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KANETKAR

17th Edition

Let Us C

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AUTHENTIC Guide To
C PROGRAMMING Language

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Let Us C

Seventeenth Edition

Yashavant Kanetkar

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Dedicated to baba

Who couldn't be here to see this day…

About the Author

Through his books and online Quest Video Courses on C, C++, Data Structures, VC++, .NET, Embedded Systems, etc. Yashavant Kanetkar has created, moulded and groomed lacs of IT careers in the last two and half decades. Yashavant's books and online courses have made a significant contribution in creating top-notch IT manpower in India and abroad.

Yashavant's books are globally recognized and millions of students / professionals have benefitted from them. His books have been translated into Hindi, Gujarati, Japanese, Korean and Chinese languages. Many of his books are published in India, USA, Japan, Singapore, Korea and China.

Yashavant is a much sought after speaker in the IT field and has conducted seminars/workshops at TedEx, IITs, NITs, IIITs and global software companies.

Yashavant has been honored with the prestigious “Distinguished Alumnus Award” by IIT Kanpur for his entrepreneurial, professional and academic excellence. This award was given to top 50 alumni of IIT Kanpur who have made significant contribution towards their profession and betterment of society in the last 50 years.

In recognition of his immense contribution to IT education in India, he has been awarded the “Best .NET Technical Contributor” and “Most Valuable Professional” awards by Microsoft for 5 successive years.

Yashavant holds a BE from VJTI Mumbai and M.Tech. from IIT Kanpur. His current affiliations include being a Director of KICIT Pvt. Ltd. He can be reached at kanetkar@kicit.com or through http://www.kicit.com.

Acknowledgments

Let Us C has become an important part of my life. I have created and nurtured it for last two decades. While doing so, I have received, in addition to the compliments, a lot of suggestions from students, developers, professors, publishers and authors. So much have their inputs helped me in taking this book up to its seventeenth edition that ideally I should put their names too on the cover page.

In particular, I am indebted to Manish Jain who had a faith in this book idea, believed in my writing ability, whispered the words of encouragement and made helpful suggestions from time to time. I hope every author gets a publisher who is as cooperative, knowledgeable and supportive as Manish.

The previous editions of this book saw several changes and facelifts. During this course many people helped in executing programs and spotting bugs. I trust that with their collective acumen, all the programs in this book would run correctly. I value the work that they did a lot. Any errors, omissions or inconsistencies that remain are, alas, my responsibility.

I thank all my family members for enduring the late nights, the clicking keyboard, and mostly for putting up with a marathon book effort.

Thinking of a book cover idea is one thing, putting it into action is a different cup of tea. This edition's cover idea has been implemented by Vinay Indoria. Many thanks to him!

And finally my heartfelt gratitude to the countless students who made me look into every nook and cranny of C. I want to remain in their debt. It is only because of them that Let Us C is now published from India, Singapore, USA, Japan, Dubai, Korea and China in multiple languages.

Preface

Let Us C has been part of learning and teaching material in most Engineering and Science Institutes round the country for years now. From last year or so, I received several suggestions that its size be pruned a bit, as many learners who learn C language in their Engineering or Science curriculum have some familiarity with it. I am happy to fulfill this request. I hope the readers would appreciate the lean look of the current edition.

In one of the previous edition I had realigned the chapters in such a manner that if a C programming course is taught using Let Us C, it can be finished in 22 lectures of one hour each, with one chapter’s contents devoted to one lecture. I am happy that many readers liked this idea and reported that this has made their learning path trouble-free. A more rational reorganization of end-of-chapter Exercises in the book has also been well-received. Riding on that feedback I had introduced one more feature in the fifteenth edition—KanNotes. These are hand-crafted notes on C programming. From the reader's emails I gather that they have turned out to be very useful to help revise their concepts on the day before the examination, viva-voce or interview.

Many readers also told me that they have immensely benefitted from the inclusion of the chapter on Interview FAQs. I have improved this chapter further. The rationale behind this chapter is simple—ultimately all the readers of Let Us C sooner or later end up in an interview room where they are required to take questions on C programming. I now have a proof that this chapter has helped to make that journey smooth and fruitful.

In this edition I have added a separate section titled 'Programs' in each chapter. It contains interesting programs based on the topics covered in the chapter. All the programs present in the book are available in source code form at www.kicit.com/books/letusc/sourcecode. You are free to download them, improve them, change them, do whatever with them. If you wish to get solutions for the Exercises in the book they are available in another book titled 'Let Us C Solutions'. If you want some more problems for practice they are available in the book titled 'Exploring C'. As usual, new editions of these two books have also been launched along with 17th edition of Let Us C.

If you like 'Let Us C' and want to hear the complete video-recorded lectures created by me on C language (and other subjects like C++, VC++, C#, Java, .NET, Embedded Systems, etc.), then you can visit http://quest.ksetindia.com for more details.

'Let Us C' is as much your book as it is mine. So if you feel that I could have done certain job better than what I have, or you have any suggestions about what you would like to see in the next edition, please drop a line to kanetkar@kicit.com or sales@bpbonline.com

Countless Indians have relentlessly worked for close to three decades to successfully establish "India" as a software brand. At times, I take secret pleasure in seeing that Let Us C has contributed in its own small little way in shaping so many careers that have made the "India" brand acceptable.

Recently I was presented with "Distinguished Alumnus Award" by IIT Kanpur. It was great to figure in a list that contained Narayan Murthy, Chief Mentor, Infosys, Dr. D. Subbarao, former Governor, Reserve Bank of India, Dr. Rajeev Motwani of Stanford University, Prof. H. C. Verma, Mr. Som Mittal President of NASSCOM, Prof. Minwalla of Harvard University, Dr. Sanjay Dhande former Director of IIT Kanpur, Prof. Arvind and Prof. Sur of MIT USA and Prof. Ashok Jhunjhunwala of IIT Chennai.

I think Let Us C amongst my other books has been primarily responsible for helping me get the "Distinguished Alumnus" award. What was a bit surprising was that almost all who were present knew about the book already and wanted to know from me what it takes to write a book that sells in millions of copies. My reply was—make an honest effort to make the reader understand what you have to say and keep it simple. I don't know how convincing was this answer, but well, that is what I have been doing with this book in all its previous sixteen editions. I have followed the same principle with this edition too.

All the best and happy programming!

Yashavant Kanetkar

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1 Getting Started

"Well begun is half done..."

You cannot be great at the start, but you have to start to be great. So making a beginning is important. This chapter will help you wet your feet, before beginning a more arduous C journey…

Contents

Before we can begin to write serious programs in C, it would be interesting to find out what really is C, how it came into existence and how does it compare with other programming languages. In this chapter, we would briefly outline these issues.

Four important aspects of any language are—the way it stores data, the way it operates upon this data, how it accomplishes input and output, and how it lets you control the sequence of execution of instructions in a program. We would discuss the first three of these building blocks in this chapter.

What is C?

C is a programming language developed at AT & T's Bell Laboratories of USA in 1972 by Dennis Ritchie. C became popular because it is simple and easy to use. An opinion that is often heard today is—“C has been already superseded by languages like C++, C# and Java, so why bother to learn C today”. I seriously beg to differ with this opinion. There are several reasons for this. These are as follows:

(a) C++, C# or Java make use of a principle called Object Oriented Programming (OOP) to organize programs which offers many advantages. While using this organizing principle, you need basic programming skills. So it makes more sense to first learn C and then migrate to C++, C# or Java. Though this two-step learning process may take more time, but at the end of it, you will definitely find it worth the trouble.

(b) Major parts of popular operating systems like Windows, UNIX, Linux and Android are written in C. Moreover, if one is to extend the operating system to work with new devices, one needs to write device driver programs. These programs are written exclusively in C.

(c) Common consumer devices like microwave ovens, washing machines and digital cameras are getting smarter by the day. This smartness comes from a microprocessor, an operating system and a program embedded in these devices. These programs have to run fast and work in limited amount of memory. C is the language of choice while building such operating systems and programs.

(d) You must have seen several professional 3D computer games where the user navigates some object, like say a spaceship and fires bullets at invaders. The essence of all such games is speed. To match this expectation of speed, the game has to react fast to the user inputs. The popular gaming frameworks (like DirectX) that are used for creating such games are written in C.

I hope that these are very convincing reasons why you should adopt C as the first step in your quest for learning programming.

Getting Started with C

There is a close analogy between learning English language and learning C language. This is illustrated in the Figure 1.1 .

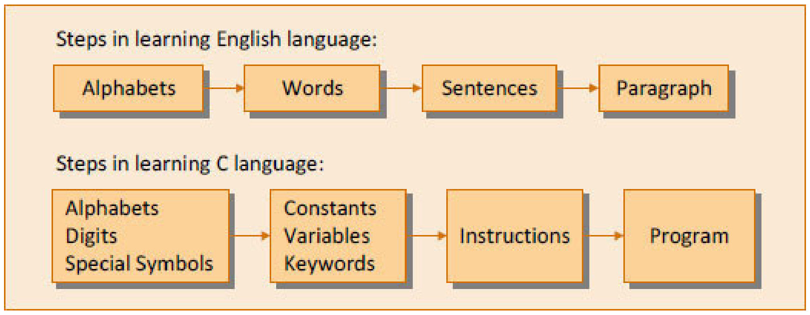
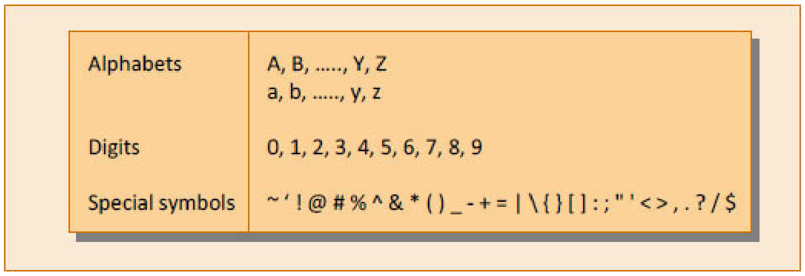

Steps in learning English language:
Alphabets
Words
Sentences
Paragraph
Steps in learning C language:
Alphabets Digits Special Symbols
Constants Variables Keywords
Instructions
Program

Figure 1.1

Alphabets, Digits and Special Symbols

Figure 1.2 shows the valid alphabets, numbers and special symbols allowed in C.



Alphabets	A, B, ..., Y, Z a, b, ..., y, z
Digits	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Special symbols	~ ' ! @ # % ^ & * ( ) _ - + = | \ { } [ ] : ; " ' < > , . ? / $

Figure 1.2

Constants, Variables and Keywords

The alphabets, digits and special symbols when properly combined form constants, variables and keywords. A constant is an entity that doesn't change, whereas, a variable is an entity that may change. A keyword is a word that carries special meaning. In programming languages, constants are often called literals, whereas variables are called identifiers. Let us now see what different types of constants and variables exist in C.

Types of C Constants

Constants in C can be divided into two major categories:

(a) Primary Constants

(b) Secondary Constants

These constants are further categorized as shown in Figure 1.3 .

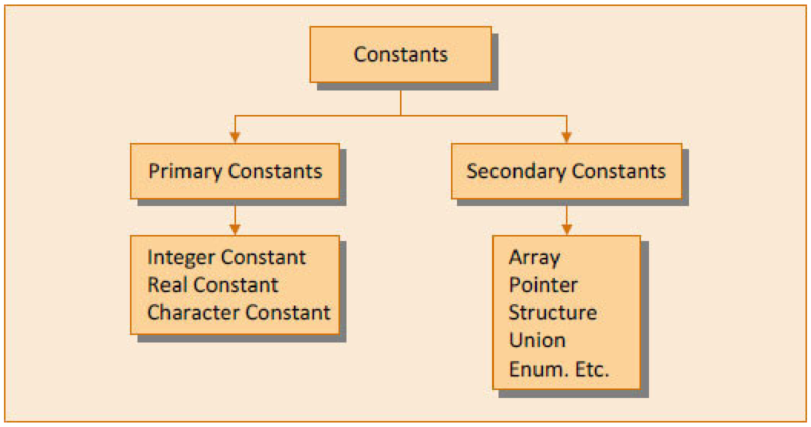

Constants
Primary Constants
Secondary Constants
Integer Constant Real Constant Character Constant
Array Pointer Structure Union Enum. Etc.

Figure 1.3

At this stage, we would restrict our discussion to only Primary constants, namely, Integer, Real and Character constants. Following Rules have been laid down for constructing these different types of constants:

Rules for Constructing Integer Constants

(a) An integer constant must have at least one digit.

(b) It must not have a decimal point.

(c) It can be any of zero, positive or negative. If no sign precedes an integer constant, it is assumed to be positive.

(d) No commas or blanks are allowed within an integer constant.

(e) The allowable range for integer constants is -2147483648 to +2147483647.

Ex.: +325.34   426.0   -32.76   -48.5792

Truly speaking, the range of an Integer constant depends upon the compiler. For compilers like Visual Studio, GCC, it is -2147483648 to +2147483647, whereas for compilers like Turbo C or Turbo C++, the range is -32768 to +32767.

Rules for Constructing Real Constants

Real constants are often called Floating Point constants. Real constants could be written in two forms—Fractional form and Exponential form. Following rules must be observed while constructing real constants expressed in fractional form:

(a) A real constant must have at least one digit.

(b) It must have a decimal point.

(c) It can be either positive or negative. Default sign is positive.

(d) No commas or blanks are allowed within a real constant.

Ex.: +325.34   426.0   -32.76   -48.5792

The exponential form is usually used if the value of the constant is either too small or too large. It, however, doesn't restrict us in any way from using exponential form for other real constants.

In exponential form, the real constant is represented in two parts. The part appearing before ‘e’ is called mantissa, whereas the part following ‘e’ is called exponent. Thus 0.000342 can be written in exponential form as 3.42e-4 (which in normal arithmetic means 3.42 x 10-4).

Following rules must be observed while constructing real constants expressed in exponential form:

(a) The mantissa part and the exponential part should be separated by a letter e or E.

(b) The mantissa part may have a positive or negative sign. Default sign is positive.

(c) The exponent must have at least one digit, which may be a positive or negative integer. Default sign is positive.

(d) Range of real constants expressed in exponential form is -3.4e38 to 3.4e38.

Ex.: +3.2e-5   4.1e8   -0.2E+3   -3.2e-5

Rules for Constructing Character Constants

(a) A character constant is a single alphabet, a single digit or a single special symbol enclosed within single inverted commas.

(b) Both the inverted commas should point to the left. For example, ‘A’ is a valid character constant, whereas ‘A’ is not.

Ex.: ’A’   ’I’   ’5’   ’=’

Types of C Variables

A particular type of variable can hold only the same type of constant. For example, an integer variable can hold only an integer constant, a real variable can hold only a real constant and a character variable can hold only a character constant. Hence there are as many types of variables in C, as the types of constants in it.

In any C program many calculations are done. The results of these calculations are stored in some cells (locations) of computer’s memory. To make the retrieval and usage of these values easy, the memory cells are given names. Since the value stored in each location may change, the names given to these locations are called variable names.

The rules for constructing different types of constants are different. However, for constructing variable names of all types, the same set of rules applies. These rules are given below.

Rules for Constructing Variable Names

(a) A variable name is any combination of 1 to 31 alphabets, digits or underscores. Some compilers allow variable names whose length could be up to 247 characters. Do not create unnecessarily long variable names as it adds to your typing effort.

(b) The first character in the variable name must be an alphabet or underscore (_).

Ex.: si*int pope89   avg   basic*salary

We should always create meaningful variable names. For example, while calculating simple interest, we should construct variable names like prin , roi , noy to represent Principle, Rate of interest and Number of years, rather than arbitrary variables like a , b , c .

Rules for creating variable names remain same for all the types of primary and secondary variables. So to help differentiate between variables, it is compulsory to declare the type of any variable that we wish to use in a program. This type declaration is done as shown below.

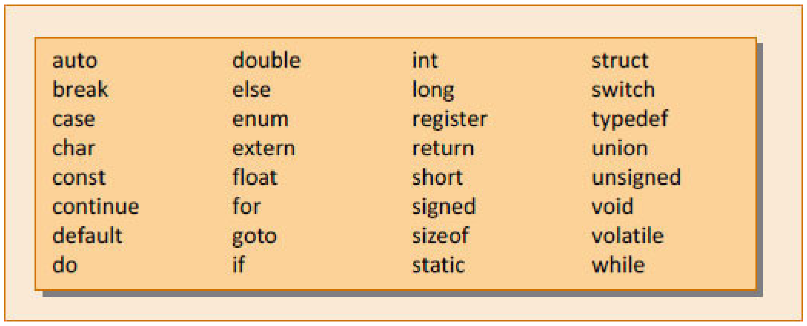
Ex.: int si, m_hra;

float bassal;

char code;

C Keywords

Keywords are the words whose meaning has already been explained to the C compiler (or in a broad sense to the computer). There are only 32 keywords available in C. Figure 1.4 gives a list of these 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

Figure 1.4

The keywords should not be used as variable names. However, some C compilers allow you to construct variable names that exactly resemble the keywords.

Compiler vendors provide more keywords apart from the ones given in Figure 1.5. Though it has been suggested by the ANSI committee that every such compiler-specific keyword should be preceded by two underscores (as in _ asm), not every vendor follows this rule.

The First C Program

Once armed with the knowledge of variables, constants and keywords, the next logical step is to combine them to form instructions. However, instead of this, we would write our first C program now. Once we have done that we would see in detail the instructions that it made use of.

The first program is very simple. It calculates simple interest for a set of values representing principal, number of years and rate of interest.

/* Calculation of simple interest */

/* Author: gekay Date: 25/03/2020 */

include

int main()

{

int p, n;

float r, si;

p = 1000;

n = 3;

r = 8.5;

/* formula for simple interest */

si = p * n * r / 100;

printf (“%f\n”, si);

return 0;

}

Let us now understand this program in detail.

Form of a C Program

Form of a C program indicates how it has to be written. There are certain rules about the form of a C program that are applicable to all C programs. These are as under:

(a) Each instruction in a C program is written as a separate statement.

(b) The statements in a program must appear in the same order in which we wish them to be executed.

(c) Blank spaces may be inserted between two words to improve the readability of the statement.

(d) All statements should be in lower case letters.

(e) Every C statement must end with a semicolon (;) . Thus ; acts as a statement terminator.

(f) A C statement can be written anywhere in a given line. That's why it is often called a free-form language.

(g) Usually each line contains one statement. However, you can write multiple statements in one line, provided each statement is terminated with a;.

Comments in a C Program

Comments are used in a C program to clarify either the purpose of the program or the purpose of some statement in the program. It is a good practice to begin a program with a comment indicating the purpose of the program, its author and the date on which the program was written.

Here are a few tips for writing comments in a C program:

(a) Comments can be in small case, capital or a combination. They should be enclosed within /* */. Thus, the first two statements in our program are comments.

(b) Sometimes it is not very obvious as to what a particular statement in a program accomplishes. At such times, a comment can be used to mention the purpose of the statement(s). For example,

/* formula for simple interest */

si = p * n * r / 100;

(c) Any number of comments can be written at any place in the program. So a comment can be written before the statement, after the statement or within the statement as shown below.

/* formula */ si = p * n * r / 100;

si = p * n * r / 100; /* formula */

si = p * n * r / /* formula */ 100;

(d) Comments cannot be nested. This means one comment cannot be written inside another comment. So following comment is invalid.

/* Cal of SI /* Author: gekay date: 25/03/2020 */ */

(e) A comment can be split over more than one line, as in,

/* This comment has

three lines

in it */

(f) ANSI C permits comments to be written in another way as follows:

// Calculation of simple interest

// Formula

What is main() ?

main() forms a crucial part of any C program. Let us understand its purpose as well as its intricacies.

(a) main() is a function. It is a container for a set of statements. A C program may have multiple functions. If it contains only one function its name has to be main() . All statements that belong to main() are enclosed within a pair of braces {}.

(b) Like functions in a calculator, functions in C also return a value. main() function always returns an integer value, hence there is an int before main() . It is known as return type of the function. The integer value that we are returning is 0. 0 indicates success. If statements in main() fail to do their intended work, we can return a non-zero number from main() . This would indicate failure.

(c) The way to watch the value returned by main() varies from one compiler to another, as shown below.

Turbo C, Turbo C++ - Alt C | Information

Visual Studio - $ReturnValue in Watch Window of Debugger

Linux - echo $? at command prompt after execution of the program

(d) Some compilers like Turbo C/C++ even permit us to return nothing from main() . In such a case we should precede it with the keyword void . But this is the non-standard way of writing the main() function. We would discuss functions and their working in detail in Chapter 8 .

Variables and their Usage

Let us understand the significance of constants and variables with reference to our program.

(a) Any variable used in the program must be declared before it is used. For example,

int p, n; /* declaration */

float r, si; /* declaration */

si = p * n * r / 100; /* usage */

(b) In the statement,

si = p * n * r / 100;

- and / are the arithmetic operators. The arithmetic operators available in C are + , - , * and / .

printf() and its Purpose

C does not contain any keyword to display output on the screen. All output to screen is achieved using readymade library functions like printf() . Let us understand this function with respect to our program.

(a) Once the value of si is calculated it needs to be displayed on the screen. We have used printf() to do so.

(b) To be able to use the printf() function, it is necessary to use #include at the beginning of the program. #include is a preprocessor directive. Its purpose will be clarified in Chapter 8 .

(c) The general form of printf() function is,

```
printf (“”, );
```

can contain,

%f for printing real values

%d for printing integer values

%c for printing character values

In addition to format specifiers like %f , %d and %c , the format string may also contain any other characters. These characters are printed as they are when printf() is executed.

(d) Given below are some more examples of usage of printf() function:

```
printf (“%f”, si);

printf (“%d %d %f %f”, p, n, r, si);

printf (“Simple interest = Rs. %f”, si);

printf (“Principal = %d\nRate = %f”, p, r);
```

The output of the last statement would look like this…

```
Principal = 1000

Rate = 8.500000
```

The output is split over two lines because of newline character ‘\n’. It sends the cursor to next line. It is one of the several Escape Sequences available in C. These are discussed in detail in Chapter 18 .

(e) printf() can print values of variables as well as result of an expressions like 3, 3 + 2, c and a + b * c - d as shown below.

```
printf (“%d %d %d %d”, 3, 3 + 2, c, a + b * c - d);
```

Note that 3 and c also represent valid expressions.

Compilation and Execution

Once you have written the program, you need to type it and instruct the machine to execute it. Two other programs are needed to do this— Editor and Compiler. Editor lets us type our program, whereas Compiler converts our program into machine language program. This conversion is necessary, since machine understands only machine language.

Apart from these two, there are other programs which you may need to improve your programming efficiency—Preprocessor, Linker and Debugger. Working with each one of them individually is a tedious job. Hence, often all these are bundled together with a layer of GUI on top of them. GUI makes using these programs easier for you. This bundle is often called Integrated Development Environment (IDE).

There are many IDEs available. Each is targeted towards different operating systems and microprocessors. Details of which IDE to use, from where to download it, how to install and use it are given in Appendix A. Please go through this appendix and install the right IDE on your machine before you try any program in this book.

Receiving Input

In our first C program we assumed the values of p , n and r to be 1000, 3 and 8.5. Every time we run the program, we would get the same value for simple interest. If we want to calculate simple interest for some other set of values then we are required to incorporate these values in the program, and again compile and execute it. This means that our program is not general enough to calculate simple interest for any set of values without being required to make changes in the program. This is not a good practice.

To make the program general, the program itself should ask the user to supply the values of p , n and r through the keyboard during execution. This can be achieved using a function called scanf() . It helps us receive input values them from the keyboard. This is illustrated in the program given below.

```
/* Calculation of simple interest */
/* Author gekay Date 25/03/2020 */
```

include

```
int main()

{

int p, n;

float r, si;

printf (“Enter values of p, n, r”);

scanf (“%d %d %f”, &p, &n, &r);

si = p * n * r / 100;

printf (“%f\n”, si);

return 0;

}
```

The first printf() outputs the message ‘Enter values of p, n, r’ on the screen. Here we have not used any expression in printf() which means that using expressions in printf() is optional.

Note the use of ampersand (&) before the variables in the scanf() function is necessary. & is the ‘Address of’ operator. It gives the location number (address) used by the variable in memory. When we say &a , we are telling scanf() at which memory location should it store the value supplied by the user from the keyboard. The detailed working of the & operator would be taken up in Chapter 9 .

Note that a blank, a tab or a new line must separate the values supplied to scanf() . A blank is created using a spacebar, tab using the Tab key and new line using the Enter key. This is shown below.

Ex.: Three values separated by blank:

```
1000 5 15.5
```

Ex.: Three values separated by tab:

```
1000 5 15.5
```

Ex.: Three values separated by newline:

```
1000

5

15.5
```

P</> Programs

Problem 1.1

Ramesh's basic salary is input through the keyboard. His dearness allowance is 40% of basic salary, and house rent allowance is 20% of basic salary. Write a program to calculate his gross salary.

Program

```
/* Calculate Ramesh’s gross salary */
```

include

```
int main()
```

```
{

float bp, da, hra, grpay;

printf (“\nEnter Basic Salary of Ramesh: ”);

scanf (“%f”, &bp);

da = 0.4 * bp;

hra = 0.2 * bp;

grpay = bp + da + hra;

printf (“Basic Salary of Ramesh = %f\n”, bp);

printf (“Dearness Allowance = %f\n”, da);

printf (“House Rent Allowance = %f\n”, hra);

printf (“Gross Pay of Ramesh is %f\n”, grpay);

return 0;

}
```

Output

```
Enter Basic Salary of Ramesh: 1200

Basic Salary of Ramesh = 1200.000000

Dearness Allowance = 480.000000

House Rent Allowance = 240.000000

Gross Pay of Ramesh is 1920.000000
```

Problem 1.2

The distance between two cities (in km.) is input through the keyboard. Write a program to convert and print this distance in meters, feet, inches and centimeters.

Program

```
/* Conversion of distance */
```

include

```
int main()

{

float km, m, cm, ft, inch;

printf (“\nEnter the distance in Kilometers: ”);

scanf (“%f”, &km);

m = km * 1000;

cm = m * 100;

inch = cm / 2.54;

ft = inch / 12;
printf (“Distance in meters = %f\n”, m);

printf (“Distance in centimeter = %f\n”, cm);

printf (“Distance in feet = %f\n”, ft);

printf (“Distance in inches = %f\n”, inch);

return 0;

}
```

Output

```
Enter the distance in Kilometers: 3

Distance in meters = 3000.000000

Distance in centimeter = 300000.000

Distance in feet = 9842.519531

Distance in inches = 118110.234375
```

Problem 1.3

If the marks obtained by a student in five different subjects are input through the keyboard, write a program to find out the aggregate marks and percentage marks obtained by the student. Assume that the maximum marks that can be obtained by a student in each subject is 100.

Program

```
/* Calculation of aggregate & percentage marks */
```

include

```
int main()

{

int m1, m2, m3, m4, m5, aggr;

float per;

printf (“\nEnter marks in 5 subjects: ”);

scanf (“%d %d %d %d %d”, &m1, &m2, &m3, &m4, &m5);

aggr = m1 + m2 + m3 + m4 + m5;

per = aggr / 5;

printf (“Aggregate Marks = %d\n”, aggr);

printf (“Percentage Marks = %f\n”, per);

return 0;

}
```

Output

```
Enter marks in 5 subjects: 85 75 60 72 56

Aggregate Marks = 348

Percentage Marks = 69.000000
```

Exercises

[A] Which of the following are invalid C constants and why?

[B] Which of the following are invalid variable names and why?

[C] State whether the following statements are True or False:

(a) C language was developed by Dennis Ritchie.

(b) Operating systems like Windows, UNIX, Linux and Android are written in C.

(c) C language programs can easily interact with hardware of a PC / Laptop.

(d) A real constant in C can be expressed in both Fractional and Exponential forms.

(e) A character variable can at a time store only one character.

(f) The maximum value that an integer constant can have varies from one compiler to another.

(g) Usually all C statements are written in small case letters.

(h) Spaces may be inserted between two words in a C statement.

(i) Spaces cannot be present within a variable name.

(j) C programs are converted into machine language with the help of a program called Editor.

(k) Most development environments provide an Editor to type a C program and a Compiler to convert it into machine language.

(l) int, char, float, real, integer, character, char, main, printf and scanf all are keywords.

[D] Match the following pairs:

[E] Point out the errors, if any, in the following programs:

```
(a) int main()

{

int a; float b; int c;

a = 25; b = 3.24; c = a + b * b - 35;

}
```

```
(b) #include

int main()

{

int a = 35; float b = 3.24;

printf (“%d %f %d”, a, b + 1.5, 235);

}
```

```
(c) #include

int main()

{

int a, b, c;

scanf (“%d %d %d”, a, b, c);
}

(d) #include

int main()

{

int m1, m2, m3

printf (“Enter values of marks in 3 subjects”)

scanf (“%d %d %d”, &m1, &m2, &m3)

printf (“You entered %d %d %d”, m1, m2, m3)

}
```

[F] Attempt the following questions:

(a) Temperature of a city in Fahrenheit degrees is input through the keyboard. Write a program to convert this temperature into Centigrade degrees.

(b) The length and breadth of a rectangle and radius of a circle are input through the keyboard. Write a program to calculate the area and perimeter of the rectangle, and the area and circumference of the circle.

(c) Paper of size A0 has dimensions 1189 mm x 841 mm. Each subsequent size A(n) is defined as A(n-1) cut in half parallel to its shorter sides. Thus paper of size A1 would have dimensions 841 mm x 594 mm. Write a program to calculate and print paper sizes A0, A1, A2, … A8.

3 top reasons for learning C :

- Good base for learning C++, C# or Java later
- Unix, Linux, Windows, Gaming frameworks are written in C
- Embedded systems programs are written in C

Constants = Literals -> Cannot change

Variables = Identifiers -> May change

Types of variables and constants : 1) Primary 2) Secondary

3 types in Primary : 1) Integer 2) Real (float) 3) Character

Ranges:

1) 2-byte integers : -32768 to +32767

2) 4-byte integers : -2147483648 to +2147483647

3) floats : -3.4 x 1038 to +3.4 x 1038

In a char constant, both quotes must slant to the left, like ‘A’

Variable has two meanings :

1) It is an entity whose value can change

2) It is a name given to a location in memory

Variable names are case-sensitive and must begin with an alphabet

Total keywords = 32. Example char, int, float etc.

printf() is a function that can print multiple constants and variables

Format specifiers in printf(), scanf() : int - %i, float - %f, char - %c

main() is a function that must always return an integer value :

0 - if it meets success, 1 - if it encounters failure

Use /* ….. */ or // for a comment in a program

& is 'address of' operator and must be used before a variable in scanf()

Captain of a Cricket team is as good as his team. If the team is not good enough, captain alone cannot do much. Same is the case with C programming. Unless you know the instructions that it offers, you can hardly write a good program. This chapter discusses these instructions…

Contents

Aprogram is nothing but a set of instructions. Different instructions help us achieve different tasks in a program. In the last chapter we saw how to write simple C programs by using different instructions. In this chapter we would explore the instructions that we used in these programs.

Types of Instructions

There are three types of instructions in C:

(a) Type Declaration Instruction - This instruction is used to declare the type of variables used in a C program.

(b) Arithmetic Instruction - This instruction is used to perform arithmetic operations on constants and variables.

(c) Control Instruction - This instruction is used to control the sequence of execution of various statements in a C program.

Let us now take a closer look at these instructions.

Type Declaration Instruction

This instruction is used to declare the type of variables being used in the program. The type declaration statement is written at the beginning of main() function. A few examples are shown below.

int bas;

float rs, grosssal;

char name, code;

Here are a few subtle variations of the type declaration instruction…

(a) While declaring the type of variable, we can also initialize it as shown below.

int i = 10, j = 25;

float a = 1.5, b = 1.99 + 2.4 * 1.44;

(b) A variable must stand defined before using it. The following statement is illegal since we are using variable a before defining it.

float b = a + 3.1, a = 1.5;

(c) The following statements would work

int a, b, c, d;

a = b = c = 10;

However, the following statement would not work

int a = b = c = d = 10;

Once again we are trying to use b (to assign to a) before defining it.

Arithmetic Instruction

An arithmetic instruction in C consists of a variable name on the left hand side of = and variable names and constants connected using operators on the right hand side of =.

Ex.: int ad;

float kot, deta, alpha, beta, gamma;

ad = 3200;

kot = 0.0056;

deta = alpha * beta / gamma + 3.2 * 2 / 5;

Here,

*, /, -, + are the arithmetic operators.

= is the assignment operator.

2, 5 and 3200 are integer constants.

3.2 and 0.0056 are real constants.

ad is an integer variable.

kot, deta, alpha, beta, gamma are real variables.

The variables and constants together are called ‘operands’. While executing an arithmetic statement, the operands on right hand side are operated upon by the ‘arithmetic operators’ and the result is assigned, using the assignment operator, to the variable on left-hand side.

An arithmetic statement in C could be of three types. These are as follows:

(a) Integer mode arithmetic statement - In this statement, all operands are either integer variables or integer constants.

Ex.: int i, king, issac, noteit;

i = i + 1;

king = issac * 234 + noteit - 7689;

(b) Real mode arithmetic statement - In this statement, all operands are either real constants or real variables.

Ex.: float qbee, antink, si, prin, anoy, roi;

qbee = antink + 23.123 / 4.5 * 0.3442;

si = prin * anoy * roi / 100.0;

(c) Mixed mode arithmetic statement - In this statement, some operands are integers and some operands are real.

Ex.: float si, prin, anoy, roi, avg;

int a, b, c, num;

si = prin * anoy * roi / 100.0;

avg = (a + b + c + num) / 4;

Note the following points about Arithmetic instructions carefully:

(a) C allows only one variable on left-hand side of = . That is, z = k * l is legal, whereas k * l = z is illegal.

(b) In addition to the division operator, C also provides a modular division operator. This operator returns the remainder on dividing one integer with another. Thus the expression 10 / 2 yields 5, whereas, 10 % 2 yields 0.

Note that the modulus operator (%) cannot be applied on a float. Also note that on using %, sign of the remainder is always same as the sign of the numerator. Thus -5 % 2 yields -1, whereas, 5 % -2 yields 1.

(c) Arithmetic operations can be performed on int s, float s and char s. Thus the following statements are valid.

char x = ’a’, y = ’b’;

int z = x + y;

ASCII codes are used to represent any character in memory. ASCII codes of ‘a’ and ‘b’ are 01100001 and 01100010. Their decimal equivalents are 97 and 98. The addition is performed on these decimal values and not on characters themselves.

(d) No operator is assumed to be present. It must be written explicitly. In the following example, the multiplication operator after b must be explicitly written.

a = c.d.b(xy) usual arithmetic statement

a = c * d * b * (x * y) C statement

(e) There is no operator in C to perform exponentiation operation. Exponentiation has to be carried out as shown below:

float a;

a = pow (3.0, 2.0);

printf (“%f”, a);

Here pow() function is a standard library function. It is being used to raise 3.0 to the power of 2.0. The pow() function works only with real numbers, hence we have used 3.0 and 2.0.

Note that for pow() to work, it is necessary to #include . #include is a preprocessor directive. We would learn more about standard library functions in Chapter 8 and about preprocessor in Chapter 12 .

You can explore other mathematical functions like abs() , sqrt() , sin() , cos() , tan() , etc., declared in math.h on your own.

Integer and Float Conversions

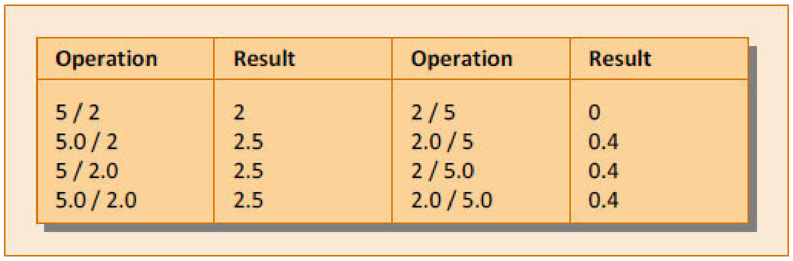
To effectively develop C programs, it is necessary to understand the rules used for implicit conversion of floating point and integer values. These are mentioned below. Note them carefully.

(a) An arithmetic operation between an integer and integer always yields an integer result.

(b) An operation between a real and real always yields a real result.

(c) An operation between an integer and real always yields a real result. In this operation, the integer is first promoted to a real and then the operation is performed. Hence the result is real.

I think a few practical examples shown in Figure 2.1 would put the issue beyond doubt.



Operation	Result	Operation	Result
5 / 2	2	2 / 5	0
5.0 / 2	2.5	2.0 / 5	0.4
5 / 2.0	2.5	2 / 5.0	0.4
5.0 / 2.0	2.5	2.0 / 5.0	0.4

Figure 2.1

Type Conversion in Assignments

If the type of the expression on RHS and LHS of = are not same then the value of the expression on RHS is promoted or demoted depending on the type of the variable on left-hand side of =. For example, consider the following assignment statements:

```
int i;

float b;

i = 3.5;

b = 30;
```

Here in the first assignment statement, though 3.5 is a float , it cannot be stored in i since it is an int . Hence 3.5 (float) is demoted to 3 (int) and then stored in i . Opposite happens in the next statement. Here, 30 is promoted to 30.0 and then stored in b , since b being a float variable cannot hold anything except a float value.

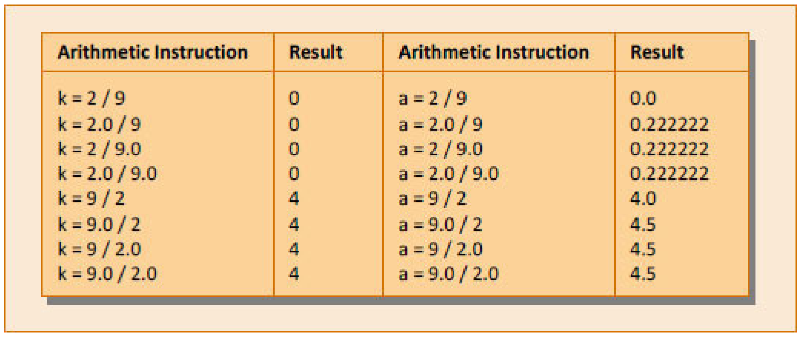
Instead of a simple expression used in the above examples, if a complex expression occurs, still the same rules apply. For example, consider the following program fragment.

```
float a, b, c; int s;

s = a * b * c / 100 + 32 / 4 - 3 * 1.1;
```

Here, in the assignment statement, some operands are int s whereas others are float s. As we know, during evaluation of the expression, the int s would be promoted to float s and the result of the expression would be a float . But when this float value is assigned to s , it is again demoted to an int and then stored in s .

Observe the results of the arithmetic statements shown in Figure 2.2 . It has been assumed that k is an integer variable and a is a real variable.



Arithmetic Instruction	Result	Arithmetic Instruction	Result
k = 2 / 9	0	a = 2 / 9	0.0
k = 2.0 / 9	0	a = 2.0 / 9	0.222222
k = 2 / 9.0	0	a = 2 / 9.0	0.222222
k = 2.0 / 9.0	0	a = 2.0 / 9.0	0.222222
k = 9 / 2	4	a = 9 / 2	4.0
k = 9.0 / 2	4	a = 9.0 / 2	4.5
k = 9 / 2.0	4	a = 9 / 2.0	4.5
k = 9.0 / 2.0	4	a = 9.0 / 2.0	4.5

Figure 2.2

Note that though the following statements give the same result, 0, the results are obtained differently.

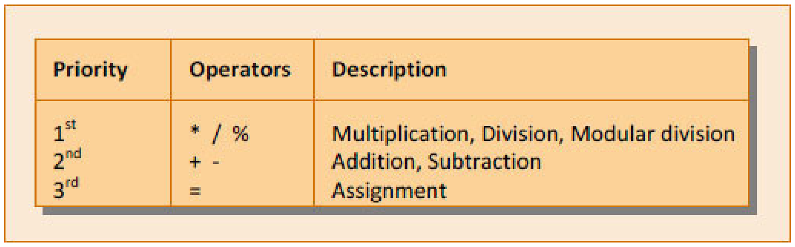
k = 2 / 9;

k = 2.0 / 9;

In the first statement, since both 2 and 9 are integers, the result is an integer, i.e. 0. This 0 is then assigned to k . In the second statement 9 is promoted to 9.0 and then the division is performed. Division yields 0.222222. However, this cannot be stored in k , k being an int . Hence it is demoted to 0 and then stored in k .

Hierarchy of Operations

While evaluating an arithmetic statement, some issues may crop up. For example, does the expression 2 * x - 3 * y correspond to (2x)-(3y) or to 2(x-3y)? Similarly, does A / B * C correspond to A / (B * C) or to (A / B) * C? To answer these questions satisfactorily, one has to understand the 'hierarchy' of operations. The priority or precedence in which the operations are performed is called the hierarchy of operations. The hierarchy of commonly used operators is shown in Figure 2.3 .



Priority	Operators	Description
1st	* / %	Multiplication, Division, Modular division
2nd	+ -	Addition, Subtraction
3rd	=	Assignment

Figure 2.3

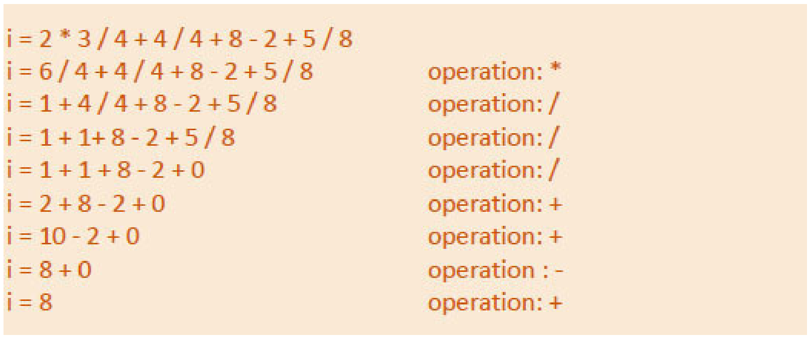
Within parentheses the same hierarchy as mentioned in Figure 2.3 is operative. Also, if there are more than one set of parentheses, the operations within the innermost parentheses would be performed first, followed by the operations within the second innermost pair and so on.

A few examples would clarify the issue further.

Example 2.1: Determine the hierarchy of operations and evaluate the following expression, assuming that i is an integer variable:

i = 2 * 3 / 4 + 4 / 4 + 8 - 2 + 5 / 8

Stepwise evaluation of this expression is shown below:



```
i = 2 * 3 / 4 + 4 / 4 + 8 - 2 + 5 / 8
i = 6 / 4 + 4 / 4 + 8 - 2 + 5 / 8          operation: *
i = 1 + 4 / 4 + 8 - 2 + 5 / 8              operation: /
i = 1 + 1+ 8 - 2 + 5 / 8                   operation: /
i = 1 + 1 + 8 - 2 + 0                      operation: /
i = 2 + 8 - 2 + 0                          operation: +
i = 10 - 2 + 0                             operation: +
i = 8 + 0                                  operation : -
i = 8                                      operation: +
```

Note that 6 / 4 gives 1 and not 1.5. This so happens because 6 and 4 both are integers and therefore 6 / 4 must evaluate to an integer. Similarly 5 / 8 evaluates to zero, since 5 and 8 are integers and hence 5 / 8 must return an integer value.

Example 2.2: Determine the hierarchy of operations and evaluate the following expression, assuming that kk is a float variable:

kk = 3 / 2 * 4 + 3 / 8

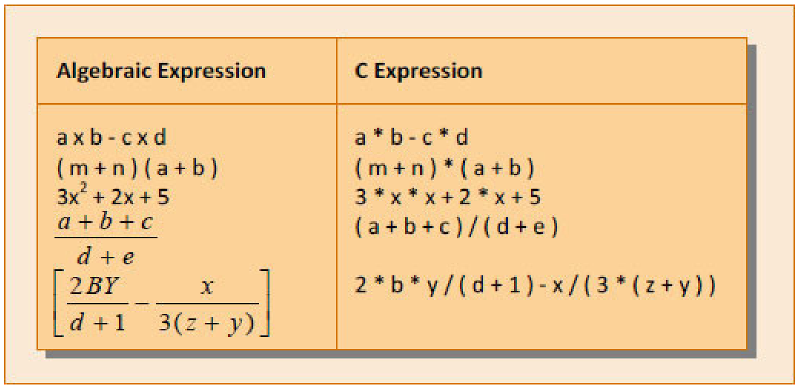
Stepwise evaluation of this expression is shown below:

```
kk = 3 / 2 * 4 + 3 / 8
kk = 1 * 4 + 3 / 8           operation: /
kk = 4 + 3 / 8               operation: *
kk = 4 + 0                   operation: /
kk = 4                       operation: +
```

Note that 3 / 8 gives zero, again for the same reason mentioned in the previous example.

All the 45 operators in C are ranked according to their precedence. We haven't encountered many out of these operators, so we won't pursue the subject of precedence any further here. A full-fledged list of all operators and their precedence is given in Appendix B.

So far we have seen how arithmetic statements written in C are evaluated. But our knowledge would be incomplete unless we know how to convert a general algebraic expression to a C statement. Some examples of algebraic expressions and their equivalent C expressions are shown in Figure 2.4 .



Algebraic Expression	C Expression
a x b - c x d	a * b - c * d
(m + n) (a + b)	(m + n) * (a + b)
$3x^2 + 2x + 5$	3 * x * x + 2 * x + 5
$\dfrac{a+b+c}{d+e}$	(a + b + c) / (d + e)
$\left[\dfrac{2BY}{d+1} - \dfrac{x}{3(z+y)}\right]$	2 * b * y / (d + 1) - x / (3 * (z + y))

Figure 2.4

Associativity of Operators

When an expression contains two operators of equal priority, the tie between them is settled using the associativity of the operators. All operators in C either have Left to Right associativity or Right to Left associativity. Let us understand this with the help of a few examples.

Consider the expression

a = 3 / 2 * 5;

Here there is a tie between operators of same priority, that is between / and *. This tie is settled using the associativity of / and *. Both enjoy Left to Right associativity. Therefore firstly / operation is done followed by *.

Consider one more expression.

a = b = 3;

Here, both assignment operators have the same priority. So order of operations is decided using associativity of = operator. = associates from Right to Left. Therefore, second = is performed earlier than first =.

Consider yet another expression.

z = a * b + c / d;

Here * and / enjoys same priority and same associativity (Left to Right). Compiler is free to perform * or / operation as per its convenience, since no matter which is performed earlier, the result would be the same.

Appendix B gives the associativity of all the operators available in C. Note that the precedence and associativity of all operators is predetermined and we cannot change it.

Control Instructions

Control Instructions control the order in which the instructions in a program get executed. In other words, the control instructions determine the ‘flow of control’ in a program. There are four types of control instructions in C. They are:

(a) Sequence Control Instruction

(b) Selection or Decision Control Instruction

(c) Repetition or Loop Control Instruction

(d) Case Control Instruction

The Sequence control instruction ensures that the instructions are executed in the same order in which they appear in the program. Decision and Case control instructions allow the computer to take a decision as to which instruction is to be executed next. The Loop control instruction helps execute a group of statements repeatedly. In the following chapters, we are going to discuss these instructions in detail.

P</> Programs

Problem 2.1

If lengths of three sides of a triangle are input through the keyboard, write a program to find the area of the triangle.

Program

```
/* Find area of a triangle, given its sides */

include

include /* for sqrt() */

int main()

{

float a, b, c, sp, area;

printf (“\nEnter sides of a triangle:”);

scanf (“%f %f %f”, &a, &b, &c);

sp = (a + b + c) / 2;

area = sqrt (sp * (sp - a) * (sp - b) * (sp - c));

printf (“Area of triangle = %f\n”, area);

return 0;

}
```

Output

```
Enter sides of a triangle: 4 5 6

Area of triangle = 9.921567
```

Problem 2.2

If a five-digit number is input through the keyboard, write a program to reverse the number.

Program

/* Reverse digits of a 5-digit number */

include

int main()

{

int n, d5, d4, d3, d2, d1;

long int revnum;

printf (“\nEnter a five digit number (less than 32767):”);

scanf (“%d”, &n);

d5 = n % 10; /* 5th digit */

n = n / 10; /* remaining digits */

d4 = n % 10; /* 4th digit */

n = n / 10; /* remaining digits */

d3 = n % 10; /* 3rd digit */

n = n / 10; /* remaining digits */

d2 = n % 10; /* 2nd digit */

n = n / 10; /* remaining digits */

d1 = n % 10; /* 1st digit */

revnum = d5 * 10000 + d4 * 1000 + d3 * 100 + d2 * 10 + d1;

/* specifier %ld is used for printing a long integer */

printf (“The reversed number is %ld\n”, revnum);

return 0;

}

Output

Enter a five digit number (less than 32767): 12345

The reversed number is 54321

Problem 2.3

Consider a currency system in which there are notes of seven denominations, namely, Re. 1, Rs. 2, Rs. 5, Rs. 10, Rs. 50, Rs. 100. If a sum of Rs. N is entered through the keyboard, write a program to compute the smallest number of notes that will combine to give Rs. N.

Program

include

int main()

{

int amount, nohun, nofifty, noten, nofive, notwo, noone, total;

```
printf ("Enter the amount:");
scanf ("%d", &amount);
nohun = amount / 100;
amount = amount % 100;
nofifty = amount / 50;
amount = amount % 50;
noten = amount / 10;
amount = amount % 10;
nofive = amount / 5;
amount = amount % 5;
notwo = amount / 2;
amount = amount % 2;
noone = amount / 1;
amount = amount % 1;
total = nohun + nofifty + noten + nofive + notwo + noone;
printf ("Smallest number of notes = %d\n", total);
return 0;
}
```

Output

```
Enter the amount: 570
Smallest number of notes = 8
```

Exercises

[A] Point out the errors, if any, in the following C statements:

(a) x = (y + 3);

(b) cir = 2 * 3.141593 * r;

(c) char = '3';

(d) 4 / 3 * 3.14 * r * r * r = vol*of*sphere;

(e) volume = a3;

(f) area = 1 / 2 * base * height;

(g) si = p * r * n / 100;

(h) area of circle = 3.14 * r * r;

(i) peri*of*tri = a + b + c;

(j) slope = (y2 - y1) ÷ (x2 - x1); (k) 3 = b = 4 = a;

(l) count = count + 1;

(m) char ch = '25 Apr 12';

[B] Evaluate the following expressions and show their hierarchy.

(a) ans = 5 * b * b * x - 3 * a * y * y - 8 * b * b * x + 10 * a * y;

(a = 3, b = 2, x = 5, y = 4 assume ans to be an int)

(b) res = 4 * a * y / c - a * y / c;

(a = 4, y = 1, c = 3, assume res to be an int)

(c) s = c + a * y * y / b;

(a = 2.2, b = 0.0, c = 4.1, y = 3.0, assume s to be an float)

(d) R = x * x + 2 * x + 1 / 2 * x * x + x + 1;

(x = 3.5, assume R to be an float)

[C] Indicate the order in which the following expressions would be evaluated:

(a) g = 10 / 5 /2 / 1;

(b) b = 3 / 2 + 5 * 4 / 3;

(c) a = b = c = 3 + 4;

(d) x = 2 - 3 + 5 * 2 / 8 % 3;

(e) z = 5 % 3 / 8 * 3 + 4

(f) y = z = -3 % -8 / 2 + 7;

[D] What will be the output of the following programs:

(a)
```
# include

int main()

{

int i = 2, j = 3, k, l;

float a, b;

k = i / j * j;

l = j / i * i;

a = i / j * j;

b = j / i * i;

printf ("%d %d %f %f\n", k, l, a, b);

return 0;

}
```

(b)
```
# include

int main()

{

int a, b, c, d;
a = 2 % 5;

b = -2 % 5;

c = 2 % -5;

d = -2 % -5;

printf (“a = %d b = %d c = %d d = %d\n”, a, b, c, d);

return 0;

}

(c) # include

int main()

{

float a = 5, b = 2;

int c, d;

c = a % b;

d = a / 2;

printf (“%d\n”, d);

return 0;

}

(d) # include

int main()

{

printf (“nn \n\n nn\n”);

printf (“nn /n/n nn/n”);

return 0;

}

(e) # include

int main()

{

int a, b;

printf (“Enter values of a and b”);

scanf (“ %d %d ”, &a, &b);

printf (“a = %d b = %d”, a, b);

return 0;

}
```

[E] State whether the following statements are True or False:

(a) * or /, + or - represents the correct hierarchy of arithmetic operators in C.

(b) [] and {} can be used in Arithmetic instructions.

(c) Hierarchy decides which operator is used first.

(d) In C, Arithmetic instruction cannot contain constants on left side of =.

(e) In C ** operator is used for exponentiation operation.

(f) % operator cannot be used with floats.

[F] Fill in the blanks:

(a) In y = 10 * x / 2 + z;_operation will be performed first.

(b) If a is an integer variable, a = 11 / 2; will store_in a .

(c) The expression, a = 22 / 7 * 5 / 3; would evaluate to_.

(d) The expression x = -7 % 2 - 8 would evaluate to_.

(e) If d is a float the operation d = 2 / 7.0 would store_in d .

[G] Attempt the following questions:

(a) If a five-digit number is input through the keyboard, write a program to calculate the sum of its digits. (Hint: Use the modulus operator '%')

(b) Write a program to receive Cartesian co-ordinates (x, y) of a point and convert them into polar co-ordinates (r,).

Hint: r = sqrt (x^2 + y^2) and = tan -1 (y / x)

(c) Write a program to receive values of latitude (L1, L2) and longitude (G1, G2), in degrees, of two places on the earth and output the distance (D) between them in nautical miles. The formula for distance in nautical miles is:

D = 3963 cos -1 (sin L1 sin L2 + cos L1 cos L2 * cos (G2 - G1))

(d) Wind chill factor is the felt air temperature on exposed skin due to wind. The wind chill temperature is always lower than the air temperature, and is calculated as per the following formula:

wcf = 35.74 + 0.6215t + (0.4275t - 35.75) * $v^{0.16}$

where t is the temperature and v is the wind velocity. Write a program to receive values of t and v and calculate wind chill factor (wcf).

(e) If value of an angle is input through the keyboard, write a program to print all its Trigonometric ratios.

(f) Two numbers are input through the keyboard into two locations C and D. Write a program to interchange the contents of C and D.

void main() is wrong. Correct form is int main()

Every compiler is targeted towards a particular OS + Microprocessor combination. This combination is known as a platform. A compiler created for one platform does not work with other platform

Standard steps in interchanging contents of two variables:

t = a; a = b; b = t;

(a) / gives quotient, % gives remainder. While taking %, sign of remainder is same as sign of numerator. % doesn't work with floats

C offers 3 types of instructions:

1) Type declaration 2) Arithmetic 3) Control

Declaration and assignment can be combined. Ex.: int a = 5;

3 types of Arithmetic instructions:

1) Integer mode 2) Real mode 3) Mixed mode

Rules for arithmetic instructions:

- If one operand is float, result is a float
- Result is int only if both operands are ints

a = pow (2, 5); would store 25 in a. Remember to #include

Every operator has 1) Priority 2) Associativity

Priority is * / %, + -, =. Priority can be changed using ()

Associativity comes into play when priority cannot decide which operation to perform first. Associativity is either L to R or R to L. +, -, *, /, % has L to R, = has R to L associativity

Format string of printf() can contain:

1) Format specifiers - %c, %d, %f

2) Escape sequences: \n, \t, many others

3) Any other character

Format string of scanf() can contain only format specifiers

Control instructions control the sequence of execution of instructions in a program

4 types of control instructions:

1) Sequence 2) Decision 3) Repetition 4) Case

As we lead our life, we have to take decisions. Similarly, as we make progress in C programming and try to implement complicated logics, our program has to take decisions. But how? Well, this chapter has the answer…

Contents

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KanNotes

We all need to alter our actions in face of changing circumstances. If the weather is fine, then I will go for a stroll. If the highway is busy, I would take a diversion. If you join our WhatsApp group, I would send you interesting videos. You can notice that all these decisions depend on some condition being met.

In C programs too, we must be able to perform different sets of actions depending on the circumstances. In the programs written in Chapters 1 and 2 , we used sequence control instruction in which the various statements are executed sequentially, i.e., in the same order in which they appear in the program. In many programming situations, we want one set of instructions to be executed in one situation, and a different set in another situation. In C programming, such situations are dealt with using a decision control instruction.

The if - else Statement

C uses the keywords if and else to implement the decision control instruction. The general form of this statement looks like this:

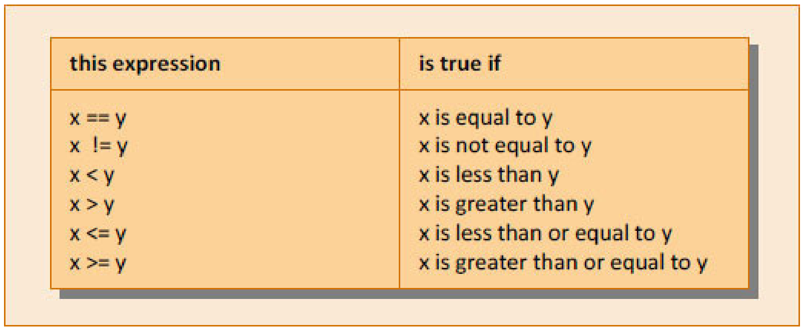
if (this condition is true)

statement1;

else

statement2;

The condition following the keyword if is always enclosed within a pair of parentheses. If the condition is true, then statement1 is executed. If the condition is not true, then statement2 is executed. The condition is expressed using ‘relational’ operators in C. These operators allow us to compare two values. Figure 3.1 shows how they look and how they are evaluated in C.



this expression	is true if
x == y	x is equal to y
x != y	x is not equal to y
x < y	x is less than y
x > y	x is greater than y
x <= y	x is less than or equal to y
x >= y	x is greater than or equal to y

Figure 3.1

Here == is the equality operator and != the inequality operator. Note that = is used for assignment, whereas, == is used for comparison of two quantities. Let us now understand with the help of an example how if - else and the relational operators are used in a program.

Example 3.1: While purchasing certain items, a discount of 10% is offered if the quantity purchased is more than 1000. If quantity and price per item are input through the keyboard, write a program to calculate the total expenses.

Given below is a program that implements this logic.

/* Calculation of total expenses */

include

int main()

{

int qty, dis;

float rate, tot;

printf (“Enter quantity and rate”);

```
scanf (“%d %f”, &qty, &rate);

if (qty > 1000)

dis = 10;

else

dis = 0;

tot = (qty * rate) - (qty * rate * dis / 100);

printf (“Total expenses = Rs. %f\n”, tot);

return 0;

}
```

Here is some sample interaction with the program.

```
Enter quantity and rate 1200 15.50

Total expenses = Rs. 16740.000000

Enter quantity and rate 200 15.50

Total expenses = Rs. 3100.000000
```

In the first run of the program, the condition evaluates to true, as 1200 (value of qty) is greater than 1000. Therefore, the variable dis gets a value 10. Using this new value, total expenses are calculated and printed.

In the second run, the condition evaluates to false, as 200 (the value of qty) isn't greater than 1000. Thus, dis , this time gets a value 0. Hence the expression after the minus sign evaluates to zero, thereby offering no discount.

Note how the statements after if and after else are indented using tab. We would adopt this style throughout this book. Also note that if we do not wish to do anything when the condition fails, we can drop the else and the statement belonging to it.

Multiple Statements within if - else

It may so happen that in a program we want more than one statement to be executed when the expression following if is satisfied. If such multiple statements are to be executed, then they must be placed within a pair of braces, as illustrated in the following example:

Example 3.2: In a company an employee is paid as under:

If his basic salary is less than Rs. 1500, then HRA = 10% of basic salary and DA = 90% of basic salary. If his salary is either equal to or above Rs. 1500, then HRA = Rs. 500 and DA = 98% of basic salary. If the employee’s salary is input through the keyboard write a program to find his gross salary.

The program that implements this logic is given below.

```
/* Calculation of gross salary */
```

include

```
int main()

{

float bs, gs, da, hra;

printf (“Enter basic salary”);

scanf (“%f”, &bs);

if (bs < 1500)
{
hra = bs * 10 / 100;
da = bs * 90 / 100;
}
else
{
hra = 500;
da = bs * 98 / 100;
}
gs = bs + hra + da;
printf ("gross salary = Rs. %f\n", gs);
return 0;
}
```

Figure 3.2 would help you understand the flow of control in the program.

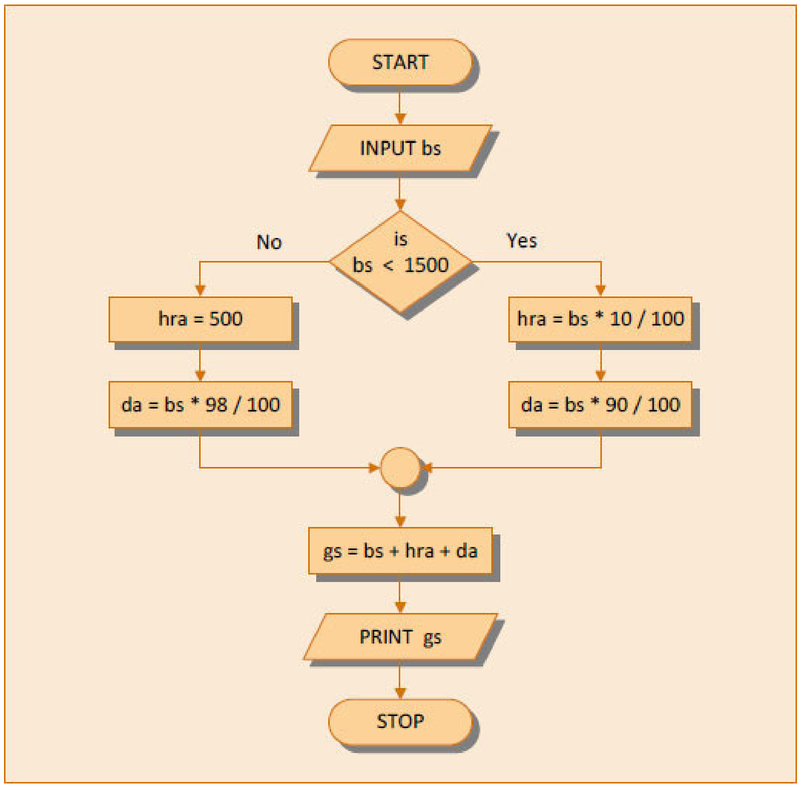


Figure 3.2

A few points worth noting about the program…

(a) The group of statements after the if up to and not including the else is called an ‘if block’. Similarly, the statements after the else form the ‘else block’.

(b) Notice that the else is written exactly below the if . The statements in the if block and those in the else block have been indented to the right. This formatting convention is followed throughout the book to enable you to understand the working of the program better.

(c) Had there been only one statement to be executed in the if block and only one statement in the else block, we could have dropped the pair of braces.

(d) The default scope of if as well as else is the statement immediately after them. To override this default scope, a pair of braces, as shown in the above example, must be used.

Nested if-else s

It is perfectly alright if we write another if-else construct within either the if block or the else block. This is called ‘nesting’ and is shown in the following code fragment:

```
if (i == 1)

printf (“You would go to heaven !\n”);

else

{

if (i == 2)

printf (“Hell was created with you in mind\n”);

else

printf (“How about mother earth !\n”);

}
```

Note that the second if-else construct is nested in the first else block. If the condition in the first if is false, then the condition in the second if is checked. If it is false as well, then the second else is executed.

You can observe how each time a if-else construct is nested within another if-else construct, it is also indented to add clarity to the program. Inculcate this habit of indentation; otherwise you would end up writing programs which nobody (you included) can understand easily at a later date. Note that whether we indent or do not indent the program, it doesn't alter the flow of execution of instructions in the program.

In the above program, an if-else occurs within the ‘ else block’ of the first if statement. Similarly, in some other program, an if-else may occur in the ‘ if block’ as well. There is no limit on how deeply the if s and the else s can be nested.

A Word of Caution

Though usually a condition is used in if statement, any valid expression will also do. Thus all the following if statements are valid.

```
if (3 + 2 % 5)

printf (“This works”);

if (a = 10)

printf (“Even this works”);

if (-5)

printf (“Surprisingly even this works”);
```

Note that in C a non-zero value is considered to be true, whereas a 0 is considered to be false. In the first if , the expression evaluates to 5 and since 5 is non-zero it is considered to be true. Hence the printf() gets executed.

In the second if , 10 gets assigned to a so the if is now reduced to if (a) or if (10) . Since 10 is non-zero, it is true hence again printf() goes to work.

In the third if , -5 is a non-zero number, hence true. So again printf() goes to work. In place of -5 even if a float like 3.14 were used, it would be considered to be true. So the issue is not whether the number is integer or float, or whether it is positive or negative. Issue is whether it is zero or non-zero.

Another common mistake while using the if statement is to write a semicolon (;) after the condition, as shown below.

```
scanf (“%d”, &i);

if (i == 5);
```

```
printf ("You entered 5\n");
```

The; makes the compiler to interpret the statement as if you have written it in following manner:

```
if (i == 5)

;

printf ("You entered 5\n");
```

Here, if the condition evaluates to true, the; (null statement, which does nothing on execution) gets executed, following which the printf() gets executed. If the condition fails, then straightaway the printf() gets executed. So irrespective of whether the condition evaluates to true or false, printf() is bound to get executed. Remember that compiler would not point out this as an error, since as far as the syntax is concerned, nothing has gone wrong but the logic has certainly gone awry.

Problem 3.1

If cost price and selling price of an item is input through the keyboard, write a program to determine whether the seller has made profit or incurred loss. Also determine how much profit he made or loss he incurred.

Program

```
/* Calculate profit or loss */
```

include

```
int main()

{

float cp, sp, p, l;

printf ("\nEnter cost price and selling price:");

scanf ("%f %f", &cp, &sp);

p = sp - cp;

l = cp - sp;

if (p > 0)

printf ("The seller made a profit of Rs. %f\n", p);

if (l > 0)

printf ("The seller incurred loss of Rs. %f\n", l);

if (p == 0)

printf ("There is no loss, no profit\n");

return 0;

}
```

Output

```
Enter cost price and selling price: 25 15

The seller incurred loss of Rs. 10.000000
```

Problem 3.2

Any integer is input through the keyboard. Write a program to find out whether it is an odd number or even number.

Program

```
/* Check whether a number is even or odd */

include

int main()

{

int n;

printf (“\nEnter any number:”);

scanf (“%d”, &n);

if (n % 2 == 0)

printf (“The number is even\n”);

else

printf (“The number is odd\n”);

return 0;

}
```

Output

```
Enter any number: 45

The number is odd
```

Problem 3.3

Any year is input through the keyboard. Write a program to determine whether the year is a leap year or not.

Program

```
/* Check whether a year is leap or not */

include

int main()

{

int yr;

printf (“\nEnter a year:”);

scanf (“%d”, &yr);

if (yr % 100 == 0)

{

if (yr % 400 == 0)

printf (“Leap year\n”);

else
printf ("Not a Leap year\n");
}
else
{
if (yr % 4 == 0)
printf ("Leap year\n");
else
printf ("Not a leap year\n");
}
return 0;
}
```

Output

```
Enter a year: 2020
Leap year
```

Exercises

[A] What will be the output of the following programs:

```
(a) # include
int main()
{
int a = 300, b, c;
if (a >= 400)
b = 300; c = 200;
printf ("%d %d\n", b, c);
return 0;
}
```

```
(b) # include
int main()
{
int x = 10, y = 20;
if (x == y);
printf ("%d %d\n", x, y);
return 0;
}
```

```
(c) # include
```

```
int main()

{

int x = 3;

float y = 3.0;

if (x == y)

printf (“x and y are equal\n”);

else

printf (“x and y are not equal\n”);

return 0;

}

(d) # include

int main()

{

int x = 3, y, z;

y = x = 10;

z = x < 10;

printf (“x = %d y = %d z = %d\n”, x, y, z);

return 0;

}

(e) # include

int main()

{

int i = 65;

char j = ‘A’;

if (i == j)

printf (“C is WOW\n”);

else

printf (“C is a headache\n”); return 0;

}
```

[B] Point out the errors, if any, in the following programs:

```
(a) # include

int main()

{

float a = 12.25, b = 12.52;
```

```
if (a = b)

printf (“a and b are equal\n”);

return 0;

}

(b) # include

int main()

{

int j = 10, k = 12;

if (k >= j)

{

{

k = j;

j = k;

}

}

return 0;

}

(c) # include

int main()

{

if (’X’ < ’x’)

printf (“ascii value of X is smaller than that of x\n”);

}

(d) # include

int main()

{

int x = 10;

if (x >= 2) then

printf (“%d\n”, x);

return 0;

}

(e) # include

int main()

{

int x = 10, y = 15;
```

if (x % 2 = y % 3)

printf (“Carpathians\n”);

}

(f) # include

int main()

{

int a, b;

scanf (“%d %d”, a, b);

if (a > b);

printf (“This is a game\n”);

else

printf (“You have to play it\n”);

return 0;

}

[C] State whether the following statements are True or False:

(a); is a valid statement.

(b) Ifs can be nested.

(c) If there are multiple statements in if or else block they should be enclosed within a pair of {}.

(d) If can occur within an if block but not in the else block.

(e) By default there is only one statement in if block and only one in the else block.

(f) Nothing happens on execution of a null statement.

[D] Match the following pairs:

[E] Which of the following are valid ifs:

(a) if (-25) (b) if (3.14)

(c) if (a)

(d) if (a + b)

(e) if (a >= b)

[F] Attempt the following questions:

(a) A five-digit number is entered through the keyboard. Write a program to obtain the reversed number and to determine whether the original and reversed numbers are equal or not.

(b) If ages of Ram, Shyam and Ajay are input through the keyboard, write a program to determine the youngest of the three.

(c) Write a program to check whether a triangle is valid or not, when the three angles of the triangle are entered through the keyboard. A triangle is valid if the sum of all the three angles is equal to 180 degrees.

(d) Write a program to find the absolute value of a number entered through the keyboard.

(e) Given the length and breadth of a rectangle, write a program to find whether the area of the rectangle is greater than its perimeter. For example, the area of the rectangle with length = 5 and breadth = 4 is greater than its perimeter.

(f) Given three points (x1, y1) , (x2, y2) and (x3, y3) , write a program to check if all the three points fall on one straight line.

(g) Given the coordinates (x, y) of center of a circle and its radius, write a program that will determine whether a point lies inside the circle, on the circle or outside the circle. (Hint: Use sqrt() and pow() functions)

(h) Given a point (x, y) , write a program to find out if it lies on the X-axis, Y-axis or on the origin.

(i) According to Gregorian calendar, it was Monday on the date 01/01/01. If any year is input through the keyboard write a program to find out what is the day on 1st January of this year.

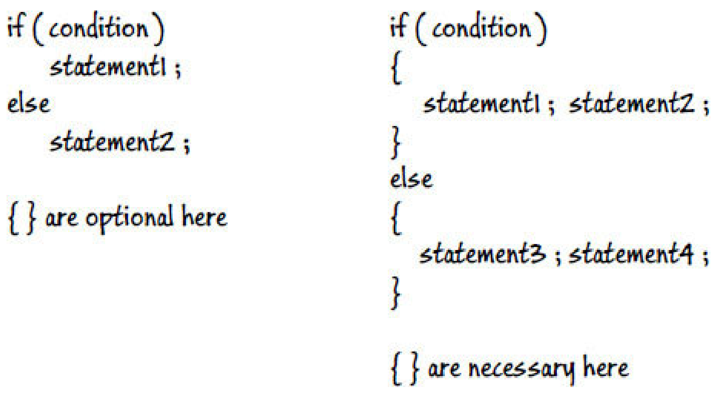
Three ways for taking decisions in a program:

1) Using if-else statement

2) Using conditional operators

3) Using the switch statement

General forms of decision control instruction:



```
if ( condition )
    statement1 ;
else
    statement2 ;

{ } are optional here
```

```
if ( condition )
{
    statement1 ; statement2 ;
}
else
{
    statement3 ; statement4 ;
}

{ } are necessary here
```

The default scope of if and else statement is only the next statement. So, to execute multiple statements they must be written in a pair of braces.

Condition is built using relation operators <, >, <=, >=, ==, !=

An if need not always be associated with an else. However, an else must always be associated with an if

An if-else statement can be nested inside another if-else statement

a = b is assignment. a == b is comparison

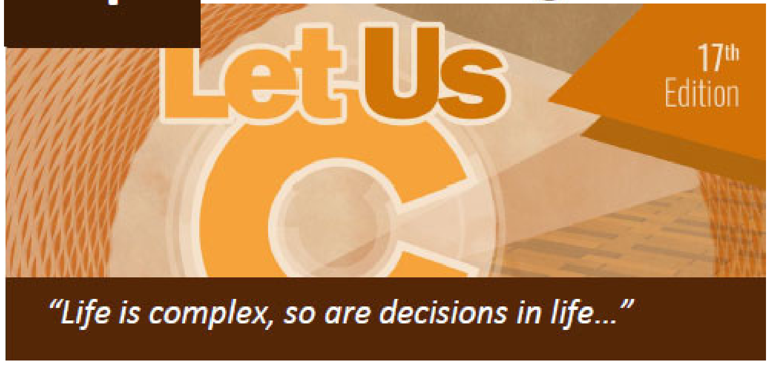
In if (a == b == c) result of a == b is compared with c

If a condition is true it is replaced by 1, if it false it is replaced by 0

Any non-zero number is true, 0 is false

; is a null statement. It doesn't do anything on execution

4 More Complex Decision Making



If I get good marks in my final year and if my GRE and TOEFL scores are good and if I get good recommendations or if I do not get a job with good prospects and if my family conditions permit me, then I would think of doing MS in US. How can such complex decision making be implemented in C? This chapter will show you how…

Contents

We all face situations where the action that we carry out is based on multiple conditions. For example, I will join a company if the company allocates a metro location, gives me a good pay package and permits a joining period of 4 weeks. In programming too, action performed may be based on the result of multiple conditions. Such programming situations can be handled elegantly using Logical Operators. This chapter explores the use of logical operators and one more type of operators called conditional operators.

Use of Logical Operators - Checking Ranges

C allows usage of three logical operators, namely, &&, || and !. These are to be read as 'AND', 'OR' and 'NOT' respectively. Of these, && and

|| operators allow two or more conditions to be. Let us see how they are used in programs. Consider the following example:

Example 4.1: The marks obtained by a student in 5 different subjects are input through the keyboard. The student gets a division as per the following rules:

Percentage above or equal to 60 - First division

Percentage between 50 and 59 - Second division

Percentage between 40 and 49 - Third division

Percentage less than 40 - Fail

Write a program to calculate the division obtained by the student.

There are two ways in which we can write a program for this example. These methods are given below.

```
/* Method - I */
```

include

```
int main()

{

int m1, m2, m3, m4, m5, per;

printf (“Enter marks in five subjects”);

scanf (“%d %d %d %d %d”, &m1, &m2, &m3, &m4, &m5);

per = (m1 + m2 + m3 + m4 + m5) * 100 / 500;

if (per >= 60)

printf (“First division\n”);

else

{

if (per >= 50)

printf (“Second division\n”);

else

{

if (per >= 40)

printf (“Third division\n”);

else

printf (“Fail\n”);

}

}

return 0;

}
```

This is a straight-forward program. Observe that the program uses nested if-else s. Though the program works fine, it has three disadvantages:

(a) As the number of conditions go on increasing the level of indentation also goes on increasing. As a result, the whole program creeps to the right. So much so that entire program is not visible on the screen. So if something goes wrong with the program, locating what is wrong where becomes difficult.

(b) It is difficult to match the corresponding if s and else s.

(c) It is difficult to match the corresponding pair of braces.

All these three problems can be eliminated by usage of ‘Logical Operators’. The following program illustrates this:

```
/* Method - II */
```

include

```
int main()
```

```
{
int m1, m2, m3, m4, m5, per;
printf (“Enter marks in five subjects”);
scanf (“%d %d %d %d %d”, &m1, &m2, &m3, &m4, &m5);
per = (m1 + m2 + m3 + m4 + m5) / 500 * 100;
if (per >= 60)
printf (“First division\n”);
if ((per >= 50) && (per < 60))
printf (“Second division\n”);
if ((per >= 40) && (per < 50))
printf (“Third division\n”);
if (per < 40)
printf (“Fail\n”);
return 0;
}
```

In the second if statement, the && operator is used to combine two conditions. ‘Second division’ gets printed only if both the conditions evaluate to true.

All the three disadvantages cited above have been overcome in this program. However, there is a negative side to the program too. Even if the first condition turns out to be true, all other conditions are still checked. This will increase the time of execution of the program. This can be avoided using the else if clause discussed in the next section.

The else if Clause

Let us now rewrite program for Example 4.1 using else if blocks.

```
/* else if ladder demo */
if (per >= 60)
printf (“First division\n”);
else if (per >= 50)
printf (“Second division\n”);
else if (per >= 40)
printf (“Third division\n”);
else
printf (“fail\n”);
```

Using if - else if - else reduces the indentation of the statements. Here the last else goes to work only if all conditions fail. Also, if a condition is satisfied, other conditions below it are not checked. Even in else if ladder, the last else is optional.

Use of Logical Operators - Yes / No Problem

Another place where logical operators are useful is when we want to write programs for complicated logics that ultimately boil down to only two answers—yes or no. The following example illustrates this:

Example 4.2: A company insures its drivers in the following cases:

- If the driver is married.
- If the driver is unmarried, male & above 30 years of age.
- If the driver is unmarried, female & above 25 years of age.

In all other cases, the driver is not insured. If the marital status, sex and age of the driver are the inputs, write a program to determine whether the driver should be insured or not.

The final outcome of the program would be—either the driver should be insured or the driver should not be insured. So the program can be conveniently written using logical operators. For this let us first identify those cases in which the driver is insured. They are—Driver is married, Driver is an unmarried male above 30 years of age, and Driver is an unmarried female above 25 years of age. Since all these cases lead to the driver being insured, they can be combined together using && and || as shown in the program below.

/* Insurance of driver - using logical operators */

include

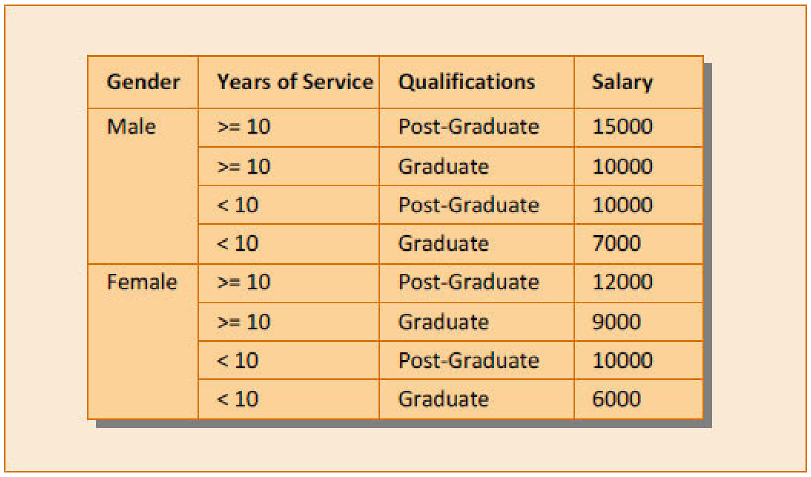
```
int main()

{

char sex, ms;

int age;

printf (“Enter age, sex, marital status”);

scanf (“%d %c %c”, &age, &sex, &ms);

if ((ms == ’M’) || (ms == ’U’ && sex == ’M’ && age > 30) || (ms == ’U’ && sex == ’F’ && age > 25))

printf (“Driver should be insured\n”);

else

printf (“Driver should not be insured\n”);

return 0;

}
```

In this program, it is important to note that:

- The driver will be insured only if one of the conditions enclosed in parentheses evaluates to true.
- For the expression in second pair of parentheses to evaluate to true, each condition in the expression separated by && must evaluate to true.
- Even if one of the conditions in the second parentheses evaluates to false, then the whole expression evaluates to false.
- The last two of the above arguments apply to third pair of parentheses as well.

In some programs we may combine the usage of if—else if—else and logical operators. This is demonstrated in the following program.

Example 4.3: Write a program to calculate the salary as per the following table:



Gender	Years of Service	Qualifications	Salary
Male	>= 10	Post-Graduate	15000
	>= 10	Graduate	10000
	< 10	Post-Graduate	10000
	< 10	Graduate	7000
Female	>= 10	Post-Graduate	12000
	>= 10	Graduate	9000
	< 10	Post-Graduate	10000
	< 10	Graduate	6000

Figure 4.1

Here is the program…

include

```
int main()

{

char g;

int yos, qual, sal = 0;

printf (“Enter Gender, Years of Service and Qualifications (0 = G, 1 = PG):”);

scanf (“%c%d%d”, &g, &yos, &qual);

if (g == ’m’ && yos >= 10 && qual == 1)

sal = 15000;

else if ((g == ’m’ && yos >= 10 && qual == 0) ||

(g == ’m’ && yos < 10 && qual == 1))

sal = 10000;

else if (g == ’m’ && yos < 10 && qual == 0)

sal = 7000;

else if (g == ’f’ && yos >= 10 && qual == 1)

sal = 12000;

else if (g == ’f’ && yos >= 10 && qual == 0)

sal = 9000;

else if (g == ’f’ && yos < 10 && qual == 1)

sal = 10000;

else if (g == ’f’ && yos < 10 && qual == 0)

sal = 6000;

printf (“\nSalary of Employee = %d\n”, sal);
return 0;

}
```

I hope you can follow the implementation of this program on your own.

The ! Operator

The third logical operator is the NOT operator, written as ! . This operator reverses the result of the expression it operates on. So if the expression evaluates to true, then applying ! operator to it results into a flase. Vice versa, if the expression evaluates to false, then applying ! to it makes it true. Here is an example showing use of ! operator.

```
! (y < 10)
```

If y is less than 10, the result will be false, since (y < 10) is true.

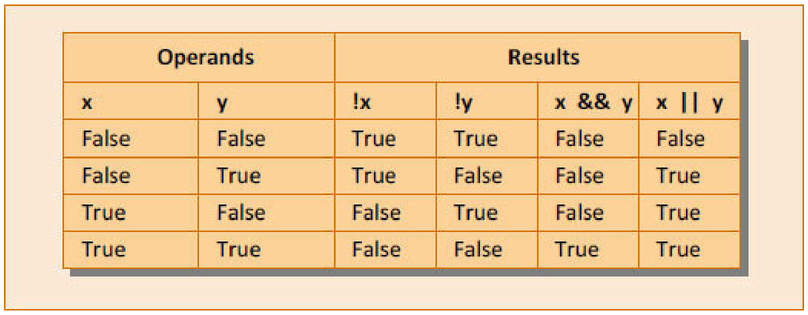
The NOT operator is often used to reverse the logical value of a single variable, as in the expression

```
if (! flag)
```

This is another way of saying:

```
if (flag == 0)
```

Figure 4.2 summarizes the working of all the three logical operators.

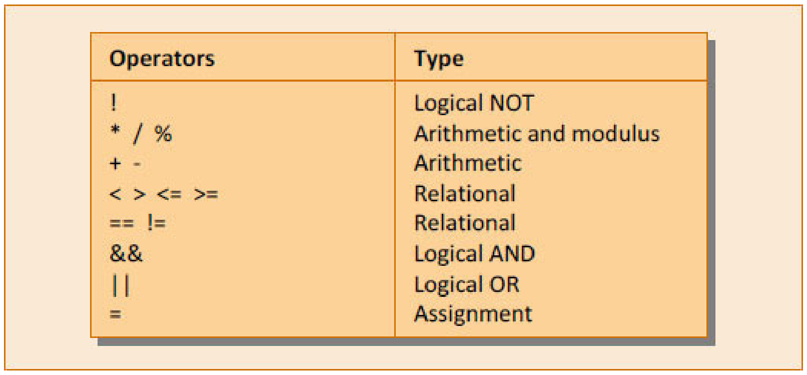


Operands		Results			
x	y	!x	!y	x && y	x || y
False	False	True	True	False	False
False	True	True	False	False	True
True	False	False	True	False	True
True	True	False	False	True	True

Figure 4.2

Hierarchy of Operators Revisited

Since we have now added the logical operators to the list of operators we know, it is time to review these operators and their priorities. Figure 4.3 summarizes the operators we have seen so far. The higher the position of an operator is in the table, higher is its priority. (A full-fledged precedence table of operators is given in Appendix B.)



Operators	Type
!	Logical NOT
* / %	Arithmetic and modulus
+ -	Arithmetic
< > <= >=	Relational
== !=	Relational
&&	Logical AND
||	Logical OR
=	Assignment

Figure 4.3

The Conditional Operators

The conditional operators ? and : are sometimes called ternary operators since they take three arguments. In fact, they form a kind of foreshortened if-then-else. Their general form is,

expression 1 ? expression 2 : expression 3

What this expression says is: “if expression 1 is true, then the value returned will be expression 2 , otherwise the value returned will be expression 3 ”. Let us understand this with the help of a few examples.

(a)
```
int x, y;

scanf (“%d”, &x);

y = (x > 5 ? 3: 4);
```

This statement will store 3 in y if x is greater than 5, otherwise it will store 4 in y.

(b)
```
char a;

int y;

scanf (“%c”, &a);

y = (a >= 65 && a <= 90 ? 1: 0);
```

Here 1 would be assigned to y if a >=65 && a <=90 evaluates to true, otherwise 0 would be assigned.

The following points may be noted about the conditional operators:

(a) It's not necessary that the statement after ? or: be only arithmetic statements. This is illustrated in the following examples:

Ex.:
```
int i;

scanf (“%d”, &i);

(i == 1 ? printf (“Amit”) : printf (“All and sundry”));
```

Ex.:
```
char a = ’z’;

printf (“%c”, (a >= ’a’ ? a : ’!’));
```

(b) The conditional operators can be nested as shown below.

```
int big, a, b, c;

big = (a > b ? (a > c ? 3: 4) : (b > c ? 6: 8));
```

(c) Check out the following conditional expression:

```
a > b ? g = a : g = b;
```

This will give you an error ‘Lvalue Required’. The error can be overcome by enclosing the statement in the : part within a pair of parentheses. This is shown below.

```
a > b ? g = a : g = b;
```

In absence of parentheses, the compiler believes that b is being assigned to the result of the expression to the left of second = . Hence it reports an error.

(d) The limitation of the conditional operators is that after the ? or after the : , only one C statement can occur.

P</> Programs

Problem 4.1

A year is entered through the keyboard, write a program to determine whether the year is leap or not. Use the logical operators && and || .

Program

```
/* Check whether a year is leap or not */
```

include

```
int main()

{

int year;

printf (“\nEnter year:”);

scanf (“%d”, &year);

if (year % 400 == 0 || year % 100 != 0 && year % 4 == 0)

printf (“Leap year\n”);

else

printf (“Not a leap year\n”);

return 0;

}
```

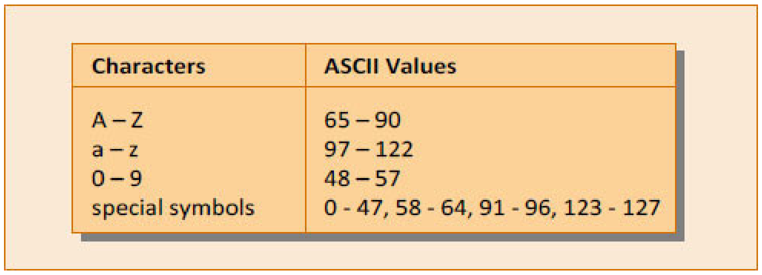
Output

```
Enter year: 1900

Not a leap year
```

Problem 4.2

If a character is entered through the keyboard, write a program to determine whether the character is a capital letter, a small case letter, a digit or a special symbol.

The following table shows the range of ASCII values for various characters:



Characters	ASCII Values
A – Z	65 – 90
a – z	97 – 122
0 – 9	48 – 57
special symbols	0 - 47, 58 - 64, 91 - 96, 123 - 127

Program

/* Check type of character entered from the keyboard */

include

```
int main()

{

char ch;

printf (“\nEnter a character from the keyboard:”);

scanf (“%c”, &ch);

if (ch >= 65 && ch <= 90)

printf (“The character is an uppercase letter\n”);
if (ch >= 97 && ch <= 122)

printf (“The character is a lowercase letter\n”);

if (ch >= 48 && ch <= 57)

printf (“The character is a digit\n”);

if ((ch >= 0 && ch < 48) || (ch > 57 && ch < 65)

|| (ch > 90 && ch < 97) || ch > 122)

printf (“The character is a special symbol\n”);

return 0;

}
```

Output

```
Enter a character from the keyboard: A

The character is an uppercase letter
```

Problem 4.3

If the three sides of a triangle are entered through the keyboard, write a program to check whether the triangle is valid or not. The triangle is valid if the sum of two sides is greater than the largest of the three sides.

Program

```
/* Check whether a triangle is valid or not */
```

include

```
int main()

{

int side1, side2, side3, largeside, sum;

printf (“\nEnter three sides of the triangle:”);

scanf (“%d %d %d”, &side1, &side2, &side3);

if (side1 > side2)

{

if (side1 > side3)

{

sum = side2 + side3; largeside = side1;

}

else

{

sum = side1 + side2; largeside = side3;

}

}
else

{

if (side2 > side3)

{

sum = side1 + side3; largeside = side2;

}

else

{

sum = side1 + side2; largeside = side3;

}

}

if (sum > largeside)

printf (“The triangle is a valid triangle\n”);

else

printf (“The triangle is an invalid triangle\n”);

return 0;

}
```

Output

```
Enter three sides of the triangle: 3 4 5

The triangle is a valid triangle
```

Exercises

[A] If a = 10, b = 12, c = 0, find the values of the expressions in the following table:

Expression	Value
a != 6 && b > 5	1
a == 9 || b < 3	
! (a < 10)	
! (a > 5 && c)	
5 && c != 8 || !c	

[B] What will be the output of the following programs:

(a)
```
# include

int main()

{

int i = 4, z = 12;

if (i = 5 || z > 50)
```

```
printf ("Dean of students affairs\n");

else

printf ("Dosa\n");

return 0;

}

(b) #include

int main()

{

int i = 4, j = -1, k = 0, w, x, y, z;

w = i || j || k;

x = i && j && k;

y = i || j && k;

z = i && j || k;

printf ("w = %d x = %d y = %d z = %d\n", w, x, y, z);

return 0;

}

(c) # include

int main()

{

int x = 20, y = 40, z = 45;

if (x > y && x > z)

printf ("biggest = %d\n", x);

else if (y > x && y > z)

printf ("biggest = %d\n", y);

else if (z > x && z > y)

printf ("biggest = %d\n", z); return 0;

}

(d) # include

int main()

{

int i = -4, j, num;

j = (num < 0 ? 0: num * num);

printf ("%d\n", j);

return 0;
```

}

(e) # include

int main()

{

int k, num = 30;

k = (num > 5 ? (num <= 10 ? 100: 200): 500);

printf (“%d\n”, num);

return 0;

}

[C] Point out the errors, if any, in the following programs:

(a) # include

int main()

{

char spy = ’a’, password = ’z’;

if (spy == ’a’ or password == ’z’)

printf (“All the birds are safe in the nest\n”);

return 0;

}

(b) # include

int main()

{

int i = 10, j = 20;

if (i = 5) && if (j = 10)

printf (“Have a nice day\n”);

return 0;

}

(c) # include

int main()

{

int x = 10, y = 20;

if (x >= 2 and y <= 50)

printf (“%d\n”, x);

return 0;

}

(d) # include

```
int main()
{
int x = 2;
if (x == 2 && x != 0);
printf ("Hello\n");
else
printf ("Bye\n");
return 0;
}
(e) # include
int main()
{
int j = 65;
printf ("j >= 65 ? %d: %c\n", j);
return 0;
}
(f) # include
int main()
{
int i = 10, j;
i >= 5 ? j = 10: j = 15;
printf ("%d %d\n", i, j);
return 0;
}
(g) # include
int main()
{
int a = 5, b = 6;
(a == b ? printf ("%d\n", a));
return 0;
}
(h) # include
int main()
{
```

int n = 9;

(n == 9 ? printf (“Correct\n”);: printf (“Wrong\n”););

return 0;

}

[D] Attempt the following questions:

(a) If the three sides of a triangle are entered through the keyboard, write a program to check whether the triangle is isosceles, equilateral, scalene or right angled triangle.

(b) In digital world colors are specified in Red-Green-Blue (RGB) format, with values of R, G, B varying on an integer scale from 0 to 255. In print publishing the colors are mentioned in Cyan-Magenta-Yellow-Black (CMYK) format, with values of C, M, Y, and K varying on a real scale from 0.0 to 1.0. Write a program that converts RGB color to CMYK color as per the following formulae:

$$White = Max(Red / 255, Green / 255, Blue / 255)$$

$$Cyan = \left(\frac{White - Red / 255}{White}\right)$$

$$Magenta = \left(\frac{White - Green / 255}{White}\right)$$

$$Yellow = \left(\frac{White - Blue / 255}{White}\right)$$

$$Black = 1 - White$$

Note that if the RGB values are all 0, then the CMY values are all 0 and the K value is 1.

(c) A certain grade of steel is graded according to the following conditions:

(i) Hardness must be greater than 50

(ii) Carbon content must be less than 0.7

(iii) Tensile strength must be greater than 5600

The grades are as follows:

Grade is 10 if all three conditions are met

Grade is 9 if conditions (i) and (ii) are met

Grade is 8 if conditions (ii) and (iii) are met

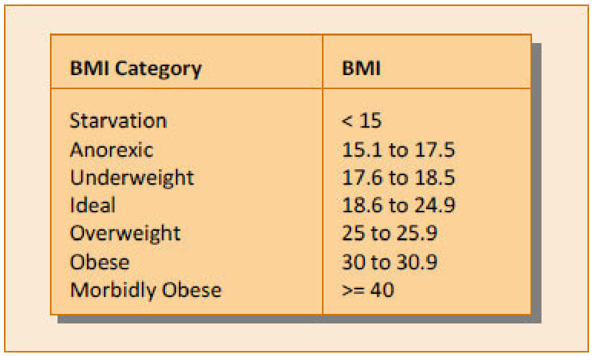
Grade is 7 if conditions (i) and (iii) are met

Grade is 6 if only one condition is met

Grade is 5 if none of the conditions are met

Write a program, which will require the user to give values of hardness, carbon content and tensile strength of the steel under consideration and output the grade of the steel.

(d) The Body Mass Index (BMI) is defined as ratio of the weight of a person (in kilograms) to the square of the height (in meters). Write a program that receives weight and height, calculates the BMI, and reports the BMI category as per the following table:



BMI Category	BMI
Starvation	< 15
Anorexic	15.1 to 17.5
Underweight	17.6 to 18.5
Ideal	18.6 to 24.9
Overweight	25 to 25.9
Obese	30 to 30.9
Morbidly Obese	>= 40

[E] Attempt the following questions:

(a) Using conditional operators determine:

(1) Whether the character entered through the keyboard is a lower case alphabet or not.

(2) Whether a character entered through the keyboard is a special symbol or not.

(b) Write a program using conditional operators to determine whether a year entered through the keyboard is a leap year or not.

(c) Write a program to find the greatest of the three numbers entered through the keyboard. Use conditional operators.

(d) Write a program to receive value of an angle in degrees and check whether sum of squares of sine and cosine of this angle is equal to 1.

(e) Rewrite the following program using conditional operators.

include

```
int main()

{

float sal;

printf (“Enter the salary”);

scanf (“%f”, &sal);

if (sal >= 25000 && sal <= 40000)

printf (“Manager\n”);

else

if (sal >= 15000 && sal < 25000)

printf (“Accountant\n”);

else

printf (“Clerk\n”);

return 0;

}
```

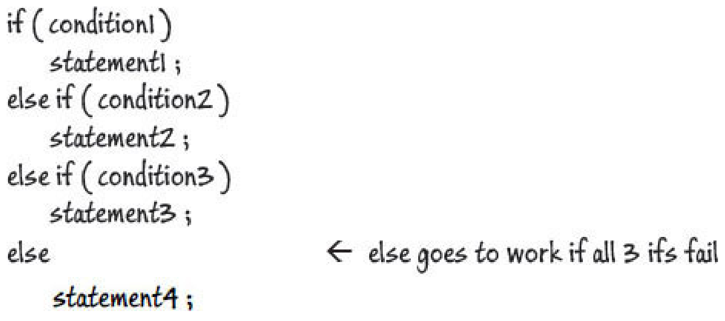
More complex decision making can be done using logical operators

Logical operators are &&, || and !

Logical operators are useful in 2 situations:

1) Checking ranges 2) Solving yes/no problem

One more form of decision control instruction is:



```
if ( condition1 )
    statement1 ;
else if ( condition2 )
    statement2 ;
else if ( condition3 )
    statement3 ;
else                         ← else goes to work if all 3 ifs fail
    statement4 ;
```

Hierarchy:

! * / % + - < > <= >= && || =

Unary operator - needs only 1 operand. Ex. ! sizeof

Binary operator - needs 2 operands. Ex. + == != && || - * / % < > <= >=

sizeof is an operator. It gives number of bytes occupied by an entity

Usage of sizeof operator:

a = sizeof (int)

b = sizeof (num);

! (a <= b) is same as (a > b). ! (a >= b) is same as (a < b)

a = !b does not change value of b

a = !a means, set a to 0 if it is 1 and set it to 1 if it is 0

lvalue required error means something is wrong on LHS of =

Conditional operators ?: are ternary operators. General form: expression1 ? expression2: expression3

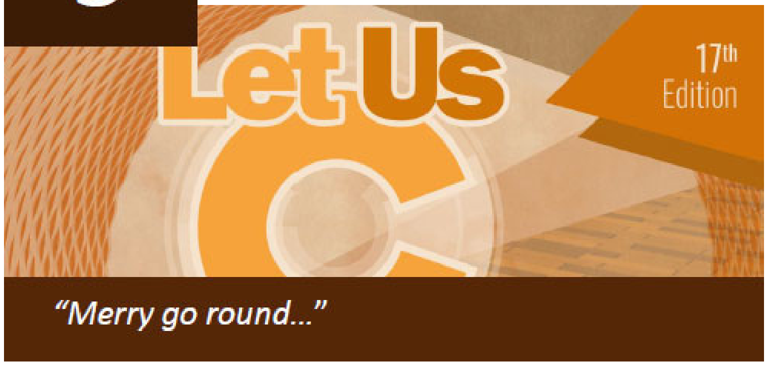
?: can have only 1 statement each

?: can be nested

?: always go together.: is not optional

Always parenthesize assignment operation if used with ?:

5 Loop Control Instruction



If you wish to find averages of 100 sets of three numbers, would you actually execute the program 100 times? Obviously not, there has to be a better way out. This chapter will show you how to accomplish this…

Contents

The programs that we have developed so far used either a sequential or a decision control instruction. These programs were of limited nature, because when executed, they always performed the same series of actions, in the same way, exactly once. In programming, we frequently need to perform an action over and over, often with variations in the details each time. The mechanism which meets this need is the ‘Loop Control Instruction’, and loops are the subject of this chapter.

Loops

The versatility of computer lies in its ability to perform a set of instructions repeatedly. This involves repeating some portion of the program either a specified number of times or until a particular condition is satisfied. This repetitive operation is done through a loop control instruction. There are three ways to repeat a part of a program. They are:

(a) Using a while statement

(b) Using a for statement

(c) Using a do-while statement

Let us begin by understanding the while loop.

The while Loop

The while loop is ideally suited for situations where we wish to repeat some instructions a fixed number of times. For example, we may wish to calculate simple interest for 3 sets of values of principal, number of years and rate of interest. Here is the program that can achieve this…

/* Calculation of simple interest for 3 sets of p, n and r */

include

```
int main()

{

int p, n, count;

float r, si;

count = 1;

while (count <= 3)

{

printf (“\nEnter values of p, n and r ”);

scanf (“%d %d %f”, &p, &n, &r);
si = p * n * r / 100;

printf ("Simple interest = Rs. %\nf", si);

count = count + 1;

}

return 0;

}
```

Given below is the interaction with this program on its execution.

```
Enter values of p, n and r 1000 5 13.5

Simple interest = Rs. 675.000000

Enter values of p, n and r 2000 5 13.5

Simple interest = Rs. 1350.000000

Enter values of p, n and r 3500 5 3.5

Simple interest = Rs. 612.500000
```

The program executes all statements after the while 3 times. The logic for calculating the simple interest is written in these statements and they are enclosed within a pair of braces. These statements form the 'body' of the while loop. The parentheses after the while contain a condition. So long as this condition remains true, the statements in the body of the while loop keep getting executed repeatedly. To begin with, the variable count is initialized to 1 and every time the simple interest logic is executed, the value of count is incremented by one. The variable count is often called either a 'loop counter' or an 'index variable'.

The operation of the while loop is illustrated in Figure 5.1 .

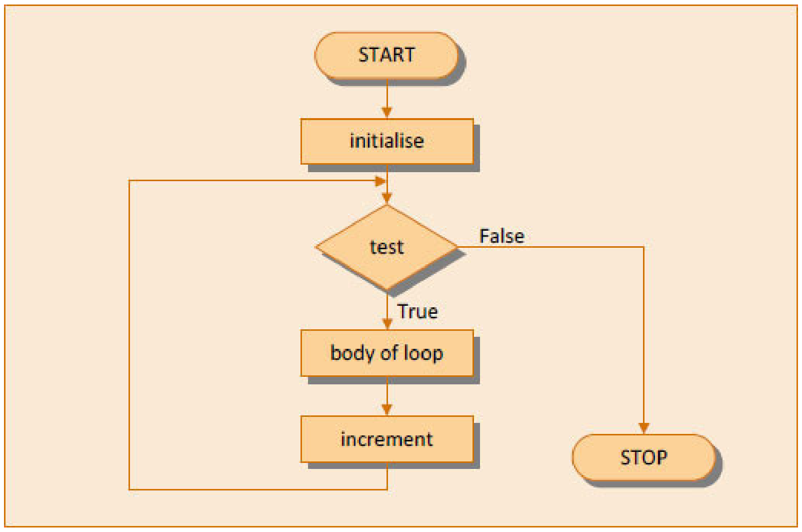


Figure 5.1

Tips and Traps

Note the following points about while…

- The statements within the while loop would keep getting executed till the condition being tested remains true. When the condition becomes false, the control passes to the first statement that follows the body of the while loop.
- Almost always, the while must test a condition that will eventually become false, otherwise the loop would keep getting executed forever, indefinitely.

```
int i = 1;
```

```
while (i <= 10)

printf (“%d\n”, i);
```

This is an indefinite loop, since i always remains equal to 1. The correct form would increment i in the body of the loop.

- Instead of incrementing a loop counter, we can decrement it and still manage to get the body of the loop executed repeatedly. This is shown below.

```
int i = 5;

while (i >= 1)

{

printf (“Make the computer literate!\n”);

i = i - 1;

}
```

- It is not necessary that a loop counter must only be an int . It can even be a float .

```
float a = 10.0;

while (a <= 10.5)

{

printf (“Raindrops on roses…”);

printf (“…and whiskers on kittens\n”);

a = a + 0.1;

}
```

- Even floating point loop counters can be decremented. Once again, the increment and decrement could be by any value, not necessarily 1.
- The condition being tested may use relational or logical operators as shown in the following examples:

```
while (i <= 10)

while (i >= 10 && j <= 15)

while (j > 10 && (b < 15 || c < 20))
```

- If there is only one statement within the loop then {} are optional.
- What will be the output of the following program:

include

```
int main()

{

int i = 1;

while (i <= 10);

{

printf (“%d\n”, i);

i = i + 1;
}
return 0;
}
```

This is an indefinite loop, and it doesn't give any output at all. The reason is, we have carelessly put a ; after the while . It would make the loop work like this…

```
while (i <= 10)
;
{
printf (“%d\n”, i);
i = i + 1;
}
```

Since the value of i is not getting incremented, the control would keep rotating within the loop eternally. Note that enclosing printf() and i = i +1 within a pair of braces is not an error. In fact, we can put a pair of braces around any individual statement or set of statements without affecting the execution of the program.

More Operators

There are several operators that are frequently used with while . To illustrate their use, let us consider a problem wherein numbers from 1 to 10 are to be printed on the screen. The program for performing this task can be written using while in following different ways:

```
(a) # include
int main()
{
int i = 1;
while (i <= 10)
{
printf (“%d\n”, i);
i = i + 1;
}
return 0;
}
```

This is the most straight-forward way of printing numbers from 1 to 10.

```
(b) # include
int main()
{
int i = 1;
while (i <= 10)
{
printf (“%d\n”, i);
```

i++;

}

return 0;

}

Note that the increment operator ++ increments the value of i by 1, every time the statement i++ gets executed. Similarly, to reduce the value of a variable by 1, a decrement operator -- is also available.

However, never use n+++ to increment the value of n by 2, since there doesn't exist an operator +++ in C.

(c) # include

int main()

{

int i = 1;

while (i <= 10)

{

printf (“%d\n”, i);

i += 1;

}

return 0;

}

Note that += is a compound assignment operator. It increments the value of i by 1. Similarly, j = j + 10 can also be written as j += 10 . Other compound assignment operators are -=, *=, / = and %= .

(d) # include

int main()

{

int i = 0;

while (i++ < 10)

printf (“%d\n”, i);

return 0;

}

In the statement while (i++ < 10) , first the comparison of value of i with 10 is performed, and then the incrementation of i takes place. Since the incrementation of i happens after the comparison, here the ++ operator is called a post-incrementation operator. When the control reaches printf() , i has already been incremented, hence i must be initialized to 0, not 1.

(e) # include

int main()

{

int i = 0;

while (++i <= 10)

```
printf (“%d\n”, i);

return 0;

}
```

In the statement while (++i <= 10) , first incrementation of i takes place, then the comparison of value of i with 10 is performed. Since the incrementation of i happens before the comparison, here the ++ operator is called a pre-incrementation operator.

P</> Programs

Problem 5.1

Write a program to calculate overtime pay of 10 employees. Overtime is paid at the rate of Rs. 12.00 per hour for every hour worked above 40 hours. Assume that employees do not work for fractional part of an hour.

Program

```
/* Determine overtime pay of 10 employees.*/
```

include

```
int main()

{

float otpay;

int hour, i = 1;

while (i <= 10) /* Loop for 10 employees */

{

printf (“\nEnter no. of hours worked: ”);

scanf (“%d”, &hour);

if (hour >= 40)

otpay = (hour - 40) * 12;

else

otpay = 0;

printf (“Hours = %d Overtime pay = Rs.%f\n”, hour, otpay);

i++;

}

return 0;

}
```

Output

```
Enter no. of hours worked: 45

Hours = 45 Overtime pay = Rs.60.000000

Enter no. of hours worked: 50

Hours = 50 Overtime pay = Rs.120.000000
```

```
Enter no. of hours worked: 20

Hours = 20 Overtime pay = Rs.0.000000
```

Problem 5.2

Write a program to find the factorial value of any number entered through the keyboard.

Program

```
/* Calculation of factorial value of a number */

include

int main()

{

int num, i, fact;

printf (“Enter a number: ”);

scanf (“%d”, &num);

fact = i = 1;

while (i <= num)

{

fact = fact * i;

i++;

}

printf (“Factorial value of %d = %d\n”, num, fact);

return 0;

}
```

Output

```
Enter a number: 14

Factorial value of 14 = 1278945280
```

Problem 5.3

Two numbers are entered through the keyboard. Write a program to find the value of one number raised to the power of another.

Program

```
/* Compute value of one number raised to another */

include

int main()

{

float x, power;

int y, i;
printf ("\nEnter two numbers: ");
scanf ("%f %d", &x, &y);
power = i = 1;
while (i <= y)
{
power = power * x;
i++;
}
printf ("%f to the power %d is %f\n", x, y, power);
return 0;
}
```

Output

```
Enter two numbers: 2.5 3
2.500000 to the power 3 is 15.625000
```

Exercises

[A] What will be the output of the following programs:

```
(a) # include
int main()
{
int i = 1;
while (i <= 10);
{
printf ("%d\n", i);
i++;
}
return 0;
}
```

```
(b) # include
int main()
{
int x = 4, y, z;
y = --x;
z = x--;
printf ("%d %d %d\n", x, y, z);
```

```
return 0;
}
(c) # include
int main()
{
int x = 4, y = 3, z;
z = x-- - y;
printf (“%d %d %d\n”, x, y, z);
return 0;
}
(d) # include
int main()
{
while (’a’ < ’b’)
printf (“malayalam is a palindrome\n”);
return 0;
}
(e) # include
int main()
{
int i;
while (i = 10)
{
printf (“%d\n”, i);
i = i + 1;
}
return 0;
}
(f) # include
int main()
{
float x = 1.1;
while (x == 1.1)
{
printf (“%f\n”, x);
```

x = x - 0.1;

}

return 0;

}

[B] Attempt the following questions:

(a) Write a program to print all the ASCII values and their equivalent characters using a while loop. The ASCII values vary from 0 to 255.

(b) Write a program to print out all Armstrong numbers between 1 and 500. If sum of cubes of each digit of the number is equal to the number itself, then the number is called an Armstrong number. For example, 153 = (1 * 1 * 1) + (5 * 5 * 5) + (3 * 3 * 3).

(c) Write a program for a matchstick game being played between the computer and a user. Your program should ensure that the computer always wins. Rules for the game are as follows:

- There are 21 matchsticks.
- The computer asks the player to pick 1, 2, 3, or 4 matchsticks.
- After the person picks, the computer does its picking.
- Whoever is forced to pick up the last matchstick loses the game.

(d) Write a program to enter numbers till the user wants. At the end it should display the count of positive, negative and zeros entered.

(e) Write a program to receive an integer and find its octal equivalent.

(Hint: To obtain octal equivalent of an integer, divide it continuously by 8 till dividend doesn't become zero, then write the remainders obtained in reverse direction.)

(f) Write a program to find the range of a set of numbers entered through the keyboard. Range is the difference between the smallest and biggest number in the list.

Repetition control instruction is used to repeat a set of statements in a program.

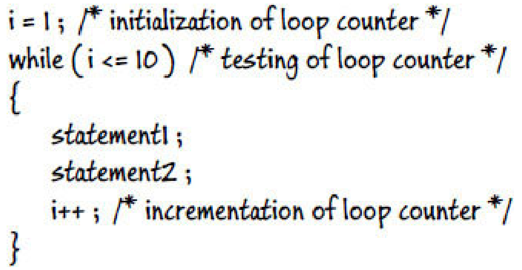
It is implemented using

1) while loop

2) for loop

3) do - while loop

General form of while:



```
i = 1 ; /* initialization of loop counter */
while ( i <= 10 ) /* testing of loop counter */
{
    statement1 ;
    statement2 ;
    i++ ; /* incrementation of loop counter */
}
```

i++ increments vale by 1

i-- decrements value of i by 1

There are no **, // and %% operators

The expressions i = i + 1, i++ and ++i are all same

j = ++i; first increments i, then assigns the incremented value to j

j = i++; first assigns current value of i to j, then increments i

while (++i < 10) first increments i, then checks condition

while (i++ < 10) first checks condition, then increments i

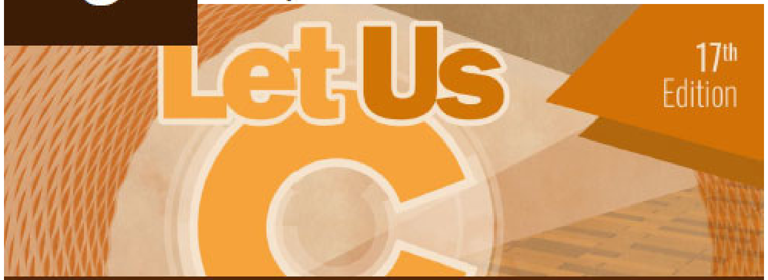
i = i + 5 is same as i += 5

Compound assignment operators: +=, -=, *=, /= and %=

Running sum and products are implemented using following:

```
s = 0 ;
p = 1 ;
while ( condition )
{
    /* calculate term */
    s = s + term ;
    p = p * term ;
}
```

6 More Complex Repetitions



"Run through the hoops..."

x takes values from 1 to 10. For every x, y takes values from 0.5 to 2.25 in steps of 0.5 and for every y, z goes from 100 to 55 in decrements of -2, and for every z, m increases in multiples of 4 starting with 4. Lost in the hoops? Well, this chapter will show you how such complex repetitions can be implemented in C…

C Contents

Exercises

KanNotes

The programs in the last chapter showed how instructions in a program can be repeated using a while loop. This chapter explores the other two loops— for and do-while . There is more to looping than just repeating instructions. For example, what if we wish to terminate the loop abruptly, or skip some instructions as the loop executes, or repeat something infinite times, unknown number of times or only once. All these scenarios are handled in this chapter.

The for Loop

The for loop allows us to specify three things about the loop in a single line:

(a) Setting a loop counter to an initial value.

(b) Testing the loop counter to determine whether its value has reached the number of repetitions desired.

(c) Increasing the value of loop counter each time the body of the loop has been executed.

The general form of for loop is as under:

```
for (initialize counter; test counter; increment counter)

{

do this;

and this;

}
```

Let us now write down the simple interest program using for . Compare this program with the one that we wrote using while .

/* Calculation of simple interest for 3 sets of p, n and r */

include

```
int main()

{

int p, n, count;

float r, si;

for (count = 1; count <= 3; count = count + 1)

{

printf (“Enter values of p, n, and r ”);

scanf (“%d %d %f”, &p, &n, &r);

si = p * n * r / 100;

printf (“Simple Interest = Rs.%f\n”, si);

}

return 0;

}
```

You can observe that the three steps—initialization, testing and incrementation—required for the loop construct have now been incorporated in one single line of for statement.

Let us now examine how the for statement gets executed:

- When for statement is executed for the first time, the value of count is set to an initial value 1.
- Next the condition count <= 3 is tested. Since count is 1, the condition is satisfied and the body of the loop is executed for the first time.
- Upon reaching the closing brace of for , control is sent back to for statement, where the value of count gets incremented by 1.
- Again the test is performed to check whether the new value of count exceeds 3.
- If the value of count is less than or equal to 3, the statements within the braces of for are executed again.
- The body of for loop continues to get executed till count doesn't exceed the final value 3.
- When count reaches the value 4, the control exits from the loop and is transferred to the statement (if any) immediately after the body of for .

It is important to note that the initialization, testing and incrementation part of a for loop can be replaced by any valid expression. Thus the following for loops are perfectly ok.

```
for (i = 10; i; i --)
printf (“%d ”, i);
for (i < 4; j = 5; j = 0)
printf (“%d ”, i);
for (i = 1; i <=10; printf (“%d ”, i++))
;
for (scanf (“%d”, &i); i <= 10; i++)
printf (“%d”, i);
```

Let us now write down the program to print numbers from 1 to 10 in different ways. This time we would use a for loop instead of a while loop.

```
(a) # include
int main()
{
int i;
for (i = 1; i <= 10; i = i + 1)
printf (“%d\n”, i);
return 0;
}
```

Instead of i = i + 1 , the statements i++ or i += 1 can also be used. Since there is only one statement in the body of the for loop, the pair of braces have been dropped. As with the while , the default scope of for is the immediately next statement after for .

```
(b) # include
int main()
{
int i;
for (i = 1; i <= 10;)
{
```

```
printf (“%d\n”, i);
i = i + 1;
}
return 0;
}
```

Here, the incrementation is done within the body of the for loop. In spite of this, the semicolon (;) after the condition is necessary.

```
(c) # include
int main()
{
int i = 1;
for (; i <= 10; i = i + 1)
printf (“%d\n”, i);
return 0;
}
```

Here the initialization is done in the declaration statement itself, but still the semicolon before the condition is necessary.

```
(d) # include
int main()
{
int i = 1;
for (; i <= 10;)
{
printf (“%d\n”, i);
i = i + 1;
}
return 0;
}
```

Here, neither the initialization nor the incrementation is done in the for statement, but still the two semicolons are necessary.

```
(e) # include
int main()
{
int i;
for (i = 0; i++ < 10;)
printf (“%d\n”, i);
return 0;
}
```

Here, the comparison as well as the incrementation is done through the same expression, i++ < 10 . Since the ++ operator comes after i , comparison is done first, followed by incrementation. Note that it is necessary to initialize i to 0.

```
(f) # include

int main()

{

int i;

for (i = 0; ++i <= 10;)

printf (“%d\n”, i);

return 0;

}
```

Here again, both, the comparison and the incrementation are done through the same expression, ++i <= 10 . Since ++ precedes i firstly incrementation is done, followed by comparison. Note that it is necessary to initialize i to 0.

Nesting of Loops

The way if statements can be nested, similarly while s and for s can also be nested. The following program shows how nested loops work.

/* Demonstration of nested loops */

include

```
int main()

{

int r, c, sum;

for (r = 1; r <= 3; r++) /* outer loop */

{

for (c = 1; c <= 2; c++) /* inner loop */

{

sum = r + c;

printf (“r = %d c = %d sum = %d\n”, r, c, sum);

}

}

return 0;

}
```

When you run this program, you will get the following output:

```
r = 1 c = 1 sum = 2

r = 1 c = 2 sum = 3

r = 2 c = 1 sum = 3

r = 2 c = 2 sum = 4
```

r = 3 c = 1 sum = 4

r = 3 c = 2 sum = 5

Here, for each value of r , the inner loop is cycled through twice, with the variable c taking values from 1 to 2. The inner loop terminates when the value of c exceeds 2, and the outer loop terminates when the value of r exceeds 3.

As you can see, the body of the outer for loop is indented, and the body of the inner for loop is further indented. These multiple indentations make the program easier to understand.

Instead of using two statements, one to calculate sum and another to print it out, we can compact them into one single statement by saying:

printf (“r = %d c = %d sum = %d\n”, r, c, r + c);

The way for loops have been nested here, similarly, two while loops can also be nested. Not only this, a for loop can occur within a while loop, or a while within a for .

Multiple Initializations in the for Loop

The initialization expression in the for loop can contain more than one statement separated by a comma. For example,

for (i = 1, j = 2; j <= 10; j++)

Multiple incrementations can also be done in a for loop. Similarly, multiple conditions are allowed in the test expression. These conditions should be linked together using logical operators && and/or ||.

The break Statement

We often come across situations where we want to jump out of a loop instantly, without waiting to get back to the condition. The keyword break allows us to do this. When break is encountered inside any loop, control automatically passes to the first statement after the loop. A break is usually associated with an if . Let's consider the following example to understand it:

Example 6.1: Write a program to determine whether a number is prime or not. A prime number is said to be prime if it is divisible only by 1 or itself.

All we have to do to test whether a number is prime or not, is to divide it successively by all numbers from 2 to one less than itself. If remainder of any of these divisions is zero, the number is not a prime. If no division yields a zero then the number is a prime number. Following program implements this logic:

include

int main()

{

int num, i;

printf (“Enter a number ”);

scanf (“%d”, &num);

i = 2;

while (i <= num - 1)

{

if (num % i == 0)

{

printf (“Not a prime number\n”);

break;

}

```
i++;

}

if (i == num)

printf (“Prime number\n”);

}
```

In this program, the moment num % i turns out to be zero, (i.e., num is exactly divisible by i), the message “Not a prime number” is printed and the control breaks out of the while loop. Why does the program require the if statement after the while loop at all? Well, there are two possibilities the control could have reached outside the while loop:

(a) It jumped out because the number proved to be not a prime.

(b) The loop came to an end because the value of i became equal to num .

When the loop terminates in the second case, it means that there was no number between 2 to num - 1 that could exactly divide num . That is, num is indeed a prime. If this is true, the program should print out the message “Prime number”.

The keyword break , breaks the control only from the while in which it is placed. Consider the following program, which illustrates this fact:

include

```
int main()

{

int i = 1, j = 1;

while (i++ <= 100)

{

while (j++ <= 200)

{

if (j == 150)

break;

else

printf (“%d %d\n”, i, j);

}

}

return 0;

}
```

In this program when j equals 150, break takes the control outside the inner while only, since it is placed inside the inner while .

The continue Statement

In some programming situations, we want to take the control to the beginning of the loop, bypassing the statements inside the loop, which have not yet been executed. The keyword continue allows us to do this. When continue is encountered inside any loop, control automatically passes to the beginning of the loop.

A continue is usually associated with an if . As an example, let’s consider the following program:

include

```
int main()

{

int i, j;

for (i = 1; i <= 2; i++)

{

for (j = 1; j <= 2; j++)

{

if (i == j)

continue;

printf (“%d %d\n”, i, j);

}

}

return 0;

}
```

The output of the above program would be…

```
1 2

2 1
```

Note that when the value of i equals that of j , the continue statement takes the control to the for loop (inner) bypassing the rest of the statements pending execution in the for loop (inner).

The do - while Loop

The do-while loop looks like this:

```
do

{

this;

and this;

} while (this condition is true);
```

There is a minor difference between the working of while and do-while loops. This difference lies in the place where the condition is tested. The while tests the condition before executing any of the statements within the while loop. As against this, the do-while tests the condition after having executed the statements within the loop.

This means that do-while would execute its statements at least once, even if the condition fails for the first time. The while , on the other hand will not execute its statements if the condition fails for the first time. This difference is brought about more clearly by the following program:

include

```
int main()

{
```

while (4 < 1)

printf (“Hello there \n”);

return 0;

}

Here, since the condition fails the first time itself, the printf() will not get executed at all. Let’s now write the same program using a do-while loop.

include

int main()

{

do

{

printf (“Hello there \n”);

} while (4 < 1);

return 0;

}

In this program, the printf() would be executed once, since first the body of the loop is executed and then the condition is tested.

break and continue can also be used with do-while loop. A break takes control out of the do-while bypassing the conditional test. A continue sends control straight to the test at the end of the loop.

The Odd Loop

The loops used so far executed the statements within them a finite number of times. However, at times one comes across a situation when it is not known beforehand, how many times the statements in the loop are to be executed. This situation can be programmed as shown below.

/* Execution of a loop an unknown number of times */

include

int main()

{

char another;

int num;

do

{

printf (“Enter a number ”);

scanf (“%d”, &num);

printf (“square of %d is %d\n”, num, num * num);

printf (“Want to enter another number y/n ”);

fflush (stdin);

scanf (“%c”, &another);

```
} while (another == 'y');

return 0;

}
```

And here is the sample output…

```
Enter a number 5

square of 5 is 25

Want to enter another number y/n y

Enter a number 7

square of 7 is 49

Want to enter another number y/n n
```

In this program, the do-while loop would keep getting executed till the user continues to answer y . The moment user answers n , the loop terminates, since the condition (another == 'y') fails. Note that this loop ensures that statements within it are executed at least once.

Perhaps you are wondering why have we used the function fflush() for. The reason is to get rid of a peculiarity of scanf() . After supplying a number when we hit the Enter key, scanf() assigns the number to variable num and keeps the Enter key unread in the keyboard buffer. So when it's time to supply Y or N for the question 'Want to enter another number (y/n)', scanf() will read the Enter key from the buffer thinking that user has entered the Enter key. To avoid this problem, we use the function fflush() . It is designed to remove or 'flush out' any data remaining in the buffer. The argument to fflush() must be the buffer which we want to flush out. Here we have used 'stdin', which means buffer related with standard input device, i.e., keyboard.

Though it is simpler to program such a requirement using a do-while loop, the same functionality, if required, can also be accomplished using for and while loops. You can try doing this as an exercise.

P</> Programs

Problem 6.1

Write a program to print all prime numbers from 1 to 300.

Program

```
/* Generate all prime numbers from 1 to 300 */
```

include

```
int main()

{

int i, n = 1;

printf ("\nPrime numbers between 1 and 300 are :\n1\t");

for (n = 1; n <= 300; n++)

{

i = 2;

for (i = 2; i < n; i++)

{

if (n % i == 0)
```

break;

}

if (i == n)

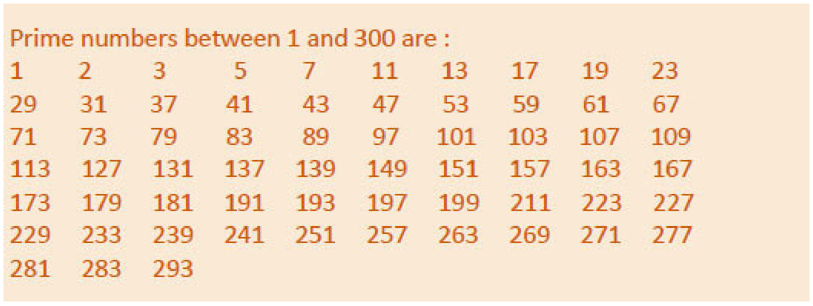
printf (“%d\t”, n);

}

return 0;

}

Output



```
Prime numbers between 1 and 300 are :
1      2      3      5      7      11     13     17     19     23
29     31     37     41     43     47     53     59     61     67
71     73     79     83     89     97     101    103    107    109
113    127    131    137    139    149    151    157    163    167
173    179    181    191    193    197    199    211    223    227
229    233    239    241    251    257    263    269    271    277
281    283    293
```

Problem 6.2

Write a program to add first seven terms of the following series using a for loop.

$$\frac{1}{1!} + \frac{2}{2!} + \frac{3}{3!} + \ldots\ldots$$

Program

/* Sum of first seven terms of a series */

include

int main()

{

int i = 1, j;

float fact, sum = 0.0;

for (i = 1; i <= 7; i++)

{

fact = 1.0;

for (j = 1; j <= i; j++)

fact = fact * j;

sum = sum + i / fact;

}

printf (“Sum of series = %f\n”, sum);

return 0;

}

Output

```
Sum of series = 2.718056
```

Problem 6.3

Write a program to generate all combinations of 1, 2 and 3 using for loop.

Program

```
/* Generate all possible combinations of 1 2 3 */
```

include

```
int main()
{
int i = 1, j = 1, k = 1;
for (i = 1; i <= 3; i++)
{
for (j = 1; j <= 3; j++)
{
for (k = 1; k <= 3; k++)
printf (“%d %d %d\n”, i, j, k);
}
}
return 0;
}
```

Output

```
1 1 1
1 1 2
..
..
2 1 1
..
..
2 3 3
3 1 1
..
..
3 3 3
```

Exercises

[A] Answer the following questions:

(a) The break statement is used to exit from:

An if statement

A for loop

A program

The main() function

(b) A do-while loop is useful when we want that the statements within the loop must be executed:

Only once

At least once

More than once

None of the above

(c) In what sequence the initialization, testing and execution of body is done in a do-while loop?

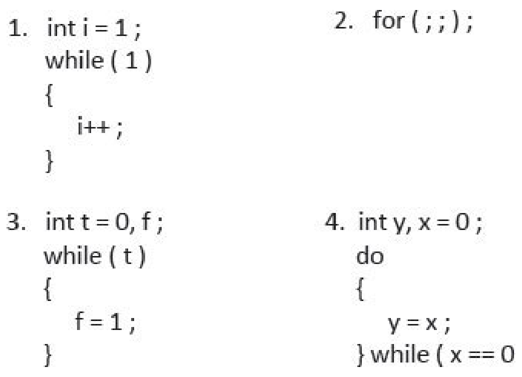
Initialization, execution of body, testing

Execution of body, initialization, testing

Initialization, testing, execution of body

None of the above

(d) Which of the following is not an infinite loop?



```
1.  int i = 1 ;                  2.  for ( ; ; ) ;
    while ( 1 )
    {
        i++ ;
    }

3.  int t = 0, f ;               4.  int y, x = 0 ;
    while ( t )                      do
    {                                {
        f = 1 ;                          y = x ;
    }                                } while ( x == 0
```

(e) Which of the following statements is true for the following program?

include

int main()

{

int x=10, y = 100 % 90;

for (i = 1; i <= 10; i++);

if (x != y);

printf (“x = %d y = %d\n”, x, y);

return 0;

}

The printf() function is called 10 times.

The program will produce the output x = 10 y = 10.

The; after the if (x!=y) would not produce an error.

The program will not produce any output.

The printf() function is called infinite times.

(f) Which of the following statement is true about a for loop used in a C program?

for loop works faster than a while loop.

All things that can be done using a for loop can also be done using a while loop.

for (;;) implements an infinite loop.

for loop can be used if we want statements in a loop to get executed at least once.

for loop works faster than a do-while loop.

[B] Attempt the following questions:

(a) Write a program to print the multiplication table of the number entered by the user. The table should get displayed in the following form:

29 * 1 = 29

29 * 2 = 58

…

(b) According to a study, the approximate level of intelligence of a person can be calculated using the following formula:

i = 2 + (y + 0.5 x)

Write a program that will produce a table of values of i , y and x , where y varies from 1 to 6, and, for each value of y , x varies from 5.5 to 12.5 in steps of 0.5.

(c) When interest compounds q times per year at an annual rate of r % for n years, the principal p compounds to an amount a as per the following formula a = p (1 + r / q) nq

Write a program to read 10 sets of p, r, n & q and calculate the corresponding a s.

(d) The natural logarithm can be approximated by the following series.

$$\frac{x-1}{x}+\frac{1}{2}\left(\frac{x-1}{x}\right)^2+\frac{1}{2}\left(\frac{x-1}{x}\right)^3+\frac{1}{2}\left(\frac{x-1}{x}\right)^4+\dots$$

If x is input through the keyboard, write a program to calculate the sum of first seven terms of this series.

(e) Write a program to generate all Pythagorean Triplets with side length less than or equal to 30.

(f) Population of a town today is 100000. The population has increased steadily at the rate of 10 % per year for last 10 years. Write a program to determine the population at the end of each year in the last decade.

(g) Ramanujan number is the smallest number that can be expressed as sum of two cubes in two different ways. Write a program to print all such numbers up to a reasonable limit.

(h) Write a program to print 24 hours of day with suitable suffixes like AM, PM, Noon and Midnight.

(i) Write a program to produce the following output:

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

3 types of loops:

1) while

2) for

3) do - while

What can be done using one loop can always be done using the other two

Usual usage:

while - to repeat something an unknown number of times

for - to repeat something a fixed number of times

do - while - to repeat something at least once

Equivalent forms:

```
i = 1 ;
while ( i <= 10 )
{
    statement1 ;
    statement2 ;
    i++ ;
}
```

```
for ( i = 1 ; i <= 10 ; i++ )
{
    statement1 ;
    statement2 ;
}
```

```
i = 1 ;
do
{
    statement1 ;
    statement2 ;
    i++ ;
} while ( i <= 10 ) ;
```

for (;;) is an infinite loop. while () results into an error

Multiple initializations, conditions and incrementations in a for loop are acceptable. Ex.:

```
for ( i = 1 , j = 2 ; i <= 10 && j <= 24 ; i++, j += 3 )
{
    statement1 ;
    statement2 ;
}
```

break - terminates the execution of the loop

continue - abandons rest of the instructions in the loop and goes for the next iteration of the loop

Usually break and continue are used in this form:

```
while ( condition1 )
{
    if ( condition2 )
        break ;
    statement1 ;
    statement2 ;
}
```

```
while ( condition1 )
{
    if ( condition2 )
        continue ;
    statement1 ;
    statement2 ;
}
```

7 Case Control Instruction

Choosing the right control instruction adds to the efficiency and speed of the program. So, though a situation where different actions are to be carried out for 5 different values of variable x can be implemented using 5 ifs, it may not be a very efficient way of doing it. This chapter will show you how this can be done in a better and more efficient way…

Contents

In programming, we are often faced with situations where we are required to make a choice between a number of alternatives rather than only one or two. C provides a special control statement that allows us to handle such cases effectively; rather than using a series of if statements. This control instruction is the topic of this chapter. Towards the end of the chapter, we would also study a keyword called goto and understand why we should avoid its usage.

Decisions using switch

The control instruction that allows us to make a decision from the number of choices is called a switch , or more correctly a switch-case-default , since these three keywords go together to make up the control statement. They most often appear as follows:

```
switch (integer expression)
{
case constant 1 :
do this;
case constant 2 :
do this;
case constant 3 :
do this;
default :
do this;
}
```

The integer expression following the keyword switch is any C expression that will yield an integer value. The keyword case is followed by an integer or a character constant. Constant used in each case must be different from those used in other cases. The “do this” lines in the above form of switch represent any valid C statement.

What happens when we run a program containing a switch statement? First, the integer expression following the keyword switch is evaluated. The value it gives is then matched, one-by-one, against the constant values that follow the case statements. When a match is found, the program executes the statements following that case , and all subsequent case and default statements as well. If no match is found with any of the case statements, the statements following the default case are executed. A few examples will show how this control instruction works.

Consider the following program:

include

```
int main()

{

int i = 2;

switch (i)

{

case 1 :

printf (“I am in case 1 \n”);

case 2 :

printf (“I am in case 2 \n”);

case 3 :

printf (“I am in case 3 \n”);

default :

printf (“I am in default \n”);

}

return 0;

}
```

The output of this program would be:

```
I am in case 2

I am in case 3

I am in default
```

The output is definitely not what we expected! We didn't expect the second and third lines in the above output. We got them because once the matching case was found all the subsequent case s and the default also got executed.

If you want that only case 2 should get executed, it is up to you to get out of the switch then and there by using a break statement. The following program shows how this is done. Note that there is no need for a break statement after the default , since on reaching the default case, the control comes out of the switch anyway.

include

int main()

{

int i = 2;

switch (i)

{

case 1 :

printf (“I am in case 1 \n”);

break;

case 2 :

printf (“I am in case 2 \n”);

break;

case 3 :

printf (“I am in case 3 \n”);

break;

default :

printf (“I am in default \n”);

}

return 0;

}

The output of this program would be:

I am in case 2

The Tips and Traps

Now let us understand a few tips about the usage of switch and a few pitfalls to be avoided.

(a) The program in the previous section may give you an impression that cases in a switch must be arranged in ascending order—1, 2, 3 and default. In fact, you can put the cases in any order you please.

(b) Even if there are multiple statements to be executed in each case , there is no need to enclose them within a pair of braces (unlike if and else).

(c) Every statement in a switch must belong to some case or the other.

(d) If we have no default case, and no case is satisfied, then the control simply falls through the entire switch and continues with the next instruction (if any,) that follows the closing brace of switch .

(e) At times we may want to execute a common set of statements for multiple case s. The following example shows how this can be achieved:

include

int main()

{

char ch;

printf (“Enter any one of the alphabets a, b, or c ”);

```
scanf (“%c”, &ch);

switch (ch)

{

case ’a’ :

case ’A’ :

printf (“a as in ashar\n”);

break;

case ’b’ :

case ’B’ :

printf (“b as in brain\n”);

break;

case ’c’ :

case ’C’ :

printf (“c as in cookie\n”);

break;

default :

printf (“wish you knew what are alphabets\n”);

return 0;

}

}
```

Here, we are making use of the fact that once a case is satisfied; control simply falls through the switch till it doesn't encounter a break statement. That is why, if alphabet a is entered, case ‘a’ is satisfied and since there are no statements to be executed in this case , control automatically reaches the next case , i.e., case ‘A’ and executes all the statements in this case .

(f) Is switch a replacement for if ? Yes and no. Yes, because it offers a better way of writing programs as compared to if , and no, because, in certain situations, we are left with no choice but to use if . The disadvantage of switch is that one cannot have a case in a switch which looks like:

```
case i <= 20 :
```

All that we can have after the case is an int constant or a char constant or an expression that evaluates to an int constant. Even a float is not allowed.

The advantage of switch over if is that it leads to a more structured program and the level of indentation is manageable, more so, if there are multiple statements within each case of a switch .

(g) We can check the value of any expression in a switch . Thus, the following switch statements are legal:

```
switch (i + j * k)

switch (23 + 45 % 4 * k)

switch (a < 4 && b > 7)
```

Expressions can also be used in cases provided they are constant expressions. Thus, case 3 + 7 is correct, however, case a + b is incorrect.

(h) The break statement when used in a switch takes the control outside the switch . However, use of continue will not take the control to the beginning of switch , as one is likely to believe.

(i) In principle, a switch may occur within another, but in practice, this is rarely done. Such statements would be called nested switch statements.

(j) The switch statement is very useful while writing menu driven programs. This aspect of switch is illustrated in Programs section of this chapter.

switch versus if-else Ladder

There are some things that you simply cannot do with a switch . These are:

(a) A float expression cannot be tested using a switch.

(b) Cases can never have variable expressions as in case a + 3: .

(c) Multiple cases cannot use same expressions. Thus the following switch is illegal:

```
switch (a)

{

case 3 :

…

case 1 + 2 :

…

}
```

(a), (b) and (c) above may lead you to believe that these are obvious disadvantages with a switch , especially since there weren't any such limitations with if-else . Then why use a switch at all? For speed— switch works faster than an equivalent if-else ladder. This is because compiler generates a jump table for a switch during compilation. As a result, during execution, it simply refers the jump table to decide which case should be executed, rather than actually checking which case is satisfied. As against this, if-else s are slower because the conditions in them are evaluated at execution time. Note that a lookup in the jump table is faster than evaluation of a condition, especially if the condition is complex.

The goto Keyword

Avoid goto keyword! There is seldom a legitimate reason for using goto . Its use is one of the reasons that programs become unreliable, unreadable, and hard to debug. And yet many programmers find goto seductive.

In a difficult programming situation, it seems easy to use a goto to take the control where you want. However, almost always, there is a more elegant way of writing the same program using if , for , while , do-while and switch . These constructs are far more logical and easy to understand.

The big problem with goto keyword is that when we do use it we can never be sure how we got to a certain point in our code. It obscures the flow of control. So as far as possible skip it. You can always get the job done without it. Trust me, with good programming skills, goto can always be avoided. This is the first and last time that we are going to use goto in this book. However, for sake of completeness of the book, the following program shows how to use goto :

include

include

```
int main()

{

int goals;

printf (“Enter the number of goals scored against India”);

scanf (“%d”, &goals);

if (goals <= 5)
goto sos;

else

{

printf (“About time soccer players learnt C\n”);

printf (“and said goodbye! adieu! to soccer\n”);

exit (1); /* terminates program execution */

}

sos :

printf (“To err is human!\n”);

return 0;

}
```

And here are two sample runs of the program…

```
Enter the number of goals scored against India 3

To err is human!

Enter the number of goals scored against India 7

About time soccer players learnt C

and said goodbye! adieu! to soccer
```

A few remarks about the program would make the things clearer.

- If the condition is satisfied, goto statement transfers control to the label sos , causing printf() following sos to be executed.
- The label can be on a separate line or on the same line as the statement following it, as in,

```
sos : printf (“To err is human!\n”);
```

- Any number of goto s can take the control to the same label.
- exit() is a standard library function that terminates the execution of the program. It is necessary to use this function since we don’t want the statement

```
printf (“To err is human!\n”);
```

to get executed after execution of the else block.

For exit() to work, we need to #include the file ’stdlib.h’.

- The only programming situation in favor of using goto is when we want to take the control out of the loop that is contained in several other loops. The following program illustrates this:

include

```
int main()

{

int i, j, k;

for (i = 1; i <= 3; i++)

{
```

```
for (j = 1; j <= 3; j++)

{

for (k = 1; k <= 3; k++)

{

if (i == 3 && j == 3 && k == 3)

goto out;

else

printf (“%d %d %d\n”, i, j, k);

}

}

}

out :

printf (“Out of the loops at last!\n”);

return 0;

}
```

Go through the program carefully and find out how it works. Also write a program to implement the same logic without using goto .

Problem 7.1

Write a menu driven program which has following options:

Factorial of a number

Prime or not

Odd or even

Exit

Once a menu item is selected the appropriate action should be taken and once this action is finished, the menu should reappear. Unless the user selects the ‘Exit’ option the program should continue to work.

Program

```
/* Menu driven program */
```

include

include

```
int main()

{

int choice, num, i, fact;

while (1)
```

```
{

printf (“\n1. Factorial\n”);

printf (“2. Prime\n”);

printf (“3. Odd / Even\n”);

printf (”4. Exit\n”);

printf (“Your choice? ”);

scanf (“%d”, &choice);

switch (choice)

{

case 1 :

printf (“\nEnter number: ”);

scanf (“%d”, &num);

fact = 1;

for (i = 1; i <= num; i++)

fact = fact * i;

printf (“Factorial value = %d\n”, fact);

break;

case 2 :

printf (“\nEnter number: ”);

scanf (“%d”, &num);

for (i = 2; i < num; i++)

{

if (num % i == 0)

{

printf (“Not a prime number\n”);

break;

}

}

if (i == num)

printf (“Prime number\n”);

break;

case 3 :

printf (“\nEnter number: ”);

scanf (“%d”, &num);
if (num % 2 == 0)

printf (“Even number\n”);

else

printf (“Odd number\n”);

break;

case 4 :

exit (0); /* Terminates program execution */

default :

printf (“Wrong choice!\a\n”);

}

}

return 0;

}
```

Output

```
  1.  Factorial

  2.  Prime

  3.  Odd / Even

  4.  Exit

Your choice?

1

Enter number: 5

Factorial value = 120

  1.  Factorial

  2.  Prime

  3.  Odd / Even

  4.  Exit

Your choice? 2

Enter number: 13

Prime number

  1.  Factorial

  2.  Prime

  3.  Odd / Even

  4.  Exit

Your choice? 3

Enter number: 13
```

Odd number

1. Factorial
2. Prime
3. Odd / Even
4. Exit

Your choice? 4

Exercises

[A] What will be the output of the following programs:

```
(a) # include
int main()
{
char suite = 3;
switch (suite)
{
case 1:
printf (“Diamond\n”);
case 2:
printf (“Spade\n”);
default:
printf (“Heart\n”);
}
printf (“I thought one wears a suite\n”);
return 0;
}
```

```
(b) # include
int main()
{
int c = 3;
switch (c)
{
case ’3’:
printf (“You never win the silver prize\n”);
break;
case 3:
```

```
printf ("You always lose the gold prize\n");

break;

default:

printf ("Of course provided you win a prize\n");

}

return 0;

}

(c) # include

int main()

{

int i = 3;

switch (i)

{

case 0:

printf ("Customers are dicey\n");

case 1 + 0:

printf ("Markets are pricey\n");

case 4 / 2:

printf ("Investors are moody\n");

case 8 % 5:

printf ("At least employees are good\n");

}

return 0;

}

(d) # include

int main()

{

int k;

float j = 2.0;

switch (k = j + 1)

{

case 3:

printf ("Trapped\n");

break;
```

default:

printf (“Caught!\n”);

}

return 0;

}

(e) # include

int main()

{

int ch = ’a’ + ’b’;

switch (ch)

{

case ’a’:

case ’b’:

printf (“You entered b\n”);

case ’A’:

printf (“a as in ashar\n”);

case ’b’ + ’a’:

printf (“You entered a and b\n”);

}

return 0;

}

[B] Point out the errors, if any, in the following programs:

(a) # include

int main()

{

int suite = 1;

switch (suite);

{

case 0;

printf (“Club\n”);

case 1;

printf (“Diamond\n”);

}

return 0;

```
}

(b) # include

int main()

{

int temp;

scanf (“%d”, &temp);

switch (temp)

{

case (temp <= 20):

printf (“Ooooooohhhh! Damn cool!\n”);

case (temp > 20 && temp <= 30):

printf (“Rain rain here again!\n”);

case (temp > 30 && temp <= 40):

printf (“Wish I am on Everest\n”);

default:

printf (“Good old nagpur weather\n”);

}

return 0;

}

(c) # include

int main()

{

float a = 3.5;

switch (a)

{

case 0.5:

printf (“The art of C\n”); break;

case 1.5:

printf (“The spirit of C\n”); break;

case 2.5:

printf (“See through C\n”); break;

case 3.5:

printf (“Simply c\n”);

}

return 0;
```

```
}
```

(d) # include

```
int main()
{
int a = 3, b = 4, c;
c = b - a;
switch (c)
{
case 1 || 2:
printf (“God give me a chance to change things\n”);
break;
case a || b:
printf (“God give me a chance to run my show\n”);
break;
}
return 0;
}
```

[C] Write a program to find the grace marks for a student using switch . The user should enter the class obtained by the student and the number of subjects he has failed in. Use the following logic:

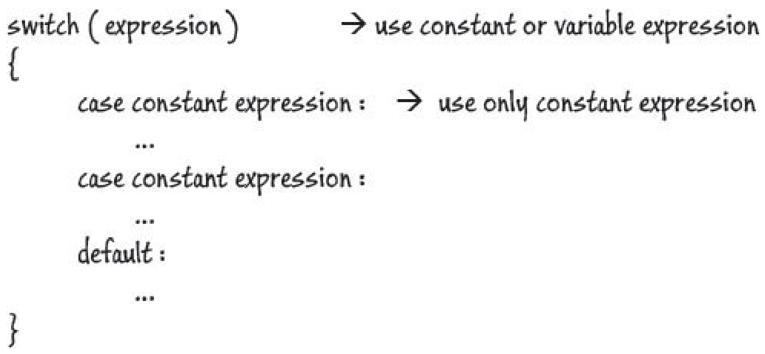
- If the student gets first class and the number of subjects he failed in is greater than 3, then he does not get any grace. Otherwise the grace is of 5 marks per subject.
- If the student gets second class and the number of subjects he failed in is greater than 2, then he does not get any grace. Otherwise the grace is of 4 marks per subject.
- If the student gets third class and the number of subjects he failed in is greater than 1, then he does not get any grace. Otherwise the grace is of 5 marks.

One more form of decision making can be done using switch - case - default

This should be used when we are to find out whether a variable or an expression has one of the several possible values

switch should not be used for checking ranges or for a yes / no problem

General form:



```
switch ( expression )          → use constant or variable expression
{
      case constant expression :   → use only constant expression
            ...
      case constant expression :
            ...
      default :
            ...
}
```

If a case fails, control jumps to the next case

If a case is satisfied, then all statements below it up to} of switch are executed

Usually a break is used at the end of statements in each case

break takes the control out of the switch

Continue DOES NOT take the control to the beginning of the switch

Order in which cases are written does not matter

Default case is optional

cases in a switch must always be unique

switch can be used with int, long int, char

switch cannot be used with float, double

switch works faster than a series of ifs

switch is popularly used in menu driven programs to check which choice from the menu has been made by the user

goto keyword can take the control from any place to any other place within the function

goto should be used only in a situation where we wish to break out of the innermost loop in a nested loop system

As far as possible, goto should be avoided since it is difficult to keep track of the control when multiple gotos are used

exit() - function - Terminates program execution

include for exit() to work

If you wish, you can write all the statements in a program within main(). But that would be a stupid way of writing a program. Programming can be done more smartly using functions. How? Well this chapter has the answer…

Contents

Acomputer program (except for the simplest one) cannot handle all the tasks by itself. Instead, it requests other program-like entities— called ‘functions’ in C—to get its tasks done. In this chapter, we will study these functions. We will look at a variety of features of these functions, starting with the simplest one and then working towards those that demonstrate the power of C functions.

What is a Function?

A function is a self-contained block of statements that performs a coherent task of some kind. Let us now look at a simple program that introduces us to the idea of a C function

include

```
void message(); /* function prototype declaration */

int main()

{

message(); /* function call */

printf (“Cry, and you stop the monotony!\n”);

return 0;

}

void message() /* function definition */

{

printf (“Smile, and the world smiles with you…\n”);

}
```

And here's the output…

```
Smile, and the world smiles with you…

Cry, and you stop the monotony!
```

Here, we have defined two functions— main() and message() . In fact, we have used the word message at three places in the program. Let us understand the meaning of each.

The first is the function prototype declaration and is written as:

```
void message();
```

This prototype declaration indicates that message() is a function which after completing its execution does not return any value. This ‘does not return any value’ is indicated using the keyword void . It is necessary to declare the prototype of every function that we intend to define in the program.

The second usage of message is…

```
void message()

{

printf (“Smile, and the world smiles with you…\n”);

}
```

This is the function definition. In this definition right now we are having only printf() , but we can also use if , for , while , switch , etc., within it.

The third usage is…

```
message();
```

Here the function message() is being called by main() . When we call the message() function, control passes to the function message() . The activity of main() is temporarily suspended; it falls asleep while the message() function wakes up and goes to work. When the message() function runs out of statements to execute, the control returns to main() , which comes to life again and begins executing its code at the exact point where it left off. Thus, main() becomes the ‘calling’ function, whereas message() becomes the ‘called’ function.

If you have grasped the concept of ‘calling’ a function, you are prepared for a call to more than one function. Consider the following example:

include

```
void italy();

void brazil();

void argentina();

int main()

{

printf (“I am in main\n”);

italy();

brazil();

argentina();

return 0;

}

void italy()

{

printf (“I am in italy\n”);

}

void brazil()

{

printf (“I am in brazil\n”);
}

void argentina()

{

printf (“I am in argentina\n”);

}
```

The output of the above program when executed would be as under:

```
I am in main

I am in italy

I am in brazil

I am in argentina
```

A number of conclusions can be drawn from this program:

- A C program is a collection of one or more functions.
- If a C program contains only one function, it must be main() .
- If a C program contains more than one function, then one (and only one) of these functions must be main() .
- There is no limit on the number of functions that might be present in a C program.
- Each function in a program is called in the sequence specified by the function calls in main() .
- After each function has done its thing, control returns to main() . When main() runs out of statements and function calls, the program ends.

Given below are a few additional tips about functions.

(a) Program execution always begins with main() . Except for this fact, all C functions enjoy a state of perfect equality. No precedence, no priorities, nobody is nobody's boss.

(b) Program execution always begins with main(). Every function gets called directly or indirectly from main() . In other words, the main() function drives other functions.

(c) Any function can be called from any other function. Even main() can be called from other functions.

(d) A function can be called any number of times.

(e) The order in which the functions are defined in a program and the order in which they get called need not necessarily be same.

However, it is advisable to define the functions in the same order in which they are called. This makes the program easier to understand.

(f) A function cannot be defined in another function. Thus, the following program would be wrong, since argentina() is being defined inside another function, main() :

```
int main()

{

printf (“I am in main\n”);

void argentina()

{

printf (“I am in argentina\n”);

}
}
```

(g) There are basically two types of functions:

Library functions Ex. printf() , scanf() , etc.

User-defined functions Ex. argentina() , brazil() , etc.

Library functions are a collection of commonly required functions grouped together and stored in a Library file on the disk. This library of functions comes ready-made with development environments like Turbo C, Visual Studio, GCC, etc. The procedure for calling both types of functions is exactly same.

Why use Functions?

Why write separate functions at all? Why not squeeze the entire logic into one function, main() ? Well, for two reasons given below.

(a) Writing functions avoids rewriting the same code over and over. Suppose you have statements in your program that calculate area of a triangle. If later in the program, you want to calculate the area of a different triangle, it would be improper to write the same instructions again. Instead, you would prefer to jump to a function that calculates area and then jump back to the place from where you left off.

(b) If the operation of a program can be divided into separate activities, and each activity placed in a different function, then each could be written and checked more or less independently. Separating the code into modular functions also makes the program easier to design and understand.

So don't try to cram the entire logic in one function. Instead, break a program into small units and write functions for each of these isolated subdivisions. Don't hesitate to write functions that are called only once. What is important is that these functions perform some logically isolated task.

Passing Values between Functions

The functions that we have used so far weren’t very flexible. We called them and they did what they were designed to do. Now we want to communicate between the ‘calling’ and the ‘called’ functions.

The mechanism used to communicate with a function is the ‘argument’. You have unknowingly used the arguments in the printf() and scanf() functions; the format string and the list of variables used inside the parentheses in these functions are arguments. The arguments are sometimes also called ‘parameters’.

Consider the following program. In this program, in main() we receive the values of a , b and c through the keyboard and then output their sum. However, sum is calculated in the function calsum() . So the values of a , b and c must be passed to calsum() . Similarly, once the sum is calculated it must be returned back to main() . That’s communication in short.

```
/* Sending and receiving values between functions */
```

include

```
int calsum (int x, int y, int z);
int main()
{
int a, b, c, sum;
printf (“Enter any three numbers ”);
scanf (“%d %d %d”, &a, &b, &c);
sum = calsum (a, b, c);
printf (“Sum = %d\n”, sum);
return 0;
}
int calsum (int x, int y, int z)
```

```
{

int d;

d = x + y + z;

return (d);

}
```

And here is the output of the program…

```
Enter any three numbers 10 20 30

Sum = 60
```

There are a number of things to note about this program:

(a) The values of a , b and c are passed from main() to calsum() by mentioning a , b and c in the parentheses while making the call.

```
sum = calsum (a, b, c);
```

In calsum() these values get collected in three variables x , y and z :

```
int calsum (int x, int y, int z)
```

Passing values of a , b , c is necessary, because variables are available only to the statements of a function in which they are defined.

(b) The variables a , b and c are called 'actual arguments', whereas the variables x , y and z are called 'formal arguments'. The type, order and number of the actual and formal arguments must always be same.

Instead of x , y and z , we could have used the same variable names a , b and c . But the compiler would still treat them as different variables since they are in different functions.

(c) Note the function prototype declaration of calsum() . Instead of the usual void , we are using int . This indicates that calsum() is going to return a value of the type int . It is not compulsory to use variable names in the prototype declaration. Hence we could have written the prototype as:

```
int calsum (int, int, int);
```

In the definition of calsum too, void has been replaced by int .

(d) In the earlier programs, the moment closing brace (}) of the called function was encountered, the control returned to the calling function. No separate return statement was necessary to send back the control.

This approach is fine if the called function is not going to return any meaningful value to the calling function. In our program, however, we want to return the sum. Therefore, it is necessary to use the return statement. It serves two purposes:

(1) It transfers the control back to the calling function.

(2) It returns the value present in the parentheses (d in our program) after return , to the calling function.

(e) There is no restriction on the number of return statements that may be present in a function. Also, the return statement need not always be present at the end of the called function. The following function illustrates these facts:

```
int fun (int n)

{

if (n <= 10)

return (n * n);

else

return (n * n * n);

}
```

In this function, different return statements would be executed depending on value of n .

(f) When control returns from calsum() , the returned value is collected in the variable sum through the statement

```
sum = calsum (a, b, c);
```

(g) All the following are valid return statements.

```
return (a); /* or return a; */

return (23); /* or return 23; */

return;
```

In the last statement, only control is returned to the calling function. Note that, the parentheses after return are optional.

(h) A function can return only one value at a time. Thus, the following statements are invalid:

```
return (a, b);

return (x, 12);
```

There is a way to get around this limitation, which would be discussed in Chapter 9 .

(i) If the value of a formal argument is changed in the called function, the corresponding change does not take place in the calling function. For example,

include

```
void fun (int);

int main()

{

int a = 30;

fun (a);

printf (“%d\n”, a);

return 0;

}

void fun (int b)

{

b = 60;

printf (“%d\n”, b);

}
```

The output of the above program would be:

```
60

30
```

Thus, even though the value of b is changed in fun(), the value of a in main() remains unchanged. This means that when values are passed to a called function, a copy of values in actual argument is made into formal arguments.

Order of Passing Arguments

Consider the following function call:

```
fun (a, b, c, d);
```

In this call, it doesn't matter whether the arguments are passed from left to right or from right to left. However, in some function calls, the order of passing arguments becomes an important consideration. For example:

```
int a = 1;

printf (“%d %d %d\n”, a, ++a, a++);
```

It appears that this printf() would output 1 2 2.

This however is not the case. Surprisingly, it outputs 3 3 1. This is because, during a function call, the arguments are passed from right to left. That is, firstly 1 is passed through the expression a++ and then a is incremented to 2. Then result of ++a is passed. That is, a is incremented to 3 and then passed. Finally, latest value of a , i.e., 3, is passed. Thus in right to left order, 1, 3, 3 get passed. Once printf() collects them, it prints them in the order in which we have asked it to get them printed (and not the order in which they were passed). Thus 3 3 1 gets printed.

It is important to note that the order of passing arguments to a function is not specified by the language, and hence is compiler-dependent. Consequently, any code that is written disregarding this is bound to show unpredictable behaviour. For instance, the printf() example in question may give different outputs with different compilers.

Using Library Functions

Consider the following program:

include

include

```
int main()

{

float a = 0.5;

float w, x, y, z;

w = sin (a);

x = cos (a);

y = tan (a);

z = pow (a, 2);

printf (“%f %f %f %f\n”, w, x, y, z);

return 0;

}
```

Here we have called four standard library functions— sin() , cos() , tan() and pow() . As we know, before calling any function, we must declare its prototype. This helps the compiler in checking whether the values being passed and returned are as per the prototype declaration. But since we didn't define the library functions (we merely called them), we do not know the prototype declarations of library functions. Hence, when the library of functions is provided, a set of ‘.h’ files is also provided. These header files contain the prototype declarations of library functions.

Library functions are divided into different groups and one header file is provided for each group. For example, prototypes of all input/output functions are provided in the file ‘stdio.h’, prototypes of all mathematical functions (like sin() , cos() , tan() and pow()) are provided in the file ‘math.h’, etc. If you open the header file ‘math.h’, the prototypes would appear as shown below.

```
double sin (double);

double cos (double);
double tan (double);
double pow (double, double);
```

Here double indicates a real number. We would learn more about double in Chapter 11 .

Whenever we wish to call any library function, we must include the header file that contains its prototype declaration.

One Dicey Issue

Now consider the following program:

include

```
int main()
{
int i = 10, j = 20;
printf ("%d %d %d\n", i, j);
printf ("%d\n", i, j);
return 0;
}
```

This program gets successfully compiled, even though there is a mismatch in the format specifiers and the variables in the list used in printf() . This is because, printf() accepts variable number of arguments (sometimes 2 arguments, sometimes 3 arguments, etc.), and even with the mismatch above, the call still matches with the prototype of printf() present in 'stdio.h'. At run-time, when the first printf() is executed, since there is no variable matching with the last specifier %d , a garbage integer gets printed. Similarly, in the second printf() , since the format specifier for j has not been mentioned, its value does not get printed.

Return Type of Function

Suppose we want to obtain square of a floating point number using a function. This is how this simple program would look like:

include

```
float square (float);
int main()
{
float a, b;
printf ("Enter any number ");
scanf ("%f", &a);
b = square (a);
printf ("Square of %f is %f\n", a, b);
return 0;
}
float square (float x)
{
float y;
y = x * x;

return (y);

}
```

And here are three sample runs of this program…

```
Enter any number 3

Square of 3 is 9.000000

Enter any number 1.5

Square of 1.5 is 2.250000

Enter any number 2.5

Square of 2.5 is 6.250000
```

Since we are returning a float value from this function, we have indicated the return type of the square() function as float in the prototype declaration as well as in the function definition. Had we dropped float from the prototype and the definition, the compiler would have assumed that square() is supposed to return an integer value. This is because, default return type of any function is int .

Problem 8.1

Write a function to calculate the factorial value of any integer entered through the keyboard.

Program

```
/* Calculate factorial value of an integer using a function */
```

include

```
int fact (int);

int main()

{

int num;

int factorial;

printf ("\nEnter a number: ");

scanf ("%d", &num);

factorial = fact (num);

printf ("Factorial of %d = %ld\n", num, factorial);

return 0;

}

int fact (int num)

{

int i;

int factorial = 1;
for (i = 1; i <= num; i++)

factorial = factorial * i;

return (factorial);

}
```

Output

```
Enter a number: 6

Factorial of 6 = 720
```

Problem 8.2

Write a function power (a, b), to calculate the value of a raised to b.

Program

```
/* Program to calculate power of a value */
```

include

```
float power (float, int);

int main()

{

float x, pow;

int y;

printf (“\nEnter two numbers: ”);

scanf (“%f %d”, &x, &y);

pow = power (x, y);

printf (“%f to the power %d = %f\n”, x, y, pow);

return 0;

}

float power (float x, int y)

{

int i;

float p = 1;

for (i = 1; i <= y; i++)

p = p * x;

return (p);

}
```

Output

```
Enter two numbers: 1.5 3

1.500000 to the power 3 = 3.375000
```

Problem 8.3

Write a general-purpose function to convert any given year into its Roman equivalent. Use these Roman equivalents for decimal numbers: 1 - I, 5 - V, 10 - X, 50 - L, 100 - C, 500 - D, 1000 - M.

Example:

Roman equivalent of 1988 is mdcccclxxxviii.

Roman equivalent of 1525 is mdxxv.

Program

/* Convert given year into its roman equivalent */

include

```
int romanise (int, int, char);

int main()

{

int yr;

printf (“\nEnter year: ”);

scanf (“%d”, &yr);

yr = romanise (yr, 1000, ’m’);

yr = romanise (yr, 500, ’d’);

yr = romanise (yr, 100, ’c’);

yr = romanise (yr, 50, ’l’);

yr = romanise (yr, 10, ’x’);

yr = romanise (yr, 5, ’v’);

romanise (yr, 1, ’i’);

return 0;

}

int romanise (int y, int k, char ch)

{

int i, j;

j = y / k;

for (i = 1; i <= j; i++)

printf (“%c”, ch);

return (y - k * j);

}
```

Output

```
Enter year: 1988
```

Exercises

[A] Point out the errors, if any, in the following programs:

```
(a) # include
int addmult (int, int)
int main()
{
int i = 3, j = 4, k, l;
k = addmult (i, j);
l = addmult (i, j);
printf (“%d %d\n”, k, l);
return 0;
}
int addmult (int ii, int jj)
{
int kk, ll;
kk = ii + jj;
ll = ii * jj;
return (kk, ll);
}
```

```
(b) # include
int main()
{
int a;
a = message();
return 0;
}
void message()
{
printf (“Viruses are written in C\n”);
return;
}
```

```
(c) # include
int main()
```

```
{

float a = 15.5;

char ch = 'C';

printit (a, ch);

return 0;

}

printit (a, ch)

{

printf ("%f %c\n", a, ch);

}
```

```
(d) # include

int main()

{

letusc()

{

printf ("C is a Cimple minded language !\n");

printf ("Others are of course no match !\n");

}

return 0;

}
```

[B] State whether the following statements are True or False:

(a) The variables commonly used in C functions are available to all the functions in a program.

(b) To return the control back to the calling function we must use the keyword return .

(c) The same variable names can be used in different functions without any conflict.

(d) Every called function must contain a return statement.

(e) A function may contain more than one return statement.

(f) Each return statement in a function may return a different value.

(g) A function can still be useful even if you don't pass any arguments to it and the function doesn't return any value back.

(h) Same names can be used for different functions without any conflict.

(i) A function may be called more than once from any other function.

[C] Answer the following questions:

(a) Any year is entered through the keyboard. Write a function to determine whether the year is a leap year or not.

(b) A positive integer is entered through the keyboard. Write a function to obtain the prime factors of this number.

For example, prime factors of 24 are 2, 2, 2 and 3, whereas prime factors of 35 are 5 and 7.

Functions are a group of instructions achieving some goal

Why create functions:

1) Better complexity management - Easy to Design, Easy to Debug

2) Provide reuse mechanism - Avoids rewriting same code repeatedly

Types of functions:

1) Library - printf(), scanf(), pow()

2) User-defined - main()

Rules for building both are same

Three things should be done while creating a function:

1) Function definition

2) Function call

3) Function prototype declaration

General form:

return-type function-name (type arg1, type arg2, type arg3)

```
{
    statement1 ;  statement2 ;
    return (variable/constant/expression) ; → can return only 1 value
}
```

A C program is a collection of one or more functions

If a C program contains 1 function, its name is main()

If it contains > 1 function, then one of them must be main()

Execution of any C program always begins with main()

Function names in a program must be unique

Any function can call any other function

Functions can be defined in any order

More the function calls, slower the execution

If values are passed to a function, the function must collect it while defining it

Arguments passed to a function are called actual arguments

Arguments received by a function are called formal arguments

Actual & Formal arguments must match in Number, Order and Type

Actual arguments can be constants / variables / expressions

Formal arguments must be variables

Nested calls are legal. Ex.: a = sin (cos (b));

Call within an expression is legal. Ex.: a = sin (b) + cos (c);

The error “Unresolved external” usually means there is a mistake in the function name spelling

return (s); - Returns control & value

return; - Returns only control

If value is returned from a function, we can choose to ignore it

To ensure that no value is returned from a function, use void as the return-type in function definition and its prototype declaration

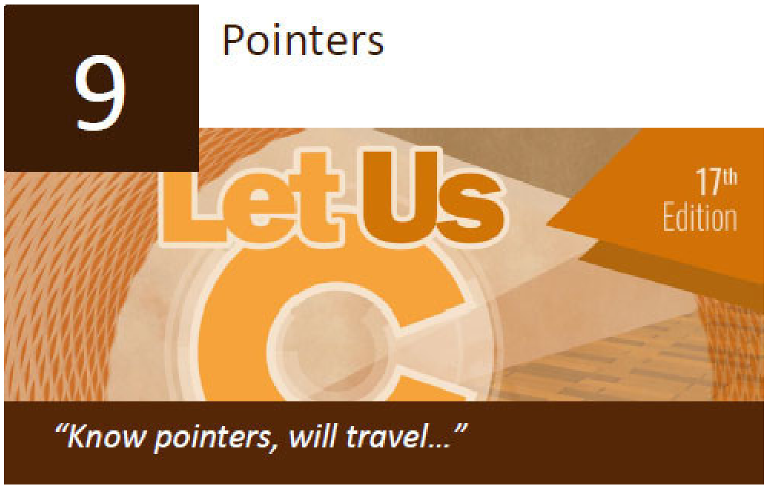
A function by default returns an integer value. If we do not specifically return an integer value then a garbage integer value would be returned

A function can return a non-integer value. The type of value must be suitably mentioned in the function definition and its prototype declaration as in:

float area (float r); /* function prototype declaration */

float area (float r) /* function definition */

{..}



When you set out on a journey and reach an important milestone, you visit a temple and thank God. Pointer is such a milestone in your journey of learning C programming. Once you know it, it will open totally new vistas for you. This chapter will show you how…

Contents

Which feature of C do beginners find most difficult to understand? The answer is easy: pointers. Other languages have pointers but few use them as frequently as C does. This chapter is devoted to pointers and their usage in function calls. Let us begin with the function calls.

Call by Value and Call by Reference

By now, we are well familiar with how to call functions. But, if you observe carefully, whenever we called a function and passed something to it we have always passed the ‘values’ of variables or expressions to the called function. Such function calls are called ‘calls by value’. The examples of call by value are shown below:

sum = calsum (a, b, c);

f = factr (a);

Instead of passing the value of a variable, we can pass the location number (also called address) of the variable to a function. Such a call is known as ‘call by reference’. To understand ‘call by reference’ and its utility, we must first equip ourselves with knowledge of a concept called ‘pointers’.

An Introduction to Pointers

The difficulty beginners have with pointers has much to do with the pointer terminology than the actual concept. So in our discussion of pointers, we will try to understand pointers in terms of programming concepts that we already know.

Consider the declaration,

int i = 3;

This declaration tells the C compiler to:

(a) Reserve space in memory to hold the integer value.

(b) Associate the name i with this memory location.

(c) Store the value 3 at this location.

We may represent i 's location in memory by the memory map shown in Figure 9.1 . We can see that the computer has selected memory location 65524 as the place to store the value 3. The location number 65524 is not a number to be relied upon, because some other time the computer may choose a different location for storing the value 3. The important point is, i 's address in memory is a number.

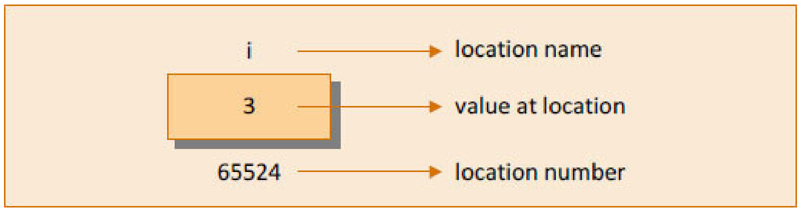


Figure 9.1

We can print this address number through the following program:

include

int main()

{

int i = 3;

printf (“Address of i = %u\n”, &i);

printf (“Value of i = %d\n”, i);

printf (“Value of i = %d\n”, *(&i));

return 0;

}

The output of the above program would be:

Address of i = 65524

Value of i = 3

Value of i = 3

The ‘&’ used in the first printf() is ‘address of’ operator. The expression &i returns the address of the variable i , which in this case happens to be 65524. Since 65524 represents an address, there is no question of a sign being associated with it. Hence it is printed out using %u , which is a format specifier for printing an unsigned integer. We have been using the ‘&’ operator all the time in the scanf() statement.

The other pointer operator available in C is ‘ *’ , called ‘value at address’ operator. It is being used in the third printf() . It gives the value stored at a address 65524, which is 3. The ‘value at address’ operator is also called ‘indirection’ operator.

Note that printing the value of *(&i) is same as printing the value of i .

The expression &i gives the address of the variable i . This address can be collected in a variable, by saying,

j = &i;

Figure 9.2 shows the memory map of i and j .

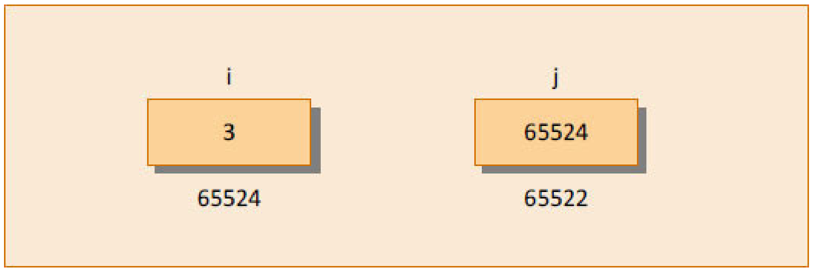


Figure 9.2

As you can see, i 's value is 3 and j 's value is i 's address. Since j is a variable that contains the address of i , it is declared as,

j = &i;

This declaration tells the compiler that j will be used to store the address of an integer value. In other words, j points to an integer. How do we justify the usage of * in this declaration? For this, let us go by the meaning of * . It stands for ‘value at address’. Thus, int *j would mean, the value at the address stored in j is an int . Here is a program that demonstrates these relationships.

include

int main()

{

int i = 3;

int *j;

j = &i;

printf (“Address of i = %u\n”, &i);

printf (“Address of i = %u\n”, j);

printf (“Address of j = %u\n”, &j);

printf (“Value of j = %u\n”, j);

printf (“Value of i = %d\n”, i);

printf (“Value of i = %d\n”, *(&i));

printf (“Value of i = %d\n”, *j);

return 0;

}

The output of the above program would be:

```
Address of i = 65524

Address of i = 65524

Address of j = 65522

Value of j = 65524

Value of i = 3

Value of i = 3

Value of i = 3
```

Work through the above program carefully, taking help of the memory locations of i and j shown in Figure 9.2 . This program summarizes everything that we have discussed so far. If you don't understand the program's output, or the meanings of &i , &j , *j and *(&i) , re-read the last few pages. Everything we say about pointers from here onwards will depend on your understanding these expressions thoroughly.

Look at the following declarations:

```
int *alpha;

char *ch;

float *s;
```

Here, alpha, ch and s are declared as pointer variables, i.e., variables that hold addresses. Remember that, addresses (location nos.) are always going to be whole numbers, therefore, pointers always contain whole numbers.

The declaration float *s does not mean that s is going to contain a floating-point value. What it means is, s is going to contain the address of a floating-point value. Similarly, char *ch means that ch is going to contain the address of a char value.

The concept of pointers has been further extended in the following progam.

include

```
int main()

{

int i = 3, j, *k;

j = &i;

k = &j;

printf (“Address of i = %u\n”, &i);

printf (“Address of i = %u\n “, j);

printf (“Address of i = %u\n ”, *k);

printf (“Address of j = %u\n ”, &j);

printf (“Address of j = %u\n ”, k);

printf (“Address of k = %u\n ”, &k);

printf (“Value of j = %u\n ”, j);

printf (“Value of k = %u\n ”, k);

printf (“Value of i = %d\n ”, i);

printf (“Value of i = %d\n ”, * (&i));
printf (“Value of i = %d\n ”, *j);

printf (“Value of i = %d\n ”, **k);

return 0;

}
```

The output of the above program would be:

```
Address of i = 65524

Address of i = 65524

Address of i = 65524

Address of j = 65522

Address of j = 65522

Address of k = 65520

Value of j = 65524

Value of k = 65522

Value of i = 3

Value of i = 3

Value of i = 3

Value of i = 3
```

Figure 9.3 would help you in tracing out how the program prints the above output.

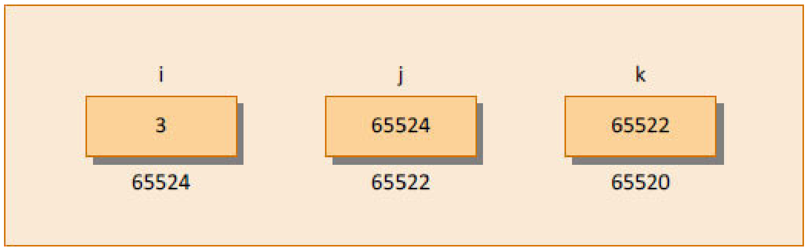


Figure 9.3

Remember that when you run this program, the addresses that get printed might turn out to be something different than the ones shown in Figure 9.3 . However, for any addresses, the relationship between i , j and k would remain same.

Observe how the variables j and k have been declared,

int i, *j,* *k;

Here, i is an ordinary int , j is a pointer to an int (often called an integer pointer), whereas k is a pointer to an integer pointer.

We can extend the above program still further by creating a pointer to a pointer to an integer pointer. Likewise, there can be a pointer to a pointer to a pointer to a pointer to a pointer. There is no limit on how far can we go on extending this definition. Possibly, till the point we can comprehend it. And that point of comprehension is usually a pointer to a pointer. Beyond this, one rarely requires to extend the definition of a pointer. But just in case…

Back to Function Calls

Having had the first tryst with pointers, let us now get back to what we had originally set out to learn—the two types of function calls—call by value and call by reference.

In ‘call by value’ the ‘value’ of each actual argument in the call is copied into corresponding formal arguments of the called function. With this method, the changes made to the formal arguments in the called function have no effect on the values of actual arguments in the calling function. The following program illustrates the ‘Call by Value’:

include

```
void swapv (int x, int y);

int main()

{

int a = 10, b = 20;

swapv (a, b);

printf (“a = %d b = %d\n”, a, b);

return 0;

}

void swapv (int x, int y)

{

int t;

t = x;

x = y;

y = t;

printf (“x = %d y = %d\n”, x, y);

}
```

The output of the above program would be:

```
x = 20 y = 10

a = 10 b = 20
```

Note that values of a and b remain unchanged even after exchanging the values of x and y .

In ‘call by reference’ the addresses of actual arguments in the call are copied into the formal arguments of the called function. This means that, using these addresses, we would have an access to the actual arguments and hence we would be able to manipulate them. The following program illustrates this fact:

include

```
void swapr (int *, int *);

int main()

{

int a = 10, b = 20;

swapr (&a, &b);

printf (“a = %d b = %d\n”, a, b);

return 0;

}
```

```
void swapr (int *x, int *y)

{

int t;

t = *x;

*x = *y;

*y = t;

}
```

The output of the above program would be:

```
a = 20 b = 10
```

Note that this program manages to exchange the values of a and b using their addresses stored in x and y .

Utility of Call by Reference

We know that the return statement can return only one value from a function at a time. We can overcome this limitation by using call by reference as shown in the following program.

include

```
void areaperi (int, float *, float *);

int main()

{

int radius;

float area, perimeter;

printf (“Enter radius of a circle ”);

scanf (“%d”, &radius);

areaperi (radius, &area, &perimeter);

printf (“Area = %f\n”, area);

printf (“Perimeter = %f\n”, perimeter);

return 0;

}

void areaperi (int r, float *a, float *p)

{

*a = 3.14 * r * r;

*p = 2 * 3.14 * r;

}
```

And here is the output…

```
Enter radius of a circle 5

Area = 78.500000
```

Perimeter = 31.400000

Here, we are making a mixed call, in the sense, we are passing the value of radius but, addresses of area and perimeter . Using the addresses stored in a and p we can change the values of area and perimeter . Hence when control returns from the function areaperi() , we are able to output the values of area and perimeter .

Conclusions

From the programs that we discussed here, we can draw the following conclusions:

(a) If we want that the value of an actual argument should not get changed in the function being called, pass the actual argument by value.

(b) If we want that the value of an actual argument should get changed in the function being called, pass the actual argument by reference.

(c) If a function is to be made to return more than one value at a time, then return these values indirectly by using a call by reference.

P</> Programs

Problem 9.1

Write a function that receives 5 integers and returns the sum, average and standard deviation of these numbers. Call this function from main() and print the results in main() .

Program

/* Function which returns sum, average and standard deviation */

include

include

void stats (int *, int *, double *);

int main()

{

int sum, avg;

double stdev;

stats (&sum, &avg, &stdev); /* Function call by reference */

printf (“Sum = %d \nAverage = %d \nStandard deviation = %lf\n”, sum, avg, stdev);

return 0;

}

void stats (int *sum, int *avg, double *stdev)

{

int n1, n2, n3, n4, n5;

printf (“\nEnter 5 numbers: ”);

scanf (“%d%d%d%d%d”, &n1, &n2, &n3, &n4, &n5);

sum = n1 + n2 + n3 + n4 + n5; / Calculate sum */

*avg = *sum / 5; /* Calculate average */

/* Calculate standard deviation */

```
*stdev = sqrt ((pow ((n1 - *avg), 2.0) + pow ((n2 - *avg), 2.0) + \ pow ((n3 - *avg), 2.0) + pow ((n4 - *avg), 2.0) + \ pow ((n5 - *avg), 2.0)) / 4);

}
```

Output

```
Enter 5 numbers: 10 20 30 40 50

Sum = 150

Average = 30

Standard deviation = 15.811388
```

Problem 9.2

Write a function that receives marks obtained by a student in 3 subjects and returns the average and percentage of these marks. Call this function from main() and print the results in main() .

Program

```
/* Function that returns average and percentage */
```

include

```
void result (int, int, int, float *, float *);

int main()

{

float avg, per;

int m1, m2, m3;

printf (“Enter marks in three subjects: ”);

scanf (“%d %d %d”, &m1, &m2, &m3);

result (m1, m2, m3, &avg, &per);

printf (“Average = %f \nPercentage = %f\n”, avg, per);

return 0;

}

void result (int m1, int m2, int m3, float *a, float *p)

{

*p = *a = (m1 + m2 + m3) / 3.0f;

}
```

Output

```
Enter marks in three subjects: 55 60 70

Average = 61.666668

Percentage = 61.666668
```

Problem 9.3

Write a C function to evaluate the series

$\sin(x) = x - (x^3 / 3!) + (x^5 / 5!) - (x^7 / 7!) + L$

up to 5 significant digits.

Program

```
/* Evaluation of a series */

include

include

float numerator (float, int);

float denominator (int);

int main()

{

float x, n, d, term, sum, oldsum;

int i, j;

printf (“\nEnter the number x: ”);

scanf (“%f”, &x);

i = j = 1;

sum = 0;

while (1)

{

n = numerator (x, j);

d = denominator (j);

term = n / d;

oldsum = sum;

(i % 2 == 0) ? sum = sum - term : (sum = sum + term);

if (abs(sum - oldsum) < 0.00001)

break;

i++;

j += 2;

}

printf (“sum = %f\n”, sum);

return 0;

}

/* Calculate Power */

float numerator (float y, int j)
```

```
{
float k = 1;
int m;
for (m = 1; m <= j; m++)
k *= y;
return (k);
}
/* Calculate factorial */
float denominator (int j)
{
int m;
float h = 1;
for (m = 1; m <= j; m++)
h = h * m;
return (h);
}
```

Output

```
Enter the number x: 0.5
sum = 0.479426
```

Exercises

[A] What will be the output of the following programs:

(a)
```
# include
void fun (int, int);
int main()
{
int i = 5, j = 2;
fun (i, j);
printf ("%d %d\n", i, j);
return 0;
}
void fun (int i, int j)
{
i = i * i;
j = j * j;
}

(b) # include

void fun (int *, int *);

int main()

{

int i = 5, j = 2;

fun (&i, &j);

printf ("%d %d\n", i, j);

return 0;

}

void fun (int *i, int *j)

{

*i = *i * *i;

*j = *j * *j;

}
```

```
(c) # include

int main()

{

float a = 13.5;

float *b, *c;

b = &a; /* suppose address of a is 1006 */

c = b;

printf ("%u %u %u\n", &a, b, c);

printf ("%f %f %f %f %f\n", a, *(&a), *&a, *b, *c);

return 0;

}
```

[B] Point out the errors, if any, in the following programs:

```
(a) # include

void jiaayjo (int, int);

int main()

{

int p = 23, f = 24;

jiaayjo (&p, &f);

printf ("%d %d\n", p, f);

return 0;
```

```
}

void jiaayjo (int q, int g)

{

q = q + q;

g = g + g;

}

(b) # include

void check (int);

int main()

{

int k = 35, z;

z = check (k);

printf (“%d\n”, z);

return 0;

}

void check (m)

{

int m;

if (m > 40)

return (1);

else

return (0);

}

(c) # include

void function (int *);

int main()

{

int i = 35, *z;

z = function (&i);

printf (“%d\n”, z);

return 0;

}

void function (int *m)

{
```

return (*m + 2);

}

[C] Attempt the following questions:

(a) Given three variables x , y , z write a function to circularly shift their values to right. In other words if x = 5, y = 8, z = 10, after circular shift y = 5, z = 8, x =10. Call the function with variables a , b , c to circularly shift values.

(b) If the lengths of the sides of a triangle are denoted by a , b , and c , then area of triangle is given by

$$area = \sqrt{S(S-a)(S-b)(S-c)}$$

where, S = (a + b + c) / 2. Write a function to calculate the area of the triangle.

(c) Write a function to compute the distance between two points and use it to develop another function that will compute the area of the triangle whose vertices are A(x1, y1) , B(x2, y2) , and C(x3, y3) . Use these functions to develop a function which returns a value 1 if the point (x, y) lines inside the triangle ABC, otherwise returns a value 0.

(d) Write a function to compute the greatest common divisor given by Euclid's algorithm, exemplified for J = 1980, K = 1617 as follows:

1980 / 1617 = 1	1980 – 1 * 1617 = 363
1617 / 363 = 4	1617 – 4 * 363 = 165
363 / 165 = 2	363 – 2 * 165 = 33
5 / 33 = 5	165 – 5 * 33 = 0

Thus, the greatest common divisor is 33.

3 ways to call a function:

1) Call by value - when values are passed to the called function

2) Call by reference - when addresses are passed to the called function

3) Mixed call - when values and addresses are passed to the called function

Pointers are variables which hold addresses of other variables

Address, Reference, Memory Location, Cell number are same

& - Address of operator, * - Value at address or Indirection operator

&, * - Pointer operators

& can be used only with a variable

- can be used with variable, constant or expression

variable is same as *&variable

Example of pointer usage:

int i = 10; int *j; int *k;

j = &i; k = &j;

printf (“%d %d %d”, i, *j, *k);

Here j is an integer pointer. k is a pointer to an integer pointer

Even if a is a 4-byte variable, &a, gives address of first out of these 4 bytes

For printing address - use %u. For printing size of any variable using sizeof operator use %d

Using an integer ptr - Use * to reach integer

Using a pointer to an integer pointer - Use ** to reach integer

Call by Value - Change in formal arguments doesn't affect actual arguments

Call by Reference: Using formal arguments actual arguments can be changed

Examples of call types:

1) swapv (a, b); - Call by value

2) swapr (&a, &b); - call by reference

3) sumprod (a, b, c, &s, &p); - Mixed call

When it comes to implementing a logic that is expressible in the form of itself, there are two ways to do it. One is the good old way of using loops; another is the smart way of using recursion. This chapter shows you how to adopt the smart way…

Contents

Recursion is an important feature associated with functions in C. Though a bit difficult to understand, it is often the most direct way of programming a complicated logic. This chapter explores recursion in detail.

Recursion

In C, it is possible for a function to call itself. A function is called 'recursive' if a statement within the body of a function calls the same function. Sometimes called 'circular definition', recursion is thus the process of defining something in terms of itself.

Let us now see a simple example of recursion. Suppose we wish to calculate factorial value of an integer. As we know, 4 factorial is 4 * 3 * 2 * 1. This can also be expressed as 4! = 4 * 3! where '!' stands for factorial. Thus factorial of a number can be expressed in the form of itself. Hence this logic can be programmed using recursion as shown in the following program.

include

int rec (int);

int main()

{

```
int a, fact;

printf ("Enter any number: ");

scanf ("%d", &a);

fact = rec (a);

printf ("Factorial value = %d\n", fact);

return 0;

}

int rec (int x)

{

int f;

if (x == 1)

return (1);

else

f = x * rec (x - 1);

return (f);

}
```

And here is the output for three runs of the program…

```
Enter any number: 1

Factorial value = 1

Enter any number: 2

Factorial value = 2

Enter any number: 5

Factorial value = 120
```

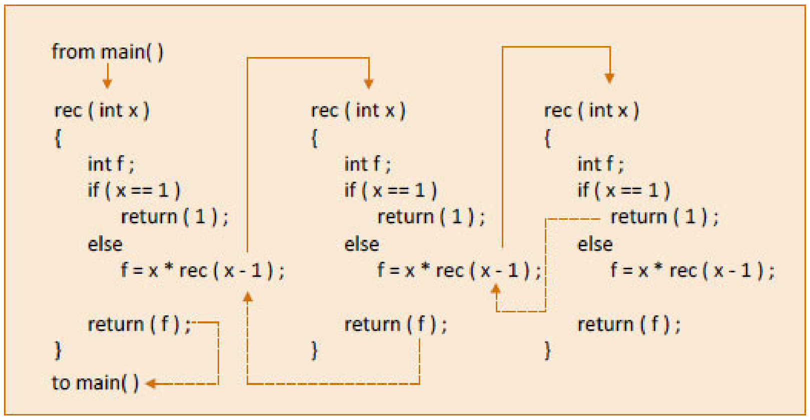
Let us understand this recursive factorial function thoroughly. In the first run when the number entered through scanf() is 1, let us see what action does rec() take. The value of a (i.e., 1) is copied into x . Since x turns out to be 1, the condition if (x == 1) is satisfied and hence 1 (which indeed is the value of 1 factorial) is returned through the return statement.

When the number entered through scanf() is 2, the (x == 1) test fails, so we reach the statement,

```
f = x * rec (x - 1);
```

And this is where we meet recursion. How do we handle the expression x * rec (x - 1) ? We multiply x by rec (x - 1) . Since the current value of x is 2, we should calculate the value (2 * rec (1)). We know that the value returned by rec (1) is 1, so the expression reduces to (2 * 1), or simply 2. Thus the expression, x * rec (x - 1) evaluates to 2, which is stored in the variable f , and is returned to main() , where it is duly printed out.

When value of a is 3, to visualize how the control flows from one function call to another, take a look at Figure 10.1 .



```
from main( )

rec ( int x )              rec ( int x )              rec ( int x )
{                          {                          {
    int f ;                    int f ;                    int f ;
    if ( x == 1 )              if ( x == 1 )              if ( x == 1 )
        return ( 1 ) ;             return ( 1 ) ;             return ( 1 ) ;
    else                       else                       else
        f = x * rec ( x - 1 ) ;    f = x * rec ( x - 1 ) ;    f = x * rec ( x - 1 ) ;

    return ( f ) ;             return ( f ) ;             return ( f ) ;
}                          }                          }
to main( )
```

Figure 10.1

First time when rec() is called from main() , x collects 3. From here, since x is not equal to 1, the if block is skipped and rec() is called again with the argument (x - 1) , i.e. 2. This is a recursive call. Since x is still not equal to 1, rec() is called yet another time, with argument (2 - 1). This time as x is 1, control goes back to previous rec() with the value 1, and f is evaluated as 2. Similarly, each rec() evaluates its f from the returned value, and finally 6 is returned to main() . The sequence would be grasped better by following the arrows shown in Figure 10.1 .

Let it be clear that while executing the program, there do not exist so many copies of the function rec() . These have been shown in the figure just to help you keep track of how the control flows during successive recursive calls.

Recursion may seem strange and complicated at first glance, but it is often the most direct way to code an algorithm, and once you are familiar with recursion, the clearest way of doing so.

Whenever we make a function call (recursive or normal), the parameters and the return address get stored at a place in memory known as stack. The stack gets unwound when the control returns from the called function. Thus, during every recursive function call, we are working with a fresh set of parameters.

Also, note that while writing recursive functions, you must have an if statement somewhere in the recursive function to force the function to return without recursive call being executed. If you don't do this and you call the function, you will fall in an indefinite loop, and the stack will keep on getting filled with parameters and the return address each time there is a call. The stack would become full soon and you would get a run-time error indicating that the stack has become full. This is a very common error while writing recursive functions. My advice is to use printf() statement liberally during the development of recursive function, so that you can watch what is going on.

Programs

Problem 10.1

A 5-digit positive integer is entered through the keyboard, write a recursive function to calculate sum of digits of the 5-digit number.

Program

/* Calculate sum of digits of a five-digit number using recursion */

include

int rsum (int); /* Function with recursion */

int main()

{

int num, sum;

int n;

printf (“Enter number: ”);

scanf (“%d”, &num);

```
sum = rsum (num);

printf (“Sum of digits is %d\n”, sum);

return 0;

}

int rsum (int n)

{

int s, remainder;

if (n != 0)

{

remainder = n % 10;

s = remainder + rsum (n / 10);

}

else

return 0;

return s;

}
```

Output

```
Enter number: 12345

Sum of digits is 15
```

Problem 10.2

A positive integer is entered through the keyboard, write a program to obtain the prime factors of the number. Modify the function suitably to obtain the prime factors recursively.

Program

```
/* Find Prime Factors of a number recursively */
```

include

```
void factorize (int, int);

int main()

{

int num;

printf (“Enter a number: ”);

scanf (“%d”, &num);

printf (“Prime factors are: ”);

factorize (num, 2);

return 0;
}
void factorize (int n, int i)
{
if (i <= n)
{
if (n % i == 0)
{
printf (“%d ”, i);
n = n / i;
}
else
i++;
factorize (n, i);
}
}
```

Output

```
Enter a number: 60
Prime factors are: 2 2 3 5
```

Problem 10.3

Write a recursive function to obtain the first 25 numbers of a Fibonacci sequence. In a Fibonacci sequence the sum of two successive terms gives the third term. Following are the first few terms of the Fibonacci sequence:

1 1 2 3 5 8 13 21 34 55 89….

Program

```
/* Generate first 25 terms of a Fibonacci sequence using recursion */
```

include

```
void fibo (int, int, int);
int main()
{
int old = 1, current = 1;
printf (“%d\t%d\t”, old, current);
fibo (old, current, 23);
return 0;
}
void fibo (int old, int current, int terms)
```

```
{
int newterm;
if (terms >= 1)
{
newterm = old + current;
printf (“%d\t”, newterm);
terms = terms - 1;
fibo (current, newterm, terms);
}
}
```

Output

```
1 1 2 3 5 8 13 21 34 55
89 144 233 377 610 987 1597 2584 4181 6765
10946 17711 28657 46368 75025
```

Exercises

[A] What will be the output of the following programs:

(a)
```
# include
int main()
{
printf (“C to it that C survives\n”);
main();
return 0;
}
```

(b)
```
# include
```

include

```
int main()
{
int i = 0;
i++;
if (i <= 5)
{
printf (“C adds wings to your thoughts\n”);
exit (0);
main();

}

return 0;

}
```

[B] Attempt the following questions:

(a) A positive integer is entered through the keyboard, write a function to find the binary equivalent of this number:

(1) Without using recursion

(2) Using recursion

(b) Write a recursive function to obtain the sum of first 25 natural numbers.

(c) There are three pegs labeled A, B and C. Four disks are placed on peg A. The bottom-most disk is largest, and disks go on decreasing in size with the topmost disk being smallest. The objective of the game is to move the disks from peg A to peg C, using peg B as an auxiliary peg. The rules of the game are as follows:

(1) Only one disk may be moved at a time, and it must be the top disk on one of the pegs.

(2) A larger disk should never be placed on the top of a smaller disk.

Write a program to print out the sequence in which the disks should be moved such that all disks on peg A are finally transferred to peg C.

A function that calls itself is called a recursive function

Any function, including main() can become a recursive function

Recursive call always leads to an infinite loop. So a provision must be made to get outside this infinite loop

The provision is done by making the recursive call either in the if block or in the else block

If recursive call is made in the if block, else block should contain the end condition logic

If recursive call is made in the else block, if block should contain the end condition logic

Fresh set of variables are born during each function call - normal call and recursive call

Variables die when control returns from a function

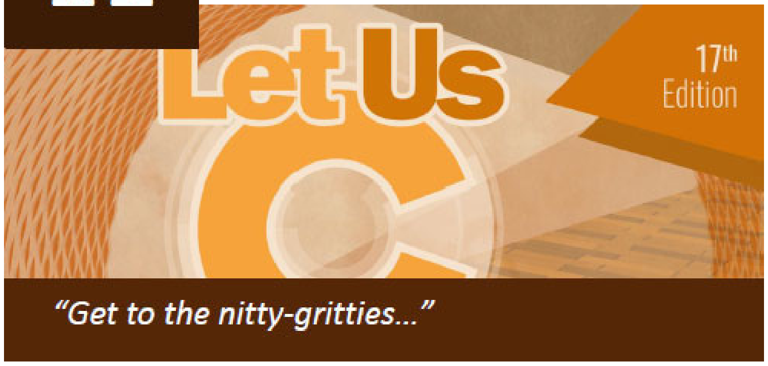
Recursive function may or may not have a return statement

Recursion is an alternative for loop in logics which are expressible in the form of themselves

Recursive calls are slower than an equivalent while / for / do-while loop

Understanding how a recursive function is working becomes easy if you make several copies of the same function on paper and then perform a dry run of the program

11 Data Types Revisited



Being able to use the data types in a program is one thing, being able to understand how they behave and why they behave that way is quite a different thing. This chapter is about the second thing…

Contents

As seen in the first chapter, the primary data types could be of three varieties— char , int , and float . Each of them has several sub-types. For example, a char can be an unsigned char or a signed char . We would take a closer look at these variations of primary data types in this chapter.

To fully define a variable, one needs to mention not only its type but also its storage class. In this chapter, we would also explore the different storage classes and their relevance in C programming.

Integers— long, short, signed, unsigned

C offers two variations of the integer data type— short and long . Though their sizes vary across compilers, following rules apply:

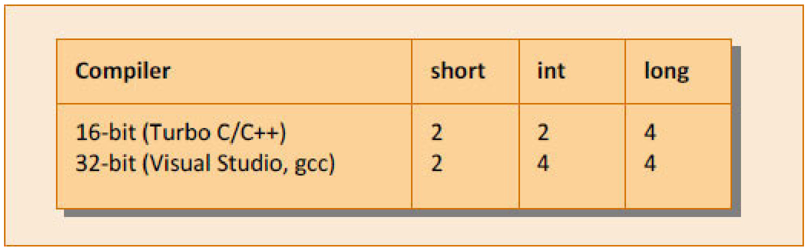
(a) short is at least 2 bytes big

(b) long is at least 4 bytes big

(c) short is never bigger than int

(d) int is never bigger than long

Figure 11.1 shows the sizes of different integers based upon the compiler used.



Compiler	short	int	long
16-bit (Turbo C/C++)	2	2	4
32-bit (Visual Studio, gcc)	2	4	4

Figure 11.1

Based on the size, the range of values that they can store would vary. A 2-byte integer can take values from -32768 to +32767, whereas a 4-byte integer can take values from -2147483648 to +2147483647.

Each of these integers has two further variations— signed and unsigned . In the signed variety, the highest (leftmost) bit stores the sign of the number—0, if the number is positive, and 1, if the number is negative.

On the other hand, in unsigned all the bits are used to store the value of the number. These variables can be declared as shown below.

short signed int a;

short unsigned int b;

signed int i;

unsigned int j;

signed long int x;

unsigned long int y;

In these declarations, signed and int can be dropped. So following declarations would have served the same purpose as the ones made above:

short a;

short unsigned b;

int i;

unsigned j;

long int x;

unsigned long y;

Depending upon the programming situation, we should use the appropriate type of integer. For example, if a variable is going to only count things, then we can declare it as,

unsigned int num_students;

With this, the range of permissible integer values (for a 32-bit compiler) will shift from the range -2147483648 to +2147483647 to the range 0 to 4294967295. This doubles the size of the largest possible value that it can take, as in an unsigned int , the left-most bit is not used to store the sign of the number and is free to store the value of the number.

Chars— signed, unsigned

Parallel to integers , char s also can be signed or unsigned . Both occupy one byte each, but have different ranges. To begin with, it might appear strange as to how a char can have a sign. Consider the statement

signed char ch = ’A’;

Here binary equivalent of the ASCII/Unicode value of ‘A’ (i.e. binary of 65) gets stored in ch . And if 65's binary can be stored, then -54's binary can also be stored.

As with integers, signed is default. So signed char is same as char and has a range from -128 to +127. Likewise, an unsigned char has a range from 0 to 255.

Note that while assigning a value to an integer or a char, if it exceeds the upper bound, then the appropriate value from negative side of the range gets assigned. Likewise, if the lower bound is exceeded, then the value from the positive side of the range gets assigned. The following program illustrates this:

include

```
int main()

{

char ch = 128;

char dh = -132;

printf (“%d %d\n”, ch, ch);

return 0;

}
```

On execution, the program produces the output -128 124. Since ch has been defined as a char , it cannot take a value bigger than +127. When we attempt to assign it a value 128, it exceeds +127 by 1. So the first value on the negative side, i.e. -128, gets assigned to ch . Similarly, -132 exceeds -128 by 4, so 4th number from positive side, i.e. 124, gets assigned to dh .

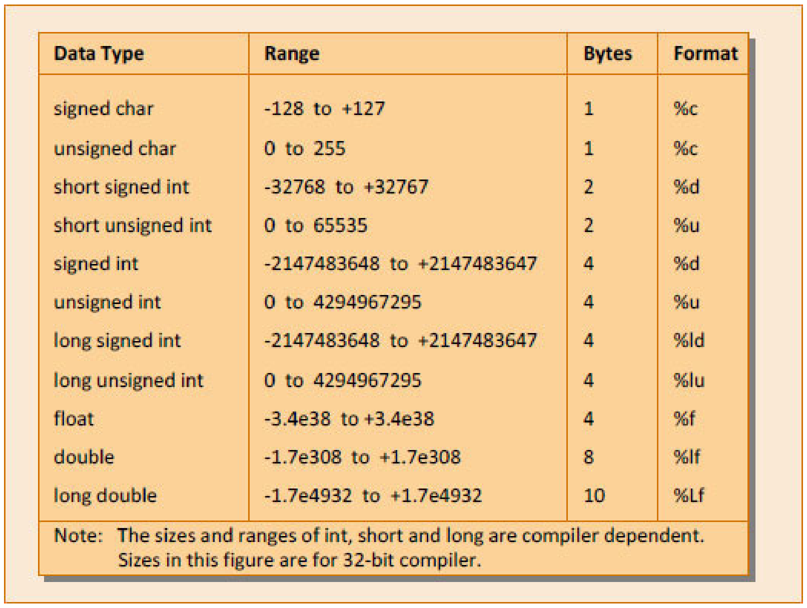
Reals— float , double, long double

A float occupies four bytes in memory and can range from -3.4e38 to +3.4e38. If this is insufficient, then C offers a double data type that occupies 8 bytes in memory and has a range from -1.7e308 to +1.7e308. A variable of type double can be declared as,

double population;

If the situation demands usage of real numbers that lie even beyond the range offered by double data type, then there exists a long double that can range from -1.7e4932 to +1.7e4932. A long double occupies 10 bytes in memory.

The essence of all the data types that we have learnt so far has been captured in Figure 11.2 .



Data Type	Range	Bytes	Format
signed char	-128 to +127	1	%c
unsigned char	0 to 255	1	%c
short signed int	-32768 to +32767	2	%d
short unsigned int	0 to 65535	2	%u
signed int	-2147483648 to +2147483647	4	%d
unsigned int	0 to 4294967295	4	%u
long signed int	-2147483648 to +2147483647	4	%ld
long unsigned int	0 to 4294967295	4	%lu
float	-3.4e38 to +3.4e38	4	%f
double	-1.7e308 to +1.7e308	8	%lf
long double	-1.7e4932 to +1.7e4932	10	%Lf

Note: The sizes and ranges of int, short and long are compiler dependent. Sizes in this figure are for 32-bit compiler.

Figure 11.2

A Few More Issues…

Having seen all the variations of the primary types let us take a look at some more related issues.

(a) In the ranges of char s and int s, there is an extra number on the negative side. This is because a negative number is stored as 2's compliment of its binary. For example, let us see how -128 is stored. Firstly, binary of 128 is calculated (10000000), then its 1's compliment is obtained (01111111). A 1's compliment is obtained by changing all 0s to 1s and 1s to 0s. Finally, 2's compliment of this number, i.e. 10000000, gets stored. A 2's compliment is obtained by adding 1 to the 1's compliment. Thus, for -128, 10000000 gets stored. This is an 8-bit number and it can be easily accommodated in a char . As against this, +128 cannot be stored in a char because its binary 010000000 (left-most 0 is for positive sign) is a 9-bit number. However, +127 can be stored as its binary 01111111 turns out to be a 8-bit number.

(b) What happens when we attempt to store +128 in a char ? The first number on the negative side, i.e. -128 gets stored. This is because from the 9-bit binary of +128, 010000000, only the right-most 8 bits get stored. But when 10000000 is stored the left-most bit is 1 and it is treated as a sign bit. Thus, the value of the number becomes -128 since it is indeed the binary of -128, as can be understood from (b) above. Similarly, you can verify that an attempt to store +129 in a char results in storing -127 in it. In general, if we exceed the range from positive side we end up on the negative side. Vice versa is also true. If we exceed the range from negative side, we end up on positive side.

(c) Sometimes, we come across situations where the constant is small enough to be an int , but still we want to give it to be treated as long . In such cases, we add the suffix ‘L’ or ‘l’ at the end of the number, as in 23L. Likewise, 3.14 is double by default. To treat it as a float we need to use 3.14f.

Storage Classes in C

We have already said all that needs to be said about constants, but we are not finished with variables. To fully define a variable, one needs to mention not only its ‘type’ but also its ‘storage class’.

In our programs, we didn't mention storage class of the variables used. We were able to get away with this because storage classes have defaults. If we don't specify the storage class of a variable in its declaration, the compiler will assume a storage class depending on where the variable is being defined.

A variable's storage class tells us:

(a) Where the variable would be stored.

(b) What would be the default initial value of the variable.

(c) What is the scope of the variable; i.e. in which functions the value of the variable would be available.

(d) What is the life of the variable; i.e. how long would the variable exist.

There are four storage classes in C:

(a) Automatic storage class

(b) Register storage class

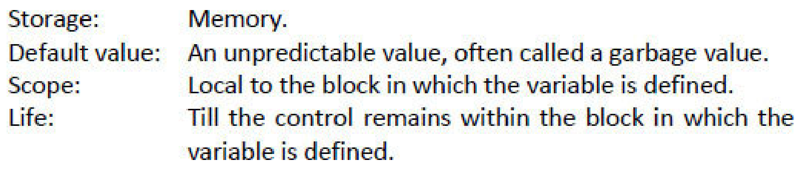
(c) Static storage class

(d) External storage class

Let us examine these storage classes one by one.

Automatic Storage Class

The features of an automatic storage class variable are as under:



Storage:	Memory.
Default value:	An unpredictable value, often called a garbage value.
Scope:	Local to the block in which the variable is defined.
Life:	Till the control remains within the block in which the variable is defined.

Following program shows how an automatic storage class variable is declared, and the fact that if the variable is not initialized, it contains a garbage value.

include

int main()

```
{
auto int i, j;
printf (“%d %d\n”, i, j);
return 0;
}
```

The output of the above program could be…

```
1211 221
```

where, 1211 and 221 are garbage values of i and j . When you run this program, you may get different values, since garbage values are unpredictable. Note that the keyword for this storage class is auto , and not automatic.

Scope and life of an automatic variable is illustrated in the following program.

include

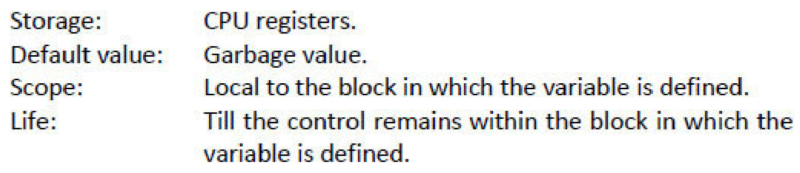
```
int main()
{
auto int i = 1;
{
auto int i = 2;
{
auto int i = 3;
printf (“%d ”, i);
}
printf (“%d ”, i);
}
printf (“%d\n”, i);
return 0;
}
```

The output of the above program would be 3 2 1. Note that the Compiler treats the three i 's as totally different variables, since they are defined in different blocks. All three i 's are available to the innermost printf() . This is because the innermost printf() lies in all the three blocks (a block is all statements enclosed {}) in which the three i 's are defined. This printf() prints 3 because when all three i 's are available, the one which is most local (nearest to printf()) is given a priority.

Once the control comes out of the innermost block, the variable i with value 3 dies, and hence the i in the second printf() refers to i with value 2. Similarly, when the control comes out of the next innermost block, the third printf() refers to the i with value 1.

Register Storage Class

The features of a register storage class variable are as under:



Storage:	CPU registers.
Default value:	Garbage value.
Scope:	Local to the block in which the variable is defined.
Life:	Till the control remains within the block in which the variable is defined.

A value stored in a CPU register can always be accessed faster than the one that is stored in memory. Therefore, if a variable is used at many places in a program, it is better to declare its storage class as register . A good example of frequently used variables is loop counters. We can name their storage class as register .

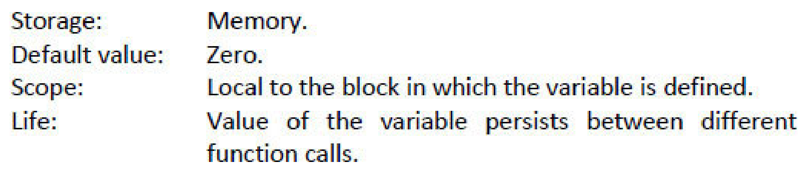
```
register int i;

for (i = 1; i <= 10; i++)

printf (“%d\n”, i);
```

Though i is of register storage class, we cannot say for sure that its value would be stored in a CPU register. That is because the number of CPU registers are limited, and they may be busy doing some other task. In such an event, i works as if its storage class is auto .

A float value requires 4 bytes. So it cannot be stored in a CPU register if the microprocessor has 16-bit CPU registers. If you use register storage class for a float in such a case, you won't get any error messages. Instead, the compiler would treat it as an auto storage class variable.

Static Storage Class

The features of a static storage class variable are as under:



Storage:	Memory.
Default value:	Zero.
Scope:	Local to the block in which the variable is defined.
Life:	Value of the variable persists between different function calls.

The following program shows the static storage class in action:

include

```
void increment();

int main()

{

increment();

increment();

increment();

return 0;

}

void increment()

{

auto int i = 1;

static int j = 1;

i = i + 1;

j = j + 1;

printf (“%d %d\n”, i, j);

}
```

Here is the output of the program…

```
2 2
```

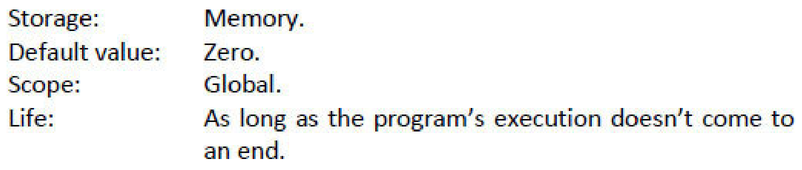
2 3

2 4

No matter how many times we call increment(), i is initialized to 1 every time, whereas j is initialized to 1 only during the first call to increment() . When control returns from increment() , the variable i dies, whereas j being static , continues to live with its latest value. j dies only when execution of the program comes to an end.

External Storage Class

The features of an external storage class variable are as follows:



Storage:	Memory.
Default value:	Zero.
Scope:	Global.
Life:	As long as the program's execution doesn't come to an end.

External variables differ from those we have already discussed in that their scope is global, not local. External variables are declared outside all functions, and are available to all functions that care to use them. Here is an example to illustrate this fact.

include

```
int i;

void increment();

void decrement();

int main()

{

printf (“\ni = %d”, i);

increment();

increment();

decrement();

decrement();

return 0;

}

void increment()

{

i = i + 1;

printf (“on incrementing i = %d\n”, i);

}

void decrement()

{

i = i - 1;

printf (“on decrementing i = %d\n”, i);

}
```

The output would be:

```
i = 0

on incrementing i = 1

on incrementing i = 2

on decrementing i = 1

on decrementing i = 0
```

As is obvious from the above output, the value of i is available to the functions increment() and decrement() since i has been declared outside all functions.

Look at the following program.

include

```
int x = 21;

int main()

{

extern int y;

printf (“%d %d\n”, x, y);

return 0;

}

int y = 31;
```

Here, x and y both are global variables. Since both of them have been defined outside all the functions, both enjoy external storage class. Note the difference between the following:

```
extern int y;

int y = 31;
```

Here the first statement is a declaration, whereas the second is the definition. When we declare a variable no space is reserved for it, whereas when we define it, space gets reserved for it in memory. We had to declare y since it is being used in printf() before its definition is encountered. There was no need to declare x since it was defined before its use. Also remember that a variable can be declared several times but can be defined only once.

Another small issue—what will be the output of the following program?

include

```
int x = 10;

void display();

int main()

{

int x = 20;

printf (“%d\n”, x);

display();
```

return 0;

}

void display()

{

printf (“%d\n”, x);

}

Here x is defined at two places, once outside main() and once inside it. When the control reaches printf() in main() which x gets printed? The local variable x , since it gets a preference over the global x . Hence the printf() outputs 20. When display() is called and control reaches the printf() there is no such conflict. Hence, this time, the value of the global x , i.e. 10 gets printed.

A Few Subtle Issues

Let us now look at some subtle issues about storage classes.

(a) All auto variables defined in a function are created on the stack each time the function is called. These variables die when control goes back from the function. However, if the variables inside the function are defined as static then they do not get created on the stack. Instead they are created in a place in memory called ‘Data Segment’. Such variables die only when program execution comes to an end.

(b) A static variable can also be declared outside all the functions. For all practical purposes, it will be treated as an extern variable. However, the scope of this variable is limited to the same file in which it is declared. This means that the variable would not be available to any function that is defined in a file other than the file in which the variable is defined.

(c) If a variable is defined outside all functions, then not only is it available to all other functions in the file in which it is defined, but is also available to functions defined in other files. In the other files, the variable should be declared as extern . This is shown in the following program:

/* PR1.C */

include

include

int i = 35;

int fun1();

int fun2();

int main()

{

printf (“%d\n”, I);

fun1();

fun2();

return 0;

}

/* FUNCTIONS.C */

extern int i;

int fun1()

{

```
i++;

printf ("%d\n", i);

return 0;

}

int fun2()

{

i--;

printf ("%d\n", i);

return 0;

}
```

The output of the program would be

```
35

36

35
```

(d) In the following statements the first three are definitions, whereas the last one is a declaration.

```
auto int i;

static int j;

register int k;

extern int l;
```

Which to Use When

We can make a few ground rules for usage of different storage classes in different programming situations with a view to:

(a) economise the memory space consumed by the variables

(b) improve the speed of execution of the program

The rules are as under:

(a) Use static storage class only if you want the variable to persist across function calls.

(b) Use register storage class for only those variables that are being used very often in a program, like loop counters.

(c) Use extern storage class for only those variables that are being used by almost all the functions in the program. This would avoid unnecessary passing of these variables as arguments when making a function call.

(d) If absence of any of the express needs mentioned above, use auto storage class.

Exercises

[A] What will be the output of the following programs:

(a) # include

```
int i = 0;

void val();
```

```
int main()

{

printf (“main’s i = %d\n”, i);

i++;

val();

printf (“main’s i = %d\n”, i);

val();

return 0;

}

void val()

{

i = 100;

printf (“val’s i = %d\n”, i);

i++;

}
```

(b) # include

```
int main()

{

static int count = 5;

printf (“count = %d\n”, count--);

if (count != 0)

main();

return 0;

}
```

(c) # include

```
void fnc();

int main()

{

func();

func();

return 0;

}

void func()

{

auto int i = 0;
register int j = 0;

static int k = 0;

i++; j++; k++;

printf (“%d % d %d\n”, i, j, k);

}
```

```
(d) # include

int x = 10;

int main()

{

int x = 20;

{

int x = 30;

printf (“%d\n”, x);

}

printf (“%d\n”, x);

return 0;

}
```

[B] Point out the errors, if any, in the following programs:

```
(a) # include

int main()

{

long num = 2;

printf (“%d\n”, num);

return 0;

}
```

```
(b) # include

int main()

{

char ch = 200;

printf (“%d\n”, ch);

return 0;

}
```

```
(c) # include

int main()
```

```
{
long float a = 25.345e454;
unsigned double b = 25;
printf ("%lf %d\n", a, b);
return 0;
}
```

```
(d) # include
static int y;
int main()
{
static int z;
printf ("%d %d\n", y, z);
return 0;
}
```

[C] State whether the following statements are True or False:

(a) The value of an automatic storage class variable persists between various function invocations.

(b) If the CPU registers are not available, the register storage class variables are treated as static storage class variables.

(c) The register storage class variables cannot hold float values.

(d) If we try to use register storage class for a float variable the compiler will report an error message.

(e) The default value for automatic variable is zero.

(f) The life of static variable is till the control remains within the block in which it is defined.

(g) If a global variable is to be defined, then the extern keyword is necessary in its declaration.

(h) The address of register variable is not accessible.

Types:

Integer - short, long, signed, unsigned, int

Char - signed, unsigned

Real - float, double, long double

Sizes of data types may vary from one compiler to another. For example, int is two bytes in TC, 4 bytes in VisualStudio

For all compilers: sizeof (short) <= sizeof (int) <= sizeof (long)

In signed, left-most bit is 0/1 (+ve/-ve). In unsigned, all bits contribute to value

Negative integers are stored as 2s complement

Number without a decimal point is by default an int. Use suitable suffix to change it:

365 - int, 365u - unsigned int, 365L, 365l - long int, 365lu, 365ul - long unsigned

Number with a decimal point is by default a double. Use suitable suffix to change it:

3.14 - double, 3.14f - float, 3.14L - long double

Two things are needed to completely define a variable:

1) Type of variable 2) Storage class of variable

Type signifies what type of value can be stored in the variable

Storage class signifies 4 things:

1) Storage - Where the variable is stored

2) Default value - What value would it hold if it is not initialized

3) Scope - Where the variable would be available

4) Life - How long would the variable be available

Automatic storage class:

Default value - garbage, Storage - memory

Scope - local to the block ({})

Life - till control is in the block in which variable is defined

Register storage class:

Default value - garbage, Storage - CPU registers

Scope - local to the block

Life - till control is in the block in which variable is defined

Static storage class:

Default value - 0, Storage - memory

Scope - local to the block

Life - till execution of program doesn't end

Extern storage class:

Default value - 0, Storage - memory

Scope - Global

Life - till execution of program doesn't end

CPU Registers - Internal memory of Microprocessor

Definition of a variable reserves space, declaration doesn't

Redeclaration of variable is ok, redefinition is not

int i; → Definition extern int i; → declaration

Local variable gets a priority over global variable of same name

Out of locals of same name, most local variable gets a priority

Usage:

Register - For frequently used variables

Static - If variable is to live across function calls

External - If variable is required by all functions

Automatic - All other cases

Do you think when a game company creates a game for different mobile phones; it maintains different programs for each phone type? It cannot afford to, as making changes in one would necessitate changes in all others. Moreover, with so many phone types around, this would be a difficult proposition. This situation can be smartly handled using preprocessor directives. This chapter shows you how…

Contents

Cpreprocessor is a program that processes our program before it is passed to the compiler. We can write C programs without knowing anything about the preprocessor or its facilities. But preprocessor is such a great convenience that virtually all C programmers rely on it. This chapter explores the preprocessor directives, and discusses the pros and cons of using them in programs.

Features of C Preprocessor

The C program is known as ‘Source Code’. When the source code is passed through ‘Preprocessor’, it creates ‘Expanded Source Code’ as per the preprocessor directives used in the source code. Each preprocessor directive begins with a # symbol. Following preprocessor directives may be used in the source code:

(a) Macro expansion

(b) File inclusion

(c) Conditional compilation

(d) Miscellaneous directives

Let us understand these preprocessor directives one-by-one.

Macro Expansion

Take a look at the following program:

include

define PI 3.1428

```
int main()

{

float r = 6.25, area;

area = PI * r * r;

printf (“Area of circle = %f\n”, area);

return 0;

}
```

In the statement

define PI 3.1428

PI is called ‘macro template’, whereas, 3.1428 is called ‘macro expansion’. During preprocessing, every macro template gets replaced with its corresponding macro expansion. Usually macro templates are written in capital letters. This makes it easy for programmers to identify macro templates when reading through the program.

And now an important question—why use #define at all? Suppose the constant 3.1428 appears many times in your program. Some day you may wish to change all these values with a more accurate 3.142857. For this you have to go through the program and manually change each occurrence of the constant. However, if you have defined PI in a #define directive, you only need to change the #define directive to:

define PI 3.142857

Once done, the change will be made in all occurrences of PI during preprocessing. This convenience may not matter for small programs shown above, but with large programs, macro definitions are almost indispensable.

You may feel that the same purpose could have been served had we used a variable pi instead of a macro template PI . But for three reasons it would have been a bad idea.

Firstly, it is inefficient, since the compiler can generate faster and more compact code for constants than it can for variables. Secondly, using a variable for what is really a constant encourages sloppy thinking—if something never changes, it is hard to imagine it as a variable. And thirdly, there is always a danger that the variable may inadvertently get altered somewhere in the program. So it's no longer a constant that you think it is.

Given below are some more sample #define s.

define AND &&

define ARANGE (a > 25 AND a < 50)

define FOUND printf (“The Yankee Doodle Virus\n”);

Macros with Arguments

The macros that we have used so far are called simple macros. Macros can have arguments, just as functions can. Here is a program that illustrates this fact.

include

define AREA(x) (3.14 * x * x)

```
int main()

{

float r1 = 6.25, r2 = 2.5, a;

a = AREA (r1);

printf (“Area of circle = %f\n”, a);

a = AREA (r2);

printf (“Area of circle = %f\n”, a);

return 0;

}
```

On execution, the program produces the following output:

```
Area of circle = 122.656250

Area of circle = 19.625000
```

The preprocessor would replace every AREA(x) with (3.14 * x * x) . As it does this, x would be substituted with the argument that we use in the macro. Thus a = AREA(r1) would be replaced with a = (3.14 * r1 * r1) .

Here are few more examples of macros with arguments:

define ISDIGIT(y) (y >= 48 && y <= 57)

define ISCAPITAL(ch) (ch >= ‘A’ && ch <= ‘Z’)

Here are some important points to remember while writing macros with arguments:

(a) Do not give a space between macro template and its argument in #define . For example, there should be no blank between AREA and (x) in the definition, #define AREA(x) (3.14 * x * x).

(b) The entire macro expansion should be enclosed within parentheses. Following program shows what would happen if we fail to enclose the macro expansion within parentheses.

include

define SQUARE(n) n * n

int main()

{

int j;

j = 64 / SQUARE (4);

printf (“j = %d\n”, j);

return 0;

}

The above program would output j = 64, whereas, what we expected was j = 4. What went wrong? Well, the macro got expanded into

j = 64 / 4 * 4;

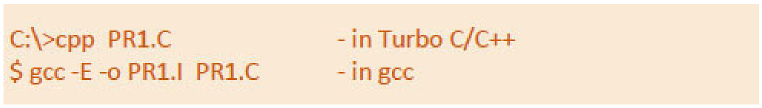
which yielded 64.

(c) Macros can be split into multiple lines, with a ‘\’ (backslash) present at the end of each line, except the last. Given below is one such multiline macro.

define HLINE for (i = 0; i < 79; i++) \

printf (“%c”, 196);

(d) If you are unable to debug a macro, you should view the expanded code of the program to see how the macro is getting expanded. If your source code is present in the file PR1.C, then the expanded source code would be stored in PR1.I. You need to generate this file at the command prompt by saying:



```
C:\>cpp  PR1.C                    - in Turbo C/C++
$ gcc -E -o PR1.I  PR1.C          - in gcc
```

These commands invoke the C Preprocessor which generates the expanded source code and stores it in a file called PR1.O. You can now open this file and see the expanded source code.

Macros versus Functions

In the above example, a macro AREA was used to calculate the area of the circle. We could have written a function area() for the same. This brings us to a question—when one to use when?

If we use a macro, it would be expanded during preprocessing. As against this, if we use a function, during execution control and value of radius would be passed to area() , area would be calculated and returned back.

So, if we use a macro hundred times in a program, the macro expansion (formula) goes into our source code at hundred different places, thus increasing the program size. On the other hand, if a function is used, the formula would occur only once in the function. The hundred places where you need this formula there would be function calls. So space requirement would now be less. But passing arguments to a function and getting back the returned value does take time and would therefore slow down the program. This gets avoided with macros since they have already been expanded and placed in the source code before compilation. Thus, the trade-off is between memory space and time.

Moral is—if the macro is simple as in our examples, it makes nice shorthand and avoids the overheads associated with function calls. On the other hand, if we have a fairly large macro and it is used fairly often, we ought to replace it with a function.

File Inclusion

The next preprocessor directive that we'll explore is file inclusion. It looks like this:

include “filename”

It causes the entire contents of filename to be inserted into the source code where we have used #include. It is common for the files that are to be included to have a .h extension. This extension stands for ‘header file’, as its contents when included go to the head of your program.

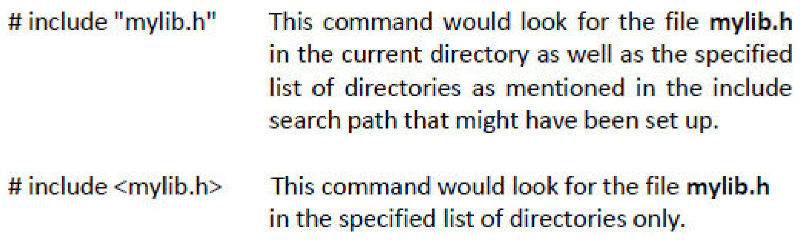
The prototypes of all the library functions are grouped into different categories and then stored in different header files. For example, prototypes of all maths related functions are stored in the file ‘math.h’, prototypes of input/output functions are stored in the file ‘stdio.h’, etc.

Actually there exist two ways to write #include statement. These are:

include “filename”

include

The meaning of each of these forms is given below.



# include "mylib.h"	This command would look for the file **mylib.h** in the current directory as well as the specified list of directories as mentioned in the include search path that might have been set up.
# include <mylib.h>	This command would look for the file **mylib.h** in the specified list of directories only.

The include search path is a list of directories that would be searched for the file being included. Different C compilers let you set the search path in different manner. For Turbo C/C++ compiler the search path can be set up by selecting ‘Directories’ from the ‘Options’ menu. On doing this, a dialog box appears. In this dialog box against ‘Include Directories’, we can specify the search path. We can also specify multiple include paths separated by ‘;’ (semicolon) as shown below.

c:\tc\lib; c:\mylib; d:\libfiles

In Visual Studio the search path for a project can be set by right-clicking the project name in Solution Explorer and selecting “Properties” from the menu that pops up. This brings up a dialog box. You can now set up the search path by going to “Include Directories” in “Configuration Properties” tab.

Suppose we wish to create our own library of functions which we wish to distribute to others. For this the functions should be defined in a “.c” file and their corresponding prototype declarations and macros be declared in a “.h” file. The definitions can then be compiled into a library file (in machine language). While distributing the compiled library file and the “.h” file should be given. Those who wish to use your library would have to link your library file and include your header file. This way the function definitions in the “.c” file remain with you and are not exposed to users of your library.

Conditional Compilation

We can, if we want, have the compiler skip over part of a source code by inserting the preprocessing commands #ifdef and #endif , which have the general form given below.

ifdef macroname

statement 1;

statement 2;

statement 3;

endif

If macroname has been #define d, the block of code will be processed as usual; otherwise not.

Where would #ifdef be useful? When would you like to compile only a part of your program? In three cases, discussed below.

(a) To “comment out” some lines of code that we do not need right now as shown below.

int main()

{

ifdef NOTNOW

statement 1;

statement 2;

endif

statement 3;

statement 4;

}

Here, statements 1 and 2 would get compiled only if the macro NOTNOW has been defined, and we have purposefully omitted the definition of this macro. At a later date, if we want that these statements should also get compiled, we can either delete the #ifdef and #endif statements or #define NOTNOW at the top.

(b) A more sophisticated use of #ifdef has to do with making the programs portable, i.e., to make them work on two computers with different configurations. You can do so by isolating the lines of code that must be different for each machine by marking them off with #ifdef , as follows:

int main()

{

ifdef INTEL

code suitable for an Intel PC

else

code suitable for a Motorola PC

endif

code common to both the computers

}

When we compile this program, it would compile only the code suitable for Mototola PC and the common code since macro INTEL has not been defined. If we want to run the program on an Intel PC, before recompiling the program we need to add a statement at the top saying,

define INTEL

Sometimes, instead of #ifdef , the #ifndef directive is used. The #ifndef (which means ‘if not defined’) works exactly opposite to #ifdef .

(c) Ideally, we should # include a file only once. But if by mistake we end up including it twice, it should get included only once. This can be achieved using # ifndef as shown below:

/* myfile.h */

ifndef _*myfile*h

define _*myfile*h

/* some declarations */

endif

First time the file ‘myfile.h’ gets included, the preprocessor checks whether a macro called**_ myfile*h has been defined or not. If it has not been, then it gets defined and the rest of the code gets included. Next time we attempt to include the same file, the inclusion is prevented since*** myfile_h already stands defined.

if and #elif Directives

The #if directive can be used to test whether an expression evaluates to a non-zero value or not. If the result of the expression is non-zero, then subsequent lines upto a #else , #elif or #endif are compiled, otherwise they are skipped. A simple example of #if directive is shown below:

int main()

{

if TEST <= 5

statement 1;

else

statement 2;

endif

}

If the expression, TEST <= 5 evaluates to true, then statement 1 is compiled, otherwise statement 2 is compiled. In place of the expression TEST <= 5 , other expressions like (LEVEL == HIGH || LEVEL == LOW) or ADAPTER == SVGA can also be used. If required, we can even use nested conditional compilation directives.

Miscellaneous Directives

There are two more preprocessor directives available, though they are not very commonly used. They are:

(a) #undef

(b) #pragma

undef Directive

On some occasions, it may be desirable to cause a defined name to become ‘undefined’. This can be accomplished by means of the #undef directive as shown below:

undef PENTIUM

This would cause the definition of PENTIUM to be removed. All subsequent #ifdef PENTIUM statements would evaluate to false. In practice, seldom are you required to undefine a macro, but if you are required to, then you know that there is something to fall back upon.

pragma Directive

This directive is used to turn on or off certain features. Pragmas vary from one build tool to another. Some pragmas deal with formatting source listings and placing comments in the object file. There are others that allow us to suppress warnings generated by the compiler. Some of these pragmas are discussed below.

(a) #pragma startup and #pragma exit : These directives allow us to specify functions that are called upon program startup (before main()) or program exit (just before the program terminates). Their usage is as follows:

include

```
void fun1();

void fun2();
```

pragma startup fun1

pragma exit fun2

```
int main()

{

printf (“Inside main\n”);

return 0;

}

void fun1()

{

printf (“Inside fun1\n”);

}

void fun2()

{

printf (“Inside fun2\n”);

}
```

And here is the output of the program.

```
Inside fun1

Inside main

Inside fun2
```

Note that the functions fun1() and fun2() should neither receive nor return any value. If we want two functions to get executed at startup then their pragmas should be defined in the reverse order in which you want to get them called.

(b) #pragma warn : On compilation the compiler reports Errors and Warnings in the program, if any. Errors have to be corrected. Warnings, on the other hand, offer the programmer a hint or suggestion that something may be wrong with a particular piece of code. Two most common situations when warnings are displayed are as under:

- If you have written code that is considered as bad programming practice. For example, if a function does not return a value and you have not declared the return type of this function as void .
- If you have written code that might cause run-time errors, such as assigning a value to an uninitialized pointer.

The #pragma warn directive tells the compiler whether or not we want to suppress a specific warning. Usage of this pragma is shown below.

include

pragma warn -rvl /* return value */

pragma warn -par /* parameter not used */

pragma warn -rch /* unreachable code */

```
int f1()

{

int a = 5;

}

void f2 (int x)

{

printf (“Inside f2\n”);

}

int f3()

{

int x = 6;

return x;

x++;

}

int main()

{

f1();

f2 (7);

f3();

return 0;

}
```

If you go through the program, you can notice three problems immediately. These are:

(a) Though promised, f1() doesn't return a value.

(b) The parameter x passed to f2() is not being used anywhere.

(c) The control can never reach x++ in f3() .

If we compile the program, we should expect warnings indicating the above problems. However, this does not happen since we have suppressed the warnings using the #pragma directives.

If we replace the ‘-’ sign with a ‘+’, then these warnings would be flashed on compilation. Though it is a bad practice to suppress warnings, at times, it becomes useful to suppress them. For example, while compiling a big program you may first want to eliminate all errors and then turn your attention to the warnings. At such times, you may suppress the warnings. Once you have eliminated all errors, then you may turn on the warnings and attend to them.

The Build Process

There are many steps involved in converting a C program into an executable form. Figure 12.1 shows these different steps along with the files created during each stage. Many software development tools hide some of these from us. However, if you understand these steps it will make you a better programmer.

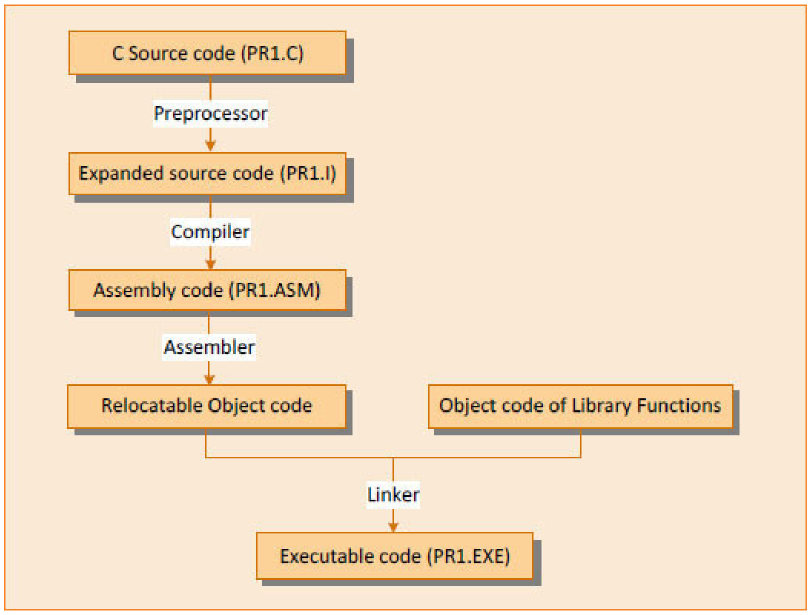
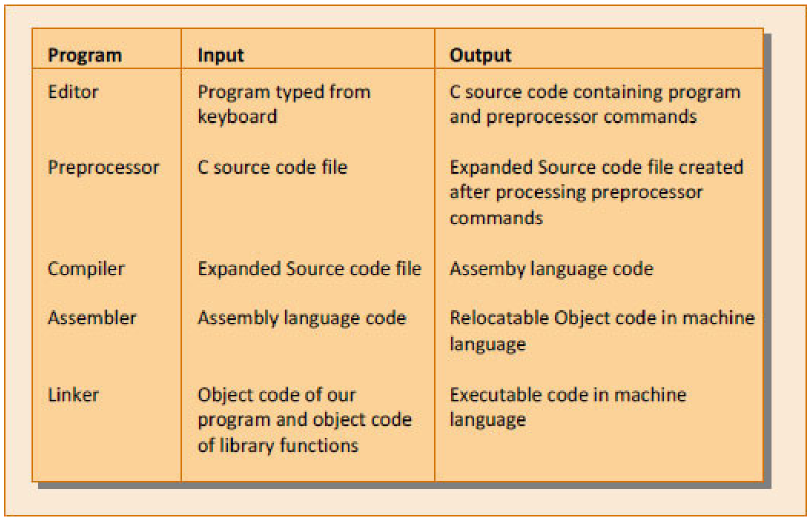


Figure 12.1

Figure 12.2 summarizes the role played by each program during the build process.



Program	Input	Output
Editor	Program typed from keyboard	C source code containing program and preprocessor commands
Preprocessor	C source code file	Expanded Source code file created after processing preprocessor commands
Compiler	Expanded Source code file	Assemby language code
Assembler	Assembly language code	Relocatable Object code in machine language
Linker	Object code of our program and object code of library functions	Executable code in machine language

Figure 12.2

P</> Programs

Problem 12.1

Write macro definitions for the following:

To test whether a character is a small case letter or not.

To test whether a character is an upper case letter or not.

To test whether a character is an alphabet or not. Make use of the macros you defined in 1 and 2 above.

To obtain the bigger of two numbers.

Program

```
/* Macros ISUPPER, ISLOWER, ISAPLHA, BIG */
```

include

define ISUPPER(x) (x >= 65 && x <= 90 ? 1 : 0)

define ISLOWER(x) (x >= 97 && x <= 122 ? 1 : 0)

define ISALPHA(x) (ISUPPER(x) || ISLOWER(x))

define BIG(x,y) (x > y ? x : y)

```
int main()
{
char ch;
int d, a, b;
printf (“\nEnter any alphabet/character: ”);
scanf (“%c”, &ch);
if (ISUPPER (ch) == 1)
printf (“You entered a capital letter\n”);
if (ISLOWER (ch) == 1)
printf (“You entered a small case letter\n”);
if (ISALPHA (ch) != 1)
printf (“You entered character other than an alphabet\n”);
printf (“Enter any two numbers: ”);
scanf (“%d%d”, &a, &b);
d = BIG (a, b);
printf (“Bigger number is %d\n”, d);
return 0;
}
```

Output

```
Enter any alphabet/character: A
You entered a capital letter
Enter any two numbers: 10 20
Bigger number is 20
```

Problem 12.2

Write macro definitions with arguments for calculation of area and perimeter of a triangle, a square and a circle. Store these macro definitions in a file called “areaperi.h”. Include this file in your program, and call the macro definitions for calculating area and perimeter for different squares, triangles and circles.

Program

/* areaperi.h */

/* Storing the macro definitions of area and perimeter of circle, triangle

and square in the “areaperi.h” header file */

define PI 3.1415

define PERIC(r) (2 * PI * r)

define AREAC(r) (PI * r * r)

define PERIS(x) (4 * x)

define AREAS(x) (x * x)

define PERIT(x, y, z) (x + y + z)

define AREAT(b, h) (0.5 * b * h)

/* Program to use macros in header file “areaperi.h” */

include

include “areaperi.h”

int main()

{

int d, a, b;

float sid1, sid2, sid3, sid, p*tri, p*cir, p*sqr, a*tri, a*cir,a*sqr;

float r, base, height;

printf (“\nEnter radius of circle: ”);

scanf (“%f”, &r);

p_cir = PERIC (r);

printf (“Circumference of circle = %f\n”, p_cir);

a_cir = AREAC (r);

printf (“Area of circle = %f\n”, a_cir);

```
printf ("Enter side of a square: ");
scanf ("%f", &sid);
p_sqr = PERIS (sid);
printf ("Perimeter of square = %f\n", p_sqr);
a_sqr = AREAS (sid);
printf ("Area of square = %f\n", a_sqr);
printf ("Enter length of 3 sides of triangle: ");
scanf ("%f %f %f", &sid1, &sid2, &sid3);
p_tri = PERIT (sid1, sid2, sid3);
printf ("Perimeter of triangle = %f\n", p_tri);
printf ("Enter base and height of triangle: ");
scanf ("%f %f", &base, &height);
a_tri = AREAT (base, height);
printf ("Area of triangle = %f\n", a_tri);
return 0;
}
```

Output

```
Enter radius of circle: 5
Circumference of circle = 31.415001
Area of circle = 78.537498
Enter side of a square: 6
Perimeter of square = 24.000000
Area of square = 36.000000
Enter length of 3 sides of triangle: 3 4 5
Perimeter of triangle = 12.000000
Enter base and height of triangle: 4 6
Area of triangle = 12.000000
```

Exercises

[A] Answer the following questions:

(a) A preprocessor directive is:

A message from compiler to the programmer

A message from compiler to the linker

A message from programmer to the preprocessor

A message from programmer to the microprocessor

(b) Which of the following are correctly formed #define statements:

define INCH PER FEET 12

define SQR (X) (X * X)

define SQR(X) X * X

define SQR(X) (X * X)

(c) State True or False:

A macro must always be written in capital letters.

A macro should always be accommodated in a single line.

After preprocessing when the program is sent for compilation the macros are removed from the expanded source code.

Macros with arguments are not allowed.

In a macro call the control is passed to the macro.

(d) A header file is:

A file that contains standard library functions

A file that contains definitions and macros

A file that contains user-defined functions

A file that is present in current working directory

(e) All macro substitutions in a program are done:

Before compilation of the program

After compilation

During execution

None of the above

[B] What will be the output of the following programs:

(a) # include

int main()

{

int i = 2;

ifdef DEF

i *= i; #

else

printf (“%d\n”, i);

endif

return 0;

}

(b) # include

define PRODUCT(x) (x * x)

int main()

{

int i = 3, j, k, l;

j = PRODUCT(i + 1);

k = PRODUCT(i++);

l = PRODUCT (++i);

printf (“%d %d %d %d\n”, i, j, k, l);

return 0;

}

(c) # include

define PI 3.14

define AREA(x, y, z) (PI * x * x + y * z);

int main()

{

float a = AREA (1, 5, 8);

float b = AREA (AREA (1, 5, 8), 4, 5);

printf (“ a = %f\n”, a);

printf (“ b = %f\n”, b);

return 0;

}

[C] Attempt the following questions:

(a) If a macro is not getting expanded as per your expectation, how will you find out how is it being expanded by the preprocessor?

(b) Write macro definitions for the following:

To find arithmetic mean of two numbers.

To find absolute value of a number.

To convert an upper case alphabet to lower case.

To obtain the biggest of three numbers.

(c) Write macro definitions with arguments for calculation of Simple Interest and Amount. Store these macro definitions in a file called “interest.h”. Include this file in your program, and use the macro definitions for calculating simple interest and amount.

Preprocessor expands the source code as per the preprocessor directives used in it.

4 types of Preprocessor directives:

1) Macro Expansion

2) File Inclusion

3) Conditional Compilation

4) Miscellaneous Directives

include “stdio.h” - Searches the file in Include path + Current dir

include - Searches the file in Include path

Macros - Every template is replaced by its expansion

Macros have a global effect

define PLANK 6.634E-34 - Simple macro

define AREA(x) PI * x * x - Macro with argument

Macros can take multiple arguments - #define CALC(a, b, c) (a + b * c / 3.14)

Macros can be split over multiple lines. Put a \ at the end of each line, except last line

Advantage of Macros - Faster than functions

Advantage of Functions - Occupy less space

Be aware of side-effects of macros with arguments

define SQUARE(y) y * y

would expand z = SQUARE(3 + 1) into z = 3 + 1 * 3 + 1

Conditional compilation - Compiles the code only if the condition is true

Conditional compilation is implemented using #ifdef, #else, #endif, #ifndef, #if

Miscellaneous directives:

undef - undefines a macro that has already been defined

pragma inline - used for compilation of program that uses assembly language statements

There are many other #pragma directives

13 Arrays

"Bringing order to chaos..."

A variable can hold one value at a time. So if you have 100 values, how many variables will you need? Well, answer is not 100. It is 1, and that variable is a special variable called Array. This chapter shows you how to work with it…

Contents

Clanguage provides a capability that enables the user to design a set of similar data types, called array. This chapter describes how arrays can be created and manipulated in C. Pointers and arrays are very closely related. This relationship is also discussed in this chapter.

What are Arrays?

Suppose we wish to arrange the percentage marks obtained by 100 students in ascending order. For this we can either construct 100 variables, each variable containing one student's marks; or construct one variable capable of storing or holding all the hundred values. Obviously, the second alternative is better as it's easier to handle one variable than handling 100 variables. Such a variable is called an array.

Now a formal definition of an array—An array is a collection of similar elements. These similar elements could be percentage marks of 100 students, or salaries of 300 employees, or ages of 50 employees. What is important is that the elements must be 'similar'. We cannot have an array of 10 numbers, of which 5 are int s and 5 are float s. Usually, the array of characters is called a 'string', whereas an array of int s or float s is called simply an array.

A Simple Program using Array

Let us write a program to find average marks obtained by a class of 30 students in a test.

include

```
int main()

{

int avg, sum = 0;

int i;

int marks[30]; /* array declaration */

for (i = 0; i <= 29; i++)

{

printf (“Enter marks ”);

scanf (“%d”, &marks[i]); /* store data in array */

}

for (i = 0; i <= 29; i++)

sum = sum + marks[i]; /* read data from an array*/

avg = sum / 30;

printf (“Average marks = %d\n”, avg);

return 0;

}
```

There is a lot of new material in this program, so let us understand it part by part.

Array Declaration

Like other variables, an array needs to be declared so that the compiler will know what type of an array and how large an array we want. In our program, we have done this through the statement:

```
int marks[30];
```

Here, [30] tells the compiler how many elements of the type int will be in our array. This number is often called the ‘dimension’ of the array.

Accessing Elements of an Array

Once an array is declared, an individual element in it is referred using marks[0], marks[1], marks[2], etc. The number used in [] specifies the element's position in the array. Array elements are counted starting from 0th element. Thus, marks[2] is not the second element of the array, but the third. 0, 1, 2 are often called subscripts and the array is called subscripted variable. In our program we have used this form to access array elements in two statements

```
scanf (“%d”, &marks[i]); /* store data in array */

sum = sum + marks[i]; /* read data from an array*/
```

In the first statement we are passing the address of marks[i] to scanf() to receive a value in marks[i] . In the second statements we are using marks[i] to get a running sum. Since both these statements are used in a loop, each time through the loop, i takes a different value. So each time we are scanning or using a new element from the array. This ability to use variables to represent subscripts is what makes arrays so useful. When all the marks have been added up, the result is divided by 30, the number of students, to get the average.

More on Arrays

Let us now discuss the features which make arrays so convenient to program. We would also learn the possible pitfalls in using them.

Array Initialization

Look at the following array declarations:

int num[6] = {2, 4, 12, 5, 45, 5};

int n[] = {2, 4, 12, 5, 45, 5};

float press[] = {12.3, 34.2, -23.4, -11.3};

long int gdp[10];

This shows that arrays can be initialized while declaring them. When we do so, mentioning the dimension of the array is optional, as in the 2 nd and 3 rd examples above. Also, note that the array gdp[] has auto storage class and it has not been initialized, so it contains garbage values. If we declare it as a static array, all elements would be set to 0.

Array Elements in Memory

Consider the following array declaration:

int arr[8];

This would reserve 32 bytes for the array in memory, 4 bytes for each of the 8 integers. The values in it would be garbage values. The array elements would occupy adjacent memory locations as shown in Figure 13.1 .

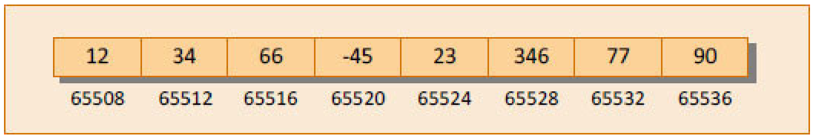


Figure 13.1

Bounds Checking

Consider the following program:

include

int main()

{

int num[40], i;

for (i = 0; i <= 99; i++)

num[i] = i;

return 0;

}

We have reserved 40 slots for num[] , whereas we are attempting to fill 100 values into it. When value of i goes past 39, the values would simply be placed in locations outside the array. If these locations contain garbage data then nothing would be lost. But if they contain useful data it would lead to unpredictable results. In some cases, the computer may just hang.

Issue is that there will be no error message to warn us that we are going beyond the array size. Thus, to see to it that we do not reach beyond the array size is entirely the programmer's botheration and not the compiler's.

Passing Array Elements to a Function

Array elements can be passed to a function by value, or by reference. These two calls are illustrated below.

/* Demonstration of call by value & call by reference */

include

```
void display1 (int);

void display2 (int *);

int main()

{

int i;

int marks[] = {55, 65, 75, 56, 78, 78, 90};

for (i = 0; i <= 6; i++)

display1 (marks[i]);

for (i = 0; i <= 6; i++)

display2 (&marks[i]);

return 0;

}

void display1 (int m)

{

printf (“%d ”, m);

}

void display2 (int *n)

{

printf (“%d ”, *n);

}
```

And here's the output…

```
55 65 75 56 78 78 90

55 65 75 56 78 78 90
```

Here, to display1() we are passing value of an array element, whereas to display2() we are passing address of an array element. Since at a time only one element or its address is being passed, this element or its address is collected in an integer variable m , or an integer pointer n . Since n contains the address of array element, to print out the array element, we are using the ‘value at address’ operator (*) .

Pointers and Arrays

To be able to see what pointers have got to do with arrays, let us first learn some pointer arithmetic. Consider the following example:

include

```
int main()

{

int i = 3, *x;

float j = 1.5, *y;
char k = 'c', *z;

printf ("Value of i = %d\n", i);

printf ("Value of j = %f\n", j);

printf ("Value of k = %c\n", k);

x = &i; y = &j; z = &k;

printf ("Original address in x = %u\n", x);

printf ("Original address in y = %u\n", y);

printf ("Original address in z = %u\n", z);

x++; y++; z++;

printf ("New address in x = %u\n", x);

printf ("New address in y = %u\n", y);

printf ("New address in z = %u\n", z);

return 0;

}
```

Here is the output of the program.

```
Value of i = 3

Value of j = 1.500000

Value of k = c

Original address in x = 65524

Original address in y = 65520

Original address in z = 65519

New address in x = 65528

New address in y = 65524

New address in z = 65520
```

Observe the last three lines of the output. 65528 is original address in x plus 4, 65524 is original address in y plus 4, and 65520 is original address in z plus 1. This so happens because every time a pointer is incremented, it points to the immediately next location of its type. So, when an integer pointer x is incremented, it points to an address four locations after the current location, since an int is always 4 bytes long (under TC/TC++, since int is 2 bytes long, new address in x would be 65526). Similarly, y points to an address 4 locations after the current location and z points 1 location after the current location. This is a very important result and can be effectively used while passing the entire array to a function.

The way a pointer can be incremented, it can be decremented as well, to point to earlier locations. Thus, the following operations can be performed on a pointer:

(a) Addition of a number to a pointer.

(b) Subtraction of a number from a pointer.

(c) Subtraction of one pointer from another.

(d) Comparison of two pointer variables.

The program given below illustrates these operations.

include

```
int main()
{
int arr[] = {10, 20, 30, 45, 67, 56, 74};
int i = 4, *j, *k, *x, *y;
j = &i;
j = j + 9; /* pointer plus number */
k = &i;
k = k - 3; /* pointer minus number */
x = &arr[1];
y = &arr[5];
printf (“%d\n”, y - x);
j = &arr [4];
k = (arr + 4);
if (j == k)
printf (“The two pointers point to the same location\n”);
else
printf (“The two pointers point to different locations\n”);
return 0;
}
```

We are already familiar with the operation of addition/subtraction of a number to/from a pointer. That brings us to the third operation— subtraction of pointers.

x and y have been declared as integer pointers and are holding addresses of first and fifth element of the array, respectively. Suppose the array begins at location 65502, then arr[1] and arr[5] would be present at locations 65506 and 65522 respectively, since each integer in the array occupies 4 bytes in memory. The expression y - x would print a value 4, as y and x are pointing to locations that are 4 integers apart.

Pointer variables can be compared provided both variables point to objects of the same data type. Such comparisons can be useful when both pointer variables point to elements of the same array. The comparison can test for either equality or inequality. Moreover, a pointer variable can be compared with zero (usually expressed as NULL).

Do not attempt the any other operations on pointers, other than the 4 operations mentioned above… they would never work out.

Accessing Array Elements using Pointers

We have learnt these two facts above:

(a) Array elements are always stored in contiguous memory locations.

(b) A pointer when incremented always points to the next location of its type.

Let us now correlate these two facts and access array elements using pointers.

include

```
int main()
```

```
{

int num[] = {24, 34, 12, 44, 56, 17};

int i, *j;

j = &num[0]; /* assign address of zeroth element */

for (i = 0; i <= 5; i++)

{

printf (“address = %u element = %d\n”, j, *j);

j++; /* increment pointer to point to next location */

}

return 0;

}
```

The output of this program would be:

```
address = 65512 element = 24

address = 65516 element = 34

address = 65520 element = 12

address = 65524 element = 44

address = 65528 element = 56

address = 65532 element = 17
```

To understand this output, let us first see how the array elements are arranged in memory. This is shown in Figure 13.2 .

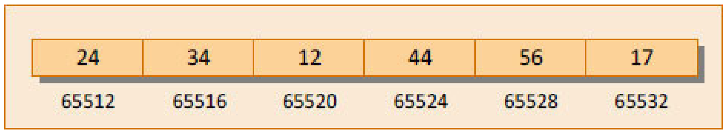


Figure 13.2

In the program, to begin with, we have collected the base address of the array (address of the 0th element) in the variable j using the statement,

```
j = &num[0]; /* assigns address 65512 to j */
```

When we are inside the loop for the first time, j contains the address 65512, and the value at this address is 24. These are printed using the statement,

```
printf (“address = %u element = %d\n”, j, *j);
```

On incrementing j , it points to the next memory location of its type (that is location no. 65516). But location no. 65516 contains the second element of the array, therefore when printf() is executed for the second time, it prints out the second element of the array and its address (i.e., 34 and 65516)… and so on till the last element of the array.

So now we know how to access array elements using subscript and using pointer. Obviously, a question arises as to which of the two methods should be used when? Accessing array elements by pointers is always faster than accessing them by subscripts. However, from the point of view of convenience in programming, we should observe the following:

Array elements should be accessed using pointers, if the elements are to be accessed in a fixed order, say from beginning to end, or from end to beginning, or every alternate element or any such definite logic.

Instead, it would be easier to access the elements using a subscript if there is no fixed logic in accessing the elements.

Passing an Array to a Function

We already know how to pass individual elements of an array or addresses of individual elements of an array to a function. Let us now see how to pass an entire array to a function. Consider the following program:

```
/* Demonstration of passing an array to a function */
```

include

```
void display1 (int *, int);

void display2 (int [], int);

int main()

{

int num[] = {24, 34, 12, 44, 56, 17};

display1 (&num[0], 6);

display2 (&num[0], 6);

return 0;

}

void display1 (int *j, int n)

{

int i;

for (i = 0; i <= n - 1; i++)

{

printf (“element = %d\n”, *j);

j++; /* increment pointer to point to next element */

}

}

void display2 (int j[], int n)

{

int i;

for (i = 0; i <= n - 1; i++)

printf (“element = %d\n”, j[i]);

}
```

Here, the address of the zeroth element and the number of elements in the array are being passed to the display1() function. The for loop accesses the array elements using pointers. Note that it is necessary to pass the total number of elements in the array, otherwise the function would not know when to terminate the for loop.

Same parameters are also being passed to display2() . But they are received in a different form

```
void display2 (int j[], int n)
```

Here, though j is still an integer pointer, the array notation gives the convenience of accessing the array elements using the expression j[i] , without being required to perform any pointer arithmetic on j .

Note that the address of the zeroth element (often called the base address) can also be passed by just passing the name of the array. Thus, the following two function calls are same:

```
display1 (&num[0], 6);

display1 (num, 6);
```

The Real Thing

If you have grasped the concept of storage of array elements in memory and the arithmetic of pointers, here is some real food for thought. Once again consider the following array:

```
int num[] = {24, 34, 12, 44, 56, 17};
```

We know, that on mentioning the name of the array, we get its base address. Thus, by saying *num , we would be able to refer to the zeroth element of the array, that is, 24. One can easily see that *num and *(num + 0) both refer to 24.

Similarly, by saying *(num + 1) , we can refer the first element of the array, that is, 34. In fact, this is what the C compiler does internally. When we say, num[i] , the C compiler internally converts it to *(num + i) . This means that all the following notations are same:

```
num[i]

*(num + i)

*(i + num)

i[num]
```

And here is a program to prove my point.

```
/* Accessing array elements in different ways */
```

include

```
int main()

{

int num[] = {24, 34, 12, 44, 56, 17};

int i;

for (i = 0; i <= 5; i++)

{

printf (“address = %u ”, &num[i]);

printf (“element = %d %d ”, num[i], *(num + i));

printf (“%d %d\n”, *(i + num), i[num]);

}

return 0;

}
```

The output of this program would be:

```
address = 65512 element = 24 24 24 24

address = 65516 element = 34 34 34 34

address = 65520 element = 12 12 12 12
address = 65524 element = 44 44 44 44

address = 65528 element = 56 56 56 56

address = 65532 element = 17 17 17 17
```

Flexible Arrays

While defining in an array we have to mention its size as positive non-zero integer constant. We cannot use a variable for it. Thus the following declaration is wrong:

```
int max;

int arr[max];

scanf (“%d”, &max);
```

During compilation value has not been supplied to max in scanf() (we get that chance during execution). So compiler is not able to decide how much space should be allocated for the array. Hence it rejects this declaration. However, the following declaration works:

define MAX 25

```
int arr[MAX];
```

This is because during preprocessing MAX gets replaced by 25. So compiler gets to see the declaration as int arr[25] , which is fine.

At times, we are unable to decide the size of an array at the time of writing the program. So we have to postpone this till execution time. If we are to create an array during execution, we have to take help of a function called malloc() . The following program shows how to use it.

```
/* Flexible array size */
```

include

include

```
int main()

{

int max, i, *p;

printf (“Enter array size: ”);

scanf (“%d”, &max);

p = (int *) malloc (max * sizeof (int));

for (i = 0; i <= 5; i++)

{

p[i] = i * i;

printf (“%d ”, p[i]);

}

return 0;

}
```

To malloc() function we need to pass the number of bytes to allocate in memory. On doing so, it allocates the bytes and returns the base address of the allocated chunk as a void pointer. We need to convert the void pointer into an int pointer. This conversion is necessary since operations cannot be performed on a void pointer. The conversion is done using the typecast operation. In this operation the target type should be enclosed within (). Once the address is assigned to p , it can be used as a normal array through expression p[i] .

Problem 13.1

Write a program that interchanges elements at odd position with elements at even position in an array of 10 elements.

Program

```
/* Interachnage adjacent elements of an array */
```

include

```
int main()

{

int num[] = {12, 4, 5, 1, 9, 13, 11, 19, 54, 34};

int i, t;

for (i = 0; i <= 9; i = i + 2)

{

t = num[i];

num [i] = num [i + 1];

num [i + 1] = t;

}

for (i = 0; i <= 9; i++)

printf (“%d\t”, num[i]);

return 0;

}
```

Output

```
4 12 1 5 13 9 19 11 34 54
```

Problem 13.2

Write a program to copy the contents of a 5 element integer array into another array in reverse order.

Program

```
/* Program to copy one array into another in reverse order */
```

include

```
int main()

{

int arr1[5], arr2[5], i, j;

printf (“\nEnter 5 elements of array:\n”);
```

for (i = 0; i <= 4; i++)

scanf (“%d”, &arr1[i]);

for (i = 0, j = 4; i <= 4; i++, j--)

arr2[j] = arr1[i];

printf (“Elements in reverse order:\n”);

for (i = 0; i <= 4; i++)

printf (“%d\t”, arr2[i]);

return 0;

}

Output

Enter 5 elements of array:

10 20 30 40 50

Elements in reverse order:

50 40 30 20 10

Problem 13.3

An array contains 10 integers. Receive the number to be searched in the array as input. Write a program to search this number in the array and display the number of times it occurs in the array.

Program

/* Program to find a number and its frequency in array */

include

int main()

{

int num[] = {7, 3, 5, 4, 6, 7, 2, 4, 6, 7};

int n, i, count;

printf (“\nEnter an element to search: ”);

scanf (“%d”, &n);

count = 0;

for (i = 0; i <= 9; i++)

{

if (num[i] == n)

count++;

}

printf (“Number %d is found %d time(s) in the array\n”, n, count);

return 0;

```
}
```

Output

```
Enter an element to search: 7

Number 7 is found 3 time(s) in the array
```

Exercises

[A] Answer the following questions:

(a) Are the following array declarations correct?

```
int a (25);

int size = 10, b[size];
```

(b) Which element of the array does this expression reference?

```
num[4]
```

(c) What is the difference between the 5's in these two expressions?

```
int num[5];

num[5] = 11;
```

(d) What will happen if you try to put so many values into an array when you initialize it that the size of the array is exceeded?

(e) What will happen if you put too few elements in an array when you initialize it?

(f) What will happen if you assign a value to an element of an array whose subscript exceeds the size of the array?

(g) When you pass an array as an argument to a function, what actually gets passed?

(h) If you don't initialize a static array, what will be the elements set to?

(i) if int s[5] is a one-dimensional array of integers, how will you refer to the third element in the array using pointer notation?

[B] Attempt the following questions:

(a) Twenty-five numbers are entered from the keyboard into an array. Write a program to find out how many of them are positive, how many are negative, how many are even and how many odd.

(b) If an array arr contains n elements, then write a program to check if arr[0] = arr[n - 1] , arr[1] = arr[n - 2] and so on.

(c) Write a program using pointers to find the smallest number in an array of 25 integers.

(d) Implement the Insertion Sort algorithm shown in Figure 13.3 on a set of 25 numbers.

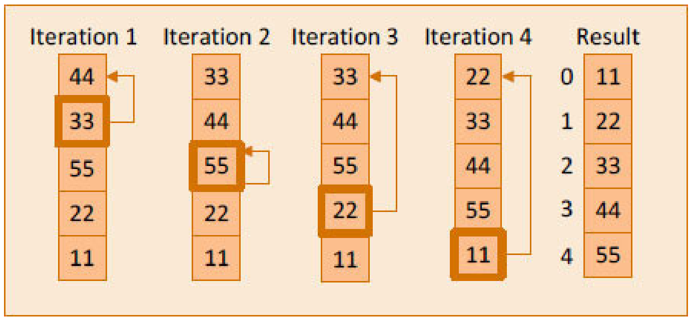


Figure 13.3

(e) Write a program which performs the following tasks:

- Initialize an integer array of 10 elements in main()
- Pass the entire array to a function modify()
- In modify() multiply each element of array by 3
- Return the control to main() and print the new array elements in main()

(f) For the following set of sample data, compute the standard deviation and the mean.

-6, -12, 8, 13, 11, 6, 7, 2, -6, -9, -10, 11, 10, 9, 2

The formula for standard deviation is

$$\frac{\sqrt{(x_i - \bar{x})^2}}{n}$$

where x_i is the data item and $\bar{x}$ is the mean.

(g) The area of a triangle can be computed by the sine law when 2 sides of the triangle and the angle between them are known.

Area = (1 / 2) ab sin (angle)

Given the following 6 triangular pieces of land, write a program to find their area and determine which is largest.

Plot No.	a	b	angle
1	137.4	80.9	0.78
2	155.2	92.62	0.89
3	149.3	97.93	1.35
4	160.0	100.25	9.00
5	155.6	68.95	1.25
6	149.7	120.0	1.75

(h) For the following set of n data points (x, y), write a program to compute the correlation coefficient r, given by

$$r = \frac{\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

x	y
34.22	102.43
39.87	100.93
41.85	97.43
43.23	97.81
40.06	98.32
53.29	98.32
53.29	100.07
54.14	97.08
49.12	91.59
40.71	94.85
55.15	94.65

(i) For the following set of point given by (x, y) fit a straight line given by y = a + bx

where,

$a = \overline{y} - b\overline{x}$ and

$$b = \frac{n\sum yx - \sum x \sum y}{[n\sum x^2 - (\sum x)^2]}$$

x	Y
3.0	1.5
4.5	2.0
5.5	3.5
6.5	5.0
7.5	6.0
8.5	7.5
8.0	9.0
9.0	10.5
9.5	12.0
10.0	14.0

(j) The X and Y coordinates of 10 different points are entered through the keyboard. Write a program to find the distance of last point from the first point (sum of distances between consecutive points).

(k) A dequeue is an ordered set of elements in which elements may be inserted or retrieved from either end. Using an array simulate a dequeue of characters and the operations retrieve left, retrieve right, insert left, insert right. Exceptional conditions such as dequeue full or empty should be indicated. Two pointers (namely, left and right) are needed in this simulation.

Array is a variable capable of holding > 1 value at a time

Two basic properties of an array:

1) Similarity - All array elements are similar to one another

2) Adjacency - All array elements are stored in adjacent memory locations

2 ways to declare an array:

int arr[10]; /* mentioning size is compulsory */

int num[] = {23, 34, 54, 22, 33}; /* size is optional */

Array elements are always counted from 0 onwards. So arr[9] is 10 th element

Arrays have storage classes. Default - auto

Array elements can be scanned OR calculated:

scanf (“%d %d %d”, &arr[7], &arr[8], &arr[9]); arr[5] = 3 + 7 % 2;

Arithmetic on array elements is allowed:

arr[6] = arr[1] + arr[3] / 16;

Caution: Bounds checking of an array is programmer's responsibility

Typical way to process an array element by element:

```
int arr[10];

for (i = 0; i <= 9; i++)

    /* process arr[i] */
```

To obtain address of 0th element of array use:

int arr[10]; int *p;

p = arr; /* method 1 */

p = &arr[0]; /* method 2 */

Sorting = Arranging array elements in ascending / descending order

Bubble sort - Compare adjacent elements repeatedly

Selection sort - compare 0th element with all others, 1st will others, etc.

On incrementing a pointer it always points to the next location of its type

On incrementing a float pointer it points to the next float which is 4 bytes away

On incrementing an int pointer it points to the next int which is 4 bytes away

On incrementing a char pointer it points to the next char which is 1 byte away

Only legal pointer operations:

pointer + number □ pointer

pointer - number □ pointer

pointer - Pointer □ number

pointer == pointer

5 ways to access array elements using pointers:

- Set up a pointer holding base address of the array:

int arr[10], *p;

p = arr;

- In a for loop use one of the five expressions:

*p; p++; OR

```
*(p+i)    OR   *(i+p)    OR
p[i]      OR   i[p]
```

To pass an array to a function we must always pass two things:

1) Base address of the array 2) Size of the array

Array can neither grow nor shrink in size during execution of the program

We cannot declare an array using int arr[n] and then receive the value of n from keyboard

We can make the array size flexible by changing the value of MAX suitably:

define MAX 20

Int arr[MAX];

To create a variable sized array, use the following:

int *p;

p = (int *) malloc (n * sizeof (int));

Then to access all elements we can use p[i]

14 Multidimensional Arrays

"More the arrays, more the dimensions..."

Multidimensional personalities are always impressive. So are multidimensional arrays. They let you accomplish so much with so few variables. This chapter shows you how to work with a 2-D array and its other cousins…

Contents

In the last chapter we he we have explored arrays with only one dimension. It is also possible for arrays to have two or more dimensions. This chapter describes how multidimensional arrays can be created and manipulated in C.

Two-Dimensional Arrays

The two-dimensional (2-D) array is also called a matrix. Let us see how to create this array and work with it. Here is a sample program that stores roll number and marks obtained by a student side-by-side in a matrix.

include

```
int main()

{

int stud[4][2];

int i, j;

for (i = 0; i <= 3; i++)

{
```

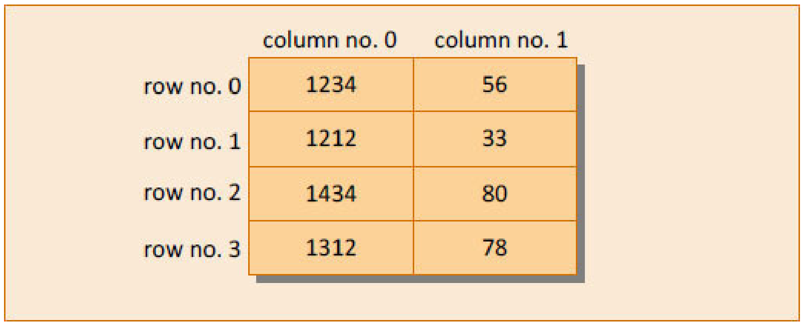
```
printf (“Enter roll no. and marks”);

scanf (“%d %d”, &stud[i][0], &stud[i][1]);

}

for (i = 0; i <= 3; i++)

printf (“%d %d\n”, stud[i][0], stud[i][1]);

return 0;

}
```

There are two parts to the program—in the first part, through a for loop, we read in the values of roll no. and marks, whereas, in the second part through another for loop, we print out these values.

Look at the scanf() statement used in the first for loop:

```
scanf (“%d %d”, &stud[i][0], &stud[i][1]);
```

In stud[i][0] and stud[i][1] , the first subscript of the variable stud , is row number which changes for every student. The second subscript tells which of the two columns are we talking about—the zeroth column which contains the roll no. or the first column which contains the marks. Remember the counting of rows and columns begin with zero. Thus, 1234 is stored in stud[0][0] , 56 is stored in stud[0][1] and so on. The complete array arrangement is shown in Figure 14.1 .



	column no. 0	column no. 1
row no. 0	1234	56
row no. 1	1212	33
row no. 2	1434	80
row no. 3	1312	78

Figure 14.1

Initializing a 2-D Array

How do we initialize a 2-D array? As simple as this…

```
int  stud[ 4 ][ 2 ] = {
                          { 1234, 56 }, { 1212, 33 }, { 1434, 80 }, { 1312, 78 }
                      } ;
```

or even this would work…

```
int stud[4][2] = {1234, 56, 1212, 33, 1434, 80, 1312, 78};
```

of course, with a corresponding loss in readability.

While initializing a 2-D array, it is necessary to mention the second (column) dimension, whereas the first dimension (row) is optional. Thus the following declarations are perfectly acceptable,

```
int arr[2][3] = {12, 34, 23, 45, 56, 45};

int arr[][3] = {12, 34, 23, 45, 56, 45};
```

whereas,

```
int arr[2][] = {12, 34, 23, 45, 56, 45};
int arr[][] = {12, 34, 23, 45, 56, 45};
```

would never work.

Memory Map of a 2-D Array

The array arrangement shown in Figure 14.1 is only conceptually true. This is because memory doesn't contain rows and columns. In memory, whether it is a 1-D or a 2-D array, the array elements are stored in one continuous chain. So the actual arrangement of array elements of the 2-D array in memory is as shown in Figure 14.2 . For want of space I have changed the array name to s .

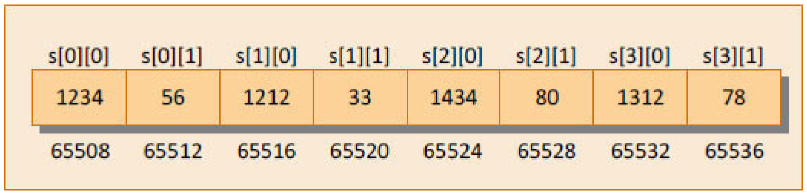


Figure 14.2

We can easily refer to the marks obtained by the third student using the subscript notation as shown below.

```
printf ("Marks of third student = %d", s[2][1]);
```

Can we not refer to the same element using pointer notation, the way we did in 1-D arrays? Answer is yes. Only the procedure is slightly difficult to understand. So, read on…

Pointers and 2-D Arrays

C language embodies an unusual but powerful capability—it can treat parts of arrays as arrays. More specifically, each row of a 2-D array can be thought of as a 1-D array.

Thus, the declaration,

```
int s[5][2];
```

can be thought of as setting up an array of 5 elements, each of which is a 1-D array containing 2 integers. We refer to an element of a 1-D array using one subscript. Similarly, if we can imagine s to be a 1-D array, then we can refer to its zeroth element as s[0] , the next element as s[1] and so on. More specifically, s[0] gives the address of the zeroth 1-D array, s[1] gives the address of the first 1-D array and so on. This fact can be demonstrated by the following program:

```
/* Demo: 2-D array is an array of arrays */
```

include

```
int main()

{

int s[4][2] = {

{1234, 56}, {1212, 33}, {1434, 80}, {1312, 78}

};

int i;

for (i = 0; i <= 3; i++)

printf ("Address of %d th 1-D array = %u\n", i, s[i]);

return 0;

}
```

And here is the output…

Address of 0 th 1-D array = 65508

Address of 1 th 1-D array = 65516

Address of 2 th 1-D array = 65524

Address of 3 th 1-D array = 65532

This output is consistent with the addresses shown in Figure 14.2 . Each 1-D array starts 8 bytes further along than the last one. Thus s[0] and s[1] would yield the addresses 65508 and 65516.

Suppose we want to refer to the element s[2][1] using pointers. We know that s[2] would give the address 65524, the address of the second 1-D array. So (s[2] + 1) or (65524 + 1) would give the address 65528. The value at this address can be obtained through _(s[2] + 1) . We have already studied while learning 1-D arrays that num[i] is same as *(num + i) . Similarly, *(s[2] + 1) is same as, *(_(s + 2) + 1) . Thus, all the following expressions refer to the same element:

s[2][1]

- (s[2] + 1)
- (* (s + 2) + 1)

Using these concepts, the following program prints out each element of a 2-D array using pointer notation:

/* Pointer notation to access 2-D array elements */

include

int main()

{

int s[4][2] = {

{1234, 56}, {1212, 33}, {1434, 80}, {1312, 78}

};

int i, j;

for (i = 0; i <= 3; i++)

{

for (j = 0; j <= 1; j++)

printf (“%d ”, ((s + i) + j));

printf (“\n”);

}

return 0;

}

And here is the output…

1234 56

1212 33

1434 80

1312 78

Pointer to an Array

If we can have a pointer to an integer, a pointer to a float, a pointer to a char, then can we not have a pointer to an array? We certainly can. The following program shows how to build and use it:

```
/* Usage of pointer to an array */
```

include

```
int main()
{
int s[4][2] = {
{1234, 56}, {1212, 33}, {1434, 80}, {1312, 78}
};
int (*p)[2];
int i, j, *pint;
for (i = 0; i <= 3; i++)
{
p = &s[i];
pint = (int *) p;
printf (“\n”);
for (j = 0; j <= 1; j++)
printf (“%d ”, *(pint + j));
}
return 0;
}
```

And here is the output…

```
1234 56
1212 33
1434 80
1312 78
```

Here p is a pointer to an array of two integers. Note that the parentheses in the declaration of p are necessary. Absence of them would make p an array of 2 integer pointers. Array of pointers is covered in a later section in this chapter.

In the outer for loop, each time we store the address of a new 1-D array. Thus, first time through this loop, p would contain the address of the zeroth 1-D array. This address is then assigned to an integer pointer pint . Lastly, in the inner for loop using the pointer pint , we have printed the individual elements of the 1-D array to which p is pointing.

But why should we use a pointer to an array to print elements of a 2-D array. Is there any situation where we can appreciate its usage better? The entity pointer to an array is immensely useful when we need to pass a 2-D array to a function. This is discussed in the next section.

Passing 2-D Array to a Function

The following program shows how we can pass a 2-D array to a function.

/* Passing 2-D array to a function */

include

```
void display (int q[][4], int, int);

int main()

{

int a[3][4] = {

1, 2, 3, 4,

5, 6, 7, 8,

9, 0, 1, 6

};

display (a, 3, 4);

return 0;

}

void display (int q[][4], int row, int col)

{

int i, j;

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

{

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

printf (“%d ”, q[i][j]);

printf (“\n”);

}

printf (“\n”);

}
```

And here is the output…

```
1 2 3 4

5 6 7 8

9 0 1 6
```

In the display() function, we have collected the base address of the 2-D array being passed to it in q , where q is pointer to an array of 4 integers. The declaration of q looks like this:

int q[][4];

This is same as saying int (*q)[4] . The only advantage in using the form q[][4] is that, we can now use the more familiar expression q[i][j] to access array elements.

Array of Pointers

The way there can be an array of int s or an array of float s, similarly, there can be an array of pointers. An array of pointers would be a collection of addresses. The addresses present in it can be addresses of isolated variables or addresses of array elements or any other addresses. All rules that apply to an ordinary array apply to the array of pointers as well. I think a program would clarify the concept.

include

```
int main()

{

int arr[4]; / array of integer pointers */

int i = 31, j = 5, k = 19, l = 71, m;

arr[0] = &i;

arr[1] = &j;

arr[2] = &k;

arr[3] = &l;

for (m = 0; m <= 3; m++)

printf (“%d\n”, * (arr[m]));

return 0;

}
```

Figure 14.3 shows the contents and the arrangement of the array of pointers in memory. As you can observe, arr contains addresses of isolated int variables i , j , k and l . The for loop in the program picks up the addresses present in arr and prints the values present at these addresses.

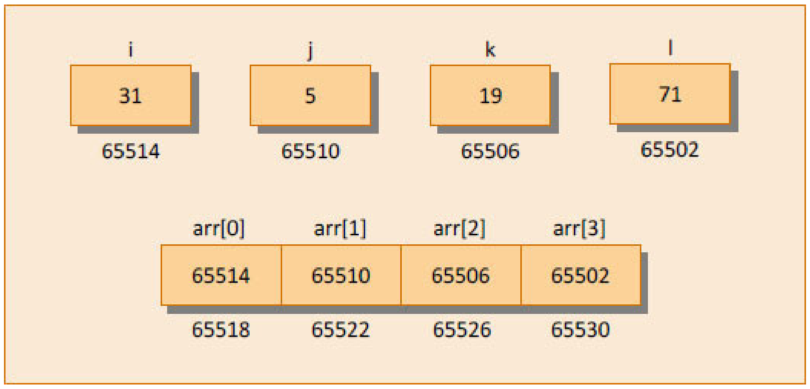


Figure 14.3

An array of pointers can even contain the addresses of other arrays' elements. The following program would justify this:

include

```
int main()

{

static int a[] = {0, 1, 2, 3, 4};

int *p[] = {a, a + 1, a + 2, a + 3, a + 4};

printf (“%u %u %d\n”, p, p, * (p));

return 0;

}
```

I would leave it for you to figure out the output of this program.

3-D Array

I am not going to show a programming example that uses a 3-D array. However, an example of initializing a 3-D array will consolidate your understanding of arrays.

```
int arr[ 3 ][ 4 ][ 2 ] = {
                            {
                                { 2, 4 }, { 7, 8 }, { 3, 4 }, { 5, 6 }
                            },
                            {
                                { 7, 6 }, { 3, 4 }, { 5, 3 }, { 2, 3 }
                            },
                            {
                                { 8, 9 }, { 7, 2 }, { 3, 4 }, { 5, 1 }
                            }
                        };
```

A 3-D array can be thought of as an array of arrays of arrays. The outer array has three elements, each of which is a 2-D array of four 1-D arrays, each of which contains two integers. Figure 14.4 would possibly help you in visualizing the situation better.

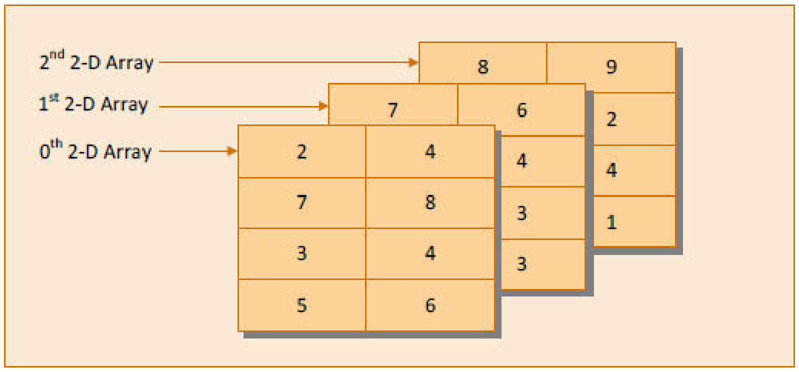


Figure 14.4

Again remember that the arrangement shown in Figure 14.4 is only conceptually true. In memory, the array elements are stored linearly as shown in Figure 14.5 .

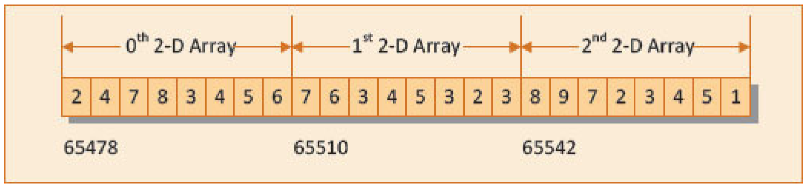


Figure 14.5

How would you refer to the array element 1 in the above array? The first subscript should be [2], since the element is in third 2-D array; the second subscript should be [3] since the element is in fourth row of the 2-D array; and the third subscript should be [1] since the element is in second position in the 1-D array. So element 1 can be referred as arr[2][3][1] .

It may be noted here that the counting of array elements even for a 3-D array begins with zero. We can also refer to this element using pointer notation as shown below.

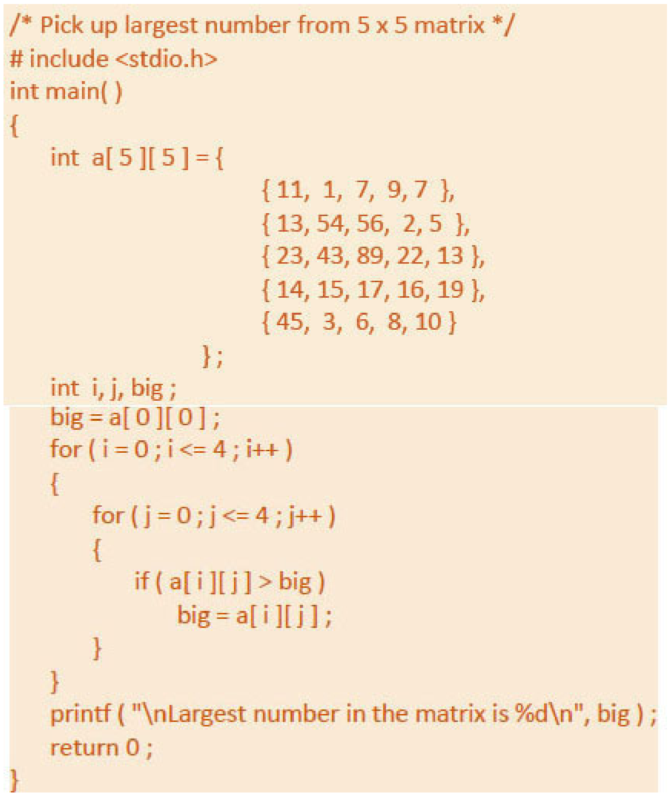
((*(arr + 2) + 3) + 1)

P</> Programs

Problem 14.1

Write a program to pick up the largest number from a 5 row by 5 column matrix.

Program



```
/* Pick up largest number from 5 x 5 matrix */
# include <stdio.h>
int main( )
{
    int  a[ 5 ][ 5 ] = {
                        { 11,  1,  7,  9, 7  },
                        { 13, 54, 56,  2, 5  },
                        { 23, 43, 89, 22, 13 },
                        { 14, 15, 17, 16, 19 },
                        { 45,  3,  6,  8, 10 }
                   } ;
    int  i, j, big ;
    big = a[ 0 ][ 0 ] ;
    for ( i = 0 ; i <= 4 ; i++ )
    {
        for ( j = 0 ; j <= 4 ; j++ )
        {
            if ( a[ i ][ j ] > big )
                big = a[ i ][ j ] ;
        }
    }
    printf ( "\nLargest number in the matrix is %d\n", big ) ;
    return 0 ;
}
```

Output

```
Largest number in the matrix is 89
```

Problem 14.2

Write a program to obtain transpose of a 4 x 4 matrix. The transpose of a matrix is obtained by exchanging the elements of each row with the elements of the corresponding column

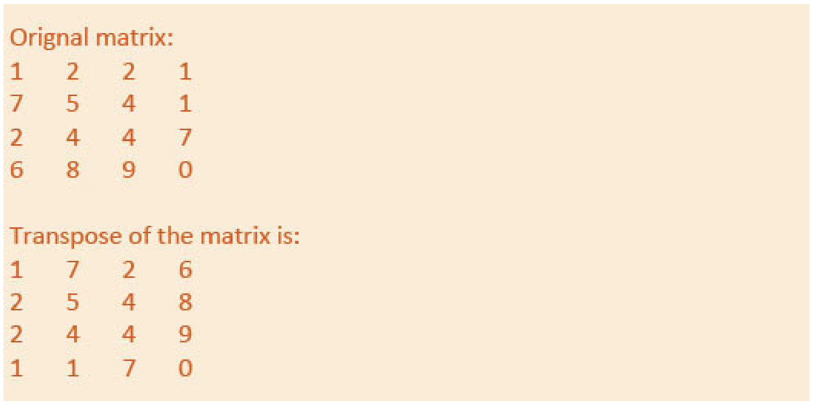
Program

/* Program to copy one array into another in reverse order */

include

```
int main()

{

int arr1[5], arr2[5], i, j;

printf (“\nEnter 5 elements of array:\n”);

for (i = 0; i <= 4; i++)

scanf (“%d”, &arr1[i]);

for (i = 0, j = 4; i <= 4; i++, j--)

arr2[j] = arr1[i];

printf (“Elements in reverse order:\n”);

for (i = 0; i <= 4; i++)

printf (“%d\t”, arr2[i]);
return 0;

}
```

Output



```
Orignal matrix:
1     2     2     1
7     5     4     1
2     4     4     7
6     8     9     0

Transpose of the matrix is:
1     7     2     6
2     5     4     8
2     4     4     9
1     1     7     0
```

Exercises

[A] What will be the output of the following programs:

```
(a) # include

int main()

{

int n[3][3] = {

{2, 4, 3}, {6, 8, 5}, {3, 5, 1}

};

printf ("%d %d %d\n", *n, n[1][1], n[2][2]);

return 0;

}
```

```
(b) # include

int main()

{

int n[3][3] = {

{2, 4, 3}, {6, 8, 5}, {3, 5, 1}

};

int i, *ptr;

ptr = &n[0][0];

for (i = 0; i <= 8; i++)

printf ("%d\n", *(ptr + i));

return 0;

}
```

(c) # include

```
int main()
{
int n[3][3] = {
2, 4, 3, 6, 8, 5, 3, 5, 1
};
int i, j;
for (i = 0; i <= 2; i++)
for (j = 0; j <= 2; j++)
printf (“%d %d\n”, n[i][j], ((n + i) + j));
return 0;
}
```

[B] Point out the errors, if any, in the following programs:

(a) # include

```
int main()
{
int twod[][] = {
2, 4, 6, 8
};
printf (“%d\n”, twod);
return 0;
}
```

(b) # include

```
int main()
{
int three[3][] = {
{2, 4, 3}, {6, 8, 2}, {2, 3, 1}
};
printf (“%d\n”, three[1][1]);
return 0;
}
```

[C] Attempt the following questions:

(a) How will you initialize a three-dimensional array threed[3][2][3] ? How will you refer the first and last element in this array?

(b) Match the following with reference to the program segment given below:

```
int i, j, = 25;
```

int *pi, *pj = & j;

/* more lines of program */

*pj = j + 5;

j = *pj + 5;

pj = pj;

*pi = i + j;

Each integer quantity occupies 2 bytes of memory. The value assigned to i begin at (hexadecimal) address F9C and the value assigned to j begins at address F9E. Match the value represented by left hand side quantities with the right.

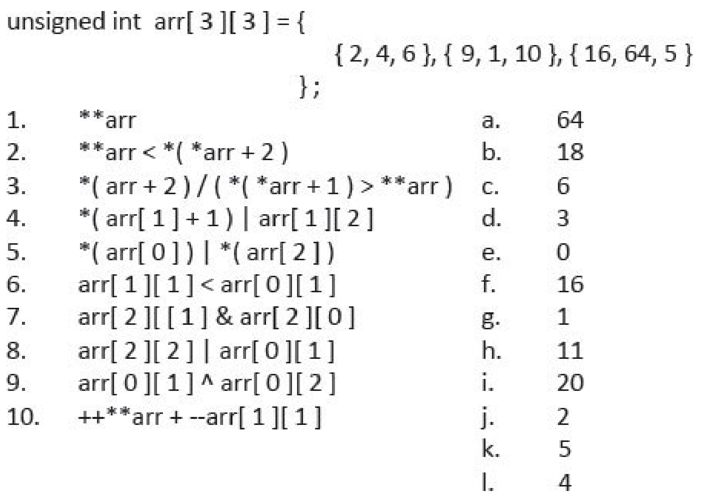
1.	&i	a.	30
2.	&j	b.	F9E
3.	pj	c.	35
4.	*pj	d.	FA2
5.	i	e.	F9C
6.	pi	f.	67
7.	*pi	g.	unspecified
8.	(pi + 2)	h.	65
9.	(*pi + 2)	i.	F9E
10.	* (pi + 2)	j.	F9E
		k.	FAO
		l.	F9D

(c) Match the following with reference to the following program segment:

```
int  x[ 3 ][ 5 ] = {
                   { 1, 2, 3, 4, 5 },
                   { 6, 7, 8, 9, 10 },
                   { 11, 12, 13, 14, 15 }
                }, *n = &x ;
```

1.	*(*(x + 2) + 1)	a.	9
2.	*(*x + 2) + 5	b.	13
3.	*(*(x + 1))	c.	4
4.	*(*(x) + 2) + 1	d.	3
5.	* (*(x + 1) + 3)	e.	2
6.	*n	f.	12
7.	*(n +2)	g.	14
8.	(*(n + 3) + 1	h.	7
9.	*(n + 5)+1	i.	1
10.	++*n	j.	8
		k.	5
		l.	10
		m.	6

(d) Match the following with reference to the following program segment:



```
unsigned int  arr[ 3 ][ 3 ] = {
                              { 2, 4, 6 }, { 9, 1, 10 }, { 16, 64, 5 }
                         } ;
```

1.	**arr	a.	64
2.	**arr < *(*arr + 2)	b.	18
3.	*(arr + 2) / (*(*arr + 1) > **arr)	c.	6
4.	*(arr[1] + 1) | arr[1][2]	d.	3
5.	*(arr[0]) | *(arr[2])	e.	0
6.	arr[1][1] < arr[0][1]	f.	16
7.	arr[2][[1] & arr[2][0]	g.	1
8.	arr[2][2] | arr[0][1]	h.	11
9.	arr[0][1] ^ arr[0][2]	i.	20
10.	++**arr + --arr[1][1]	j.	2
		k.	5
		l.	4

(e) Write a program to find if a square matrix is symmetric.

(f) Write a program to add two 6 x 6 matrices.

(g) Write a program to multiply any two 3 x 3 matrices.

(h) Given an array p[5] , write a function to shift it circularly left by two positions. Thus, if the original array is {15, 30, 28, 19, 61} then after shifting it will be {28, 19, 61, 15, 30} Call this function for a 4 x 5 matrix and get its rows left shifted.

2-D array is a collection of several 1-D arrays

If 2-D arrays is initialized at the same place where it is declared, then mentioning the column dimension is optional

A 2-D array is laid out linearly in memory in row-major fashion i.e. row after row

Given a 2-D array int a[4][5];

a[2][3] == * a[2] + 3 == * (* (a + 2) + 3)

int *p[4]; - p is an array of 4 integer pointers. Size of p = 16 bytes

int (*p)[4]; - p is a pointer to an array of 4 integers. Size of p = 4 bytes

Typical applications of 2-D arrays:

All matrix and determinant operations

Applications of 2-D arrays in games:

Chess, Ludo, Snakes and Ladders, Brainvita, Any other board game

3-D array is a collection of several 2-D arrays

Size of a 3-D array is sum of sizes of all its elements

Following expressions are referring to the element in the 1 st row, 3 rd column of the 2 nd 2-D array:

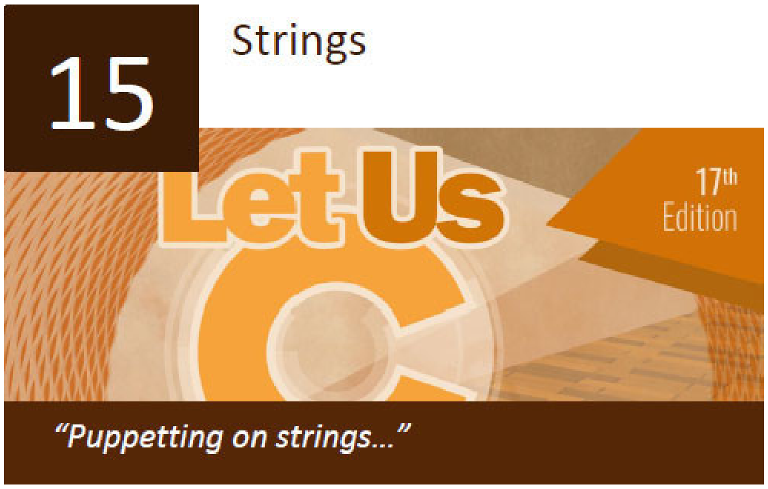
a[2][1][3]

- (a[2][1] + 3)
- (* (a[2] + 1) + 3)
- (* (* (a + 2) + 1) + 3)

For a 3-D array:

a, *a*, *a, will give address

*a will give the integer at a[0][0][0]



The way an integer array is a collection of several integers, a character array is a collection of several characters. Well, almost. The 0 that is present at the end of a character array makes it different. What is the importance of this 0, why it matters and what convenience it provides? Well, this chapter has all these answers and more…

Contents

In the last chapter, we learnt how to define arrays of various sizes and dimensions, how to initialize them, how to pass them to a function, etc. With this knowledge under our belt, we are ready to handle strings, which are, simply put, a special kind of array.

What are Strings?

The way a group of integers can be stored in an integer array, similarly a group of characters can be stored in a character array. A string is a 1-D array of characters terminated by a null ('\0'). For example,

char name[] = {'H', 'A', 'E', 'S', 'L', 'E', 'R', '\0'};

'\0' is called null character. Note that '\0' and '0' are not same. ASCII value of '\0' is 0, whereas ASCII value of '0' is 48. Figure 15.1 shows the way a string is stored in memory. Note that the elements of the string are stored in contiguous memory locations.

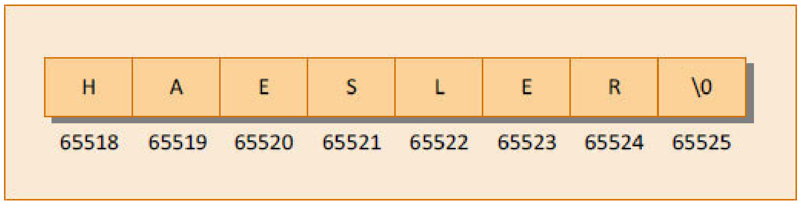


Figure 15.1

The terminating null (‘\0’) is important, because it is the only way the functions that work with a string can know where the string ends. In fact, a string not terminated by a ‘\0’ is not really a string, but merely a collection of characters.

C concedes the fact that you would use strings very often and hence provides a shortcut for initializing strings. For example, the string used above can also be initialized as,

char name[] = “HAESLER”;

Note that, in this declaration ‘\0’ is not necessary. C inserts the null character automatically.

More about Strings

We can use the ’\0’ present at the end of a string to our advantage while accessing its elements as shown below:

/* Program to demonstrate printing of a string */

include

int main()

{

char name[] = “Klinsman”;

i = 0;

while (name[i] != ’\0’)

{

printf (“%c”, name[i]);

i++;

}

printf (“\n”);

return 0;

}

And here is the output…

No big deal. We have initialized a string and then printed its elements in a while loop. But instead of changing i from 0 to 7 in the while loop, we printed characters in the string till we did not encounter ’\0’.

Here is another version of the same program; this one uses a pointer to access the array elements.

include

int main()

{

char name[] = “Klinsman”;

```
char *ptr;
ptr = name; /* store base address of string */
while (*ptr != ’\0’)
{
printf (“%c”, *ptr);
ptr++;
}
printf (“\n”);
return 0;
}
```

As with the integer array, by mentioning the name of the array, we get the base address (address of the zeroth element) of the array. This base address is stored in the variable ptr . Once the base address is obtained in ptr , *ptr would yield the value at this address, which gets printed promptly through,

```
printf (“%c”, *ptr);
```

Then, ptr is incremented to point to the next character in the string. This derives from two facts: array elements are stored in contiguous memory locations and on incrementing a pointer, it points to the immediately next location of its type. This process is carried out until ptr points to the last character in the string, that is, ‘\0’.

In fact, the character array elements can be accessed exactly in the same way as the elements of an integer array. Thus, all the following notations refer to the same element:

```
name[i]
*(name + i)
*(i + name)
i[name]
```

Even though there are so many ways (as shown above) to refer to the elements of a character array, rarely is any one of them used. This is because printf() function has got a sweet and simple way of doing it, as shown below. Note that printf() doesn't print the ‘\0’.

```
char name[] = “Klinsman”;
printf (“%s”, name);
```

The %s used in printf() is a format specification for printing out a string. The same specification can be used to receive a string from the keyboard, as shown below.

```
char name[25];
printf (“Enter your name ”);
scanf (“%s”, name);
```

While entering the string using scanf() , we must be cautious about two things:

(a) The length of the string should not exceed the dimension of the character array. This is because the C compiler doesn't perform bounds checking on arrays. Hence, if you carelessly exceed the bounds, there is a danger of overwriting something important.

(b) scanf() is not capable of receiving multi-word strings. Therefore, names such as ‘Debashish Roy’ would be unacceptable. The way to get around this limitation is by using the function gets() . The usage of functions gets() and its counterpart puts() is shown below.

include

```
int main()

{

char name[25];

printf (“Enter your full name: ”);

gets (name);

puts (“Hello!”);

puts (name);

return 0;

}
```

And here is the output…

```
Enter your full name: Debashish Roy

Hello!

Debashish Roy
```

The program and the output are self-explanatory except for the fact that, puts() can display only one string at a time (hence the use of two puts() in the program above). Also, on displaying a string, unlike printf() , puts() places the cursor on the next line. Though gets() is capable of receiving only one string at a time, the plus point with gets() is that it can receive a multi-word string.

If we are prepared to take the trouble, we can make scanf() accept multi-word strings by writing it in this manner:

```
char name[25];

printf (“Enter your full name ”);

scanf (“%[^\n]s”, name);
```

Here, [^\n] indicates that scanf() will keep receiving characters into name[] until \n is encountered. Though workable, this is not the best of the ways to call a function, you would agree.

Pointers and Strings

Suppose we wish to store “Hello”. We may either store it in a string or we may ask the C compiler to store it at some location in memory and assign the address of the string in a char pointer. This is shown below.

```
char str1[] = “Hello”, str2[20] = ”Hi”;

char *p = “Hello”, *s = “Hi”;
```

There is a subtle difference in usage of these two forms.

Here str1 acts as a constant pointer to a string, whereas, p acts as a pointer to a constant string. As a result, observe which operations are permitted on them, and which are not:

```
str1 = “Adieu”; /* error, constant pointer cannot change */

str1 = str2; /* error, constant pointer cannot change */

str1++; /* error, constant pointer cannot change */

str1 = ‘Z’; / works, because string is not constant */

p = “Adieu”; /* works, because pointer is not constant */
```

p = s; /* works, because pointer is not constant */

p++; /* works, because pointer is not constant */

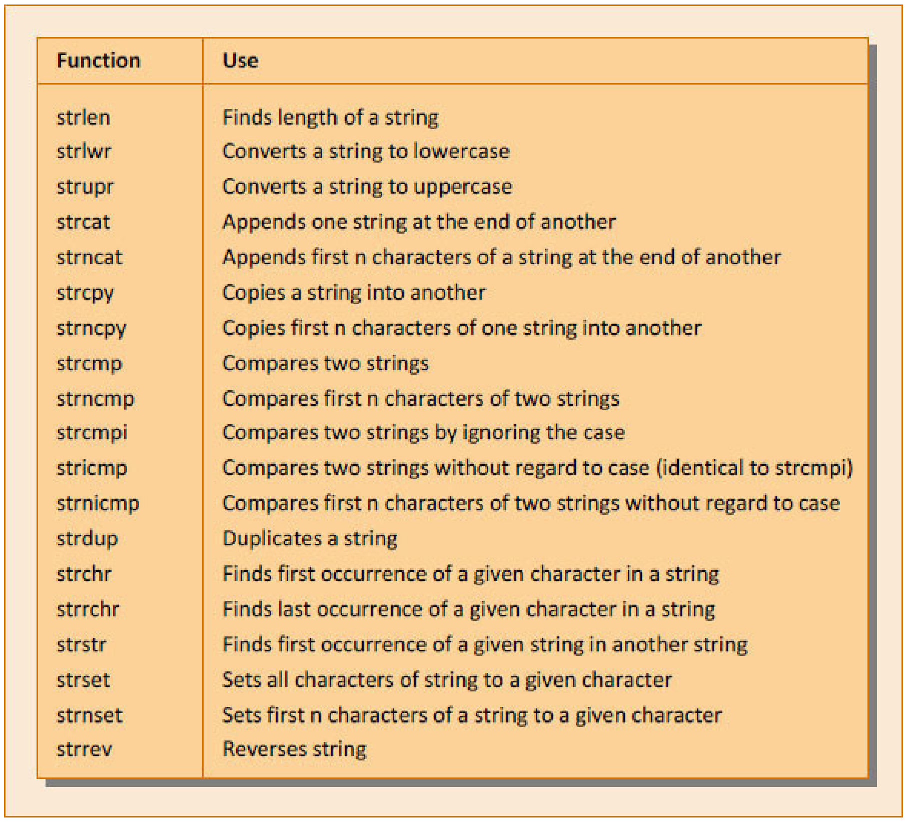
*p = ‘M’; / error, because string is constant */*

The keyword const can also be used in context of ordinary variables of type int , float , etc. as shown below:

const float pi = 3.14;

Standard Library String Functions

With every C compiler, a large set of useful string handling library functions are provided. Figure 15.2 lists the more commonly used functions along with their purpose.



Function	Use
strlen	Finds length of a string
strlwr	Converts a string to lowercase
strupr	Converts a string to uppercase
strcat	Appends one string at the end of another
strncat	Appends first n characters of a string at the end of another
strcpy	Copies a string into another
strncpy	Copies first n characters of one string into another
strcmp	Compares two strings
strncmp	Compares first n characters of two strings
strcmpi	Compares two strings by ignoring the case
stricmp	Compares two strings without regard to case (identical to strcmpi)
strnicmp	Compares first n characters of two strings without regard to case
strdup	Duplicates a string
strchr	Finds first occurrence of a given character in a string
strrchr	Finds last occurrence of a given character in a string
strstr	Finds first occurrence of a given string in another string
strset	Sets all characters of string to a given character
strnset	Sets first n characters of a string to a given character
strrev	Reverses string

Figure 15.2

From the list given in Figure 15.2 , we shall discuss functions strlen() , strcpy() , strcat() and strcmp() , since these are very commonly used. This will also illustrate how the library functions in general handle strings. Let us study these functions one-by-one.

strlen()

This function counts the number of characters present in a string. Its usage is illustrated in the following program:

include

include

int main()

{

char arr[] = “Bamboozled”;

int len1, len2;

```
len1 = strlen (arr);

len2 = strlen (“Humpty Dumpty”);

printf (“string = %s length = %d\n”, arr, len1);

printf (“string = %s length = %d\n”, “Humpty Dumpty”, len2);

return 0;

}
```

The output would be…

```
string = Bamboozled length = 10

string = Humpty Dumpty length = 13
```

Note that, while calling the function strlen() , we are passing the base address of the string. This function returns the length of the string. While calculating the length, it doesn't count ‘\0’.

Can we not write a function xstrlen() , which imitates the standard library function strlen() ? Let us give it a try…

```
/* A look-alike of the function strlen() */
```

include

```
int xstrlen (char *);

int main()

{

char arr[] = “Bamboozled”;

int len1, len2;

len1 = xstrlen (arr);

len2 = xstrlen (“Humpty Dumpty”);

printf (“string = %s length = %d\n”, arr, len1);

printf (“string = %s length = %d\n”, “Humpty Dumpty”, len2);

return 0;

}

int xstrlen (char *s)

{

int length = 0;

while (*s != ’\0’)

{

length++;

s++;

}

return (length);
}
```

The output would be…

```
string = Bamboozled length = 10

string = Humpty Dumpty length = 13
```

The function xstrlen() is fairly simple. All that it does is, it keeps counting the characters till it reaches the end of the string, i.e. up to ‘\0’.

strcpy()

This function copies the contents of one string into another. The base addresses of the target and source strings should be supplied to this function. Here is an example of strcpy() in action…

include

include

```
int main()

{

char source[] = “Sayonara”, target[20];

strcpy (target, source);

printf (“source string = %s\n”, source);

printf (“target string = %s\n”, target);

return 0;

}
```

And here is the output…

```
source string = Sayonara

target string = Sayonara
```

On supplying the base addresses, strcpy() goes on copying the characters in source string into the target string till it encounters the end of source string (‘\0’). It is our responsibility to see to it that the target string's dimension is big enough to hold the string being copied into it. Thus, a string gets copied into another, piece-meal, character-by-character. There is no short-cut for this. Let us now attempt to mimic strcpy() , via our own string copy function, which we will call xstrcpy() .

include

```
void xstrcpy (char *, char *);

int main()

{

char source[] = “Sayonara”, target[20];

xstrcpy (target, source);

printf (“source string = %s\n”, source);

printf (“target string = %s\n”, target);

return 0;
}

void xstrcpy (char *t, char *s)

{

while (*s != ’\0’)

{

*t = *s; s++; t++;

}

*t = ’\0’;

}
```

The output of the program would be…

```
source string = Sayonara

target string = Sayonara
```

Note that having copied the entire source string into the target string, it is necessary to place a ‘\0’ into the target string, to mark its end.

If you look at the prototype of strcpy() standard library function, it looks like this…

```
strcpy (char *t, const char *s);
```

We didn't use the keyword const in our version of xstrcpy() and still our function worked correctly. So what is the need of the const qualifier?

What would happen if we add the following line before the while loop in xstrcpy()?

```
*s = ’K’;
```

This would change the source string to “Kayonara”. We can ensure that the source string doesn't change even accidentally in xstrcpy() by changing the definition as follows:

```
void xstrcpy (char *t, const char *s)

{

/* copying code */

}
```

By declaring char *s as const , we are declaring that the source string should remain constant (should not change). It also reminds anybody reading the program listing that the variable is not intended to change.

strcat()

This function concatenates the source string at the end of the target string. For example, “Bombay” and “Nagpur” on concatenation would result into a string “BombayNagpur”. Here is an example of strcat() at work.

include

include

```
int main()

{

char source[] = “Folks!”, target[30] = “Hello”;
strcat (target, source);

printf (“source string = %s\n”, source);

printf (“target string = %s\n”, target);

return 0;

}
```

And here is the output…

```
source string = Folks!

target string = HelloFolks!
```

Note that the target string has been made big enough to hold the final string. I leave it to you to develop your own xstrcat() on lines of xstrlen() and xstrcpy() .

strcmp()

This function compares two strings to find out whether they are same or different. The two strings are compared character-by-character until there is a mismatch or we reach end of both strings, whichever occurs first. If the two strings are identical, strcmp() returns a value zero. If they're not, it returns the numeric difference between the ASCII values of the first non-matching pair of characters. Here is a program which puts strcmp() in action.

include

include

```
int main()

{

char string1[] = “Jerry”, string2[] = “Ferry”;

int i, j, k;

i = strcmp (string1, “Jerry”);

j = strcmp (string1, string2);

k = strcmp (string1, “Jerry boy”);

printf (“%d %d %d\n”, i, j, k);

return 0;

}
```

And here is the output…

```
0 4 -32
```

In the first call to strcmp() , the two strings are identical—“Jerry” and “Jerry”—and the value returned by strcmp() is zero. In the second call, the first character of “Jerry” doesn’t match with the first character of “Ferry” and the result is 4, which is the numeric difference between ASCII value of ‘J’ and ASCII value of ‘F’. In the third call to strcmp() , “Jerry” doesn't match with “Jerry boy”, because the null character at the end of “Jerry” doesn't match the blank in “Jerry boy”. The value returned is -32, which is the value of null character minus the ASCII value of space, i.e., ‘\0’ minus ‘ ‘, which is equal to -32.

The exact value of mismatch rarely concerns us. All that we usually want to know is whether or not the first string is alphabetically before the second string. If it is, a negative value is returned; if it isn't, a positive value is returned. Try to implement this logic in a user-defined function xstrcmp() .

Problem 15.1

Write a program that extracts part of the given string from the specified position. For example, if the sting is “Working with strings is fun”, then if from position 3, 4 characters are to be extracted then the program should return string as “king”.

Program

/* To extract a substring from a string */

include

include

include

int main()

{

char str[20], news[20];

char *s, *t;

int pos, n, i;

printf (“\nEnter a string: “);

scanf (“%s”, str);

printf (“Enter position and no. of characters to extract: ”);

scanf (“%d %d”, &pos, &n);

s = str;

t = news;

if (pos < 0 || pos > strlen (str))

{

printf (“Improper position value”);

exit (1);

}

if (n < 0)

n = 0;

if (n > strlen (str))

n = n - strlen (str) - 1;

s = s + pos;

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

{

```
*t = *s;
s++;
t++;
}
*t = '\0';
printf ("The substring is: %s\n", news);
return 0;
}
```

Output

```
Enter a string: Nagpur
Enter position and no. of characters to extract: 3 10
The substring is: pur
```

Problem 15.2

Write a program that converts a string like "124" to an integer 124.

Program

```
/* To convert a string to an integer */
```

include

```
int main()
{
char str[6];
int num = 0, i;
printf ("Enter a string containing a number: ");
scanf ("%s", str);
for (i = 0; str [i] != '\0'; i++)
{
if (str[i] >= 48 && str[i] <= 57)
num = num * 10 + (str[i] - 48);
else
{
printf ("Not a valid string\n");
return 1;
}
}
printf ("The number is: %d\n", num);
return 0;

}
```

Output

```
Enter a string containing a number: 237

The number is: 237
```

Problem 15.3

Write a program that generates and prints the Fibonacci words of order 0 through 5. If f(0) = “a”, f(1) = “b”, f(2) = “ba”, f(3) = “bab”, f(4) = “babba”, etc.

Program

```
/* Generate Fibonacci words of order 0 through 5 */

include

include

int main()

{

char str[50];

char lastbutoneterm[50] = “A”;

char lastterm[50] = “B”;

int i;

for (i = 1; i <= 5; i++)

{

strcpy (str, lastterm);

strcat (str, lastbutoneterm);

printf (“%s\n”, str);

strcpy (lastbutoneterm, lastterm);

strcpy (lastterm, str);

}

return 0;

}
```

Output

```
BA

BAB

BABBA

BABBABAB

BABBABABBABBA
```

Exercises

[A] What will be the output of the following programs:

(a)
```
# include
int main()
{
char c[2] = “A”;
printf (“%c\n”, c[0]);
printf (“%s\n”, c);
return 0;
}
```

(b)
```
# include
int main()
{
char s[] = “Get organized! Learn C!!”;
printf (“%s\n”, &s[2]);
printf (“%s\n”, s);
printf (“%s\n”, &s);
printf (“%c\n”, s[2]);
return 0;
}
```

(c)
```
# include
int main()
{
char s[] = “No two viruses work similarly”;
int i = 0;
while (s[i] != 0)
{
printf (“%c %c\n”, s[i], *(s + i));
printf (“%c %c\n”, i[s], *(i + s));
i++;
}
return 0;
}
```

(d)
```
# include
```

```
int main()

{

char str1[] = {‘H’, ‘e’, ‘l’, ‘l’, ‘o’, 0};

char str2[] = “Hello”;

printf (“%s\n”, str1);

printf (“%s\n”, str2);

return 0;

}
```

```
(e) # include

int main()

{

printf (5 + “Good Morning ”);

printf (“%c\n”, “abcdefgh”[4]);

return 0;

}
```

```
(f) # include

int main()

{

printf (“%d %d %d\n”, sizeof (‘3’), sizeof (“3”), sizeof (3));

return 0;

}
```

[B] Fill in the blanks:

(a) “A” is a***whereas ‘A’ is a***.

(b) A string is terminated by a_character.

(c) The array char name[10] can consist of a maximum of _ characters.

(d) The array elements are always stored in_memory locations.

[C] Attempt the following questions:

(a) If the string “Alice in wonder land” is fed to the following scanf() statement, what will be the contents of the arrays str1 , str2 , str3 and str4 ?

```
scanf (“%s%s%s%s”, str1, str2, str3, str4);
```

(b) To uniquely identify a book a 10-digit ISBN (International Standard Book Number) is used. The rightmost digit is a checksum digit. This digit is determined from the other 9 digits using the condition that d1 + 2d2 + 3d3 + … + 10d10 must be a multiple of 11 (where di denotes the i th digit from the right). The checksum digit d1 can be any value from 0 to 10: the ISBN convention is to use the value X to denote 10. Write a program that receives a 10-digit integer, computes the checksum, and reports whether the ISBN number is correct or not.

(c) A Credit Card number is usually a 16-digit number. A valid Credit Card number would satisfy a rule explained below with the help of a dummy Credit Card number—4567 1234 5678 9129. Start with the rightmost - 1 digit and multiply every other digit by 2.

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

8 12 2 6 10 14 18 4

Then subtract 9 from any number larger than 10. Thus we get:

8 3 2 6 1 5 9 4

Add them all up to get 38.

Add all the other digits (5, 7, 2, 4, 6, 8, 1, 9) to get 42.

Sum of 38 and 42 is 80. Since 80 is divisible by 10, the Credit Card number is valid.

Write a program that receives a Credit Card number and checks using the above rule whether the Credit Card number is valid.

Strings are character arrays ending with ‘\0’. ‘\0’ is called String Terminator

Other arrays do not end with ‘\0’

ASCII Values: ‘0’ = 48 ‘\0’ = 0

Ways to output strings:

```
char name[] = “Sanjay”;

printf (“%s\n”, name);

puts (name);
```

Ways to input strings:

```
char name[30];

scanf (“%s”, name);

gets (name);
```

To receive multiword strings:

```
scanf (“%[^\n]s”, name); /* ^ means from beginning, \n means up to end */

gets (name);
```

Prefer scanf() for receiving name of city, gets() for receiving name and surname

3 = integer 3.0 = double

‘3’ = character “3” = string ending with ‘\0’

Standard way of processing a string:

```
char str[] = “Blah blah blah”; char *p;

p = str;

while (*p != ‘\0’)

{

   /* process current character given by *p */

   p++;

}
```

printf (“Hello”); - passes base address of string to printf()

Useful string functions:

int l = strlen (str); /* returns length of string str */

strcpy (target, source); /*copies source string to target string*/*

strcat (target, source); /* appends source at the end of target*/

int l = strcmp (str1, str2); /* returns 0 if strings are equal, nonzero if they are unequal */

strupr (str); /* converts string str to uppercase */

strlwr (str); /* converts string str to lowercase */

toupper (ch); /* converts character ch to uppercase */

tolower (ch); /* converts character ch to lowercase */

include for prototypes of library string functions

char p[] = “Nagpur”;

p is a constant pointer to string

p cannot be changed

Nagpur can be changed

char *p = “Nagpur”;

p is a pointer to a constant string

p can be changed

Nagpur cannot be changed

Instead of creating several arrays of integers, create a 2D array of integers. Instead of creating several arrays of characters, create a 2D array of characters. Well, don’t. Why? Read on, this chapter provides the answer…

Contents

Programs

Exercises

KanNotes

In the last chapter, we learnt how to deal with individual strings. But often we are required to deal with a set of strings rather an isolated string. This chapter discusses how such situations can be handled effectively.

2-D Array of Characters

In Chapter 14 we saw several examples of 2-D integer arrays. Let's now look at a similar entity, but one dealing with characters. Our example program asks you to type your name. When you do so, it checks your name against a master list to see if you are worthy of entry to the palace. Here's the program…

include

include

```
int main()

{

char masterlist[6][20] = {

“akshay”, “parag”, “raman”,

“srinivas”, “gopal”, “rajesh”

};

int i;

char yourname[20];

printf (“Enter your name ”);

scanf (“%s”, yourname);

for (i = 0; i <= 5; i++)

{

if (strcmp (&masterlist[i][0], yourname) == 0)

{

printf (“Welcome, you can enter the palace\n”);

return 0;

}

}

printf (“Sorry, you are a trespasser”);

return 0;

}
```

And here is the output for two sample runs of this program…

```
Enter your name dinesh
```

```
Sorry, you are a trespasser

Enter your name raman

Welcome, you can enter the palace
```

Notice how the two-dimensional character array has been initialized. The first subscript gives the number of names in the array, while the second subscript gives the length of each item in the array.

Instead of initializing names, had these names been supplied from the keyboard, the program segment would have looked like this…

```
for (i = 0; i <= 5; i++)

scanf (“%s”, &masterlist[i][0]);
```

While comparing the strings using strcmp() , the addresses of the strings are being passed to it. If the two strings match, strcmp() would return a value 0, otherwise it would return a non-zero value.

The names would be stored in the memory as shown in Figure 16.1 . Note that each string ends with a ‘\0’. The arrangement, as you can appreciate, is similar to that of a 2-D numeric array.

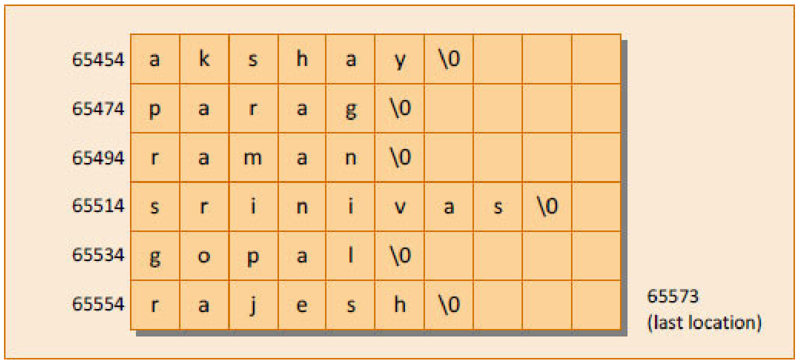


Figure 16.1

Here, 65454, 65474, etc., are the base addresses of successive names. As seen in Figure 16.1 some of the names do not occupy all the bytes reserved for them. For example, even though 20 bytes are reserved for storing the name “akshay”, it occupies only 7 bytes. Thus, 13 bytes go waste. Similarly, for each name, there is some amount of wastage. This can be avoided using an ‘array of pointers to strings’.

Array of Pointers to Strings

As we know, a pointer variable always contains an address. Therefore, if we construct an array of pointers, it would contain a number of addresses. Following code snippet shows how names can be stored using an array of pointers.

```
char *names[] = {

“akshay”, “parag”, ”raman”,

“srinivas”, “gopal”, “rajesh”

};
```

In this declaration, names[] is an array of pointers. It contains base addresses of different names. This is depicted in Figure 16.2 .

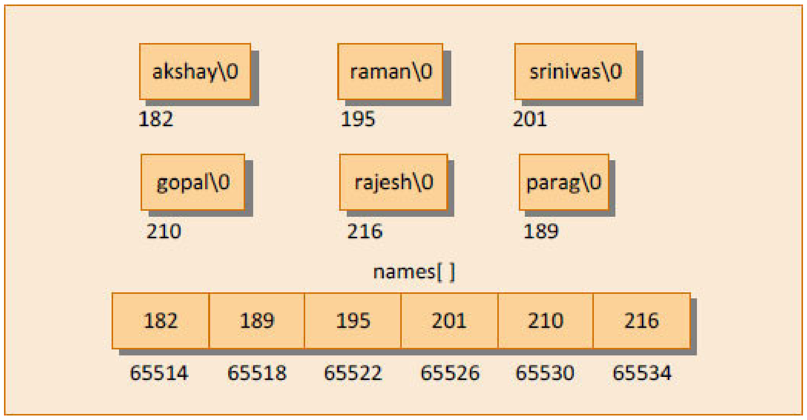


Figure 16.2

In 2-D array of characters, the strings occupied 120 bytes. As against this, in array of pointers, the strings occupy only 41 bytes and the array occupies 24 bytes—a total of 65 bytes. Thus there is a net saving of 55 bytes. A substantial saving, you would agree.

Another advantage of use of array of pointers to store strings is it permits easy manipulation of the strings. This is shown by the following programs. The first one uses a 2-D array of characters to store the names, whereas the second uses an array of pointers to strings. The purpose of both the programs is very simple. We want to exchange the position of the names “raman” and “srinivas”.

/* Exchange names using 2-D array of characters */

include

int main()

{

char names[][20] = {

“akshay”, “parag”, “raman”,

“srinivas”, “gopal”, “rajesh”

};

int i;

char t;

printf (“Original: %s %s\n”, &names[2][0], &names[3][0]);

for (i = 0; i <= 19; i++)

{

t = names[2][i];

names[2][i] = names[3][i];

names[3][i] = t;

}

printf (“New: %s %s\n”, &names[2][0], &names[3][0]);

return 0;

}

And here is the output…

```
Original: raman srinivas

New: srinivas raman
```

Note that in this program to exchange the names, we are required to exchange corresponding characters of the two names. In effect, 20 exchanges are needed to interchange two names.

Let us see, if the number of exchanges can be reduced by using an array of pointers to strings. Here is the program…

include

```
int main()

{

char *names[] = {

“akshay”, “parag”, “raman”,

“srinivas”, “gopal”, “rajesh”

};

char *temp;

printf (“Original: %s %s\n”, names[2], names[3]);

temp = names[2];

names[2] = names[3];

names[3] = temp;

printf (“New: %s %s\n”, names[2], names[3]);

return 0;

}
```

And here is the output…

```
Original: raman srinivas

New: srinivas raman
```

The output is same as the earlier program. In this program to exchange the names we have just exchanged their addresses stored in the array of pointers. Thus, by effecting just one exchange, we are able to interchange names. This makes handling strings very convenient.

Thus, from the point of view of efficient memory usage and ease of programming, an array of pointers to strings definitely scores over a 2-D character array.

Limitation of Array of Pointers to Strings

To set up strings in a 2-D array of characters, we can either initialize it while declaring it, or receive the strings using scanf() function. Unlike this, while using an array of pointers to strings we can only initialize it during declaration. Thus, the following code would never work:

```
char *names[6];

scanf (“%s”, names[0]);
```

Here while declaring the array it contains garbage addresses. And it would be incorrect to send one of these garbage address to scanf().

To overcome this difficulty we should first use scanf() to receive a name in string n[] . Then using malloc() allocate the space needed to accommodate the name and then copy the name into this space. This is shown below.

```
char *names[6], n[50];
```

int len, i;

char *p;

scanf (“%s”, n);

len = strlen (n);

p = (char) *malloc (len + 1); /* +1 for accommodating \0 */

strcpy (p, n);

names[0] = p;

malloc() is a standard library function to allocate space in memory. We have to pass the number of bytes to be allocated to malloc() . It returns the base address of the chunk of memory that it allocates. The returned address is of the type void * . A void * means a pointer which is a legal address but it is not address of a char , or address of an int , or address of any other datatype. Hence it has been converted into char * using a C language feature called typecasting. Typecasting will be discussed in detail in Chapter 22 . The prototype of malloc() has been declared in the header file ‘stdlib.h’.

But why didn’t we use array to allocate memory? That’s because with arrays we have to commit to the size of the array at the time of writing the program. Moreover, there is no way to increase or decrease the array size during execution of the program. In other words, when we use arrays, static memory allocation takes place. Unlike this, using malloc() , we can allocate memory dynamically, during execution. The argument that we pass to malloc() can be a variable whose value can change during execution.

This solution suffers in performance because we need to allocate memory and then do the copying of string for each name received through the keyboard.

P</> Programs

Problem 16.1

Write a program to stores a few strings using an array of pointers to strings. Receive a string and check if it is present in the array.

Program

/* Search a string in an array */

include

include

int main()

{

char *str[] = {

“We will teach you how to…”,

“Move a mountain”, “Level a building”,

“Erase the past”, “Make a million”,

“…all through C!”

};

char str1[20], *p;

int i;

printf (“\nEnter string to be searched: ”);

```
scanf (“%s”, str1);

p = NULL;

for (i = 0; i < 6; i++)

{

p = strstr (str[i], str1);

if (p != NULL)

{

printf (“%s found in the array”, str1);

return 0;

}

}

printf (“%s not found in the array”, str1);

return 0;

}
```

Output

```
Enter string to be searched: Million

Million not found in the array
```

Problem 16.2

Write a program to alphabetically sort a set of names stored using an array of pointers to strings.

Program

```
/* Sort strings alphabetically */
```

include

include

```
int main()

{

char *str[] = {

“Rajesh”, “Ashish”, “Milind”,

“Pushkar”, “Akash”

};

char *t;

int i, j;

for (i = 0; i < 5; i++)

{
```

```
for (j = i + 1; j < 5; j++)

{

if ((strcmp (str[i], str[j])) > 0)

{

t = str[i]; str[i] = str[j]; str[j] = t;

}

}

}

for (i = 0; i < 5; i++)

printf (“%s\t”, str[i]);

return 0;

}
```

Output

```
Akash Ashish Milind Pushkar Rajesh
```

Problem 16.3

Write a program to reverse the strings stored in an array of pointers to strings:

Program

```
/* Reverse strings stored in an array of pointers */
```

include

include

```
void xstrrev (char *ss);

int main()

{

char str[][35] = {

“To ere is human…”,

“But to really mess things up…”,

“One needs to know C !!”

};

int i;

for (i = 0; i <= 2; i++)

{

xstrrev (str[i]);

printf (“%s\n”, str[i]);
}
return 0;
}
void xstrrev (char *s)
{
int l, i;
char *t, temp;
l = strlen (s);
t = s + l - 1;
for (i = 1; i <= l / 2; i++)
{
temp = *s; *s = *t; *t = temp;
s++; t--;
}
}
```

Output

```
…namuh si ere oT
…pu sgniht ssem yllaer ot tuB
!! C wonk ot sdeen enO
```

Exercises

[A] Answer the following questions:

(a) How many bytes in memory would be occupied by the following array of pointers to strings? How many bytes would be required to store the same strings, if they are stored in a two-dimensional character array?

```
char *mess[] = {
“Hammer and tongs”, “Tooth and nail”,
“Spit and polish”, “You and C”
};
```

(b) Write a program to delete all vowels from a sentence. Assume that the sentence is not more than 80 characters long.

(c) Write a program that will read a line and delete from it all occurrences of the word ‘the’.

(d) Write a program that takes a set of names of individuals and abbreviates the first and middle name to their first letter.

(e) Write a program to count the number of occurrences of any two vowels in succession in a line of text. For example, in the following sentence:

“Please read this application and give me gratuity”

such occurrences are ea, ea, ui.

(f) Write a program that receives an integer (less than or equal to nine digits in length) and prints out the number in words. For example, if the number input is 12342, then the output should be Twelve Thousand Three Hundred Forty Two.

2 ways to handle multiple related strings:

1) Using 2D array of strings

2) Using array of pointers to strings

Pros and cons of using 2D array of strings:

Pros:

Easy to process using 2 for loops and expression str[i][j]

Cons:

Leads to wastage of precious memory space

Leads to tedious processing of array elements

Pros and cons of using array of pointers to strings:

Pros:

Easy to process

Saves space

Cons:

Cannot change strings. Their relative positions in the array can be changed

Cannot receive strings from keyboard easily. Can be done by allocating space for each string using malloc() and then assigning the addresses returned by malloc() to the array elements

Imagine a railway reservation system. The data in it like name, age, gender, address, distance of travel, source and destination stations, is dissimilar. How can this dissimilar data be kept together? Well, this chapter has the answer…

Contents

Clanguage provides arrays and strings to let us handle similar data. But real world data is usually dissimilar. For example, a ‘book’ is a collection of items like title, author, publisher, number of pages, date of publication, etc. For dealing with such data C provides a data type called ‘structure’, which is the topic of this chapter.

Why use Structures?

Suppose we wish to store in memory name (a string), price (a float) and number of pages (an int) of 3 books. To do this we can take following approaches:

(a) Construct 3 arrays for storing names, prices and number of pages.

(b) Use a structure variable.

Let us examine these two approaches one-by-one. For the sake of programming convenience, let us assume that the names of books would be single character long. Here is a program that uses arrays.

include

```
int main()
{
char name[3];
float price[3];
int pages[3], i;
printf (“Enter names, prices and no. of pages of 3 books\n”);
for (i = 0; i <= 2; i++)
scanf (“%c %f %d”, &name[i], &price[i], &pages[i]);
printf (“And this is what you entered\n”);
for (i = 0; i <= 2; i++)
printf (“%c %f %d\n”, name[i], price[i], pages[i]);
return 0;
}
```

And here is the sample run…

```
Enter names, prices and no. of pages of 3 books
A 100.00 354
```

```
C 256.50 682

F 233.70 512

And this is what you entered

A 100.000000 354

C 256.500000 682

F 233.700000 512
```

Though this approach works, it has following limitations:

(a) It obscures the fact that we are dealing with characteristics related to a single entity—the book.

(b) If we wish to store more items relatied to a book (publisher, date of publication, etc.), we would be required to create more arrays.

These limitations can be overcome by following the second approach— using a special data type called structure. It lets us group a number of similar/dissimilar data types together. The following example illustrates the use of this data type:

include

```
int main()

{

struct book

{

char name; float price; int pages;

};

struct book b1, b2, b3;

printf (“Enter names, prices & no. of pages of 3 books\n”);

scanf (“%c %f %d”, &b1.name, &b1.price, &b1.pages);

scanf (“%c %f %d”, &b2.name, &b2.price, &b2.pages);

scanf (“%c %f %d”, &b3.name, &b3.price, &b3.pages);

printf (“And this is what you entered\n”);

printf (“%c %f %d\n”, b1.name, b1.price, b1.pages);

printf (“%c %f %d\n”, b2.name, b2.price, b2.pages);

printf (“%c %f %d\n”, b3.name, b3.price, b3.pages);

return 0;

}
```

And here is the output…

```
Enter names, prices and no. of pages of 3 books

A 100.00 354

C 256.50 682

F 233.70 512
```

And this is what you entered

```
A 100.000000 354

C 256.500000 682

F 233.700000 512
```

The program begins with declaration of a user-defined data type called struct book , containing 3 structure elements— name , price and pages . Then we have defined 3 structure variables b1 , b2 , b3 of the type struct book . Each of these variables consists of a character variable called name , a float variable called price and an integer variable called pages .

Then we have received values into these variables using scanf() and printed them out using printf() . Note that to access each element of a structure variable we have used the dot (.) operator, as in, b1.name , b1.price and b1.pages .

You would agree that this second approach is better than the previous approach using arrays as it keeps dissimilar but related characteristics of a book (name, price, pages) together.

Array of Structures

In the second approach used above, if the number of books increase, instead of creating more variables like b4 , b5 , b6 , etc. we should create an array of structures as illustrated in the following program:

/* Usage of an array of structures */

include

```
void linkfloat();

int main()

{

struct book

{

char name; float price; int pages;

};

struct book b[10];

int i; int dh;

for (i = 0; i <= 9; i++)

{

printf (“Enter name, price and pages\n”);

scanf (“%c %f %d”, &b[i].name, &b[i].price, &b[i].pages);

while ((dh = getchar()) != ’\n’)

;

}

for (i = 0; i <= 9; i++)

printf (“%c %f %d\n”, b[i].name, b[i].price, b[i].pages);

return 0;

}
```

```
void linkfloat()

{

float a = 0, *b;

b = &a; /* cause emulator to be linked */

a = b; / suppress the warning - variable not used */

}
```

Notice how the array of structures is declared…

```
struct book b[10];
```

This array provides space in memory for 10 structures of the type struct book . Thus, by using one array we can take care of many books, each having many data items.

To refer to zeroth book's price we use b[0].price , to refer to first book's price we use b[1].price , etc.

When we supply first record to scanf() the values entered are assigned to different structure elements, but the enter that we hit remains in the keyboard buffer. If we leave it there, the next call to scanf() would take this enter and move ahead. To prevent this from happening we have to flush out the keyboard buffer. This is what is being achieved through the while loop following the scanf() . Some texts may use fflush (stdin) instead of the while loop to get the same effect. But this is not a portable way of clearing the input buffer, and may not work with all compilers.

If we don't define the linkfloat() function, we may get an error “Floating-Point Formats Not Linked” with some C Compilers. How can we force the formats to be linked? That's where the linkfloat() function comes in. It forces linking of the floating-point emulator into an application. There is no need to call this function; we just need to define it in our program.

Intricacies of Structures

We now know how to declare a structure, how to create structure variables, how to create an array of structures and how to access structure elements. It is time to explore the intricacies of structures.

Structure Declaration

Declaration of a structure does not reserve any space in memory. All that it does is, it defines the ‘form’ of the structure.

We can combine the declaration of the structure type and definition of structure variables in one statement as shown below. When we do so, mentioning the structure name is optional.

```
struct

{

char name; float price; int pages;

} b1, b2, b3;
```

Like primary variables, pointers, arrays and strings, structure variables too can be initialized where they are declared. The format used is quite similar to that used to initialize arrays.

```
struct book

{

char name[10]; float price; int pages;

};

struct book b1 = {“Basic”, 130.00, 550};

struct book b2 = {“Physics”, 150.80, 800};

struct book b3 = {0};
```

If a structure variable is initiated to a value {0}, then all its elements are set to value 0, as in b3 above. This is a handy way of initializing structure variables. In absence of this, we would have been required to initialize each individual element to a value 0.

Usually structure type declaration appears at the top of the source code file, before any variables or functions are defined. In very large programs they are put in a separate header file, and the file is #included in the program we wish to use this structure type.

Storage of Structure Elements

Structure elements are always stored in contiguous memory locations. The following program would illustrate this:

/* Memory map of structure elements */

include

```
int main()

{

struct book

{

char name; float price; int pages;

};

struct book b1 = {'B', 130.00, 550};

printf ("Address of name = %u\n", &b1.name);

printf ("Address of price = %u\n", &b1.price);

printf ("Address of pages = %u\n", &b1.pages);

return 0;

}
```

Here is the output of the program…

```
Address of name = 65518

Address of price = 65519

Address of pages = 65523
```

Actually, the structure elements are stored in memory as shown in the Figure 17.1 .

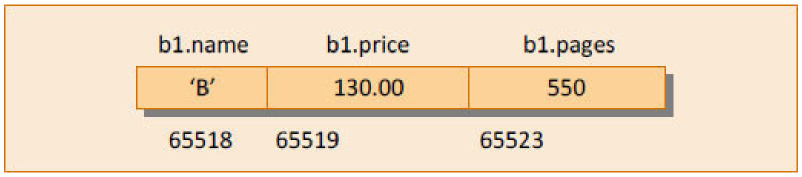


Figure 17.1

In an array of structures, all elements of the array are stored in adjacent memory locations.

Copying of Structure Elements

Structure elements can be copied either piece-meal or all at one shot. Both these approaches are shown in the following example:

include

include

```
int main()

{

struct employee

{

char name[10]; int age; float salary;

};

struct employee e1 = {“Sanjay”, 30, 5500.50};

struct employee e2, e3;

/* piece-meal copying */

strcpy (e2.name, e1.name); /* e2.name = e1. name is wrong */

e2.age = e1.age;

e2.salary = e1.salary;

/* copying all elements at one go */

e3 = e2;

printf (“%s %d %f\n”, e1.name, e1.age, e1.salary);

printf (“%s %d %f\n”, e2.name, e2.age, e2.salary);

printf (“%s %d %f\n”, e3.name, e3.age, e3.salary);

return 0;

}
```

The output of the program would be…

```
Sanjay 30 5500.500000

Sanjay 30 5500.500000

Sanjay 30 5500.500000
```

If all elements are to be copied copying at one shot is preferred, whereas, if we wish to copy only some of the elements, we need to take the piece-meal approach.

Nested Structures

One structure can be nested within another structure. Using this facility, complex data types can be created. The following program shows nested structures at work:

include

```
int main()

{

struct address

{
```

```
char phone[15]; char city[25]; int pin;

};

struct emp

{

char name[25]; struct address a;

};

struct emp e = {“jeru”, “531046”, “nagpur”, 10};

printf (“name = %s phone = %s\n”, e.name, e.a.phone);

printf (“city = %s pin = %d\n”, e.a.city, e.a.pin);

return 0;

}
```

And here is the output…

```
name = jeru phone = 531046

city = nagpur pin = 10
```

Notice the method used to access the element of a structure that is part of another structure. For this, the dot operator is used twice, as in the expression, e.a.pin or e.a.city .

Nested structures can be surprisingly self-descriptive, for example:

maruti.engine.bolt.large.qty

This clearly signifies that we are referring to the quantity of large sized bolts that fits on an engine of a maruti car.

Passing Structure Elements / Structure Variables

We may either pass individual structure elements or the entire structure variable to a function as shown in the following program:

/* Passing individual structure elements */

include

```
struct book

{

char name[25]; char author[25]; int pages;

};

void display1 (char *, char *, int);

void display2 (struct book);

void display3 (struct book *);

int main()

{

struct book b1 = {“Let us C”, “YPK”, 643};

display1 (b1.name, b1.author, b1.pages);
display2 (b1);

display3 (&b1);

return 0;

}

void display1 (char *n, char *a, int pg)

{

printf ("%s %s %d\n", n, a, pg);

}

void display2 (struct book b)

{

printf ("%s %s %d\n", b.name, b.author, b.pages);

}

void display3 (struct book *pb)

{

printf ("%s %s %d\n", pb->name, pb->author, pb->pages);

}
```

And here is the output…

```
Let us C YPK 101

Let us C YPK 101

Let us C YPK 101
```

Observe that in the declaration of the structure, name and author are arrays. Therefore, when we called the display1() using,

display1 (b1.name, b1.author, b1.callno);

we passed base addresses of the arrays name and author , but the value stored in callno . Thus, this is a mixed call—a call by reference as well as a call by value. display1() proceeds to print the two strings and integer.

The structure variable b1 has been passed by value to display2() and by reference to display3() . b1 passed to display2() is collected in variable b of the type struct book . Likewise, address of b1 passed to display3() is collected in 'structure pointer' or 'pointer to a structure' pb . (Refer Figure 17.2 .)

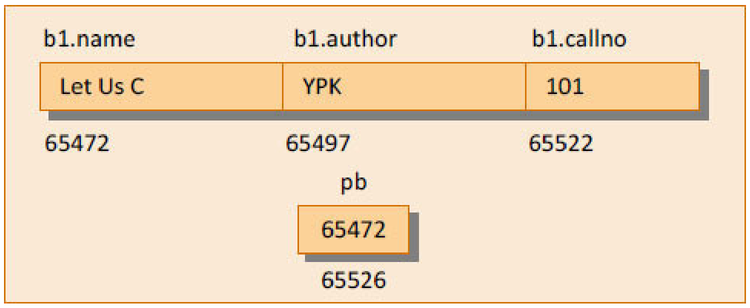


Figure 17.2

Since we need struct book in both display2() and display3() it has been declared globally. display2() accesses and prints the elements of b using the '.' operator.

Observe carefully, how printf() is used in display3() to print structure elements. We can't use pb.name or pb.callno because pb is not a structure variable but a pointer to a structure. In such cases C provides an operator -> to refer to the structure elements. Remember that on the left hand side of the ‘ ->’ operator, there must always be a pointer to a structure.

Packing Structure Elements

Consider the following code snippet:

```
struct emp

{

int a; char ch; float s;

};

struct emp e;

printf (“%u %u %u\n”, &e.a, &e.ch, &e.s);
```

If we execute this program using TC/TC++ Compiler we get the addresses as:

```
65518 65520 65521
```

As expected, in memory the char begins immediately after the int and float begins immediately after the char .

However, if we run the same program using Visual Studio compiler then the output turns out to be:

```
1245044 1245048 1245052
```

It can be observed from this output that the float doesn't get stored in the immediately next location after the char . In fact there is a hole of three bytes after the char . Let us understand the reason for this.

Visual Studio is a 32-bit compiler targeted to generate code for a 32-bit microprocessor. The architecture of this microprocessor is such that it is able to fetch the data that is present at an address, which is a multiple of four much faster than the data present at any other address. Hence the compiler aligns every element of a structure at an address that is multiple of four. Hence the three holes between the char and the float .

However, some programs need to exercise precise control over the memory areas where data is placed. For example, suppose we wish to read the contents of the boot sector (first sector on the hard disk) into a structure. For this the byte arrangement of the structure elements must match the arrangement of various fields in the boot sector of the disk. The #pragma pack directive offers a way to fulfil this requirement. This directive specifies packing alignment for structure members. The pragma takes effect at the first structure declaration after the pragma is seen.

Visual Studio compiler supports this feature, whereas Turbo C/C++ doesn't. The following code shows how to use this directive:

pragma pack(1)

```
struct emp

{

int a; char ch; float s;

};
```

pragma pack()

```
struct emp e;

printf (“%u %u %u\n”, &e.a, &e.ch, &e.s);
```

Here, #pragma pack (1) lets each structure element to begin on a 1-byte boundary as justified by the output of the program given below.

```
1245044 1245048 1245049
```

Uses of Structures

Structures are very useful in Database Management to maintain data about employees in an organization, books in a library, items in a store, financial accounting transactions in a company, etc. They are also used for many other purposes like:

(a) Changing the size of the cursor

(b) Clearing the contents of the screen

(c) Placing the cursor at an appropriate position on screen

(d) Drawing any graphics shape on the screen

(e) Receiving a key from the keyboard

(f) Checking the memory size of the computer

(g) Finding out the list of equipment attached to the computer

(h) Formatting a disk

(i) Hiding a file from the directory

(j) Displaying the directory of a disk

(k) Sending the output to printer

(l) Interacting with the mouse

And that is certainly a very impressive list! At least impressive enough to make you realize how important a data type a structure is and to be thorough with it if you intend to program any of the above applications.

Problem 17.1

A stack is a data structure in which addition of new element or deletion of existing element always takes place at the same end known as 'top' of stack. Write a program to implement a stack using a linked list.

Program

/* Implementation of stack using a linked list */

include

include

struct node

{

int data; struct node *link;

};

void push (struct node **s, int item);

int pop (struct node **s);

int main()

{

struct node *top;

int t, i, item;

```
top = NULL;

push (&top, 45); push (&top, 28);

push (&top, 63); push (&top, 55);

item = pop (&top);

printf (“Popped : %d\n”, item);

item = pop (&top);

printf (“Popped : %d\n”, item);

return 0;

}

void push (struct node **s, int item)

{

struct node *q;

q = (struct node *) malloc (sizeof (struct node));

q -> data = item;

q -> link = *s;

*s = q;

}

int pop (struct node **s)

{

int item;

struct node *q;

if (*s == NULL)

printf (“Stack is empty\n”);

else

{

q = *s;

item = q -> data;

*s = q -> link;

free (q);

return (item);

}

}
```

Output

```
Popped : 55
```

Popped : 63

Problem 17.2

In a data structure called queue the addition of new element takes place at the end (called ‘rear’ of queue), whereas deletion takes place at the other end (called ‘front’ of queue). Write a program to implement a queue using a linked list.

Program

/* Implementation of a queue using linked list */

include

include

```
struct queue

{

int item; struct queue *link;

};

struct queue *rear, *front;

void add (int item);

int del_queue();

int main()

{

int item;

rear = front = NULL;

add (10); add (20); add (30);

add (40); add (50); add (60);

item = del_queue();

printf (“Deleted Item = %d\n”, item);

item = del_queue();

printf (“Deleted Item = %d\n”, item);

return 0;

}

void add (int item)

{

struct queue *q = (struct queue *) malloc (sizeof (struct queue));

q -> item = item;

q -> link = NULL;

if (rear == NULL)

{
```

```
rear = q; front = q;

}

else

{

q -> link = rear; rear = q;

}

}

int del_queue()

{

int item;

struct queue *q = rear;

if (front == NULL)

{

printf (“Queue is empty\n”);

return -1;

}

else

{

if (front == rear)

{

item = q -> item; front = rear = NULL;

free(q);

}

else

{

while(q -> link -> link != NULL)

q = q -> link;

item = q -> link -> item;

free(q -> link);

front = q;

q -> link = NULL;

}

}

return item;
```

```
}
```

Output

```
Deleted Item = 10

Deleted Item = 20
```

Exercises

[A] Answer the following questions:

(a) Given the statement,

```
maruti.engine.bolts = 25;
```

which of the following is True?

Structure bolts is nested within structure engine

Structure engine is nested within structure maruti

Structure maruti is nested within structure engine

Structure maruti is nested within structure bolts

(b)

```
struct time

{

int hours; int minutes; int seconds;

} t;

struct time *pt;

pt = &t;
```

With reference to the above declarations which of the following refers to seconds correctly:

pt.seconds

pt -> seconds

time.seconds

time->seconds

[B] Attempt the following questions:

(a) Create a structure called student that can contain data given below: Roll number, Name, Department, Course, Year of joining

Assume that there are not more than 450 students in the college.

(1) Write a function to print names of all students who joined in a particular year.

(2) Write a function to print the data of a student whose roll number is received by the function.

(b) Create a structure that can contain data of customers in a bank. The data to be stored is Account number, Name, Balance in account. Assume maximum of 200 customers in the bank.

(1) Write a function to print the Account number and name of each customer with balance below Rs. 100.

(2) If a customer requests for withdrawal or deposit, the form contains the fields:

Acct. no, amount, code (1 for deposit, 0 for withdrawal)

Write a function that prints a message, “The balance is insufficient for the specified withdrawal”, if on withdrawal the balance falls below Rs. 100.

(c) An automobile company has serial number for engine parts starting from AA0 to FF9. The other characteristics of parts are year of manufacture, material and quantity manufactured.

(1) Create a structure to store information corresponding to a part.

(2) Write a program to retrieve information on parts with serial numbers between BB1 and CC6.

(d) A record contains name of cricketer, his age, number of test matches that he has played and the average runs that he has scored in each test match. Create an array of structures to hold records of 20 such cricketers and then write a program to read these records and arrange them in ascending order by average runs. Use the qsort() standard library function.

(e) There is a structure called employee that holds information like employee code, name and date of joining. Write a program to create an array of structures and enter some data into it. Then ask the user to enter current date. Display the names of those employees whose tenure is greater than equal to 3 years.

(f) Create a structure called library to hold accession number, title of the book, author name, price of the book, and flag indicating whether book is issued or not. Write a menu-driven program that implements the working of a library. The menu options should be:

Add book information

Display book information

List all books of given author

List the title of specified book

List the count of books in the library

List the books in the order of accession number

Exit

(g) Write a function that compares two given dates. To store a date use a structure that contains three members namely day, month and year. If the dates are equal the function should return 0, otherwise it should return 1.

Structure is a collection of dissimilar (usually) elements stored in adjacent locations

Structure is also known as - User-defined data type / Secondary data type / Aggregate data type / Derived data type

Terminology:

struct employee {char name; int age; float salary;}; struct employee e1, e2, e[10];

struct - Keyword employee - Structure name / tag

name, age, salary - Structure elements / Structure members e1, e2 - Structure variables e[] - Array of structures

Structure elements are stored in adjacent memory locations

Size of structure variable = sum of sizes of structure elements

2 ways to copy structure elements:

struct emp e1 = {“Rahul”, 23, 4000.50};

struct emp e2, e3;

e2.n = e1.n; e2.a = e1.a; e2.s = e1.s; → Piecemeal copying

e3 = e1; → Copying at one shot

Structures can be nested:

struct address {char city[20]; long int pin;};

struct emp {char n[20]; int age; struct address a; float s;};

struct emp e;

To access city and pin we should use e.a.city and e.a.pin

To access structure elements using structure variable, use . operator as in

struct emp e; printf (“%s %d %f”, e.name, e.age, e.sal);

To access structure elements using structure pointer, use -> operator as in

struct emp e; struct emp *p;

p = &e;

printf (“%s %d %f”, p->name, p->age, p->sal);

Uses of structures:

Database Management	Displaying characters
Printing on printer	Mouse Programming
Graphics Programming	All Disk Operations

18 Console Input / Output

“Input from keyboard, Output to screen”

I want to print names, ages and salaries of 5 persons on the screen. The names and ages should be left justified and properly aligned one below the other. The salaries should be aligned with the decimal point and only two digits should be printed after decimal point. To achieve all this, you need formatted console printing functions. This chapter shows you which and how of it…

Contents

Canguage has no provision for receiving data from any of the input devices (like say keyboard, disk, etc.), or for sending data to the output devices (like say monitor, disk, etc.). Then how do we manage I/O? Well, that is what we intend to explore in this chapter.

Types of I/O

Though C has no keywords to perform I/O, it, of course, has to be dealt with at some point or the other. There is not much use of writing a program that spends all its time telling itself a secret.

Each Operating System (OS) has its own facility for inputting and outputting data from and to the files and devices. So functions are defined that can carry out I/O keeping in mind the particular operating system's I/O facilities. These functions are then compiled and made available to users in the form of libraries.

Since I/O facilities are OS dependent, definition of an I/O function for one OS would be different than the one for another OS, even though the behavior of both functions would be same.

There are numerous library functions available for I/O. These can be classified into two broad categories:

(a) Console I/O functions - Functions to receive input from keyboard and write output to screen.

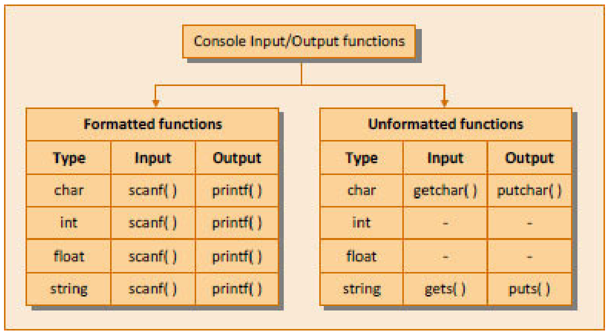
(b) File I/O functions - Functions to perform I/O operations on a disk.

In this chapter we would be discussing only Console I/O functions. File I/O functions would be discussed in Chapter 19 .

Console I/O Functions

The screen and keyboard together are called a console. Console I/O functions can be further classified into two categories—formatted and unformatted console I/O functions.

The basic difference between them is that the formatted functions allow the input read from the keyboard or the output displayed on the screen to be formatted as per our requirements. For example, if values of average marks and percentage marks are to be displayed on the screen, then the details like where this output would appear on the screen, how many spaces would be present between the two values, the number of places after the decimal points, etc., can be controlled using formatted functions. The functions available under each of these two categories are shown in Figure 18.1 .


Console Input/Output functions

Formatted functions		
Type	**Input**	**Output**
char	scanf( )	printf( )
int	scanf( )	printf( )
float	scanf( )	printf( )
string	scanf( )	printf( )

Unformatted functions		
Type	**Input**	**Output**
char	getchar( )	putchar( )
int	-	-
float	-	-
string	gets( )	puts( )

Figure 18.1

Let us now discuss these console I/O functions in detail.

Formatted Console I/O Functions

As can be seen from Figure 18.1 , the functions printf(), and scanf() fall under the category of formatted console I/O functions. These functions allow us to supply input in a fixed format and obtain output in specified form. Let us discuss these functions one-by-one.

General form of printf() looks like this…

printf (“format string”, list of variables);

The format string can contain:

(a) Characters that are simply printed as they are

(b) Format specifications that begin with a % sign

(c) Escape sequences that begin with a \ sign

For example, look at the following program:

include

```
int main()

{

int avg = 346;

float per = 69.2;

printf (“Average = %d\nPercentage = %f\n”, avg, per);

return 0;

}
```

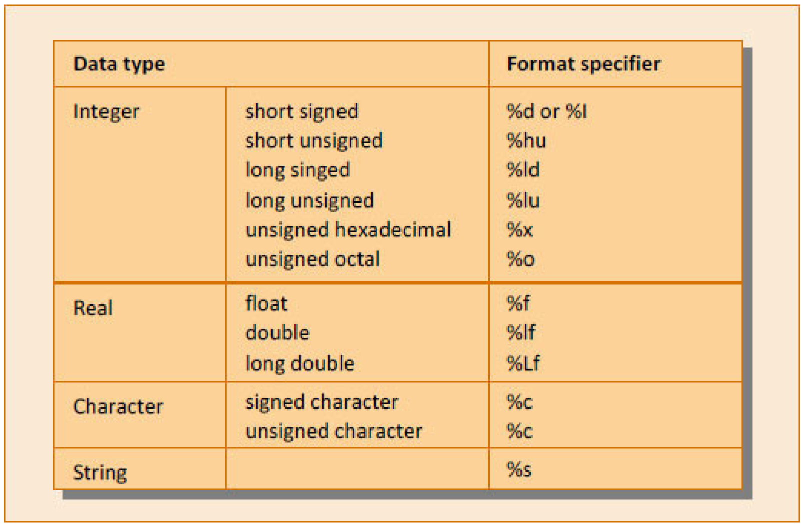
The output of the program would be…

```
Average = 346

Percentage = 69.200000
```

During execution printf() function examines the format string from left to right. Till it doesn't come across either a % or a \, it continues to display the characters that it encounters, on to the screen. In this example, Average = is displayed on the screen. When it comes across a format specifier, it picks up the first variable in the list of variables and prints its value in the specified format. In this example, when %d is met, the variable avg is picked up and its value is printed. Similarly, when an escape sequence is met, it takes suitable action. In this example, when \n is met, it places the cursor at the beginning of the next line. This process continues till the end of format string is reached.

Format Specifications

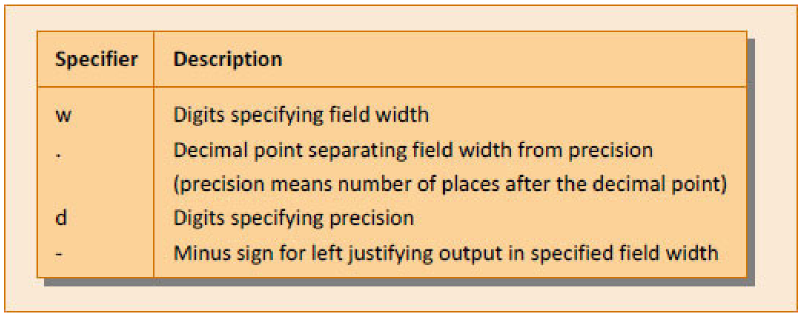
The %d and %f used in the printf() are called format specifiers. They tell printf() to print the value of avg as a decimal integer and the value of per as a float. Figure 18.2 gives a list of format specifiers that can be used with the printf() function.



Data type		Format specifier
Integer	short signed	%d or %I
	short unsigned	%hu
	long singed	%ld
	long unsigned	%lu
	unsigned hexadecimal	%x
	unsigned octal	%o
Real	float	%f
	double	%lf
	long double	%Lf
Character	signed character	%c
	unsigned character	%c
String		%s

Figure 18.2

We can provide optional specifiers shown in Figure 18.3 in the format specifications.



Specifier	Description
w	Digits specifying field width
.	Decimal point separating field width from precision (precision means number of places after the decimal point)
d	Digits specifying precision
-	Minus sign for left justifying output in specified field width

Figure 18.3

The field-width specifier tells printf() how many columns on screen should be used while printing a value. For example, %10d says, “print the variable as a decimal integer in a field of 10 columns”. If the value to be printed happens not to fill up the entire field, the value is right justified and is padded with blanks on the left.

If we include the minus sign in format specifier (as in %-10d), this means left justification is desired and the value will be padded with blanks on the right.

If the field-width used turns out to be less than what is required to print the number, the field-width is ignored and the complete number is printed. Here is an example that illustrates all these features.

include

int main()

{

int weight = 63;

printf (“weight is %d kg\n”, weight);

printf (“weight is %2d kg\n”, weight);

printf (“weight is %4d kg\n”, weight);

printf (“weight is %6d kg\n”, weight);

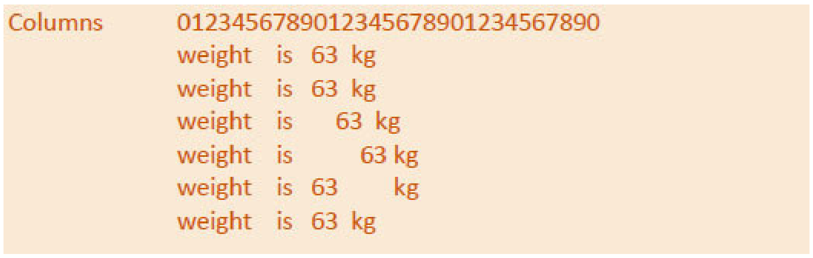
printf (“weight is %-6d kg\n”, weight);

printf (“weight is %1d kg\n”, weight);

return 0;

}

The output of the program would look like this …



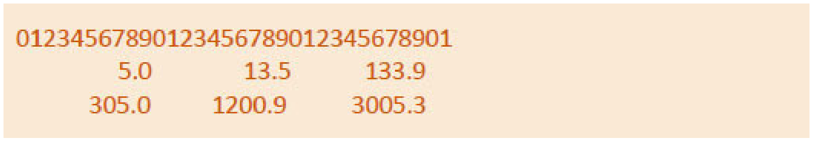
```
Columns    0123456789012345678901234567890
           weight is 63 kg
           weight is 63 kg
           weight is   63 kg
           weight is     63 kg
           weight is 63     kg
           weight is 63 kg
```

Specifying the field width can be useful in creating tables of numeric values with the numbers lined up properly, as the following program demonstrates:

include

```
int main()

{

printf ("%10.1f %10.1f %10.1f\n", 5.0, 13.5, 133.9);

printf ("%10.1f %10.1f %10.1f\n", 305.0, 1200.9, 3005.3);

return 0;

}
```

This results into a much better output…



```
01234567890123456789012345678901
       5.0       13.5      133.9
     305.0     1200.9     3005.3
```

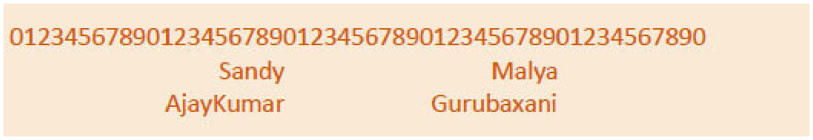
Note that the specifier %10.1f specifies that a float be printed right-aligned within 10 columns, with one place beyond the decimal point.

The format specifiers can be used even while displaying a string of characters. The following program would clarify this point:

include

```
int main()

{

char firstname1[] = "Sandy";

char surname1[] = "Malya";

char firstname2[] = "AjayKumar";

char surname2[] = "Gurubaxani";

printf ("%20s%20s\n", firstname1, surname1);

printf ("%20s%20s\n", firstname2, surname2);

return 0;

}
```

And here's the output…



```
01234567890123456789012345678901234567890
               Sandy               Malya
           AjayKumar          Gurubaxani
```

The format specifier %20s prints the string in these 20 columns with right justification. This helps lining up names of different lengths properly. Obviously, the format %-20s would have left-justified the string. Had we used %20.10s it would have meant left justify the string in 20 columns and print only first 10 characters of the string.

Escape Sequences

We know that when the newline character, \n , is inserted in a printf() 's format string, it takes the cursor to the beginning of the next line. The newline character is an 'escape sequence', so called because the backslash symbol () is considered as an 'escape' character—it causes an escape from the normal interpretation of a string, so that the next character is recognized as one having a special meaning.

The following example shows usage of \n and a new escape sequence \t , called 'Tab'. A 80-column screen is divided into 10 print zones of 8 columns each. Using a \t moves the cursor to the beginning of next print zone. For example, if cursor is positioned in column 5, then printing a \t takes the cursor to column 8. Following program shows \t in action.

include

int main()

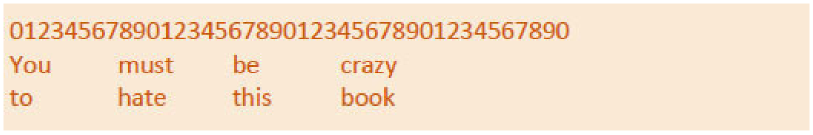
{

printf (“You\tmust\tbe\tcrazy\nto\thate\tthis\tbook\n”);

return 0;

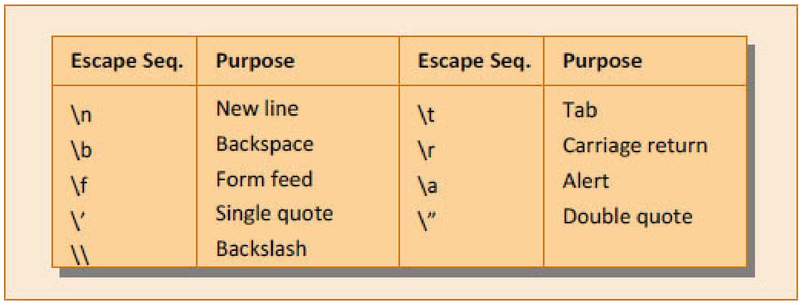
}

And here's the output…



```
01234567890123456789012345678901234567890
You       must      be        crazy
to        hate      this      book
```

The \n character causes a new line to begin following ‘crazy’. The Tab and newline are probably the most commonly used escape sequences, but there are others as well. Figure 18.4 shows a complete list of these escape sequences.



Escape Seq.	Purpose	Escape Seq.	Purpose
\n	New line	\t	Tab
\b	Backspace	\r	Carriage return
\f	Form feed	\a	Alert
\’	Single quote	\”	Double quote
\\	Backslash		

Figure 18.4

\b moves the cursor one position to the left of its current position. \r takes the cursor to the beginning of the line in which it is currently placed. \a alerts the user by sounding the speaker inside the computer. Form feed advances the computer stationery attached to the printer to the top of the next page. Characters that are ordinarily used as delimiters… the single quote, double quote, and the backslash can be printed by preceding them with the backslash. Thus, the statement,

printf (“He said, \“Let’s do it!\””);

will print…

He said, “Let’s do it!”

Ignoring Characters

Sometimes we may wish to ignore some of the characters supplied as input. For example, while receiving a date we may wish to ignore the separator like ’.’, ’/’ or ’-’. This can done using %*c . This means if a ’.’ or ’/’ or ’-’ is entered it would be matched and ignored. The * ensures that the character entered doesn’t get assigned to any variable in the variable list.

printf (“Enter date in dd/mm/yy or dd.mm.yy or dd-mm-yy format\n”);

scanf (“%d%*c%d%*c%d”, &dd, &mm, &yy);

printf (“%d/%d%/%d\n”, dd, mm, yy);

Mismatch

Suppose there is a mismatch in the specifier that we use and the type of value is being printed using it. When this happens printf() attempts to perform the specified conversion, and does its best to produce a proper result. Sometimes the result is nonsensical, as in case when we ask it to print a string using %d . Sometimes the result is useful, as in the case we ask printf() to print ASCII value of a character using %d . Sometimes the result is disastrous and the entire program blows up.

The following program shows a few of these conversions, some sensible, some weird:

include

```
int main()

{

char ch = ’z’;

int i = 125;

float a = 12.55;

char s[] = “hello there !”;

printf (“%c %d %f\n”, ch, ch, ch);

printf (“%s %d %f\n”, s, s, s);

printf (“%c %d %f\n”,i,i, i);

printf (“%f %d\n”, a, a);

return 0;

}
```

And here's the output…

```
z 122 -9362831782501783000000000000000000000000000.000000

hello there ! 3280 -

9362831782501783000000000000000000000000000.000000

} 125 -9362831782501783000000000000000000000000000.000000

12.550000 0
```

I would leave it to you to analyze the results by yourselves. Some of the conversions you would find are quite sensible.

Let us now turn our attention to scanf() . The scanf() function allows us to enter data from keyboard that will be formatted in a certain way.

The general form of scanf() statement is as follows:

```
scanf (“format string”, list of addresses of variables);
```

For example:

```
scanf (“%d %f %c”, &c, &a, &ch);
```

Note that we are sending addresses of variables to scanf() function. This is necessary because the values received from keyboard must be dropped into variables corresponding to these addresses. The values that are supplied through the keyboard must be separated by either blank(s), Tab(s), or newline(s). Do not include these escape sequences in the format string. All the format specifications that we learnt in printf() function are applicable to scanf() function as well.

sprintf() and sscanf() Functions

The sprintf() function works similar to the printf() function except for one small difference. Instead of sending the output to the screen as printf() does, this function writes the output to an array of characters. The following program illustrates this:

include

```
int main()
```

```
{
int i = 10;
char ch = ’A’;
float a = 3.14;
char str[20];
printf (“%d %c %f\n”, i, ch, a);
sprintf (str, “%d %c %f”, i, ch, a);
printf (“%s\n”, str);
return 0;
}
```

In this program, the printf() prints out the values of i , ch and a on the screen, whereas sprintf() stores these values in the character array str . Since the string str is present in memory, what is written into str using sprintf() doesn't get displayed on the screen. Once str has been built, its contents can be displayed on the screen. In our program this was achieved by the second printf() statement.

The counterpart of sprintf() is the sscanf() function. It allows us to read characters from a string and to convert and store them in C variables according to specified formats. The sscanf() function comes in handy for in-memory conversion of characters to values. You may find it convenient to read in strings from a file and then extract values from a string by using sscanf() . The usage of sscanf() is same as scanf() , except that the first argument is the string from which reading is to take place.

Unformatted Console I/O Functions

There are several standard library functions available under this category—those that can deal with a single character and those that can deal with a string of characters. For openers, let us look at those which handle one character at a time.

getchar() and putchar()

The getchar() function lets you read a single character entered from keyboard. The character that is typed has to be followed by Enter key. Its counterpart is putchar() which displays a character on the screen. Their usage is shown in the following program:

include

```
int main()
{
char ch;
printf (“\nType any alphabet”);
ch = getchar(); /* must be followed by enter key */
printf (“You typed ”);
putchar (ch);
return 0;
}
```

With getchar() you need to hit the Enter key before the function can digest what you have typed. However, we may want a function that will read a single character the instant it is typed without waiting for the Enter key to be hit. There is no standard function to achieve this and there are different solutions for different OS.

MS-DOS based compiler like Turbo C and Windows based compiler like Visual Studio provide function called getch() to achieve this. Its prototype is present in the file conio.h . This function reads a single character from keyboard. But it does not use any buffer, so the entered character is immediately returned without waiting for the enter key. In Linux-based systems the same effect can be obtained by doing some terminal settings using stty command.

gets() and puts()

gets() receives a string from the keyboard. It is terminated when an Enter key is hit. Thus, spaces and tabs are perfectly acceptable as part of the input string. More exactly, gets() function gets a newline (\n) terminated string of characters from the keyboard and replaces the \n with a \0 .

The puts() function works exactly opposite to gets() function. It outputs a string to the screen.

Here is a program which illustrates the usage of these functions.

include

```
int main()

{

char footballer[40];

puts (“Enter name”);

gets (footballer); /* sends base address of array */

puts (“Happy footballing!”);

puts (footballer);

return 0;

}
```

Following is the sample output:

```
Enter name

Jonty Rhodes

Happy footballing!

Jonty Rhodes
```

Why did we use two puts() functions to print “Happy footballing!” and “Jonty Rhodes”? Because, unlike printf(), puts() can output only one string at a time. If we attempt to print two strings using puts(), only the first one gets printed. Similarly, unlike scanf(), gets() can be used to read only one string at a time.

A word of caution! While using gets() if the length of the input string is bigger than the size of the string passed to gets() then we may end up exceeding the bounds of the string, which is dangerous. This can be avoided using fgets() function as shown below:

```
char str[20];

puts (“Enter a string: ”);

fgets (str, 20, stdin);

puts (str);
```

Here is the sample interaction with this code snippet…

```
Enter a string:

It is safe to use fgets than gets

It is safe to use f
```

Note that only 19 characters were stored in str[] followed by a ’\0’. So bounds of the string were not exceeded. Here stdin represents standard input device, i.e. keyboard.

Exercises

[A] What will be the output of the following programs:

(a) # include

include int main()

```
{
char ch;
ch = getchar();
if (islower (ch))
putchar (toupper (ch));
else
putchar (tolower (ch));
return 0;
}
```

(b) # include

```
int main()
{
int i = 2;
float f = 2.5367;
char str[] = “Life is like that”;
printf (“%4d\t%3.3f\t%4s\n”, i, f, str);
return 0;
}
```

(c) # include

```
int main()
{
printf (“More often than \b\b not \rthe person who \ wins is the one who thinks he can!\n”);
return 0;
}
```

(d) # include

```
char p[] = “The sixth sick sheikh’s sixth ship is sick”;
int main()
{
```

```
int i = 0;

while (p[i] != '\0')

{

putchar (p[i]);

i++;

}

return 0;

}
```

[B] Point out the errors, if any, in the following programs:

```
(a) # include

int main()

{

int i;

char a[] = “Hello”;

while (a != '\0')

{

printf (“%c”, *a);

a++;

}

return 0;

}

(b) # include

int main()

{

double dval;

scanf (“%f”, &dval);

printf (“Double Value = %lf\n”, dval);

return 0;

}

(c) # include

int main()

{

int ival;

scanf (“%d\n”, &n);
printf (“Integer Value = %d\n”, ival);
return 0;
}
(d) # include
int main()
{
int dd, mm, yy;
printf (“Enter date in dd/mm/yy or dd-mm-yy format\n”);
scanf (“%d%c%d%c%d”, &dd, &mm, &yy);
printf (“The date is: %d - %d - %d\n”, dd, mm, yy);
return 0;
}
(e) # include
int main()
{
char text;
sprintf (text, “%4d\t%2.2f\n%s”, 12, 3.452, “Merry Go Round”);
printf (“%s\n”, text);
return 0;
}
(f) # include
int main()
{
char buffer[50];
int no = 97;
double val = 2.34174;
char name[10] = “Shweta”;
sprintf (buffer, “%d %lf %s”, no, val, name);
printf (“%s\n”, buffer);
sscanf (buffer, “%4d %2.2lf %s”, &no, &val, name);
printf (“%s\n”, buffer);
printf (“%d %lf %s\n”, no, val, name);
return 0;
}
```

[C] Answer the following questions:

(a) To receive the string “We have got the guts, you get the glory!!” in an array char str[100] which of the following functions would you use?

scanf (“%s”, str);

gets (str);

getchar (str);

fgetchar (str);

(b) If an integer is to be entered through the keyboard, which function would you use?

scanf()

gets()

getche()

getchar()

(c) Which of the following can a format string of a printf() function contain:

Characters, format specifications and escape sequences

Character, integers and floats

Strings, integers and escape sequences

Inverted commas, percentage sign and backslash character

(d) The purpose of the field-width specifier in a printf() function is to:

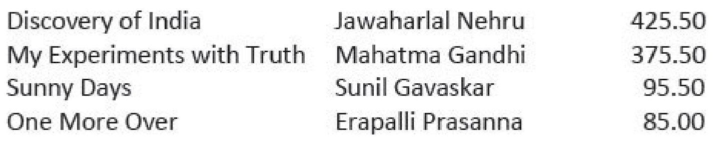
Control the margins of the program listing

Specify the maximum value of a number

Control the size of font used to print numbers

Specify how many columns would be used to print the number

(e) If we are to display the following output properly aligned which format specifiers would you use?



```
Discovery of India           Jawaharlal Nehru        425.50
My Experiments with Truth    Mahatma Gandhi          375.50
Sunny Days                   Sunil Gavaskar           95.50
One More Over                Erapalli Prasanna        85.00
```

IO in C is always done using functions, not using keywords

All IO functions can be divided into 2 broad categories:

1) Console IO functions: a) Formatted b) Unformatted

2) Disk IO functions

The formatted console I/O functions can force the user to receive the input in a fixed format and display the output in a fixed format.

All formatted Console IO is done using printf() and scanf()

Examples of formatting:

%20s - right align a string in 20 columns

%-10d - left align an integer in 10 columns

%12.4f - right align a float in 12 columns with 4 places beyond decimal point

Escape sequences:

\n - positions cursor on next line

\r - positions cursor at beginning of same line

When we hit enter \r is generated and is converted into \r\n combination

\t - positions cursor at beginning of next print zone. 1 print zone = 8 columns

\', \", \ - produces ' " \ in the output

scanf() can contain format specifier like %10.2f, but it is too restrictive, hence rarely used

Unformatted console IO functions:

char - getchar() - Waits for enter

int / float - no functions

string - gets(), puts()

Once you know how to read / write data from / to file, you have crossed a major hurdle. With this knowledge under your belt you will be able to write many useful programs. This chapter shows you how…

Contents

Often data is so large that all of it cannot be stored in memory and only a limited amount of it can be displayed on the screen. Also, memory is volatile and its contents would be lost once the program is terminated. At such times, it becomes necessary to store the data in a 'file' on disk so that it can be later retrieved, used and displayed either in part or in whole. This chapter discusses how file I/O operations can be performed.

File Operations

There are different operations that can be carried out on a file. These are:

(a) Creation of a new file

(b) Opening an existing file

(c) Reading from a file

(d) Writing to a file

(e) Moving to a specific location in a file (seeking)

(f) Closing a file

Let us write a program to read a file and display its contents on the screen. We will first list the program and show what it does, and then dissect it line-by-line. Here is the listing…

```
/* Display contents of a file on screen. */
include
int main()
{
FILE *fp;
char ch;
fp = fopen ("PR1.C", "r");
while (1)
{
ch = fgetc (fp);
if (ch == EOF)
break;
printf ("%c", ch);
}
printf ("\n");
fclose (fp);
```

return 0;

}

On execution of this program it displays the contents of the file ‘PR1.C’ on the screen. Let us now understand how it does the same.

Opening a File

The basic logic of the program is as follows:

(a) Read a character from file.

(b) Display the character read on the screen.

(c) Repeat steps (a) and (b) for all characters in the file.

It would be quite inefficient to access the disk every time we want to read a character from it. It would be more sensible to read the contents of the file into a buffer while opening the file and then read the file character by character from the buffer rather than from the disk. This is shown in Figure 19.1 .

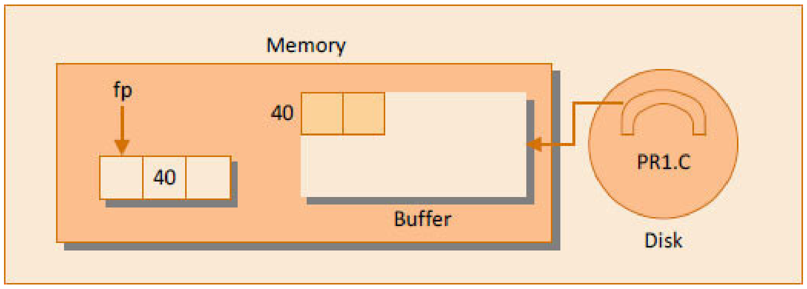


Figure 19.1

Same argument also applies to writing information in a file. Instead of writing characters in the file on the disk one character at a time, it would be more efficient to write characters in a buffer and then finally transfer the contents from the buffer to the disk.

Before we can read (or write) information from (to) a file on a disk we must open the file. To open the file we have called the function fopen() . It would open a file “ PR1.C ” in ‘ read ’ mode, which means that we would be reading the contents of the file. In fact fopen() performs three important tasks when you open the file in “ r ” mode:

(a) Firstly, it searches the file to be opened, on the disk.

(b) Then it loads the file from the disk into a buffer.

(c) It sets up a character pointer which points to the first character of the buffer.

(d) It sets up a FILE structure and returns its address.

Let us understand the purpose of the FILE structure. To be able to successfully read from a file, information like mode of opening, size of file, place in the file from where the next read operation would be performed, etc., has to be maintained. Since all this information is inter-related, all of it is set by fopen() in a structure called FILE . fopen() returns the address of this structure, which we have collected in the structure pointer called fp . We have declared fp as follows:

FILE *fp;

The FILE structure has been defined in the header file “stdio.h” (standing for standard input/output header file).

Reading from a File

Call to fopen() sets up a pointer that points to the first character in the buffer. This pointer is one of the elements of the structure to which fp is pointing (refer Figure 19.1).

To read the file's contents from buffer we have called fgetc() as under.

ch = fgetc (fp);

fgetc() reads the character from the current pointer position, advances the pointer position so that it now points to the next character, and returns the character that is read, which we collected in the variable ch . Note that once the file has been opened, we no longer refer to the file by its name, but through the file pointer fp .

We have used the function fgetc() in an infinite while loop. We should break out of this loop when all the characters from the file have been read. But how would we know this? Well, fgetc() returns a macro EOF (End of File), once all the characters have been read and we attempt to read one more character. The EOF macro is defined in the file “stdio.h”.

Closing the File

When we have finished reading from the file, we need to close it. This is done using the function fclose() through the statement,

fclose (fp);

Once we close the file, we can no longer read from it using fgetc() . Note that to close the file, we don't use the filename but the file pointer fp .

On closing the file, the buffer associated with the file is removed from memory.

In this program we have opened the file for reading. Suppose we open a file with an intention to write characters into it. This time too, a buffer would get associated with it. When we attempt to write characters into this file using fputc() the characters would get written to the buffer. When we close this file using fclose() two operations would be performed:

(a) The characters in the buffer would be written to the file on the disk.

(b) The buffer would be eliminated from memory.

You can imagine a possibility when the buffer may become full before we close the file. In such a case the buffer's contents would be written to the disk the moment it becomes full. All this buffer management is done for us by the library functions.

Counting Characters, Tabs, Spaces, …

Having understood the first file I/O program, let us write a program that will read a file and count how many characters, spaces, tabs and newlines are present in it. Here is the program…

/* Count chars, spaces, tabs and newlines in a file */

include

```
int main()

{

FILE *fp;

char ch;

int nol = 0, not = 0, nob = 0, noc = 0;

fp = fopen (“PR1.C”, “r”);

while (1)

{

ch = fgetc (fp);

if (ch == EOF)

break;

noc++;

if (ch == ’ ’)

nob++;

if (ch == ’\n’)
nol++;

if (ch == '\t')

not++;

}

fclose (fp);

printf (“Number of characters = %d\n”, noc);

printf (“Number of blanks = %d\n”, nob);

printf (“Number of tabs = %d\n”, not);

printf (“Number of lines = %d\n”, nol);

return 0;

}
```

Here is a sample run…

```
Number of characters = 125

Number of blanks = 25

Number of tabs = 13

Number of lines = 22
```

The above statistics are true for a file “PR1.C”, which I had on my disk. You may give any other filename and obtain different results. I believe the program is self-explanatory. In this program too, we have opened the file for reading and then read it character-by-character. Let us now try a program that needs to open a file for writing.

A File-Copy Program

We have already used the function fgetc() which reads characters from a file. Its counterpart is a function called fputc() which writes characters to a file. As a practical use of these character I/O functions, we can copy the contents of one file into another, as demonstrated in the following program. This program takes the contents of a file and copies them into another file, character-by-character.

include

include

```
int main()

{

FILE *fs, *ft;

char ch;

fs = fopen (“pr1.c”, “r”);

if (fs == NULL)

{

puts (“Cannot open source file”); exit (1);

}

ft = fopen (“pr2.c”, “w”);
if (ft == NULL)

{

puts (“Cannot open target file”);

fclose (fs); exit (2);

}

while (1)

{

ch = fgetc (fs);

if (ch == EOF)

break;

else

fputc (ch, ft);

}

fclose (fs); fclose (ft);

return 0;

}
```

There is a possibility that when we try to open a file using the function fopen() , the file may not be opened. While opening the file in “ r ” mode, this may happen because the file being opened may not be present on the disk at all. And you obviously cannot read a file that doesn't exist.

Similarly, while opening the file for writing, fopen() may fail due to a number of reasons, like, disk space may be insufficient to create a new file, or the disk may be write protected or the disk is damaged and so on.

If fopen() fails to open a file it returns a value NULL (defined in “stdio.h” as #define NULL 0). In this program we have handled this possibility by checking whether fs and ft are set to NULL. If any of them has been set to NULL we have called the exit() function to terminate the execution of the program.

Usually, a value 0 is passed to exit() if the program termination is normal. A non-zero value indicates an abnormal termination of the program. If there are multiple exit points in the program, then the value passed to exit() can be used to find out from where the execution of the program got terminated.

The fputc() function writes a character to a file pointed to by ft . The writing process continues till all characters from the source file have been written to the target file, following which the while loop terminates.

Note that this file-copy program is capable of copying only text files. To copy binary files with extension .EXE or .JPG, we need to open the files in binary mode, which is dealt with in detail in a later section.

File Opening Modes

Following is a list of modes in which a file can be opened along with the tasks performed by fopen() when the file is opened.

String (Line) I/O in Files

For many purposes, character I/O is just what is needed. However, in some situations, the usage of functions that read or write entire strings might turn out to be more efficient. Here is a program that writes strings to a file using fputs() and then reads them back using fgets() .

/* Receives strings from keyboard and writes them to file */

include

include

include

```
int main()

{

FILE *fp;

char s[80];

fp = fopen (“POEM.TXT”, “w”);

if (fp == NULL)

{

puts (“Cannot open file”); exit (1);

}

printf (“\nEnter a few lines of text:\n”);

while (strlen (gets (s)) > 0)

{

fputs (s, fp); fputs (“\n”, fp);

}

fclose (fp);

/* read the file back */

printf (“\nFile contents are being read now…\n”, s);

fp = fopen (“POEM.TXT”, “r”);

if (fp == NULL)

{

puts (“Cannot open file”); exit (2);

}

while (fgets (s, 79, fp) != NULL)

printf (“%s”, s);

fclose (fp);

return 0;

}
```

And here is a sample run of the program…

```
Enter a few lines of text:

Shining and bright, they are forever,

so true about diamonds,
```

more so of memories,

especially yours!

File contents are being read now…

Shining and bright, they are forever,

so true about diamonds,

more so of memories,

especially yours!

During execution, after entering each string hit Enter. To terminate the execution of the loop, hit Enter at the beginning of a line. This creates a string of zero length, which the program recognizes as the signal to end the loop.

We have set up a character array to receive a string; the fputs() function writes the contents of this array to the file. Since fputs() does not automatically add a newline character to the end of the string, we must do this explicitly to make it easier to read the string back from the file.

While reading the file, the function fgets() takes three arguments. The first is the address where the string is stored, and the second is the maximum length of the string. This argument prevents fgets() from reading in too long a string and overflowing the array. The third argument, is the pointer to the structure FILE . On reading a line from the file, the string s would contain the line contents a '\n' followed by a '\0'. Thus the string is terminated by fgets() and we do not have to terminate it specifically. When all the lines from the file have been read, we attempt to read one more line, in which case fgets() returns a NULL .

Text Files and Binary Files

All the programs that we wrote in this chapter so far worked on text files. A text file contains only textual information like alphabets, digits and special symbols. A good example of a text file is any C program, say PR1.C.

As against this, a binary file is merely a collection of bytes. This collection might be a compiled version of a C program (say PR1.EXE), or music data stored in a MP4 file or a picture stored in a JPG file.

A very easy way to find out whether a file is a text file or a binary file is to open that file in Notepad. If on opening the file you can make out what is displayed then it is a text file, otherwise it is a binary file.

From the programming angle there are two main areas where text and binary mode files are different. These are discussed below.

Text versus Binary Mode: Newlines

In text mode, a newline character is converted into the carriage return-linefeed combination before being written to the file. Likewise, the carriage return-linefeed combination in the file is converted back into a newline when the file is read back. If a file is opened in binary mode, these conversions do not take place.

Text versus Binary Mode: Storage of Numbers

While using fprintf() , numbers are stored as character strings. Thus, the integer 12579 occupies 4 bytes in memory, but when written to the file using fprintf() , it would occupy 5 bytes, 1 byte per character. Similarly, the floating-point number 1234.56 would occupy 7 bytes in file. Thus, numbers with more digits would require more storage space.

Hence if large amount of numerical data is to be stored in a disk file, using text mode may turn out to be inefficient. The solution is to open the file in binary mode and use functions fread() and fwrite() which work with numbers in binary format. As a result, each number would occupy same number of bytes on disk as it occupies in memory.

Record I/O in Files

Suppose we wish to perform I/O of data about employees from/to file. For this we would have to create a struct employee and then use the following functions to read/write employee data from/to file.

File opened in text mode - fscanf() / fprintf()

File opened in binary mode - fread() / fwrite()

Given below is the code snippet that shows how to use these functions. You may replace the comments with actual code to make it a fully workable program.

/* Writes / Reads records to / from a file in text / binary mode */

include

```
int main()

{

FILE *fp;

struct emp

{

char name[40]; int age; float bs;

};

struct emp e;

fp = fopen (“EMPLOYEE.DAT”, “w”);

/* run a loop to repeat following statements */

/* add code read a record from keyboard into e */

/* write record to file */

fprintf (fp, “%s %d %f\n”, e.name, e.age, e.bs);

fclose (fp);

fp = fopen (“EMPLOYEE.DAT”, “r”);

/* read records */

while (fscanf (fp, “%s %d %f”, e.name, &e.age, &e.bs) != EOF)

printf (“%s %d %f\n”, e.name, e.age, e.bs);

fclose (fp);

fp = fopen (“EMP.DAT”, “wb”);

/* run a loop to repeat following statements */

/* add code read a record from keyboard into e */

/* write record to file */

fwrite (&e, sizeof (e), 1, fp);

fclose (fp);

fp = fopen (“EMP.DAT”, “rb”);

while (fread (&e, sizeof (e), 1, fp) == 1)

printf (“%s %d %f\n”, e.name, e.age, e.bs);

fclose (fp);

return 0;

}
```

Note that we have opened the binary file ‘EMP.DAT’ in “ rb ” and “ wb ” modes. While opening the file in text mode we can use either “ r ” or “ rt ”, but since text mode is the default mode we usually drop the ‘ t ’.

To read / write a record in a text mode file we have used fscanf() and fprintf() respectively. They work same as scanf() and printf() except that they have an additional first argument fp . This argument indicates the file on which they are supposed to work.

To read / write a record in a binary mode file we have used fread() and fwrite() respectively. Let us understand the following call:

```
fwrite (&e, sizeof (e), 1, fp);
```

Suppose the address of e is 400 and size of e is 48 bytes. So the above call means—starting with address 400, write next 48 bytes, once, into a file pointed to by fp .

Likewise the call,

```
fwrite (&e, sizeof (e), 1, fp);
```

would mean—from a file pointed to by fp , read once, 48 bytes and store them at an address starting from 400.

The text file based record I/O has two disadvantages:

(a) The numbers would occupy more number of bytes, as each number is stored as a character string.

(b) If the number of fields in the structure increase (say, by adding address, house rent allowance, etc.), writing structures using fprintf () , or reading them using fscanf (), would become tedious.

Modifying Records

We know how to read or write records from / to a binary mode fle. But what if we are to modify an existing record? Well, when we open a file fopen() returns a pointer to a structure. This structure contains a pointer which points to the first record in the file. fread() always reads that record where the pointer is currently placed. Similarly, fwrite() always writes the record where the pointer is currently placed. On using the function fread() or fwrite() , the pointer moves to the beginning of the next record. On closing a file the pointer is deactivated.

The rewind() function places the pointer to the beginning of the file, irrespective of where it is present right now. The fseek() function lets us move the pointer from one record to another. These functions have been used in the following code to modify an existing record in a file.

```
printf (“\nEnter name of employee to modify: ”);

scanf (“%s”, empname);

rewind (fp);

while (fread (&e, recsize, 1, fp) == 1)

{

if (strcmp (e.name, empname) == 0)

{

printf (“\nEnter new name, age & bs ”);

scanf (“%s %d %f”, e.name, &e.age, &e.bs);

fseek (fp, -recsize, SEEK_CUR);

fwrite (&e, recsize, 1, fp);

break;

}

}
```

To move the pointer to the previous record from its current position, we have used the function,

```
fseek (fp, -recsize, SEEK_CUR);
```

-recsize moves the pointer back by recsize bytes from the current position. SEEK _ CUR is a macro defined in “stdio.h”.

Similarly, if we wish to place the pointer beyond the last record in the file we can use

fseek (fp, 0, SEEK_END);

In fact, - recsize or 0 are just the offsets that tell the compiler by how many bytes should the pointer be moved from a reference position. The reference position could be SEEK _ END , SEEK _ CUR or SEEK _ SET . SEEK _ END means move the pointer from the end of the file, SEEK _ CUR means move the pointer with reference to its current position and SEEK _ SET means move the pointer with reference to the beginning of the file.

Once the pointer has been properly positioned, we have written a new record that overwrites an existing record.

If we wish to know where the pointer is positioned right now, we can use the function ftell() . It returns this position as a long int which is an offset from the beginning of the file. A sample call to ftell() is shown below.

position = ftell (fp);

where position is a long int .

Low-Level File I/O

In low-level File I/O, data cannot be written as individual characters, or as strings or as formatted data. There is only one way data can be written or read in low-level file I/O functions—as a buffer full of bytes.

Writing a buffer full of data resembles the fwrite() function. However, unlike fwrite() , the programmer must set up the buffer for the data, place the appropriate values in it before writing, and take them out after writing. Thus, the buffer in the low-level I/O functions is part of the program, rather than being invisible as in high-level file I/O functions.

Low-level file I/O functions offer following advantages:

(a) Since these functions parallel the methods that the OS uses to write to the disk, they are more efficient than high-level file I/O functions.

(b) Since there are fewer layers of routines to go through, low-level I/O functions operate faster than their high-level counterparts.

Let us now write a program that uses low-level file input/output functions.

A Low-Level File-Copy Program

Earlier we had written a program to copy the contents of one file to another on a character-by-character basis. We can rewrite the same program to read a chunk of bytes from the source file and then write this chunk into the target file. While doing so the chunk would be read into the buffer and would be written to the file from the buffer. We would manage the buffer ourselves, rather than relying on the library functions to do so. This is what is low-level about this program. Here is a program which shows how this can be done.

/* File-copy program which copies text, .com and .exe files */

include

include

include

include

include

int main()

{

```
char buffer[512], source [128], target [128];

int in, out, bytes;

printf ("\nEnter source file name: ");

gets (source);

in = open (source, ORDONLY | OBINARY);

if (in == -1)

{

puts ("Cannot open file"); exit (1);

}

printf ("\nEnter target file name: ");

gets (target);

out = open (target, OCREAT | OBINARY | OWRONLY, SIWRITE);

if (out == -1)

{

puts ("Cannot open file");

close (in); exit (2);

}

while (1)

{

bytes = read (in, buffer, 512);

if (bytes > 0)

write (out, buffer, bytes);

else

break;

}

close (in); close (out);

return 0;

}
```

Declaring the Buffer

The first difference that you will notice in this program is that we declare a character buffer,

```
char buffer[512];
```

This is the buffer in which the data read from the file will be placed. The size of this buffer is important for efficient operation. Depending on the operating system, buffers of certain sizes are handled more efficiently than others.

Opening a File

We have opened two files in our program, one is the source file from which we read the information, and the other is the target file into which we write the information read from the source file.

As in high-level file I/O, the file must be opened before we can access it. This is done using the statement,

in = open (source, O*RDONLY* | *O*BINARY);

As usual, we have to supply to open() , the filename and the mode in which we want to open the file. The possible file opening modes are given below.

These 'O-flags' are defined in the file "fcntl.h". So this file must be included in the program while using low-level file I/O. When two or more O-flags are used together, they are combined using the bitwise OR operator (|). Chapter 21 discusses bitwise operators in detail.

The other statement used in our program to open the file is,

out = open (target, O*CREAT* | *O*BINARY | O*WRONLY, S*IWRITE);

Note that since the target file doesn't exist when it is being opened, we have used the O*CREAT flag, and since we want to write to the file we have used O*WRONLY. And finally, since we want to open the file in binary mode we have used O_BINARY.

Whenever O_CREAT flag is used, another argument must be added to open() function to indicate the read/write status of the file to be created. This argument is called 'permission argument'. Permission arguments could be any of the following:

S_IWRITE - Writing to the file permitted

S_IREAD - Reading from the file permitted

To use these permissions, both the files "types.h" and "stat.h" present in "sys" folder must be #include d in the program along with "fcntl.h".

File Handles

Instead of returning a FILE pointer as fopen() did, in low-level file I/O, open() returns an integer value called 'file handle'. This is a number assigned to a particular file, which is used thereafter to refer to the file. If open() returns a value of -1, it means that the file couldn't be successfully opened.

Interaction between Buffer and File

The following statement reads the file or as much of it as will fit into the buffer:

bytes = read (inhandle, buffer, 512);

Here the first argument is file handle, the second is the address of the buffer and the third is the maximum number of bytes we want to read.

For copying the file, we must use both the read() and the write() functions in a while loop. The read() function returns the number of bytes actually read. This is assigned to the variable bytes . This variable is used to tell write() how many bytes to write from the buffer to the target file.

P</> Programs

Problem 19.1

Write a program to read a file and display its contents along with line numbers before each line.

Program

/* Program to display a file with line numbers */

include

include

int main()

{

FILE *fp;

```
char ch, source[67];

int count = 1;

printf (“\nEnter file name: ”);

scanf (“%s”, source);

fp = fopen (source, “r”);

if (fp == NULL)

{

puts (“Unable to open the file.”); exit (0);

}

printf (“\n%3d: ”, count);

while ((ch = getc(fp)) != EOF)

{

if (ch == ’\n’)

{

count++;

printf (“\n%3d: ”, count);

}

else

printf (“%c”, ch);

}

fclose (fp);

return 0;

}
```

Output

```
Enter the file name: Sample.txt

1: What is this life

2: if full of care

3: We have not time

4: to stand and stare!
```

Problem 19.2

Write a program to append the contents of one file at the end of another.

Program

```
/* Append contents of one file at the end of another */
```

include

include

include

```
int main()
{
FILE *fs, *ft;
char source[67], target[67], str[80];
puts (“Enter source file name: ”);
gets (source);
puts (“Enter target file name: ”);
gets (target);
fs = fopen (source, “r”);
if (fs == NULL)
{
puts (“Unable to open source file”); exit (0);
}
ft = fopen (target, “a”);
if (ft == NULL)
{
fclose (fs);
puts (“Unable to open target file”); exit (0);
}
while (fgets (str, 79, fs) != NULL)
fputs (str, ft);
printf (“Appending file completed!!”);
fclose (fs);
fclose (ft);
return 0;
}
```

Output

```
Enter source file name:
Sample.txt
Enter target file name:
```

```
NewSample.txt

Appending file completed!!
```

Exercises

[A] Answer the following questions:

(a) In which file FILE structure is defined?

(b) If a file contains the line “I am a boy\r\n” then on reading this line into the array str[] using fgets() what would str[] contain?

(c) State True or False:

The disadvantage of high-level file I/O functions is that the programmer has to manage the file buffers.

If a file is opened for reading, it is necessary that the file must exist.

If a file opened for writing already exists, its contents would be overwritten.

For opening a file in append mode it is necessary that the file should exist.

(d) On opening a file for reading which of the following activities are performed:

The disk is searched for existence of the file.

The file is brought into memory.

A pointer is set up which points to the first character in the file.

All the above.

(e) Is it necessary that a file created in text mode must always be opened in text mode for subsequent operations?

[B] Attempt the following questions:

(a) Suppose a file contains student's records with each record containing name and age of a student. Write a program to read these records and display them in sorted order by name.

(b) Write a program to copy contents of one file to another. While doing so replace all lowercase characters to their equivalent uppercase characters.

(c) Write a program that merges lines alternately from two files and writes the results to new file. If one file has less number of lines than the other, the remaining lines from the larger file should be simply copied into the target file.

(d) Write a program to encrypt/decrypt a file using:

(1) Offset cipher: In this cipher each character from the source file is offset with a fixed value and then written to the target file.

For example, if character read from the source file is ‘A’, then write a character represented by ‘A’ + 128 to the target file.

(2) Substitution cipher: In this cipher each for character read from the source file a corresponding predetermined character is written to the target file.

For example, if character ‘A’ is read from the source file, then a ‘!’ would be written to the target file. Similarly, every ‘B’ would be substituted by ‘5’ and so on.

(e) In the file ‘CUSTOMER.DAT’ there are 10 records with the following structure:

```
struct customer

{

int accno; char name[30]; float balance;

};
```

In another file ‘TRANSACTIONS.DAT’ there are several records with the following structure:

struct trans

{

int accno; char trans_type; float amount;

};

The element trans*type contains D/W indicating deposit or withdrawal of amount. Write a program to update ‘CUSTOMER.DAT’ file, i.e., if the trans*type is ‘D’ then update the balance of ‘CUSTOMER.DAT’ by adding amount to balance for the corresponding accno . Similarly, if trans_type is ’W’ then subtract the amount from balance . However, while subtracting the amount ensure that the amount should not get overdrawn, i.e., at least 100 Rs. should remain in the account.

(f) There are 10 records present in a file with the following structure:

struct date {int d, m, y;};

struct employee

{

int empcode[6]; char empname[20];

struct date join_date; float salary;

};

Write a program to read these records, arrange them in ascending order by join_date and write them to a target file.

(g) A hospital keeps a file of blood donors in which each record has the format:

Name: 20 Columns Address: 40 Columns

Age: 2 Columns Blood Type: 1 Column (Type 1, 2, 3 or 4)

Write a program to read the file and print a list of all blood donors whose age is below 25 and whose blood type is 2.

(h) Given a list of names of students in a class, write a program to store the names in a file on disk. Make a provision to display the n th name in the list, where n is read from the keyboard.

(i) Assume that a Master file contains two fields, roll number and name of the student. At the end of the year, a set of students join the class and another set leaves. A Transaction file contains the roll numbers and an appropriate code to add or delete a student.

Write a program to create another file that contains the updated list of names and roll numbers. Assume that the Master file and the Transaction file are arranged in ascending order by roll numbers. The updated file should also be in ascending order by roll numbers.

(j) Given a text file, write a program to create another text file deleting the words “a”, “the”, “an” and replacing each one of them with a blank space.

File IO functions:

a) High level:

1) Text mode -(i) Formatted (ii) Unformatted

2) Binary mode

b) Low Level

High level text mode formatted file IO functions: fprintf(), fscanf()

High level text mode, unformatted file IO functions:

char - fgetc(), fputc()

int, float - no functions

string - fgets(), fputs()

IO is always done using a buffer of suitable size

High level file IO functions manage the buffer themselves

While using Low level file IO functions we have to manage the buffer

Functions to open and close a file:

High level - fopen(), fclose()

Low level - open(), close()

FILE *fp = fopen (“temp.dat”, “r”);

FILE is a structure declared in stdio.h

fopen() - Creates buffer, Creates structure

- Returns address of structure and assigns to fp

ch = fgetc (fp); - Reads char, Shifts pointer to next char

Returns ASCII value of character read

Returns EOF if no character is left for reading

To read a file character by character till we do not reach the end:

while ((ch = fgetc (fp)) != EOF)

To read a file line by line till we do not reach the end:

char str[80];

while (fgets (fp, str, 79) != NULL)

EOF and NULL are macros defined in stdio.h

define EOF -1

define NULL 0

fopen():

To open file for reading in text mode - “rt” or “r”

To open file for writing in text mode - “wt” or “w”

To open file for reading in binary mode - “rb”

To open file for writing in binary mode - “wb”

Difference:

fs = fopen (s,“r”); - Returns NULL if file is absent

Returns address of FILE structure, if present

ft = fopen (t, “w”); - Creates new file if file is absent

Overwrites file, if present

fclose (fs); - Vacates the buffer

fclose (ft); - Writes buffer to disk, vacates the buffer

To read / write record to a file in text mode:

struct emp e = {“Ajay”, 24, 4500.50};

fprintf (fp, “%s %d %f\n”, e.name, e.age, e.sal);

while (fscanf (fp, “%s %d %f\n”, e.name, &e.age, &e.sal) != EOF)

To read / write record to a file in binary mode:

struct emp e = {“Ajay”, 24, 4500.50};

fwrite (&e, sizeof (e), 1, fp);

while (fread (&e, sizeof (e), 1, fp) ! = EOF)

To move the pointer in a file;

fseek (fp, 512L, SEEK_SET);

Moves the pointer 512 bytes from the beginning of file

Other macros:

SEEK_END - from end of file

SEEK_CUR - from the current position of the pointer

To read / write a buffer of 512 characters using low level file IO functions:

int in, out; char buffer[512];

out = open (“trial.dat”, O*WRONLY* | *O*BINARY | O_CREAT);

in = open (“sample.dat”, O*RDONLY* | *O*BINARY);

write (out, buffer, 512);

n = read (in, buffer, 512); /* n - no. of bytes read successfully */

Include three files while doing low level file IO:

include

include

include

Ever wondered how some programs are able to receive input at command-line itself? And how they are able to redirect their input and output with ease? Well, nothing great, that is, once you have gone through this chapter…

Contents

In Chapters 18 and 19 we saw how Console I/O and File I/O operations are done in C. There are still some more issues related with input/output that remain to be understood. These issues help in making the I/O operations more elegant.

Using argc and argv

While executing the file-copy program in Chapter 18 , we are prompted to enter the source and target filenames. Instead of the program prompting us to enter these filenames, we must be able to supply them at command prompt, in the form:

filecopy PR1.C PR2.C

where, 'filecopy' is the executable form of our C program, 'PR1.C' is the source filename and 'PR2.C' is the target filename. The command prompt is C:> if you are using command window, Windows button if you are using Windows and $ prompt if you are using Linux.

This improvement is possible by passing the source filename and target filename to the function main() . This is illustrated in the program given below.

include

include

int main (int argc, char *argv[])

{

```
FILE *fs, *ft;

char ch;

if (argc != 3)

{

puts (“Improper number of arguments\n”);

exit (1);

}

fs = fopen (argv[1], “r”);

if (fs == NULL)

{

puts (“Cannot open source file\n”);

exit (2);

}

ft = fopen (argv[2], “w”);

if (ft == NULL)

{

puts (“Cannot open target file\n”);

fclose (fs);

exit (3);

}

while (1)

{

ch = fgetc (fs);

if (ch == EOF)

break;

else

fputc (ch, ft);

}

fclose (fs);

fclose (ft);

return 0;

}
```

The arguments that we pass on to main() at the command prompt are called command-line arguments. The function main() can have two arguments, traditionally named as argc and argv . Out of these, argv is an array of pointers to strings and argc is an int whose value is equal to the number of strings to which argv points.

When the program is executed, the strings on the command line are passed to main() . More precisely, the strings at the command line are stored in memory and address of the first string is stored in argv[0] , address of the second string is stored in argv[1] and so on. The argument argc is set to the number of strings given at the command line. For example, in our sample program, if at the command prompt we give,

```
filecopy PR1.C PR2.C
```

then,

argc would contain 3

argv[0] would contain base address of the string ‘filecopy’

argv[1] would contain base address of the string ‘PR1.C’

argv[2] would contain base address of the string ‘PR2.C’

Whenever we pass arguments to main() , it is a good habit to check whether the correct number of arguments have been passed to main() or not. In our program this has been done through,

```
if (argc != 3)

{

puts (“Improper number of arguments\n”);

exit (1);

}
```

Rest of the program is same as the earlier file-copy program.

One final comment… the while loop that we have used in our program can be written in a more compact form, as shown below.

```
while ((ch = fgetc (fs)) != EOF)

fputc (ch, ft);
```

This avoids the usage of an indefinite loop and a break statement to come out of this loop. Here, first fgetc (fs) gets the character from the file, assigns it to the variable ch , and then ch is compared against EOF . Remember that it is necessary to put the expression

```
ch = fgetc (fs)
```

within a pair of parentheses, so that first the character read is assigned to variable ch and then it is compared with EOF .

There is one more way of writing the while loop. It is shown below.

```
while (!feof (fs))

{

ch = fgetc (fs);

fputc (ch, ft);

}
```

Here, feof() is a macro that returns a 0 if end of file is not reached. Hence we use the ! operator to negate this 0 to the truth value. When the end of file is reached, feof() returns a non-zero value, ! makes it 0 and since now the condition evaluates to false, the while loop gets terminated.

Note that the following three methods for opening a file are same, since in each one of them, essentially a base address of the string (pointer to a string) is being passed to fopen() .

```
fs = fopen (“PR1.C”, “r”);

fs = fopen (filename, “r”);

fs = fopen (argv[1], “r”);
```

Detecting Errors in Reading/Writing

Not at all times when we perform a read or write operation on a file, are we successful in doing so. So, there must be a provision to test whether our attempt to read/write was successful or not.

The standard library function ferror() reports any error that might have occurred during a read/write operation on a file. It returns a zero if the read/write is successful and a non-zero value in case of a failure. The following program illustrates the usage of ferror() :

include

```
int main()
{
FILE *fp;
char ch;
fp = fopen (“TRIAL”, “w”);
while (!feof (fp))
{
ch = fgetc (fp);
if (ferror())
{
printf (“Error in reading file\n”);
break;
}
else
printf (“%c”, ch);
}
fclose (fp);
return 0;
}
```

In this program, the fgetc() function would obviously fail first time around since the file has been opened for writing, whereas fgetc() is attempting to read from the file. The moment the error occurs, ferror() returns a non-zero value and the if block gets executed. Instead of printing the error message using printf() , we can use the standard library function perror() which prints the error message specified by the compiler. Thus, in the above program the perror() function can be used as shown below.

```
if (ferror())
{
perror (“TRIAL”);
break;
}
```

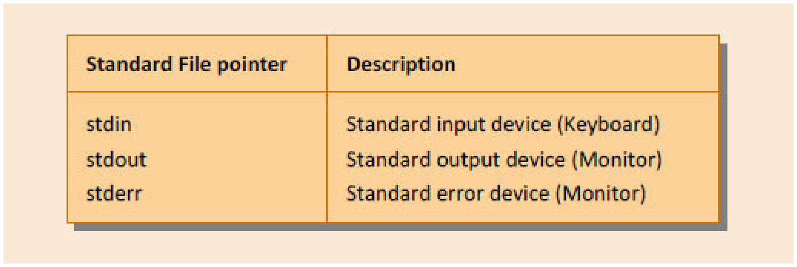
Now when the error occurs, the error message that is displayed is:

```
TRIAL: Permission denied
```

This means we can precede the system error message with any message of our choice. In our program, we have just displayed the filename in place of the error message.

Standard File Pointers

To perform reading or writing operations on a file, we need to use fopen() to set up a file pointer to refer to this file. Most OSs also predefine pointers for three standard files. To access these pointers, we need not use fopen() . These standard file pointers are shown in Figure 20.1 .



Standard File pointer	Description
stdin	Standard input device (Keyboard)
stdout	Standard output device (Monitor)
stderr	Standard error device (Monitor)

Figure 20.1

So if we use the statement ch = fgetc (stdin) , it would read a character from the keyboard rather than from a file. We can use this statement without any need to use fopen() or fclose() function calls.

I/O Redirection

Most operating systems incorporate a powerful feature that allows a program to read form and write to files, even when such a capability has not been incorporated in the program. This is done through a process called ‘redirection’.

Normally a C program receives its input from the standard input device, which is assumed to be the keyboard, and sends its output to the standard output device, which is assumed to be the monitor. In other words, the OS makes certain assumptions about where input should come from and where output should go. Redirection permits us to change these assumptions.

For example, using redirection the output of the program that normally goes to the monitor can be sent to the disk or the printer without really making a provision for it in the program. This is often a more convenient and flexible approach than providing a separate function in the program to write to the disk or printer. Similarly, redirection can be used to read information from disk file directly into a program, instead of receiving the input from keyboard.

To use redirection facility we need is to execute the program from the command prompt, inserting the redirection symbols at appropriate places. Let us understand this process with the help of a program.

Redirecting the Output

Let's see how we can redirect the output of a program, from the screen to a file. We'll start by considering the simple program shown below.

/* File name: util.c */

include

```
int main()

{

char ch;

while ((ch = fgetc (stdin)) != EOF)

fputc (ch, stdout);

return 0;

}
```

On compiling this program, we would get an executable file UTIL.EXE. Normally, when we execute this file, the fputc() function will cause whatever we type to be printed on screen, until we type Ctrl-Z, at which point the program will terminate, as shown in the following sample run. The Ctrl-Z character is often called end of file character.

```
C>UTIL.EXE

perhaps I had a wicked childhood,

perhaps I had a miserable youth,

but somewhere in my wicked miserable past,

there must have been a moment of truth ^Z

C>
```

Now let's see what happens when we invoke this program from in a different way, using redirection:

```
C>UTIL.EXE > POEM.TXT

C>
```

Here we are causing the output to be redirected to the file POEM.TXT. Can we prove that this output has indeed gone to the file POEM.TXT? Yes, by opening the file POEM.TXT in any editor. You would see the result of our typing sitting in the file. The redirection operator, ‘>’, causes any output intended for the screen to be written to the file whose name follows the operator.

Note that the data to be redirected to a file doesn't need to be typed by a user at the keyboard; the program itself can generate it. Any output normally sent to the screen can be redirected to a disk file. As an example, consider the following program for generating the ASCII table on screen:

```
/* File name: ascii.c*/
```

include

```
int main()

{

int ch;

for (ch = 0; ch <= 255; ch++)

printf (“%d %c\n”, ch, ch);

return 0;

}
```

When this program is compiled and then executed at command prompt using the redirection operator,

```
C>ASCII.EXE > TABLE.TXT
```

the output is written to the file. This can be a useful capability any time you want to capture the output in a file, rather than displaying it on the screen.

Redirecting the Input

We can also redirect input to a program so that, instead of reading a character from the keyboard, a program reads it from a file. Let us now see how this can be done.

To redirect the input, we need to have a file containing something to be displayed. Suppose we use a file called NEWPOEM.TXT containing the following lines:

Let’s start at the very beginning,

A very good place to start!

We'll assume that using some text editor these lines have been placed in the file NEWPOEM.TXT. Now, we use the input redirection operator ‘<’

before the file, as shown below.

```
C>UTIL.EXE < NEWPOEM.TXT

Let’s start at the very beginning,

A very good place to start!

C>
```

The lines are printed on the screen with no further effort on our part.

Both Ways at Once

Redirection of input and output can be done together; the input for a program can come from a file via redirection, at the same time its output can be redirected to a file. Such a program is called a filter. The following command demonstrates this process:

```
C>UTIL.EXE < NEWPOEM.TXT > POETRY.TXT
```

In this case, our program receives the redirected input from the file NEWPOEM.TXT and instead of sending the output to the screen; it redirects it to the file POETRY.TXT.

While using such multiple redirections, don't try to send output to the same file from which you are receiving input. This is because the output file is erased before it is written to. So by the time we manage to receive the input from a file, it is already erased.

Redirection can be a powerful tool for developing utility programs to examine or alter data in files. Another OS operator can be used to relate two programs directly, so that the output of one is fed directly into another, with no files involved. This is called ‘piping’, and is done using the operator ‘|’, called pipe. We won’t pursue this topic, but you can read about it in the OS Help.

Exercises

[A] Answer the following:

(a) How will you use the following program to:

- Copy the contents of one file into another.
- Create a new file and add some text to it.
- Display the contents of an existing file.

include

```
int main()

{

char ch, str[10];

while ((ch = fgetc (stdin)) != -1)

fputc (ch, stdout);

return 0;

}
```

(b) State True or False:

We can send arguments at command line even if we define main() function without parameters.

To use standard file pointers we don't need to open the file using fopen() .

The zeroth element of the argv array is always the name of the executable file.

(c) Write a program using command line arguments to search for a word in a file and replace it with the specified word. The usage of the program is shown below.

C> change

(d) Write a program that can be used at command prompt as a calculating utility. The usage of the program is shown below.

C> calc

Where, n and m are two integer operands. switch can be any arithmetic operator. The output should be the result of the operation.

C>, $ are called command prompts in Windows and Linux respectively

Command-line arguments are arguments provided to main() from command-line

Command-line args are collected in main() in variables argc and argv

argc - Count of arguments

argv - Vector (array) of arguments

Any variable names other than argc, argv are ok

char *argv[] is an array of pointers to strings. So all arguments are received as strings and their addresses are stored in argv[]

Errors in reading / writing from / to a file can be detected using ferror() and reported using perror():

```
ch = fgetc (fp);

if (ferror())

    perror (“ERROR while reading”);
```

Most OSs predefine pointers for three standard files:

stdin - standard input device (keyboard)

stdout - standard output device - monitor

stderr - standard error device - monitor

To use and give up these pointers, we need not use fopen() and fclose()

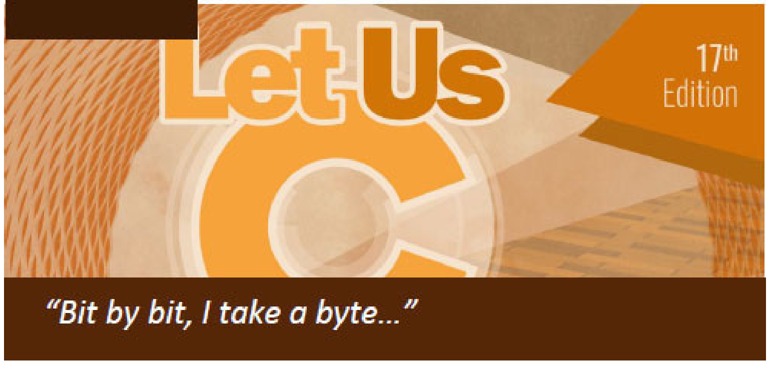
The statement ch = fgetc (stdin) would read a character from the keyboard

If a program uses stdin then using < at command prompt input can be redirected to be received from a file

If a program uses stdout and stderr then using > at command prompt output and error messages can be redirected to a file

The operators < and > are called redirection operators

21 Operations On Bits



"Bit by bit, I take a byte..."

Char is one byte long, and char is the smallest entity that we can handle in a C program. But, at times, we may want to access or manipulate individual bits of a byte. How can this be done? Well, this chapter has the answer…

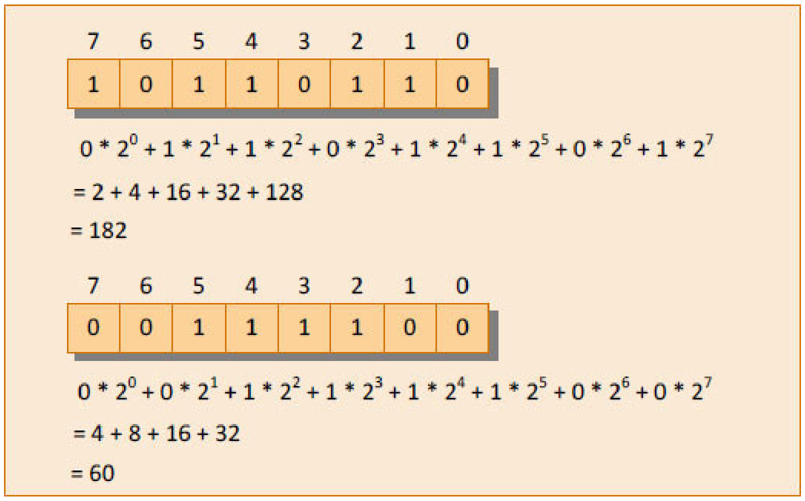
Contents

So far the smallest element in memory on which we were able to operate is a byte, i.e. a char . However, we haven't attempted to look within a byte to see how it is constructed out of individual bits, and how these bits can be manipulated. Being able to operate on a bit-level, can be very important in programming, especially when a program must interact with the hardware. Let us now delve inside the byte and see how it is constructed and how it can be manipulated effectively.

Bit Numbering and Conversion

A bit (short for Binary Digit) is the most basic unit of information. It can take a value 0 or 1. 4 bits together form a nibble, 8 bits form a byte, 16 bits form a word and 32 bits form a double-word. Bits are numbered from zero onwards, increasing from right to left as shown in Figure 21.1 .

C language understands decimal, octal and hexadecimal numbering systems. It doesn't understand binary numbering system. As against this, hardware understands only binary. Hence while programming a hardware we are often required to convert the binary numbers in to decimal or hexadecimal numbers. Let us see how this conversion can be done. Figure 21.1 shows how binary values 10110110 and 00111100 are converted to decimal numbers.

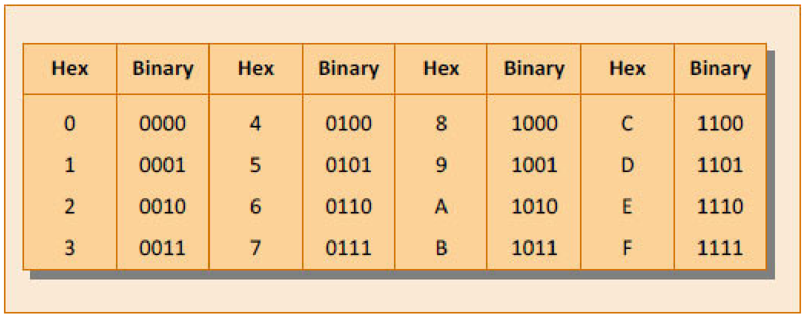


$$0 * 2^0 + 1 * 2^1 + 1 * 2^2 + 0 * 2^3 + 1 * 2^4 + 1 * 2^5 + 0 * 2^6 + 1 * 2^7$$
$$= 2 + 4 + 16 + 32 + 128$$
$$= 182$$

$$0 * 2^0 + 0 * 2^1 + 1 * 2^2 + 1 * 2^3 + 1 * 2^4 + 1 * 2^5 + 0 * 2^6 + 0 * 2^7$$
$$= 4 + 8 + 16 + 32$$
$$= 60$$

Figure 21.1

As you can see from Figure 21.1 , the binary to decimal conversion process involves remembering powers of 2. This is alright if the binary number is a 8-bit number, but if it is a 16-bit number then remembering powers like 2^{15} , 2^{14} , 2^{13} , etc., is difficult. A much easier method is to convert binary numbers to hexadecimal numbers. In hexadecimal numbering system each number is built using a combination of digits 0 to 9 and A to F. Digits A to F are symbols that are used to represent values 10 to 15. Each hexadecimal digit can be represented using a 4-bit nibble as shown in Figure 21.2 .



Hex	Binary	Hex	Binary	Hex	Binary	Hex	Binary
0	0000	4	0100	8	1000	C	1100
1	0001	5	0101	9	1001	D	1101
2	0010	6	0110	A	1010	E	1110
3	0011	7	0111	B	1011	F	1111

Figure 21.2

Using Figure 21.2 , it is very easy to convert binary values into their equivalent hexadecimal values. This is shown in Figure 21.3 .

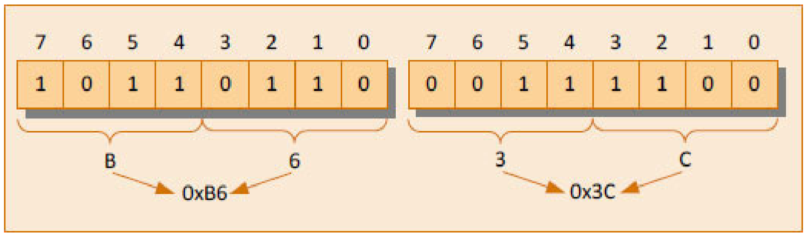


Figure 21.3

You would agree this is an easier way to represent the binary number in hex rather than in decimal as it involves neither multiplication nor addition. Quick now, what's binary 1100 in hex? That's right—C. You are already getting the feel of it. With a little practice, it is easy to translate even long numbers into hex. Thus, 1100 0101 0011 1010 binary is C53A hex.

Bit Operations

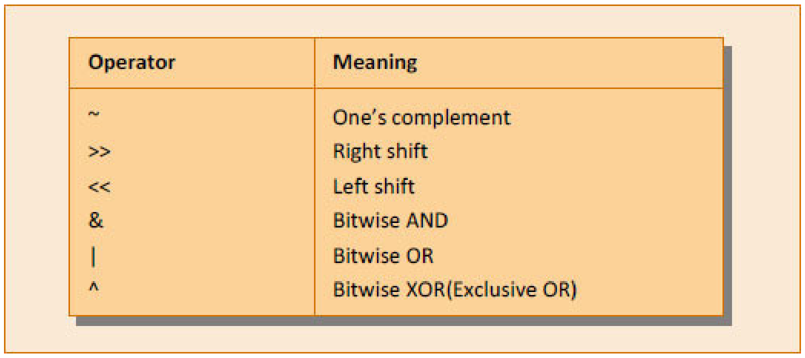
Now that we have understood the bit numbering and the binary to hex conversion process, it is time to access and manipulate bits. Here are some examples of operations that we may wish to perform on bits:

(a) Set bit 3 to 0

(b) Set bit 5 to 1

(c) Check whether bit 6 is 1 (on) or 0 (off)

In (a) and (b) bits are being manipulated (a write operation), whereas, in (c) a bit is being accessed (a read operation). To be able to access or manipulate individual bits, C language provides a powerful set of operators. These are shown in Figure 21.4 .



Operator	Meaning
~	One's complement
>>	Right shift
<<	Left shift
&	Bitwise AND
|	Bitwise OR
^	Bitwise XOR(Exclusive OR)

Figure 21.4

These operators can operate on int s and char s but not on float s and double s. Before we examine these operators, let me introduce you to a function called showbits() . Its job is to display binary equivalent of the value that it receives. We are going to use this function at several palces, but we are going to discuss its details only towards the end of this chapter. Let us now explore the various bitwise operators one-by-one.

One's Complement Operator

On taking one's complement of a number, all 1's present in it are changed to 0's and all 0's are changed to 1's. For example, one's complement of 65, i.e. one's complement of 01000001 (binary equivalent of 65) is 10111110. One's complement operator is represented by the symbol ~ (tilde). Following program shows one's complement operator in action:

include

```
int main()

{

unsigned char ch = 32, dh;

dh = ~ch;

printf (“~ch = %d\n”, dh);

printf (“~ch = %x\n”, dh);

printf (“~ch = %X\n”, dh);

printf (“~ch = %#X\n”, dh);

return 0;

}
```

On execution the program produces the following output:

```
~ch = 223

~ch = df

~ch = DF

~ch = 0xDF
```

Here ch contains a value 32, whose binary equivalent is 00100000. On taking one’s complement of it, we get 11011111, which in decimal is 223. As we learnt earlier, hexadecimal equivalent of 11011111 is DF. The hexadecimal equivalent gets printed in smallcase if we use %x and in capital if we use %X . #X prints 0x before the hexadecimal number.

Right Shift and Left Shift Operators

The right shift operator is represented by >>. It needs two operands. Thus, ch >> 3 would shift all bits in ch three places to the right. Similarly, ch >> 5 would shift all bits 5 places to the right. If ch contains the bit pattern 11010111, then, ch >> 1 would give 01101011 and ch >> 2 would give 00110101.

Note that as the bits are shifted to the right, blanks are created on the left. These blanks get filled with zeros.

The left shift operator (<<) is similar to the right shift operator (>>), the only difference being that the bits are shifted to the left, and for each bit shifted, a 0 is added to the right of the number.

The following program demonstrates the use of >> and << operators:

include

```
void showbits (unsigned char);

int main()

{

unsigned char num = 225, k;

printf ("\nDecimal %d is same as binary ", num);

showbits (num);

k = num >> 1;

printf ("\n%d right shift 1 gives ", num); showbits (k);

k = num >> 2;

printf ("\n%d right shift 2 gives ", num); showbits (k);

k = num << 1;

printf ("\n%d left shift 1 gives ", num); showbits (k);

k = num << 2;

printf ("\n%d left shift 2 gives ", num); showbits (k);

return 0;

}

void showbits (unsigned char n)

{

int i;

unsigned char j, k, andmask;

for (i = 7; i >= 0; i--)

{

j = i;

andmask = 1 << j;

k = n & andmask;

k == 0 ? printf ("0") : printf ("1");

}
```

}

The output of the above program would be…

Decimal 225 is same as binary 11100001

225 right shift 1 gives 01110000

225 right shift 2 gives 00111000

225 left shift 1 gives 11000010

225 left shift 2 gives 10000100

Note that if the operand is a multiple of 2, then shifting the operand 1 bit to right is same as dividing it by 2 and ignoring the remainder. Thus,

64 >> 1 gives 32

64 >> 2 gives 16

128 >> 2 gives 32

but,

27 >> 1 is 13

49 >> 1 is 24

Likewise, left-shifting by 1 would mean multiplying by 2.

A Word of Caution

In the expression a >> b if b is negative the result is unpredictable. If a is negative then its left most bit (sign bit) would be 1. On right shifting a it would result in extending the sign bit. For example, if a contains -5, then its binary equivalent would be 11111011. On right shifting it by 1, right-most bit, i.e. 1 is lost; other bits are shifted one position to the right and the sign is extended, i.e., it is preserved as 1. This yields 11111101, which is equal to -3. The following program would help you get a clear picture of this:

include

void showbits (unsigned char);

int main()

{

char num = -5, j, k;

printf (“\nDecimal %d is same as binary ”, num);

showbits (num);

for (j = 1; j <= 3; j++)

{

k = num >> j;

printf (“\n%d right shift %d gives ”, num, j);

showbits (k);

}

return 0;

}

```
void showbits (unsigned char n)

{

int i;

unsigned char j, k, andmask;

for (i = 7; i >= 0; i--)

{

j = i;

andmask = 1 << j;

k = n & andmask;

k == 0 ? printf (“0”) : printf (”1”);

}

}
```

The output of the above program would be…

```
Decimal -5 is same as binary 11111011

-5 right shift 1 gives 11111101

-5 right shift 2 gives 11111110

-5 right shift 3 gives 11111111
```

Utility of << Operator

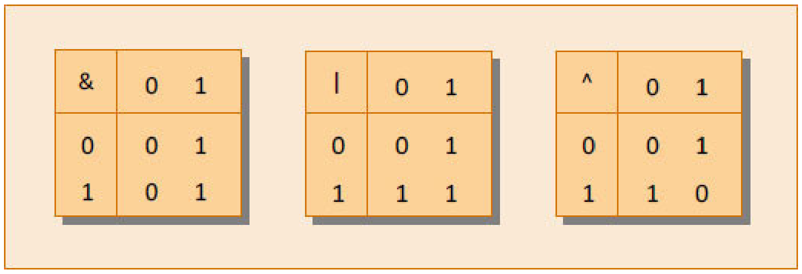
The left shift operator is often used to create a number with a particular bit in it set to 1. For example, we can create a number with its 3 rd bit set to 1 by using the expression 1 << 3. Binary value of 1 is 00000001. On left-shifting this by 3 we get 00001000. Thus we are able to create a value with its 3 rd bit set to 1. Such operations are frequently required while writing programs that interact with hardware or while building embedded systems or IoT systems. Hence it is often done using a macro as shown below.

define _BV(x) (1 << x)

The _ BV macro stands for Bit Value . Its argument indicates which bit in the number would be set when this macro is used. As you must have guessed, during processing the macro _ BV(3) would get expanded to 1 << 3 .

Bitwise AND, OR and XOR Operators

These operators are represented using &, | and ^ respectively. All of them operate on two operands of same type (either char or int). The second operand is often called a mask. These operators operate on pairs of bits to yield resultant bits. The rules that decide the values of resultant bits are given by Truth Tables shown in Figure 21.5 .



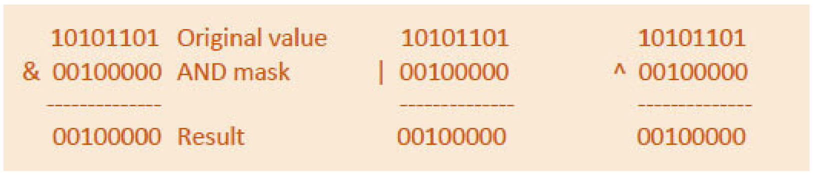
&	0	1
0	0	1
1	0	1

|	0	1
0	0	1
1	1	1

^	0	1
0	0	1
1	1	0

Figure 21.5

The examples given below show what happens when these operators are used. The rules given in the Figure 21.5 are applied to each pair of bits one-by-one to obtain the result. Work through the Truth Tables and confirm that the results obtained are really correct.



```
   10101101  Original value      10101101            10101101
 & 00100000  AND mask          | 00100000          ^ 00100000
  -------------                 -------------       -------------
   00100000  Result             00100000            00100000
```

Thus, it must be clear that the operation is being performed on individual bits, and the operation performed on one pair of bits is completely independent of the operation performed on the other pairs.

Utility of & Operator

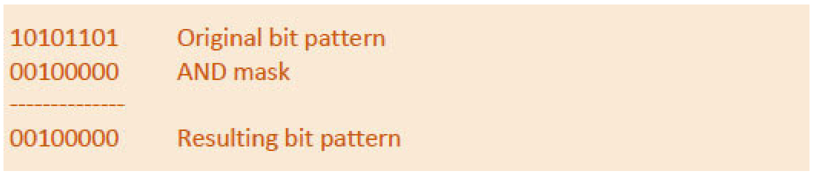
& operator is used in two situations:

(a) To check whether a particular bit of an operand is ON or OFF.

(b) To turn OFF a particular bit.

Both these uses are discussed in the following example.

Suppose, from the bit pattern 10101101 (0xAD), we want to check whether bit number 5 is ON (1) or OFF (0). Since we want to check the bit number 5, the second operand for the AND operation should be 00100000. This second operand if often known as AND mask. The ANDing operation is shown below.

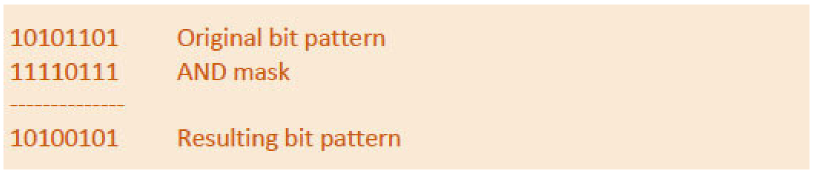


```
10101101       Original bit pattern
00100000       AND mask
-------------
00100000       Resulting bit pattern
```

The resulting value that we get is 32 (or 0x20), which is same as the value of the second operand. The result turned out to be 32 (or 0x20) since the fifth bit of the first operand was ON. Had it been OFF, the bit number 5 in the resulting bit pattern would have evaluated to 0 and the complete bit pattern would have been 00000000.

Thus, depending upon the bit number to be checked in the first operand, we decide the second operand, and on ANDing these two operands the result decides whether the bit was ON or OFF. If the bit is ON (1), the resulting value turns out to be a non-zero value, which is equal to the value of second operand. If the bit is OFF (0), the result is zero, as seen above.

Let us now turn our attention to the second use of the AND operator. As you can see, in the bit pattern 10101101 (0xAD), 3 rd bit is ON. To put it off, we need to AND the 3 rd bit with 0. While doing so the values of other bits in the pattern should not get disturbed. For this we need to AND the other bits with 1. This operation is shown below.



```
10101101       Original bit pattern
11110111       AND mask
-------------
10100101       Resulting bit pattern
```

The following program puts this logic into action:

include

void showbits (unsigned char);

int main()

{

unsigned char num = 0xAD, j;

printf (“\nValue of num = ”);

```
showbits (num);

j = num & 0x20;

if (j == 0)

printf ("\nIts fifth bit is off");

else

printf ("\nIts fifth bit is on");

j = num & 0x08;

if (j == 0)

printf ("\nIts third bit is off");

else

{

printf ("\nIts third bit is on");

num = num & 0xF7;

printf ("\nNew value of num = ");

showbits (num);

j = num & 0x08;

if (j == 0)

printf ("\nNow its third bit is turned off");

}

return 0;

}

void showbits (unsigned char n)

{

int i;

unsigned char j, k, andmask;

for (i = 7; i >= 0; i--)

{

j = i;

andmask = 1 << j;

k = n & andmask;

k == 0 ? printf ("0") : printf ("1");

}

}
```

And here is the output…

```
Value of num = 10101101
```

Its fifth bit is on

Its third bit is on

New value of num = 10100101

Now its third bit is turned off

Note the use of & operator in the statements:

j = num & 0x20;

j = num & 0x08;

num = num & 0xF7;

A quick glance at these statements does not indicate what operation is being carried out through them. Hence a better idea is to use the macro _BV as shown below.

define _BV(x) (1 << x)

j = num & _BV(5);

j = num & _BV(3);

num = num & ~ _BV(3);

In the last statement _BV(3) would yield 00001000 and one’s complement of this number would fetch 11110111.

Utility of | Operator

Bitwise OR operator is usually used to put ON a particular bit in a number.

Let us consider the bit pattern 11000011. If we want to put ON bit number 3, then the OR mask to be used would be 00001000. Note that all the other bits in the mask are set to 0 and only the bit, which we want to set ON in the resulting value is set to 1. The code snippet which will achieve this is given below.

define _BV(x) (1 << x)

unsigned char num = 0xC3;

num = num | _BV(3);

Utility of ^ Operator

XOR operator is used to toggle (change) a bit ON or OFF. A number XORed with another number twice gives the original number. This is shown in the following program:

include

int main()

{

unsigned char b = 0x32; /* Binary 00110010 */

b = b ^ 0x0C;

printf (“%#02x\n”, b); /* this will print 0x3E */

b = b ^ 0x0C;

printf (“%#02x\n”, b); /* this will print 0x32 */

```
return 0;

}
```

The showbits() Function

We have used this function quite often in this chapter. Now we have sufficient knowledge of bitwise operators and hence are in a position to understand it. The function is given below followed by brief explanation.

```
void showbits (unsigned char n)

{

int i;

unsigned char k, andmask;

for (i = 7; i >= 0; i--)

{

andmask = 1 << i;

k = n & andmask;

k == 0 ? printf (“0”) : printf (“1”);

}

}
```

All that is being done in this function is, using an AND operator and a variable andmask , we are checking the status of individual bits of n . If the bit is OFF we print a 0, otherwise we print a 1.

First time through the loop, the variable andmask will contain the value 10000000, which is obtained by left-shifting 1, seven places. If the variable n' s most significant bit (leftmost bit) is 0, then k would contain a value 0, otherwise it would contain a non-zero value. If k contains 0, then printf() will print out 0, otherwise it will print out 1.

In the second go-around of the loop, the value of i is decremented and hence the value of andmask changes, which will now be 01000000. This checks whether the next most significant bit is 1 or 0, and prints it out accordingly. The same operation is repeated for all bits in the number.

Bitwise Compound Assignment Operators

Consider the following bitwise operations:

```
unsigned char a = 0xFA, b = 0xA7, c = 0xFF, d = 0xA3, e = 0x43;

a = a << 1;

b = b >> 2;

c = c | 0x2A;

d = d & 0x4A;

e = e ^ 0x21;
```

These operations can be written more elegantly and in a compact fashion as shown below.

```
unsigned char a = 0xFA, b = 0xA7, c = 0xFF, d = 0xA3, e = 0x43;

a <<= 1;

b >>= 2;

c |= 0x2A;
```

```
d &= 0x4A;

e ^= 0x21;
```

The operators <<= , >>= , |= , &= and ^= are called bitwise compound assignment operators. Note that there does not exist an operator ~= . This is because ~ is a unary operator and needs only one operand.

Problem 21.1

Write a function to calculate the factorial value of any integer entered through the keyboard.

The information about colors is to be stored in bits of a unsigned cha r variable called color . Bit numbers 0 to 6, each represent 7 colors of a rainbow, i.e., bit 0 represents violet, 1 represents indigo, and so on. Write a program that asks the user to enter a number and based on this number it reports which colors in the rainbow do the number represents.

Program

/* To determine the color */

include

define _BV(x) (1 << x)

```
void showbits (unsigned char n);

int main()

{

unsigned char color, i;

int c;

char *rbcolors[] = {“Violet”, “Indigo”, “Blue”, “Green”, “Yellow”, “Orange”, “Red”};

printf (“\nEnter any number: ”);

scanf (“%d”, &c);

color = (unsigned char) c;

printf (“Colors represented are:\n”);

for (i = 0; i <= 6; i++)

{

if ((color & _BV (i)) == _BV (i))

printf (“%s\n”, rbcolors[i]);

}

return 0;

}
```

Output

```
Enter any number: 3

Colors represented are:
```

Violet

Indigo

Problem 21.2

The time field in a structure is 2 bytes long. Distribution of different bits which account for hours, minutes and seconds is given in Figure 21.6 . Write a function that would receive the 2-byte time and return to the calling function, the hours, minutes and seconds.

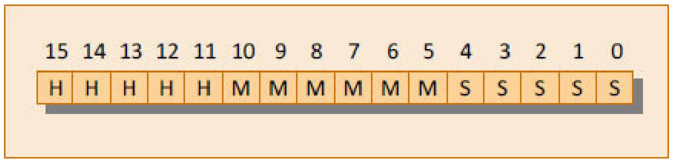


Figure 21.6

Program

```
/* Program to display hour, minute, and seconds */
```

include

```
void display (unsigned short int time);

int main()

{

unsigned short int time;

puts (“Enter any number less than 24446: ”);

scanf (“%hu”, &time);

display (time);

return 0;

}

void display (unsigned short int tm)

{

unsigned short int hours, minutes, seconds, temp;

hours = tm >> 11;

temp = tm << 5;

minutes = temp >> 10;

temp = tm << 11;

seconds = (temp >> 11) * 2;

printf (“For Time = %hu\n”, tm);

printf (“Hours = %hu\n”, hours);

printf (“Minutes = %hu\n”, minutes);

printf (“Seconds = %hu\n”, seconds);

}
```

Output

```
Enter any number less than 24446:

15500

For Time = 15500

Hours = 7

Minutes = 36

Seconds = 24
```

Exercises

[A] Answer the following:

(a) In an inter-college competition, various sports like cricket, basketball, football, hockey, lawn tennis, table tennis, carom and chess are played between different colleges. The information regarding the games won by a particular college is stored in bit numbers 0, 1, 2, 3, 4, 5, 6, 7 and 8, respectively of an integer variable called game . The college that wins in 5 or more than 5 games is awarded the Champion of Champions trophy. If a number representing the bit pattern mentioned above is entered through the keyboard then write a program to find out whether the college won the Champion of the Champions trophy or not, along with the names of the games won by the college.

(b) An animal could be a canine (dog, wolf, fox, etc.), a feline (cat, lynx, jaguar, etc.), a cetacean (whale, narwhal, etc.) or a marsupial (koala, wombat, etc.). The information whether a particular animal is canine, feline, cetacean, or marsupial is stored in bit number 0, 1, 2 and 3, respectively of a integer variable called type . Bit number 4 of the variable type stores the information about whether the animal is Carnivore or Herbivore.

For the following animal, complete the program to determine whether the animal is a herbivore or a carnivore. Also determine whether the animal is a canine, feline, cetacean or a marsupial.

```
struct animal

{

char name[30]; int type;

}

struct animal a = {“OCELOT”, 18};
```

(c) In order to save disk space, information about student is stored in an integer variable. If bit number 0 is on then it indicates I st year student, bit number 1 to 3 stores II nd year, III rd year and IV th year student respectively. Bits 4 to 7 store the stream Mechanical, Chemical, Electronics and CS. Rest of the bits store room number. Such data for 4 students is stored in the following array:

```
int data[] = {273, 548, 786, 1096};
```

Write a program that uses this data and displays the information about the student.

(d) What will be the output of the following program: # include

```
int main()

{

int i = 32, j = 65, k, l, m, n, o, p;

k = i | 35; l = ~k; m = i & j;

n = j ^ 32; o = j << 2; p = i >> 5;

printf (“k = %d l = %d m = %d\n”, k, l, m);

printf (“n = %d o = %d p = %d\n”, n, o, p);
```

return 0;

}

[B] Answer the following:

(a) What is hexadecimal equivalent of the following binary numbers:

01011010 11000011

1010101001110101 1111000001011010

(b) Rewrite the following expressions using bitwise compound assignment operators:

a = a | 3 a = a & 0x48 b = b ^ 0x22 c = c << 2

(c) Consider an unsigned integer in which rightmost bit is numbered as 0. Write a function checkbits (x, p, n) which returns true if all “n” bits starting from position “p” are turned on, false otherwise. For example, checkbits (x, 4, 3) will return true if bits 4, 3 and 2 are 1 in number x .

(d) Write a program to scan a 8-bit number into a variable and check whether its 3 rd , 6 th and 7 th bit is on.

(e) Write a program to receive an unsigned 16-bit integer and then exchange the contents of its 2 bytes using bitwise operators.

(f) Write a program to receive a 8-bit number into a variable and then exchange its higher 4 bits with lower 4 bits.

(g) Write a program to receive a 8-bit number into a variable and then set its odd bits to 1.

(h) Write a program to receive a 8-bit number into a variable and then check if its 3 rd and 5 th bit are on. If these bits are found to be on then put them off.

(i) Write a program to receive a 8-bit number into a variable and then check if its 3 rd and 5 th bit are off. If these bits are found to be off then put them on.

(j) Rewrite the showbits() function used in this chapter using the _BV macro.

Bit = Binary Digit = Basic unit of information

A bit can take a value 0 or 1

Units:

4 bits = Nibble 8 bits = Byte 16 bits = Word 32 bits = Dword

4 Numbering systems:

1) Binary - 0, 1

2) Octal - 0…7

3) Decimal - 0…9

4) Hexadecimal - 0…9, A…F

PC/Laptop understand only Binary numbering system

C/C++ understand Octal, Decimal, Hexadecimal numbering systems

Always try to convert Binary into Hexadecimal instead of Decimal, as while converting to Hex a nibble can be replaced by its equivalent Hex digit

Bitwise Operations:

Set a bit to a value 0/1 → Write operation

Check whether bit 6 is 1 (on) or 0 (off) → Read operation

Bitwise operators purpose:

~ - Converts 0s to 1s and 1s to 0s

<< >> - shift out desired number of bits from left or right

& - Check whether a bit is on / off. Put off a particular bit

| - Put on a particular bit

^ - Toggle a bit

<<= >>= &= |= ^= - Bitwise compound assignment operators

a = a << 5; is same as a <<= 5;

Except ~ all other bitwise operators are binary operators

Remember:

Anything ANDed with 0 is 0

Anything ORed with 1 is 1

1 XORed with 1 is 0

printf ("%#x", var); prints the hexadecimal output preceded by 0x

_BV(3) macro prepares a mask with value 00001000

_BV(4) macro prepares a mask with value 00010000

The _BV macro can be defined as #define _BV(x) 1 << x

22 Miscellaneous Features

"Features that separate men from boys..."

You don't need them. But you should not avoid them. This is because, once you know how to use them, you are well on your way to become a star C programmer. This chapter puts you on that way…

Contents

The topics discussed in this chapter were either too large or far too removed from the mainstream C programming for inclusion in the earlier chapters. These topics provide certain useful programming features, and could prove to be of immense help in certain programming strategies. These include enumerated data types, the typedef keyword, typecasting, bit fields, function pointers, functions with variable number of arguments and unions. Let us understand them one by one.

Enumerated Data Type

The enumerated data type gives us an opportunity to invent our own data type and define what values the variable of this data type can take. This can help in making the program listings more readable, which can be an advantage when a program gets complicated or when more than one programmer would be working on it. Using enumerated data type can also help us reduce programming errors.

As an example, one could invent a data type called mar*status which can have four possible values—single, married, divorced or widowed. The enum declaration of mar*status and definition of variable of type mar_status is given below.

```
enum mar_status

{

single, married, divorced, widowed

};

enum mar_status person1, person2;
```

Now we can give values to these variables.

```
person1 = married;

person2 = divorced;
```

Remember, we can't use values that aren't in the original declaration.

Thus, the following expression would cause an error:

```
person1 = unknown;
```

Internally, the compiler treats the enumerators as integers. Each value on the list of permissible values corresponds to an integer, starting with 0. Thus, in our example, single is stored as 0, married is stored as 1, divorced as 2 and widowed as 3.

This way of assigning numbers can be overridden by the programmer by initializing the enumerators to different integer values as shown below.

```
enum mar_status

{

single = 100, married = 200, divorced = 300, widowed = 400
};
```

Uses of Enumerated Data Type

Enumerated variables are usually used to clarify the operation of a program. For example, if we need to use employee departments in a payroll program, it makes the listing easier to read if we use values like Assembly, Manufacturing, Accounts rather than the integer values 0, 1, 2, etc. The following program illustrates the point I am trying to make:

include

include

```
int main()

{

enum department

{

assembly, manufacturing, accounts, stores

};

struct employee

{

char name[30]; int age; enum department dept;

};

struct employee e;

strcpy (e.name, “Lothar Mattheus”);

e.age = 28;

e.dept = manufacturing;

printf (“Name = %s\n”, e.name);

printf (“Age = %d\n”, e.age);

printf (“Department = %d\n”, e.dept);

if (e.dept == accounts)

printf (“%s is an accounant\n”, e.name);

else

printf (“%s is not an accounant\n”, e.name);

return 0;

}
```

And here is the output of the program…

```
Name = Lothar Mattheus

Age = 28

Department = 1
```

Lothar Mattheus is not an accountant

Let us now dissect the program. We first defined the data type enum department and specified the four possible values, namely, assembly, manufacturing, accounts and stores. Then we defined a variable dept of the type enum department in a structure. The structure employee has two other elements containing employee information.

The program first assigns values to the variables in the structure. The statement,

e.dept = manufacturing;

assigns the value manufacturing to e.dept variable. This is much more informative to anyone reading the program than a statement like,

e.dept = 1;

The next part of the program shows an important weakness of using enum variables… there is no way to use the enumerated values directly in input/output functions like scanf() and printf() .

The printf() function is not smart enough to perform the translation; the department is printed out as 1 and not manufacturing. Of course, we can write a function to print the correct enumerated values, using a switch statement, but that would reduce the clarity of the program. Even with this limitation, however, there are many situations in which enumerated variables are god sent!

Are Enums Necessary?

Can we not achieve the same convenience and readability by using macros like

define ASSEMBLY 0

define MANUFACTURING 1

define ACCCOUNTS 2

define STORES 3

We can, but macros have a serious limitation—they have a global scope, whereas, scope of enum can either be global (if declared outside all functions) or local (if declared inside a function).

Renaming Data Types with typedef

There is one more technique, which, in some situations, can help to clarify the source code of a C program. This technique is to make use of the typedef declaration. Its purpose is to redefine the name of an existing variable type.

For example, consider the following statement in which the type unsigned long int is given a new name UTI :

typedef unsigned long int UTI;

Now we can declare variables of the type unsigned long int by writing,

UTI var1, var2;

instead of

unsigned long int var1, var2;

Thus, typedef provides a nice shortcut. Usually, uppercase letters are used to make it clear that we are dealing with a renamed data type.

While the increase in readability is probably not great in this example, it can be significant when the name of a particular data type is long and unwieldy, as it often is with structure declarations. For example, consider the following structure declaration:

struct employee

{

```
char name[30]; int age; float bs;

};

struct employee e;
```

This structure declaration can be made more handy to use when renamed using typedef as shown below.

```
struct employee

{

char name[30]; int age; float bs;

};

typedef struct employee EMP;

EMP e1, e2;
```

Thus, by reducing the length and apparent complexity of data types, typedef can help to clarify source listing and save time and energy spent in understanding a program.

The above typedef can also be written as

```
typedef struct employee

{

char name[30]; int age; float bs;

} EMP;

EMP e1, e2;
```

typedef can also be used to rename pointer data types as shown below.

```
struct employee

{

char name[30]; int age; float bs;

}

typedef struct employee * PEMP;

PEMP p;

p -> age = 32;
```

Typecasting

Sometimes we are required to force the compiler to explicitly convert the value of an expression to a particular data type. This would be clear from the following example:

include

```
int main()

{

float a, b;

int x = 6, y = 4;

a = x / y;
printf (“Value of a = %f\n”, a);

b = (float) x / y;

printf (“Value of b = %f\n”, b);

return 0;

}
```

And here is the output…

```
Value of a = 1.000000

Value of b = 1.500000
```

The answer turns out to be 1.000000 and not 1.5. This is because, 6 and 4 are both integers and hence 6 / 4 yields an integer, 1. This 1 when stored in a is converted to 1.000000. But what if we don't want the quotient to be truncated? One solution is to make either x or y as float . Let us say that other requirements of the program do not permit us to do this. In such a case what do we do? Use typecasting. This consists of putting a pair of parentheses around the name of the target data type. In this program we said,

```
b = (float) x / y;
```

The expression (float) causes the variable x to be converted from type int to type float before being used in the division operation.

Bit Fields

Suppose we want to store the following data about an employee. Each employee can:

(a) Be male or female

(B) Be single, married, divorced or widowed

(c) Have one of the eight different hobbies

(d) Can choose from any of the fifteen different schemes proposed by the company to pursue his/her hobby.

This means we need 1 bit to store gender, 2 to store marital status, 3 for hobby, and 4 for scheme (with one value used for those who are not desirous of availing any of the schemes). Thus, we need 10 bits altogether to store this data. So why waste multiple integers when 10 bits will do? In such cases we can use ‘bit fields’ to store several values in a single integer. The following program shows how to use bit fields.

include

define MALE 0;

define FEMALE 1;

define SINGLE 0;

define MARRIED 1;

define DIVORCED 2;

define WIDOWED 3;

```
int main()
```

```
{
struct employee
{
unsigned gender : 1; unsigned mar_stat : 2;
unsigned hobby : 3; unsigned scheme : 4;
};
struct employee e;
e.gender = MALE;
e.mar_status = DIVORCED;
e.hobby = 5;
e.scheme = 9;
printf (“Gender = %d\n”, e.gender);
printf (“Marital status = %d\n”, e.mar_status);
printf (“Bytes occupied by e = %d\n”, sizeof (e));
return 0;
}
```

And here is the output…

```
Gender = 0
Marital status = 2
Bytes occupied by e = 2
```

Observe the declaration of struct employee . The colon (:) in the declaration tells the compiler that we are talking about bit fields and the number after it tells how many bits to allot for the field. Once we have established a bit field, we can reference it just like any other structure element.

Pointers to Functions

Like variables, functions are also stored in memory. So they also have addresses. So if we store the address of a function in a variable it would be a function pointer. Function pointers provide one more way to invoke functions. Let us see how this can be done.

include

```
void display();
int main()
{
void (*ptr)();
ptr = display; /* assign address of function */
printf (“Address of function display is %u\n”, ptr);
(ptr)(); / invokes the function display() */
display(); /* usual way of invoking a function */
return 0;
}
void display()
{
printf ("Long live excellence!!\n");
}
```

The output of the program would be:

```
Address of function display is 4198924
Long live excellence!!
Long live excellence!!
```

Note that, to obtain the address of a function, all that we have to do is mention the name of the function. This is similar to mentioning the name of the array to get its base address.

We have assigned the address of display() to ptr . The declaration of ptr states that it is a pointer to a function that receives nothing and returns nothing. To call the function using ptr , we are just required to write the statement,

(*ptr)(); /* or simply, ptr(); */

There are two possible uses of function pointers:

(a) In implementing callback mechanisms used popularly in Windows programming.

(b) In binding functions dynamically, at run-time in C++ programming.

These topics are beyond the scope of this book. If you want to explore them further you can refer the book "Let Us C++" or "Test Your C++ Skills" by Yashavant Kanetkar.

Functions Returning Pointers

A function can even return a pointer. This has to be explicitly mentioned in the prototype declaration as well as in the function definition. The following program illustrates this:

```
int *fun();
int main()
{
int *p;
p = fun();
return 0;
}
int *fun()
{
static int i = 20;
return (&i);
}
```

This program just indicates how an integer pointer can be returned from a function. Beyond that, it doesn't serve any useful purpose. This concept can be put to use while handling strings. For example, a function can copy one string into another and return the pointer to the target string. Try defining this function as an exercise.

Functions with Variable Number of Arguments

Functions like printf() can receive different number of arguments during different calls. How can we define such functions? Well, this can be done using three macros va*start , va*arg and va_list . These macros are defined in the file “ stdarg.h ”.

These macros provide a method for accessing the arguments of the function when a function takes a fixed number of arguments followed by a variable number of arguments. The fixed number of arguments are accessed in the normal way, whereas the optional arguments are accessed using these macros. Out of these macros, va*start is used to initialize a pointer to the beginning of the list of optional arguments. On the other hand, the macro va*arg is used to advance the pointer to the next argument.

Let us put these concepts into action in a program. Suppose we wish to define a function findmax() which can find out the maximum value from a set of values, irrespective of the number of values passed to it. Here is how we can do it…

include

include

```
int findmax (int, …);

int main()

{

int max;

max = findmax (5, 23, 15, 1, 92, 50);

printf (“maximum = %d\n”, max);

max = findmax (3, 100, 300, 29);

printf (“maximum = %d\n”, max);

return 0;

}

int findmax (int tot_num, …)

{

int max, count, num;

va_list ptr;

vastart (ptr, totnum);

max = va_arg (ptr, int);

for (count = 1; count < tot_num; count++)

{

num = va_arg (ptr, int);

if (num > max)

max = num;

}

return (max);

}
```

Note how the findmax() function has been declared. The ellipses (…) indicate that the number of arguments after the first argument would be variable.

Here we are making two calls to findmax() , first time to find maximum out of 5 values and second time to find maximum out of 3 values. Note that for each call the first argument is the count of arguments that follow the first argument. The value of the first argument passed to findmax() is collected in the variable tot*num . findmax() begins with a declaration of a pointer ptr of the type va*list . Observe the next statement carefully.

va*start (ptr, tot*num);

This statement sets up ptr such that it points to the first variable argument in the list. If we are considering the first call to finndmax() , ptr would now point to 23. The statement max = va_arg (ptr, int) would assign the integer being pointed to by ptr to max . Thus, 23 would be assigned to max , and ptr would now start pointing to the next argument, i.e. 15. The rest of the program is fairly straightforward. We just keep picking up successive numbers in the list and keep comparing them with the latest value in max , till all the arguments in the list have been scanned. The final value in max is then returned to main() .

Unions

Unions are derived data types that enable us to treat the same space in memory as a number of different variables. Let us take a look at a simple program that illustrates this.

/* Demo of union at work */

include

```
int main()

{

union u

{

short int i; char ch[2];

};

union u key;

key.i = 512;

printf (“key.i = %d\n”, key.i);

printf (“key.ch[0] = %d\n”, key.ch[0]);

printf (“key.ch[1] = %d\n”, key.ch[1]);

return 0;

}
```

And here is the output…

```
key2.i = 512

key2.ch[0] = 0

key2.ch[1] = 2
```

To begin with, we have declared a data type union a . Then we have defined variable key o f this type. Next, the union elements are printed. Like structure elements, union elements too are accessed using the ‘ .’ operator. To understand the output of the program we first need to understand how key looks like. This is shown in Figure 22.1

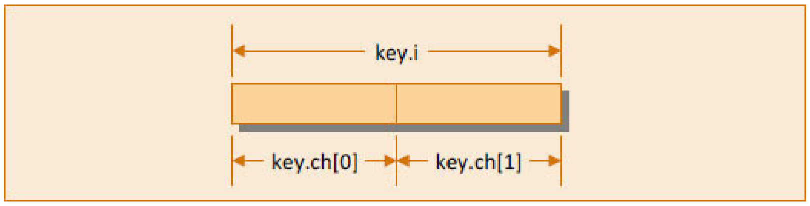


Figure 22.1

As you can see, key occupies 2 bytes in memory. The same memory locations used by key.i are also being used by key.ch[0] and key.ch[1] . What purpose does this serve? Well, now we can access the 2 bytes taken together by using key.i , or the same 2 bytes individually by using key.ch[0] and key.ch[1] .

Let us now understand the output of the program. Binary equivalent of 512 is 00000010 00000000. So output of union elements key.ch[0] and key.ch[1] should have been 2 and 0 respectively. But, the output is exactly the opposite. Why is it so? Because, in CPUs that follow little-endian architecture (Intel CPUs, for example), when a 2-byte number is stored in memory, the low byte is stored before the high byte. It means, actually 512 would be stored in memory as 00000010 00000000. These converted to decimal turn out to be 2 and 0. In CPUs with big-endian architecture this reversal of bytes does not happen.

One last thing. We can't assign different values to the different union elements at the same time. That is, if we assign a value to key.i , it gets automatically assigned to key.ch[0] and key.ch[1] . Vice versa, if we assign a value to key.ch[0] or key.ch[1] , it is bound to get assigned to key.i .

Before we move on to the next section, let us reiterate that a union provides a way to look at the same data in several different ways. For example, suppose we declare a union as shown below.

```
union b

{

double d; float f[2]; short int i[4]; char ch[8];

};

union b data;
```

In what different ways can the data be accessed from it? Sometimes, as a complete set of 8 bytes (data.d), sometimes as two sets of 4 bytes each (data.f[0] and data.f[1]), sometimes as four sets of 2 bytes each (data.i[0] , data.i[1] , data.i[2] and data.[3]) and sometimes as 8 individual bytes (data.ch[0] , data.ch[1]… data.ch[7]).

Also note that there can exist a union, each of whose elements is of different size. In such a case, the size of the union variable will be equal to the size of the longest element in the union.

Utility of Unions

Suppose we wish to store information about employees in an organization. The items of information are as shown below.

Name, Grade, Age

If Grade = HSK (Highly Skilled) - hobbie name, credit card no.

If Grade = SSK (Semi Skilled) - Vehicle no., Distance from Co.

Since this is dissimilar information we can gather it together using a structure as shown below.

```
struct employee

{

char n[20]; char grade[4]; int age; char hobby[10];

int crcardno; char vehno[10]; int dist;

};

struct employee e;
```

Though grammatically this structure declaration is correct, it suffers from a disadvantage. For any employee, depending upon his/her grade, either the elements hobby and credit card no. or the elements vehicle number and distance would get used. Both sets of elements would never get used. This would lead to wastage of memory with every structure variable that we create, since every structure variable would have all the four fields apart from name, grade and age.

This can be avoided by creating a union between these sets of elements as shown below.

```
struct info1

{

char hobby[10]; int crcardno;

};

struct info2

{

char vehno[10]; int dist;

};

union info

{

struct info1 a; struct info2 b;

};

struct employee

{

char n[20]; char grade[4]; int age; union info f;

};

struct employee e;
```

The volatile Qualifier

When we define variables in a function the compiler may optimize the code that uses the variable. That is, the compiler may compile the code in a manner that will run in the most efficient way. The compiler achieves this by using a CPU register to store the variable's value rather than storing it in stack.

However, if we declare the variable as volatile, then it serves as a warning to the compiler that it should not optimize the code containing this variable. In such a case whenever we use the variable its value would be loaded from memory into register, operations would be performed on it and the result would be written back to the memory location allocated for the variable.

We can declare a volatile variable as:

```
volatile float temperature;
```

We may want to prevent optimization when the variable is not within the control of the program and is likely to get altered from outside the program.

P</> Programs

Problem 22.1

Write a function to calculate the factorial value of any integer entered through the keyboard.

The information about colors is to be stored in bits of a unsigned cha r variable called color . Bit numbers 0 to 6, each represent 7 colors of a rainbow, i.e., bit 0 represents violet, 1 represents indigo, and so on.

Write a program that asks the user to enter a number and based on this number it reports which colors in the rainbow do the number represents.

Program

/* Call function using an array of function pointers */

include

```
float fun1 (int, int);
float fun2 (int, int);
float fun3 (int, int);
float fun1 (int i, int j)
{
printf ("In fun1\n"); return 1.0f;
}
float fun2 (int i, int j)
{
printf ("In fun2\n"); return 2.0f;
}
float fun3 (int i, int j)
{
printf ("In fun3\n"); return 3.0f;
}
int main()
{
float (*ptr[3]) (int, int);
float f; int i;
ptr[0] = fun1; ptr[1] = fun2; ptr[2] = fun3;
for (i = 0; i < 3; i++)
{
f = (*ptr[i])(100, i);
printf ("%f\n", f);
}
return 0;
}
```

Output

```
In fun1
1.000000
```

```
In fun2

2.000000

In fun3

3.000000
```

Problem 22.2

Define a function which can find average of the arguments passed to it. Note that in different calls the function may receive different number of arguments.

Program

include

include

```
int findavg (int, …);

int main()

{

int avg;

avg = findavg (5, 23, 15, 1, 92, 50);

printf (“avg = %d\n”, avg);

avg = findavg (3, 100, 30, 29);

printf (“avg = %d\n”, avg);

return 0;

}

int findavg (int tot_num, …)

{

int avg, i, num, sum;

va_list ptr;

vastart (ptr, totnum);

sum = 0;

for (i = 1; i <= tot_num; i++)

{

num = va_arg (ptr, int);

sum = sum + num;

}

return (sum / tot_num);

}
```

Output

```
avg = 36

avg = 53
```

Exercises

[A] What will be the output of the following programs:

```
(a) # include

int main()

{

enum status {pass, fail, atkt};

enum status stud1, stud2, stud3;

stud1 = pass;

stud2 = fail;

stud3 = atkt;

printf (“%d %d %d\n”, stud1, stud2, stud3);

return 0;

}
```

```
(b) # include

int main()

{

printf (“%f\n”, (float) ((int) 3.5 / 2));

printf (“%d\n”, (int) (((float) 3 / 2) * 3));

return 0;

}
```

[B] Point out the error, if any, in the following programs:

```
(a) # include

int main()

{

typedef struct patient

{

char name[20]; int age;

int systolicbp; int diastolicbp;

} ptt;

ptt p1 = {“anil”, 23, 110, 220};

printf (“%s %d\n”, p1.name, p1.age);

printf (“%d %d\n”, p1.systolicbp, p1.diastolicbp);
return 0;
}
```

(b) # include

```
void show();
int main()
{
void (*s)();
s = show;
(*s)(); s();
return 0;
}
void show()
{
printf (“don’t show off. It won’t pay in the long run\n”);
}
```

(c) # include

```
void show (int, float);
int main()
{
void (*s)(int, float);
s = show;
(*s)(10, 3.14);
return 0;
}
void show (int i, float f)
{
printf (“%d %f\n”, i, f);
}
```

[C] Attempt the following:

(a) Write a program, which stores information about a date in a structure containing three members—day, month and year. Using bit fields the day number should get stored in first 5 bits of day, the month number in 4 bits of month and year in 12 bits of year. Write a program to read date of joining of 10 employees and display them in ascending order of year.

(b) Write a program to read and store information about insurance policy holder. The information contains details like gender, whether the holder is minor/major, policy name and duration of the policy. Make use of bit-fields to store this information.

We can write programs without using miscellaneous features like union, enum, etc. But that is not advisable

Often we are required to handle an ordered listing of items. Example, colors like red, green, blue or marital status like married, unmarried or divorced. Instead of handling these as integers, enums are a better way.

Usage of enums:

enum color {red, green, blue};

enum color windowcolor, buttoncolor;

windowcolor = green; buttoncolor = blue;

printf (“%d %d”, windowcolor, buttoncolor);

A typedef declaration can be used to redefine the name of an existing data type as in

typedef unsigned long int ULI;

ULI var1, var2;

Usually, uppercase letters are used to make it clear that we are dealing with a renamed data type

typecasting can be used to forcibly convert the value of an expression to a particular data type

Multiple items of information can be stored in a byte using bit fields

struct employee

{

unsigned gender: 1; unsigned mar_stat: 2;

};

The number after colon (:) indicates the number of bits to allot for the field

void *p(); - Prototype of a function p()that receives nothing and returns a void *

void (*P)(); - p is pointer to a function that receives nothing and returns nothing

float * (*p)(int, float); - Pointer to a function that receives int & float and returns a float *

Usage of function pointer:

void (*p)();

P = display; /* stores address of display function in p */

(*p)(); /* first way to call display() */

p(); /* one more way to call display() */

We can write a function that receives a variable number of arguments using macros va*list, va*start, va_arg.

Size of a structure is sum of sizes of its elements. Elements are accessed using.

Size of union variable is size of biggest element of the union. Elements are accessed using .

Utility of union - Permits access to same memory locations in multiple ways

Usage:

union a

```
{

int i; char ch[4];

};

union a z;

z.i = 512;

printf ("%d %d %d %d %d", z.i, z.ch[0], z.ch[1], z.ch[2], z.ch[3]);
```

If a number is ABCD then in little endian architecture it is stored as DCBA

Little Endian - Low byte is stored first. Big Endian - High byte is stored first. Endianness is a matter of convenience. So both are good

All that you learnt in this book would be put to test, when you attend an interview for a programmer's post in a software company. You may know the answer to the question, but the way it is presented is what makes all the difference. This chapter will guide you through those "expected" answers for typical C interview questions…

In the interview room you would be tested for three skills— Knowledge, Problem Solving Skills and Social Skills. You might be led to believe that in the interview room what matter is your personality, how smartly you answer questions, how are your mannerisms, etc. In fact the truth is much farther than that. All of these in my estimate have only 10% importance. Much more weightage is given to your knowledge and problem solving skills. If you are found good in these areas, then only the interview panel would be even interested in checking your social skills. With this in mind, I have given below questions that are very commonly asked in the interview rooms.

Question 1

What is a Programming Paradigm?

Answer

Programming paradigm means the principle that is used for organizing programs. There are two major Programming Paradigms, namely, Structured Programming and Object Oriented Programming (OOP). C language uses the Structured Programming Paradigm, whereas, C++, C#, VB.NET or Java make use of OOP. OOP has lots of advantages to offer. But even while using this organizing principle you would still need a good hold over the language elements of C and the basic programming skills.

Question 2

Is it true that Operating Systems like Windows, Linux and UNIX are written in C?

Answer

Major parts of popular operating systems like Windows, UNIX, Linux are still written in C. This is because even today when it comes to performance (speed of execution) nothing beats C. Also, the functions exposed by the Operating System API can be easily called through any language.

Moreover, if one is to extend the operating system to work with new devices one needs to write Device Driver programs. These programs are exclusively written in C.

Question 3

What do you mean by scope of a variable? What are the different types of scopes that a variable can have?

Answer

Scope indicates the region over which the variable's declaration has an effect. The four kinds of scopes are—file, function, block and prototype.

Question 4

Which of the following statement is a declaration and which is a definition?

```
extern int i;

int j;
```

Answer

First is declaration, second is definition.

Question 5

What are the differences between a declaration and a definition?

Answer

There are two differences between a declaration and a definition:

In the definition of a variable space is reserved for the variable and some initial value is given to it, whereas a declaration only identifies the type of the variable. Thus definition is the place where the variable is created or assigned storage, whereas declaration refers to places where the nature of the variable is stated but no storage is allocated.

Secondly, redefinition is an error, whereas, redeclaration is not an error.

Question 6

Is it true that a global variable may have several declarations, but only one definition? [Yes/No]

Answer

Yes

Question 7

Is it true that a function may have several declarations, but only one definition? [Yes/No]

Answer

Yes

Question 8

When we mention the prototype of a function are we defining the function or declaring it?

Answer

We are declaring it. When the function, along with the statements belonging to it is mentioned, we are defining the function.

Question 9

Some books suggest that the following definitions should be preceded by the word static . Is it correct?

```
int a[] = {2, 3, 4, 12, 32};

struct emp e = {“sandy”, 23};
```

Answer

Pre-ANSI C compilers had such a requirement. Compilers which conform to ANSI C standard do not have such a requirement.

Question 10

If you are to share the variables or functions across several source files how would you ensure that all definitions and declarations are consistent?

Answer

The best arrangement is to place each definition in a relevant '.c' file. Then, put an external declaration in a header file ('.h' file) and use #include to bring in the declaration wherever needed. The '.c' file which contains the definition should also include the header file, so that the compiler can check that the definition matches the declaration.

Question 11

Global variables are available to all functions. Does there exist a mechanism by way of which I can make it available to some and not to others?

Answer

No. The only way this can be achieved is to define the variable locally in main() instead of defining it globally and then passing it to the functions which need it.

Question 12

What are the different types of linkages?

Answer

There are three different types of linkages—external, internal and none. External linkage means global, non-static variables and functions, internal linkage means static variables and functions with file scope, and no linkage means local variables.

Question 13

What is size_t ?

Answer

It is the type of the result of the sizeof operator. size_t is used to express the size of something or the number of characters in something. For example, it is the type that you pass to malloc() to indicate how many bytes you wish to allocate. Or it is the type returned by strlen() to indicate the number of characters in a string.

Each implementation chooses a type like unsigned int or unsigned long (or something else) to be its size*t , depending on what makes most sense. Each implementation publishes its own choice of size*t in several header files like 'stdio.h', 'stdlib.h', etc. In most implementations size_t is defined as:

typedef unsigned int size_t;

This means that on this particular implementation size_t is an unsigned int . Other implementations may make other choices.

What is important is that you should not worry about what size_t looks like for a particular implementation; all you should care about is that it is the right type for representing object sizes and count.

Question 14

What is more efficient, a switch statement or an if-else chain?

Answer

As far as efficiency is concerned there would hardly be any difference, if at all. If the cases in a switch are sparsely distributed the compiler may internally use the equivalent of an if-else chain instead of a compact jump table. However, one should use switch where one can. It is definitely a cleaner way to program and certainly is not any less efficient than the if-else chain.

Question 15

Can we use a switch statement to switch on strings?

Answer

No. The cases in a switch must either have integer constants or constant expressions.

Question 16

In which order do the Relational, Arithmetic, Logical and Assignment operators get evaluated in C?

Answer

Arithmetic, Relational, Logical, Assignment

Question 17

How come that the C standard says that the expression

j = i++ * i++;

is undefined, whereas, the expression

j = i++ && i++;

is perfectly legal?

Answer

According to the C standard an object's stored value can be modified only once (by evaluation of expression) between two sequence points. A sequence point occurs:

- At the end of full expression (expression which is not a sub-expression in a larger expression)
- At the &&, || and ?: operators
- At a function call (after the evaluation of all arguments, just before the actual call)

Since in the first expression i is getting modified twice between two sequence points the expression is undefined. Also, the second expression is legal because a sequence point is occurring at && , and i is getting modified once before and once after this sequence point.

Question 18

If a[i] = i++ is undefined, then by the same reason i = i + 1 should also be undefined. But it is not so. Why?

Answer

The standard says that if an object is to get modified within an expression then all accesses to it within the same expression must be for computing the value to be stored in the object. The expression a[i] = i++ is disallowed because one of the accesses of i (the one in a[i]) has nothing to do with the value that ends up being stored in i . In this case the compiler may not know whether the access should take place before or after the incremented value is stored. Since there's no good way to define it, the standard declares it as undefined. As against this, the expression i = i + 1 is allowed because i is accessed to determine i 's final value.

Question 19

Will the expression *p++ = c be disallowed by the compiler?

Answer

No. Because here even though the value of p is accessed twice it is used to modify two different objects p and *p .

Question 20

Why should I use functions at all?

Answer

There are two reasons for using functions:

(a) Writing functions avoids rewriting the same code over and over. Suppose you have a section of code in your program that calculates area of a triangle. If later in the program you want to calculate the area of a different triangle, you won't like it if you are required to write the same instructions all over again. Instead, you would prefer to jump to a 'section of code' that calculates area and then jump back to the place from where you left off. This section of code is nothing but a function.

(b) By using functions it becomes easier to write programs and keep track of what they are doing. If the operation of a program can be divided into separate activities, and each activity placed in a different function, then each could be written and checked more or less independently. Separating the code into modular functions also makes the program easier to design and understand.

So don't try to cram the entire logic in one function. It is a very bad style of programming. Instead, break a program into small units and write functions for each of these isolated subdivisions. Don't hesitate to write functions that are called only once. What is important is that these functions perform some logically isolated task.

Question 21

In what form are the library functions provided?

Answer

Library functions are never provided in source code form. They are always made available in object code form obtained after compilation.

Question 22

What is the type of the variable b in the following declaration?

define FLOATPTR float *

FLOATPTR a, b;

Answer

float and not a pointer to a float , since on expansion the declaration becomes:

float *a, b;

Question 23

Is it necessary that the header files should have a .h extension?

Answer

No. However, traditionally they have been given a .h extension to identify them as something different than the .c program files.

Question 24

What do the header files usually contain?

Answer

Header files contain Preprocessor directives like #define , structure , union and enum declarations, typedef declarations, global variable declarations and external function declarations. You should not write the actual code (i.e., function bodies) or global variable definition (that is defining or initializing instances) in header files. The #include directive should be used to pull in header files, not other '.c' files.

Question 25

Will it result into an error if a header file is included twice? [Yes/No]

Answer

Yes, unless the header file has taken care to ensure that if already included it doesn't get included again.

Question 26

How can a header file ensure that it doesn't get included more than once?

Answer

All declarations must be written in the manner shown below. Assume that the name of the header file is ' funcs.h '.

/* funcs.h */

ifndef _FUNCS

define _FUNCS

/* all declarations would go here */

endif

Now if we include this file twice as shown below, it will get included only once.

include “funcs.h”

include “funcs.h”

int main()

{

/* some code */

return 0;

}

Question 27

On doing #include where are the header files searched?

Answer

If #include d using < > the files get searched in the predefined include path. It is possible to change the predefined include path. If #include d with the “ ” syntax in addition to the predefined include path the files also get searched in the current directory (usually the directory from which you invoked the compiler).

Question 28

Can you combine the following two statements into one?

char *p;

p = (char *) malloc (100);

Answer

char *p = (char *) malloc (100);

Note that the typecasting operation can be dropped completely if this program is built using gcc compiler.

Question 29

Are the expressions *ptr++ and* ++ptr same?

Answer

No. *ptr++ increments the pointer and not the value pointed by it, whereas* ++ptr increments the value being pointed to by ptr .

Question 30

Can you write another expression which does the same job as ++*ptr does?

Answer

(*ptr)++

Question 31

What would be the equivalent pointer expression for referring the array element a[i][j][k][l] ?

Answer

- (* (* (* (a + i) + j) + k) + l)

Question 32

Where can one think of using pointers?

Answer

At lot of places, some of which are:

- Accessing array or string elements
- In passing big objects like arrays, strings and structures to functions
- Dynamic memory allocation
- Call by reference
- Implementing linked lists, trees, graphs and many other data structures

Question 33

How will you declare an array of three function pointers where each function receives two int s and returns a float ?

Answer

float (*arr[3]) (int, int);

Question 34

Is the NULL pointer same as an uninitialized pointer? [Yes/No]

Answer

No

Question 35

In which header file is the NULL macro defined?

Answer

In files “ stdio.h ” and “ stddef.h ”.

Question 36

Is there any difference between the following two statements?

char *p = 0;

char *t = NULL;

Answer

No. NULL is #define d as 0 in the ’stdio.h’ file. Thus, both p and t are null pointers.

Question 37

What is a null pointer?

Answer

For each pointer type (like say a char pointer) C defines a special pointer value, which is guaranteed not to point to any object or function of that type. Usually, the null pointer constant used for representing a null pointer is the integer 0.

Question 38

What's the difference between a null pointer, a NULL macro, the ASCII NUL character and a null string?

Answer

A null pointer is a pointer, which doesn't point anywhere.

A NULL macro is used to represent the null pointer in source code. It has a value 0 associated with it.

The ASCII NUL character has all its bits as 0 but doesn't have any relationship with the null pointer.

The null string is just another name for an empty string "".

Question 39

Is there any difference in the following two statements?

char *ch = "Nagpur";

char ch[] = "Nagpur";

Answer

Yes. In the first statement, the character pointer ch stores the address of the string "Nagpur". The pointer ch can be made to point to some other character string (or even nowhere). The second statement, on the other hand, specifies that space for 7 characters be allocated and that the name of the location is ch . Thus, it specifies the size as well as initial values of the characters in array ch .

Question 40

When are char a[] and char *a treated as same by the compiler?

Answer

When using them as formal parameters while defining a function.

Question 41

What is the difference in the following declarations?

char *p = "Samuel";

char a[] = "Samuel";

Answer

Here a is an array big enough to hold the message and the '\0' following the message. Individual characters within the array can be changed but the address of the array will remain same.

On the other hand, p is a pointer, initialized to point to a string constant. The pointer p may be modified to point to another string, but if you attempt to modify the string at which p is pointing the result is undefined.

Question 42

While handling a string do we always have to process it character-by-character or there exists a method to process the entire string as one unit.

Answer

A string can be processed only on a character-by-character basis.

Question 43

What is the similarity between a structure, union and an enumeration?

Answer

All of them let you define new data types.

Question 44

Can a structure contain a pointer to itself?

Answer

Certainly. Such structures are known as self-referential structures.

Question 45

How are structure passing and returning implemented by the compiler?

Answer

When structures are passed as arguments to functions, the entire structure is pushed on the stack. For big structures this is an extra overhead. This overhead can be avoided by passing pointers to structures instead of actual structures. To return structures a hidden argument generated by the compiler is passed to the function. This argument points to a location where the returned structure is copied.

Question 46

What is the difference between a structure and a union?

Answer

A union is essentially a structure in which all of the fields overlay each other. At a time only one field can be used. We can write to one field and read from another.

Question 47

What is the difference between an enumeration and a set of preprocessor #defines ?

Answer

There is hardly any difference between the two, except that a #define has a global effect (throughout the file), whereas, an enumeration can have an effect local to the block, if desired. Some advantages of enumerations are that the numeric values are automatically assigned, whereas, in #define we have to explicitly define them. A disadvantage of enumeration is that we have no control over the sizes of enumeration variables.

Question 48

Is there an easy way to print enumeration values symbolically?

Answer

No. You can write a small function (one per enumeration) to map an enumeration constant to a string, either by using a switch statement or by searching an array.

Question 49

What is the use of bit fields in a structure declaration?

Answer

Bit fields are used to save space in structures having several binary flags or other small fields. Note that the colon notation for specifying the size of a field in bits is valid only in structures (and in unions); you cannot use this mechanism to specify the size of arbitrary variables.

Question 50

Can we have an array of bit fields? [Yes/No]

Answer

No.

Question 51

Can we specify variable field width in a scanf() format string? [Yes/No]

Answer

No. In scanf() a * in format string after a % sign is used for suppression of assignment. That is, the current input field is scanned but not stored.

Question 52

Out of fgets() and gets() which function is safe to use?

Answer

fgets() , because unlike fgets() , gets() cannot be told the size of the buffer into which the string supplied will be stored. As a result, there is always a possibility of overflow of buffer.

Question 53

To which numbering system can the binary number 1011011111000101 be easily converted to?

Answer

Hexadecimal, since each 4-digit binary represents one hexadecimal digit.

Question 54

Which bitwise operator is suitable for checking whether a particular bit is on or off?

Answer

The & operator.

Question 55

Which bitwise operator is suitable for turning off a particular bit in a number?

Answer

The & operator.

Question 56

Which bitwise operator is suitable for putting on a particular bit in a number?

Answer

The | operator.

Question 57

What is the type of compare in the following code segment?

```
typedef int (*ptrtofun)(char *, char *);

ptrtofun compare;
```

Answer

It is a pointer to function that receives two character pointers and returns an integer.

Question 58

What are the advantages of using typedef in a program?

Answer

There are three main reasons for using typedef s:

- It makes writing of complicated declarations a lot easier. This helps in eliminating a lot of clutter in the program.
- It helps in achieving portability in programs. That is, if we use typedef s for data types that are machine-dependent, only the typedef s need change when the program is moved to a new machine platform.
- It helps in providing a better documentation for a program. For example, a node of a doubly linked list is better understood as ptrtolist rather than just a pointer to a complicated structure.

Question 59

What does the following prototype indicate?

void strcpy (char *target, const char *source)

Answer

We can modify the pointers source as well as target . However, the object to which source is pointing cannot be modified.

Question 60

What does the following prototype indicate?

const char *change (char *, int)

Answer

The function change() receives a char pointer and an int , and returns a pointer to a constant char .

Question 61

What do you mean by const correctness?

Answer

A program is ’const correct’ if it never changes (a more common term is mutates) a constant object.

Question 62

What is the difference in the following declarations?

const char *s;

char const *s;

Answer

There is no difference.

Question 63

To free() we only pass the pointer to the block of memory that we want to deallocate. Then how does free() know how many bytes it should deallocate?

Answer

In most implementations of malloc() the number of bytes allocated is stored adjacent to the allocated block. Hence, it is simple for free() to know how many bytes to deallocate.

Question 64

Suppose we use realloc() to increase the allocated space for a 20-integer array to a 40-integer array. Will it increase the array space at the same location at which the array is present or will it try to find a different place for the bigger array?

Answer

Both. If the first strategy fails then it adopts the second. If the first is successful it returns the same pointer that you passed to it otherwise it returns a different pointer for the newly allocated space.

Question 65

When reallocating memory if any other pointers point into the same piece of memory do we have to readjust these other pointers or do they get readjusted automatically?

Answer

If realloc() expands allocated memory at the same place then there is no need of readjustment of other pointers. However, if it allocates a new region somewhere else the programmer has to readjust the other pointers.

Question 66

What’s the difference between malloc() and calloc() functions?

Answer

As against malloc() , calloc() needs two arguments, the number of elements to be allocated and the size of each element. For example,

p = (int *) calloc (10, sizeof (int));

will allocate space for a 10-integer array. Additionally, calloc() will also set each of this element with a value 0. Thus the above call to calloc() is equivalent to:

p = (int *) malloc (10 * sizeof (int));

memset (p, 0, 10 * sizeof (int));

Question 67

Which function should be used to free the memory allocated by calloc() ?

Answer

The same that we use with malloc() , i.e., free() .

Question 68

How much maximum memory can we allocate in a single call to malloc() ?

Answer

The largest possible block that can be allocated using malloc() depends upon the host system—particularly the size of physical memory and the OS implementation.

Theoretically the largest number of bytes that can be allocated should be the maximum value that can be held in size_t which is implementation dependent. For TC/TC++ compilers the maximum number of bytes that can be allocated is equal to 64 KB.

Question 69

What is difference between Dynamic memory allocation and Static memory allocation?

Answer

In Static memory allocation during compilation arrangements are made to facilitate memory allocation memory during execution. Actual allocation is done only at execution time. In Dynamic memory allocation no arrangement is done at compilation time. Memory allocation is done at execution time.

Question 70

Which header file should be included to dynamically allocate memory using functions like malloc() and calloc() ?

Answer

stdlib.h

Question 71

When we dynamically allocate memory is there any way to free memory during run time?

Answer

Yes. Memory can be freed using free() function.

Question 72

Is it necessary to cast the address returned by malloc() ?

Answer

It is necessary to do the typecasting if you are using TC / TC++ / Visual Studio compilers. If you are using gcc there is no need to typecast the returned address. Note that ANSI C defines an implicit type conversion between void pointer types (the one returned by malloc()) and other pointer types.

Question 73

Mention any variable argument-list function that you have used and its prototype.

Answer

int printf (const char *format, …);

Question 74

How can %f be used for both float and double arguments in printf() ?

Answer

In variable length arguments lists, types char and short int are promoted to int , and float is promoted to double .

Question 75

Can we pass a variable argument list to a function at run-time? [Yes/No]

Answer

No. Every actual argument list must be completely known at compile time. In that sense it is not truly a variable argument list.

Question 76

How can a called function determine the number of arguments that have been passed to it?

Answer

It cannot. Any function that takes a variable number of arguments must be able to determine the number of arguments from the arguments themselves. For example, the printf() function does this by looking for format specifiers (% , etc.) in the format string. This is the reason why such functions fail badly if there is a mismatch in the format specifiers and the argument list.

If the arguments passed are all of same type we can pass a sentinel value like -1 or 0 or a NULL pointer at the end of the variable argument list. Alternately, we can also pass the count of number of variable arguments.

Question 77

Input / output function prototypes and macros are defined in which header file?

Answer

stdio.h

Question 78

What are stdin , stdout and stderr ?

Answer

Standard input, standard output and standard error streams.

A Compilation And Execution

"Tools offer convenience..."

In principle, you don't need an IDE to create, compile, assemble and debug C programs. It is like saying, well, you don't need an airplane to crisscross India, you can do it in a bullock-cart. Modern times need modern solutions. IDE is the solution for modern times. This chapter shows how to use it…

To understand C language and gain confidence in working with it you would be required to type programs in this book and then instruct the machine to execute them. To type any program you need another program called Editor. Once the program has been typed it needs to be converted to machine language (0s and 1s) before the machine can execute it. To carry out this conversion we need another program called Compiler. Compiler vendors provide an Integrated Development Environment (IDE) which consists of an Editor as well as the Compiler. These IDEs are discussed in this appendix.

IDEs

There are several such IDEs available, each targeted towards different processor and operating system combinations. Given below is a brief description of the popular IDEs along with the links from where they can be downloaded.

Turbo C/C++ under Windows

If you wish to use Turbo C/C++ it is available at

https://www.developerinsider.in/download-turbo-c-for-windows-7-8-8-1-and-windows-10-32-64-bit-full-screen/

It is very easy to install and it works for Windows 7, 8, 8.1 and Windows 10 (32-64 bit) with full/window screen mode.

NetBeans under Windows

NetBeans is not a compiler. It is merely an IDE. It's Windows version can be downloaded from

http://www.netbeans.org

For developing C programs using NetBeans under Windows, you would also have to install Cygwin software. Cygwin comes with GCC compiler.

It is available at https://www.cygwin.com/

There are nice tutorials available at the following links should you face any difficulty in setting up Cygwin and NetBeans:

https://netbeans.org/community/releases/80/cpp-setup-instructions.html

https://www.wikihow.com/Run-C/C%2B%2B-Program-in-Netbeans-on-Windows

NetBeans under Linux

If you propose to use NetBeans under Linux you won't need Cygwin as with most Linux installations (like say, Ubuntu) GCC compiler comes preinstalled. So you need to just download and install NetBeans for Linux environment.

Visual Studio under Windows

If you wish to use VisualStudio Express it is available at https://www.visualstudio.com/vs/express/

You are free to use any of the IDEs mentioned above for compiling programs in this book. If you wish to know my personal choice, I would prefer NetBeans + Cygwin or Visual Studio Express Edition. All the IDEs are easy to use and are available free of cost.

Compilation and Execution Steps

The compilation and execution process with each of the IDEs mentioned in the previous section are a bit different. So for your benefit I am giving below these steps for each IDE.

Compilation and Execution using Turbo C++

Carry out the following steps to compile and execute programs using Turbo C++:

(a) Start NetBeans from Start | All Programs | Turbo C++.

(b) Click 'Start Turbo C++' from the dialog that appears.

(c) Select File | New from menu.

(d) Type the program.

(e) Save the program using F2 under a proper name (say Program1.c).

(f) Use Ctrl + F9 to compile and execute the program.

(g) Use Alt + F5 to view the output.

Compilation and Execution using NetBeans

Carry out the following steps to compile and execute programs using NetBeans:

(a) Start NetBeans from Start | All Programs | NetBeans.

(b) Select File | New Project… from the File menu. Select Project Category as C/C++ and Project Type as C/C++ Application from the dialog that pops up. Click Next button.

(c) Type a suitable project name (say Program1) in Project Name TextBox. Click Finish.

(d) Type the program.

(e) Save the program using Ctrl + S .

(f) Use F6 to compile and execute the program.

Compilation and Execution using Visual Studio Express

Carry out the following steps to compile and execute programs using Visual Studio Express:

(a) Start Visual Studio Express from Start | All Programs | Microsoft Visual C++ Express.

(b) Select File | New Project… from the File menu. Select Project Type as Visual C++ | Win32 Console Application from the dialog that pops up. Type a suitable project name (say Program1) in Name TextBox. Click OK and Finish.

(c) Type the program.

(d) Save the program using Ctrl+S .

(e) Use Ctrl+F5 to compile and execute the program.

When you use Visual Studio to create a Win32 Console Application for the above program the wizard would insert the following code by default:

include "stdafx.h"

int _tmain (int argc, _TCHAR* argv[])

{

return 0;

}

You can delete this code and type your program in its place. If you now compile the program using Ctrl+F5 you would get the following error:

Fatal error C1010:

unexpected end of file while looking for precompiled header.

Did you forget to add '#include "stdafx.h"' to your source?

If you add #include "stdafx.h" at the top of your program then it would compile and run successfully. However, including this file makes the program Visual Studio-centric and would not get compiled with other compilers. This is not good, as the program no longer remains portable. To eliminate this error, you need to make a setting in Visual Studio. To make this setting carry out the following steps:

(a) Go to 'Solution Explorer'.

(b) Right click on the project name and select 'Properties' from the menu that pops up. On doing so, a dialog box called 'Property Pages' would appear.

(c) From the left pane of this dialog first select 'Configuration Properties' followed by 'C/C++'.

(d) Select 'Precompiled Headers'.

(e) From the right pane of the dialog click on 'Create/Use Precompiled Header'. On doing so in the value for this option a triangle would appear.

(f) Click on this triangle and a drop-down list box would appear.

(g) From the list box select 'Not using Precompiled Header'.

(h) Click on OK button to make the setting effective.

In addition to this, you need to make one more setting. By default Visual Studio believes that your program is a C++ program and not a C program. So by making a setting you need to tell it that your program is a C program and not a C++ program. Carry out the following steps to make this setting:

(a) Go to 'Solution Explorer' window.

(b) Right click on the project name and select 'Properties' from the menu that pops up. On doing so, a 'Property Pages' dialog box would appear.

(c) From the left pane of this dialog box first select 'Configuration Properties' followed by 'C/C++'.

(d) In C/C++ options select 'Advanced'.

(e) Change the 'Compile As' option to 'Compile as C code (/TC)'.

Once this setting is made you can now compile the program using Ctrl+F5. This time no error would be flagged, and the program would compile and execute successfully.

Compilation and Execution at Linux Command-line

C programs can be compiled and executed even at command-line, i.e. without using any IDE. Many programmers prefer this mode. In such cases we need to use an editor to type the program and a compiler to compile it. For example, if you wish to compile and execute programs at Linux command prompt, then you may use an editor like vi or Vim and a compiler like GCC. In such as case you need to follow the following steps to compile and execute your program.

(a) Type the program and save it under a suitable name, 'hello.c'.

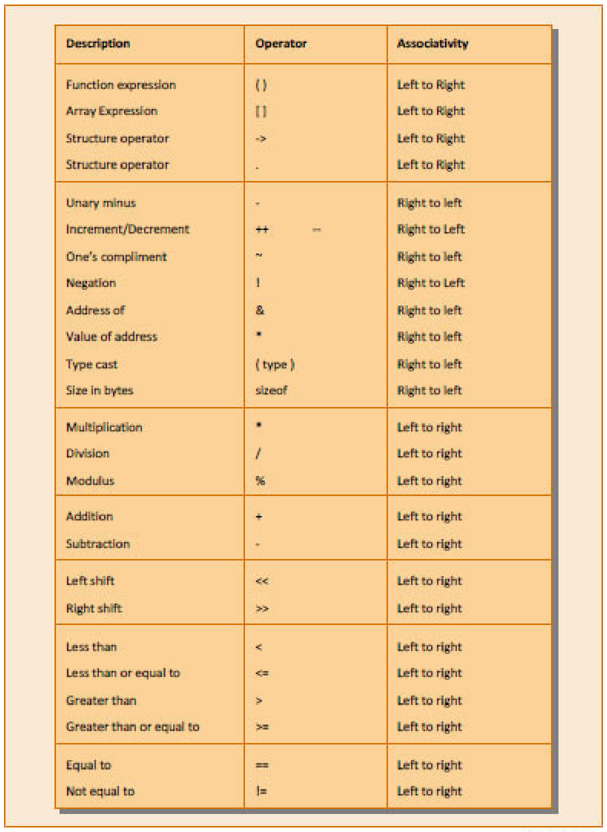
(b) At the command prompt switch to the directory containing 'hello.c' using the cd command.

(c) Compile the program using GCC compiler as shown below.

(d) On successful compilation, GCC produces a file named 'a.out'. This file contains the machine language code of the program which can now be executed.

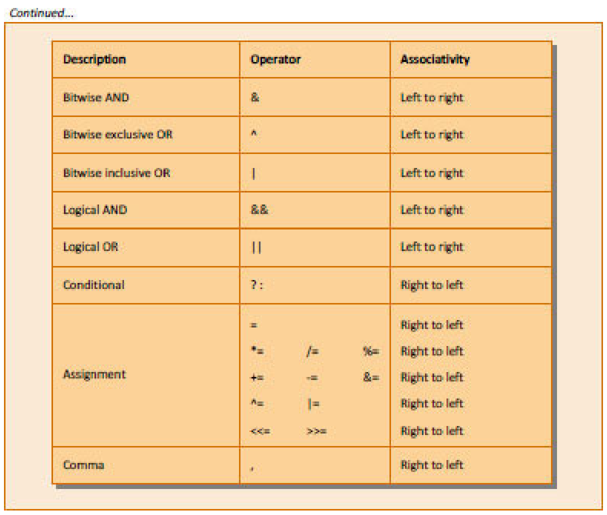
(e) Execute the program using the following command:

Whether we like it, or we don't, we live in an unequal world. Somebody gets a priority over somebody else. C programming is no different. With 45 operators in place, somebody has to get a priority over others. This chapter shows the exact order of their priority…



Description	Operator	Associativity
Function expression	( )	Left to Right
Array Expression	[ ]	Left to Right
Structure operator	->	Left to Right
Structure operator	.	Left to Right
Unary minus	-	Right to left
Increment/Decrement	++ --	Right to Left
One's compliment	~	Right to left
Negation	!	Right to Left
Address of	&	Right to left
Value of address	*	Right to left
Type cast	(type)	Right to left
Size in bytes	sizeof	Right to left
Multiplication	*	Left to right
Division	/	Left to right
Modulus	%	Left to right
Addition	+	Left to right
Subtraction	-	Left to right
Left shift	<<	Left to right
Right shift	>>	Left to right
Less than	<	Left to right
Less than or equal to	<=	Left to right
Greater than	>	Left to right
Greater than or equal to	>=	Left to right
Equal to	==	Left to right
Not equal to	!=	Left to right

Continued...



Continued...

Description	Operator	Associativity
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
	*= /= %=	Right to left
	+= -= &=	Right to left
	^= |=	Right to left
	<<= >>=	Right to left
Comma	,	Right to left

Figure B.1

C Chasing The Bugs

There are only two types of C programmers. Those who face problems while creating a program and those who don't. The second variety is the one who never wrote any program. This chapter is for the first variety. It highlights some of the common mistakes that every C programmer makes…

There is no shortage of horror stories about programs that took twenty times to 'debug' as they did to 'write'. Many a time programs had to be rewritten all over again because the bugs present in them could not be located. So how do we chase them away? No sure-shot way for that. I thought if I make a list of more common programming mistakes, it might be of help. They are not arranged in any particular order. But I think, surely a great help!

Bug 1

Omitting the ampersand before the variables used in scanf() . For example,

int choice;

scanf ("%d", choice);

scanf (" %d ", &choice);

Here, the & before the variable choice is missing. Another common mistake with scanf() is to give blanks either just before the format string or immediately after the format string as in the second scanf() above. Note that this is not a mistake, but till you don't understand scanf() thoroughly, this is going to cause trouble. Safety is in eliminating the blanks.

Bug 2

Using the operator = instead of the operator == . For example, the following while loop becomes an infinite loop since every time, instead of checking the value of i against 10, it assigns the value 10 to i . As 10 is a non-zero value the condition will always be treated as true, forming an infinite loop.

```
int i = 10;

while (i = 10)

{

printf (“got to get out”);

i++;

}
```

Bug 3

Ending a loop with a semicolon. Observe the following program:

```
int j = 1;

while (j <= 100);

{

printf (“\nCompguard”);

j++;

}
```

Here, inadvertently, we have fallen in an indefinite loop. Cause is the semicolon after while . This semicolon is treated as a null statement by the compiler as shown below.

```
while (j <= 100)

;
```

This is an indefinite loop since the null statement keeps getting executed indefinitely as j never gets incremented.

Bug 4

Omitting the break statement at the end of a case in a switch statement. Remember that, if a break is not included at the end of a case , then execution will continue into the next case .

```
int ch = 1;

switch (ch)

{

case 1 :

printf (“\nGoodbye”);

case 2 :

printf (“\nLieutenant”);

}
```

Here, since there is no break after printf() in case 1 , the control runs into case 2 and executes the second printf() as well. However, this sometimes turns out to be a blessing in disguise. Especially, when we want same set of statements to get executed for multiple cases.

Bug 5

Using continue in a switch . It is a common error to believe that the way the keyword break is used with loops and a switch ; similarly the keyword continue can also be used with them. Remember that continue works only with loops, never with a switch .

Bug 6

A mismatch in the number, type and order of actual and formal arguments. Consider the following call:

yr = romanise (year, 1000, ’m’);

Here, three arguments in the order int , int and char are being passed to romanise() . When romanise() receives these arguments into formal arguments, they must be received in the same order. A careless mismatch might give strange results.

Bug 7

Omitting provisions for returning a non-integer value from a function. If we make the following function call,

area = area_circle (1.5);

then, while defining area_circle() function later in the program, care should be taken to make it capable of returning a floating-point value. Note that unless otherwise mentioned, the compiler would assume that this function returns a value of the type int .

Bug 8

Inserting a semicolon at the end of a macro definition. This might create a problem as shown below.

define UPPER 25;

would lead to a syntax error if used in an expression, such as:

if (counter == UPPER)

This is because on preprocessing, the if statement would take the form

if (counter == 25;)

Bug 9

Omitting parentheses around a macro expansion. Consider the following macro:

define SQR(x) x * x

If we use this macro as,

int a;

a = 25 / SQR (5);

we expect the value of a to be 1, whereas it turns out to be 25. This is because, on preprocessing, the statement takes the form

a = 25 / 5 * 5;

Bug 10

Leaving a blank space between the macro template and the macro expansion.

define ABS (a) (a = 0 ? a : -a)

Here, the space between ABS and (a) makes the preprocessor believe that you want to expand ABS into (a) , which is certainly not what you want.

Bug 11

Using an expression that has side effects in a macro. Consider the following macro:

define SUM (a) (a + a)

int w, b = 5;

w = SUM(b++);

On preprocessing, the macro would be expanded to,

```
w = (b++) + (b++);
```

Thus, contrary to expectation, b will get incremented twice.

Bug 12

Confusing a character constant and a character string. In the statements

```
ch = ’z’; dh = “z”;
```

a single character is assigned to ch , whereas a pointer to the character string “z” is assigned to dh .

Note that their declarations should be,

```
char ch; char *dh;
```

Bug 13

Forgetting the bounds of an array.

```
int num[50], i;

for (i = 1; i <= 50; i++)

num[i] = i * i;
```

Here, array num has no such element as num[50] , since array counting begins with 0 and not 1. Compiler would not give a warning if our program exceeds the bounds. If not taken care of, in extreme cases, the above code might even hang the computer.

Bug 14

Forgetting to reserve an extra location in a string for the null terminator. Remember each string ends with a ‘\0’, therefore its dimension should be declared big enough to hold the normal characters as well as the ‘\0’. For example, dimension of the array word[] should be 9, if a string “Jamboree” is to be stored in it.

Bug 15

Confusing the precedences of the various operators.

```
char ch;

FILE *fp;

fp = fopen (“text.c”, “r”);

while (ch = getc (fp) != EOF)

putch (ch);

fclose (fp);
```

Here, the value returned by getc() will be first compared with EOF, since != has a higher priority than = . As a result, the value that is assigned to ch will be the true/false result of the test—1 if the value returned by getc() is not equal to EOF , and 0 otherwise. The correct form of the above while would be,

```
while ((ch = getc (fp)) != EOF)

putch (ch);
```

Bug 16

Confusing the operator -> with the operator . while referring to a structure element. On the left of . operator a structure variable should occur, whereas, on the left of -> operator a pointer to a structure should occur. Following example demonstrates this:

```
struct emp {char name[35]; int age;};
```

struct emp e = {“Dubhashi”, 40};

struct emp *p;

printf (“\n%d”, e.age);

p = &e;

printf (“\n%d”,p->age);

Bug 17

Exceeding the range of integers and chars. Consider the following code snippet:

char ch;

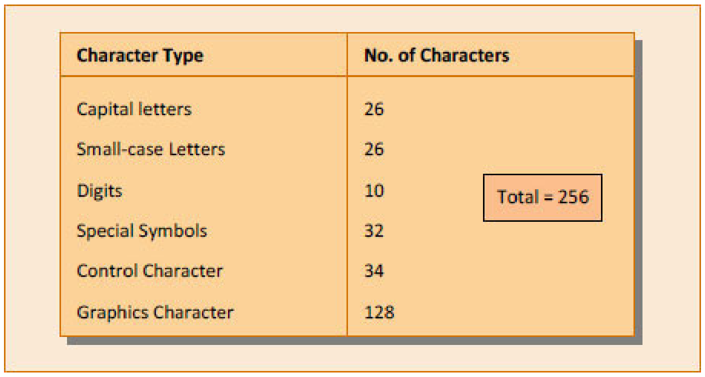
for (ch = 0; ch <= 255; ch++)

printf (“\n%c %d”, ch, ch);

This is an indefinite loop. Reason is, ch has been declared as a char and its valid range is -128 to +127. So when ch tries to become 128 (through ch++), the range is exceeded. As a result, the -128, gets assigned to ch . So the condition is satisfied and the control remains within the loop.

When it is time to represent an A in memory, whether I press it or you press it from keyboard, the same binary should get used. This calls for a standard way of representing it. This chapter shows which is that standard…

There are 256 distinct characters used by PCs and Laptops. They can be grouped as shown in Figure D.1 .



Character Type	No. of Characters
Capital letters	26
Small-case Letters	26
Digits	10
Special Symbols	32
Control Character	34
Graphics Character	128

Total = 256

Figure D.1

This 256 character set is listed in the following pages. Out of the 128 graphic characters the ones that can be used for drawing single line and double line boxes are shown in Figure D.2 .

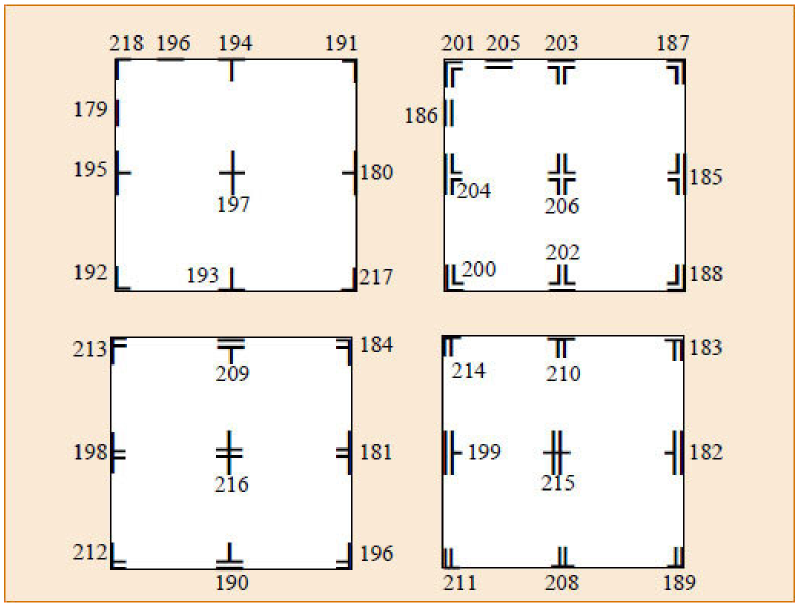
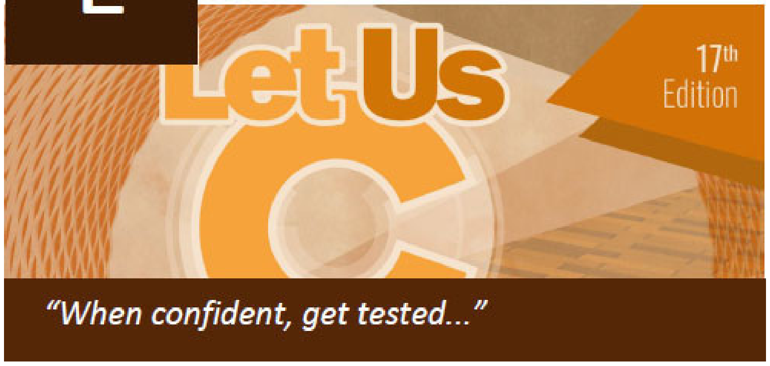


Figure D.2

Value	Char	Value	Char	Value	Char	Value	Char	Value	Char	Value	Char
0		22	▬	44	,	66	B	88	X	110	n
1	☺	23	↕	45	-	67	C	89	Y	111	o
2	☻	24	↑	46	.	68	D	90	Z	112	p
3	♥	25	↓	47	/	69	E	91	[	113	q
4	♦	26	→	48	0	70	F	92	\	114	r
5	♣	27	←	49	1	71	G	93	]	115	s
6	♠	28	⌐	50	2	72	H	94	^	116	t
7	•	29	↔	51	3	73	I	95	_	117	u
8	◘	30	▲	52	4	74	J	96	`	118	v
9	○	31	▼	53	5	75	K	97	a	119	w
10	◙	32		54	6	76	L	98	b	120	x
11	♂	33	!	55	7	77	M	99	c	121	y
12	♀	34	"	56	8	78	N	100	d	122	z
13	♪	35	#	57	9	79	O	101	e	123	{
14	♫	36	$	58	:	80	P	102	f	124	|
15	☼	37	%	59	;	81	Q	103	g	125	}
16	►	38	&	60	<	82	R	104	h	126	~
17	◄	39	'	61	=	83	S	105	i	127	^{M}H
18	↕	40	(	62	>	84	T	106	j	128	Ç
19	‼	41	)	63	?	85	U	107	k	129	ü
20	¶	42	*	64	@	86	V	108	l	130	é
21	§	43	+	65	A	87	W	109	m	131	â

Value	Char	Value	Char	Value	Char	Value	Char	Value	Char	Value	Char
132	ä	154	Ü	176	░	198	╞	220	▄	242	≥
133	à	155	¢	177	▒	199	╟	221	▌	243	≤
134	å	156	£	178	▓	200	╚	222	▐	244	⌠
135	ç	157	¥	179	│	201	╔	223	▀	245	⌡
136	ê	158	₧	180	┤	202	╩	224	α	246	÷
137	ë	159	ƒ	181	╡	203	╦	225	ß	247	≈
138	è	160	á	182	╢	204	╠	226	Γ	248	°
139	ï	161	í	183	╖	205	═	227	π	249	∙
140	î	162	ó	184	╕	206	╬	228	Σ	250	·
141	ì	163	ú	185	╣	207	╧	229	σ	251	√
142	Ä	164	ñ	186	║	208	╨	230	µ	252	ⁿ
143	Å	165	Ñ	187	╗	209	╤	231	τ	253	²
144	É	166	ª	188	╝	210	╥	232	Φ	254	■
145	æ	167	º	189	╜	211	╙	233	Θ	255	
146	Æ	168	¿	190	╛	212	╘	234	Ω		
147	ô	169	⌐	191	┐	213	╒	235	δ		
148	ö	170	¬	192	└	214	╓	236	∞		
149	ò	171	½	193	┴	215	╫	237	ø		
150	û	172	¼	194	┬	216	╪	238	ε		
151	ù	173	¡	195	├	217	┘	239	∩		
152	ÿ	174	«	196	─	218	┌	240	≡		
153	Ö	175	»	197	┼	219	█	241	±		

E Periodic Tests



You should never take a test, when you are not prepared. You should never give up an opportunity to get tested, when you are fully prepared and confident. This chapter will help you check your strengths and weaknesses, once you are prepared and confident…

Periodic Test I

(Based on Chapters 1 to 7)

Time: 90 Minutes Maximum Marks: 40

[A] Fill in the blanks: [5 Marks, 1 Mark each]

(1) The expression i++ is same as_.

(2) _type of values cannot be checked using switch-case .

(3) Every instruction in a C program must end with a_.

(4) The size of an int data type is_bytes.

(5) Statements written in_loop get executed for once even if the condition is false.

[B] State True or False: [5 Marks, 1 Mark each]

(1) The statement for (;;) is a valid statement.

(2) The else clause in an if - else if - else statement goes to work if all the if s fail.

(3) The ^ operator is used for performing exponentiation operations in C.

(4) C allows only one variable on the left hand side of = operator.

(5) Conditional operators cannot be nested.

[C] What would be the output of the following programs: [5 Marks, 1 Mark each]

(a) # include

```
int main()
{
int x = 5, y, z;
y = x++;
z = x--;
printf (“%d %d %d”, x, y, z);
return 0;
}
```

(b) # include

```
int main()
{
int i = 65;
char ch = i;
printf (“%d %c”, ch, i);
return 0;
}
```

(c) # include

```
int main()
{
int i, j;
for (i = 1; i <= 2; i++)
{
for (j = 1; j <= 2; j++)
{
if (i == j)
break;
printf (“%d %d”, i, j);
}
}
return 0;
}

(d) # include

int main()

{

int x = 3, i = 1;

while (i <=2)

{

printf (“%d ”, x *= x + 4);

i++;

}

return 0;

}

(e) # include

int main()

{

int a, b = 5;

a = !b;

b = !a;

printf (“%d %d”, a, b);

return 0;

}
```

[D] Point out the error, if any, in the following programs: [5 Marks, 1 Mark each]

```
(a) # include

int main()

{

int i = 10, j = 20;

if (i = 5) && if (j = 10)

printf (“Have a nice day”);

return 0;

}

(b) # include

int main()

{

int x = 10;

if (x >= 2) then
```

printf ("\n%d", x);

return 0;

}

(c) # include

int main()

{

int x = 0, y = 5, z = 10, a;

a = x > 1 ? y > 1: z > 1 ? 100: 200: 300;

printf ("%d", a);

return 0;

}

(d) # include

int main()

{

int x = 0, y = 5, z;

float a = 1.5, b = 2.2, c;

z = x || b;

c = a && b;

printf ("%d %f", z, c);

return 0;

}

(e) # include

int main()

{

int a = 10, b = 5, c;

c += a *= b;

printf ("%d %d %d", a, b, c);

}

[E] Attempt the following: [20 Marks, 5 Marks each]

(1) Write a program to calculate the sum of the following series: 1! 2! + 2! 3! + 3! 4! + 4! 5! + …… + 9! 10!

(2) Write a program to enter the numbers till the user wants and at the end it should display the count of positive, negative and zeros entered.

(3) Write a program to find the range of a set of numbers that are input through the keyboard. Range is the difference between the smallest and biggest number in the list.

(4) If three integers are entered through the keyboard, write a program to determine whether they form a Pythogorean triplet or not.

Periodic Test II

(Based on Chapters 8 to 12)

Time: 90 Minutes Maximum Marks: 40

[A] Fill in the blanks: [5 Marks, 1 Mark each]

(1) _function is used to clear the screen.

(2) _are variables, which hold addresses of other variables.

(3) _is called an 'address of' operator.

(4) The preprocessor directive that is used to give convenient names to difficult formulae is called_.

(5) For a call by reference we should pass_of variables to the called function.

[B] State True or False: [5 Marks, 1 Mark each]

(1) A function can return more than one value at a time.

(2) A fresh set of variables are created every time a function gets called.

(3) All types of pointers are 4 bytes long.

(4) Any function can be made a recursive function.

(5) The correct build order is Preprocessing - Compilation - Assembling

- Linking.

[C] Answer the following: [10 Marks, 2 Marks each]

(1) Why are addresses of functions stored on the stack?

(2) How do we decide whether a variable should be passed by value or by reference?

(3) Size of a pointer is not dependent on whose address is stored in it. Justify.

(4) At times there may be holes in a structure? Why do they exist? How can they be avoided?

(5) A recursive call should always be subjected to an if. Why? Explain with an example.

[D] Attempt the following: [20 Marks, 5 Marks each]

(1) Define a function that receives 4 integers and returns sum, product and average of these integers.

(2) Write a recursive function which prints the prime factors of the number that it receives when called from main() .

(3) Write macros for calculating area of circle, circumference of circle, volume of a cone and volume of sphere.

(4) Write a program that prints sizes of all types of chars, ints and reals.

Periodic Test III??

(Based on Chapters 13 to 17)

Time: 90 Minutes Maximum Marks: 40

[A] Fill in the blanks: [5 Marks, 1 Mark each]

(1) Mentioning name of the array yields_of the array.

(2) C permits us to exceed***and***bounds of an array.

(3) Size of an array is_of sizes of individual elements of an array.

(4) Array elements are always counted from_onwards.

(5) A structure is usually a collection of_elements.

[B] State True or False: [5 Marks, 1 Mark each]

(1) If the array is big its elements may get stored in non-adjacent locations.

(2) All strings end with a '\0'.

(3) Using #pragma pack you can control the layout of structure elements in memory.

(4) Elements of 2D array are stored in the form of rows and columns in memory.

(5) 3D array is a collection of several 1D arrays.

[C] Answer the following: [10 Marks, 2 Marks each]

(1) What is likely to happen if the bounds of an array are exceeded?

(2) When you prefer a structure over an array to store similar elements? Explain with an example.

(3) What is the limitation of an array of pointers to strings? How can it be overcome?

(4) In a two-dimensional array a[4][4] , why do expressions a and *a give base address?

(5) How can we receive multi-word strings as input using scanf() and using gets() ?

[D] Attempt the following: [20 Marks, 5 Marks each]

(1) Write a function that receives as parameters, a 1D array, its size and an integer and returns number of times the integer occurs in the array.

(2) Create an array of pointers containing names of 10 cities. Write a program that sorts the cities in reverse alphabetical order and prints this reversed list.

(3) Declare a structure called student containing his name, age and address. Create and initialize three structure variables. Define a function to which these variables are passed. The function should convert the names into uppercase. Print the resultant structure variables.

(4) Write a program that checks and reports whether sum of elements in the i th row of a 5 x 5 array is equal to sum of elements in i th column.

Periodic Test IV

(Based on Chapters 18 to 22)

Time: 90 Minutes Maximum Marks: 40

[A] Fill in the blanks: [5 Marks, 1 Mark each]

(1) 0xAABB | 0xBBAA evaluates to_.

(2) The values of an enum are stored as_.

(3) An existing data type can be given a new name using the _ keyword.

(4) The_operator can be used to eliminate 3 least significant bits from a character.

(5) The_operator is used to invert the bits in a byte.

[B] State True or False: [5 Marks, 1 Mark each]

(1) To check whether a particular bit in a byte is on or off, the bitwise | operator is useful.

(2) It is possible to create a union of structures.

(3) The callback mechanism can be implemented using function pointers.

(4) On evaluating the expression a ^ 5 value of a would change.

(5) Bitwise operators can work on float s and double s.

[C] Answer the following: [10 Marks, 2 Marks each]

(1) What is the utility of <<, >>, & and | bitwise operators?

(2) Define the BV macro. How would the following expressions involving the BV macro be expanded by the preprocessor?

int a = BV (5);

int b = ~ BV (5);

(3) What does the following expression signify?

long (*p[3]) (int, float);

(4) Suggest a suitable printf() that can be used to print the grocery items and their prices in the following format:

Tomato Sauce: Rs. 225.50

Liril Soap: Rs. 55.45

Pen Refill: Rs. 8.95

(5) When it is useful to make use of a union? What is the size of a union variable? How can the elements of a union variable be accessed?

[D] Attempt the following: [20 Marks, 5 Marks each]

(1) Write a program to multiply two integers using bitwise operators.

(2) Write a program to count number of words in a given text file.

(3) Write a program that receives a set of numbers as command-line arguments and prints their average.

(4) Write a program to check whether contents of the two files are same by comparing them on a byte-by-byte basis.

Course Test I

(Based on all Chapters)

Time: 150 Minutes Maximum Marks: 70

[A] Fill in the blanks: [5 Marks, 1 Mark each]

(1) A function that calls itself is known as a_function.

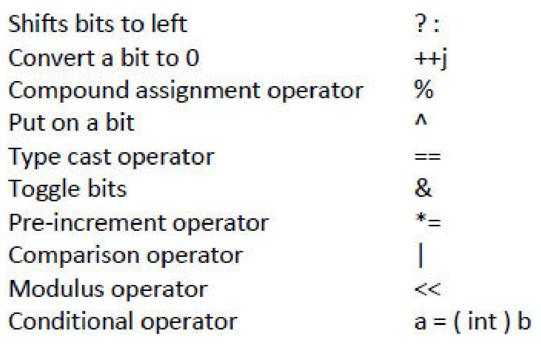
(2) Preprocessor directives always begin with_.

(3) The expression a[i][j] in pointer notation is _.

(4) A string always ends with the character_ .

(5) The keywords used to implement a case control instructions are ,and_.

[B] Match the following: [5 Marks, 1/2 Mark each]



Shifts bits to left	? :
Convert a bit to 0	++j
Compound assignment operator	%
Put on a bit	^
Type cast operator	==
Toggle bits	&
Pre-increment operator	*=
Comparison operator	|
Modulus operator	<<
Conditional operator	a = (int) b

[C] Answer the following: [30 Marks, 3 Mark each]

(1) Allocate space for a 3D array of dimensions 3 x 5 x 4. Set up each elements of this array with a value 10. Report an error, if enough memory space is not available.

(2) Create an array of pointers to strings for storing names of 5 persons. What is the limitation of this array?

(3) Create a data structure for storing following data:

Name of the fruit

Color of the fruit

Diameter of the fruit

Price of the fruit

Weight of the fruit

(4) If a function is to be called, is it necessary to mention its prototype declaration? If yes, why?

(5) For a file being pointed to by FILE *fp , write function calls for carrying out the following operations?

- Set pointer at 5 th positions from beginning of file.
- Set pointer at 20 th positions from current position.
- Set pointer at 15 th position before end of file.

(6) Suppose there is a user-defined file called 'myfunctions.h'.

- Write a statement to include this file in you program?
- What provision will you make in 'myfunctions.h' to prevent it from getting included twice?

(7) What do argc and argv represent with regards to command-line arguments?

(8) How will you redefine the types unsigned long int to ULI and int ** to DOUBLEPTR ? What is the scope of a typedef statement?

(9) Point out errors, in any, in the following code snippet:

int a;

float b;

char ch;

scanf ("%d %f %c", a, b, ch);

printf ("%d %f %c", &a, &b, &ch);

(10) What will be the output of the following code snippet?

int a = 10, b = 20, c= 0;

if (a && b || c)

printf ("Hello");

else

printf("Hi");

if (!a && !b)

printf ("Good Morning!!");

else

printf("Good Evening");

[D] Attempt the following: [30 Marks, 6 Marks each]

(1) Write a program that defines a function called isalnum() . The function should receive a string and check if all characters in it are alphabets or digits. If so, it should return a true, otherwise false. Call this function for the following strings:

“ABCD1234”

“Nagpur - 440010”

(2) Define an enumeration to represent colors red, green, yellow, magenta and brown. Create two variables Apple and Banana of this enum type and assign colors red and yellow to them respectively. Print these color values and indicate what output will they produce.

(3) Define a function called showbits( ) which displays all the bits of an unsigned char that it receives. Call this function for values 45 and 30. Indicate what output will showbits() produce for these values?

(4) Write a program to generate and print all unique combinations of numbers 1, 2, 3 and 4.

(5) Write an iterative function and recursive function to print first ten terms of a Fibonacci series. Which one of these two functions will run faster and why?

Course Test II

(Based on all Chapters)

Time: 150 Minutes Maximum Marks: 70

[A] State True or False: [5 Marks, 1 Mark each]

(1) Any function can be made a recursive function.

(2) Macro expansion directory can be used to replace a complicated formula with an convenient template.

(3) In the expression, * (* (a + i) + j) , the variable a must be a 2D array.

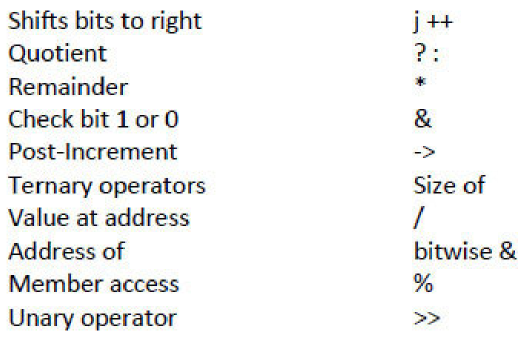
(4) A char array may not end with ‘\0’, but a string must.

(5) In the expression,

b = (int *) a;

(int *) represents a type cast operation.

[B] Match the following: [5 Marks, 1/2 Mark each]



Shifts bits to right	j ++
Quotient	? :
Remainder	*
Check bit 1 or 0	&
Post-Increment	->
Ternary operators	Size of
Value at address	/
Address of	bitwise &
Member access	%
Unary operator	>>

[C] Answer the following: [30 Marks, 3 Marks each]

(1) Create a data structure for storing the following data:

Name of document - Leaflet / Flier / Broucher

Number of colors - 1 / 2 / 4 / 5

Size - Small / Medium / Big

Type of paper - Maplitho / Bond / Artcard

Number of copies

Number of printing - Positive / Negative

(2) For storing names of month in a year, which out of array of strings and array of pointer to string is preferable, and why?

(3) Consider the following structure:

```
struct Flower

{

char name[20];

int color;

int noofpetals;

};

struct Flower f[3];
```

Write statements to receive values into array f[] and print them on the screen.

(4) Given two matrices A 3 X 3 and B 3 X 3 , define a function that checks whether matrix A is transpose of matrix B.

(5) What is the difference between function declaration and function definition? Which of the two— function redefinition or function redeclaration is an error, and Why?

(6) Write a code snippet to carry out the following operations:

- Open a file ‘records.dat’ in read binary mode.
- Skip first 200 bytes from the beginning of the file.
- Read next 20 bytes into an array arr[] .

(7) While using command-line arguments, is it necessary to use variables argc and argv ? Write statements to print the name of the executable file and the first and second argument passed to the program?

(8) Once a type has been given a new name using typedef , can we use the previous type? Can the effect of typedef be also obtained using a macro? If yes, how?

(9) What is the difference between the following declarations?

```
int * p[4];

int (*q)[4];
```

(10) What is the difference between a structure and a union as regards:

- Sharing of memory locations
- Size
- Accessing elements

[D] Attempt the following: [30 Marks, 6 Marks each]

(1) Consider the following statements:

```
int a = 20;

int *p;

p = &a;
```

Write statements only using p to:

- set a value 45 in a .
- multiply a with 40 and store the result in a
- print current value of a

Also write statements to perform the following operations:

- Increment p
- After incrementation, what will be present in p if variable a is at location 4004?
- Does incrementing p cause a memory leak?

(2) Write a program that defines a function called isalpha() . The function should receive a string and check if all characters in it are alphabets. If so, it should return a true, otherwise false. Call this function for the following strings:

“NambyPamby”

“Mumbai - 400010”

(3) Define an enumeration to represent marital status of a person— single, married, divorced. Create two variables he and she of this enum type and assign values single and married to them respectively. Print these values and indicate what output will they produce.

(4) Define functions countzeros( ) and countones() which count number of 0s and 1s in an unsigned char that they receive. Call both these functions for values 101 and 111. Indicate what values will these functions return?

(5) Write a program to find maximum out of three given numbers in a single statement. What are the pros and cons of using this statement?

Some people like help, some people don’t. But everybody likes “quick” help. This index will help you jump to that quick help…

C LANGUAGE
PROGRAMMER'S INSTANT REFERENECE CARD

STORAGE CLASSES

STORAGE CLASS	STORAGE	DEFAULT INITIAL VALUE	SCOPE	LIFE
Automatic	Memory	Garbage	Local to the block	Till control remains in the block in which the variable is defined
Register	CPU / Registers	Garbage	Local to the block	Till control remains in the block in which the variable is defined
Static	Memory	Zero	Local to the block	Variable persists between different function calls
External	Memory	Zero	Global	Till the execution of the program doesn't come to an end

PREPROCESSOR DIRECTIVES

STATEMENT	DESCRIPTION
# define id text	text will be substituted for id wherever it later appears in the program: if construct id (a1,a2,...) is used,arguments a1, a2,...will be replaced where they appear in text by corresponding arguments of macro call
# if expr	if constant expression expr is TRUE,statements up to #else
...	will be processed, otherwise they will not be
#endif	
# if expr	if constant expression expr is TRUE,statements up to #else l
...	will be processed, otherwise those between the #else and
#else	#endif will be processed.
...	
#endif	
#idef id	if id is defined (with #define or on the command line) statements
...	up to #endif will be processed, otherwise they will not be processes
#endif	(optional #else)
#ifndef id	if id has not been defined, statements up to #endif will be processed (optional #else construct)
...	
#endif	
#include "file"	Inserts contents of file in program. Double quotes mean look first in same
or	directory as source program , then in the
#include <file>	include directory: corner brackets mean only include directory.
#undef id	Remove definition of id.
#pragma inline	Tells the compiler that the source program contains inline assembly language statements.

Notes: Preprocessor statements can be continued over multiple lines provided each line to be continued ends with a backslash character (\). Statements can also be nested.

ARRAYS

A single- dimensional array aname of n elements of a specified type and with specified type and with specified initial values (optional) is declared with:

```
type aname[n] = {val1,val2...} ;
```

If complete list of initial values is specified, n can be omitted. Char arrays can be initialised by a string of chars in double quotes. Valid subscripts of the array range from 0 through n-1. Multi dimensional arrays are declared as :

```
type aname[n1] [n2]... = {init_list};
```

Values listed in the initialization list are assigned in 'dimension order' (i.e. as if last dimension were increasing first). Here are some examples:

```
char name[ ] = "anil",/* char array */
/* array of char pointers */
char *days[ ] = {"Sun","Mon","Tue"};
int mat[2][4] = {
                { 2,4,5,8},
                { -5,0,4,7}
            };/* 2X4 array of ints */
struct emp e[100];/*array of structs */
```

STRUCTURES

A structure sname of specified elements is declared with a statement of the form:

```
struct sname
{
      element_declaration ;
      element_declaration ;
} ;
```

struct sname variable_list ;

Each element_declaration is a type followed by one or more member names. If structure declaration and variable list definition are combined then sname is optional. Elements of a structure are accessed using. Operator or - > operator. If structure elements are to be accessed using a structure variable use the. Operator and if they are to be accessed using a structure pointer then use - > operator. Example :

```
struct emp
{
     char n[20] ; int age ;
} ;
struct emp e1 = { "Anil,30},*e2=&e1 ;
printf ( "\n%s%d", e1.n,e2.age ) ;
printf ( "\n%d", e2 - >.n,e2 - > age ) ;
```

FUNCTIONS

Functions follow this format:

```
ret_type name ( type arg1, type arg2,...}
{
        localvar_declartions
        statement ;
        statement ;
        return value ;
}
```

ret_type the return type for the function and can be void if the function returns non value or omitted if it returns an int. If the functions receives or returns some–thing other than an int it is necessary to mention its prototype.

UNIONS

A union permits us to access the same locations in memory in more than one way. For Example :

```
union a
{
        int I ; char ch[2] ;
} ;
union a z ;
```

The 2 bytes occupied by this union can be accessed as a two byte entity by saying z.i and as individual bytes by saying z.ch[0] and z.ch[1].

Note: union cannot be initialized.

THIS SPACE IS DEDICATED IN MEMORY OF THOSE WHO DO NOT USE THIS CARD REGULARLY!!

typedef

typedef is used to give a new name to data type. For example, in the following code struct employee has been renamed as EMP.

```
Struct employee
{
     char name[20] ; int age ;
} ;
typedef struct employee EMP ; s
```

C LANGUAGE
PROGRAMMER'S INSTANT REFERENECE CARD

DATA TYPES

DATA TYPE	RANGE	BYTES	FORMAT
signed char	-128 to +127	1	%c
unsigned char	0 to 255	1	%c
short signed int	-32768 to +32767	2	%d,%i,%0,%x
short unsigned int	0 to 65535	2	%u
long signed int	-2147483648 to +2147483647	4	%ld
long unsigned int	0 to 4294967295	4	%lu
float	-3.4e38 to +3.4e38	4	%f
double	-1.7e308 to +1.7e308	8	%lf
long double	-1.7e4932 to +1.7e4932	10	%Lf

STATEMENT SUMMARY

STATEMENT	DESCRIPTION
break ;	Terminates execution of for,while,do,or switch..
continue ;	Skips statements that follow in a do, for, or, while; then continues executing the loop.
do statement ;	Executes statement until expr is FALSE ; statement is executed at least once.
while (expr) for (e1;e2;e3) statement ;	Evaluates expression el once; then repeatedly evaluates e2, statement, and e3 (in that order) until e2 is FALSE. The statement might not be executed if e2, is FALSE on first evaluation.
goto label ;	Branches to statement preceded by label, which must be in same function as the goto.
If (expr) statement ;	If expr is TRUE, then executes statement, otherwise skips it.
If (expr) statement1 ;	If expr is TRUE, then executes statement1, otherwise statement2.
else statement2 ; ; (null statement)	No effect; satisfies statement requirement in do, for, and while
return ;	Returns from function back to caller ; no value returned.
return expr	Returns from function back to caller with value of expr.

Switch (iexpr)
{
case const1 :
statement ;break;
case const2 :
statement2;break;
default :
statement ; break;
}
	iexpr is evaluated and then compared against integer constant expressions const1,const2,etc.. If a match is found, then the statements that follow the case (up to the break) will be executed; if no match is found, then the statements in the default case (if supplied) will be executed; iexpr must be an integer- valued expression.

While (expr) statement ;	Executes statement as long as is TRUE, statement might not be executed if expr is FALSE the first time it is evaluated.

OPERATORS

OPERATOR	DESCRIPTION	EXAMPLE	ASSO.
( )	Function call	pow (x,y)	
[ ]	Array element reference	arr[10]	L-R
- >	Pointer to structure	e->name	
.	structure element reference	emp.name	
-	Unary minus	-a	
++	Increment	ptr++	
–	Decrement	count--	
!	Logical negation	!done	R-L
~	One's complement	-32	
*	Value at address	*ptr	
&	Address of	&a	
sizeof	Size in bytes	sizeof (int)	
(type)	Type conversion	(float) total / n	
*	Multiplication	i * j	
/	Division	i / j	L-R
%	Modulus	i % j	
+	Addition	i+ j	L-R
-	Subtraction	i – j	
<<	Left shift	i << 4	L-R
>>	Right shift	i >> 2	
<	Less than	I < 10	
< =	Less than or equal to	I <= j	L – R
>	Greater than	I > 0	
> =	Greater or equal to	grade > = 90	
= =	Equal to	result = = 0	L – R
! =	Not equal to	c != 10	
&	Bitwise AND	a & 7	L – R
^	Bitwise XOR	a ^ b	L – R
I	Bitwise OR	a I b	L – R
&&	Logical AND	I > 0 && j < 1	L – R
II	Logical OR	I > 8 I I j < 4	L – R
? :	Conditional expression	a > b ? 10 : 20	R – L
= *= /= %= += -=	Compound Assignment	count += 2	R – L
&= ^ = I= <<= >>==		a *. = 5	
,	comma operator	I = 10, j = 0	L – R

L – R means left to right. Operators are listed in decreasing precedence. Operators in the same box have the same precedence. Associativity determines order of evaluation for operators with the same precedence. For example, a = b = c ; is evaluated right to left as a = (b = c) ;

EXPRESSIONS

An expression is a variable name, function name, array name, constant, function call, array element reference, or structure member reference. Applying an operator (this can be an assignment operator) to one or more of these (where appropriate) is also an expression. Expression may be parenthesized. An expression is a "constant expression" if each term is constant.

POINTERS

A pointer is a variable which stores address of another variable or function. A variable name can be declared to be a pointer to a specified type by a statement of the form: type *name; Here are a few examples:

float numptr; /numptr points to floating number */

struct complex cp ; /*pointer to struct complex */

if (cp - > real = = 0.0) /* if the real part of the complex struct pointed to by cp is 0.0.*/

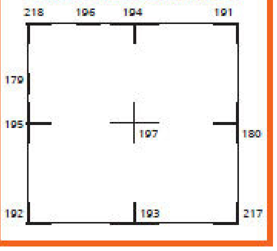
sptr = 'c' ; / store 'c' into location pointed to by sptr */

int (*fptr) ( ); /* fptr is pointer to function returing an int */

ESC SEQUENCES

\b	Backspace
\f	Form feed
\n	Newline
\r	Carriage return
\t	Tab
\\	Backslash
\"	Double quote
\'	Single quote

BOX DRAWING CHARACTER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