program execution.
- The storage specifiers in C are `auto`, `static`, `extern`, `register` and `typedef` and the storage modifiers are `const` and `volatile.`
- The reserved words have special meaning within the language and are predefined in the language's formal specifications.
- A character constant is a single character enclosed in single quotes as in `'x'`. Characters can be alphabets, digits or special symbols.
- A string constant is a number of characters, arranged consecutively and enclosed within double quotes.

NOTES

2.9 KEY WORDS

- **Variable:** These are the identifiers whose value changes during the execution of a program.
- **Constants:** These are programming elements whose values are fixed during the execution of a program.

2.10 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. What are data types?
2. What are reserved words in C? Give examples.
3. Write the maximum and minimum magnitude of the data types.

Long Answer Questions

1. What are variables? How are they declared in a C program?
2. Discuss the different types of constants.
3. Discuss the scope of data types.

2.11 FURTHER READINGS

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UNIT 3 OPERATORS AND EXPRESSIONS

NOTES

Structure

3.0 INTRODUCTION

In this unit, you will learn about the operators and evaluation of expressions. The symbols which represent various computations (such as addition, subtraction, etc.) performed on various data items are known as operators. The data items on which the operators act are known as operands. Depending on the function they perform, C operators are classified into various categories. This includes *arithmetic operators*, *relational operators*, *logical operators*, *the conditional operator assignment operators, bitwise operators* and *other operator.* Operators, functions, constants and variables are combined together to form expressions. The expressions give a result when computed.

3.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain arithmetic, relational, logical, assignment and conditional operators
- Understand the evaluation of expressions
- Analyse operator precedence and associativity

3.2 TYPES OF OPERATORS

NOTES

Various types of operators are explained below.

3.2.1 Arithmetic Operators

The basic arithmetic operators are:

+ addition, e.g., `c = a + b`

– subtraction, e.g., `c = a – b`

* multiplication, e.g., `c = a * b`

/ division, e.g., `c = a/b`

% modulus, e.g., `c = a % b`

When we divide two numbers, we get a quotient and a remainder. To get the quotient we use `c = a/b;`

```
/* c   contains quotient */
```

To get the remainder we use `c = a % b;`

```
/* c   contains the remainder */.
```

% is also popularly called modulus operator. Modulus cannot be used with floating-point numbers.

Therefore, `c = 100/6;` will produce `c = 16`.

`c = 100 % 6`, will produce `c = 4`.

In expressions, the operators can be combined.

For example, `a = 100 + 2/4;`

What is the right answer?

Is it 100 + 0.5 = 100.5

or 102/4 = 25.5

To avoid ambiguity, there are defined precedence rules for operators in 'C'. Precedence refers to the evaluation order of operators. However, in an expression there may be the same type of operators at a number of places, which may lead to ambiguity as to which one to evaluate first. In addition, more than one operator may have the same precedence. For example, * and / have the same precedence. To avoid ambiguity in such cases, there is a rule called associativity. The precedence and associativity of operators in 'C' are given in Table 3.3.

Have a look at Annexure 1. Associativity says either left to right or vice versa. This means that when operators of the same precedence are encountered, the operators of the same precedence have to be evaluated from left to right, if the associativity is left to right.

Now refer to the previous example. Since / has precedence over +, the expression will be evaluated as `100 + 0.5 = 100.5`.

In the precedence table, operators in the same row have the same precedence. The lower the row, the lower the precedence.

For example, `()`, which represents a function, has a higher precedence than `!`, which is in the lower row. Similarly `*` and `/` have higher precedence over `+` and `−`.

Whenever you are in doubt about the outcome of an expression, it would be better to use parentheses to avoid the ambiguity.

Consider the following examples:

```
1) 12 - 3 * 3 = 12 - 9 = 3 and not 27.
2) 24 / 6 * 4 = 4 * 4 = 16 and not 1.
3) 4 + 3 * 2 = 4 + 6 = 10 and not 14.
4) 8 + 8 / 2 - 4 * 6 / 2
   = 8 + 4 - 4 * 6 / 2
   = 8 + 4 - 24 / 2
   = 8 + 4 - 12 = 0
```

Note the steps involved in the previous example.

3.2.2 Relational Operators

Two variables of the same type may have a relationship between them. They can be equal or one can be greater than the other or less than the other. You can check this by using relational operators. While checking, the outcome may be true or false.

For example, if `a = 5` and `b = 6`;

`a` equals `b` is false.

`a` greater than `b` is false.

`a` greater than or equal to `b` is false.

`a` less than `b` is true.

`a` less than or equal to `b` is true.

Any two variables or constants or expressions can be compared using **relational operators**. Table 3.1 below gives the relational operators available in 'C'.

Table 3.1 *Relational Operations in C*

Operator	Example	Read as
< less than	`a < b`	Is `a < b`
> greater than	`a > b`	Is `a > b`
<= less than or equal to	`a <= b`	Is `a < or = b`
>= greater than or equal to	`a >= b`	Is `a > or = b`
== equal to	`a == b`	Is `a` equal to `b`
!= not equal to	`a != b`	Is `a` not equal to `b`

NOTES

Note that for checking equality the double equal sign is used, which is different from other programming languages. The statement `a = b` assigns the value of `b` to `a`. For example, if `b = 5`, then `a` is also assigned the value of `5`. The statement `a == b` checks whether `a` is equal to `b` or not. If they are equal, the output will be true; otherwise, it will be false.

Now look at their precedence from Table 3.3.

`> >= < <=` have precedence over `== !=`

Note that arithmetic operators `+ - * /` have precedence over the relational and logical operators.

Therefore, in the following statement:

```
(x - 3 > 5)
```

`x - 3` will be evaluated first and only then the relation will be checked. Therefore, there is no need to enclose `x - 3` within parenthesis as in `((x - 3) > 5`.

3.2.3 Logical Operators

You can use logical operators in programs. These logical operators are:

`&&` denoting logical `And`

`||` denoting logical `Or`

`!` denoting logical `Negation`

The relational and logical operators are evaluated to check whether they are true or false. 'True' is represented as 1 and 'False' is represented as 0.

It is also by convention that any non-zero value is considered as 1 (true) and zero value is considered as 0 (false).

For example,

```
if      (a - 3)
        {s1}
else
        {s2}
```

If `a` is 5, then `s1` will be executed.

If `a` = 3, then `s2` will be executed.

If `a` = –5, `s1` will still be executed.

To summarize, the relational and logical operators are used to take decisions based on the value of an expression.

3.2.4 Assignment Operators

Assignment operators are written as follows:

identifier = expression;

For example,

```
i = 3;
```

Note: 3 is an expression

```
const A = 3;
```

'C' allows multiple assignments in the following form:

identifier 1 = identifier 2 = ...= expression.

For example,

```
a = b = z = 25;
```

However, you should know the difference between an assignment operator and an equality operator. In other languages, both are represented by =.
In 'C' the equality operator is expressed as = = and assignment as =.

Shorthand Assignment Operators

You have been looking at simple and easily understandable assignment statements. This can be written in a different manner when the RHS includes LHS; or in other words, when the result of computation is stored in one of the variables in the RHS.

The general form is `exp1 = exp1 + exp2`.

This can be also written as exp1 + = exp2.

Examples:

simple form	special form
`a = a + b;`	`a += b;`
`a = a + 1;`	`a += 1;`
`a= a - b;`	`a - = b;`
`a = a - 2;`	`a - = 2;`
`a = a*b;`	`a*= b;`
`a = a*(b + c);`	`a*= b + c;`
`a = a/b;`	`a / = b;`
`a = a/2;`	`a / = 2;`
`d = d - (a + b);`	`d - = a + b`

The **assignment operators** `=, + =, - =, * =, / =, % =,` have the same precedence or priority; however, they all have a much lower priority or precedence than the arithmetic operators. Therefore, the arithmetic operations will be carried out first before they are used to assign the values.

3.2.5 Conditional Operator

The condition operator is also termed as ternary operator and is denoted by?:

The syntax for the conditional operator is as follows:

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(Condition)? statement1: statement2;

What does it mean? If the condition is true, execute statement1; else, execute statement2. The conditional operator is quite handy in simple situations as follows:

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```
(a > b)?  print a greater
       :  print b greater
```

Thus, the operator has to be used in simple situations. If nothing is written in the position corresponding to `else`, then it means nothing is to be done when the condition is false.

An example is as follows:

```
/*Example 3.1
Demonstrates use of the ? operator*/
#include <stdio.h>
int main()
{
    unsigned int a,b;
    printf ("enter two integers\n");
    scanf("%u%u", &a, &b);
    (a==b)?printf("you typed equal numbers\n"):
    printf("numbers not equal\n");
}
```

Result of the program

```
enter two integers
123 456
numbers not equal
```

3.2.6 Increment and Decrement Operators

C contains two increment and decrement operators which are present in postfix and prefix forms. Both forms are used to increment or decrement the appropriate variable. The statement `++i` (prefix form) increments `i` before using its value, while `i++` (postfix form) increments it after its value has been used. Both the forms will produce different outputs when evaluated.

Increment operator ++

The **++ (increment) operator** adds 1 to the value of a scalar operand or if the operand is a pointer then increments the operand by the size of the object to which it points. The operand receives the result of the increment operation. The operand must be a modifiable `lvalue` of arithmetic or pointer type. You can put ++ before or after the operand. If it appears before the operand, the operand is incremented first and then used in the expression. If you put ++ after the operand, the value of the operand is used in the expression *before* the operand is incremented. The following statement shows the increment operator concept:

```
play = ++play1 + play2++;
```

This statement is similar to the following expressions:

```
int temp, temp1, temp2;
temp1 = play1 + 1;
temp2 = play2;
play1 = temp1;
temp = temp1 + temp2;
play2 = play2 + 1;
play = temp;
```

The result has the same type as the operand after integral promotion. The usual arithmetic conversions on the operand are performed. In prefix operation, the value is incremented or decremented first and then applied, while in postfix the value is applied first and then incremented or decremented.

```
/*Example 3.2
#include<stdio.h>
main( )
{
    int i = 3,j = 4,k;
    k = i++ + ++j;
    printf("i = %d, j = %d, k = %d",i,j,k);
}
```

Result of the Program

```
i = 4, j = 5, k = 8
```

Decrement operator

The **– (decrement) operator** subtracts `1` from the value of a scalar operand or if the operand is a pointer decreases the operand by the size of the object to which it points. The operand receives the result of the decrement operation. The operand must be a modifiable `lvalue`. You can put – before or after the operand. If it appears before the operand the operand is decremented and the decremented value is used in the expression. But if – appears after the operand then the current value of the operand is first used in the expression and then the operand is decremented. The following statement shows the decrement operator concept:

```
play = –play1 + play2–;
```

This statement is similar to the following expressions:

```
int temp, temp1, temp2;
temp1 = play1 - 1;
temp2 = play2;
play1 = temp1;
temp = temp1 + temp2;
play2 = play2 - 1;
play = temp;
```

3.3 EXPRESSION IN C

NOTES

An **expression** is a combination of variables, constants and operators written according to the syntax of C language. In C, every expression evaluates to a value, i.e., every expression results in some value of a certain type that can be assigned to a variable. Some examples of C expressions are shown in Table 3.2.

Table 3.2 *Representation of Arithmetic Expressions in C*

Algebraic Expression	C Expression
a × b – c	`a * b - c`
(m + n) (x + y)	`(m + n) * (x + y)`
(ab / c)	`a * b / c`
$3x^2$ +2x + 1	`3*x*x+2*x+1`
(x / y) + c	`x / y + c`

Evaluation of Expressions

Expressions in C are evaluated using an assignment statement of the following form: `variable = expression;`
`variable` is any valid C variable name. When the statement is encountered then the `expression` is evaluated to replace the previous value of the variable on the left hand side. All variables used in the expression must be assigned values so that no error occurs at the time of evaluation. The following are some examples of evaluation statements:

```
x = a * b - c;
y = b / c * a;
z = a - b / c + d;
```

The following program illustrates the effect of presence of parenthesis in expressions.

```
/*Example 3.3
void main ()
{
float a, b, c, x, y, z;
a = 9;
b = 12;
c = 3;
x = a - b / 3 + c * 2 - 1;
y = a - b / (3 + c) * (2 - 1);
```

```
z = a - ( b / (3 + c) * 2) - 1;
printf ("x = %fn",x);
printf ("y = %fn",y);
printf ("z = %fn",z);
}
```

NOTES

Result of the program

```
x = 10.00
y = 7.00
z = 4.00
```

An arithmetic expression without parenthesis will be evaluated from left to right using the rules of precedence of operators. The two distinct priority levels of arithmetic operators in C are as follows:

```
High priority * / %
Low priority + -
```

Rules for Evaluation of Expression

The following are the rules for evaluation of expression in C language:

- First parenthesized sub expressions are evaluated from left to right.
- If parenthesis is nested, the evaluation begins with the innermost sub expression.
- The precedence rule is applied in determining the order of application of operators in evaluating sub expressions.
- The associability rule is applied when two or more operators of the same precedence level appear in the sub expression.
- Arithmetic expressions are evaluated from left to right using the rules of precedence.
- When parenthesis is used, the expressions within the parenthesis assume the highest priority.

Types of Expressions

The three types of expressions in C language are as follows:

1. **Arithmetic:** It evaluates a number, for example `a=12;`.
2. **String:** It evaluates character or text string, for example `'text'` or `'12345'`.
3. **Logical:** It retains 'true' or 'false' value.

Conditional Expression in C

The conditional expression holds two values based on the generated condition. The following syntax is used to write a conditional expression:

```
(condition) ? val1 : val2;
```

NOTES

In C, the standard expression can be declared as follows:

```
Status_of_person = (age >= 18) ? "adult" : "minor";
```

In this conditional expression either of the two values can be returned which is based on the value of age. If age is greater than 18 the assigned value to the Status_of_person will be 'adult', and if age is less than 18 then the assigned value will be 'minor'.

Check Your Progress

1. List the basic arithmetic operators.
2. What is the use of modulus operator?
3. What is a conditional operator?
4. Define an expression.

3.4 PRECEDENCE AND ASSOCIATIVITY OF OPERATORS

C permits mixing of constants and variables of different types in an expression. C automatically converts any intermediate value to the proper type so that the expression can be evaluated without losing any significance. Each operator in C has a precedence associated with it. The **precedence** is used to determine how an expression involving more than one operator is evaluated. There are distinct levels of precedence and an operator may belong to any one of these levels. The operators of higher precedence are evaluated first. The operators of same precedence are evaluated from right to left or from left to right depending on the level. This is known as associativity property of an operator. Operator precedence describes the order in which C reads expressions. For example, the expression `a=4+b*2` contains two operations, an addition and a multiplication. Questions are raised like does the C compiler evaluate `4+b` first, then multiply the result by `2` or does it evaluate `b*2` first, then add `4` to the result? The given operator precedence chart will help you to get the correct answers. Operators higher in the chart have a higher precedence, meaning that the C compiler evaluates them first. Operators on the same line in the chart have the same precedence and the associativity column on the right gives their evaluation order. Two operator characteristics determine how operands group with operators: precedence and associativity. Precedence is the priority for grouping different types of operators with their operands. **Associativity** is the left-to-right or right-to-left order for grouping operands to operators that have the same precedence. An operator's precedence is meaningful only if other operators with higher or lower precedence are present. Expressions with higher-precedence operators are evaluated first. The grouping of operands can be forced by using parentheses. For example, in

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the following statements, the value of 5 is assigned to both a and b because of the right-to-left associativity of the = operator. The value of c is assigned to b first and then the value of b is assigned to a.

```
b = 9;
c = 5;
a = b = c;
```

The above statements only assign value to the expression. To evaluate these expressions we have to use arithmetic operators. The * and / operations are performed before + because of precedence. The variable b is multiplied by c before it is divided by d because of associativity rule. The order of precedence and associativity is given in the given table that C uses for evaluating declared expressions.

```
a + b * c / d
```

You can explicitly force the grouping of operands with operators by using parentheses to specify the order of precedence.

Table 3.3 *Operators Precedence and Associativity*

Operator Name	**Associativity**	**Operators**
Primary	left to right	`()  [ ]  . ->`
Unary	right to left	`++  --  +  -` `!  ~  &  *  (type_name)  sizeof`
Multiplicative	left to right	`*  /  %`
Additive	left to right	`+  -`
Bitwise Shift	left to right	`<<  >>`
Relational	left to right	`<  >  <=  >=`
Equality	left to right	`==  !=`
Bitwise AND	left to right	`&`
Bitwise Exclusive OR	left to right	`^`
Bitwise Inclusive OR	left to right	`|`
Logical AND	left to right	`&&`
Logical OR	left to right	`||`
Conditional	right to left	`? :`
Assignment	right to left	`=  +=  -=  *=  /=  <<=  >>=` `%=  &=  ^=  |=`
Comma	left to right	`,`

NOTES

Check Your Progress

5. What is operator precedence?
6. What is associativity?

3.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The basic arithmetic operators include addition, subtraction, multiplication and modulus operators.
2. A modulus operator is used to obtain the remainder and is denoted by %. It cannot be used with floating-point numbers.
3. A conditional operator checks and compares the relationship between two variables or constants or expressions for greater than, greater than or equal to, equal to, less than, less than or equal to and not equal to.
4. An expression is a combination of variables, constants and operators written according to the syntax of C language.
5. Precedence refers to the evaluation order of operators. In an expression, there may be the same type of operators at a number of places, which may lead to ambiguity as to which one to evaluate first. To avoid ambiguity, there are defined precedence rules for operators in C.
6. Associativity is the left-to-right or right-to-left order for grouping operands to operators that have the same precedence.

3.6 SUMMARY

- The basic arithmetic operators include addition, subtraction, multiplication and modulus operators.
- Two variables of the same type may have a relationship between them. They can be equal or one can be greater than the other or less than the other. You can check this by using relational operators.
- The relational and logical operators are evaluated to check whether they are true or false.
- The condition operator is also termed as ternary operator and is denoted by ?:
- The ++ **(increment) operator** adds 1 to the value of a scalar operand or if the operand is a pointer then increments the operand by the size of the object to which it points. The operand receives the result of the increment operation.

- The **- - (decrement) operator** subtracts 1 from the value of a scalar operand or if the operand is a pointer decreases the operand by the size of the object to which it points. The operand receives the result of the decrement operation.
- An **expression** is a combination of variables, constants and operators written according to the syntax of C language.
- The **precedence** is used to determine how an expression involving more than one operator is evaluated. There are distinct levels of precedence and an operator may belong to any one of these levels. The operators of higher precedence are evaluated first. The operators of same precedence are evaluated from right to left or from left to right depending on the level. This is known as associativity property of an operator.

3.7 KEY WORDS

- **Assignment operators:** These are operators that assign values to variables.
- **Expression:** It is any legal combination of symbols that represents a value.

3.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Write a short note on expression in C.
2. What are the different types of expression?
3. What do you understand by precedence and associativity of operators?

Long Answer Questions

1. Write short notes on:
   (a) Operator precedence
   (b) Unary operator
   (c) Binary operator
2. Differentiate between relational and logical operators.
3. Why are conditional operators used? Write a program using conditional operator.

3.9 FURTHER READINGS

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NOTES

BLOCK - II

I/O OPERATIONS AND DECISION MAKING

NOTES

UNIT 4 MANAGING I/O OPERATIONS

Structure

4.0 INTRODUCTION

In this unit, you will learn about the various types of functions for reading and writing data on the console. The input and output functions of a computer facilitate interactions between the computer and the user. The user has to input data in order to process it in the computer and get the result as the output. The `printf()` statement can be programmed to give the output in the desired manner. The functions `gets()` and `puts()` are appropriate when strings are to be received from the screen or sent to the screen without errors.

4.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the different input/output functions
- Define string
- Understand the use of `gets()` and `puts()`

4.2 INPUT/OUTPUT FUNCTIONS

The input and output functions of a computer facilitate communication with the external world. They also facilitate interaction between the computer and the user.

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The user has to input data in order to process it in the computer and get the result as output. The peripheral device for input is the **keyboard**. Keying in of the input data into the computer at run-time is achieved easily by library functions, which are supplied along with the 'C' compiler and have been standardized. The functions, which enable keying in of the input data in the keyboard, are given as follows:

- `scanf()`
- `getchar()`
- `getch()`
- `getche()`
- `gets()`

The computer communicates its output, i.e., the result of computation, either through the console video monitor, printer, disk drive or input/output ports. Since we are learning 'C' through the PC, we will get the output through the video monitor. Just as there are library functions for input, there are standard library functions for output as well. They are given as follows:

- `printf()`
- `putchar()`
- `putch()`
- `puts()`

Giving input and getting output are achieved by using the standard library functions. Note that all the function names are followed by parentheses. The parentheses are meant for passing arguments or getting arguments. The arguments may be absent in certain functions as in the case of `main()`. However, function names must be followed by parentheses to indicate to the compiler that they are functions. Arguments can be either variables or constants.

4.2.1 Use of `printf()`

Initially, formatted input/output statements will be discussed. Here, one must categorically specify the data type of variables to be read or written and their formats. The `printf()` and `scanf()` are formatted input and output statements. The `printf()` statement can be programmed to give the output in the desired manner. Example 4.1 is given below to illustrate the use of the `printf()` function in printing the required values.

```
/*Example 4.1*/
/* To demonstrate the print function*/
#include <stdio.h>
main()
{
    printf("welcome to more serious programming\n");
}
```

Here the first statement after the comment line directs the compiler to include the standard input/output header file. Note that in the `printf()` statement whatever is given within quotes except those immediately following `'\'` and `'%'` symbols will be printed as it is. Those with the `'\'` symbol like `'\n'`, `'\t'` are escape sequences. Those of the `'%'` symbol such as `'%d'`, `'%f'` are known as conversion characters. They have a specific meaning to the `printf()` function.

Result of Program

```
welcome to more serious programming
```

Then the cursor will go to the next line. The cursor is made to go to the next line because of the new line character `\n`. The escape sequences carry out the functions assigned when their turn for execution is reached in the `printf()` statement.

Now correct the statement as given below:

`printf("\tWelcome");` and execute the program.

Welcome will appear from the first tab.

Execute the program again. You will find that the message is printed from the next available tab position on the same line.

4.2.2 Single Character Input/Output

Characters can be scanned through the `scanf()` function and printed through the `printf()` function as given in Example 4.2.

```
/*Example 4.2*/
/*input and output of character through scanf() and printf()*/
#include<stdio.h>
int main()
{
    char alpha;
    printf("Enter a character\n");
    scanf("%c", &alpha);
    printf("\n The character typed by you is:- %c\n", alpha);
}
```

The program is simple to understand.

A variable `alpha` is declared of type `char`. The message directs the user to enter a character. The `scanf()` function uses the conversion character `%c` since we have to scan a character type variable. The (ampersand) `&alpha` indicates the address where the scanned character is to be stored.

There are two points to be noted here. We have to specify the format as `%c` and after entering the character, we have to hit the `Return` key. The interaction with the computer while executing the program was captured and given below:

```
Enter a character
S
```

```
The character typed by you is:- S
```

4.2.3 Strings—gets() and puts()

NOTES

A **string** is an array of characters. The functions `gets()` and `puts()` are appropriate when strings are to be received from the screen or sent to the screen without errors.

Standard Library for Strings

There are a number of library functions for string manipulation as given below:

`strlen (CS)`—returns the length of string `CS`.

`char * strcpy (s, ct)`—copy string `ct` to string `s`, including NULL and return `s`.

`char * strcat (s, ct)`—concatenate string `ct` to end of string `s`; return `s`.

`int strcmp (cs, ct)`—compare string `cs` to string `ct`; return < 0 if `cs < ct`,

`0 if cs = = ct or > 0 if cs > ct`

`char * strchr (cs, c)`—returns the pointer to the first occurrence of `c` in `cs` or NULL if not present.

There are some more string functions.

If these are to be used, `<string.h>` should be included before the main function.

Use of gets() and puts()

One can use `scanf()` to receive strings from the screen. The program using `scanf()` for reading a name is as follows:

```
char name [25];
scanf ("%s", name);
```

Strings can be declared as an array of characters as shown above. In the `scanf()` function, when we get the array of characters as a string, it is enough to indicate the name of the array without a subscript. When we get a string, there is no need for writing `'&'` in the `scanf()` function. We can indicate the name of the string variable itself.

Strings may contain blanks in between. If you use a `scanf()` function to get the string with a space in between such as 'Rama Krishnan', Krishnan will not be taken note of since space is an indicator of the end of entry of the input. But `gets()` will take all that is entered till the enter key is pressed. Therefore, after entering the full name, the `enter()` key can be pressed. Thus, using `gets()` is a better way for strings. We can get a string in a much simpler way using `gets()`. The syntax for `gets` is, `gets(name);`

Similarly `puts()` can be used for printing a variable or a constant as given below:

```
puts (name);
puts ("Enter the word");
```

However, there is a limitation. `printf()` can be used to print more than one variable and `scanf()` to get more than one variable at a time in a single statement. However, `puts()` can output only one variable and `gets()` can input only one variable in one statement. In order to input or output more than one variable, separate statements have to be written for each variable. As you know that `gets()` and `puts()` are unformatted I/O functions, there are no format specifications associated with them.

NOTES

We will take another interesting example. If a word is a palindrome, we will get the same word when we read the characters from the right to the left as well.

Examples are : nun

malayalam

These words when read from either side give the same name. We will write a program to check whether a word is a palindrome or not.

This program uses a library function called `strlen()`. The function `strlen(str)` returns the size or length of the given string. Now let us look at the program.

```
/*Example 4.3*/
/* To check whether a string is palindrome*/
#include <stdio.h>
#include <string.h>
#define FALSE 0
int main()
{
    int flag = 1;
    int right, left, n;
    char w[50]; /* maximum width of string 50*/
    puts("Enter string to be checked for palindrome");
    gets(w);
    n=strlen(w)-1;
    for ((left = 0, right = n); left <= n/2; ++left,
--right)
    {
       if (w[left]!=w[right])
       {
          Flag = FALSE;
          break;
       }
    }
```

NOTES

```
        if (flag)
        {
            puts(w);
            puts("is a palindrome");
        }
        else
            printf("%s is NOT a palindrome");
    }
```

Result of the program

```
Enter string to be checked for palindrome
palap
palap
is a palindrome
```

If `strlen()` or `gets()` or `puts()` are used in a program, we have to include <`string.h`> before the `main()`.

Step 1

Now let us analyse the functioning of the above example.

We are defining a symbolic constant FALSE as 0.

We initialize `flag` as 1. We define a string `w` as an array of 50 characters.

`gets(w);` returns the word typed and stores it from location `&w[0]`

Let us assume that we typed 'nun' and analyse what happens in the program.

`strlen (w)` will return the length of the word typed. In this case `strlen (w) = 3`.

We subtract this by 1 to get the subscript of the rightmost character. The subscript of the leftmost character is obviously 0.

We are initializing the `for` loop with the following:

`left = 0` `right = n = 2`

`flag = 1`

We check whether `left <= n/2` and

Since it is so, we check whether `w[0] != w[2]`.

The condition is false since `w[0] = w[2] = 'n'`.

Therefore, the groups of statements following `if` are skipped : `flag` remains 1.

Step 2

Now left is incremented to 1 and right is decremented to 1.

Again `w[1] != w[1]` is false, `flag` remains 1.

Therefore, control returns to the `for` statement.

Now, `left = 2` `right = 0`

Since left is greater than `n/2`, control comes out of the `for` loop. Now the statement `if (flag)` will be executed.

It will check whether `flag` is true. In this case, `flag` is still true.

Therefore, the computer prints that the word is palindrome. If the word is not a palindrome, then what happens?

Let us now assume that we typed 'book' and see what happens in the program.

To start with, `left = 0` `right = 3`

```
w[left] != w[right],
```

Therefore, the statements within the `{ }` will be executed, `flag` will be set to false and then the `break` statement will be executed.

The statement `break` causes immediate exit from the loop. Now `flag` is false. Therefore, the `else` statement is executed to say that the word is NOT a palindrome.

Check Your Progress

1. What is the significance of `printf()` statement?
2. What are the functions that are appropriate when strings are to be received from the screen or sent to the screen?

4.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The `printf()` statement can be programmed to give the output in the desired manner.
2. The functions `gets()` and `puts()` are appropriate when strings are to be received from the screen or sent to the screen without errors.

4.4 SUMMARY

- The input and output functions of a computer facilitate communication with the external world.
- The `printf()` and `scanf()` are formatted input and output statements. The `printf()` statement can be programmed to give the output in the desired manner.
- Characters can be scanned through the `scanf()` function and printed through the `printf()` function.

- A string is an array of characters. The functions `gets()` and `puts()` are appropriate when strings are to be received from the screen or sent to the screen without errors.

NOTES

4.5 KEY WORDS

- **`printf()`:** It is a function used to print the "character, string, float, integer, octal and hexadecimal values" onto the output screen.
- **`Scanf()`:** It is a function used to take input from the user or console.

4.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. What are the different input and output functions?
2. What is the significance of `printf()` and `scanf()` function?

Long Answer Questions

1. Write a program to demonstrate the use of `printf()` and `scanf()` function.
2. Write a program to explain the use of gets () and puts () function.

4.7 FURTHER READINGS

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UNIT 5 DECISION MAKING AND BRANCHING

NOTES

Structure

5.0 INTRODUCTION

In this unit, you will learn about the control statements used in C programs. These are used for solving complex problems. Depending on the occurrence of a particular situation, `if` and `else` keywords are used for branching to different segments of the program. C is ideal for handling branching because the syntax is clear and unambiguous. If the condition is true, then a single statement or group of statements following if will be executed. If more than one statement is to be executed, then the statements are grouped within braces. To perform the same operation a number of times, loop or iteration is used. In this unit, you will also learn about `while`, `do ...while`, `switch`, `break`, `continue` and `return` statements.

5.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the basic concepts of branching
- Use `if` and `if...else` branching statements in your C programs

- Define `switch`, `break`, `continue` and `goto` statements
- Understand the importance of loop and control constructs in a C program
- Use `if`, `for`, `while` and `do...while` in a program

NOTES

5.2 CONDITIONAL STATEMENTS

Real-life application programs do not merely consist of simple multiplication or addition. They call for solving complex problems. Depending on the occurrence of a particular situation, we may follow different paths; the `if` and `else` keywords are quite handy in branching to different segments of the program. 'C' is ideal for handling branching because the syntax is clear and unambiguous. We will now discuss the branching constructs. Relational operators are used in conjunction with branching constructs. Hence, we look at them first.

5.2.1 `If` Statement

The syntax of the `if` statement is given below.

```
if (condition)
    {statements}
```

If the condition is true, then a single statement or group of statements following the `if` will be executed. If more than one statement is to be executed, then the statements are grouped within braces. If it is a single statement, then curly braces are not required.

If the condition turns out to be false, then the next statement after those belonging to the `if` will be executed. Example 5.1 will make the concept clear.

Input two integers from the keyboard. If they are equal, then the program will print, 'you typed equal numbers'; otherwise, it will print nothing.

```
/*Example 5.1
To demonstrate the use of if*/
#include <stdio.h>
main()
{
unsigned int a,b;
printf ("enter two integers\n");
scanf("%u%u", &a, &b);
if (a==b)
    {
    printf("you typed equal numbers\n");
    }
}
```

NOTES

Each open curly brace has to have a matching closing curly brace. In Example 3.4 the first closing curly brace corresponds to the `if` statement and the second one to the main function. Execute the program by first keying in two equal valued unsigned integers.

Result of the program

```
enter two integers
56 56
you typed equal numbers
```

After you are satisfied, you can try the program with unequal numbers. You will not get any message.

5.2.2 `If...else` Statement

We did not get any message when the numbers were unequal and this can be avoided by using the else statement.

The usage of `if .. else` is shown below.

```
if (condition true)
{
   statements s1
}
else
{
   statements s2
}
statements s3;
```

The statement `else` is always associated with an `if`.

If the condition is true, then statements `s1` will be executed. After executing them, the program will skip the `else` block and control goes to statement `s3` that follows the `else` block.

If the condition is false, then the statements in the `else` block, i.e., `s2` will be executed followed by statement `s3`.

Statements `s1` will not be executed at all when the condition becomes false. The usage of braces clearly brings out which statements belong to the `if` block and which to the `else` block.

Example 5.2 brings out the usage of `if...else`.

```
/*Example 5.2
To demonstrate the use of if..else*/
#include <stdio.h>
main()
{
    unsigned int a,b;
```

NOTES

```
    printf ("enter two integers\n");
    scanf("%u%u", &a, &b);
    if (a==b)
    {
       printf("you typed equal numbers\n");
    }
    else
    {
       printf("numbers not equal\n");
    }
}
```

The output of the program when unequal numbers were keyed in is as follows.

Result of the program

```
enter two integers
17 13
numbers not equal
```

5.2.3 Nesting of the `if...else` Statements

We witnessed the usage of a single `if` statement in Example 5.1. We saw `if` followed by `else` in Example 5.2. There is no restriction to the number of `if`, which can be used in a program. This applies to `else` as well, but `else` can only follow an `if` statement.

We can have the following in a program:

```
{
if (condition1)
    {
       if (condition2)
          {statements-s1}
       else
          if (condition3)
             {statements-s2,}
    }
else
    {statements-s4}
statements-s5
}
```

This is called a nested `if` and `else` statement. As the level of nesting increases, it will be difficult to analyse and logical mistakes will be made more easily.

In the above example, when `condition1` is false, `statements-s4` will be executed. If `condition1` is true and `condition2` is also true, then `statements-s1` will be executed.

If `condition1` is true and `condition2` and `condition3` are false, `statements-s5` will be executed directly.

To execute statements–`s2`

`Condition1` has to be true;

`Condition2` has to be false,

And `condition3` has to be true.

Try to analyse this yourself. There are better methods to solve the above problem, which will be discussed later.

For example, three unequal integers are keyed in and are called `x`, `y` and `z`. Write a program to find the greatest of the three numbers.

Before writing a program, we must write the algorithm. We should not straight away get down to programming.

Algorithm 1

Algorithm for finding the largest of 3 integers.

Step 1. Print a message to enter 3 integers.

Step 2. Get three numbers and store them at `&x`, `&y` and `&z`.

Step 3. Check if `x > y`

Step 4. If false, go to step 9

Step 5. If true

Step 6. Check if `x > z`

Step 7. If true, write `x` is the largest; End

Step 8. If false, write `z` is the largest; End

Step 9. Check if `y>z`

Step 10. If true, write `y` is the largest; End

Step 11. If not, write `z` is the largest.

End

Let us now code these steps into a 'C' program, which is shown in Example 5.3.

```
/*Example 5.3
To demonstrate the use of the nested if..else*/
#include <stdio.h>
main()
{
```

NOTES

```
int x,y,z;
printf ("enter three unequal integers\n");
scanf("%d%d%d", &x, &y, &z);
if(x>y)
{
  if(x>z)
    {
       printf("x is largest\n");
    }
  else
    {
       printf("z is largest\n");
    }
}
else
{
   if(y>z)
   {
      printf("y is largest");
   }
   else
   {
      printf("z is largest");
   }
}
}
```

Test the correctness of the program by giving a different set of values for `x`, `y` and `z`.

Result of the program

```
enter three unequal integers
908 231 907
x is largest
```

Look at the example. It uses multiple nesting of `if ... else`.

Take care to see that every opening brace has a corresponding closing brace. It is better to indent the braces as shown in the example so that no mistake is committed. Take care to see that `else` matches with the corresponding `if` and each opening brace `{`matches with a corresponding closing brace`}`; if either an opening {or closing} is extra, then an error will result.

NOTES

5.2.4 Logical Operators and Branching

In the above examples we have been checking one condition at a time. It would be nice if we could check more than one condition at a time. 'C' provides three logical operators for combining more than one condition. These are as follows:

Logical `and` represented as `&&`

Logical `or` represented as ||

`Negation` or `not` represented as `!` (exclamation).

Let us see some examples of usage of the logical operators. In Example 5.3 we concluded that,

`if x > y` and `if x > z`, then `x` is the largest.

We will represent the same as,

```
if ((x > y) && (x > y))
printf ("x is the largest");
```

You will see that the program has become much more elegant.

The syntax for `&&` is,

```
if ((condition1) && (condition2))
    {
    statements-s1
    }
```

Statements–s1 will be executed only if both the conditions are true.

The syntax for 'or' is as follows:

```
if ((condition 1) ||(condition 2))
    {
    statements-s2
    }
```

In this case, even if one of the conditions is true, the `statements-s2` will be executed. At least one condition has to be true for the execution of `s2`. However, if both are false, `s2` will not be executed.

The ***NOT* operator** with symbol **!** can be used along with any other relational or logical operator or as a stand-alone operator. It simply negates the operator following it. The syntax of `'!'` is as follows:

```
if ! (condition) statement s3;
```

`s3` will be executed only when the condition is not true or the condition is false.

Let us rewrite Algorithm 1 by using the logical operators. The revised Algorithm 2 is given below:

NOTES

Algorithm 2

Step 1: If (x > y) and (x > z), x is the largest.

Step 2: Else if (x<y) and (y>z), y is the largest.

Step 3: Else print z is the greatest.

The complete program is given in Example 5.4.

```
/*Example 5.4
To demonstrate the use of logical operators*/
#include <stdio.h>
main()
{
    int x,y,z;
    printf ("enter three unequal integers\n");
    scanf("%d%d%d", &x, &y, &z);
    if ((x>y) && (x>z))
       printf("x is largest\n");
    else
    {
       if((x<y) && (y>z))
          printf("y is largest\n");
       else
          printf("z is largest\n");
    }
}
```

Result of the program

```
enter three unequal integers
12 23 78
z is greatest
```

Let us now write a program to convert a lower case letter typed into an upper case letter. For this purpose you may have to refer to the ASCII table in Annexure 2.

It is obvious that if we subtract 32 from the ASCII value of a lower case alphabet we will get the ASCII value of the corresponding upper case letter. Let us write an algorithm for the conversion of lower case to an upper case letter. It is given in Algorithm 3.

Algorithm 3

Step 1: Send a message for getting a character

Step 2: Get a character

Step 3: Check whether the character typed is >=a and <=z

(This is essential since we can only convert a lower case alphabet into upper case.)

Step 4: If so, subtract 32 from the value of the character; if not, go to step 6

Step 5: Output the character with the revised ASCII value; END

Step 6: Print "an invalid character" END

The algorithm is implemented in Example 5.5.

```
/*Example 5.5
Conversion of lower case letter to upper case*/
#include <stdio.h>
main()
{
    char alpha;
    printf ("enter lower case alphabet\n");
    alpha=getchar();
    if ((alpha >='a') && (alpha<='z'))
    {
       alpha= (alpha-32);
       putchar (alpha);
    }
    else
       printf("invalid entry; retry");
}
```

Now you can test the program by giving both the valid and invalid inputs; valid inputs are the lower case letters and invalid inputs are all other characters.

Result of the program

The result for the invalid input is given below:

```
enter lower case alphabet
8
invalid entry; retry
```

The result when tried with a valid input is given below:

```
enter lower case alphabet
n
N
```

The programs should be executed, i.e., tested with both the valid and invalid inputs.

NOTES

5.2.5 Conditional Operator and `if...else`

The syntax for the conditional operator is given below:

```
(Condition)? statement1: statement2;
```

What does it mean? If the condition is true, execute `statement1`; else, execute `statement2`. Here nesting is not possible. The `if...else` statement is more readable than the `conditional (?)` operator. However, the conditional operator is quite handy in simple situations as given below:

```
(a > b) ?  print a greater
         :  print b greater;
```

Thus, the operator has to be used in simple situations. If nothing is written in the position corresponding to `else`, then it means nothing is to be done when the condition is false.

Example 5.2 is rewritten using the ? operator in Example 5.6.

```
/*Example 5.6
To demonstrate the use of the ? operator*/
#include <stdio.h>
main()
{
    unsigned int a,b;
    printf ("enter two integers\n");
    scanf("%u%u", &a, &b);
    (a==b)?printf("you typed equal numbers\n"):
    printf("numbers not equal\n");
}
```

Result of the program

```
enter two integers
123 456
numbers not equal
```

5.3 `SWITCH` STATEMENT

Switch statements allow clear and easy implementation of multiway decision-making. Assuming that a number is received from the keyboard and that depending on the value, we want to carry out some operations, the `switch` statement can be used effectively in this situation. In simpler situations `if...else` could be used, and in complex situations, `switch` can be used. For example, if we get numbers starting from 1 to 4 and print their values in words, we can use the `if...else` statement as given in Example 5.7:

```
/*Example 5.7
Converts the digits 1-4 in words using if*/
```

NOTES

```
#include<stdio.h>
#include<conio.h>
main()
{
    int a;
    char ch='c';
    while (ch=='c')
       {
       printf("\nEnter a digit 1 to 4\n");
       scanf("%d",&a);
       if(a== 1)
          printf("One\n");
       else
          if (a== 2)
             printf("Two\n");
          else
             if(a== 3)
                printf("Three\n");
             else
                if(a==4)
                      printf("Four\n");
                else
       printf("Illegal character\n");
       printf("enter 'c' if you want to continue\n");
       printf("or any other character to end\n");
                          ch=getche();
                          if (ch!='c')
                                printf("End     of
Session");
          }
}
```

Result of the program

```
Enter a digit 1 to 4
3
Three
enter 'c' if you want to continue
or any other character to end
c
Enter a digit 1 to 4
1
One
enter 'c' if you want to continue
```

NOTES

```
or any other character to end
c
Enter a digit 1 to 4
2
Two
enter 'c' if you want to continue
or any other character to end
nEnd of Session
```

We have struggled hard to do this exercise. Assuming that we want to get a one digit number up to 9 and print its value in words, it would become a more complex task. The `switch` statement comes in handy in such situations. The syntax of the `switch` statement is as follows:

```
switch (expression)
{
   case  constant or expression : statements
   case  constant or expression : statements
   ..
default : statements }
```

When the **`switch`** keyword is encountered, the associated expression is evaluated. The program now looks for the **`case`**, which matches with the value of the expression. Execution then starts from the statement corresponding to the **`case`** which matches. Each **`case`** has to be accompanied by integer expressions, which must be unique, as otherwise the program will not know where to start. For example, if the first two cases are as given below:

```
case 10 : s1;
case 10 : s2;
```

In this case the program would not know whether to execute `s1` or `s2` when the expression of `switch` evaluates to 10. Therefore, the constant expressions following the `case` keyword should all be unique. There may be occasions when none of the constant expressions matches the `switch` expression in which case the `default` statements will be executed. Thus `switch` allows branching of the program execution to appropriate place. A program to print the values of the digits in words is given below:

```
/*Example 5.8
converts the digits 0-9 in words*/
#include <stdio.h>
#include <conio.h>
main()
{
    int a;
    char ch ='c';
    while (ch=='c')
       {
```

NOTES

```
            printf("\nEnter a digit 0 t0 9\n");
            scanf("%d",&a);
            switch(a)
            {
               case 0:printf("Zero\n");
                  break;
               case 1:printf("One\n");
                  break;
               case 2:printf("Two\n");
                  break;
               case 3:printf("Three\n");
                  break;
               case 4:printf("Four\n");
                  break;
               case 5:printf("Five\n");
                  break;
               case 6:printf("Six\n");
                  break;
               case 7:printf("Seven\n");
                  break;
               case 8:printf("Eight\n");
                  break;
               case 9:printf("Nine\n");
                  break;
               default:printf("Illegal character\n");
            }
            printf("enter 'c' if you want to continue\n");
            printf("or any other character to end\n");
            ch=getche();
            if (ch!='c')
               printf("End of Session");
         }
   }
```

Result of the program

```
Enter a digit 0 t0 9
6
Six
enter 'c' if you want to continue
or any other character to end
c
```

NOTES

```
Enter a digit 0 t0 9
7
Seven
enter 'c' if you want to continue
or any other character to end
nEnd of Session
```

The `do...while` concept has been used in this example also. The program first enters the `do` loop. After the execution of the loop, the program asks you to enter `c` if you want to continue or any other character to end the program. If you enter `c`, the program will continue. Thus, if you want to exit, you can press any other letter, say `'n'`. If you press `'n'` the program stops instantly. This is the right way of using the `do...while` loop.

Now, the `switch` is analysed. The program asks for entry of a digit `0` to `9`. The entered digit is stored in variable `a`. If `a = 5`, then the program goes to case `5`. It is followed by printing the value Five and then break. If you press 8, then case 8 matches and Eight will be printed.

What is a `break` statement ?

Assume that all the `break` statements are removed from the program. Then if you press 1, 'One' will be printed and all the statements following that will be executed. This means that Two, Three, ... till Nine will be printed. If you enter 7, it will print all the numbers starting from Seven, which in not desirable. The `break` statement has, therefore, been introduced. After printing the value of the number, the `break` statement takes the program to the end of the `switch` statement. The end is just the closing brace corresponding to `switch` after the default `printf()` statement. Therefore, the combination of `switch` and `break` does the trick.

Assuming that a character other than 0 to 9 is entered, none of the cases match. Therefore, default is executed. The program will print 'illegal character'. The **default** is optional and even in its absence, when no match is found, the program will come out of the switch statement without any action.

The `case` statements need not be in any specified order. The default can be on top before `case` 0 and the `case` can occur in any order. The program is made to execute, as long as you want, by the `do` statement. If `do` is absent, then the program will be executed only once. The `do...while` is necessary to make it an iterative program.

Every `switch` statement, therefore, contains a condition in the form of an expression. The expression could also be a single variable as in this case. The expression will be evaluated at the time of program execution and must be an integer. Then, depending on the value it goes to a `case` label, which is like a label in a `goto` statement. The label should match with the value of the expression.

Unless the program is made to exit by statements such as `break` after executing the group of statements corresponding to a particular case, the program will execute all the statements in the program from then on. This should be noted. Therefore, the programmer has to specify where to end. In the case of `if...else`, where to begin and where to end is clear as also in the case of `switch`. The program starts at the beginning of the `case` that meets the condition, but ends at the bottom of the `switch` unless otherwise specified. It will also execute the statements following default. It will of course not bother about the keywords. That is the reason for the `break` statement, since we do not want the program to execute irrelevant statements.

It is a good programming practice to include a break statement after the default as well. If this is not done at the inception, at a later stage when more case statements are added after default, this would lead to problems. Whenever default is executed all the statements following it, even if they belong to some other case, will also be executed if `break` is not included after default.

Now the program can be extended to print the value of the number up to 99 in words. This makes it more complicated since the words are unique up to nineteen. A program is given below for achieving the task. This is made to loop using `do...while`.

```
/*Example 5.9
to print out in words the value
of a number typed in the range 1-99*/
#include <stdio.h>
#include<conio.h>
main()
{
    int num,m,ch='y';
    do
    {
       printf("Type a number 1 to 99\n");
       scanf("%d",&num);
       if ((num>0)&&(num<100))
       /*only if the number is within the valid range 0 to 99
the following will be executed*/
       {
          if (num >= 20)
          {
             m=num/10;
             switch(m)
             {
                case 2:printf("TWENTY ");
```

NOTES

```
            break;
        case 3:printf("THIRTY ");
            break;
        case 4:printf("FORTY ");
            break;
        case 5:printf("FIFTY ");
            break;
        case 6:printf("SIXTY ");
            break;
        case 7:printf("SEVENTY ");
            break;
        case 8:printf("EIGHTY ");
            break;
        case 9:printf("NINETY ");
            break;
    }
}
if (num>20)
    num= num%10;
    switch(num)
    {
        case 1:printf("ONE\n");
            break;
        case 2:printf("TWO\n");
            break;
        case 3:printf("THREE\n");
            break;
        case 4:printf("FOUR\n");
            break;
        case 5:printf("FIVE\n");
            break;
        case 6:printf("SIX\n");
            break;
        case 7:printf("SEVEN\n");
            break;
        case 8:printf("EIGHT\n");
            break;
        case 9:printf("NINE\n");
            break;
        case 10:printf("TEN\n");
            break;
```

NOTES

```
                case 11:printf("ELEVEN\n");
                        break;
                case 12:printf("TWELVE\n");
                        break;
                case 13:printf("THIRTEEN\n");
                        break;
                case 14:printf("FOURTEEN\n");
                        break;
                case 15:printf("FIFTEEN\n");
                        break;
                case 16:printf("SIXTEEN\n");
                        break;
                case 17:printf("SEVENTEEN\n");
                        break;
                case 18:printf("EIGHTEEN\n");
                        break;
                case 19:printf("NINETEEN\n");
                        break;
             }
          }
          else
             printf("number outside range\n");
             printf("\nenter y if you want to continue\n");
             ch=getche();
          if (ch!='y')
             printf("End of session");
          }
       while (ch=='y');
    }
```

Result of the program

```
Type a number 1 to 99
123
number outside range
enter y if you want to continue
yType a number 1 to 99
78
SEVENTY EIGHT
enter y if you want to continue
yType a number 1 to 99
6
SIX
```

```
enter y if you want to continue
nEnd of session
```

How does it work ?

NOTES

The entered number is checked. If it is 20 or above, the following action takes place. For example, assume that a number 64 is entered. It is > = 20.

Therefore, m = num/10 will give m as 6. Hence, SIXTY will be printed (with a space at the end), corresponding to case 6.

Now since num > 20, the second if condition will be true.

Num = num % 10 will assign the remainder equal to 4 to num. Therefore, case 4 in the second switch will be true and four will be printed.

Assume you have expressed your desire to continue and enter 16.

Since num > = 20 will be false and switch (m) will be ignored. Hence, switch (num) will be executed. Case 16 matches with switch (16). Therefore, SIXTEEN will be printed. The correctness of the program can be checked for any number in the range of 0 – 99.

The expression associated with the switch can be of type char since char can also be considered an integer. For example, the switch statement can be of the form,

```
char m ;
switch (m)
{
   case 'a' : s1 ;
      break ;
   case 'b' : s2 ;
      break ;
}
```

If m evaluates to 'a', s1 will be executed and if it is 'b', s2 will be executed. Remember the label of case has to be a constant expression.

Other characters such as +, –, etc. can be used as case labels since their integer values are known from the ASCII table.

```
Int op ;
switch (op)
{
   case '+' : s1; break;
   case '/' : s2 ; break;
}
```

Here when op is +, s1 will be executed and when it is /, s2 will be executed.

You can try these by writing programs.

5.4 BREAK, CONTINUE, GOTO STATEMENTS

NOTES

The keywords `while`, `for` and `switch` test the condition on top, while `do...while` checks at the bottom for quitting the loop. The `break` statement helps immediate exit from any part of the loop as demonstrated with the `switch` statement. It can be used with any other loop construct or anywhere in the program. When the `break` statement is executed it goes to the bottom of the block. Recall that a block is a group of statements enclosed between an opening brace and the corresponding closing brace.

The **`continue` statement** is related to `break`. When `continue` is executed, it causes the next iteration of the corresponding `for`, `do...while` or `while` loop to begin. Therefore, `continue` takes the program to the top of the block and in the `for` loop, it will cause the next increment operation, followed by checking whether the condition is true or false in order to decide the next course of action. This is similar to skipping the current execution and continuing with the next operation after incrementing. The statement `continue` skips the rest of the statements in the loop for that iteration, whereas `break` terminates the loop.

Write a program to check whether a given number is positive or negative. If it is zero, the program should terminate after printing the value. If it is a positive integer above zero and <=20000, the value will be printed; if negative, it will go to fetch the next number. If the number is >20000, the program terminates. The program is given below:

```
/*Example 5.10
/*program to demonstrate continue*/
#include <stdio.h>
main()
{
    int a;
    do
    {
       printf("enter a number-enter 0 to end session\n");
       scanf("%d", &a);
       if(a > 20000)
       {
          printf("you entered a high value-going out of
range\n");
             break;
       }
       else
       if(a>=0)
```

NOTES

```
            printf("you entered %d\n", a);
        if (a<0)
        {
            printf("you entered a negative number\n");
        continue;
        }
    }
    while(a !=0);
    printf(" End of session\n");
}
```

Result of the program

```
enter a number-enter 0 to end session
33
you entered 33
enter a number-enter 0 to end session
-60
you entered a negative number
enter a number-enter 0 to end session
45
you entered 45
enter a number-enter 0 to end session
25000
you entered a high value-going out of range
End of session
```

If the number typed > 20000, or if it is equal to zero, the program comes out of the loop and prints "End of session". If the number is negative, a < 0 and hence, continue will be executed. It will go to the top of the loop. The next integer will be received. The program, therefore, terminates when a = 0 as well as a > 20000, but there is a difference. If the number entered is zero, the program checks whether a > 20000. Since the condition fails, it checks whether a > = 0 and since it is true, 0 will be printed and then the while condition is checked. The program terminates after the while condition is checked.

However, if the number entered is >20000, the loop terminates instantly without transacting any business except printing messages as given above.

The return statement can appear anywhere in a function and when it is encountered a value is returned to the called function. The return may also not return a value in statements as given below:

```
return ;
return (0) ;
```

The return statement may appear anywhere in the function and not necessarily at the end of the function. Whenever return is executed, the program

returns to the function called the current function. The program returns to the place from where it called the function. Thus `return` is also used to suddenly exit from a function or a loop in a function.

Exit Function

The library function **`exit()`** causes the termination of the current program. Note that, `exit()` terminates the execution of the program itself, and not the block. The statement `break` enables coming out of the block or loop in which it is executed but `exit` terminates the program at whatever stage the program may be. `exit` is a powerful function.

Check Your Progress

1. Give the syntax of `if` statement.
2. What are the logical operators provided by 'C'?
3. Why is `goto` not used in a program? What can be used instead of `goto`?
4. What is a `break` statement?
5. How are `continue` and `break` statements related?
6. Define the `exit()` function.

5.5 CONCEPT OF LOOPS

Quite often we have to perform the same operation a number of times. We may also have to repeat the same operation with one or more of the values changed, which is known as loop or iteration. It is definitely possible to write a program for such situations with the concepts we have learnt so far. However, there are special constructs in any programming language for carrying out repeated calculations.

5.5.1 Iteration Using `if`

Before we look at loop constructs, let us consider an example to see the need for repetitive calculations. Assume that we want to find the sum of the first ten natural numbers, 1 – 10. This can be achieved through successive addition, i.e., first we initialize the sum to 0 and then add 1 to the sum. Next we add 2 to the sum, then 3, and so on till we add 10 to the sum. Thus, by repeated addition 10 times, we have found the sum of first ten natural numbers.

The following algorithm summarizes what we have done.

Step 1: `Sum = 0`

Step 2: `I = 1`

Step 3: `If I < = 10` perform the following operations:

```
sum = sum + I; I = I + 1;
```

NOTES

Step 4: Print the sum

Let us analyse the algorithm.

At the beginning, steps 1 and 2 are entered with `sum = 0` and `I = 1`

`since I < = 10`

`Sum` will be equal to `sum + I`,

i.e., `sum = 0 + 1 = 1`

`I = I + 1`, i.e., `I = 2`

Now the program goes to Step 3.

with `I = 2` and `sum = 1`

Since `I < = 10`

`sum = sum + I`

sum was 1 and I is 2

`sum = 1 + 2 = 3`

Next `I` will be incremented to `3`.

Third iteration:

Step 3 is approached with `I = 3` and `sum = 3`.

since `I < = 10`

`sum = sum + I = (1 + 2) + 3`

`I = 4`

Ninth iteration:

Step 3 is approached with `I = 9`.

since `I < = 10`

`sum = (1 + 2 + 3 +.....+ 8) + 9`

`I` is incremented to `10`.

Tenth iteration:

Step 3 is approached with `I = 10`.

since `I < = 10`

```
sum  = sum + I
   = (1 + 2 + 3 +.....+ 8 + 9) + 10
```

Now I is incremented to 11.

since `I <= 10` is not true, the program does not execute the statements following the `if` and jumps to Step 4.

In Step 4 the sum is printed.

This algorithm is implemented in Example 5.11.

NOTES

```
/*Example 5.11
Demonstrates the use of if for iteration*/
#include <stdio.h>
main()
{
    int sum=0, i=1; /*declaration and initialization
combined*/
    step3:      /*label- loop starts here*/
    if (i <=10)
       {
          Sum = sum + i;
          i = i + 1;
          goto step3;
       }
    printf("sum of first 10 natural numbers=%d\n", sum);
}
```

Result of the program

```
sum of first 10 natural numbers = 55
```

The program uses `if` and `goto` keywords. According to the algorithm, the program has to go to Step3. Step3 in this program is called a label, which is followed by a colon. The rules for coining a label name are the same as for an identifier. The label can be placed anywhere in the same function where the `goto` statement is found. Usage of `goto` is considered to be bad programming practice since it leads to errors when changes are made in the program and also affects the readability. It is always possible to write a program without using `goto`. This can be done by using a `for` statement.

5.5.2 `For` Statement

The `for` statement is meant for easy implementation of iterations unlike `if`. The syntax of `for` is as follows:

```
for (exp1; exp2; exp3)
{statements;}
```

Note the keyword, the parentheses and semicolons. There is no semicolon after `exp3`. `exp1`, `exp2` and `exp3` are expressions. The usage of the `for` loop is given below:

`exp1`– Contains the initial value of an index or a variable.

`exp3`– Contains the alteration to the index after each iteration of the body of the `for` statement. The body of the statement is either a single statement or a group of statements enclosed within braces.

If a single statement has to be executed, then braces are not required.

NOTES

exp2– Condition that must be satisfied if the body of statements is to be executed.

An example of a for loop is given below:

```
for (i = 0;  i < 5; i++)
printf("%d", i);
```

The loop will start with an initial value of i = 0. Since i < 5, the body of the for loop will be executed and it will print 0. Now the exp3 will be executed and i will be incremented to 1. Since i is less than 5, body of the loop will again be executed to print 1. This will continue till 4 is printed. i will now be incremented to 5 and since i is not less than 5, the for loop will be terminated. This is how for is used to carry out repetitive operations.

Let us now write a program for finding the sum of the first ten natural numbers using the for statement.

The program is given in Example 5.12

```
/*Example 5.12
Demonstrates the use of the for statement to find the sum of
the first 10 natural numbers*/
#include <stdio.h>
main()
{
    int sum=0, i; /*declaration and initialization combined*/
    for (i=1; i<=10; i++)     /*loop starts here*/
       {
          Sum = sum + i;
       }
    printf("sum of the first 10 natural numbers=%d\n", sum);
}
```

Result of the program

```
sum of first 10 natural numbers = 55
```

Note the difference between Example 5.11 and Example 5.12.

We have eliminated the label Step 3 and the goto statement.

The initialization of i = 1 is carried out as part of the for statement.

The incrementing of i is also carried out as part of the for statement. The program has, therefore, been simplified.

How does the program work?

Step 1: i = 1

NOTES

i is checked with i <= 10

Since i is less than 10, the for loop is executed.

sum = sum + i = 0 + 1 = 1

Step 2: i is incremented to 2

2 is <=10

Therefore, the for loop is executed.

sum = sum + i = (1) + 2

Steps 3 to 8: Same logic applies till the condition is met.

Step 9: i is incremented to 9

9 is < = 10

Therefore, the for loop is executed.

sum = sum + i = (1 + 2 +.....+ 8) + 9

Step 10: i is incremented to 10

10 is < = 10

sum = sum + I = (1 + 2 +.....+ 9) + 10

Step 11: i is incremented to 11.

11 is not < = 10.

Therefore, the for loop is now terminated.

The printf() function is now executed automatically.

Let us summarize the operation of the for loop.

When a program encounters a for loop, it first checks the condition through the expression in the middle. If the condition is satisfied it executes the group of statements. After executing the statements in the body of the loop, the program transfers the execution to the for statement and the third expression is executed, which is usually incrementing or decrementing. Then the condition is checked. If the condition is not satisfied, the group of statements will not be executed and the program will skip to the next statement after the statements pertaining to the for statement.

By chance if the initial value was typed as 11 instead of 1 in the program, the condition will turn out to be false and the group of statements will not be executed at all.

Three Components of for

The three components of a for statement are as follows:

exp1 and exp3 are assignments or function calls. We will discuss function calls at a later stage; exp2 is a relational expression. The three expressions may not always be present. However, even if an expression is not present, the associated semicolon should be present.

NOTES

For example,

```
for (; exp2 ;)
    {s1}
```

Here the initial value is not specified and the incrementing does not take place after every iteration. Presumably, the initial value is assigned elsewhere and incrementing or a similar operation takes place as part of the group of statements following the `for`. However, since `exp2` is present, the loop will terminate.

However, if all three expressions are omitted as given below,

```
for  ( ; ; )
```

the loop will never terminate because the conditional statement is absent. If `exp2` is not present, it is assumed that the condition is true always. Such a statement should not be used.

Instead of incrementing, we can use `i + = 2` as `exp3` when `i` will be incremented by 2 every time.

Let us try to print the list of even numbers up to 50. The program is given below:

```
/*Example 5.13
variation in for statement - to print even numbers*/
#include <stdio.h>
main()
{
    int i=2;
    for (; i<50; i+=2)  /*loop starts here*/
       {
          printf("%i is an even number\n",i);
       }
}
```

Here we initialize `i = 2` before the `for` loop itself. However, the corresponding semicolon is present at the right place.

Result of the program

```
2 is an even number
4 is an even number
6 is an even number
8 is an even number
10 is an even number
12 is an even number
14 is an even number
16 is an even number
18 is an even number
```

```
20 is an even number
22 is an even number
24 is an even number
26 is an even number
28 is an even number
30 is an even number
32 is an even number
34 is an even number
36 is an even number
38 is an even number
40 is an even number
42 is an even number
44 is an even number
46 is an even number
48 is an even number
```

5.5.3 Other forms of `for` Loop

The `for` loops can be nested as follows:

```
for (i = 1; i <= 10; i++)
{
    for (j = 1; j <= 5; j++)
    {
       for (k = 1; k <= 2; k++)
       {
          s1
       }
    }
}
```

The statement `s1` will be executed as follows:

First time	`i = 1, j = 1, k = 1`
Second time	`i = 1, j = 1, k = 2`
Third time	`i = 1, j = 2, k = 1`
	`i = 1, j = 2, k = 2`
	`i = 1, j = 3, k = 1`
	`i = 1, j = 3, k = 2`
Lastly	`i = 10, j = 5, k = 2`

`s1` will be executed `2*5*10 = 100` times.

Any level of nesting is acceptable; however, the higher the level of nesting is, the more easy it will be to commit mistakes and more difficult to understand.

NOTES

Let us look at some more `for` loops.

```
For ( x = -5;  - -x >= -10; )
{
 }
```

Here the decrement and conditional statements are combined in `exp2`.

Since decrement is a prefix, the decrement of `x` is carried out first. The condition is then checked in order to decide whether to continue or not. Then the loop is executed. Therefore, the first iteration will be carried out with `x = −6` and the last with `x = −10`.

Another variation of the statement is given as follows:

```
for (y = 100;  y ++<= 200;)
{
    s2
}
```

Here too `exp2` and `exp3` are combined. This is a postfix notation. The following sequence is carried out: condition check, increment and execute the loop. Therefore, the statement `s2` following the `for` loop will be executed the first time with `y = 101` and finally with `y = 201` as well.

The `for` loop is a popular iteration construct not only in 'C' but also in other languages. Here the initial value, the step and the final value are clear and unambiguous and simple to write. There are other loop statements also. In the next section, we will study the `while` loop.

5.5.4 The `while` Loop

The `while` loop is a subset of the `for` loop. The syntax for the `while` loop is given as follows:

```
while (expression)
    {statements;}
```

This means that the statement(s), which is a single statement or multiple statements, will be executed while the expression is true. When it becomes false, the execution will stop.

The `while` loop is similar to the `for` loop without `exp1` and `exp3`. The `for` loop can be simulated or replaced with the `while` loop as follows.

```
exp1;
    while (exp2)
    {
       statements
       exp3;
    }
```

NOTES

The programmer can use `while` or `for` at his discretion. The `for` loop is preferred when the initialization and incrementation are simpler.

Let us look at some examples.

Let us write a program for the generation of any multiplication table.

The program is as follows:

```
/*Example 5.14
use of while - You can generate multiplication
tables of your choice using this program.
caution: Don't exceed maximum limits of integer */
#include <stdio.h>
main()
    {
       int a,b,product;
       a=1;
       b=0;
       product=0;
       printf("Enter which table you want");
       scanf("%d",&b);
       while (a <=10)
       {
          product = a*b;
          printf("%2d X %d= %3d\n",a,b,product);
          a++;
       }
    }
```

When the program asks you to enter a table and you type 12, you will get the 12th table. This is shown as follows:

Result of the program

```
Enter which table you want 12
1 X 12 = 12
2 X 12= 24
3 X 12= 36
4 X 12= 48
5 X 12= 60
6 X 12= 72
7 X 12= 84
8 X 12= 96
```

```
9 X 12= 108
10 X 12= 120
```

Note here that the condition is (a <=10); incrementing is done within the loop in a++. Variable a is initialized as 1 before entering the while loop.

NOTES

If you want to print the table up to 16*12 = 192 then simply change the condition to while (a <=16). Simple, isn't it?

Let us now write a program to reverse a given number. For example, if 345 is the given number, we should get the reversed number as 543. The program is given below.

```
/*Example 5.15
/*Program to reverse a number*/
#include<stdio.h>
main()
{
    long unsigned n, reverse;
    printf("enter the number to be reversed\n");
    scanf("%lu", &n);
    reverse=0;
    while (n>0)
    {
       reverse=reverse*10+(n%10);
          n=n/10;
    }
    printf("Reversed number=%lu", reverse);
}
```

Result of the program:

```
enter the number to be reversed
4562
Reversed number=2654
```

How does the program work? Let us discuss for n = 345.

Before entering the while loop, n = 345

reverse = 0

Since 345 > 0, the condition is true and the loop is entered.

Iteration 1

```
reverse  = 0 *10 + (345 % 10)
         = 0 + 5 = 5
n        = 345 / 10 = 34
```

NOTES

Iteration 2

```
reverse  = 5 * 10 + (34 % 10) because n = 34 now
         = 50 + 4 = 54
 n = 34 / 10 =3
```

Iteration 3

```
reverse  = 54 * 10 + (3 % 10)
         = 540 + 3 = 543
       n  = 3 / 10 = 0
```

Now since `n` is not greater than `0`, the program will come out of the loop and will, print.

```
Reversed number = 543
```

5.5.5 `Do ... While` Loop

The `Do ... While` loop is a modification of the `while` statement. In the `while` statement, before the group of statements following the `while` are executed, the condition associated with the `while` is checked. If the condition is true or fulfilled, then the associated statements are executed. If not, the program skips the statements associated with the `while` loop. This is depicted in Figure 5.1.

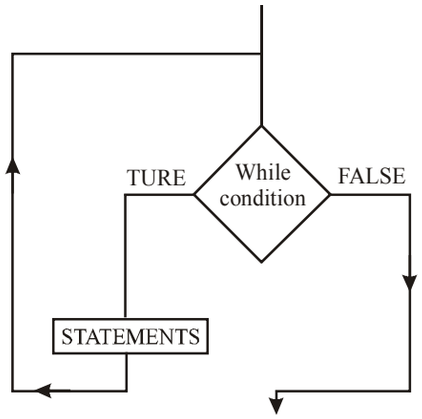

Fig. 5.1 `while` Loop

After execution of the statements, the program will check again whether the condition is true and then continue to execute or skip the statements depending on the condition. The statements may not be executed even once if the condition was false at the entry point.

However, the `do...while` loop works differently as shown in Figure 5.2.

NOTES

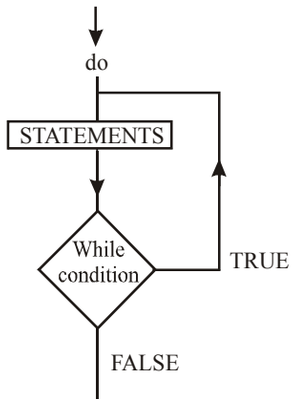

Fig. 5.2 `do...while` Loop

Here the statements following `do` will be executed once before the condition is checked. If it is true, then the statements will be executed again. If not, the program will skip the statements and proceed further. Thus, whatever be the condition, the statements following `do` will be executed once before checking the condition. This is the essential difference between `do...while` and `while`. The `while` loop tests the condition on top of the loop; but `do...while` tests at the bottom after executing the statements. The `while` loop executes the statements after checking the condition; but `do...while` executes the statements before testing the condition. The syntax of `do...while` is as follows:

```
do
{
   statements
}
while (expression);
```

The statement `do...while` is not used as frequently as the `while` loop.

Example 5.16 converts upper case alphabets to lower case. In case you want to convert more alphabets you will have to execute the program again and again. This can be avoided by the `while` loop. The program will continue to run as long as you want to convert more and more alphabets. The program has been rewritten with `while` for converting upper case to lower case. You can convert as long as you want. When you want to stop, enter 1. The program, which uses `while` for converting an upper case character to a lower case is given in Example 5.16.

```
/*Example 5.16
Conversion of upper case to lower case alphabet*/
#include <stdio.h>
#include<conio.h>
main()
```

NOTES

```
{
    int alpha=0;
    while (alpha!='1')
    {
       printf ("\nenter upper case alphabet- enter 1 to
quit\n");
       alpha=getche();
       if ( alpha >='A' && alpha<='Z')
       {
          alpha= (alpha+32);
          putch(alpha);
       }
       else
       {
          if(alpha!='1')
             printf("\ninvalid entry; retry");
          else
          printf("End of session");
       }
    }
}
```

Result of the program

```
enter upper case alphabet- enter 1 to quit
Pp
enter upper case alphabet- enter 1 to quit
p
invalid entry; retry
enter upper case alphabet- enter 1 to quit
Qq
enter upper case alphabet- enter 1 to quit
1End of session
```

This program works till 1 is pressed. It continues to convert upper case to lower case till 1 is pressed. The program has been designed in such a manner that it will perform at least one iteration of the statements following while. This can be rewritten using do...while. The rewritten program is given below:

```
/*Example 5.17
Conversion of upper case to a lower case alphabet*/
#include <stdio.h>
#include<conio.h>
```

NOTES

```
main()
{
    int alpha=0;
    do
    {
       printf ("\nenter upper case alphabet- enter 1 to
quit\n");
       alpha=getche();
       if ( alpha >='A' && alpha<='Z')
       {
          alpha=(alpha+32);
          putch(alpha);
       }
       else
       {
          if(alpha=='1')
             printf("End of Session");
          else
             printf("\ninvalid entry; retry");
        }
    }while(alpha!='1');
}
```

Result of the program

```
enter upper case alphabet- enter 1 to quit
Gg
enter upper case alphabet- enter 1 to quit
o
invalid entry; retry
enter upper case alphabet- enter 1 to quit
Dd
enter upper case alphabet- enter 1 to quit
1End of Session
```

How does it differ? Here too, the program will attempt to convert one character before it can be terminated. Assuming that the first character was 1, the program will still attempt to convert it and print the message "End of Session" before it quits.

Suppose the first character is a valid one and a number of characters are converted in succession; when you want to terminate the program, 1 has to be pressed and even then the program will not stop immediately. It will stop only after the statements are executed. Since the problem is the same, a detailed look at both the examples will bring out the similarity in operation between both the constructs. However, there are occasions when it is quite suitable as given in the next section.

Check Your Progress

7. Write the syntax for `for` statement.
8. Define `while` loop.

5.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The syntax of the `if` statement is given below.

   ```
   if (condition)
   {statements}
   ```

   If the condition is True, then a single statement or group of statements following the `if` will be executed. If more than one statement is to be executed, then the statements are grouped within braces. If it is a single statement, then curly braces are not required.

2. 'C' provides three logical operators for combining more than one condition. These are as follows:

   Logical `and` represented as `&&`

   Logical `or` represented as ||

   Negation or `not` represented as `!` (exclamation).

3. Usage of `goto` is considered to be bad programming practice since it leads to errors when changes are made in the program and also affects readability. It is always possible to write a program without using `goto`. The program can be rewritten without `goto` by using a `for` statement.
4. The `break` statement takes the program to the end of the `switch` statement. The end is just the closing brace corresponding to `switch` after the default `printf()` statement.
5. The `continue` statement is related to `break`. When `continue`is executed, it causes the next iteration of the corresponding `for`, `do...while` or `while` loop to begin. Therefore, `continue` takes the program to the top of the block and in the `for` loop, it will cause the next increment operation, followed by checking whether the condition is

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true or false in order to decide the next course of action. This is similar to skipping the current execution and continuing with the next operation after incrementing. The statement `continue`skips the rest of the statements in the loop for that iteration, whereas `break` terminates the loop.

6. There is a library function `exit()`, which causes the termination of the current program. Note that, `exit()` terminates the execution of the program itself, and not the block. The statement `break`enables coming out of the block or loop in which it is executed but `exit()` terminates the program at whatever stage the program may be. The `exit()` is a powerful function.
7. The `for` statement is meant for the easy implementation of iterations unlike `if`. The syntax of `for` is given below:

```
for (exp1; exp2; exp3)
{statements;}
```

8. The `while` loop is a subset of the `for` loop. The syntax for the `while` loop is given below:

```
while (expression)
    {statements;}
```

5.7 SUMMARY

- `if...else` is a useful construct when different statements or groups of statements are to be executed depending upon a condition. The `if...else` can be nested to multiple levels. However, as more and more nesting is carried out, it becomes difficult to follow what is going on and increases the chances of logical mistakes.
- The usage of braces with indentation reduces errors and improves readability.
- Before attempting to write a program, the algorithm has to be finalized stepwise. This also improves the quality of the program.
- `if...else` is suitable for simple programs, but there are better constructs such as `switch... case`, which are suitable for more complex problems. However, `if...else` remains an important building block in C language programming.
- Repetitive operations known either as loops or iterations, are quite common in scientific applications. Implementing recursion with the `if...else` statement needs the use of the `goto` statement and the corresponding label. However, `goto` statements reduce the readability of programs and are likely to cause errors. Therefore, `goto` should be avoided as much as possible.

- The `while` loop will be executed so long as the associated condition is true.
- The `for` loop is an improvement of the `while` loop containing three expressions on the header of the statement. The condition appears in the middle followed by a semicolon.
- The first expression usually initializes a variable and the last expression increments it.
- `for` and `while` loops should be constructed so that they terminate after execution; otherwise, an endless loop will be made, which will halt the computer.
- A variation of the `while` loop is the `do...while` loop, which checks the condition after the loop has been executed once. Therefore, `do...while` will execute the body of the loop at least once. This is because the `do...while` loop starts with `do` and has the condition checked only at the end of the loop. The loop body starts after `do` and ends just before the `while`.
- `switch ... case` is a multi-way branching construct. The `switch` is followed by an expression in parentheses, which is evaluated as an integer at the time of program execution.
- The statements following the `switch` begin with `case` labels where each case label has a unique integer, like `case 10`, `case 9`, etc. Therefore, the program, after executing the `switch`, goes to the label corresponding to the `switch` expression.
- At the end of all the `case` statements, a `default` statement can be included, which will also contain a group of statements. If the `switch` expression does not match with any of the `case` expressions, then the `default` statement will be executed.
- A switch statement need not have a default statement and in such a case the program will come out of the `switch` if no match is found.
- `continue` statement serves to skip the rest of the statements in the loop and execute the loop after incrementing or decrementing and checking the condition.
- The `return` statement enables the function to instantly return program execution to the called function.

5.8 KEY WORDS

- **Loop or Iteration:** It is used to perform the same operation a number of times by repeating the same operation with one or more of the values changed.

- **Switch:** When the switch keyword is encountered, the associated expression is evaluated.

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5.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Define the term loops.
2. What is a `while` loop?
3. What is a `switch` statement?

Long Answer Questions

1. What is the significance of branching in C program?
2. Write a program to illustrate the use of `switch` statement.
3. What are the three component of `for` loop?
4. Discuss the difference between `while` and `do...while` loop.

5.10 FURTHER READINGS

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UNIT 6 ARRAYS

NOTES

Structure

6.0 INTRODUCTION

C facilitates the arrangement of same data types in the memory as an array. Arrays are also used in other computer languages, such as Pascal and BASIC. However, in C, it is very popular to make a larger unit of same data types. It makes repetitive tasks easy if elements of the same data type need to be processed repetitively. In essence, an array holds a fixed number of same data elements. Data items can be grouped in an array, which temporarily stores the data. In C array declaration is done by using `int` and `char` keywords, such as `int` a[5]; and `char` Student_Name[]= "Student"; respectively. In daily life, similar objects are grouped into units; for example, in a library, all English fiction and non-fiction works are kept in separate shelves. The same concept is used in C arrays. Subscripts or indices are arranged in square brackets in arrays for addressing in the memory location. Each indexed value is called an element. The types of arrays used in C are one-dimensional, two-dimensional and multi-dimensional arrays.

6.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the basics of arrays
- Write programs on arrays
- Discuss the advantage and disadvantages of arrays

6.2 BASIC CONCEPT OF ARRAYS

NOTES

Thus far we studied a number of basic, or fundamental, or primitive data types, such as *int*, *float*, *char* and *double*. Now we focus our attention on the user defied data types. The rules governing the size of basic data types are fixed, according to which each basic data type can hold only one value at a time. For instance, a data type *unsigned int* will hold one number at a time and will occupy 2 or 4 bytes (depending on the computer system used) for storing it. But for programming real application we need a number of basic types. For instance, if we want to store the marks obtained by 60 students in a subject in a class we may need to declare 60 *unsigned int* variable. Declaring so many variables to solve such a simple problem unnecessarily increases the complexity of the program. This can be avoided by using user defined data type. An array is one of the user defined of data types. An array can hold a number of data of the same type. In a program we can declare arrays of integers, arrays of characters and arrays of floating point numbers, etc. depending on the need. What does an array mean? It means a number of integers or floats or data of the same type.

For instance, int $A = \{ 2, 3, 5, 7\}$;

Here *A* is an array of prime numbers of type int.

```
char  B = { 'a', 'b', 'c', 'd'};
```

B is an array of characters.

Thus an array has a name or identifier which is *A* in the former case and *B* in the latter. It is of a particular type; *int* in the case of A and *char* in the case of B. It means all the elements of an array should be of the same type. How do we give a name to each element? We can use an index with the name of the array to indicate the elements. While in mathematics, the first element is identified with an index [1], in "C" the first element is identified with the index [0]. Index or subscript is used to indicate the position of the element in the array.

Thus, $A[0] = 2$

$A[1] = 3$

$A[2] = 5$

& $A[3] = 7$

Similarly, $B[0] =$ Red

$B[1] =$ Green

$B[2] =$ Yellow

Array *A* has four elements and hence the size of *A* is 4. Similarly, *B* has three elements and hence its size is 3. Therefore, the first element of any array will have a subscript of 0 and the final element a subscript of $n-1$, where n is the size of the array.

6.2.1 Array Declaration

NOTES

Assuming that there are 40 employees in an office and we want to store their ages, we would have to create 40 variables of type integer or float and store their ages. While such a definition seems alright, it would cause complications while programming. Instead, this can be declared as an array of size 40.

For instance,

```
short emp_age [40];
```

Here, we have declared an integer variable known as *emp_age* with a dimension of 40. A single variable has been declared to store the ages of 40 employees. But for this feature, we would have to write 40 lines to declare the same with 40 different names.

An array is also variable and hence must be declared like any other variable. The naming convention is the same as in the case of other variables. The array name cannot be a reserved word and must be unique in the program. An array variable name and another ordinary variable name cannot be identical. Since there is no limit to variable names, do not use similar names for a basic variable and an array. What distinguishes an array variable from a single variable in their declaration is the dimension within the square brackets.

What does variable declaration do? It allots memory space for the variable. If we declare an array variable of type integer and dimension 40, then the computer will allot a memory size of 40 words for the variable contiguously. The last word is important. The elements in an array will be stored in consecutive memory locations. Since an integer of type *short* needs two bytes for storage and if the memory is organized and addressed in terms of bytes, the following allocation would be carried out for emp_age elements.

emp_age [0]	1000
emp_age [1]	1002
emp_age [2]	1004

If *emp_age* [0] is stored at the location with address 1000, *emp_age* [1] will be at 1002. It is enough for us to indicate the starting address to find the address of any of the elements of the array. The *emp_age* [2] will be stored at 1004. The formula for finding the address of element *emp_age* [*n*] = starting address + *n* * 2.

If *emp_age* had been defined as a float variable and if *emp_age* [0] starts at the location 1000, then *emp_age* [10] would be found at location 1040. The formula is: address of n^{th} element = starting address + *n* * (size of variable). The important point to be noted is that if the starting address is known and the type of variable is known, the exact location where an element of the array is stored can be computed. An array has to contain elements of the same type. A float array cannot have integers or characters.

We must always specify the array size. We would normally expect to get an error message if the array size is exceeded; but, this does not happen in C language.

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In the above example, if we try to read the value of *emp_age* [50] nothing will happen. No error message will be printed. Therefore, it is the responsibility of the programmer not to exceed the array size. Since we have a single subscript, the arrays declared so far are known as one-dimensional arrays.

Examples of one-dimensional arrays are given below:

```
int  emp_age[100];/* no space between variable name & dimension */
float        mark[100];
char         name[25];       /* name contains 25 characters */
```

6.2.2 Array Initialisation

If the array elements are known beforehand, they can be declared right at the beginning. If the employees' ages are known beforehand, they can be declared as:

```
int  emp_age [5] = {40, 32, 45, 22, 27};
```

The data elements are written within braces separated by commas. In this case, when data elements are declared, there is no need to declare the size; we can write:

```
int  emp_age [] = { 40, 32, 45, 22, 27 };
```

The latter is advantageous. If the size is not declared, the compiler will count the number of elements and automatically allot the size. On the other hand, if we specify the size and give lesser number of elements, then the compiler will assume the other elements to be zero.

For instance, if we declare

```
int  Marks  [ 5 ] = { 100, 70, 80 };
```

In this case, Marks [0] = 100
Marks [1] = 70
Marks [2] = 80

What happens to the other elements? The computer will assign 0 to them.

Marks [3] = 0
Marks [4] = 0

If we declare size 5 and give 7 elements then there will be an error. Therefore, if we know the data elements in advance, we can allow the compiler to calculate the size.

Now let us try some programs.

Example 6.1

We want to get 10 integers, one at a time, and print them after they are collected.

The program is given below:

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```
Ten integers of an array are scanned the
scan function and printed */
#include <stdio.h>
int main()
{
   int s1[10];
   int i;
   printf("Enter 10 integers \n");
   for (i=0; i<=9; i++)
   {
      scanf("%d",&s1[i]);
   }
   printf("you have entered:\n");
   for (i=0; i<=9; i++)
   {
      printf ("%d\n", s1[i]);
   }
}
```

Result of the program

```
Enter 10 integers
1   2  3  4  5  6  7  8  9  0
you have entered:
1
2
3
4
5
6
7
8
9
0
```

Analyze the program carefully. We declare *s1* as an integer array of size 10.

Next we use the first *for* loop to scan the entered integers from the keyboard. At the first iteration, s1[0] will be received and stored at location & s1[0]. This is similar to a simple variable where "&" denotes the address of the variable. This is repeated till s1[9] is received and stored at & s1[9].

The next *for* loop prints the value of s1[0] to s1[9], i.e., 10 integers one at a time and in new line.

Thus, the array is handled the same way and each element has a distinct identification. The elements of an array have the same name with a subscript corresponding to the position, i.e., the array name with the subscript written in square brackets.

Consider another program to understand one-dimensional arrays more clearly.

Assume the existence of an array of integers. We want to find the greatest number in the array and its location. To do that, we set up two other variables known as *max* and *ind*. We initialize them to zero. Then we compare each number

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with *max*. If it is greater than the *max* then we note the location in *ind* and the associated value in *max*. When we have checked all the elements in the array we would have got the greatest number and its location. Since the first element has a subscript 0, we have to add 1 to the subscript to get the position. The program is given below:

```
to find the greatest number and
its position in an array*/
#include<stdio.h>
int main()
{
   int a[5]= {1,5,2,6,3};
   int max=0, i, ind=0;
   for(i=0; i<=4; i++)
   {
      if (a[i] > max)
      {
         max =a[i];
         ind=i+1;
      }
   }
   printf("maximum number=%d location=%d\n", max, ind);
}
```

Result of the program

```
maximum number=6 location=4
```

Let us see how the program works.

Iteration 1

i = 0 max = 0 ind = 0

a[0] = 1

since a[0] > max

max = 1

ind = 1

Iteration 2

i = 1 max = 1 ind = 1

a[1] = 5

since a[1] > max

max = 5 ind = 2

Iteration 3

i = 2 max = 5 ind = 2

a[2] = 2

since a[2] < max no change

Iteration 4

i = 3 max = 5 ind = 2

a[3] = 6
Since a[3] > max
max = 6 ind = 4

Iteration 5

i = 4 Max = 6 ind = 4
a[4] = 3
since a [4] < max no change

The program prints

max = 6 location = 4

Thus, arrays are very useful for solving real problems encountered every day.

6.2.3 Multi-Dimensional Arrays

Multi-dimensional arrays operate on the same principle as single dimensional arrays. They are also a user defined data type. We have to give the dimensions of the two subscripts in case of a 2-dimensional array.

For instance, w [10][5]

is a two-dimensional array with different subscripts. Here, there will be 50 different elements. The first element can be denoted as w [0][0].

The next element will be w[0][1].

The fifth element will be w[0][4].

The sixth element will be w[1][0].

The last element will be w [9][4].

This can be considered as a row and column representation. There are 10 rows and 5 columns in this example. When data is stored in the array, the second subscript will change from 0 to 4, one at a time, with the first subscript remaining constant at 0. Then the first subscript will become 1 and the second subscript will keep increasing from 0 to 4. This is repeated till the first subscript becomes 9 and the second 4. This array can be used to represent the names of 10 persons, with each name containing 5 characters. The first subscript refers to the name of the 0th person, 1st person, 2nd person and so on. The second subscript refers to the 1st character, 2nd character and so on of the name of a person. Thus, 10 such names can be stored in this array.

The dimension of the array can be increased to 3 with 3 square brackets as given below: *Marks* [50][3][3];

The name of the first element will be *Marks* [0] [0] [0]

The last element will be *Marks* [49] [2] [2].

It would be easy to add more dimensions to an array but it would also become more difficult to comprehend under normal circumstances. It may, therefore, be useful to solve complicated scientific applications, however. Now let us focus on the concept of multi-dimensional arrays using a simple problem.

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Assume that we need to write a program to read two arrays (both 2 dimensional) and multiply the corresponding elements and store them in another 2-dimensional array. To make the problem simpler, we will use [2][2] arrays.

Let us call the arrays x, y & z.

We have x = {x[0][0] x[0][1] } y = {y[0][0] y[0][1] }
{x[1][0] x[1][1] } {y[1][0] y[1][1] }

We want to multiply x [0][0] and y [0][0] and store the result in z [0][0] and so on.

The values of x and y are given in the program itself.

Example 6.2

```
/* multiplication of corresponding elements of two 2-dimensional arrays*/
#include <stdio.h>
int main()
{
   int i,j;
   int z[2][2];
   int x[2][2]= {1, 2, 3, 4};
   int y[2][2]= {5, 6, 7, 8};
   for (i=0; i<=1; i++)
   {
      for (j=0; j<=1; j++)
      {
         z[i][j]=x[i][j]*y[i][j];
         printf("z[%d][%d]=%d\n", i, j, z[i][j]);
      }
   }
}
```

We have declared two arrays x[2] & y[2] as follows:

x = { 1 2 } y = { 5 6 }
{ 3 4 } { 7 8 }

x [0][0] = 1 x [1][1] = 4

y [0][0] = 5 y [1][1] = 8

Therefore, after multiplication of the respective elements, we get

z = { 5 12 }
{ 21 32 }

The program prints the values of the products stored in array z.

The output of the program appears as follows:

z[0][0]=5

z[0][1]=12

z[1][0]=21

z[1][1]=32

Note that the elements are stored contiguously, row by row.

In the above example, we have declared elements with a two-dimensional array and initialized its one-dimensional array as given below:

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```
x [2] [2] = {1, 2, 3, 4} ;
```

The system correctly interpreted the same and we got the result correctly. We can actually present the above in another manner as given below:

```
int x [2] [2] = {
                    {1, 2},
                    {3, 4}
              };
```

In this method, we are indicating the elements closer to the matrix form. Both the above definitions are equivalent. In the latter definition, we can easily visualize a two-dimensional array. The first row represents the first row of the two-dimensional array. The values in the second row represent the second row of the two-dimensional array.

To practise the above representation, let us take another example of a two-dimensional array.

```
x [3] [2] = {10, 20, 30, 40, 50, 60} ;
```

The same can be represented in the second form as given below:

```
x [3] [2] = {
              {10, 20},
              {30, 40},
              {50, 60}
    };
```

Note that there is no comma at the end of the last row.

Finding Transpose of a Matrix

Arrays can be used to represent matrices. Inter-changing rows and columns in a matrix obtain transpose of a matrix.

For instance,

$$\text{If } A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

$$\text{Transpose of } A = A^t = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$$

The algorithm for finding transpose is very simple. After reading the elements of A [i] [j], we get transpose matrix B [i] [j] by just assigning each element as follows:

B[i] [j] = A [j] [i]

It is so simple.

The algorithm is given below:

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Algorithm for finding transpose of a matrix

Matrix_Transpose(int A[i][j])

Step 1: Declare int i, j, row, column;

Step 2: Declare int A[10] [10], B[10] [10];

Step 3: read values of row & column of given matrix A

Step 4: /*getting given matrix row by row*/

for [i=0; i<row; i++)

{

print("Enter row number of given matrix\n");

for (j=0; j<column; j++)

read A[i] [j]

}

Step 5: /*transpose of given Matrix */

for (i=0; i<column; i++)

for (j=0; j<row; j++)

{

B [i] [j] = A [j] [i];

}

Step 6: /*Printing values of Product matrix */

print ("Elements of transpose matrix are:");

for (i=0; i<column; i++)

{

for (j=0; j<row; j++)

print (B[i] [j]);

}

Step 7: End

The program implementing the above algorithm is given below:

Example 6.3

```
finding transpose of a matrix*/
#include<stdio.h>
int main()
{
int i,j;
```

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```
int row, column;
int A[10][10], B[10][10];
printf("Enter number of rows of given matrix\n");
scanf("%d", &row);

printf("Enter number of columns of given matrix\n");
scanf("%d", &column);

/*getting given matrix row by row*/
for(i=0; i<row; i++)
{
printf("Enter row number %d of given matrix\n", i+1);
for(j=0; j<column; j++)
scanf("%d", &A[i][j]);
}

/*transpose of given Matrix */
 for(i=0; i<column; i++)
 for(j=0; j<row; j++)
    {
      B[i][j]=A[j][i];
       }
/*Printing values of Product matrix*/
printf("Elements of transpose matrix are:\n");
for(i=0; i<column; i++)
   {
   printf("\n");
   for(j=0; j<row; j++)
   printf("%d\t",  B[i][j]);
        }
    }
```

The result of the program is given below:

```
Enter number of rows of given matrix
3
Enter number of columns of given matrix
4
Enter row number 1 of given matrix
1       2       3       4
Enter row number 2 of given matrix
5       6       7       8
Enter row number 3 of given matrix
9       10      11      12
Elements of transpose matrix are:

1       5       9
2       6       10
3       7       11
4       8       12
```

Notice that we had entered a 3x4 matrix. After transpose it has become a 4x3 matrix. Essentially, each row of matrix A has become a column of B. Finding the transpose of a matrix is required in many applications.

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The input in the above program was a rectangular matrix. What will happen if we input a square matrix in the above program? Let us execute the program and see.

```
Enter number of rows of given matrix
3
Enter number of columns of given matrix
3
Enter row number 1 of given matrix
1       2       3
Enter row number 2 of given matrix
4       5       6
Enter row number 3 of given matrix
7       8       9
Elements of transpose matrix are:

1       4       7
2       5       8
3       6       9
```

During the second time, we wanted to transpose a square matrix. So a 3x3 matrix was given as input. The output is a perfect transpose of a given matrix. The columns and rows have interchanged. Thus, the program works correctly, both for square matrix as well as the rectangular matrix.

Triangular Matrices

Upper Triangular Matrix

We may recall that a principal diagonal or leading diagonal of a square matrix A contains the elements whose row index and column index are same, i.e., it includes the elements A[1] [1], A[2] [2], A[3] [3], etc. A square matrix in which all the elements below the leading diagonal are zero is called an upper triangular matrix. For instance, the following is an upper triangular matrix.

{10, 20, 30}

{ 0, 50, 60}

{ 0, 0, 40}

Notice that all the elements below the leading diagonal are zero. This can be expressed mathematically as A [i] [j] = 0 for i>j.

Now let us write an algorithm to print the elements of an upper triangular matrix. Essentially, we need not print those elements, which we know will be zero in an upper triangular matrix.

Algorithm for printing elements of upper triangular matrix

Matrix_Upper_Triangular (int A[i][j])

Step 1: int i,j, row;

Step 2: int A[10][10];

Step 3: read row

Step 4: /*getting given matrix row by row*/

```
for(i=0; i<row; i++)
{
for(j=0; j<row; j++)
scanf("%d", &A[i][j]);
}
```

Step 5: /*Printing values of matrix*/

```
for(i=0; i<row; i++)
{
 for(j=0; j<row; j++)
{if(i>j) continue;
else
print(A[i][j]);
}
}
}
```

Step 6: End

A program implementing the above algorithm is given below:

Example 6.4

```
/* printing elements of upper triangular matrix*/
#include<stdio.h>
int main()
{
int i,j;
int row;
int A[10][10];
printf("Enter number of rows of given matrix\n");
scanf("%d", &row);

/*getting given matrix row by row*/
for(i=0; i<row; i++)
{
printf("Enter row number %d of given matrix\n", i+1);
for(j=0; j<row; j++)
scanf("%d", &A[i][j]);
}
/*Printing values of  matrix*/
```

NOTES

```
printf("Elements of upper triangular matrix are:\n");
for(i=0; i<row; i++)
  {
   printf("\n");
   for(j=0; j<row; j++)
   {if(i>j) continue;
   else
    printf("A[%d][%d]=%d\t", i,j, A[i][j]);
        }
    }
    }
```

Let us take a square matrix of size 4x4. However, we will enter all the values of the matrix. The program will print only the non-zero values along with the index. The result of the program is given below:

```
Enter number of rows of given matrix
4
Enter row number 1 of given matrix
1       2       3       4
Enter row number 2 of given matrix
0       5       6       7
Enter row number 3 of given matrix
0       0       8       9
Enter row number 4 of given matrix
0       0       0       10
Elements of upper triangular matrix are:
A[0][0]=1       A[0][1]=2       A[0][2]=3       A[0][3]=4
A[1][1]=5       A[1][2]=6       A[1][3]=7
A[2][2]=8       A[2][3]=9
A[3][3]=10
```

Lower Triangular Matrix

A square matrix in which all the elements above the leading diagonal are zero is called a lower triangular matrix. For instance, the following is a lower triangular matrix.

$$\{10,\ 0,\ 0\}$$
$$\{60,\ 50,\ 0\}$$
$$\{40,\ 30,\ 70\}$$

Notice that all the elements above the leading diagonal are zero. This can be mathematically expressed as A [i] [j] = 0 for i<j.

Multiplication of Matrices

Recall that a matrix multiplication is possible when the number of columns in the first matrix is equal to the number of rows in the second matrix. Let us understand the problem with an example.

Let matrix

$$A[2][3] = \begin{bmatrix} 10 & 20 & 30 \\ 40 & 50 & 60 \end{bmatrix}$$

$$B[3][2] = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

Number of columns in matrix A = 3

Number of columns in matrix B = 3

Hence, multiplication A x B is possible.

Let P be the product matrix. Let us use C notation for subscript, i.e., the first element will have a subscript of zero.

P [0] [0] = [10×1 + 20×3 + 30×5] = 220

P [0] [1] = [10×2 + 20×4 + 30×6] = 280

P [1] [0] = [40×1 + 50×3 + 60×5] = 490

P [1] [1] = [40×2 + 50×4 + 60×6] = 640

Thus, multiplication of 2x3 matrix by 3x2 matrix results in a 2x2 matrix as given below:

$$P[2][2] = \begin{bmatrix} 220 & 280 \\ 490 & 640 \end{bmatrix}$$

We can generalize the calculation of each element as given below:

$$P[i][j] = \sum_{k=9}^{n-1} A(i,K)K\ B(K,j)$$

where n is the number of columns of the first matrix as well as the number of rows of the second matrix.

i is the number of rows of the first matrix and the product matrix

j is the number of columns of first matrix and the product matrix.

Let us confirm this through an example. For the sake of simplicity, the values are given in the program itself.

Example 6.5

```
/* To demonstrate matrix multiplication*/
#include<stdio.h>
int main()
{
int i,j,k;
int A[2][3]={
              {10, 20, 30},
              {40, 50, 60}
              };
```

NOTES

NOTES

```
int B[3][2]={
                {1, 2},
                {3, 4},
                {5, 6}
                };
int P[2][2];
 /*Matrix multiplication*/
        for(i=0; i<2; i++)
           for(j=0; j<2; j++)
           {
               P[i][j]=0; /*Initializing product matrix*/
                 for(k=0; k<3; k++)
P[i][j]=P[i][j]+A[i][k]*B[k][j];/*calculating elements*/
            }
     /*Printing values of Product matrix*/
     printf("Elements of Product matrix are:\n");
     for(i=0; i<2; i++)
        for(j=0; j<2; j++)
        {
         printf("P[%d][%d]=%d\n", i,j, P[i][j]);
            }
          }
```

We initialize matrices A & B with actual values. Then, we declare a product matrix P [2] [2]. The dimension of the matrix requires a little explanation.

We have A [2] [3] &

B [3] [2]

Since the number of columns of the first matrix is the same as the number of rows of the second matrix, we can multiply them. The dimensions of the resultant matrix are as given below:

P [number of rows of first matrix] [number of columns of second matrix]

Assume A [3] [2] & B [2] [4]

The product matrix in this case will be P [3] [4]. This has to be understood clearly.

The number of rows of product matrix will be equal to the number of rows of the first matrix and number columns of the product matrix will be equal to the number of columns of the second matrix. Now, look at the section where we carry out matrix multiplication. We initialize the elements of the product matrix. Then each element value is calculated. We are using a nested *for* loops and inside them, another *for* loop. Finally, we print the values. The result of the program is given below:

Result of Example 6.5

```
Elements of Product matrix are:
P[0][0]=220
P[0][1]=280
P[1][0]=490
P[1][1]=640
```

Let us now formulate an algorithm for multiplication of matrices. The algorithm shall be such that it shall be able to accept different sizes of matrices for multiplication. However, multiplication is possible only if the number of columns in the first matrix is equal to the number of columns in the second matrix. The algorithm is given below:

Algorithm for multiplication of matrices

```
Step 1:   int I, j, k, row, colrow, column;
          /*the first matrix subscripts are the first two and
          the second matrix subscripts are the last two.
          Colrow gives the number of columns of first matrix
          and number of rows of second matrix */
Step 2:   int A[10] [10], B[10] [10], P[10] [10];
Step 3:   read row, colrow, column
Step 4:   /*getting first matrix row by row*/
          for (I=0; I<row; I++)
          for (j=0; j<colrow; j++)
          read A[I] [j]
          }
Step 5:   /*getting second matrix row by row*/
          for (I=0; I<colrow; I++)
          for (j=0; j<column; j++)
          read B[I] [j]
          }
Step 6:   /*Matrix multiplication*/
                    for (I=0; I<row; I++)
                              for (j=0; j<column; j++)
                              {
          P[I] [j]=0; /*Initializing product matrix*/
          for (k=0; k<colrow; k++)
          P[I] [j] = P[I] [j] + A[I] [k] * B[k] [j];
          /*calculating elements*/
                    }
          /*Printing values of Product matrix*/
Step 7:   printf ("Elements of Product matrix are :\n");
```

for (I=0; I<row; I++)
for (j=0; j<column; j++)
print P[I] [j];

NOTES

Step 8: End

Let us now generalize the program to carry out matrix multiplication. The generalized program implementing the above algorithm for matrix multiplication is given below:

Example 6.6

```
/* Matrix multiplication generalized*/
#include<stdio.h>
int main()
{
int i,j,k;
int row, colrow, column;
/*the first matrix subscripts are first two and
the second matrix subscripts are the last two.
colrow gives the number of columns of first matrix and
and number of rows of second matrix*/
int A[10][10], B[10][10], P[10][10];
printf("Enter number of rows of first matrix\n");
scanf("%d", &row);
printf("Enter number of columns of first matrix\n");
scanf("%d", &colrow);
printf("Enter number of columns of second matrix\n");
scanf("%d", &column);
/*getting first matrix row by row*/
for(i=0; i<row; i++)
{
printf("Enter row number %d of first matrix\n", i+1);
for(j=0; j<colrow; j++)
scanf("%d", &A[i][j]);
}

/*getting second matrix row by row*/
for(i=0; i<colrow; i++)
{
printf("Enter row number %d of second matrix\n", i+1);
for(j=0; j<column; j++)
scanf("%d", &B[i][j]);
}

/*Matrix multiplication*/
       for(i=0; i<row; i++)
```

NOTES

```
          for(j=0; j<column; j++)
          {
      P[i][j]=0; /*Initializing product matrix*/
      for(k=0; k<colrow; k++)
P[i][j]=P[i][j]+A[i][k]*B[k][j];/*calculating elements*/

             }
      /*Printing values of Product matrix*/

       printf("Elements of Product matrix are:\n");
       for(i=0; i<row; i++)
          for(j=0; j<column; j++)
           printf("P[%d][%d]=%d\n", i,j, P[i][j]);
             }
```

Look at the program. Since the number of columns of first matrix is same as the number of rows of the second, we call the number as colrow. The row refers to the number of rows in the first matrix and column refers to the number of columns in the second matrix. Thus, we are going to compute

P [row] [column] = A [row] [colrow] x

B [colrow] [column]

After declaration of the three variables, we also declare the three matrices. Since we have to give a constant as the dimension of the matrix, size of 10 has been given. Any large size can also be given. Then, we get the values for the variables row, colrow and column at runtime.

The next section gets the elements of the first matrix A row by row. Thereafter, we get the values of elements of the second matrix B. Then each element of the product matrix is computed. Then the elements of the product matrix are printed.

The interactions with the system and result of first execution follow:

Result of first execution

```
Enter number of rows of first matrix
2
Enter number of columns of first matrix
3
Enter number of columns of second matrix
2
Enter row number 1 of first matrix
10      20      30
Enter row number 2 of first matrix
40      50      60
Enter row number 1 of second matrix
1       2
Enter row number 2 of second matrix
3       4
Enter row number 3 of second matrix
5       6
Elements of Product matrix are:
```

```
P[0][0]=220
P[0][1]=280
P[1][0]=490
P[1][1]=640
```

NOTES

The matrices multiplied are same as in the previous program. The result confirms that our generalized algorithm and the corresponding program work correctly. Now, let us try two different matrices for confirming the correctness of the program.

Result of second execution

```
Enter number of rows of first matrix
4
Enter number of columns of first matrix
3
Enter number of columns of second matrix
2
Enter row number 1 of first matrix
1       2       3
Enter row number 2 of first matrix
4       5       6
Enter row number 3 of first matrix
7       8       9
Enter row number 4 of first matrix
10      20      30
Enter row number 1 of second matrix
40      50
Enter row number 2 of second matrix
60      70
Enter row number 3 of second matrix
80      90
Elements of Product matrix are:
P[0][0]=400
P[0][1]=460
P[1][0]=940
P[1][1]=1090
P[2][0]=1480
P[2][1]=1720
P[3][0]=4000
P[3][1]=4600
```

Let us confirm the correctness of the results manually.

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \\ 10 & 20 & 30 \end{bmatrix}$$

$$B = \begin{bmatrix} 40 & 50 \\ 60 & 70 \\ 80 & 90 \end{bmatrix}$$

$$P[0][0] = [1 \times 40 + 2 \times 60 + 3 \times 80]$$
$$= 400$$

P [0] [1] = [1×50 + 2×70 + 3×90]
= 460
P [3] [1] = [10×50 + 2×70 + 3×90]
= 4600

Thus, the generalized program for matrix multiplication works correctly.

NOTES

Designated Initializers

The ANSI/ISO standard issued in the year 1990 permitted assignment of values to array elements directly as given in the following program.

Example 6.7

```
#include<stdio.h>
int main()
{
   int i;
   int m[5];
 m[0] = 10;
 m[4] = 20;
for(i=1;i<4;i++)
{
   m[i] = 0;
 }
   printf("the elements of the array array follow \n");
for(i=0;i<5;i++)
{
   printf("%d\n",m[i]);
}
}
```

In the above program, we assign the values for 0th element and 4th element directly as 10 and 20 respectively. The values of the other elements (1st, 2nd and 3rd) are assigned as zero in the for loop.

The output of the program is given below:

```
the elements of the array array follow
10
0
0
0
20
```

In the next example, we show the program again but rather than assigning values to the first and last elements of the array directly as in the above program, we initialize them explicitly by subscript, using designated initializers.

Example 6.8

```
#include<stdio.h>
 int main()
 {   int i;
     int m[5]=
       { [0]=10,  // initialize elements with designated
         initializers
          [4]=20
```

```
};
   printf("The elements of the array follow \n");
   for(i=0;i<5;i++)
   printf("%d\n",m[i]);
}
```

NOTES

The result of the program follows

```
The elements of the array follow
10
0
0
0
20
```

Look at the above program carefully. We assign values to the array elements explicitly using designated initializers [0] and [4]. Note, there is no comma after the last assignment. The initialization is carried out within braces and the closing brace is followed by a semicolon. Any element which is not explicitly initialized is implicitly initialized to zero. This type of syntax was not allowed in earlier versions of C90.

The designated initializers are supported for user defined data types, such as arrays, structures, and unions. A designated initializer, or designator, points to a particular element to be initialized. A designator list is a comma-separated list of one or more designators. A designator list followed by an equal sign constitutes a designation.

Designated initializers allow for the following flexibility:

Elements within a user defined data type can be initialized in any order.

The initializer list can omit elements that are declared anywhere in the data type. Elements that are omitted are initialized as if they are static objects: arithmetic types are initialized to 0; pointers are initialized to NULL.

6.2.4 Variable Length Array/ Dynamic array

In C90, arrays are of constant and predetermined size. Suppose we do not know an array size at compilation time then how to handle this situation without using dynamic memory allocation? C99 allows us to handle array of unknown size by using variable length array. A variable length array is that whose length or size is defined at execution time. The following example shows a method of using variable length arrays. In the example we are declaring an array called *printarray* which takes as arguments an integer for size of the array and another integer array. We get *arraysize* at run time. In the *for* loop we generate the values for array elements as square of the array index *i* for the sake of simplicity. We could have obtained different values through *scanf* function in the for loop, if needed. Then we call the function *printarray* and pass the array size and all the elements of the array. See the simplicity of the statement

printarray (arraysize, array);

Values of array elements are printed in the called function.

Example 6.9

```
#include<stdio.h>
int main ()
{
void  printarray(int  size, int  arr[size]);
int i, arraysize;
printf("enter size of array ");
scanf("%d",&arraysize);
int array[arraysize];          // declare variable length
array
printf("\nsize of (array) array size of %d bytes\n",
          sizeof(array));
for(i=0; i<arraysize; i++)
{    array[i]=i*i;
}
printf("\n one-dimensional Array\n");
printarray(arraysize, array);
}

void printarray (int size, int array[size])
{
    int i;
   for( i=0; i<size; i++)
      {printf("array[%d]=%d\n",i,array[i]);
       }
}
```

NOTES

Result of Program

```
enter size of array 6
size of (array) array size of 24 bytes
 one-dimensional Array
array[0]=0
array[1]=1
array[2]=4
array[3]=9
array[4]=16
array[5]=25
```

Binary Search

There are a number of search methods. Here we look at Binary search. An important pre-condition for binary search is that the data is ordered or arranged in ascending or descending order in an array, like names are arranged alphabetically in a telephone directory.

Let us now study the algorithm for binary search to understand the concept. We will assume that the array of numbers is arranged in increasing order.

NOTES

```
Algorithm for Binary Search(a[n], x, left, right)
{
   int a[n]; /* subscript of left most element will be 0
and right most n-1 */
left = 0
right = n-1
found = false;
while (left < right)
   {
mid = (left + right)/2;
   if (a (mid) = =x) found = true;
   else
      if (a (mid) < x) left = mid + 1;
         else right = (mid-1);
}
          if (found) print ("found"); else print ("Not
found");
}
```

A program implementing binary search algorithm is given below:

```
/*Example 6.10*/
/*Binary search- The numbers are ordered*/
#include <stdio.h>
#define UPPER 5
#define TRUE 1
#define FALSE 0
int main ()
{
   int left =0, mid=0, right=UPPER, found=FALSE;
   int x;
   int a [] = {10, 20, 30, 40, 50, 60};
   printf("ENTER THE NUMBER TO SEARCH\n");
   scanf("%d", &x);
   while ((left <= right) && (!found))
   {
      mid = (left+right)/2;
      if (a[mid]==x) found = TRUE;
      else
         if (a[mid] < x)
            left = (mid +1);
         else
            right = (mid-1);
   }
   if (found)
      printf("found the number %d in position %d\n", x,
            mid+1);
   else
      printf("NOT found the number %d", x);
}
```

Result of program when searched for a number in the array

```
ENTER THE NUMBER TO SEARCH
60
found the number 60 in position 6
```

Result of program when searched for a number NOT in the array

```
ENTER THE NUMBER TO SEARCH
25
NOT found the number 25
```

NOTES

Try to understand how the program functions. It implements the algorithm truthfully.

Check Your Progress

1. Define array.
2. What does a variable declaration do?
3. What are dynamic arrays?

6.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. An array is one of the user defined of data types. An array can hold a number of data of the same type. In a program we can declare arrays of integers, arrays of characters and arrays of floating point numbers, etc. depending on the need.
2. Variable declaration allots memory space for the variable. If we declare an array variable of type integer and dimension 40, then the computer will allot a memory size of 40 words for the variable contiguously.
3. A variable length array/dynamic array is that whose length or size is defined at execution time.

6.4 SUMMARY

- An array is one of the user defined of data types. An array can hold a number of data of the same type. In a program we can declare arrays of integers, arrays of characters and arrays of floating point numbers, etc. depending on the need.
- We can use an index with the name of the array to indicate the elements.
- An array is also variable and hence must be declared like any other variable. The naming convention is the same as in the case of other variables. The array name cannot be a reserved word and must be unique in the program.
- Variable declaration allots memory space for the variable. If we declare an array variable of type integer and dimension 40, then the computer will allot a memory size of 40 words for the variable contiguously.
- If the array elements are known beforehand, they can be declared right at the beginning.

NOTES

- Multi-dimensional arrays operate on the same principle as single dimensional arrays.
- A variable length array is that whose length or size is defined at execution time.

6.5 KEY WORDS

- **Arrays:** It is the fixed-size sequence of elements of the same data type.
- **Base Address:** It is the memory location, where the first element of an array is stored.

6.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Write a short note on single dimensional arrays.
2. Write in brief about multi-dimensional arrays.

Long Answer Questions

1. Write a C program to add two matrices.
2. Write a C program to find the smallest and largest values in an array.
3. Write a C program to check whether the row and column of matrix1 is equal to the row and column of matrix2. Multiply both the matrices and store the result in a matrix3.

6.7 FURTHER READINGS

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UNIT 7 STRINGS

NOTES

Structure

7.0 INTRODUCTION

We know that arrays are user-defined data types containing same data type such as integers or real numbers. We also discussed one-dimensional and multi-dimensional arrays. We know how to address each element. In C language, string is a special type of array. When a data item, constant or variable consists of array of characters, such arrays are known as strings. We will study more operations using strings in this unit.

7.1 OBJECTIVES

After going through this unit, you will be able to:

- Define string
- Discuss the use of `scanf` and `printf` with strings
- Understand how to read and write strings using `gets` and `puts`
- Explain the library functions for string handling

7.2 BASIC CONCEPT OF STRINGS

String—An Array of Characters

As we know *char* is a basic data type. A string is formed using an array of the basic data type *char*. We can define a string variable as well as string literal. String literals are words surrounded by double quotation marks. In reality, both of these string types are collections of characters stored contiguously, i.e., next to each other in the memory. The only difference is that we cannot modify string literals,

NOTES

whereas we can modify string variables. We can define a single character by enclosing it within single quotes as given below.

char ch = 's';

The above declares a *ch* of type *char* and initializes with a character constant s.

A *string* is an array of characters, which means that it may contain zero to many characters. A *string* is enclosed within double quotes.

For instance,

```
char st[1] = "s" ;
```

The variable *st* is a string since it is of type array of characters. It is initialized with constant *s*. When we initialize a string variable as above a NULL character will be appended to the end of the *string* automatically by the system.

The following declaration and initialization create a *string* consisting of the word *'Seven'*. To hold the *null* character at the end of the array, the size of the character array containing the string is one more than the number of characters in the word *'Seven'*.

```
char str1[6] = {'S', 'e', 'v', 'e', 'n', '\0'};
```

We can write the same easily as given below:

```
char str1[ ] = "Seven";
```

Following is the memory presentation of above defined string in C:

S	e	v	e	n	\0

Actually, we do not place the *null* character at the end of a string constant. The C compiler automatically places the '\0' at the end of the string when it initializes the array. Note that the ASCII value of NULL, i.e., '\0' is zero, whereas the ASCII value of number zero is 48.

7.2.1 Use of *scanf()* and *printf()* with Strings

One can use *scanf()* to receive strings from the screen. The code for using *scanf* for reading a name is given below:

```
char name [25];
scanf (" %s ", str);
```

Strings can be declared as an array of characters as shown above. In the *scanf* function when we get the array of characters as a string, it is enough to indicate the name of the array without a subscript. In this case the identifier or the name of the string is *str,* When we get a string, there is no need for writing '&' before *str* in this case in the *scanf* argument list. We can indicate the name of the string variable itself. Let us now write a program to read a *string* with *scanf*() and write with *printf*().

The program is given below:

Example 7.1

```
/* Reading and writing with formatted I/O functions*/
#include<stdio.h>
int main ()
{
char str [10];
printf ("Enter your name\n");
scanf ("%s", str);
printf ("You Entered: %s\n");
}
```

NOTES

Look at the program. We are declaring a *string str* as a character array of size 10. Look at the way we receive the array. We do not prefix ampersand (&) to the variable name *str* when we use the *scanf* function. We do not even suffix it with square brackets. Then, we print the contents of variable *str*. The format specifier in both the cases is %s. Look at the result of the program.

Result of Example 7.1

```
Enter your name
Rama Krishnan
You Entered: Rama
```

We typed 'Rama Krishnan'. But we got 'Rama' since the white space following the first word was considered to be end of character array. Hence, the computer stopped reading thereafter. This is because we used a formatted input function, namely *scanf* ().

It is to be noted carefully that we cannot exceed the dimension of the character array which is 10 in this case. Also, it cannot receive a multi-word string as the above example demonstrated.

7.2.2 Reading and Writing Strings: *gets* and *puts*

Strings may contain blanks in between. If we use a *scanf()* function to get the string with a space in between such as "Rama Krishnan", Krishnan will not be taken note of since space is an indicator of the end of entry of the input as indicated by the result of the previous example. But *gets* will take all that is entered till the enter key is pressed. Therefore, after entering the full name, the *enter* key can be pressed. Thus, using *gets* is a better way for strings. We can get a string in a much simpler way using *gets ()*. The syntax for *gets (*name*)*;

Similarly, *puts ()* can be used for printing a variable or a constant as given below:

puts (name);

puts ("Enter the word");

However, there is a limitation. *printf* can be used to print more than one variable and *scanf* to get more than one variable at a time, in a single statement. However, *puts* can output only one variable and *gets* can input only one variable in one statement. In order to input or output more than one variable, separate

NOTES

statements have to be written for each variable. As we know that *gets* and *puts* are unformatted I/O functions, there are no format specifications associated with them.

The example below gives the modified version of the above program.

Example 7.2

```
/* Reading and writing with unformatted I/O functions*/
#include<stdio.h>
int main ()
{
char str [10];
printf ("Enter your name\n");
gets (str);
printf ("You Entered :");
puts (str);
}
```

Look at the program. We have declared str as a one-dimensional character array. We read the string as shown below:

```
gets (str);
```

No format needs to be specified. Writing also is similar. The argument to *puts* () as well as *gets* () are *str* of type *string*. Look at the result of the program.

Result of Example 7.2

```
Enter your name
Rama Krishnan
You Entered:Rama Krishnan
```

The entire *string* has been received although there is white space in between. Thus, *gets*() is more suitable for handling strings. But, if we have to receive two strings, we need to call *gets*() twice. Though any number of strings can be received with one *scanf*() statement, it will treat white space as a *string* terminator as in Example 7.1. Similarly, *puts*() can display only one string at a time. Whereas *printf*() can print any number of strings with one statement.

String COPY

Let us write a program to copy one string to another.

Example 7.3

```
/*String copy*/
#include<stdio.h>
int main()
{
char str1[10], str2[10];
int i;
printf("Enter a string\n");
gets (str1);
for(i=0; i<10; i++)
str2[i]=str1[i];
printf("you Entered:\n");
puts(str1);
```

```
printf("copied string is:\n");
puts(str2);
}
```

NOTES

Let us analyze the program. Two strings *str1* and *str2* are declared with size 10. Then we get *str1*. In the *for* loop, we assign *str1* to *str2,* one character at a time. Finally, we print both the strings.

The result of the program is given below:

Result of Example 7.3

```
Enter a string
Vinayagar
you Entered:
Vinayagar
copied string is:
Vinayagar
```

We have written a program for copying one string to another. But a library function *strcpy*() is available for this purpose. Let us write a program for copying a string to another using the library function. The program is given below:

Example 7.4

```
/*String copy using library function*/
#include<stdio.h>
#include<string.h>
int main()
{
char str1[]="Subramaniar", str2[11];
strcpy(str2,str1);
printf("you Entered:\n");
puts(str1);
printf("copied string is:\n");
puts(str2);
}
```

Look at the declaration statement. We have declared and initialized *str1* and declared *str2* in one statement. There is no need to give the dimension when we initialize the array as given in the program. The compiler will count the number of elements and add the dimension by itself. Look at the string copy statement, reproduced below:

```
strcpy (str2, str1) ;
```

Contents of the second named string will be copied to first named string. *strcpy()* is a library function and it receives two string variables, the first one is the destination string and the last one the source string. Look at the result of execution of the program.

Result of Example 7.4

```
you Entered:
Subramaniar
copied string is:
Subramaniar
```

NOTES

The program works correctly. Thus, we can use the library function easily without writing a program for copying strings.

The library function is part of header file<string.h>. Therefore, some compilers may require us to include <string.h> in the program for using the function.

Finding String Length

Many times we may need to find the length of a given string. Let us now write a program to find the length of a string.

Example 7.5

```
/*Finding length of a string*/
#include<stdio.h>
int main()
{
char str1[]="Shri Rama Jeyam";
int length;
for(length=0; str1[length]!='\0'; length++);
printf("you Entered: ");
puts(str1);
printf("\nits length=% d ", length);
}
```

Look at the program. Look at the following statement carefully.

```
for(length=0; str1[length]!='\0'; length++);
```

The length of the string is computed in this statement only. In the first iteration of the *for* statement, str1 [0] will be compared with NULL ('/0'). Since it is not NULL, length will be incremented to 1. This continues till the last character of the string is compared. After that, we would have reached the end of the string or NULL. Hence, execution of the *for* loop will be terminated. The variable length will thus contain the actual length of the string. It is then printed. Thus, the program works correctly as the result below indicates.

Result of Example 7.5

```
you Entered: Shri Rama Jeyam
its length= 15
```

Even for finding the length of the string there is a library function called *strlen()*. Let us use it and modify the above program. The modified program is given below:

Example 7.6

```
/*String length using library function strlen()*/
#include<stdio.h>
#include<string.h>
int main()
{
char str1[]="Shri Rama Jeyam";
printf("you Entered: ");
puts(str1);
printf("\nits length=%d", strlen(str1));
}
```

Look at the program. We find the length and print it in the last statement reproduced below:

```
printf("\nits length=%d", strlen(str1));
```

When the program execution reaches the line, the cursor will go to the beginning of the next line because of the appearance of \n. Then the text "its length = " will be printed. Then, it will look for an integer specified outside the quote, to print because of the appearance of %d. Here the integer will come out of executing the library function *strlen(str1)*. Thus, we get identical result as given below.

NOTES

Result of Example 7.6

```
you Entered: Shri Rama Jeyam

its length=15
```

From the above examples, it will be clear that the use of library functions conserves the effort and also shortens the program. We have used a few library functions, which facilitate string manipulation.

7.2.3 Library Functions for String Handling

There are a number of library functions to handle strings. A list of such functions available for string manipulation is given in Table 7.1.

Table 7.1 *String Library Functions*

Function name	**Application**
strrev()	Reverses a string
strlen()	Finds length of a given string
strcat()	String concatenation; appends one string at the end of another
strncat()	Appends first *n* characters of one string at the end of another
strcmp()	Compares two strings
strncmp()	Compares first *n* characters of two strings
strnicmp()	Compares first *n* characters of two strings without regard to case
strmcpi()	Compares two strings without regard to case
strlwr()	Converts the given string to lower case
strupr()	Converts the given string to upper case
strcpy()	Copies a string to another
strncpy()	Copies first *n* characters of one string to another
strdup()	Duplicates a string
strchr()	Finds the first occurrence of a given character in a string
strrchr()	Finds the last occurrence of a given character in a string
strstr()	Finds the first occurrence of a given string in another string
strset()	Sets all characters of a string to a given character
strnset()	Sets first *n* characters of a string to a given character

NOTES

If these are to be used, <*string.h*> should be included before the main function. Some examples of the uses of the above library functions are discussed below:

strlen (CS) — returns the length of string CS.

char * *strcpy* (s, ct) — copies string ct to string s, including NULL and return s.

char * *strcat* (s, ct) — concatenates string ct to end of string s; return s.

int *strcmp* (cs, ct) — compares string cs to string ct; returns < 0 if cs < ct, 0 if cs = = ct, or > 0 if cs > ct.

char * strchr (cs, c) — returns the pointer to the first occurrence of c in cs or NULL if not present.

7.2.4 Two-dimensional Character Arrays

In the above examples we created strings, which are essentially one-dimensional arrays of characters. We can create an array of strings. This will be a two-dimensional array of characters. For instance,

char name[5][10];

declares a two-dimensional array of characters. This can be used to deal with five strings of size 10 each.

Let us now write a program as below to read five names and display them.

Example 7.7

```
/*Two Dimensional array*/
#include<stdio.h>
int main()
{
int i;
char name[5][10];
/*Receiving strings*/
for (i=0; i<5; i++)
   {
   printf("Enter name[%d]: \n", i+1);
        scanf("%s", name[i]);
      }

/*displaying strings*/
for (i=0; i<5; i++)
   {
   printf("name[%d]: %s\n", i+1, name[i]);
      }
      }
```

Look at the program. We declare a two-dimensional character array, called name[5][10].

Then we receive the names. Look at the ease with which we receive it.

```
scanf("%s", name[i]);
```

We do not even give the second dimension. This is possible only in the case of strings. Recall that when *str* was a one-dimensional array, we read it in the *scanf*()

function by simply specifying *str* and not its address. But since we are specifying *scanf*(), we cannot give white spaces in between the names.

As we know, the elements of an array will be stored contiguously. In name[i], we are specifying the address of 0^{th} location of the i^{th} row. The array received will be stored thereon continuously. In the next section, we print each string the same way by specifying the first subscript alone. The result of the program is given below:

Result of Example 7.7

```
Enter name[1]:
Ganapathy
Enter name[2]:
Subramani
Enter name[3]:
Narayanan
Enter name[4]:
Joseph
Enter name[5]:
Mohammed
name[1]: Ganapathy
name[2]: Subramani
name[3]: Narayanan
name[4]: Joseph
name[5]: Mohammed
```

The result demonstrates the use of two-dimensional character arrays.

Be cautious not to exceed the size of the array. Although we did not enter 10 characters, the computer recognized the end of the string due to Null character generated by the pressing of Enter key each time.

We will take another interesting example. If a word is a palindrome, we will get the same word when we read the characters from the right to the left as well, as already discussed.

Examples are : nun

malayalam

These words when read from either side give the same name. We will write a program to check whether a word is a palindrome or not.

This program uses a library function called *strlen( )*. The function *strlen (*str*)* returns the size or length of the given string. Now let us look at the program.

Example 7.8

```
/* to check whether a string is palindrome*/
#include <stdio.h>
#include <string.h>
#define FALSE 0
int main()
{
   int flag=1;
   int right, left, n;
```

NOTES

```
    char w[50]; /* maximum width of string 50*/
    puts("Enter string to be checked for palindrome");
    gets(w);
    n=strlen(w)-1;
    for ((left=0, right=n); left<=n/2; ++left, --right)
    {
       if (w[left]!=w[right])
       {
          flag=FALSE;
          break;
       }
    }
    if (flag)
    {
       puts(w);
       puts("is a palindrome");
    }
    else
       printf("%s is NOT a palidrome");
}
```

Result of the program

```
Enter string to be checked for palindrome
palap
palap
is a palindrome
```

If *strlen* or *gets* or *puts* are used in a program we have to include <*string.h*> before the *int main()*.

Now let us analyze the functioning of the above example.

We are defining a symbolic constant *FALSE* as 0.

We initialize flag as 1. We define a string *w* as an array of 50 characters.

gets(w); returns the word typed and stores it from location &w [0]

Let us assume that we had typed "nun" and go on to analyze what happens in the program.

strlen (w) will return the length of the word typed. In this case *strlen* (w) = 3.

We subtract this by 1 to get the subscript of the extreme right character. The subscript of the extreme left character is obviously 0.

We are initializing the *for* loop with the following:

left = 0 right = n = 2

flag = 1

We check whether left < = n/2 and

since it is so, we check whether w [0]!=w [2].

The condition is false since w[0] = w[2] = 'n'.

Therefore, the group of statements following *if* is skipped: flag remains 1.

Step 2

Now left is incremented to 1 and right is decremented to 1.

Again w[1] ! = w[1] is false, *flag* remains 1

Therefore, control returns to the *for* statement.

Now, left = 2 right = 0

Since left is greater than n/2, the control comes out of the *for* loop. Now, the statement *if* (*flag*) will be executed.

NOTES

It will check whether *flag* is true. In this case, *flag* is still true.

Therefore, the computer prints that the word is palindrome. But, had the word not been a palindrome what would happen?

To check this, let us assume that we typed "book" and see what happens in the program.

To start with, left = 0 right = 3

w [left] ! = w[right]

Therefore, the statements within the { } will be executed, *flag* will be set to false and then the *break* statement will be executed.

The statement *break* causes immediate exit from the loop. Now *flag* is false. Therefore, the *else* statement is executed to say that the word is NOT a palindrome.

Now let us write a program to reverse a given string.

Example 7.9

```
/* to  reverse a string*/
#include <stdio.h>
#include <string.h>
int main()
{
   char w1[]="abcdefghij";
   void rev(char w1[]);
   rev(w1);
}
/*function definition*/
void rev(char w2[])
{
   char w3[]="          "; /*array w3 initialized with 10
blanks*/
   int i=0, j=0;
   for (i= 9, j=0; i>=0, j<=9; i—, j++)
   w3[j]=w2[i];
   printf("original string:\t");
   puts(w2);/*original string printed*/
   printf("Reversed string:\t");
   puts(w3);/*reversed string printed*/
}
```

Result of program

```
original string:        abcdefghij
Reversed string:        jihgfedcba
```

The purpose of the program is to reverse a string. A string is declared as an array of characters and initialized, w1[]="abcdefghij"; and a NULL character will be inserted at the end of the string by the compiler. The programmer need not worry. A function called *rev* is then declared as given below:

```
void rev(char w1[]);
```

The function returns nothing. The function can be called in a simple manner as given below:

```
rev(w1);
```

NOTES

In the called function, a character array w3 is initialized with 10 blanks. Initialization is important to avoid surprises. The *for* loop reverses the string by copying w2 in the reverse order to w3; W2[0] is copied to w3[9], w2[1] is copied to w3[8] and so on. Then, w2 and w3 are printed one after other.

See how each character is accessed in the *rev* function. Note also the direct initialization of string w1 as an array of characters, in the main function.

Check Your Progress

1. Write the drawback of gets and puts functions.
2. What does `strlen` () function provides?

7.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. `puts` can output only one variable and `gets` can input only one variable in one statement.
2. `Strlen ()` function provides the length of a given string.

7.4 SUMMARY

- A string is formed using an array of the basic data type char. We can define a string variable as well as string literal. String literals are words surrounded by double quotation marks.
- A string is an array of characters, which means that it may contain zero to many characters.
- One can use `scanf` () to receive strings from the screen.
- Strings may contain blanks in between. If we use a `scanf` () function to get the string with a space in between such as "Rama Krishnan", Krishnan will not be taken note of since space is an indicator of the end of entry of the input.
- `printf` can be used to print more than one variable and `scanf` to get more than one variable at a time, in a single statement. However, puts can output only one variable and gets can input only one variable in one statement.

7.5 KEY WORDS

- **`gets:`** This function is used to scan or read a line of text from a standard input (stdin) device, and store it in the string variable.
- **`Strrev ():`** It is a function that reverse the given string.

NOTES

7.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Define string.
2. Discuss how you will declare a string array.
3. Write a program to illustrate the use of `gets` and `puts`.

Long Answer Questions

1. Write a program to compare two strings.
2. Write a program to concatenate the two strings.
3. Write program to convert the given string to lower case.

7.7 FURTHER READINGS

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BLOCK - III

USER DEFINED FUNCTIONS

NOTES

UNIT 8 FUNCTIONS BASICS

Structure

8.0 INTRODUCTION

In this unit, you will learn about user-defined functions, and about function declaration, function call and how to define a function. A function, when declared in a program, is a function prototype which may be declared at the beginning of a main program. A function, on execution, is supposed to do something: either return a value as integer, character or float; or perform some operation. A function consists of two parts, declarator and declaration. A function declaration has the format in which the type of data returned, name of the function and arguments on which the function is to operate, are mentioned. Arguments declared as part of the function prototype are called formal parameters, which are enclosed in a pair of parentheses. A function may not contain any parameter, in which case an empty pair of parentheses should follow the name of the function. A function may not return a value, in which case `void` is written as the return data type.

A function may be called directly or indirectly by another function. For this, there should be one-to-one correspondence between formal arguments declared and actual arguments sent and should be of the same data type. A function declarator is a replica of a function declaration; the difference lies in the way they are written inside a program body. A declaration in a calling function will end with a semicolon and a declarator in a called function will not end with a semicolon.

NOTES

8.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand user-defined functions
- Call a function
- Declare a function
- Define a function
- Explain formal and actual parameters
- Use recursion in writing more compact programs

8.2 GENERAL FORMS OF FUNCTIONS

A function in a program consists of three characteristics:

(a) Function prototype

(b) Function call

(c) Function definition

8.2.1 Function Prototype

A function prototype is called a function declaration. A function may be declared at the beginning of the main function. Function declaration is of the following type:

```
return data - type  function name  (formal argument 1,
argument 2, ..... );
```

A function after execution may return a value to the function, which called it. It may not return a value at all but may perform some operations instead. It may return an integer, character, or float. If it returns a float, we may declare the function as

```
float f1(float arg 1, int arg 2);
```

If it does not return any value we may write the above as

```
void fun2(float arg1, int arg2);   /*void means nothing*.
```

If it returns a character, we may write

```
char fun3(float arg1, int arg2);
```

If no arguments are passed into a function, an empty pair of parentheses must follow the function name. For example,

```
char fun4( );
```

NOTES

The arguments declared as part of the prototype are also known as formal parameters. The formal arguments indicate the type of data to be transferred from the calling function.

8.2.2 Function Call – Passing Arguments to a Function

We may call a function either directly or indirectly. When we call the function, we pass the actual arguments or values. Calling a function is also known as function reference.

There must be a one-to-one correspondence between formal arguments declared and the actual arguments sent. They should be of the same data type and in the same order. For example,

```
sum=f1 (20.5, 10); fun4( );
```

8.2.3 Function Definition

Function definition can be written anywhere in the file with a proper declarator, followed by the declaration of local variables and statements. **Function definition** consists of two parts, namely function declarator or heading and function declarations. The function heading is similar to function declaration but will not terminate with a semicolon.

The use of functions will be demonstrated with simple programs in this unit.

Suppose you wish to get two integers. Pass them to a function `add`. `Add` them in the `add` function. Return the value to the main function and print it. The algorithm for solving the problem will be as follows:

Main Function

Step 1: Define function add
Step 2: Get 2 integers
Step 3: Call add and pass the 2 values
Step 4: Get the sum
Step 5: Print the value

function `add`

Step 1: Get the value
Step 2: Add them
Step 3: Return the value to main

Thus, you have divided the problem. The program is as follows:

```
/*Example 8.1*
  /* use of function*/
  #include <stdio.h>
```

NOTES

```
int main()
{
    int a=0, b=0, sum=0;
    int add(int a, int b); /*function declaration*/
    printf("enter 2 integers\n");
    scanf("%d%d", &a, &b);
    sum =add(a, b);   /*function call*/
    printf("sum of %d and %d =%d", a, b, sum);
}
/*function definition*/
int add (int c, int d)   /*function declarator*/
{
    int e;
    e= c+d;
    return e;
}
```

Result of the program

```
enter 2 integers
6667  4445
sum of 6667 and 4445 =11112
```

The explanation as to how the program works is given below:

On the fifth statement (seventh line), the declaration of the function `add` is given. Note that the function will return an integer. Hence, the return type is defined as `int`. The formal arguments are defined as `int a` and `int b`. The function name is `add`. You cannot use a variable without declaring it, as also a function without telling the compiler about it. Note also that function declaration ends with a semicolon, similar to the declaration of any other variable. Function declaration should appear at the beginning of the calling function. It hints to the compiler that the function is going to call the function `add`, later in the program. If the calling function is not going to pass any arguments, then empty parentheses are to be written after the function name. The parentheses must be present in the function declaration. This happens when the function is called to perform an operation without passing arguments. In this case, if `a` and `b` are part of the called function `(add)` itself, then we need not pass any parameters. In such a case, the function declaration will be as follows assuming that the called function returns an integer:

```
int add  ( ) ;
```

In Example 8.1, you get the values of a and b. After that you call the function `add` and assign the value returned by the function to an already defined `int` variable `sum` as follows:

```
sum  =  add ( a , b );
```

Note that `add(a, b)` is the function call or function reference. Here, the return type is not to be given. The type of arguments are also not to be given. It is a simple statement without all the elements of the function declaration. However, the function name and the names of the arguments passed, if any, should be present in the function call. When the program sees a function reference or function call, it looks for and calls the function and transfers the arguments.

NOTES

The function definition consists of two parts, i.e., the function declarator and function declarations.

The **function declarator** is a replica of the function declaration. The only difference is that while the declaration in the calling function will end with a semicolon, the declarator in the called function will not end with a semicolon. As in `main()`, the entire functions body will be enclosed within braces. The whole function can be assumed to be one program statement. This means that all the statements within the body will be executed one after another before the program execution returns to the place in the main function from where it was called.

The important points to be noted are:

(a) The declarator must agree totally with the declaration in the called function, i.e., the return data type, the function name, the argument type should all appear in the same order. The declarator will not end with a semicolon.

(b) You can also give the same name as in the calling function—in declaration statement or function call—or different names to the arguments in the function declarator. Here, we have given the names `c` and `d`. What is important; however, is that the type of arguments should appear, as it is in the declaration in the calling program. They must also appear in the same order.

(c) At the time of execution, when the function encounters the closing brace `}`, it returns control to the calling program and returns to the same place at which the function was called.

In this program, you have a specific statement `return (e)` before the closing brace. Therefore, the program will go back to the main function with the value of `e`. This value will be substituted as

```
sum = (returned value)
```

Therefore, `sum` gets the value which is printed in the next statement. This is how the function works.

Assume now that the program gets `a` and `b` values, gets their `sum1`, gets `c` and `d` and gets their `sum2` and then both the sums are passed to the function to get their total. The program for doing this is as follows:

```
/*Example 8.2*
  /* A function called many times */
```

NOTES

```
#include <stdio.h>
int main()
{
    float a, b, c, d, sum1, sum2, sum3;
    float add(float a, float b); /*function declaration*/
    printf("enter 2 float numbers\n");
    scanf("%f%f", &a, &b);
    sum1 =add(a, b);   /*function call*/
    printf("enter 2 more float numbers\n");
    scanf("%f%f", &c, &d);
    sum2 =add(c, d);   /*function call*/
    sum3 =add(sum1, sum2);   /*function call*/
    printf("sum of %f and %f =%f\n", a, b, sum1);
    printf("sum of %f and %f =%f\n", c, d, sum2);
    printf("sum of %f and %f =%f\n", sum1,sum2, sum3);
}
/*function definition*/
float add (float c, float d)   /*function declarator*/
{
    float e;
    e= c+d;
    return e;
}
```

Result of the program

```
enter 2 float numbers
1.5    3.7
enter 2 more float numbers
5.6    8.9
sum of 1.500000 and 3.700000 =5.200000
sum of 5.600000 and 8.900000 =14.500000
sum of 5.200000 and 14.500000 =19.70000
```

You have defined `sum1, sum2` and `sum3` as `float` variables.

You are calling the function `add` three times with the following assignment statements:

```
sum1 = add( a, b );
sum2 = add( c, d);
sum3 = add( sum1 , sum2 );
```

Thus, the program goes back and forth between `main()` and `add` as given below:

NOTES

```
int main()
add (a, b)
int main()
add (c, d)
int main()
add (sum 1, sum 2)
int main()
```

Had you not used the function `add`, you would have to write statements pertaining to `add` 3 times in the main program. Such a program would be large and difficult to read. In this method, you have to code for `add` only once and hence, the program size is small. This is one of the reasons for the usage of functions.

In Example 8.2, you could add another function call by `add (10.005, 3.1125)`; This statement will also work perfectly. After the function is executed, the sum will be returned to the `main()` function. Therefore, both variables and constants can be passed to a function by making use of the same function declaration.

You have seen a program, which calls a function thrice. You will now discuss a problem, which calls three functions.

Problem

The user gives a four-digit number. If the number is odd, then the number has to be reversed. If it is even, then the number is to be doubled. If it is evenly divisible by three, then the digits are to be added. Now, let us write the algorithm for solving the problem.

Step 1: Get the number.

Step 2: `If` the number is odd call, the `reverse` function.

Step 3: `Else` multiply the number by 2 and hence call `multiply`.

Step 4: `If` the number is evenly divisible by 3, call `add-digits`.

These are the steps. The first one, namely writing a function to multiply by 2 is simple. We will look at the other two steps now.

Reverse

The following steps show the reversing of number.

```
Step 1:  reverse = 0
step 2:  while ( number > 0 )
         reverse = reverse * 10 +  (number % 10 )
         number = number/10
Step 3:  return (reverse).
```

add–digits function

```
Step 1:  sum = 0
Step 2:  while number > 0
```

```
            sum = sum + (number % 10)
            number = number / 10
    Step 3: return (sum)
```

Let us see how the above algorithm add–digits works.

Let us give 4321 as the number.

```
    Step 1: sum = 0
    Step 2: Iteration 1
            sum = 0 +  modulus of  (4321/10)
                = 0 + 1 = 1
          number = 4321/10 = 432
       Iteration 2
            sum = 1 + modulus of (432/10)
                =  1 + 2
```

After 4 iterations:

```
    sum =1+2+3+4
Step 3: sum is returned.
```

The program is given below:

```
/*Example 8.3*/
  /*program to demonstrate calling
  multiple functions*/
  #include<stdio.h>
  int main()
  {
      long nummul=0;
      long num=0, rev=0, add_digit=0;
         /*good practice to inialize all variables*/
      long reverse(long num);
      long mult(long num);
      int sum_digit(long num);
      printf("enter unsigned number\n");
      scanf("%lu", &num);
      if (num%2)  /*remainder 1*/
      {
         rev = reverse(num);
         printf("number is odd\n");
         printf("number entered=%lu\n number reversed=%lu\n",
  num, rev);
      }
      else
      {
```

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```
        nummul=mult(num);
        printf("number is even\n");
        printf("number=%lu\n its multiple=%lu\n", num,
nummul);
    }
    if (num%3 ==0)
    {
        add_digit= sum_digit(num);
        printf("number evenly divisible by 3\n");
        printf("sum of digits =%lu", add_digit);
    }
}
long reverse(long n)
{
    long r=0;
    while (n>0)
    {
        r=r*10+(n%10);
        n=n/10;
    }
    return r;
}
long mult(long p)
{
    long sq;
    sq=2*p;
    return sq;
}
int sum_digit(long num)
{
    long sum=0;
    while (num >0)
    {
        sum=sum+(num%10);
        num=num/10;
    }
    return sum;
}
```

Result of the program

```
enter unsigned number
4321
```

```
number is odd
number entered=4321
number reversed=1234
```

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Look at the program. After getting the number from the user, it evaluates if the remainder of `(num/2) = true`; i.e., if the remainder is 1, then it is true. If the `remainder = 1`, then the number is odd and hence the reverse function is called. The returned value is assigned to `rev` and printed.

If the number is even, the number is doubled. Since the doubled value may exceed the maximum of the unsigned integer, we have declared it as a `long` integer.

Next, we check if the number is evenly divisible by 3.

If it is so, then we add the digits. Thus, the main function of Example 8.3 calls three functions for carrying out specific tasks. All the three functions are supplied with the same arguments but return different values.

8.2.4 Function Arguments

You know now that an argument is a parameter or value. It could be of any of the valid types, such as all forms of integers or a float or char. You come across two types of arguments when you deal with functions:

```
formal arguments
actual arguments
```

Formal arguments are defined in the function declaration in the calling function. What is actual argument? Data, which is passed from the calling function to the called function, is called the actual argument. The actual arguments are passed to the called function through a function call.

Each actual argument supplied by the calling function should correspond to the formal arguments in the same order. The new ANSI standard permits declaration of the data types within the function declaration to be followed by the argument name. You have used only this type of declaration as it will help students follow the C++ program easily. This helps in understanding one to one correspondence between the actual arguments supplied and those received in the function and facilitates the compiler to verify that one to one correspondence exists and that the right number of parameters have been passed. It may be noted that formal arguments cannot be used for any other purposes. They only give a prototype for the function. Thus, the names of the formal arguments are dummy and will not be recognized elsewhere, even in the functions in which they are defined.

Although, the types of variables in the function declaration, also known as prototype and function call are to be the same, the names need not be the same. You have already used this concept in Example 8.2 after defining `float a` and `float b` in the functions prototype, you first called `add (a, b), add (c, d)` and then `add (sum1, sum2)`. Thus, the formal arguments defined in the prototype and the actual arguments were not the same in two of the above cases.

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When the actual arguments are passed to a function, the function notes the order in which they are received and appropriately stores them in different locations. You must note that even if you use `a` and `b` in the `add` function, they will be stored in different locations. They will have no relationship with `a` and `b` of the main function. Therefore, even if `a` and `b` are assigned different values in the called function, the corresponding values in the calling function would not have changed. You will verify this point in the program in the next section.

8.2.5 Scope: Rules for Functions

The scope of the variable is local to the function, unless it is a global variable. For instance,

```
int function1(int I )
{ int j=100;
   double  function2 (int j) ;
   function2 (j) ;
}
double function2 (int p)
{   double m;
   return m;
}
```

The variable `j` in `function1` is not known to `function2`. You pass it to `function2` through the argument `j`. This will be assigned as equal to `int p`. Similarly, `m` in `function2` is not known to `function1`. It can be made known to `function1` through the return statement. This makes the scope rules of variables in function quite clear. The scope of variables is local to the function where defined. However, global variables are accessible by all the functions in the program if they are defined above all functions.

```
/*Example 8.4*
  /* To demonstrate that the scope of a
  variable is local to the function*/
  #include <stdio.h>
  int main()
  {
      float a=100.250, b=200.50;
      void change (float a, float b);
      change(a, b);
      printf("a= %f b= %f\n ", a, b);
      printf("these are the original values");
  }
```

```
/*function definition*/
void change (float a, float b)  /*function declarator*/
{
    a +=1000;
    b-=200.5;
}
```

Result of the program

```
a= 100.250000 b= 200.500000
these are the original values
```

We passed `a = 100.25` and `b = 200.5` to the function. In the function, you modified `a` as `1100.25` and `b` as `zero`. However, when you print `a` and `b` in the main function, you get the same old values. This confirms that variables are local to the function unless otherwise specified.

Notice; however, that in the calling function, the type declaration of formal parameters is symbolic and used only to indicate the format. You will notice, for example in Example 8.1, that the `int a` has been declared and assigned a value of 0. This has no relationship with `int a` in the function declaration. You could even omit the variable name and declare as `int add(int, int)`. It will still work. Here `a` and `b` have been given for better readability.

This is the reverse in the case of a called function. In the same program, `int c` and `int d` are explicitly defined in function `add`, in the declarator. The variables are used further in the function `add`. This is not the case with the variables in the declaration statement or prototype of the calling function, which will never be used further.

This method of invoking a function is called call by value, i.e., you call the functions with values as arguments.

8.2.6 Return Values

The return data type is declared in the function declaration in the `main()` function or the calling function and the declarator is indicated in the first line of the function definition. If no value is to be returned, the return data type `void` is specified. `Void` simply means NULL or nothing. Therefore, it does not fall in any other data types, such as `integer` or `float` or `char`.

The return value as you have seen is the result of computation in the called function. You return a value, which is stored in a data type in the called function. The return value means that the value, thus stored in the called function is assigned or copied to a variable in the `main()` or calling function. Therefore, to receive the result, a data type should have been declared and preferably initialized in the calling function.

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The return statement can be any of the following types:

```
return (sum) ;
return V1;
return  " true" ;
return ' Z ' ;
return 0;
return 4.0 + 3.0;
```

In some examples, you have returned variables whose values are known when they are returned and in other examples, you return constants. You can even return expressions. If the return statement is not present, it means the return data type is `void`.

You can also have multiple return statements in a function. However, for every call, only one of the return statements will be active and only one value will be returned.

8.2.7 Arrays and Functions

There is no restriction in passing any number of values to a function; the restriction is only in the return of values from a function. Therefore, arrays can be passed to a function without any difficulty, one element at a time, as follows:

```
#include <stdio.h>
int main()
{
    int a[]={1,2,3,4,5};
    int j;
    int func(int a);
    for (j=0; j<=4; j++)
       func (a[j]);
    ..........
}
int func(int c)
{
    ......
}
```

Here, `func` has been declared as a function passing a single integer. Note here that the declaration or the prototype gives only the format of the parameters passed. The values are only indicative and are not actual values. They are the formal values. Therefore, the parameters declared inside the parentheses act only as a checklist. They cannot be used in the main function elsewhere without actually declaring them on top of the function. But, for this rule, there would have been a conflict between `a[]` which is an array and `a` which is a simple variable. Here, no conflict arises because `a` is not recognized in the main function. It is only a checklist

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to see that whenever the function calls `func`, an integer has to be passed. If we try to pass a `float`, the compiler will detect an error. This is not so in the case of variables defined in the function declarator above the functions body, as they are recognized as actual names. In this case, `int c` is declared as a variable in `func`. The initial value will be the same as passed by the calling function. Thus, since `a` is used in the function declaration, only one integer can be passed to the function `func`. Actually, the entire array can be passed to a function irrespective of its size, by suitable declaration, as the following example indicates.

```
/*Example 8.5*/
  /* To find the greatest number in an array*/
  #include <stdio.h>
  int main()
  {
      int array[]= {8, 45, 5, 911, 2};
      int size=5, max;
      int fung(int array[], int size);
      max=fung(array, size);
      printf("%d\n", max);
  }
  int fung(int a1[], int size)
  {
      int i, j, maxp=0;
      for (j=0; j<size; j++)
      {
         if (a1[j] > maxp)
         {
            maxp=a1[j];
         }
      }
      return maxp;
  }
```

Result of the program

```
911
```

The objective of Example 8.5 is to find the greatest number in an array. In the program, an array called array is initialized with 5 values as given below:

`int array[]= {8, 45, 5, 911, 2};` size is declared as 5 and a function called `fung` has been declared. It will pass an array and an integer to the called function. The array size has been kept open and the called function will return an integer. The next statement calls `fung` and passes all elements of the array and an integer 5 equal to `size`. The function gets the actual values and `size=5`. The maximum value in the array is found in the `for` loop and stored in

maxp. The value maxp is returned to the main function and printed there. Thus, the function is called by value.

8.2.8 Call by Value

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In this section, you have been calling functions by passing values. For example, function calls in some of the above programs are as follows:

```
change(a, b);
rev = reverse(num);
```

The values passed to the function change are a & b which are known. Similarly, while calling function reverse, we pass num. This is called call by value. When you call functions by value, the called functions can return only one value.

8.2.9 Call by Reference

The call by reference method of parring agreements to a function copies the address of an argument into the formal parameter. So, it results into the modification in the values of actual parameters.

8.3 FORMAL AND ACTUAL PARAMETERS

Parameters are written in the function prototype and function header of the definition. They are local variables which are assigned values from the arguments when the function is called. When a function is called, the values (expressions) that are passed in the call are called the *arguments* or *actual parameters*. At the time of the function call each actual parameter is assigned to the corresponding formal parameter in the function definition. For value parameters (default) the value of the actual parameter is assigned to the formal parameter variable. For reference parameters, the *memory address* of the actual parameter is assigned to the formal parameter. By default, argument values are simply copied to the formal parameter variables at the time of the call. This type of parameter passing is called *pass-by-value*. It is the only kind of parameter passing used in C language. Thus, parameters define information that is passed to a function and are of the following types:

- *Actual parameters* —parameters that appear in function calls.
- *Formal parameters*—parameters that appear in function declarations.

A parameter cannot be both a formal and an actual parameter, but both formal parameters and actual parameters can be either value parameters or variable parameters. The following example shows how the actual parameters work with calc_consumer_bill function:

```
/*Program Example 8.6/
#include <stdio.h>
#include <stdlib.h>
int main (void);
```

```
int calc_consumer_bill (int, int, int);
int main()
{
  int bill;
  int a = 25;
  int b = 32;
  int c = 27;
  bill = calc_consumer_bill (a, b, c);
  printf("The total bill comes to %d\n", bill);
  exit (0);
}
int calc_consumer_bill (int consumer1, int consumer2,
int consumer3)
{
  int total;
  total = consumer1 + consumer2 + consumer3;
  return total;
}
```

In the function `main()` in this example `a`, `b`, and `c` are actual parameters in the function call `calc_consumer_bill`. On the other hand, the corresponding variables in `calc_consumer_bill`, namely `consumer1`, `consumer2` and `consumer3` are formal parameters because they appear in a function definition.

Formal parameters are always variables; this does not mean that they are always variable parameters. You can use numbers, expressions or function calls as actual parameters. Here are some examples of valid actual parameters in the function call `calc_consumer_bill`:

```
bill = calc_consumer_bill (25, 32, 27);
bill = calc_consumer_bill (50+60, 25*2, 100-75);
bill = calc_consumer_bill (a, b, (int) sqrt(25));
```

The last line in this example code will use `math.h` header file because `sqrt` is the square root function and returns `double value`, so it must be cast into an `int` to be passed to `cal_consumer_bill`.

8.4 RECURSIVE FUNCTION

8.4.1 Basic Concepts

The previous section dealt with the concept of a function calling another function, as well as multiple functions, being called by a number of functions. A function calling itself is called **recursion** and the function may call itself either directly or

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indirectly. This concept is difficult to understand unless explained through examples. Every program can be written without using recursion but the reverse is not true. Some problems; however, are suitable for recursion. For instance, the factorial problem can be solved using recursion as shown in program below:

```
/* Example 8.7*
   To find the factorial of a given number*/
   #include <stdio.h>
   int main()
   {
       int n;
       long int result;
       long int fact(int n);
       printf("Enter the number whose ");
       printf("factorial is to be found\n");
       scanf("%d", &n);
       result=fact(n);
       printf("result=%ld", result);
   }
   long int fact(int n)
   {
       if (n<1) return 0;
       else
          if (n==1) return 1;
          else
             return (n*fact(n-1));
   }
```

Result of the program

```
Enter the number whose factorial is to be found
10
result=3628800
```

Now, let us analyse how the program proceeds. You get an integer `n` from the keyboard. In order to find `factorial n`, you call `fact(n)`, where `fact` is the function for finding the factorial of number `n`. The recursion takes place in function `fact`. Assume that `n=1`. The main function calls `fact(1)`, which will be assigned to `result` in the main function after return from the function. In the function, since `n` is equal to 1, 1 is returned and printed in `main()`.

Next, assume you want to find out the factorial of say, 2 and `fact(2)` is called. In the function `fact`, since `n` is not equal to `1`, `n * fact(n-1)` is returned, i.e., `2 * fact (1)` is returned to `result. Result = 2 * fact(1)`. This intermediate result is stored somewhere and can be called stack. Stack is an array which stores values and gives the last element first. The writing

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into stack is popularly called push and getting information from stack is called pop. You have not defined any stack and therefore, you can assume that the system does this for you. After pushing the intermediate result into stack, the program calls `fact(1)`, which returns 1. Now, the intermediate result is popped and the value of `fact 1` is substituted to get the factorial of 2 as 2.

Now call factorial 5. You call `fact` and get back,

```
result = 5 * fact(4)                                    [1]
```

Now, `fact(4)` is called to `get 4 * fact(3.)` Substituting this in equation [1], we get

```
result = 5 * 4 * fact(3)
```

`fact(3)` again is called to get `3 * fact(2)` and so on till we get `fact(1)` which will be returned as 1. Therefore, we get `factorial 5` as `5 x 4 x 3 x 2 x 1`. Such repetitive calling of the same function is called recursion. The calls are recursive calls. The `result` and function `fact` has been declared to be of type `long` so as to take care of large numbers. If the `fact` function were not called repeatedly, the program size would have become very large. Thus, recursion keeps the program size small but understanding recursion is not easy. If the program can be visualized as recursive, it will result in compact code. Recursive functions can easily become infinite loops. Therefore, the functions should have a statement with `if` so that the program will definitely terminate. In the factorial program, assume for a moment that the first statement in fact function is absent. Then we have to end the program only when `n` becomes 1. What will happen, if by chance, `n` is entered as a negative number? The program will get into an endless loop. Therefore, to avoid such eventualities, you can either have a statement as follows:

```
If (n<1)      exit().
```

Or you could do this by the statement `if (n<1) return` 0, as has been done here.

This will ensure that if either 0 or a negative number is entered, you get the factorial as 0 and the program will terminate gracefully.

You should also note that recursive programs simulate the use of stack. You write to the stack and retrieve information from the stack. Writing to stack is called `push` and retrieving or reading or getting value from the stack is known as `pop`. The feature of stack is last in, first out and therefore, you get the value of the data entered last first, as illustrated in the following example.

You `push` or `pop` only through the top of the stack. Assume that you want to `push a, b & c`, one at a time. You `push 'a'`. It will be on top of the stack. When you push `b, a` will be pushed to the next lower location and `b` will occupy the top of the stack. Next, when you `push 'c'`, `'c'` will occupy the top of the stack, `'b'` one location before and `'a'` one location before `'b'`. Thus, you can push data till the stack becomes full. If you pop the stack now, it will eject `'c'`, then `'b'` and so on. Thus, you `pop` on a last-in-first-out basis.

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Reconsider the factorial program in which you were storing intermediate results in a stack-like manner and popping LIFO. Take the example of finding the factorial of 4. On the first call, you get `4 * fact(3)`. You push this into the stack and in the next call, you get `3 * fact(2)`. Again, you push the intermediate result to stack and evaluate `fact(2)` to `get 2 * fact(1)`. This is also put to stack. Now, you pass `fact 1` and `get fact(1)` as 1, after which you get the value of `fact(2)` by popping `fact(2)` as `2 * fact(1)`. The popping continues till the result is obtained. Such a conceptualization will help you to understand recursion easily.

8.4.2 Implementation of Euclid's gcd Algorithm

Euclid's `gcd` algorithm is quite suitable for recursion. The modified algorithm, which uses recursion, is as follows:

Algorithm using recursion

Main function

```
Step 1 Read two integers m and n
Step 2 Call function gcd (m, n)
Step 3 Print gcd
```

Function `gcd (m, n)`

```
Step 1 if (n==0) return m;
else
return (gcd(n, m%n));
Step 3 End
```

When two integers are received, the main function calls `gcd` function. In the `gcd` function, it is checked whether `n` equals zero. If so, `m` is the `gcd` if not, the function calls `gcd` again by changing the arguments as follows:

```
m=n
n=m%n
```

See the clarity in the above function.

You can easily observe that by using recursion, even the number of steps in the program has gone down. But, it requires a little skill to convert the program into a recursive function. The program implementing the above algorithm is as follows:

```
/*Example 8.8*
  Euclid's GCD*/
  #include<stdio.h>
  int main()
  {
  int m, n;
  int gcd(int m, int n);
```

```
printf("Enter 2 integers\n");
scanf("%d %d", &m,&n);
printf("GCD of %d and %d=%d", m, n, gcd(m,n));
}
int gcd(int m, int n)
{
if (n==0) return m;
else
return (gcd(n, m%n));
}
```

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The program was executed twice and the result of the program is as follows:

Result of the program

```
First Time
Enter 2 integers
12 256
GCD of 12 and 256=4
Second Time
Enter 2 integers
1225 625
GCD of 1225 and 625=25
```

You can even enter the first number to be lower than the second number as executed during the first time. The program works all right because in one iteration, the numbers get reversed namely the first number is larger than the second number after iteration. Thus, recursion is quite suitable for solving this problem.

Check Your Progress

1. What are formal parameters?
2. Where a function definition should be written in a program?
3. What does a function definition consist of?
4. What is recursion?

8.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Arguments declared as part of the function prototype is known as 'formal parameters'.
2. A function definition can be written anywhere in the file with a proper declarator, followed by the declaration of local variables and statements.
3. Function definition consists of function declarator and function declarations.

Function declaration is terminated by a semicolon but function declarators are not terminated with colon.

4. When a function calls itself, directly or indirectly, it is known as recursion.

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8.6 SUMMARY

- A function consists of two parts, declarator and declaration.
- A function declaration has the format in which the type of data returned, name of the function and arguments on which the function is to operate, are mentioned.
- Arguments declared as part of the function prototype are called formal parameters, which are enclosed in a pair of parentheses.
- A function prototype is called a function declaration. A function may be declared at the beginning of the main function.
- We may call a function either directly or indirectly. When we call the function, we pass the actual arguments or values. Calling a function is also known as function reference.
- The function declarator is a replica of the function declaration. The only difference is that while the declaration in the calling function will end with a semicolon, the declarator in the called function will not end with a semicolon.
- Formal arguments are defined in the function declaration in the calling function. Data which is passed from the calling function to the called function, is called the actual argument.
- A function calling itself is called **recursion** and the function may call itself either directly or indirectly.

8.7 KEY WORDS

- **Actual parameters**: These are the parameters that appear in function calls.
- **Formal parameters**: These are the parameters that appear in function declarations.

8.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. What is a function declarator?
2. How do you call a function?
3. Write a short note on function arguments.

Long Answer Questions

1. Find the output of the following program and then confirm your findings by executing the same.

```
#include <stdio.h>
   int main()
   {
   float z=0.0;
   int y;
`  float div(int x);
      for (y=0; y<=10; y++)
   {
      z=div(y+2);
   printf("result=%f\n", z);
   }
}
   float div(int n)
{
   float b, c=2.0;
   b=n/c;
   return b;
}
```

2. Explain the following:
   (a) Function
   (b) Formal vs actual parameters
   (c) Return statement
   (d) A function calling multiple functions
3. Explain the recursive factorial algorithm for finding the factorial of 7.
4. Describe what the following programs do:
   (a)

```
#include <stdio.h>
   int main()
{
   int j, k=100;
   int functn(int m);
   functn(k);
   printf("%d",k);
}
int functn(int k)
```

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```
{
   if (k<=0) return 0;
      if(k==1) return 1;
   else
   return functn(k-1);
}
```

(b)

```
#include <stdio.h>
int main()
{
   int j, k=100;
      int functn(int m);
   j=functn(k);
printf("%d", j);
}
int functn(int k)
{
   if (k<=0) return 0;
      if(k==1) return 1;
   else
return (k+functn(k-1));
}
```

8.9 FURTHER READINGS

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UNIT 9 STRUCTURE AND UNION

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Structure

9.0 INTRODUCTION

In this unit, you will learn about structures and union. A structure is a user-defined data type like an array. While an array contains elements of the same data type, a structure contains members of varying data types. A structure declaration ends with a semicolon and the keyword is `struct`. The tag for structure is optional. Structures can be passed by reference and can be nested. Unions help in conserving memory as only one of the many variables will be used at a time. The syntax of a `union` is similar to that of structure.

9.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the basic concept of structure
- Declare a structure
- Process a structure

9.2 DEFINITION OF STRUCTURE

A structure is synonymous with a record. A **structure**, similar to a record, contains a number of fields or variables. The variables can be of any of the valid data types. In order to use structures, you have to first define a unique structure. The definition of the record `book`, which you call a structure, is as follows:

NOTES

```
struct book
{
   char title [25];
   char author [15];
   char publisher [25];
   float price ;
   unsigned year;
};
```

`struct` is a keyword or a reserved word of 'C'. A structure tag or name follows which is `book` in this case. This is not a must but giving a tag to structure will improve the reader's understanding. The beginning of the structure is indicated by an opening brace. Thereafter, the fields of the record or data elements are declared one by one. The variables or fields declared are also called members of the structure. Structure consists of different types of data elements which is different from an array. Let us now look at the members of `struct book`.

The `title` of the book is declared as a string with width 25; similarly, the `author` and `publisher` are arrays of characters or strings of the specified width. The price is defined as a `float` to take care of the fractional part of the currency. The `year` is defined as an `unsigned integer`.

Note carefully the appearance of a semicolon after the closing brace. This is unlike other blocks. The semicolon indicates the end of the declaration of the structure. Thus, you have to understand the following when you want to declare a structure:

(a) `struct` is the header of a structure definition.
(b) It can be followed by an optional name for the structure.
(c) Then the members of the structure are declared one by one within a block.
(d) The block starts with an opening brace but ends with a closing brace followed by a semicolon.
(e) The members can be of any data type.
(f) The members have a relation with the structure; i.e., all of them belong to the defined structure and they have identity only as members of the structure and not; otherwise. Therefore, if you assign a name to the author, it will not be accepted. You can only assign values to `book.author`.

9.2.1 Declaration

The structure definition given above is similar to the prototype in a function in so far as memory allocation is considered. The system does not allocate memory as soon as it finds the structure definition, which is for information and checking consistency later on. The allocation of memory takes place only when structure

variables are declared. What is a structure variable? It is similar to other variables. For example, `int I` means that `I` is an integer variable. Similarly, the following is a structure variable declaration:

```
struct book s1;
```

NOTES

Here `s1` is a variable of type structure book. Suppose, you define,

```
struct book s1, s2 ;
```

This means that there are two variables `s1` and `s2` of type `struct book`. These variables can hold different values for their members.

Another point to be noted is that the structure declaration appears above all other declarations. An example which does nothing but defines structure and declares structure variables is as follows:

```
main ( )
{
   struct book
   {
   char title [25];
   char author [15];
   char publisher [25];
   float price;
   unsigned year;
   };
struct book s1, s2, s3 ;
}
```

If you want to define a large number of books, then how will you modify the structure variable declaration? It will be as follows:

```
struct book s[1000];
```

This will allocate space for storing 1000 structures or records of books. However, how much storage space will be allocated for each element of the array? It will be the sum of storage spaces required for each member. In `struct book`, the storage space required will be as follows:

```
title 25 + 1 (for NULL to indicate end of string)
author 15 + 1
publisher 25 + 1
price 4
year 2
```

Therefore, the system allots space for 1000 structure variables each with the above requirement. Space is allocated only after seeing the structure variable declaration.

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Look at another example to make the concept clear. You know that the bank account of each account holder is a record. Now, define a structure for it.

```
struct account
{
unsigned number;
char name [15];
int balance ;
} a1, a2;
```

Instead of declaring separate structure variables, such as `struct account a1, a2`; we can use coding as in the example given above. Here, the variables are declared just after the closing brace of the structure declaration and terminated with a semicolon. This is perfectly correct. The declaration of the members of the structure is clear; the balance has been declared as an integer instead of a `float` to make it simple. This means that the minimum transaction is a rupee.

9.2.2 Processing a Structure

The structure variable declaration is of no use unless the variables are assigned values. Here, each member has to be specifically accessed for each structure variable. For example, to assign the account number for variable `a1`, you have to specify as follows:

```
a1. number = 0001 ;
```

There is a dot operator between the structure variable name and the member name or tag.

Suppose, you then want to assign account no.2 to `a2`, it can be assigned as follows:

```
a2. number = 2;
```

If you want to know the address where `a2` number is stored, you can use

```
printf (" %u " , & a2 . number) ;
```

This is similar to other data types. The structure is a complex data type and therefore, you have to indicate which structure variable to which the member belongs as; otherwise, the number is common to all the structure variables, such as `a1, a2, a3`, etc., Therefore, it is necessary to be specific. Assuming that you want to get the value from the keyboard, you can use `scanf()` as follows:

```
scanf ( " % u ", & a1 . number ) ;
```

You can also assign initial values directly as follows:

```
struct account a1 = { 0001, "Vasu", 1000};
struct account a2 = { 0002, "Ram", 1500 };
```

NOTES

All the members are specified. This is similar to the declaration of initial values for arrays. However, note the semicolon after the closing brace. The `struct a1` will, therefore, receive the values for the members in the order in which they appear. Therefore, you must give the values in the right order and they will be accepted automatically as follows:

```
a1 .  number  =  0001
a1 . name     =  Vasu
a1 . balance  =  1000
```

Note too that if the initial values are assigned as above, inside a function, they will be treated as `static` variables. If they are declared before main, they will be treated as global variables.

Let us write a program to create a structure account, open 2 accounts with initial deposits in the accounts. Deposit Rs 1000 to Vasu's account, withdraw 500 from Ram's account and print the balance. The following example demonstrates the above.

```
/*Example 9.1 - structures*
#include<stdio.h>
int main()
{
    struct account
    {
       unsigned number;
       char name[15];
       int balance;
    };
    static struct account a1= {001, "VASU", 1000};
    static struct account a2= {002, "RAM", 2000};
    a1.balance+=1000;
    a2.balance-=500;
    printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
    a1.number, a1.name, a1.balance);
    printf("A/c No:=%u\t Name:=%s\t  balance:=%d\n",
    a2.number, a2.name, a2.balance);
}
```

Result of the program

```
A/c No:=1       Name:=VASU      Balance:=2000
A/c No:=2       Name:=RAM       balance:=1500
```

A simple program was written for a bank transaction. For a deposit, we write

```
a1 . balance  =  a1 . balance + 1000 ;
```

NOTES

Therefore, the balance is updated. Similarly, when an amount is withdrawn, the balance is adjusted. However, in practice, the user cannot write a program for each credit and deposit. You will develop a program soon which will not require the user to do programming.

9.2.3 User-Defined Data Type

A structure is also a data type. It is not a basic type defined in C language like `int, float`, etc. But, it is defined by the programmer. Hence, it is called as user-defined data type.

Array of Structures

Let us now create an array of structures for the account. This is nothing but an array of accounts, declared with size. Let us restrict the size to 5. The records will be created by using keyboard entry. The program is given below:

```
/*Example 9.2 - to demonstrate structures*
     #include<stdio.h>
     int main()
     {
         struct account
         {
            unsigned number;
            char name[15];
            int balance;
         }a[5];
         int i;
         for(i=0; i<=4; i++)
         {
            printf("A/c No:=\t Name:=\t Balance:=\n");
            scanf("%u%s%d",  &a[i].number,  a[i].name,
     &a[i].balance);
         }
         for(i=0; i<=4; i++)
         {
            printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
            a[i].number, a[i].name, a[i].balance);
         }
     }
```

Result of the program

```
A/c No:=  Name:=          Balance:=
1         suresh          5000
A/c No:=  Name:=          Balance:=
2         Lesley          3000
A/c No:=  Name:=          Balance:=
3         Ahmed           5500
A/c No:=    Name:=        Balance:=
4         Lakshmi         10900
A/c No:=  Name:=          Balance:=
5         Thomas          29000
A/c No:=1       Name:=suresh    Balance:=5000
A/c No:=2       Name:=Lesley    Balance:=3000
A/c No:=3       Name:=Ahmed     Balance:=5500
A/c No:=4       Name:=Lakshmi   Balance:=10900
A/c No:=5       Name:=Thomas    Balance:=29000
```

The structure array has been declared as a part of structure declaration as `a[5]`. The individual elements of the 5 accounts are scanned and printed in the same order. Note that when you scan a name, you do not give the address but the actual name of the variable as in `a[I].name`, since it is a string variable. Remember this uniqueness. This program basically gets the 5 structures or records pertaining to 5 account holders. Thereafter, the details of the 5 accounts are printed using the `for` statement. The first half of the result was typed by the user and the last 5 lines are the output of the program.

9.2.4 Structure Elements Passing to Functions

Structures can be copied individually, member wise as well as at one go.

For example, let `a3` and `a1` be `struct account`. The following are valid:

```
a3.number = a1.number;
a3.balance = a1.balance;
```

Here, the members of `a1` are copied into `a3`, one by one.

You can also write `a3=a1`; when all the elements of a1 will be copied to `a3`. The latter coding can be used if all the elements are to be copied and the former, if some members are to be copied selectively.

Note that structures cannot be compared as: for example if `(a4 == a2)`. This is not a valid operation.

Let us pass a structure into a function, element by element. This is implemented and shown in Example 9.3.

NOTES

NOTES

```
/*Example 9.3 - passing structure element
     to function*/
     #include<stdio.h>
     #include<string.h>
     int main()
     {
         struct account
         {
            unsigned number;
            char name[15];
            int balance;
         };
         static struct account a1= {001, "VASU", 1000};
         int credit(unsigned a, char *n, int d);
         printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
         a1.number, a1.name, a1.balance);
         a1.balance=credit(a1.number, a1.name, a1.balance);
         printf("A/c No:=%u\t Name:=%s\t new balance:=%d\n",
         a1.number, a1.name, a1.balance);
     }
     int credit(unsigned a, char *name, int b)
     {
         int d;
         unsigned num;
         char *client;
         printf("Enter account number\n");
         scanf("%u", &num);
         if(a==num)
         {
            printf("Enter name in caps\n");
            scanf("%s", client);
            if(strcmp(name, client)== 0)
            {
               printf("enter deposit made\n");
               scanf("%d", &d);
               b+=d;
               return b;
            }
```

NOTES

```
        else
        {
            printf("name does not match\n");
            return b;
        }
    }
    else
    {
        printf("account number does not match\n");
        return b;
    }
}
```

Result of the program

```
A/c No:=1       Name:=VASU      Balance:=1000
Enter account number
1
Enter name in caps
VASU
enter deposit made
4600
A/c No:=1       Name:=VASU      new balance:=5600
```

Now, look at the program carefully. A function prototype has been declared in `main()` as given below:

```
int credit(unsigned a, char *n, int d);
```

Here, there is no reference to structure at all. A structure `a1` is passed to function `credit` by passing individual elements of a structure. In function `credit`, these values are received. Then, the deposit is entered and added to the balance after checking the correctness of the details of the account. The new balance is returned to `main` and stored in `a1`.

9.2.5 Structure Passing to Functions

Passing each member of the structure is a tedious job. The entire structure can instead be passed to the function making for easy handling. The above example can be altered by passing an entire structure, as follows:

```
/*Example 9.4 - passing entire structure to function*/
#include<stdio.h>
struct account
{
    unsigned number;
```

NOTES

```
    char name[15];
    int balance;
};
int main()
{
    static struct account a1= {001, "Vasu", 1000};
    struct account credit(struct account x);
    printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
    a1.number, a1.name, a1.balance);
    a1=credit(a1);
    printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
    a1.number, a1.name, a1.balance);
}
struct account credit(struct account y)
{
    int x;
    printf("enter deposit made");
    scanf("%d", &x);
    y.balance+=x;
    return y;
}
```

Result of the program

```
A/c No:=1       Name:=Vasu     Balance:=1000
enter deposit made  6700
A/c No:=1       Name:=Vasu     Balance:=7700
```

If you want to pass a structure, the called function should also know the structure and hence, the structure has to be declared before the main function. Therefore, structure `account` has been declared as a global structure. The function `credit` is declared with return data type `structure` as follows:

```
struct account credit(struct account x);
```

Thus, you pass and `return struct account`. Then, credit is called by simply passing structure `a1`. In the called program, the deposit is added to the balance and updated. This is returned to the `main()` where the updated record is printed.

9.2.6 Structure Within Structure

You have been nesting `if` statement and loops so far. You can now create structures within structures. Here, a structure defined earlier can become a member of another structure. For example, you can create a structure called deposit using other data

types and structure account. The declaration of the basic structure should precede the desired structure as follows:

```
struct  account
{
   Unsigned number ;
   char name [15];
   int balance ;
};
struct deposit
{
   struct account ac ;
   int amount;
   int years;
};
```

NOTES

You can write a program to demonstrate the concept.

```
/*Example 9.5 - structure within structure*/
#include<stdio.h>
int main()
{
    struct account
    {
       unsigned number;
       char name[15];
       int balance;
    };
    struct deposit
    {
       struct account ac;
       unsigned amount;
       int years;
    }d2;
    static struct deposit d1= {001, "VASU", 1000, 50000,
3};
    d2=d1; /*structure copy*/
    printf("A/c     No:=%u\t     Name:=%s\t
Balance:=%d\tdeposit=%u\tterm=%d\n",
    d2.ac.number, d2.ac.name, d2.ac.balance, d2.amount,
d2.years);
```

```
}
A/c No:=1          Name:=VASU        Balance:=1000
deposit=50000  term=3
```

NOTES

You have created the structure `account`. Then, you have created another structure `deposit`. In the deposit structure, `struct account ac` is one of the members and 2 more members, amount and years have been declared.

Next structure `deposit d1` is initialized. The first 3 elements pertain to the members of `struct account` and the last two for `amount` and `years`, respectively.

Now `d1` is copied to `d2` in a simple manner and the deposit details of `d2` are printed.

Whenever members of included structures are accessed, you will find two dots, instead of the usual one dot. This is essential since `d1.name` is invalid. Since name is in `ac`, you have to access it as `d1.ac.name`.

However, nesting can be up to any level. You can create one more level of nesting as shown:

```
struct account
{
    unsigned number ;
    char name [15];
    int balance ;
};
struct deposit
{
    struct account ac;
    int amount ;
    int years ;
};
struct loan
{
    struct deposit dep ;
    int amount;
    char date [10];
};
```

You see that `struct deposit` is included as a member of loan.

Let us declare:

```
struct loan loan1;
```

Now, to access loan amount, we have to specify:

```
loan1 . amount
```

To access deposit amount, we have to specify:

```
oan1 . dep . amount
```

To access the balance, we have to specify:

```
loan1 . dep . ac . balance
```

Therefore, usage of the same variable name `amount` has not resulted in a conflict since it has to be seen in which context it is defined. Thus, structures can be used within structures without difficulty.

Structure containing arrays

You saw some members of structures being arrays. You used them to represent an array of characters. You can also have integer, `float` arrays as members of structures. For example,

```
struct fixed_deposit
{
unsigned Ac_Number;
char name[25];
double deposit[4];
}rama;
```

Here, you have defined a structure `fixed_deposit` and declared a variable `rama` of the same type. In the structure definition, you have a member `deposit` as an array of double of size 4. This means, you can store 4 deposits of `rama`. This is called array within structure.

You can access the first deposit of `rama` by the following:

```
rama.deposit[0]
```

The last deposit of `rama` can be accessed by:

```
rama.deposit[3]
```

Application of structures

Structures, as you know, can be used for database management. They can be used in several applications, such as libraries, departmental stores, banking, etc. Structures are also used in C++. The syntax of structures is similar to classes in C++. Structures contain data but classes contain data and functions.

Structures are also used in a variety of other applications, such as:

- Graphics
- Formatting floppy discs
- Mouse movement
- Payroll

Thus, structure is a very useful construct.

NOTES

Check Your Progress

1. What is the basic difference between a structure and an array?
2. What is the keyword to declare a structure?
3. What do you understand by members of a structure?
4. How is a structure declared?

9.3 UNION DEFINITION

Union is a variable which holds at a common assigned area different data types of varying sizes at different points in time. Assume that a program, at different points in time of execution uses a `double`, a `float`, an `integer` and a `string`. In the normal course, you would have to allocate memory space for each data type. Assuming that you want to use only one of them at any time and if you do not mind losing the values, you can save a lot of memory space by declaring a common area for storing them. If you use dedicated memory for each variable, the space would remain unutilized most of the time during program execution. This common storage area can be declared as a `union` as shown here:

```
union uname
   {
      double d;
      float f;
      char s[ ];
      int i ;
   } un1 ;
```

See the resemblance between `structure` declaration and `union` declaration. The common properties are :

(i) They can have a name optionally, such as `uname`.

(ii) They can contain members of varying data types.

(iii) The declarations end with a semicolon.

(iv) These `union` members can be accessed in the same way as structure members, as shown:

```
union_name. member or union_pointer -> member
```

(v) A `union` can be assigned to another `union`, such as

```
un2   =   un1;
```

where the structure of `un1` along with its members are copied to `un2`.

However, the difference is:

(i) The memory size of the structure variable is the sum of the sizes of its members, whereas in `union`, it is the largest size of its members.

(ii) It is the programmer's responsibility to keep track of which type is currently in use unlike in structure where no member is lost.

(iii) In structures, all members can be initialized, whereas a `union` can only be initialized with a value of the type of its first member.

A program using `union` to store either an `int` value or `float` value is given as follows:

```
/* Example 9.6 – Demonstrate union */
     #include <stdio.h>
     #include <conio.h>
     union sel
     {   int n;
         float f;
     };
      int main()
     {   union sel m1;
         void printval(union sel *m1,char type);
         char type ='p';
         char cont ='y';
         while(cont=='y')
         {
            printf("\nWant to enter Integer Or Float (i/
     f):");
            type=getche();
            if(type=='i')
            {
               printf("\nEnter Integer Value :");
               scanf("%d",&m1.n);
            }
            else
            {
               printf("\nEnter Float Value :");
               scanf("%f",&m1.f);
            }
         printval(&m1,type);
         printf("\nWant to continue- enter (y/n):");
         cont=getche();
```

NOTES

```
    }
}
void printval(union sel *m1,char type)
{
    if(type=='i')
       printf("Integer Value Is %d\n",m1->n);
    else
       printf("Float Value Is %f\n",m1->f);
}
```

Result of the program

```
Want to enter Integer Or Float (i/f):i
Enter Integer Value :456
Integer Value Is 456
Want to continue- enter (y/n):y
Want to enter Integer Or Float (i/f):3
Enter Float Value :300.30
Float Value Is 300.299988
Want to continue- enter (y/n):n
```

The `union sel` is declared before `main`, with two members `int n` and `float f`. A function `printval` is also declared. Depending upon whether the user wants an `integer` value or `float` value, type is set to `i` or `f`. If type is `i`, integer value is received and if it is `f`, a `float` value is received. The value received is printed in the function `printval`. Note carefully how the pointer to `union` is declared in the function prototype and header. You have to declare `union` whenever you pass a `union` to a function. It is declared as `union sel * m1`. As you would have declared `int * i`, the type here is `union sel`.

If you have perused the result, you would find that the program asks for `float` value, although 3 has been typed instead of `f`. It is because of the design of the program. It will ask for `float` value when a character other than `i` is typed. You can take this as an exercise to correct the program to ask for float value only when `'f'` is typed.

Now, consider another example.

In the case of an employee database, you would like to store either the father's name (in the case of men and unmarried women), the husband's name in the case of married women or the guardian's name. This can be represented as a `union` as shown below:

```
Union guardian
{
   char father [10];
```

```
    char husband [10];
    char guardian [10];
} e ;
```

NOTES

You have defined a `union guardian` of employees. By using this, you can save memory space. The memory required will be 10 bytes. Had you considered this as a structure, you would have used 30 bytes and all three variables will be used. This is not required since only one value will be present at any time and `union` is useful in such cases.

You can now define a structure for an employee database with `union` embedded. You have to declare `union` above structure since `union` will be one of the members of the structure. You can define it as follows :

```
union guardian
{  char father [10];
   char husband [10];
   char guardian [10];
} u;
struct employee
{  char name [15];
   float basic;
   char birthdate [10];
   union guardian u;
} emp [2] ;
```

You know how to refer to members of structures, for example, you can refer to the name of the employee's father as: `emp[0]. u . father`.

Now look at Example 9.7.

```
/*Example 9.7/
     union within structure*/
     #include <stdio.h>
     int main()
     {
         union guardian
         {
            char *father;
            char *husband;
            char *guardian;
         }u;
         struct employee
         {
```

NOTES

```
        char *name;
        float basic;
        char  *birthdate;
        union guardian u;
    }emp[2];
    int i;
    emp[0].name="RAM";
    emp[0].basic= 20000.00;
    emp[0].birthdate= "19/11/1948";
    emp[0].u.father= "SWAMY";
    emp[1].name="SITA";
    emp[1].basic= 12000.00;
    emp[1].birthdate= "19/11/1958";
    emp[1].u.husband="RAM";
    for(i=0;i<2;i++)
    {
        if( emp[i].basic ==12000)

printf("Name:%s\nbirthdate:%s\nguardian:%s\n",
        emp[i].name,    emp[i].    birthdate,
emp[i].u.husband);
    }
}
```

Result of the program

```
Name:SITA
birthdate:19/11/1958
guardian:RAM
```

The employee details are given in the form of `struct emp` which also contains `union` for `guardian`. All the string variables have been given as pointers to `char`. The `struct` is defined as an array of size 2 and the initial values of `emp[0]` and `emp[1]` are assigned for each member. Next, the data of employees whose basic equals 12000 are printed. Note how the `union` is handled. You will note that in such cases when only one of the three will be entered, there is no need to reserve memory for storing 3 variables. It is enough to store only one of them. A `union` provides a methodology for achieving this.

Check Your Progress

5. What is union? How is it declared?
6. Write any one difference between structure and union.

9.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

NOTES

1. A structure contains different data elements whereas an array contains same data elements.
2. Keyword `struct` is used to declare a structure.
3. A structure is like a record that contains fields as name of variables. These variables are known as members.
4. A structure is created with the keyword `struct` followed by a name which is optional. The beginning of a structure is denoted by an opening brace in which members of the structure are declared. These members can be of different data types. Declaration of structure is completed by a closing brace followed by a semicolon.
5. A `union` is a variable that holds a common assigned area for different data types but only one is used at a time. It is declared with a keyword `union` followed by a name (which is optional) above the opening brace and defining members as done in case of structure.
6. In structures, all members can be initialized, whereas a `union` can only be initialized with a value of the type of its first member.

9.5 SUMMARY

- A structure is synonymous with a record. A structure, similar to a record, contains a number of fields or variables. The variables can be of any of the valid data types.
- The allocation of memory takes place only when structure variables are declared.
- Structures find application in departmental stores, graphics, formatting floppy discs and mouse movement, among others.
- Structures can be passed by reference after defining it as a global variable.
- Union is a variable which holds at a common assigned area different data types of varying sizes at different instances of time.

9.6 KEY WORDS

- **Structure**: It is the collection of variables of different types under a single name for better handling.
- **Union:** In C they are related to structures and are defined as objects that may hold objects of different types and sizes. They are analogous to various records in other programming languages.

9.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

NOTES

Short Answer Questions

1. Write the rules to declare a structure.
2. How you will access a structure?
3. What are the applications of structures?

Long Answer Questions

1. Write a program to explain the use of array of structures.
2. Write a program to illustrate the structure within structure.
3. Write a program to create structure within structure and access their members. Create a structure date for DOB and use it within the structure student.

9.8 FURTHER READINGS

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BLOCK - IV

POINTERS

NOTES

UNIT 10 POINTERS

Structure

10.0 INTRODUCTION

In this unit, you will learn about the pointers. The pointer is a powerful concept of C and is closely associated with memory addressing. It is an integer variable, which contains the address of a variable. These variables are stored in the memory and each location in the memory has an address. It can point to any data type. The storage capacity varies from machine to machine. Pointer arithmetic will make the concept of pointers clear and unambiguous. You can call a function and pass actual values to them. The function call using pointers is known as call by reference where the address of the variable is passed. Functions can also return reference or pointers.

10.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the concept of pointers
- Declare and initialise the pointers
- Explain why pointer is a variable

10.2 CONCEPT OF POINTER

Pointer is a one of the unique concepts of C since it facilitates direct access to the hardware and results in compact coding. It also facilitates returning more than one value from a function. Pointers are closely associated with memory addressing.

NOTES

We know that constants and variables are stored in memory, and that each location in memory has an address just as a person has an address. The memory locations are available in groups of 8 bits or a byte. Each byte in memory has an address. Therefore, each location has an address and stores a value. The value stored can correspond to any data type such as *float* or char or int and their type modifiers. However, the addresses themselves will be of type integers. All these data types are stored in terms of 1s and 0s. We will not go into further details of storage except to state that each memory location stores a value and has an address. The memory locations are arranged in increasing order of addresses, starting from 0000, and increases one by one. We may have the address of the last location as FFFF. What does F denote? The addresses are denoted in terms of hexadecimal numbers. We can calculate the decimal equivalent of this and find the decimal address of the last location. The storage capacity varies from machine to machine.

The *&* operator has been used to denote the address of the variable in the *scanf* function. If *var* is the name of a data type, *&var* denotes the address of the location where it is stored. Whenever a data type is declared, a memory location needs to be allocated depending on the data type. The allocation of memory space takes place at the time of execution of the program, and therefore the address of a variable may be different at different times of execution, since the computer allots it at random depending upon the availability of memory locations. However, memory locations for each data type will be contiguous so as to make for easy handling. For instance, a double needs 8 bytes of storage and therefore all the 8 bytes will be stored continuously or contiguously. Each byte of the value of the variable will be stored one after the other in continuous locations.

For, instance, the following is declared:

float ft =100.52;

Here *ft* is the name of the variable. Its value is 100.52. This number will be stored in 4 bytes in the memory in sequentially numbered storage locations. When we print the value of the address of a variable, it will always print the starting address. If the starting address and the data type are known it is easy to find out the locations which are occupied by the variable. For instance, if the starting address of the *float ft* is 0011, then the variable will occupy up to memory location 0014. However, if we print the address of *ft*, i.e., *&ft*, we will get 0011.

A similar concept can be extended to a string. A string is an array of characters, with each character occupying a byte of memory. If Peter is stored in string *w*, and if *w*[o], i.e., *p* is stored in location 0020, then '*e*' will be stored in 0021, 't' in 0022 and so on. Every element of an array will also be stored contiguously. The formula for finding out the location of an element or address of pth element in an array is given below:

address of *p*th element= starting address of array + *p* * (storage space for the data type)

Example 10.1

If an integer array *ia* is stored from location 992 onwards, find out the location of the 10 the element.

Address of 10th element = 992 + 10*4 = 1032. It is the starting point. However, the second byte of the integer will be stored in location 1033.

Note: The 10th element will have the subscript 9, since the 1st element has the subscript 0.

Note: We know that *int* data type is allocated 2 bytes in some systems and 4 bytes in some systems. For the sake of simplicity we assume that *int* occupies 2 bytes in this chapter.

Example 10.2

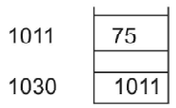
If the 10th element of a long double is stored from location 2000 onwards, find the location of the 15th element and the first element assuming that long double occupies 10 bytes.

The 1st element will be stored at location 2000-10*10=1900.

The 15th element will be stored at 1900+15*10=2050.

Let us now consider a pointer to an integer. Let the integer be *mark*. Then the address will be denoted as *&mark*. Note that all addresses will be in integers for all data types. In the case of pointers, the address of *mark* will be stored in another location. The pointer is a variable that contains the address of the variable. We can assign the address of the integer to an integer pointer. Usually we declare:

int mark; *mark*=75; we can also declare *int *ip*; This means *ip* is a pointer to the integer. We can assign *ip* = *&mark*; i.e. we have assigned the address of *mark* to *ip*. Let us pictorially explain this.



Here, *mark* = 75 and the address of *mark* is 1011. Therefore, *ip* = 1011. This value will also be stored at another location 1030. Here *ip* points to an integer mark, and holds the address of *mark*. Since the pointer is also a variable, it will be stored in another location. The * is called the indirection or dereferencing operator.

Similarly, we can write

float f = 101. 23;

*float * fp;*

fp=&f;

Here, *fp* points to a *float* because we have assigned the address of *f* to *fp*. Remember that the pointer can point to any type of variable such as a *float* or *char* or *int* or string. Pointers themselves are always of type *int* because it is the value of the address.

NOTES

It is necessary to become familiar with pointers. Therefore, let us apply the concepts learnt.

We can have the definitions of the following types:

```
int i = 204;
float f = 101. 23;
int * ip ; / * ip  is a pointer to integer */
float * fp ;  /* fp is a pointer to float  */
```

We must assign the pointers to the specific integers and floats, as otherwise they will not point to anything. This is carried out as follows:

```
ip  =  &i;
fp  =  &f;
```

By assigning *ip* to the address of *i*, *ip* points to integer *i*. Similarly, *fp* points to float *f*.

Suppose we now assign

```
i =  100;
```

ip automatically points to 100.

Similarly, if we assign

f = 100.05 ; then *fp* points to the new value. What actually happens? The variables i & f are assigned storage locations; *ip* holds the address of where *i* is stored and *fp* holds the address of *f*. When we assign new values to *i* and *f*, the values stored in *ip* and *fp* are not affected. They continue to point to *i* and *f*, but the values of *i* and *f* have been actually changed.

If we now add the following assignment statements

```
int a [ 5 ];
ip  =  &a[0]
```

We have defined an array of integer a with five elements. When we assign the address of *a*[0], i.e., the 0th element of *a* to *ip*, *ip* will point to the array. The old assignment to *ip* is lost. It is irrecoverable.

We can also perform arithmetic operations on pointer variables, such as:

```
ip  =  ip + 5 ; /*pointer moved up by 5 locations*/
ip = ip–10; /* ip moved down  by 10 locations/
ip––; /*decremented*/
ip++; /*pointer incremented*/
*ip++; /*value incremented*/
*ip––; /*value decremented*/
```

However, such operations on pointers are limited. We cannot carry out the following operations on pointers:

ip+*fp*; /*invalid*/

*ip***fp*; /*invalid*/

*ip**2; /*invalid*/

fp/10; /*invalid*/

ip = *ip**10; /*invalid*/

NOTES

If we say *ip* = *fp*; then both *fp* and *ip* will point to the same location, and hence *fp* will point to the same variable pointed to by *ip*.

Pointer is variable too

A pointer is a variable that contains the address of another variable. As you know, any variable has the following four properties:

(a) name

(b) value

(c) address

(d) data type

For instance, consider the following declaration of a simple integer.

int var = 10;

Here, the name is *var*, and its value is 10. Its address is not declared here since we want to give flexibility to the compiler to store it wherever it wants. If we specify an address, then the compiler must store the value at the same address. Specifying actual address is carried out during machine language programming. However, this is not required in High-Level Language (HLL) programming, and by printing the value of *&var,* we can find out the address of the variable. When the statement to find the address is executed at different times, different addresses will be printed. What is important is that the compiler allocates an address at run time for each variable and retains this till program execution is completed. This is not strictly so, in the case of auto variables. The compiler forgets the address of a variable when the program comes out of the block in which the variable is declared. At this point you may also recall that in the case of function declarations in the calling function, the compiler does not allocate memory to the variables in the declaration. That is the reason why the parameters in the declaration part are not recognized in the calling function. It is only a prototype.

The fourth feature of a variable is its data type. In the above example, *var* is an integer. A pointer has all the four properties of variables. However, the data type of every pointer is always an integer because it is the value of the memory address. Memory addresses are integers. They cannot be floats or any other data types. They may point to an integer or a *float* or a character or a function, etc. They have a name. They have a value. For instance the following is a valid declaration of a pointer to an integer.

int * *ip*;

NOTES

Here, *ip* is the name of a pointer. It points to or it contains the address of an integer, which is the value. It will also be stored in another location in memory like any other variables. The pointer itself is an integer even though it is not declared as such.

10.2.1 Pointer Arithmetic

Let us look at some examples involving pointers:

Example 10.3

int dat = 100;

int * *var*;

var = &dat;

Here, *dat* is an integer variable. Its value is 100; its name is *dat*; it will be stored in memory in a location with an address.

The next declaration means that *var* is a pointer to an integer, and is a variable. It is an integer, and will be stored at a location in memory with an address. The value of *var* is the address of the integer variable it points to. We do not know as yet which integer it points to. It can, however, be made to point to any integer we like, by a proper assignment.

Now look at the next assignment. The variable *var* is assigned the value of *&dat*. This means *var* has the same value as the address of *dat*. By taking into consideration the previous statements we can conclude that *var* is a pointer and it points to *dat*.

Now if we specify *dat* or * *var,* they point to the same value 100. Similarly, if we specify *&dat* or *var* it is the address or to be precise, the starting address of *dat* or * *var*.

Example 10.4

int * *var*

* *var* = 100

The above statements declare *var* as a pointer to an integer, and later propose to assign 100 to the integer variable. We do not know or do not want to make public the name of the variable. However, we can always access the variable as * *var*. This works well in Borland C++ compilers, but could lead to run time errors in other compilers.

Both the statements cannot be combined into one as int * *var* = 100. This will be flagged as an error even in the Borland C++ compiler. Therefore it is not possible to combine both the declaration and assignment insofar as a pointer variable and integer constant are concerned. It would be safer to make *var* point to another variable as given in Example 10.3.

Example 10.5

int * var;

* *var* = 100;

NOTES

Note: If this gives an error while compiling or while running the program, modify this as in Example 10.3 above.

What will be the value of the output of the following statements after the execution of the following statements?

printf ("%d", * *var);*

printf ("%d", (* *var*) ++);

printf ("%d", * *var);*

printf ("%d", *var);*

We can easily guess that the first printf will give the value of * *var* as 100.

What is the significance of the parentheses and the increment operation, in the second statement? As the bracket or parentheses has precedence over other operators, the value of * var will be printed as 100. After printing, it will be incremented as 101, because the increment is postfix the value of * *var* after execution of the statement will be 101. The next statement will confirm this when it prints 101.

The fourth printf case prints the address of *var*. It printed 1192 at one of the attempts. We are unlikely to get the same address on execution. The location where the variable is stored will not vary till the execution of the program is completed. If we try the program again, we will get a different address.. It does not affect our work. However, we may note down the value and substitute it for the values mentioned here for understanding the concept of pointers.

Remember to enclose the pointer variable within parenthesis as given in the example. The postfix of the increment operator, enables increment of the variable after printing.

Note: In the examples we are assuming that int occupies 2 bytes.

Example 10.6

After execution of the above 4-printf statements, we execute the following statements:

printf ("%d", * *var* ++);

printf ("%d", * *case);*

What happens? The value of * *var*, i.e., 101 is the first to be printed out and then *var* will be incremented, i.e., instead of incrementing the value as desired, the address is incremented, and therefore var now points to the next location. Remember, var was pointing to 1192! Will it go to 1193? No. Since *var* is an integer, 1192 and 1193 (2 bytes) are already occupied and hence *var* points to 1194. The next statement prints the value of * *var*. We had stored 101 in location

NOTES

1192. We don't know what is contained in 1194. Hence the next printf will print garbage value. Note carefully what happened. We wanted to increment * *var* in the first statement of example 4. However, the compiler has assumed that we wanted to increment the pointer which underlines the importance of parenthesis. Also note that whenever we use postfix notation, the postfix operation is effective only after execution of the statement.

Is everything lost now? Can we not go back to address 1192? Yes, we can as the following indicates. Note that the following statements are executed in continuation of all the above statements.

Example 10.7

printf ("%d", *var)* ;

printf ("%d", *−− var)* ;

printf ("%d", * *var)* ;

The first statement in this example prints the address of the location in memory pointed to by *var*. As expected the pointer is at the location 1194. The second statement carries out two operations in the sequence given below:

(a) decrement the pointer

(b) print the new address.

Decrementing takes place before printing because it is a prefix operator. Now it prints 1192, the original address is restored. Now the third statement prints the value of * *var* or the value stored in location 1192, i.e., 101.

Note that prefix, carries out the increment or decrement before printing or any desired operation, whereas postfix does that after printing. Note that we are discussing the fundamentals of pointers, and that they should be understood clearly before you proceed further.

We now have 101 stored in address 1192 and pointed to by *var*. Let us see what happens on execution of the following statements, in continuation.

Example 10.8

printf ("%d", ++ (* *var))*;

printf ("%d", *var)*;

These statements are perfectly correct. * *var* is incremented and the new value printed in the first statement. Therefore 102 will be printed. Has the address been changed? No. Hence the second statement will print the address as 1192.

Can we increment and decrement addresses? Yes, as the following indicates.

Example 10.9

printf ("%d", *var* ++);

printf ("%d", *var*) ;

What will be printed in the first statement above, 1192, or 1194? It will be 1192, because incrementing *var* will take place after the first printf. Obviously the second statement will print the address incremented after the previous printf, viz., 1194. Let us not lose track, but get back to the old address, and try prefixing increment / decrement operators to the address.

Example 10.10

var – –; (a)

printf ("%d", *var)* ; (b)

printf ("% d", ++ *var)* ; (c)

printf ("% d", – – *var)* ; (d)

printf ("% d", *var)* ; (e)

printf ("% d", * *var)* (f)

Before execution of the first statement in this example, we have:

var = 1194

location 1192 contains 102

Let us now analyze the execution statement-wise.

(a) decrements *var* to 1192

(b) confirms that *var* is 1192 indeed.

(c) ++ *var*, increments var and then prints as 1194.

(d) – – *var* decrements var and then prints as 1192

(e) confirms *var* is 1192

(f) The value in *var* is 102.

Now the concepts are becoming clearer. Let us carry out one more exercise as in Example 10.11 Assume that all the above statements were executed and the following are now executed.

Example 10.11

printf ("%d", * *(var* ++)) ; (g)

printf ("%d", * (– – *var))* ; (h)

printf ("%d", *var*) ; (i)

printf ("%d", * var) ; (j)

(g)Here, * *var* is printed as 102 because of the postfix operator. Then *var*, i.e., the address is incremented to 1194.

(h)Here because of the prefix, *var* is decremented to 1192 and then the value at 1192, i.e., 102 is printed.

The next 2 statements confirm this.

NOTES

Now you would be familiar with intricacies of pointers, prefix, suffix and parenthesis. To gain more confidence do the exercise at the end of the chapter before proceeding further. In order to confirm our discussions regarding the basic principles of pointers a program involving all these statements and the output are given below.

Example 10.12

```
/* pointers*/
#include <stdio.h>
int main()
{
   int * var;
   int a =100;
   var = &a;
   printf("value of * var=%d\n", *var);
   printf("value of (*var)++=%d\n", (*var)++);
   printf("value of * var=%d\n", *var);
   printf("address var=%d\n", var);
   printf("value of *var++=%d\n", *var++);
   printf("value of * var=%d\n", *var);
   printf("address var=%d\n", var);
   printf("original address var again=%d\n", —var);
/*original address restored*/
   printf("value of * var=%d\n", *var);
   printf("value of ++(*var)=%d\n", ++(*var));
   printf("address var=%d\n", var);
   printf("address var++=%d\n", var++);
   printf("address var=%d\n", var);
   var—;
   printf("address var after decrementing=%d\n", var);
   printf("address ++var=%d\n", ++var);
   printf("address – –var=%d\n", – –var);
   printf("address var=%d\n", var);
   printf("value of * var=%d\n", *var);
   printf("value of *(var++)=%d\n", *(var++));
   printf("value of *(– –var) = %d\n", *(– –var));
   printf("address var=%d\n", var);
   printf("value of * var=%d\n", *var);
}
```

Result of program when executed subsequently

```
value of * var=100
value of (*var)++=100
value of * var=101
address var=9106
value of *var++=101
```

```
value of * var=9108
address var=9108
original address var again=9106
value of * var=101
value of ++(*var)=102
address var=9106
address var++=9106
address var=9108
address var after decrementing=9106
address ++var=9108
address – –var=9106
address var=9106
value of * var=102
value of * (var++)=102
value of *(– –var) = 102
address var=9106
value of * var=102
```

NOTES

function 'Call by Reference'

We have been calling functions and passing actual values to them. When we call functions, we pass actual arguments as per the list provided in the declaration. These are all values, which are passed to a function, and this method is called call by value. In call by value, we can return only one value from a function, and therefore it puts restrictions on the usage of functions. This can be overcome by using call by reference, where any number of values can be indirectly returned. Call by reference can be implemented by using pointers as in the example 10.13:

Assume that we want to pass *a* and *b* to a function, divide *a* by *b* and return both the quotient and remainder to the main function. It is not possible to do this by call by value. Call by value can return only a single value, either the quotient or remainder, but not both. This can be achieved by call by reference as the following example demonstrates.

Example 10.13

```
/* to demonstrate function call by reference*/
#include <stdio.h>
int main()
{
   int a=100, b=13;
   void div(int *p, int *q);/*indicates call by reference*/
   div(&a, &b);/*addresses of a and b are passed*/
   printf("quotient= %d remainder= %d\n ", a, b);
}
/*function definition*/
void div(int *px, int *py)   /*function declarator*/
{
```

NOTES

```
    int temp1, temp2;
    temp1=*px;
    temp2=*py;
    *px=temp1/temp2;
    *py=temp1%temp2;
}
```

Result of program

```
quotient= 7 remainder= 9
```

How does the program work?

In the declaration part, we have declared *div* as a function passing two pointer variables and getting back void or none. We call div(&a, &b). We don't pass the values, but reference to the values. We actually pass the address of *a* and *b* to function div.

The function *div* receives the reference, i.e., addresses of *a* & *b*.

px = &*a*;

py = &*b*;

px points to *a* and *py* points to *b*. Hence **px* gets the value of *a* and **py* gets the value of *b*. Now the contents of *px and **py,* i.e., *a* and *b* are copied to *temp1* and *temp2*.

We divide *temp1* by *temp2* and place the result in variable **px* whose address is known to both main and the function *div*. In the main function the address corresponds to *a* and in the function it corresponds to **px*. Therefore the address of the quotient is returned to the main function indirectly. Similarly **py* contains the remainder. It will be stored in b through the reference. Thus, the values of the quotient and remainder are stored in locations *&a* and *&b,* and we have indirectly returned 2 values to main through call by reference. The concept, though, may seem hazy at this point, will become clear as we see more examples. Some more points are to be noted carefully;

The function declaration indicates that there is a function *div*, which returns nothing. It passes two pointers to integers. The pointers are declared as int**p* and *int***q*. You will notice that they are not declared in the main function and therefore *p* and *q* have no significance except to indicate that they are pointers to integers. They also indicate that the addresses of two integers are to be passed while calling the function.

Check Your Progress

1. What is the use of & operator?
2. Define pointer.
3. How you will declare an integer pointer?

10.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

NOTES

1. The & operator has been used to denote the address of the variable in the scanf function. If var is the name of a data type, &var denotes the address of the location where it is stored.
2. A pointer is a variable that contains the address of another variable.
3. The following is a valid declaration of a pointer to an integer.

   `int` *ip;

10.4 SUMMARY

- Pointer is a one of the unique concepts of C since it facilitates direct access to the hardware and results in compact coding. It also facilitates returning more than one value from a function. Pointers are closely associated with memory addressing.
- The & operator has been used to denote the address of the variable in the scanf function. If var is the name of a data type, &var denotes the address of the location where it is stored.
- The allocation of memory space takes place at the time of execution of the program, and therefore the address of a variable may be different at different times of execution, since the computer allots it at random depending upon the availability of memory locations.
- A pointer is a variable that contains the address of another variable.

10.5 KEY WORDS

- **Pointer:** A variable that contains the address (not the value) of another variable or a literal.
- **& operator:** It provides the address of the pointer variable where it is stored in the memory.

10.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. How will you find out the location of an element or address of p_{th} element in an array?

2. Write a program that print the value and address of a pointer.
3. Write a program that prints the values of an array using pointers.

Long Answer Questions

NOTES

1. Describe the pointer arithmetic with the help of examples.
2. Discuss the properties of pointers.
3. Write a program to illustrate the concept of pointers.

10.7 FURTHER READINGS

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UNIT 11 POINTER AS FUNCTIONS

NOTES

Structure

11.0 INTRODUCTION

In this unit, you will learn about the pointer as function, array of pointers and pointer scale factors. Pointer as a function parameter is used to hold addresses of arguments passed during function call. This is also known as call by reference. When a function is called by reference any change made to the reference variable will effect the original variable. Array of pointers is the array that holds memory locations.

11.1 OBJECTIVES

After going through this unit, you will be able to:

- Pass pointers to functions
- Understand the relationship between pointers and functions, pointers and one dimensional arrays, pointers and strings
- Define pointer notations for arrays and array of pointers

11.2 POINTERS AND FUNCTIONS

The function call using pointers is known as 'call by reference'. Here, the address of the variable is passed. Note that calling by reference has to be indicated in the function declaration such as these:

```
fun (int *p, char *cp, float *fp, int *array);
```

NOTES

This is an indication that the function is to be called by reference for those parameters which are pointers. A mixed declaration could also be used as given below:

```
fun1(int a, char *cp);
```

Here, we are indicating that an integer is passed by value and a character variable is passed by reference. In the above example, while we can either pass a character array (string) or a character through the second declaration, we can only pass one integer variable through the first parameter.

The function declarator above the function body has to match the declaration. Hence when fun1 is called, an integer followed by an address of character will be passed. In the function fun1 we may have a declarator as follows:

```
fun1(int d, char * ch)
```

Here, the value of the integer variable will be automatically get assigned *d*, and the *ch* will be assigned the address of the character variable. This means both *ch* and the address of the character variable in the calling function will point to the same location. Thus, both in the calling function and in the called function, the variable is accessible, although under different names. Any modification made to the character variable either in the calling function or the called function affects both.

While calling by reference, we have to pass the address of the variable. If the variable is declared by value such as int *a*, then we have to pass *&a*. If it was declared as a pointer to say, an integer such as int * *ip*, then *ip* has to be passed.

Function 'Return by Reference'

So far we have seen functions returning only a value, irrespective of whether they were called by value or by reference. Functions can also return reference or pointers.

Whenever a function is to return a pointer, this has to be indicated by the following:

Function Declaration

Declare the function as returning pointers. For instance,

```
int * fun1() ;
char * fun2() ;
float * fun3 (int a, float * b, char * c)  ;
```

The difference is the insertion of pointer(*) between the return data type and the function name.

Function Declarator

This will be in the same format as the prototype or function declaration. For instance,

float * fun3 (int a, float * b, char * c)

to match the third function declaration in above example.

Function Call

NOTES

We may call

fun3 (x, &y, z);

Here, *x* is a variable and &y is an address. Although *z* looks like a value, it is in fact a reference to character, since prototype has the declaration char * c.

Return Statements

The program will obviously return an address or pointer.

11.2.1 Pointer and one dimensional Array

The example below explains the concept of a function returning a pointer.

```
   Example 11.1 To find the greatest number in an array.
   #include <stdio.h>
   int main()
   {
      int array[]= {8, 45, 5, 131, 2};
      int size=5, * max;
      int* fung(int *p1, int size);/*function retuns pointer
to
         int*/
      max=fung(&array[0], size); /*max is a pointer*/
      printf("%d\n", *max);
   }
   int * fung(int *p2, int size)
   {
      int i, j, maxp=0;
      for (j=0; j<size; j++)
      {
         if (*(p2+j) > maxp)
         {
            maxp=*(p2+j);
            i=j;
         }
      }
      return (p2+i);  /*pointer returned*/
   }
```

Result of program

```
131
```

The called function returns the address of the greatest number in the array. Look at the function declaration. The function returning a pointer is indicated by the following (a starmark between the return data type and function name).

int * fung(...)

The address of array [0] is received by fung() and stored in **p2*. In other words, *p2* points to the 0th location of the array.

NOTES

Pointer Notations for Arrays

At this point we must note another way of representing the elements of the array.

The address of the 0th element is stored at the location *p2* or address *p*2 +0. The element with a subscript 1 of the array will be at one location above or at *p*2 + 1. Thus the address of the n^{th} element of this array **p2* will be at address *p2* + *n*. If we know the value of the pointer variable, i.e., the address of the pointer, then it would be easy to express its value. The value of the integer stored at the n^{th} location can be represented as * (p2 + n) just as the value at address (p2+0) is *(p2 + 0) or * p2. This notation is, therefore, quite handy.

The *if* statement compares *maxp* with **(p2 + j)* or *p2 [j]* or *array [j]*. You will easily understand the logic of getting the maximum or greatest number in * *(p2 + j)*. At the end of the iterations, * *(p2 + j)* which is stored at location p2 + j contains the maximum value in the array, and therefore we are returning an address or reference to the called function. In this example (p2 + 3) is the address of the greatest number in the array. After return from the function, *max* gets the value of p2 + j. In the printf **max* which is the value stored in *max* is printed. We have already defined *max* as a pointer to an integer in the main function. Thus, the function *fung* returns the address of a value or a pointer, and by returning the address, the value is retrieved automatically by the main function.

Arrays and Pointers

Example 11.1 involved arrays and pointers. Use of a pointer made the passing of an array to a function a simple task. We define array as an integer. However, in order to pass an address, the prototype was defined with a pointer argument int * *p1*. This means an address will be passed to the function while calling it. No distinction was made between a simple integer variable and an integer array. int * *p1* can be a single valued integer or an array. This is possible because arrays are stored contiguously in memory. If the address of the 0th element is known, and the data type is known, it would not be difficult to calculate the address of any element in the array. Therefore, it is enough if the address of the 0th element is passed to a function. **p1* refers to the address of a variable or to the 0th element of an array. Note the flexibility of arrays in "C" and how intelligently the language uses pointers.

While calling, a function, the address has to be passed, and this is achieved in the above example by passing & array[0].

In the called program **p2* is treated as an array without any additional efforts. By adding the index to *p2* we get the address of the various elements in the array. Getting value is achieved by placing * before the address. Let us look at another example using arrays and pointers, as given below:

Example 11.2 Passing an array of integers to function.

```
*method2*/
#include<stdio.h>
int main()
{
   int array[]={10, 20, 30, 40, 50};
   int *a;
   void pass(int *a, int k);
   a=&array[0];
   pass(a, 4);
}
void pass(int *b, int j)
{
   int k=0;
   while (k <= j)
   {
      (*b)=(*b)/2;
      printf("value %d @ address %d\n", *b, b);
      k++;
      b++;
   }
}
```

Result of program

```
value 5 @ address 8694
value 10 @ address 8696
value 15 @ address 8698
value 20 @ address 8700
value 25 @ address 8702
```

Here, * *a* has been declared as a pointer to integer. The variable *a* has been assigned the address of the 0th element of the array. Now the function call is made using pass (a, 4); Again a is the address of the variable array [0].

In the function pass, b received the address of *a*, and the next element of the array is accessed each time by incrementing the address *b*. Note that the values of the elements in the array are divided by 2 in the called function. As we become familiar with pointers we can write programs very easily.

11.2.2 Pointer Notation for Multi-dimensional Arrays

We may represent a two-dimensional array conventionally as a[i][j].

The elements of a two-dimensional array of size 3x3 can be represented symbolically as given below:

a00	a01	a02
a10	a11	a12
a20	a21	a22

NOTES

We can then visualize this as an array of arrays. Do not get puzzled. Each row is an array, and we have three such arrays. Thus, a two-dimensional array can be considered as an array of one-dimensional arrays. Therefore, we can expect the following type of memory allocation by the system:

0	1	2	0	1	2	0	1	2
a[0][0]			a[1][0]			a[2][0]		

This means all the elements of the 0th row are stored contiguously. a[0][0] is stored first, followed by all elements of the 0th row. Next, the first row starts with the first element a[1][0]. At the end of the first row, the second row starts with a[2][0]. Try to visualize how the elements of a two-dimensional array are stored contiguously.

You know that

a[i] = * (air)

where a + i is the address of the element.

You also know that

a [0] = * a and its address is stored in location a.

You can now transform a two dimensional array into this convenient form.

You can visualize **b[0], **b[1] and **b[2] to represent the values of row first elements which are stored at locations *b[0], *b[1] and *b[2] as given below:

	0	1	2	0	1	2	0	1	2
Address	*b[0]			*b[1]			*b[2]		

** indicates pointer to pointer. This is acceptable since the row pointers in turn point to column pointers. If you assume the first row elements as pointers, then the addresses of elements of the two-dimensional arrays can be addressed by simple arithmetic.

**b* points to the value in the one-dimensional array. Then ***b* refers to the value in the two-dimensional array. All elements of the two dimensional array are stored contiguously. From the storage pattern we declare the following:

**b refers to the value at the 0th row of a two-dimensional array. Naturally, the address of the 0th row will be *b.

**(b+1) refers to the value of the 0th element in the 1st row. Its address will be *(b+1)

In general the 0th element in ith row contains the value **(b+i) and its address is *(b+i).

We have only talked about the 0th element in each row, i.e., where the row starts conceptually. How do we address the other elements? You know that an element b[i][j] is the jth element in the ith row,

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We know the address of the 0th element. It is * (b+i). Therefore, the address of the jth element in ith row will be (* (b+i) + j). Note, j is the offset. Therefore, the value at this location can be expressed as * (* (b + i) + j). We have just added a star outside the address.

Now the address of the 2nd element in the 2nd row will be

(*(b + 2) + 2)

Its value will be

*(* (b + 2) + 2)

What will be the address of the 0th element in the second row

(*(b + 2))

What will the value be?

*(* (b + 2))

Note the parentheses and *. To understand this clearly, execute the following program.

Example 11.3 To understand pointers to 2 dimensional array.

```
#include<stdio.h>
int main()
{
int i,j;
int a[3][3];
   printf("Enter the values of 3x3 matrix\n");
   for (i=0; i<=2; i++)
   for(j=0; j<=2; j++)
      scanf("%d", (*(a+i)+j));
      for (i=0; i<=2; i++)
      {
         for (j=0; j<=2; j++)
         {
            printf("address=%d\n", (*(a+i)+j));
            printf("value=%d\n", *(*(a+i)+j));
         }
      }
}
```

Result of program

```
Enter the values of 3x3 matrix
00   01    02
10   11    12
20   21    22
address=9098
value=0
address=9100
value=1
address=9102
value=2
```

NOTES

```
address=9104
value=10
address=9106
value=11
address=9108
value=12
address=9110
value=20
address=9112
value=21
address=9114
value=22
```

This example helps us to understand how a two-dimensional array is stored in the memory. The array has been declared in the normal way without pointers, but the array elements have been received, stored and printed using pointer notation. When we execute the above program, we can type the numbers in any one of the ways given below:

- Enter one integer at a time followed by Return
- Enter all integers in a row with spaces between them and finally hit Return
- Enter three integers in a row as the result of the program indicates.

Since it is a two-dimensional array we would like to input the value in the form of rows and columns and get the output in the same form. It would be better if the computer accepts the inputs at the given places and prompts us to do so, as in the example 11.4

Case Study: Receiving Inputs at Chosen Points

Example 11.4- To accept and print in matrix form.

```
#include <stdio.h>
#include <conio.h>
int main()
{
   int a[3][2];
   int i,j;
   printf("Enter values of 3x2 matrix-\n");
   printf("Press Enter after each value");
   for (i=0; i<=2; i++)
   {
      for (j=0; j<=1; j++)
      {
         gotoxy (j*10+10,4+i*2);
         scanf("%d",(*(a+i)+j));
      }
   }
   for (i=0; i<=2; i++)
   {
      for (j=0; j<=1; j++)
      {
         gotoxy (j*10+40, 4+i*2);
```

```
            printf("%d", *(*(a+i)+j));
        }
    }
}
```

Result of program

```
Enter values of 3x2 matrix-
Press Enter after each value
          00        01                  0         1
          10        11                 10        11
          20        21                 20        21
```

A library function *gotoxy*(*x*, *y*) has been used in the program. This function makes the cursor go to the point (*x*, *y*) on the screen. At the first iteration when both *j* and *i* are 0, we will call goto(10,4) while scanning the values and call goto(40, 4) while printing the values. Therefore, the first value will be scanned on the 4th line from the top and at the 10th character position. The first value will be printed at the same line and 40th character position as the result of the program indicates. Therefore, we can direct the cursor to any position as we like. Thus, *gotoxy*() will be quite useful in advanced programming.

This has been used both for *scanf()* and *printf()*. The system will scan inputs from those points and print outputs at the points specified. We can specify any point on the screen to take inputs and print outputs. When we execute the program the cursor will go to the specified position. After we have typed one value and entered the return key, the cursor will blink at the next point, giving the impression of inputting a matrix. After the values are given, the output also appears in the form of a matrix. The left pair of numbers is what were entered. Since the same vertical position, but a different horizontal position has been specified in the program, the printout appears on the same lines, but to the right of the input values. Try the program and see for yourself.

Look at the address specification along with the *scanf()*. It is

(* (a + i) + j) which is equivalent to &a [i][j].

Putting a star before this converts this to the value a [i][j].

This program clearly illustrates the way to handle a two-dimensional array with pointers.

Although the array could have been declared as **a, it has been declared with the dimensions of the array. Since it does not know exactly the total number of elements in the former definition, garbage values may be stored in some more locations adjacent to the array elements, which can create problems. Some compilers will cause a run time error, if the array has been declared as **a. Therefore, it would be better to specify the dimension of the array as given in the above two examples.

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11.3 CHAIN OF POINTERS/ARRAY OF POINTERS

NOTES

We had discussed that a pointer to a one-dimensional array can be denoted as **b* and two-dimensional array can be denoted as ***b*. In this section, an array of pointers will be discussed.

Case Study: Sorting Character Strings

As you know, names of students in a class can be denoted by a two dimensional array like b[50][20], with the second subscript denoting the width of the names and the first 50 denoting the number of students. There may be insufficient space for names longer than 20 characters, leading to truncation. If the name is short it will lead to wastage of space. By using an array of pointers, we can declare char * name [50] as an array to store the names of 50 students. The number of students in a class is definitely known. Here, name is an array and points to character. Thus, it is an array of pointers. Actually what happens is that 50 addresses are stored in the array name [50], name [0] corresponds to the address of first name, name [1] to the address of second name and so on. Using this concept a program is developed to sort names. It is given below:

Example 11.5 – For sorting character strings.

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#define N 5   /*5 names sorted*/
int main()
{
   int ret,i,j,p=0;
   char *name[N], t[50];
   for(i=0;i<N;i++)
   {
      printf("Enter name size\n");
      scanf("%d", &p);
      name[i]=(char *)(malloc(p*1));
      printf("Enter name\n");
      scanf("%s",name[i]);
   }
   for(i=0;i<N-1;i++)
   for(j=i+1;j<N;j++)
   {
      ret=strcmp(name[j],name[i]);
      if (ret<0)
      {
         strcpy(t,name[i]);
         strcpy(name[i],name[j]);
         strcpy(name[j],t);
      }
   }
   printf("\nSorted Names Are :\n");
   for(i=0;i<N;i++)
```

```
        printf("%s\n",name[i]);
}
```

Result of program

```
Enter name size
5
Enter name
Raman
Enter name size
5
Enter name
Gopal
Enter name size
6
Enter name
Sharma
Enter name size
7
Enter name
Ramanan
Enter name size
4
Enter name
Basu
Sorted Names Are :
Basu
Gopal
Raman
Ramanan
Sharma
```

Here, the user is asked to first enter the number of characters in a name to be entered. After that the name is entered. This helps in allocating the right size to each name, no space more, no space less.

We call *strcmp* and pass references to names being compared. The function *strcmp* returns 0 if strings are equal; <0 if string 1 is less than string 2 in ASCII value; >0 if string 1 is greater than string 2. Thus, names will be exchanged if **name*[*j*] is less than **name*[*i*]. The string comparison starts from the first character of each word. If they are equal it will go to the next character and so on, till they are unequal or *NULL* is reached in either of them. Then the difference in the ASCII values of the characters compared last is returned. This is what we wanted in arranging the names alphabetically. Key in the program and you will find that it works correctly.

Pointers to functions

We have discussed various aspects of pointers such as pointers to variables, functions returning pointers, etc. What then, is a pointer to a function? Consider the following programs.

NOTES

NOTES

```
#include <stdio.h>
int main()
{  char y='a';
   void func (  char z);
   void (*fp) (   char x);
   fp = func ;
   (*fp) (y) ;
   }
   void func (  char x)
   { ...
}
```

A perusal of the above program indicates that the address of *func* is assigned to the function pointer *fp*. While calling the function, (*fp) (y) is used. Thus fp gets the address of *func,* indicating that functions also have addresses. Such function pointers are used in searching and memory resident programs.

11.4 POINTER INCREMENTS AND SCALE FACTORS/POINTER COMPARISON

The addresses or pointers can be stepped up or stepped down. For instance,

float *fp;

float f;

fp = &f;

fp++;

If the original address of *fp* was 1000, fp++ will take the pointer to 1004, since it is a float pointer.

What happens when *fp* = fp + 2; is executed? It will skip two locations or eight locations. You can verify this yourself.

Similarly, *fp* = fp – 4; is also valid. Two pointers of the same type can be compared also. Assuming that we declare float * fp1.

Then we can compare their relationship with *if* statements given below:

if (fp == fp1) ...

or if (fp < fp1) ...

Thus when we say we are comparing pointers, we are comparing their addresses.

Check Your Progress

1. Define call by reference.
2. What does ** indicate?
3. What will the function `goto xy (x, y)` do?

11.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

NOTES

1. The function call using pointers is known as call by reference. Here the address of the variable is passed. Note that calling by reference has to be indicated in the function declaration such as these:

```
fun (int *p, char *cp, float *fp, int *array);
```

2. ** indicates pointer to pointer. This is acceptable since the row pointers in turn point to the column pointers.
3. The function `goto xy (x, y)` makes the cursor go to the point `(x, y)` on the screen.

11.6 SUMMARY

- The function call using pointers is known as 'call by reference'. Here, the address of the variable is passed.
- While calling by reference, we have to pass the address of the variable. If the variable is declared by value such as int a, then we have to pass &a. If it was declared as a pointer to say, an integer such as int * ip, then ip has to be passed.
- We had discussed that a pointer to a one-dimensional array can be denoted as*b and two-dimensional array can be denoted as **b.
- The addresses or pointers can be stepped up or stepped down.
- When we say we are comparing pointers, we are comparing their addresses.

11.7 KEY WORDS

- **Null pointer:** It is a type of pointer of any data type and generally takes a value as zero. It can also take any pointer type, but do not point to any valid reference or memory address. It is different from a pointer that is not initialized.
- **`gotoxy(x,y)`:** It is a library function and is used in advanced programming to direct the cursor to go to the point (`x,y`) on the screen.

11.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

NOTES

Short Answer Questions

1. Write the syntax for declaring the pointer function.
2. Discuss the pointer notation for arrays.

Long Answer Questions

1. Write a program that illustrate the call by reference using pointers.
2. Write a program to access arrays using pointers.
3. Write a program for sorting character strings using pointers.

11.9 FURTHER READINGS

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UNIT 12 STRINGS WITH POINTER

NOTES

Structure

12.0 INTRODUCTION

In this unit, you will learn about the pointer and character strings. A String is a sequence of characters stored in an array. Strings can also be declared using pointers. You will learn about dynamic memory allocation and structures pointers. Static allocation of memory in case of arrays through dimension leads either to excessive allocation or short allocation. This can be managed by dynamically allocating memory at run-time through the functions namely `malloc()` and `calloc()`. The memory allocated using these functions can be freed, when it is not required using the function `free()`.

12.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the concept of pointer and strings
- Explain dynamic allocation of memory
- Define structure pointers

12.2 POINTERS AND CHRACTER STRINGS

It is amply clear that a string is an array of characters. Since we have seen an array of numbers, we may want to represent a string in the same manner. We can initialize a string as given below:

```
char        str [ ] = { 'c', 'h', 'a', 'r' };
```

This is absolutely correct. At the end of every string a NULL character '\0' is automatically inserted. However, strings can be written very easily as given below:

char **str = "char";* The compiler accepts it when it is a string. *str[0]* is the address of the 0th location of str. Since the character array is stored contiguously,

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there is no need to know the address of each element. A program to find the length of a string is given below:

Example 12.1 To find the length of a string.

```
#include <stdio.h>
int main()
{
   int wlength;
   char *wp =”shri durgaya namaha”;
   int wlen(char *wp);
   wlength=wlen(wp);
   printf(“length of the word=%d”,wlength);
}
/*function to find length*/
int wlen(char *w)
{
   int n;
   for (n=0; *w!=’\0’; w++)
       n++;
   return n;
}
```

Result of program

```
length of the word=19
```

We have a library function *strlen()* to find the length of the string. This program carries out the same task although *strlen()* could be used to find the length of any string. The program serves to illustrate the concept of strings and pointers easily. It prints the length of the string in terms of the number of characters. The white spaces in between will also be counted.

We have initialized **wp* while declaring it as a pointer to a character. The compiler will not normally accept such initialization, but makes an exception for strings, since there is no anomaly as to whether the initialization is for the value or the address, as a string cannot be an address, unlike an integer.

Note the statements in the function. The address as well as n are incremented when the **w* is not NULL. NULL indicates the end of string since NULL will be appended to all the strings. When *w* points to NULL, there will be no further increment of *w* as well as *n*. Therefore, *n* indicates the length of the string *wp*; *n* is returned to the main function. You will notice that just by incrementing the address, we can scan the string.

The same program to find length of string is modified and shown below:

Example 12.2- Alternate method to find the length of a string.

```
#include <stdio.h>
int main()
{
   int wlength;
   char *wp=”shri durgaya namaha”;
   int wlen(char *wp);
   wlength=wlen(wp);
```

```
    printf("length of the word=%d",wlength);
}
/*function to find length*/
int wlen(char *w)
{
    char *p = w;
    while (*p!='\0')
        p++;
    return p-w;
}
```

You get the same result.

Here, the address *w* is assigned to *p* through the assignment and declaration statement in the called function. Hence, *p* also points to the same string that is *p* points to the first character in the word. When *p* points to the first character or 0th element *p* is incremented to the 1st location. When *p* points to the $(n\text{-}1)^{th}$ element, *p* is incremented to n^{th} location. Here, only *p* is incremented, not *w*. It continues to point to the 0th location. Therefore at the time of termination of while loop, *p* will point to the location corresponding to NULL. Thus *p* - *w*, i.e., the difference in the addresses that is equal to the number of characters in *wp*, is returned to the main function and printed there.

Case Study: To Print a Substring

Let us write a function to print a substring of given length and starting position. This is illustrated in Example 12.3.

Example 12.3 Gets substring beginning with specified character position.

```
#include <stdio.h>
#include <string.h>
void substring(char *str,char *substr,int len);
int main()
{
    char text[80],substr[20];
    int len,pos;
    printf("Enter any Text :");
    gets(text);
    printf("Enter the Length of Substring Required :");
    scanf("%d",&len);
    printf("Enter the Position From which Required :");
    scanf("%d",&pos);
    substring(text+(pos-1),substr,len);
    printf("Substring Is %s \n",substr);
}
void substring(char *str,char *substr,int len)
{
    int cnt=0;
    while(*str &&cnt <len)
    {
        *(substr++)=*(str++);
        cnt++;
    }
```

```
*(substr)=0;
}
```

Result of program

NOTES

```
Enter any Text :This is a program to get a substring
Enter the Length of Substring Required :7
Enter the Position From which Required :11
Substring Is program
```

Try to understand how the program works. The following statement, which is a call to the function, needs explanation.

substring(text+(pos-1),substr,len);

Usually we count the first character of a word as the 1st position, whereas C will recognize it as the 0th position. *text* points to the address of the 0th position of the *text.* Therefore, *text+(pos-1)* points to the address of the character in text from which the substring starts.

Although *substr* is empty, we are passing the address of the 0th location of the substring as the next argument. We will store the substring in *substr,* which is empty when it is passed to the called function.

The third argument is the length of the substring.

Now look at the called function:

In the *while* loop we carry out the following operations:

Copy *(str)* to *substr*, i.e., from the starting position indicated by the user, copy one character of text to substring

Increment *str*

Increment *substr*

Increment local counter *cnt*

Copying will terminate either on finding no characters in *str* or when the required number of characters have been copied

Thus, the program works correctly.

Note the following features:

Since the strings are passed by reference, there is no need to return the addresses or values, as the addresses of strings are known to the main function.

12.3 DYNAMIC ALLOCATION OF MEMORY

The dimension or array size declaration of an array is an important subject. The array dimension is to be declared before compiling. For example, some valid declarations are:

```
char name[25];
int mark[40];
```

You have not come across any problem since you were initializing the arrays and hence, the array size was known. If you were to get the array elements at run-

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time, sometimes you could give either a lesser number of elements or more elements. In the former case, garbage values will be stored in the empty spaces in the array misleading the user. In the latter case, the elements will be lost. To avoid this problem, you may think that you can specify `marks [n]` and give the value of `n` later at run-time. However, this will not work, and the compiler will force you to give the actual dimension. Hence, dynamic memory allocation is useful. `malloc` and `calloc` serve to specify the actual dimension at run-time and hence, enable memory allocation dynamically. Next time when you execute the program, you can specify any value for `n`. It will definitely work.

The functions `malloc()` and `calloc()` allot memory dynamically. The specifications are given below in the following statement.

```
void * malloc (n*size n );
```

It returns the pointer to n bytes of the memory or NULL if allotment is not possible. Since it returns a pointer you have to specify the array as a pointer variable as given below:

```
int *b ; / * array declared * /
b = (int *) malloc (x * 2) ;    / * x is the array size * /
```

Similarly the `calloc` is defined as `void * calloc (sizen, size_size)`. Here the number of arguments is two. The first one is the array size and the second one is the bytes occupied per element, i.e., the storage space required for the data type. The function returns a pointer allocating space for an array of size `sizen`, of data type size `size`, but the array contents will be initialized to zero. In `malloc`, the initial contents will be garbage values. You can use it as follows:

```
int * b;
b = (int *) calloc (x, 4);
```

Here 4 indicates the array is of type `float` and space is allocated to store `x floats`. When you use `calloc` or `malloc`, you must include `alloc.h`.

A program to demonstrate `malloc` and `calloc` is as follows:

Program 12.4 To do string concatenation by using dynamic allocation of memory.

```
#include <stdio.h>
#include <alloc.h>
#include <string.h>
main()
{
    char *newstrcat(char *dest, char *src);
    char *name1, *name2;
    int n1, n2;
    printf("Enter size of 2 names:\n");
```

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```
    scanf("%d%d", &n1, &n2);
    name1 = (char *) calloc(n1, 1);
    name2 = (char *) calloc(n2, 1);
    printf("Enter 2 names\n");
    scanf("%s%s", name1, name2);
    printf("New name:%s\n",newstrcat(name1,name2));
}
char *newstrcat(char *dest, char *src)
{
    char *w;
    int i,len,len1,cnt=0;
    len=strlen(dest);
    len1=strlen(src);
    w=(char *)malloc(len+len1+1);
    for(i=0;i<len;i++)
       w[cnt++]=dest[i];
    for(i=0;i<len1;i++)
       w[cnt++]=src[i];
       w[cnt]=0;
    return(w);
}
```

Result of the program

```
Enter size of 2 names:
4 4
Enter 2 names
Rama samy
New name:Ramasamy
```

`calloc` is used to allot memory to `name1` and `name2`. The function `newstrcat` is called while printing. In the called function, `malloc` is used to allot space equal to the size of `name1, name2 +1`. The additional space is for placing NULL. The string is concatenated by copying one character at a time using two `for` statements. Finally, the concatenated string is returned to the main function where it is printed.

The memory allocated using `malloc, calloc` can also be freed, when it is no longer necessary by using the function `free()`. For example, in the `main ()` of the above example, after the last statement you can add the following statements:

```
free(name1);
free(name2);
```

These statements will deallocate the memory space allocated to them after the job of printing the concatenated string is over. Thus, dynamic allocation of the

memory according to the exact need and freeing it after use is quite useful for conserving the memory. This concept is used by professional programmers when they develop commercial software products. Memory saved is more than money saved in such product development.

12.4 POINTERS AND STRUCTURES

You know how to declare pointers to various datatypes and arrays. Similarly, pointers to structures can also be declared. For instance, in the case of the structure `account`, you can declare a pointer as follows:

```
struct account a1 = { 1, "Vasu", 1000 };
struct account * sp;
struct sp = &a1 ;
```

Now, `sp` is a pointer to structure. Therefore, if you assume structure as another basic datatype, declaring it as an array and declaring it as a pointer, etc. follow the same rules. Structure is in fact, a user defined datatype.

Access to individual elements of a structure defined in the form of a pointer is similar but instead of dot, we use an arrow pointer ->. Arrow pointer is formed by typing minus followed by the greater sign. However, on to the left of the arrow operator, there must be a pointer to a structure. The following example will clarify the point:

```
/*Example 12.5- structure pointers */
#include<stdio.h>
int main()
{
   struct account
   {
     unsigned number;
     char name[15];
     int balance;
   }a5;
   static struct account a1= {001, "VASU", 1000};
   struct account *sp;
   sp=&a1;
   printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
   sp->number, sp->name, sp->balance);
   a5=*sp;
   printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
   a5.number, a5.name, a5.balance);
}
```

Result of the program

```
A/c No:=1 Name:=VASU Balance:=1000
A/c No:=1 Name:=VASU Balance:=1000
```

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In this program, `sp` is a pointer to **structure `account`** and therefore, `sp` is assigned the address of structure `a1`. Then, the contents of structure *sp are printed. The elements of `*sp` are copied to `a5` and then, printed (to demonstrate copying of structures). Note the difference between the notations when accessing elements of a structure and a structure pointer.

Passing Structure by Reference

Structures can be passed by reference. Remember however, that the structure should be defined as a global variable. The following passes structure by reference and withdrawal of money is processed in the called function.

```
/*Example 12.6 - structure pointers & functions*/
    #include<stdio.h>
    struct account
       {
        unsigned number;
        char name[15];
        int balance;
       };
    int main()
    {
       static struct account a1={001, "VASU", 1000};
       struct account debit(struct account *sp, int y);
       int deb;
       printf("Enter amount to be withdrawn");
       scanf("%d", &deb);
       debit(&a1, deb);
       printf("A/c No:=%u\t Name:=%s\t Balance:=%d\n",
       a1.number, a1.name, a1.balance);
    }
    struct account debit(struct account *x, int y)
    {
       x->balance-=y;
       return *x;
    }
```

Result of the program

```
Enter amount to be withdrawn299
A/c No:=1 Name:=VASU Balance:=701
```

Note that the address of `a1` is passed. The prototype declares passing structure by reference and the amount of debit by value. In the called program,

debit is adjusted. Note the pointer notation in subtracting the debit amount from the balance.

Now, look at some more examples to understand structure pointers but before that you must know now to allocate dynamic memory allocation for structures.

Let us say, `struct cycle * cp`; then to allocate memory dynamically, we can write:

```
cp = (struct cycle *) malloc (sizeof (struct cycle) * n));
```

- n is the number of structure variables of type `struct cycle`.

In the above, you have treated structure similar to other datatype. The size of the structure is not fixed like basic datatype. However, you can use the `sizeof` operator to get the size of the structure variable.

Check Your Progress

1. Why is `strlen()` function used?
2. How is a memory allocated dynamically?
3. Write the specifications for `malloc()` and `calloc()` memory allocation.

12.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Library function `strlen()` could be used to find the length of any `string`.
2. `malloc` and `calloc` serves to specify the actual dimension at run-time and hence, enable memory allocation dynamically.
3. The functions `malloc()` and `calloc()` allot memory dynamically. The specifications are given below in the following statements.

```
void * malloc (n*size n)
void * calloc (sizen, size-size)
```

12.6 SUMMARY

- At the end of every string a NULL character '\0' is automatically inserted.
- We have a library function `strlen` () to find the length of the string.
- NULL indicates the end of string since NULL will be appended to all the strings.
- `malloc` and `calloc` serve to specify the actual dimension at run-time and hence, enable memory allocation dynamically.

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- The memory allocated using `malloc, calloc` can also be freed, when it is no longer necessary by using the function `free ( )`.
- Access to individual elements of a structure defined in the form of a pointer is similar but instead of dot, we use an arrow pointer →. Arrow pointer is formed by typing minus followed by the greater sign.
- Structures can be passed by reference.

12.7 KEY WORDS

- **`Strlen ()`**: It is a function that returns the length of the given string.
- **`Calloc ():`** It is a function that allocate the multiple blocks of memory dynamically.

12.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. State whether True or False and give reasons:
   (a) In call by value, the values of arguments are actually passed.
   (b) The pointer contains the address of a variable.
   (c) Float pointer is of type `float`.
   (d) `*var = 100`; assigns 100 to `*var`.
   (e) `char *fun();` is not a valid declaration.
   (f) A pointer can be assigned to another pointer.
   (g) The variables declared in the function declaration in the calling function can be used in it later.
   (h) `* (p2 + 0)` is valid.
   (i) `malloc` stores zeros in the allotted memory locations initially.
   (j) Pointers to functions denote the address of function.
2. What is printed in each of the print statements given below, if they are executed one after another? After evaluation, confirm your answers by trying it in a program.

   Declaration:

   ```
   * np = 10;
   ```

   `printf()` statement arguments:

   (a) `np`
   (b) `*np`
   (c) `np`

(d) `np++`

(e) `np = np - 2`

(f) `*np ++`

(g) `np++`

(h) `*np++`

(i) `++np`

(j) `*np`

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Long Answer Questions

1. Describe the following with the help of examples:
   (a) Pointer arithmetic.
   (b) Pointers and two-dimensional arrays.
   (c) Advantage and operation of:
      (i) `malloc`
      (ii) `calloc`
   (d) String functions.
   (e) Call by reference and similarity with global variables.
2. Write programs for the following:
   (a) A function `nstrcmp` to compare string `cs` to string `ct`; return `<0 if cs <ct`, `0 if cs = = c or >0 if cs > ct.`
   (b) A function to check whether characters `+, –, *, /` present in a string.
   (c) To find the k_{th} smallest element in an array using pointers.
   (d) To check whether a string is palindrome.
   (e) To reverse a number using pointers.

12.9 FURTHER READINGS

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BLOCK - V

FILES

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UNIT 13 INTRODUCTION TO FILES

Structure

13.0 INTRODUCTION

In this unit, you will learn about data files. In C programming, you include `<stdio.h>`: a file essential for any program to read from a standard input device or to write to a standard output device. It has declaration pointers to three files, namely `stdin`, `stdout` and `stderr` which means that the contents of these files are added to the program, when the program executes. In this unit, you will learn how to use either the hard disk drive or the floppy disk drive as the input/output medium. In day-to-day usage of large applications, the standard input/output is neither convenient nor adequate to handle large volumes of data and hence, the disk drives only serve as Input/Output (I/O) devices. You will also learn about the usage of files for storing data, popularly known as data files. Data files stored in the secondary or auxiliary storage devices, such as hard disk drives or floppy disks, are permanent unless deleted. In contrast, what is written to the monitor is only for immediate use. The data stored in disk drives can be accessed later and modified, if necessary. Further, in this unit, you will learn about file pointers, binary mode and text mode operations, reading a data file and processing a data file.

13.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the basic concept of data files
- Explain the significance of file pointers

- Discuss the steps to open and close a data file
- Understand the importance of binary files
- Understand formatted I/O operations with files
- Discuss how to write and read a data file
- Identify unformatted data files
- Know how to process a data file

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13.2 INTRODUCTION TO FILES

We have been including program files in our programs. We have been including <*stdio.h*> ritually in every file. This file is essential for any program to read from standard input device or to write to the standard output device. The file <*stdio.h*> has declarations to the pointers to three files, namely *stdin*, *stdout* and *stderr*. It means that the contents of these files are added to the program when the program executes. Each of the files performs an essential task as given below:

(a) *stdin* facilitates usage of the standard input device for program execution, and normally points to the keyboard which is the default input device.

(b) *stdout* facilitates the usage of a standard output device where program output is displayed, and points to the video monitor.

(c) *stderr* facilitates sending error messages to the standard device that is again the monitor.

The *stdin*, *stdout* and *stderr* are pointers or file pointers and are declared in <*stdio.h*>. So far we have been using *stdin* and *stdout* for input and output. In this chapter we will learn to use either the hard disk drive (including other storage media such as USB, CD, Tape Drive etc.) or the floppy disk drive as the input/output medium. In day to day usage of large applications the standard input/output is neither convenient nor adequate to handle large volumes of data and hence the disk drives only serve as I/O devices. We will discuss the usage of files for storing data, popularly known as data files. Data files stored in secondary or auxiliary storage devices such as hard disk drives or floppy disks are permanent unless deleted. In contrast, what is written to monitor is only for immediate use. The data stored in disk drives can be accessed later and modified, if necessary.

In "C", we come across two types of files:

1. Stream oriented
2. System oriented.

System oriented files or low level files are more closely related to the operating system and hence require more complex programming skills to use them. They may be found to be more efficient than the former in some cases, but we will not discuss them further because of their complexity. Instead, we will discuss stream oriented files only in this chapter.

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Stream oriented files are also called standard files. Data can be stored in standard files in two ways as given below:

- Storing characters or numerals consecutively. Each character is interpreted as an individual data item.
- The data items are arranged in blocks in an unformatted manner. Each block may be an array or a structure.

Let us see how disk I/O is organized. If the file is stored in a floppy or hard disk drive, the following actions are involved in reading from the file:

- finding out where the data is
- positioning the head over the correct location on the disk
- reading the content
- transmitting to the main memory.

Similar activities are involved in writing to a disk as well. If the computer, or more specifically the operating system which handles files in a computer, reads or writes one character at a time comprising of the 4 steps listed above, then it will be uninteresting, and the response will be too slow. It may cause wear out of the storage system quickly. Therefore it would be better to receive large volumes of data or characters to a buffer in the computer system and then perform whatever actions are dictated by the program. Similarly, all characters to be written can be collected in a buffer and written on to the disk, either after the buffer is full, or after the operation is completed. This will minimize the overheads required for read or write operations. The buffer is also memory which is used to store data temporarily without the knowledge of the user. In fact we created a buffer and stored values into it before printing them using the *sprintf* function. The concept is similar here also. This is a good practice. Therefore the characters are read or written through a buffer assigned by the system. The operations are essentially performed as depicted pictorially below:

What is a file pointer? It is a pointer to a file, just like other pointers to arrays, structures etc. It points to a structure that contains information about the file. The information connected with a file is as given below:

- location of the buffer.
- the position in the file of the character currently being pointed to.
- whether the file is being read or written.
- whether an error has occurred or the end of the file has been reached.

We don't need to know the details of these because *stdio.h* handles it elegantly. There is a structure with *typedef FILE* in *stdio.h* which handles all file

related tasks as above, whether it is in the floppy or the hard disk drive. Therefore in order to use a file without difficulty, we have to include *stdio.h* and declare a file pointer which points to *FILE* as given below:

*FILE * fp*;

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Therefore the file pointer points to a structure which contains information about the file management functions. When we open a file, and the opening of the file is successful, the file pointer will point to the first character in the file. In other words, the file gets opened and loaded to the buffer. NULL is a macro defined in *stdio.h* which indicates that file open has failed. Therefore, when file open is successful the file pointer will point to the address of the buffer which will be a non-zero integer value. If not, the file pointer will get a value of NULL which is 0.

The file pointer will point to the next character after the first one is fetched or copied on to the system. The structure *FILE* keeps track of where the pointer remains at any point in time after opening the file. It keeps track of which files are being used. It also knows whether the file is empty, the end of the file has been reached or an error has occurred. We don't have to worry about file management tasks once a file pointer has been declared in our program to point to *FILE*. Since *FILE* is known to <*stdio.h*>, we do not have to bother about it. This declaration of structure *FILE* has relieved the programmer from most of the mundane jobs.

13.3 OPENING AND CLOSING FILES

Files are formats that save data for future use. Any file has to be opened for any further processing, such as reading, writing or appending, i.e., writing at the end of the file. The characters will be written or read one after another from the beginning to the end, unless otherwise specified. You have to open the file and assign the file pointer to take care of further operations. Hence, you can declare,

```
FILE * fp;
fp = fopen ("filename", "r");
```

`Filename` is the name of the file, which you want to open. You must give the path name correctly so that the file can be opened. `'r'` indicates that the file has to be opened for reading purposes.

`fp = fopen ("Ex1.C", "r");` will enable opening file `Ex1.C`.

Therefore, the arguments to `fopen()` are the name of the file and the mode character. Obviously `w` is for write, `a` for append, i.e., adding at the end of the file. If these characters are specified, the operations as indicated can be performed after opening the file. It is, therefore, essential to indicate the operations to be performed before opening the file. When the file is opened in the `'w'` mode, the data will be written to the file from the beginning. This means that if the named file is already in existence, the previous contents will be lost due to overwriting. If

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the file does not exist, then a file with the assigned name will be opened. When the append mode is specified, the writing will start after the last entry, or in other words, previous contents of the file will be preserved.

`FILE` provides the link between the operating system and the program currently being executed. `FILE` is a structure containing information about the corresponding files, including information such as:

- The location of the file
- The location of the buffer
- The size of the file

After the command is executed in the read mode, the file will be loaded into the buffer if it is present. If the file is absent, or the file specification is not correct, then the file will not be opened. If the opening of the file is successful, the pointer will point to the first character in the file, and if not, NULL is returned, meaning that the access is not successful. The `fopen()` function returns a pointer to the starting address of the buffer area associated with the file and assigns it to the file pointer, `fp` in this case.

After the operations are completed, the file has to be closed. The syntax for closing file is given below:

```
fclose(filepointer);
```

`fclose()` also flushes or empties the buffer. The function `fputc()` performs putting one character into a file. If for every `fputc()`, the computer prints a character to a file, then it will get tired. Therefore, it collects all the characters to be written onto a file in the buffer. When the buffer is full or when `fclose()` is executed, the buffer is emptied by writing to the hard disc drive in the assigned file name.

Concept of Binary Files

You can open files in the text mode or the binary mode. In the binary, data will be stored in the binary form and the storage space will be equal to the number of bytes required for the storage of various data types. In the text mode, they will be stored as alphanumeric characters. If you require to use the file in the binary mode, you must use `'rb'` for reading, `'wb'` for writing, and `'ab'` for appending. If you want to store data in the text mode, you have to append *t* to the mode character as `'rt'`, `'wt'`, `'at'`, etc. Since the default is in the text mode, `t` will be assumed if nothing is specified after the mode character. Therefore, mode `'w'` means opening a text file for writing.

The difference between opening files in the binary mode and the text mode are given in Table 13.1.

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Table 13.1 *Difference between Binary Mode and Text Mode Operations*

Text Mode	Binary Mode
New line character (\n) is converted to CR|LF combination while writing to file.	No such conversion.
While reading, CR|LF is converted back to \n.	Does not arise.
A special character is inserted at the end of the file. While reading the file, EOF is detected.	There is no such arrangement.
Text mode needs more than the 2 bytes for storing an integer, since it treats each digit as a character. e.g., 30,000 needs 5 bytes.	In binary mode the numbers will be stored in the specified width. 30000 needs 2 bytes only.

Therefore, binary files and text files are to be processed taking into account their properties as above, although the file could be opened in any mode. The file I/O functions, such as `fgetc`, `fputc`, `fscanf`, `fprintf`, `fgets`, `fputs`, are applicable to the operations in any of the modes.

The files can be used to store employee records using structures in a payroll program. Book records can be stored in a file in a library database. Inventories can be stored in a file. However, storing all these in the text mode will consume more space on the file. Hence, the binary mode can be used to create the files. Some files cannot be stored in the text mode at all, such as executable files.

13.4 I/O OPERATIONS ON FILES

You are familiar with reading and writing. So far you were reading from and writing to standard input/output. Therefore, you used functions for the formatted I/O with `stdio` such as `scanf()` and `printf()`. We also used unformatted I/O such as `getch()`, `putch()` and other statements. When dealing with files, there are similar functions for I/O. The functions `getc()`, `fgetc()`, `fputc()` and `putc()` are unformatted file I/O functions similar to `getch()` and `putch()`. You will consider the formatted file operations in this section. When it pertains to standard input or output, you use `scanf()` and `printf()`. To handle formatted I/O with files, you have to use `fscanf()` and `fprintf()`.

You can write numbers, characters, etc. to the file using **`fprintf()`**. This helps in writing to the file neatly with a proper format. In fact, any output can be directed to a file instead of the monitor. However, you have to indicate which file you are writing to by giving the file pointer. The following syntax has to be followed for `fprintf()`:

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```
fprintf (filepointer, "format specifier", variable names);
```

You are only adding the file pointer as one of the parameters before the format specifier. This is similar to `sprintf()`, which helps in writing to a buffer. In the case of `sprintf()`, buffer was a pointer to a string variable. Here, instead of a pointer to a string variable, a pointer to a file is given in the `fprintf()` statement. Like the string pointer in `sprintf()`, the file pointer should have been declared in the function and should be pointing to the file.

Before writing to a file, the file must be opened in the write mode. You can declare the following:

```
FILE * fp ;
fp = fopen ("filename", "wb");
```

You have to write `wb` within double quotes for opening a file for writing in the binary mode. Therefore, `fopen()` searches the named file. If the file is found, it starts writing. Obviously the previous contents will be lost. If a file is not found, a new file will be created. If unable to open a file for writing, NULL will be returned.

You can also append data to the file after the existing contents. In this manner, we will be able to preserve the contents of a file. However, when you open the file in the append mode, and the file is not present, a new file will be opened. If a file is present, then writing is carried out from the current end of the file. After writing is completed either in the write mode or the append mode, a special character will be automatically included at the end of the text in case of text files. In case of binary files, no special character will be appended. This can be read back as EOF. Usually it is – 1, but it is implementation-dependent. Hence, it is safer to use EOF to check the end of the text files.

Reading and Writing

Let us look at a program to write numbers to a binary file using `fprintf()` and then read from the file using `fscanf()`.

Example 13.1 - Writing digits to a binary file and then reading.

```
#include<stdio.h>
int main()
{
    int alpha,i;
    FILE *fp;
    fp=fopen("ss.doc","wb");
    if(fp==NULL)
       printf("could not open file\n");
    else
    {
       for (i=0; i<=99; i++)
```

```
            fprintf(fp," %d", i);
            fclose(fp);
            /*now read the contents*/
            fp=fopen("ss.doc","rb");
         for (i=0; i<100; i++)
         {
            fscanf(fp,"%d", &alpha);
            printf(" %d", alpha);
         }
         fclose (fp);
      }
   }
```

Result of the program

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

What does the program do?

(a) The file `ss.doc` is opened in the binary mode for writing. If the opening of the file was not successful, the message will be displayed and program execution will stop. If successful, the program will enter the `else` block. Numbers 0 to 99 are generated one after another and written then and there to the file using the `fprintf()` function. There should be space before `%d` as shown in `fprintf()`, otherwise the program may not work.

(b) The file is closed using `fclose()`.

(c) Now the same file is opened for reading in the binary mode.

(d) Next the text is scanned using `fscanf()`, one at a time, and written on the monitor using simple `printf()`. The difference between `scanf()` and `fscanf()` is the specification of the file pointer before the format specifier.

(e) After reading, the file is closed.

The result of the program is read from the file `ss.doc` and printed on the monitor.

In all the programs involving files, a similar check to see that file opening was successful should be made. For the sake of improved readability, this statement has been skipped in the rest of the programs.

Let us look at one more example of writing, appending and then reading one integer at a time with the help of the `for` loop. Look at the following program.

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Example 13.2 – writing, then appending digits to a file and then reading.

```
#include<stdio.h>
int main()
{
    int alpha,i;
    FILE *fp;
    fp=fopen("ss.doc","wb");
    for (i=0; i<20; i++)
       fprintf(fp," %d", i);
       fclose(fp);
       fp=fopen("ss.doc","ab");
    for (i=20; i<100; i++)
       fprintf(fp," %d", i);
       fclose(fp);
    /*now read the contents*/
    fp=fopen("ss.doc","rb");
    for (i=0; i<100; i++)
    {
       fscanf(fp,"%d", &alpha);
       printf(" %d", alpha);
    }
    fclose (fp);
}
```

Result of the program

The result will be same as Example 13.1.

A binary file is opened in the write mode, and digits from 0 to 19 are written on to the file. The file is then closed using `fclose()`. The same file is opened in the append mode again, and numbers from 20 to 99 are appended to the file. After the file is closed, the file is opened in the read mode. The contents of the file are read using `fscanf()` and written to the monitor. Remember to leave a space before `%d` in `fprintf()` as otherwise you may have a problem. The file is closed again. We have used the same file pointer, since at any time only one file is in use. If more than one file is to be kept open simultaneously, it may call for multiple pointers.

Unformatted data files

After having worked with the formatted I/O, let us now look at the unformatted I/O. If you want to read a character from the file, you can use the `getc()` or `fgetc()` functions. If `alpha` is the name of the character variable, you can write,

```
alpha = fgetc (fp);
```

NOTES

This means the character pointed to by fp is read and assigned to alpha. You can go to the help screen of the 'C' language system to get more details as well as search for help on any of the library functions. The help screen gives the syntax of the functions and also provides examples in which the function or command is used. Even after reading this book or any other book on 'C', you will not be able to use all the functions. Hence, the best way is to take the help from the help screen whenever other functions are to be used.

fgetc() reads the character pointed to by fp. It then increments fp so that fp points to the next character. We can keep on incrementing fp till the end of file, i.e., end of data is reached. When a file is created in the text mode, the system inserts a special character at the end of the text. Therefore, while reading a file, when the last character has been read and the end of the file is reached, EOF is returned by the file pointer. The following program reads one character at a time till EOF is reached from an already created text file, ss.doc. The program is implemented using the do...while statement.

Example 13.3 - reading characters from a file.

```
#include<stdio.h>
int main()
{
    int alpha;
    FILE *fp;
    fp=fopen("ss.doc","r");
    do
    {
       alpha=fgetc(fp);
       putchar(alpha);
    }while(alpha!=EOF);
    fclose (fp);
}
```

Result of the program

Since file ss.doc is read, the output will be same as Example 13.1, if no change has been made in the file. If we were to read from a binary file, EOF may not be recognized. Therefore, a counter can be set up to read a predefined number of characters as given in the previous examples.

Processing a data file

File Copy

File copy can be achieved by reading one character at a time and writing to another file either in the write mode or the append mode. Here it is proposed to read from

a file and write to two different files, one in the write mode and another in the append mode. This means you have to open three files in the following manner:

```
FILE * fr, *fw; *fa;
```

NOTES

You can assign three file pointers as given above. Three files are then opened. You can use any name for the file pointers and there may be as many file pointers as the number of files to be used. The program is as follows:

Example 13.4 - reading from file ss, writing to file ws and appending to file as, all at a time.

```
#include <stdio.h>
int main()
{
    int alpha;
    FILE *fr,*fw, *fa;
    fr=fopen("ss.doc", "r");
    fw=fopen("ws.doc", "w");
    fa=fopen("as.doc", "a");
    do
    {
       alpha=fgetc(fr);
       fputc(alpha, fw);
       fputc(alpha, fa);
       putchar(alpha);
    }while(alpha!=EOF);
    fclose (fr);
    fclose (fw);
    fclose (fa);
}
```

After opening the three files, `alpha()` gets the character, which is written to both the files using `fputc()`, and the character is also displayed on the screen. This is continued till EOF is received in `alpha` from `ss.doc`, the source file.

Finally, the files are closed. Verify that your program has worked alright.

Since, you are also writing to the monitor, in addition to writing and appending to files, the program output appears as follows.

Result of the program

```
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
93 94 95 96 97 98 99
```

There are some more mode specifiers with `fopen` like `r+`, `w+` and `a+`, which are given in the table below:

Mode Specifier	Purpose
`r+`	Opens an already existing file for reading and writing.
`w+`	Opens a new file for writing as well as reading.
`a+`	Opens an already existing file for appending and reading.

NOTES

Line Input/Output

You have discussed writing to and reading from a file, one character at a time, using both the unformatted and formatted I/O for the purpose. You can also read one line at a time. This is enabled by the `fgets()` function. This is a standard library function with the following syntax:

```
Char * fgets (char * buf, int max line, FILE * fp);
```

`fgets()` reads the next line from the file pointed to by `fp` into the character array `buf`. The line means characters up to `maxline` –1, i.e., if `maxline` is 80, each execution of the function will permit reading of up to 79 characters in the next line. Here 79 is the maximum, but you can even read 10 characters at a time, if it is specified.

```
fgets(alpha, 10, fr);
```

Here `alpha` is the name of the buffer from where 10 characters are to be read at a time. The file pointer `fr` points to the file from which the line is read, and the line read is terminated with NULL. Therefore, it returns a line if available and NULL if the file is empty or an error occurs in opening the file or reading the file.

The complementary function to `fgets()` is `fputs()`. Obviously `fputs()` will write a line of text into the file. The syntax is as follows:

```
int fputs (char * buf , file * fp );
```

The contents of array `buf` are written onto the file pointed to by `fp`. It returns EOF on error and zero otherwise. Note that the execution of `fgets()` returns a line and `fputs()` returns zero after a normal operation.

The functions `gets()` and `puts()` were used with `stdio`, whereas `fgets()` and `fputs()` operate on files.

We can write a program to transfer two lines of text from the buffer to a file and then read the contents of the file to the monitor. This is shown in Example 13.5.

Example 13.5 - writing and reading lines on files.

```
#include <stdio.h>
#include<string.h>
```

NOTES

```
int main()
{
    int i;
    char alpha[80];
    FILE *fr,*fw;
    fw=fopen("ws.doc","wb");
    for(i=0; i<2; i++)
    {
       printf("Enter a line up to 80 characters\n");
       gets(alpha);
       fputs(alpha, fw);
    }
    fclose(fw);
    fr=fopen("ws.doc","rb");
    while
    (  fgets(alpha,20, fr)!=NULL)
       puts(alpha);
       fclose (fr);
}
```

Note carefully the `fgets()` statement. Here, `alpha` is the buffer with a width of 80 characters. Each line can be up to 80 characters and two lines are entered through `alpha` to `ws.doc`. Later on, 20 characters are read into `alpha` at a time from same file till NULL is returned.

Result of the program

```
Enter a line upto 80 characters
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
Enter a line upto 80 characters
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
aaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaabbbb
bbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbb
bb
```

More than 20 numbers of `a & b` were written on to the file. However, since we have specified reading 20 characters at a time. The output appears in 6 lines. Had we specified reading more characters at a time, the number of reads would have reduced. You can try this yourself.

Thus, you can read and write one line at a time.

Check Your Progress

1. What are the two types of files?
2. What are the two ways of storing data in standard files?
3. Write the syntax for creating and opening a file.
4. What are the two modes of opening a file?
5. How is a file copied?

NOTES

13.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. In "C", we come across two types of files:
    1. Stream oriented
    2. System oriented.
2. Data can be stored in standard files in two ways as given below:
    - Storing characters or numerals consecutively. Each character is interpreted as an individual data item.
    - The data items are arranged in blocks in an unformatted manner. Each block may be an array or a structure.
3. You have to open the file and assign the file pointer to take care of further operations. Hence, you can declare,

    FILE * fp;

    fp = fopen ("filename", "r");
4. Text and binary are the two modes of opening a file.
5. File copy can be achieved by reading one character at a time and writing to another file either in the write mode or the append mode.

13.6 SUMMARY

- In real life, a large volume of data will be generated and requires the use of files.
- C provides an easy way to access files. A pointer to the file has to be assigned for each file, which is to be opened, to facilitate their handling.
- Files are to be opened specifically in one of the modes such as read, write or append.
- After the operation is complete, the file has to be closed using `fclose()`.

NOTES

- Opening and closing of files cannot be assumed to take place correctly at all times. Hence, suitable error statements are to be included in the program and the file can be read one character at a time using the `fgetc()` and `fscanf()` commands.

13.7 KEY WORDS

- **`stdin`:** It facilitates usage of the standard input device for program execution
- **`stdout`:** It facilitates the usage of a standard output device where the program output is to be displayed
- **`stderr`:** It sends error messages to the standard output device
- **System oriented files or low-level files:** These are closely related to the operating system and require complex programming

13.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. How is a data file opened and closed?
2. Differentiate between text mode and binary mode.
3. What is file copy?

Long Answer Questions

1. What do you mean by formatted I/O with files?
2. Write a program to write and read a data file.
3. Write a program to copy content of one file to another.

13.9 FURTHER READINGS

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UNIT 14 ERROR HANDLING METHODS

NOTES

Structure

14.0 INTRODUCTION

In this unit, you will learn about the error handling methods during I/O operations and command line arguments. `ferror ()` function is used to detect any error during file accessing. It is possible to pass some values from the command line to your C programs when they are executed. These values are called command line arguments and many times they are important for your program especially when you want to control your program from outside instead of hard coding those values inside the code. The command line arguments are handled using `main` () function arguments.

14.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the measures to avoid errors during file processing
- Discuss the use of command line arguments

14.2 ERROR HANDLING DURING I/O OPERATIONS

When an error is encountered during file processing, the program execution will be terminated and error messages will be displayed. Following measures may be adopted to identify or avoid errors during file processing.

(i) `ferror()` function can be used to detect any error during file accessing. This function will return a zero when there is no error, otherwise it will return

NOTES

a non-zero number.

```
FILE *fptr;
if(ferror(fptr) == 0)
   printf("\n The file is available for processing");
else
   printf("\n Error in accessing the file!!!");
```

(ii) To verify whether a file exists in the disk, the following definitions will help.

```
if(fptr == NULL)
   printf("\n No content or file does not exist");
```

(iii) When data in a file may be exhausted, end of file condition will be encountered. Use the following definition to display end of file condition.

```
if(feof(fptr) == EOF)
   printf("\n End of file is reached");
```

Note that EOF is a macro which specifies the end of file condition.

Entering an invalid file name or trying to write data to a write protected disk are some of the other reasons for errors during file processing.

14.3 COMMAND LINE ARGUMENTS

This can be used to copy a file to another file. Assume that the first named file is to be copied to the second named file. You may write a program and convert it into an executable file, specifying the argument in the DOS command line.

You may specify as follows at the C> prompt:

```
C > prgname . exe f1.cpp f2.cpp.
```

This means that you want to copy the contents of `f1.cpp` to `f2.cpp`. Here, the number of arguments are 3, and therefore `argc` will contain 3.

```
*agrv[0] = prgname.exe
*agrv[1] = f1.cpp - source to copy from
*agrv[2] = f2.cpp - file where to be copied
```

A character at a time is to be fetched from `f1.cpp` and put into `f2.cpp`.

Personal file of an employee

A menu-based program to create employee records on file and calculate the age of any employee on date is given below:

Example 14.1

Create a Personal File for Employees & calculate the age of any employee ON DATE.

```
#include <stdio.h>
#include <dos.h>
#include <string.h>
#include <stdlib.h>
```

NOTES

```
#include <conio.h>
typedef struct
{
    char name[40];
    char code[5];
    char dob[9];
    char qual[40];
}employee;
    FILE *fp;
    struct date today;
int main()
{
    int create_emp();
    int calc_age();
    int ret,ch,onscrn=1;
    getdate(&today);
    printf("Today's Date Is %d/%d/%d\nIs It O.K :",
       today.da_day,today.da_mon,today.da_year);
    scanf("%c",&ch);
    onscrn=1;
    while(onscrn)
    {
       clrscr();
       printf("1: Create Employee Data File\n");
       printf("2: Calculate Age Of Employee\n");
       printf("3: Exit From Program\nEnter Your Choice :");
       scanf("%d",&ch);
       switch(ch)
       {
          case 1:
             create_emp();
             break;
          case 2:
             calc_age();
             break;
          case 3:
             onscrn=0;
             break;
       }
    }
    fclose(fp);
```

NOTES

```
}
int create_emp()
{
    employee emp1;
    int i,n;
    fp=fopen("emp.dat","a");
    clrscr();
    printf("How Many Employees :");
    scanf("%d",&n);
    for(i=0;i<n;i++)
    {
       clrscr();
       printf("Employee %d Details :\n",i+1);
       printf("\n\nEmployee Name :");
       scanf("%s",&emp1.name);
       printf("Employee Code :");
       scanf("%s",&emp1.code);
       printf("Date Of Birth :(dd/mm/yy)");
       scanf("%s",&emp1.dob);
       printf("Qualification :");
       scanf("%s",&emp1.qual);
       fprintf(fp, "%40s%5s%9s%40s\n", emp1.name,
emp1.code,emp1.dob, emp1.qual);
    }
    fclose(fp);
    return(0);
}
int calc_age()
{
    int ret,nyob,age,llfound=0,onscrn=1;
    employee emp1;
    char nam[40],*sear,*ori;
    char yob[5];
    fp=fopen("emp.dat","r");
    clrscr();
    printf("Employee Name To Search :");
    scanf("%s",nam);
    sear=strlwr(nam);
    while(onscrn)
    {
       ret=fscanf(fp, "%40s%5s%9s%40s\n", emp1.name,
```

```
emp1.code, emp1.dob, emp1.qual);
        if(ret==EOF)
        {
           onscrn=0;
           continue;
        }
        ori=strlwr(emp1.name);
        if(strcmp(sear,ori)==0)
        {
           clrscr();
           printf("Employee Name :%s\n",emp1.name);
           printf("Employee Code :%s\n",emp1.code);
           printf("Date of Birth :%s\n",emp1.dob);
           printf("Qualification :%s\n",emp1.qual);
           strcpy(yob,"19");
           strncat(yob,emp1.dob+6,2);
           yob[4]=0;
           nyob=atoi(yob);
           age = today.da_year - nyob;
           printf("Age of Employee :%d\n",age);
           getch();
           onscrn=0;
           llfound=1;
        }
     }
     fclose(fp);
     if (!llfound)
     {
        printf("%s Not found in emp.dat\n",nam);
        getch();
     }
     return(0);
}
```

Result of the program

```
Employee Name      :   saravanan
Employee Code      :   06
Date of Birth      :   02/06/63
Qualification      :   MBA
Age of Employee    :   36
```

You should be able to understand the program by reading the following:

NOTES

NOTES

The function <dos.h> is included. Look at the online help and see what it does. You will find that it defines various constants and declarations needed for DOS and 8086 specific calls. We can use it to get the system date to calculate the age of the employee. After the system date is confirmed, the menu appears. If you choose 1, it calls `create_emp` and asks for the number of employees. Then it accepts the records of a specified number of employees. The employee record is a structure.

After creating the records, you can opt to calculate the employee's ages by entering 2. This invokes the function `calc_age`. The function asks for the name of employee it must search for. If the name matches, the age will be calculated and displayed. The records are written in the append mode, so you will not lose the records. Note that the structures are written to the file using `fprintf()` and read from the file using `fscanf()`. Note also that `date` is a structure with three members `da_day, da_mon, da_year.`

This example has demonstrated that structures can be written to a file.

Check Your Progress

1. What happened when an error occur during file processing?
2. Write the definition or code that helps to check whether a file exists in the disk.

14.4 SEEKING FORWARD AND BACKWARD

Files are the formats that are required for saving data for future use. Random Access Memory (RAM) holds data temporarily. **File structures** are used to save data permanently. The C program files can be stored at the user specified location. Figure 14.1 shows the file sequence hierarchy in C language.

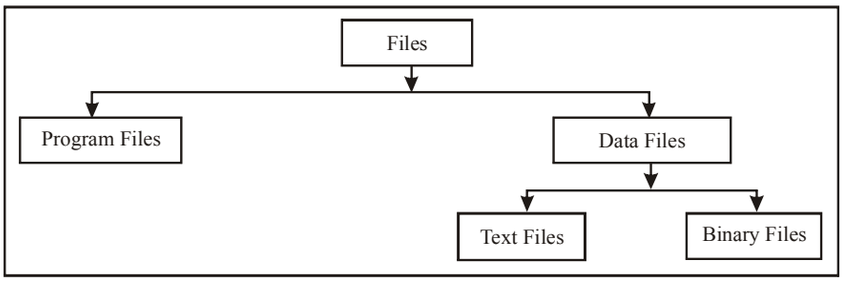

Fig. 14.1 *File Sequence Hierarchy*

True random access file handling only accesses the file at the point at which the data should be read or written rather than having to process it sequentially. A different approach is also possible whereby a part of the file is used for sequential access to locate something in the random access portion of the file in the same way as a File Allocation Table (FAT) works. The three main functions that seek

forward and backward with file handling are as follows:

(i) `rewind()` – This function returns the file pointer to the beginning.

(ii) `fseek()` – This function returns the position of the file pointer.

(iii) `ftell()` – This function returns the current offset of the file pointer.

NOTES

Each of these functions operates on the C file pointer, which is just the offset from the start of the file, and can be positioned at will. All read/write operations take place at the current position of the file pointer.

The rewind() Function

The `rewind()` function can be used in sequential or random access C file programming. It simply tells the file system to position the file pointer at the start of the file. Any error flags are also cleared and no value is returned.

Using `fseek()` and `ftell()` to Process Files

The `fseek()` function is very useful in random access files where either the record or block size is known or there is an allocation system that denotes the start and end positions of records in an index portion of the file. The `fseek()` function takes three parameters:

(i) `FILE * f` – It represents the file pointer;

(ii) `long offset` – It represents the position offset;

(iii) `int origin` – It represents the point from which the offset is applied.

The `origin` parameter can be one of the following three values:

(i) `SEEK_SET` – It works from the start.

(ii) `SEEK_CUR` – It works from the current position.

(iii) `SEEK_END` – It works from the end of the file.

There are two fundamental types of files, text and binary. Of these, binary is generally simpler to deal with. Random access means you can move to any part of a file and read or write data from it without having to read through the entire file. Basically, seeking forward and backward pointer in file handling is done with `fseek` function. The general format of `fseek` function is as follows:

```
fseek(file * Fileptr, offset, position);
```

This function is used to move the file position to a desired location within the file. `Fileptr` is a pointer to the file concerned. `offset` is a number or variable of type long and `position` is an integer number. `offset` specifies the number of positions (in bytes) to be moved from the location specified at the `position`.

Input and output are normally sequential in which each read or write takes place at a position in the file right after the previous one. When necessary, however, a file can be read or written in any arbitrary order. The system call `lseek` provides a way to move around in a file without reading or writing any data:

```
long lseek(int fd, long offset, int origin);
```

NOTES

This function sets the current position in the file whose descriptor is `fd` to `offset` which is taken relative to the location specified by `origin`. Subsequent reading or writing will begin at that position. The `origin` can be `0`, `1` or `2` to specify that `offset` is to be measured from the beginning, from the current position or from the end of the file, respectively. With `lseek` it is possible to treat files more or less like arrays at the price of slower access. For example, the following function reads any number of bytes from any arbitrary place in a file. It returns the number `read` or `-1` on error.

```
#include "syscalls.h"
/*get:  read n bytes from position pos */
int get(int fd, long pos, char *buf, int n)
   {
      if (lseek(fd, pos, 0) >= 0) /* get to pos */
          return read(fd, buf, n);
       else
           return -1;
   }
```

The return value from `lseek` is a `long` integer type that gives the new position in the file which depend on the setting conditions, such as seeking forward or seeking backward or `-1` if an error occurs. The standard library function `fseek` is similar to `lseek` except that the first argument is a `FILE *` and the return value is non-zero if an error occurs. To determine whether the functions `fseek()` or `lseek()` operates correctly check its return value.

14.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. When an error is encountered during file processing, the program execution will be terminated and error messages will be displayed.
2. To verify whether a file exists in the disk, the following definitions will help.

```
if(fptr == NULL)
printf("\n No content or file does not exist");
```

14.6 SUMMARY

- When an error is encountered during file processing, the program execution will be terminated and error messages will be displayed.

NOTES

- `ferror` () function can be used to detect any error during file accessing. This function will return a zero when there is no error, otherwise it will return a non-zero number.
- Entering an invalid file name or trying to write data to a write protected disk are some of the other reasons for errors during file processing.
- The `rewind()` function can be used in sequential or random access C file programming. It simply tells the file system to position the file pointer at the start of the file.
- There are two fundamental types of files, text and binary. Of these, binary is generally simpler to deal with. Random access means you can move to any part of a file and read or write data from it without having to read through the entire file.

14.7 KEY WORDS

- **`ferror ():`** It is a function to detect errors which return a zero when there is no error, otherwise it will return a non-zero number.
- **`fseek():`** `It is a` function which is very useful in random access files where either the record or block size is known or there is an allocation system that denotes the start and end positions of records in an index portion of the file.

14.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Discuss the measures to avoid errors during file processing.
2. Discuss the concept of command line arguments with the help of a program.

Long Answer Questions

1. Write a program that reads one character at a time till EOF is reached.
2. Write a program to transfer two lines of text from the buffer to a file and then read the contexts of the file to the monitor.

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