3

Operators and Expressions

3.1 INTRODUCTION

C supports a rich set of built-in operators. We have already used several of them, such +, –, *, & and <. An *operator* is a symbol that tells the computer to perform certain m ematical or logical manipulations. Operators are used in programs to manipulate data variables. They usually form a part of the mathematical or logical *expressions*.

C operators can be classified into a number of categories. They include:

1. Arithmetic operators
2. Relational operators
3. Logical operators
4. Assignment operators
5. Increment and decrement operators
6. Conditional operators
7. Bitwise operators
8. Special operators

An expression is a sequence of operands and operators that reduces to a single valu example,

10 + 15

is an expression whose value is 25. The value can be any type other than ***void***.

3.2 ARITHMETIC OPERATORS

C provides all the basic arithmetic operators. They are listed in Table 3.1. The operato , *, and / all work the same way as they do in other languages. These can operate o built-in data type allowed in C. The unary minus operator, in effect, multiplies its operand by –1. Therefore, a number preceded by a minus sign changes its sign.

Table 3.1 *Arithmetic Operators*

Operator	*Meaning*
+	Addition or unary plus
–	Subtraction or unary minus
*	Multiplication
/	Division
%	Modulo division

Integer division truncates any fractional part. The modulo division operation produces the remainder of an integer division. Examples of use of arithmetic operators are:

```
a – b     a + b
a * b     a / b
a % b     – a * b
```

Here **a** and **b** are variables and are known as *operands*. The modulo division operator % cannot be used on floating point data. Note that C does not have an operator for *exponentiation*. Older versions of C does not support unary plus but ANSI C supports it.

Integer Arithmetic

When both the operands in a single arithmetic expression such as a+b are integers, the expression is called an *integer expression*, and the operation is called *integer arithmetic*. Integer arithmetic always yields an integer value. The largest integer value depends on the machine, as pointed out earlier. In the above examples, if **a** and **b** are integers, then for **a** = 14 and **b** = 4 we have the following results:

```
a – b   =   10
a + b   =   18
a * b   =   56
a / b   =   3 (decimal part truncated)
a % b   =   2 (remainder of division)
```

During integer division, if both the operands are of the same sign, the result is truncated towards zero. If one of them is negative, the direction of trunction is implementation dependent. That is,

6/7 = 0 and –6/–7 = 0

but –6/7 may be zero or –1. (Machine dependent)

Similarly, during modulo division, the sign of the result is always the sign of the first operand (the dividend). That is

```
–14 % 3    =  –2
–14 % –3   =  –2
14 % –3    =   2
```

Example 3.1 The program in Fig. 3.1 shows the use of integer arithmetic to convert a given number of days into months and days.

Program

```
main ()
{
  int months, days ;

  printf("Enter days\n") ;
  scanf("%d", &days) ;

  months = days / 30 ;
  days = days % 30 ;
  printf("Months = %d Days = %d", months, days) ;
}
```

Output

```
Enter days
265
Months = 8 Days = 25
Enter days
364
Months = 12 Days = 4
Enter days
45
Months = 1 Days = 15
```

Fig. 3.1 *Illustration of integer arithmetic*

The variables months and days are declared as integers. Therefore, the statement

months = days/30;

truncates the decimal part and assigns the integer part to months. Similarly, the stateme[nt]

days = days%30;

assigns the remainder part of the division to days. Thus the given number of days [is] converted into an equivalent number of months and days and the result is printed as sho[wn] in the output.

Real Arithmetic

An arithmetic operation involving only real operands is called *real arithmetic*. A real opera[nd] may assume values either in decimal or exponential notation. Since floating point values [are] rounded to the number of significant digits permissible, the final value is an approximati[on] of the correct result. If **x, y,** and **z** are **floats**, then we will have:

x = 6.0/7.0 = 0.857143
y = 1.0/3.0 = 0.333333
z = –2.0/3.0 = –0.666667

The operator % cannot be used with real operands.

Mixed-mode Arithmetic

When one of the operands is real and the other is integer, the expression is called a *mixed-mode arithmetic* expression. If either operand is of the real type, then only the real operation is performed and the result is always a real number. Thus

15/10.0 = 1.5

whereas

15/10 = 1

More about mixed operations will be discussed later when we deal with the evaluation of expressions.

3.3 RELATIONAL OPERATORS

We often compare two quantities and depending on their relation, take certain decisions. For example, we may compare the age of two persons, or the price of two items, and so on. These comparisons can be done with the help of *relational operators*. We have already used the symbol '<', meaning 'less than'. An expression such as

a < b or 1 < 20

containing a relational operator is termed as a *relational expression*. The value of a relational expression is either *one* or *zero*. It is *one* if the specified relation is *true* and *zero* if the relation is *false*. For example

10 < 20 is true

but

20 < 10 is false

C supports six relational operators in all. These operators and their meanings are shown in Table 3.2.

Table 3.2 *Relational Operators*

Operator	*Meaning*
<	is less than
<=	is less than or equal to
>	is greater than
>=	is greater than or equal to
==	is equal to
!=	is not equal to

A simple relational expression contains only one relational operator and takes the following form:

ae-1 relational operator ae-2

ae-1 and *ae-2* are arithmetic expressions, which may be simple constants, variables or combination of them. Given below are some examples of simple relational expressions and their values:

4.5 <= 10 TRUE

4.5 < –10 FALSE

–35 >= 0 FALSE

10 < 7+5 TRUE

a+b = c+d TRUE only if the sum of values of a and b is equal to the sum of values of c and d.

When arithmetic expressions are used on either side of a relational operator, the arithmetic expressions will be evaluated first and then the results compared. That is, arithmetic operators have a higher priority over relational operators.

Relational expressions are used in *decision statements* such as **if** and **while** to decide the course of action of a running program. We have already used the **while** statement in Chapter 1. Decision statements are discussed in detail in Chapters 5 and 6.

Relational Operator Complements

Among the six relational operators, each one is a complement of another operator.

>	is complement of	<=
<	is complement of	>=
==	is complement of	!=

We can simplify an expression involving the *not* and the *less than* operators using the complements as shown below:

Actual one	*Simplified one*
!(x<y)	x >= y
!(x>y)	x <= y
!(x!=y)	x == y
!(x<=y)	x > y
!(x>=y)	x < y
!(x == y)	x != y

3.4 LOGICAL OPERATORS

In addition to the relational operators, C has the following three *logical operators*.

&& meaning logical AND
|| meaning logical OR
! meaning logical NOT

The logical operators && and || are used when we want to test more than one condition and make decisions. An example is:

a > b && x == 10

An expression of this kind, which combines two or more relational expressions, is termed as a *logical expression* or a *compound relational expression*. Like the simple relational expressions, a logical expression also yields a value of *one* or *zero*, according to the truth table shown in Table 3.3. The logical expression given above is true only if **a > b** is *true* and **x == 10** is *true*. If either (or both) of them are false, the expression is *false*.

Table 3.3 *Truth Table*

op-1	*op-2*	*Value of the expression*	
		op-1 && op-2	*op-1 || op-2*
Non-zero	Non-zero	1	1
Non-zero	0	0	1
0	Non-zero	0	1
0	0	0	0

Some examples of the usage of logical expressions are:

1. if (age > 55 && salary < 1000)
2. if (number < 0 || number > 100)

We shall see more of them when we discuss decision statements.

NOTE: Relative precedence of the relational and logical operators is as follows:

```
Highest     !
            > >=  < <=
            == !=
            &&
Lowest      ||
```

It is important to remember this when we use these operators in compound expressions.

3.5 ASSIGNMENT OPERATORS

Assignment operators are used to assign the result of an expression to a variable. We have seen the usual assignment operator, '='. In addition, C has a set of '*shorthand*' assignment operators of the form

v op= exp;

Where *v* is a variable, *exp* is an expression and *op* is a C binary arithmetic operator. The operator **op=** is known as the shorthand assignment operator.

The assignment statement

```
v op= exp;
```

is equivalent to

```
v = v op (exp);
```

with **v** evaluated only once. Consider an example

```
x += y+1;
```

This is same as the statement

```
x = x + (y+1);
```

The shorthand operator += means 'add y+1 to x' or 'increment x by y+1'. For y = 2, the above statement becomes

```
x += 3;
```

and when this statement is executed, 3 is added to x. If the old value of x is, say 5, then the new value of x is 8. Some of the commonly used shorthand assignment operators are illustrated in Table 3.4.

Table 3.4 *Shorthand Assignment Operators*

Statement with simple assignment operator	*Statement with shorthand operator*
a = a + 1	a += 1
a = a – 1	a –= 1
a = a * (n+1)	a *= n+1
a = a / (n+1)	a /= n+1
a = a % b	a %= b

The use of shorthand assignment operators has three advantages:

1. What appears on the left-hand side need not be repeated and therefore it becomes easier to write.
2. The statement is more concise and easier to read.
3. The statement is more efficient.

These advantages may be appreciated if we consider a slightly more involved statement like

```
value(5*j-2) = value(5*j-2) + delta;
```

With the help of the += operator, this can be written as follows:

```
value(5*j-2) += delta;
```

It is easier to read and understand and is more efficient because the expression 5*j–2 is evaluated only once.

Example 3.2 Program of Fig. 3.2 prints a sequence of squares of numbers. Note the use of the shorthand operator *= .

The program attempts to print a sequence of squares of numbers starting from 2. The statement

```
a *= a;
```

which is identical to

```
a = a*a;
```

replaces the current value of **a** by its square. When the value of **a** becomes equal or greater than **N** (=100) the **while** is terminated. Note that the output contains only three values 2, 4 and 16.

Program

```
#define   N    100
#define   A    2
main()
{
          int a;
          a = A;
          while( a < N )
          {
               printf("%d\n", a);
               a *= a;
          }
}
```

Output

```
2
4
16
```

Fig. 3.2 *Use of shorthand operator *=*

3.6 INCREMENT AND DECREMENT OPERATORS

C allows two very useful operators not generally found in other languages. These are the increment and decrement operators:

```
++ and --
```

The operator ++ adds 1 to the operand, while -- subtracts 1. Both are unary operators and takes the following form:

```
++m; or m++;
--m; or m--;
```

```
++m; is equivalent to m = m+1; (or m += 1;)
--m; is equivalent to m = m-1; (or m -= 1;)
```

We use the increment and decrement statements in **for** and **while** loops extensively.

While ++m and m++ mean the same thing when they form statements independently, they behave differently when they are used in expressions on the right-hand side of an assignment statement. Consider the following:

```
m = 5;
y = ++m;
```

In this case, the value of y and m would be 6. Suppose, if we rewrite the above statements as

```
m = 5;
y = m++;
```

then, the value of y would be 5 and m would be 6. *A prefix operator first adds 1 to the operand and then the result is assigned to the variable on left. On the other hand, a postfix operator first assigns the value to the variable on left and then increments the operand.*

Similar is the case, when we use ++ (or --) in subscripted variables. That is, the statement

```
a[i++] = 10;
```

is equivalent to

```
a[i] = 10;
i = i+1;
```

The increment and decrement operators can be used in complex statements. Example:

```
m = n++ -j+10;
```

Old value of n is used in evaluating the expression. n is incremented after the evaluation. Some compilers require a space on either side of n++ or ++n.

Rules for ++ and -- Operators

- Increment and decrement operators are unary operators and they require variable as their operands.
- When postfix ++ (or --) is used with a variable in an expression, the expression is evaluated first using the original value of the variable and then the variable is incremented (or decremented) by one.
- When prefix ++ (or --) is used in an expression, the variable is incremented (or decremented) first and then the expression is evaluated using the new value of the variable.
- The precedence and associatively of ++ and -- operators are the same as those of unary + and unary -.

3.7 CONDITIONAL OPERATOR

A ternary operator pair "? :" is available in C to construct conditional expressions of the form

exp1 ? exp2 : exp3

where *exp1*, *exp2*, and *exp3* are expressions.

The operator ? : works as follows: *exp1* is evaluated first. If it is nonzero (true), then the expression *exp2* is evaluated and becomes the value of the expression. If *exp1* is false, *exp3* is evaluated and its value becomes the value of the expression. Note that only one of the expressions (either *exp2* or *exp3*) is evaluated. For example, consider the following statements.

```
a = 10;
b = 15;
x = (a > b) ? a : b;
```

In this example, x will be assigned the value of b. This can be achieved using the **if..else** statements as follows:

```
if (a > b)
   x = a;
else
   x = b;
```

3.8 BITWISE OPERATORS

C has a distinction of supporting special operators known as *bitwise operators* for manipulation of data at bit level. These operators are used for testing the bits, or shifting them right or left. Bitwise operators may not be applied to **float** or **double**. Table 3.5 lists the bitwise operators and their meanings. They are discussed in detail in Appendix I.

Table 3.5 *Bitwise Operators*

Operator	*Meaning*
&	bitwise AND
|	bitwise OR
^	bitwise exclusive OR
<<	shift left
>>	shift right

3.9 SPECIAL OPERATORS

C supports some special operators of interest such as comma operator, **sizeof** operator, pointer operators (& and *) and member selection operators (. and ->). The comma and **sizeof** operators are discussed in this section while the pointer operators are discussed in

Chapter 11. Member selection operators which are used to select members of a structure are discussed in Chapters 10 and 11. ANSI committee has introduced two preprocessor operators known as "string-izing" and "token-pasting" operators (# and ##). They will be discussed in Chapter 14.

The Comma Operator

The comma operator can be used to link the related expressions together. A comma-linked list of expressions are evaluated *left to right* and the value of *right-most* expression is the value of the combined expression. For example, the statement

```
value = (x = 10, y = 5, x+y);
```

first assigns the value 10 to **x**, then assigns 5 to **y**, and finally assigns 15 (i.e. 10 + 5) to **value**. Since comma operator has the lowest precedence of all operators, the parentheses are necessary. Some applications of comma operator are:

In **for** loops:

```
for ( n = 1, m = 10, n <=m; n++, m++)
```

In **while** loops:

```
while (c = getchar( ), c != '10')
```

Exchanging values:

```
t = x, x = y, y = t;
```

The sizeof Operator

The **sizeof** is a compile time operator and, when used with an operand, it returns the number of bytes the operand occupies. The operand may be a variable, a constant or a data type qualifier.

Examples:

m = **sizeof** (sum);
n = **sizeof** (long int);
k = **sizeof** (235L);

The **sizeof** operator is normally used to determine the lengths of arrays and structures when their sizes are not known to the programmer. It is also used to allocate memory space dynamically to variables during execution of a program.

Example 3.3 In Fig. 3.3, the program employs different kinds of operators. The results of their evaluation are also shown for comparison.

Notice the way the increment operator ++ works when used in an expression. In the statement

```
c = ++a - b;
```

new value of **a** (= 16) is used thus giving the value 6 to c. That is, a is incremented by 1 before it is used in the expression. However, in the statement

```
d = b++ + a;
```

the old value of **b** (=10) is used in the expression. Here, b is incremented by 1 after it is used in the expression.

We can print the character % by placing it immediately after another % character in the control string. This is illustrated by the statement

```
printf("a%%b = %d\n", a%b);
```

The program also illustrates that the expression

```
c > d ? 1 : 0
```

assumes the value 0 when c is less than d and 1 when c is greater than d.

Program

```
main()
{
    int a, b, c, d;
    a = 15;
    b = 10;
    c = ++a - b;
    printf("a = %d b = %d c = %d\n",a, b, c);
    d = b++ +a;
    printf("a = %d b = %d d = %d\n",a, b, d);
    printf("a/b = %d\n", a/b);
    printf("a%%b = %d\n", a%b);
    printf("a *= b = %d\n", a*=b);
    printf("%d\n", (c>d) ? 1 : 0);
    printf("%d\n", (c<d) ? 1 : 0);
}
```

Output

```
a = 16 b = 10 c = 6
a = 16 b = 11 d = 26
a/b = 1
a%b = 5
a *= b = 176
0
1
```

Fig. 3.3 *Further illustration of arithmetic operators*

3.10 ARITHMETIC EXPRESSIONS

An arithmetic expression is a combination of variables, constants, and operators arranged as per the syntax of the language. We have used a number of simple expressions in the examples discussed so far. C can handle any complex mathematical expressions. Some of the examples of C expressions are shown in Table 3.6. Remember that C does not have an operator for exponentiation.

Table 3.6 *Expressions*

Algebraic expression	*C expression*
a x b - c	a * b - c
(m+n) (x+y)	(m+n) * (x+y)
$\left(\frac{ab}{c}\right)$	a * b/c
$3x^2+2x+1$	3 * x * x + 2 * x + 1
$\left(\frac{x}{y}\right) + c$	x/y+c

3.11 EVALUATION OF EXPRESSIONS

Expressions are evaluated using an assignment statement of the form:

variable = expression;

Variable is any valid C variable name. When the statement is encountered, the expression is evaluated first and the result then replaces the previous value of the variable on the left-hand side. All variables used in the expression must be assigned values before evaluation is attempted. Examples of evaluation statements are

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

The blank space around an operator is optional and adds only to improve readability. When these statements are used in a program, the variables a, b, c, and d must be defined before they are used in the expressions.

Example 3.4 The program in Fig. 3.4 illustrates the use of variables in expressions and their evaluation.

Output of the program also illustrates the effect of presence of parentheses in expressions. This is discussed in the next section.

```
Program
    main()
    {
            float a, b, c, x, y, z;
```

```
        a = 9;
        b = 12;
        c = 3;

        x = a - b / 3 + c * 2 - 1;
        y = a - b / (3 + c) * (2 - 1);
        z = a - (b / (3 + c) * 2) - 1;

        printf("x = %f\n", x);
        printf("y = %f\n", y);
        printf("z = %f\n", z);
    }
```

Output

```
x = 10.000000
y = 7.000000
z = 4.000000
```

Fig. 3.4 *Illustrations of evaluation of expressions*

3.12 PRECEDENCE OF ARITHMETIC OPERATORS

An arithmetic expression without parentheses will be evaluated from *left to right* using the rules of precedence of operators. There are two distinct priority levels of arithmetic operators in C:

High priority * / %

Low priority + –

The basic evaluation procedure includes 'two' left-to-right passes through the expression. During the first pass, the high priority operators (if any) are applied as they are encountered. During the second pass, the low priority operators (if any) are applied as they are encountered. Consider the following evaluation statement that has been used in the program of Fig. 3.4.

x = a–b/3 + c*2–1

When a = 9, b = 12, and c = 3, the statement becomes

x = 9–12/3 + 3*2–1

and is evaluated as follows

First pass

Step1: x = 9–4+3*2–1

Step2: x = 9–4+6–1

Second pass

Step3: x = 5+6–1
Step4: x = 11–1
Step5: x = 10

These steps are illustrated in Fig. 3.5. The numbers inside parentheses refer to step numbers.

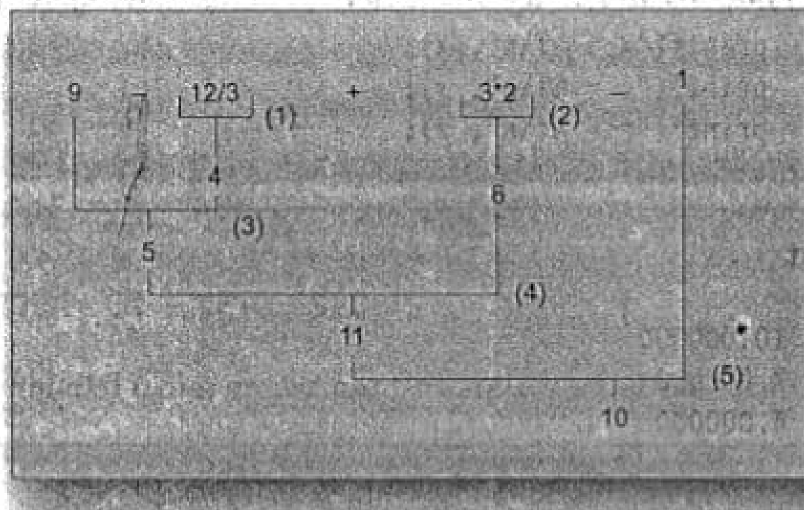


Fig. 3.5 *Illustration of hierarchy of operations*

However, the order of evaluation can be changed by introducing parentheses into an expression. Consider the same expression with parentheses as shown below:

9–12/(3+3)*(2–1)

Whenever parentheses are used, the expressions within parentheses assume highest priority. If two or more sets of parentheses appear one after another as shown above, the expression contained in the left-most set is evaluated first and the right-most in the last. Given below are the new steps.

First pass

Step1: 9-12/6 * (2-1)
Step2: 9-12/6 * 1

Second pass

Step3: 9-2 * 1
Step4: 9-2

Third pass

Step5: 7

This time, the procedure consists of three left-to-right passes. However, the number of evaluation steps remains the same as 5 (i.e equal to the number of arithmetic operators).

Parentheses may be nested, and in such cases, evaluation of the expression will proceed outward from the innermost set of parentheses. Just make sure that every opening parenthesis has a matching closing parenthesis. For example

$$9 - (12/(3+3) * 2) - 1 = 4$$

whereas

$$9 - ((12/3) + 3 * 2) - 1 = -2$$

While parentheses allow us to change the order of priority, we may also use them to improve understandability of the program. When in doubt, we can always add an extra pair just to make sure that the priority assumed is the one we require.

Rules for Evaluation of Expression

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

3.13 SOME COMPUTATIONAL PROBLEMS

When expressions include real values, then it is important to take necessary precautions to guard against certain computational errors. We know that the computer gives approximate values for real numbers and the errors due to such approximations may lead to serious problems. For example, consider the following statements:

```
a = 1.0/3.0;
b = a * 3.0;
```

We know that (1.0/3.0) 3.0 is equal to 1. But there is no guarantee that the value of **b** computed in a program will equal 1.

Another problem is division by zero. On most computers, any attempt to divide a number by zero will result in abnormal termination of the program. In some cases such a division may produce meaningless results. Care should be taken to test the denominator that is likely to assume zero value and avoid any division by zero.

The third problem is to avoid overflow or underflow errors. It is our responsibility to guarantee that operands are of the correct type and range, and the result may not produce any overflow or underflow.

Example 3.5 Output of the program in Fig. 3.6 shows round-off errors that can occur in computation of floating point numbers.

Program

```
/*____________ Sum of n terms of 1/n ____________*/
main()
{
      float sum, n, term ;
      int count = 1 ;

      sum = 0 ;
      printf("Enter value of n\n") ;
          scanf("%f", &n) ;
      term = 1.0/n ;
      while( count <= n )
      {
              sum = sum + term ;
              count++ ;
      }
      printf("Sum = %f\n", sum) ;
}
```

Output

```
Enter value of n
99
Sum = 1.000001
Enter value of n
143
Sum = 0.999999
```

Fig. 3.6 *Round-off errors in floating point computations*

We know that the sum of n terms of 1/n is 1. However, due to errors in floating point representation, the result is not always 1.

3.14 TYPE CONVERSIONS IN EXPRESSIONS

Implicit Type Conversion

C permits mixing of constants and variables of different types in an expression. C automatically converts any intermediate values to the proper type so that the expression can be evaluated without loosing any significance. This automatic conversion is known as *implicit type conversion*.

During evaluation it adheres to very strict rules of type conversion. If the operands are of different types, the 'lower' type is automatically converted to the 'higher' type before the operation proceeds. The result is of the higher type. A typical type conversion process is illustrated in Fig. 3.7.

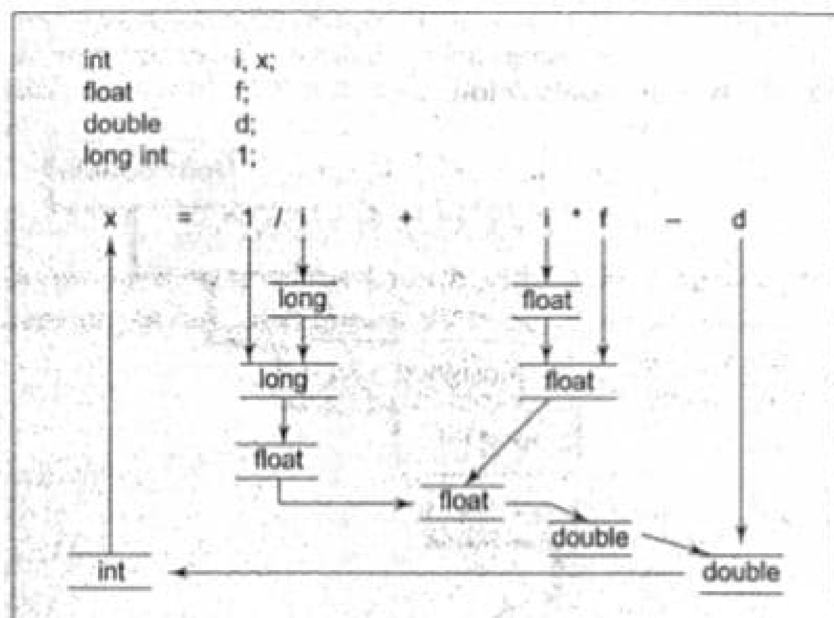


Fig. 3.7 *Process of implicit type conversion*

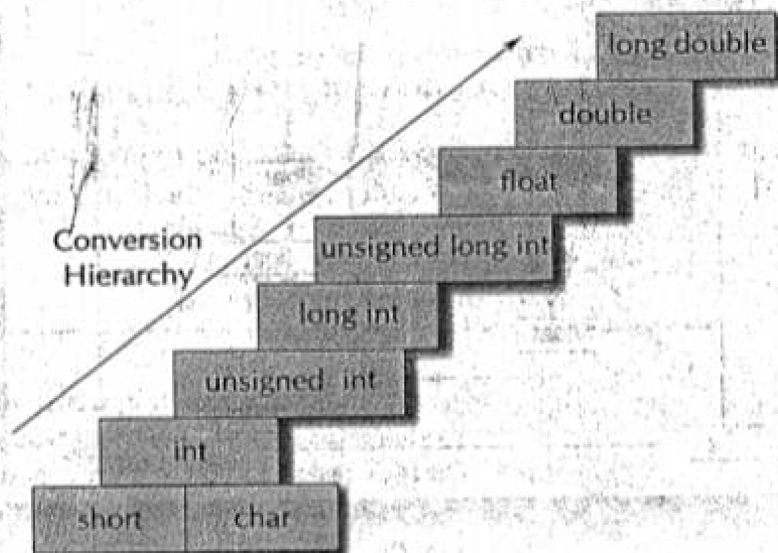
Given below is the sequence of rules that are applied while evaluating expressions.

All **short** and **char** are automatically converted to **int**; then

1. if one of the operands is **long double,** the other will be converted to **long double** and the result will be **long double**;
2. else, if one of the operands is **double,** the other will be converted to **double** and the result will be **double**;
3. else, if one of the operands is **float,** the other will be converted to **float** and the result will be **float**;
4. else, if one of the operands is **unsigned long int**, the other will be converted to **unsigned long int** and the result will be **unsigned long int**;
5. else, if one of the operands is **long int** and the other is **unsigned int,** then
   (a) if **unsigned int** can be converted to **long int**, the **unsigned int** operand will be converted as such and the result will be **long int**;
   (b) else, both operands will be converted to **unsigned long int** and the result will be **unsigned long int**;
6. else, if one of the operands is **long int,** the other will be converted to **long int** and the result will be **long int;**
7. else, if one of the operands is **unsigned int,** the other will be converted to **unsigned int** and the result will be **unsigned int.**

Conversion Hierarchy

Note that, C uses the rule that, in all expressions except assignments, any implicit type conversions are made from a lower size type to a higher size type as shown below:



Note that some versions of C automatically convert all floating-point operands to double precision.

The final result of an expression is converted to the type of the variable on the left of the assignment sign before assigning the value to it. However, the following changes are introduced during the final assignment.

1. **float** to **int** causes truncation of the fractional part.
2. **double to float** causes rounding of digits.
3. **long int to int** causes dropping of the excess higher order bits.

Explicit Conversion

We have just discussed how C performs type conversion automatically. However, there are instances when we want to force a type conversion in a way that is different from the automatic conversion. Consider, for example, the calculation of ratio of females to males in a town.

ratio = female_number/male_number

Since **female_number** and **male_number** are declared as integers in the program, the decimal part of the result of the division would be lost and **ratio** would represent a wrong figure. This problem can be solved by converting locally one of the variables to the floating point as shown below:

ratio = (**float**) female_number/male_number

The operator (**float**) converts the **female_number** to floating point for the purpose of valuation of the expression. Then using the rule of automatic conversion, the division is erformed in floating point mode, thus retaining the fractional part of result.

Note that in no way does the operator (**float**) affect the value of the variable **female umber.** And also, the type of **female number** remains as **int** in the other parts of the rogram.

The process of such a local conversion is known as *explicit conversion* or *casting a value.* he general form of a cast is:

(type-name)*expression*

here *type-name* is one of the standard C data types. The expression may be a constant, ariable or an expression. Some examples of casts and their actions are shown in Table 3.7.

Table 3.7 *Use of Casts*

Example	*Action*
x = (**int**) 7.5	7.5 is converted to integer by truncation.
a = (**int**) 21.3/(int)4.5	Evaluated as 21/4 and the result would be 5.
b = (**double**)sum/n	Division is done in floating point mode.
y = (**int**) (a+b)	The result of a+b is converted to integer.
z = (**int**)a+b	a is converted to integer and then added to b.
p = cos((**double**)x)	Converts x to double before using it.

asting can be used to round-off a given value. Consider the following statement:

x = (**int**) (y+0.5);

If **y** is 27.6, **y**+0.5 is 28.1 and on casting, the result becomes 28, the value that is signed to **x**. Of course, the expression, being cast is not changed.

Example 3.6 Figure 3.8 shows a program using a cast to evaluate the equation

$$sum = \sum_{i=1}^{n}(1/i)$$

Program

```
main()
{
    float   sum ;
    int          n ;

    sum = 0 ;

    for( n = 1 ; n <= 10 ; ++n )
    {
        sum = sum + 1/(float)n ;
        printf("%2d %6.4f\n", n, sum) ;
    }
}
```

```
Output
     1  1.0000
     2  1.5000
     3  1.8333
     4  2.0833
     5  2.2833
     6  2.4500
     7  2.5929
     8  2.7179
     9  2.8290
    10  2.9290
```

Fig. 3.8 *Use of a cast*

3.15 OPERATOR PRECEDENCE AND ASSOCIATIVITY

As mentioned earlier each operator, in C has a precedence associated with it. This precedence is used to determine how an expression involving more than one operator is evaluated. There are distinct *levels of precedence* and an operator may belong to one of these levels. The operators at the higher level of precedence are evaluated first. The operators of the same precedence are evaluated either from 'left to right' or from 'right to left', depending on the level. This is known as the *associativity* property of an operator. Table 3.8 provides a complete list of operators, their precedence levels, and their rules of association. The groups are listed in the order of decreasing precedence. Rank 1 indicates the highest precedence level and 15 the lowest. The list also includes those operators, which we have not yet been discussed.

It is very important to note carefully, the order of precedence and associativity of operators. Consider the following conditional statement:

```
if (x == 10 + 15 && y < 10)
```

The precedence rules say that the ***addition*** operator has a higher priority than the logical operator (&&) and the relational operators (== and <). Therefore, the addition of 10 and 15 is executed first. This is equivalent to :

```
if (x == 25 && y < 10)
```

The next step is to determine whether **x** is equal to 25 and **y** is less than 10. If we assume a value of 20 for x and 5 for y, then

```
x == 25 is FALSE (0)
y < 10 is TRUE (1)
```

Note that since the operator < enjoys a higher priority compared to ==, y < 10 is tested first and then x == 25 is tested.

Finally we get:

```
if (FALSE && TRUE)
```

```
Output

 1  1.0000
 2  1.5000
 3  1.8333
 4  2.0833
 5  2.2833
 6  2.4500
 7  2.5929
 8  2.7179
 9  2.8290
10  2.9290
```

Fig. 3.8 *Use of a cast*

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```
x == 25 is FALSE (0)
y < 10 is TRUE (1)
```

Note that since the operator < enjoys a higher priority compared to ==, y < 10 is tested first and then x == 25 is tested.

Finally we get:

```
if (FALSE && TRUE)
```

Because one of the conditions is FALSE, the complex condition is FALSE.

In the case of **&&**, it is guaranteed that the second operand will not be evaluated if the first is zero and in the case of | |, the second operand will not be evaluated if the first is non-zero.

Table 3.8 *Summary of C Operators*

Operator	*Description*	*Associativity*	*Rank*
()	Function call	Left to right	1
[ ]	Aray element reference		
+	Unary plus	Right to left	2
–	Unary minus		
++	Increment		
– –	Decrement		
!	Logical negation		
~	Ones complement		
*	Pointer reference (indirection)		
&	Address		
sizeof	Size of an object		
(type)	Type cast (conversion)		
*	Multiplication	Left to right	3
/	Division		
%	Modulus		
+	Addition	Left to right	4
–	Subtraction		
<<	Left shift	Left to right	5
>>	Right shift		
<	Less than	Left to right	6
<=	Less than or equal to		
>	Greater than		
>=	Greater than or equal to		
==	Equality	Left to right	7
!=	Inequality		
&	Bitwise AND	Left to right	8
^	Bitwise XOR	Left to right	9
|	Bitwise OR	Left to right	10
&&	Logical AND	Left to right	11
||	Logical OR	Left to right	12
?:	Conditional expression	Right to left	13
= *= /= %= += –= &= ^= |= <<= >>=	Assignment operators	Right to left	14
,	Comma operator	Left to right	15

Rules of Precedence and Associativity

- Precedence rules decides the order in which different operators are applied
- Associativity rule decides the order in which multiple occurrences of the same level operator are applied

3.16 MATHEMATICAL FUNCTIONS

Mathematical functions such as cos, sqrt, log, etc. are frequently used in analysis of real-life problems. Most of the C compilers support these basic math functions. However, there are systems that have a more comprehensive math library and one should consult the reference manual to find out which functions are available. Table 3.9 lists some standard math functions.

Table 3.9 *Math functions*

Function	*Meaning*
Trigonometric	
acos(x)	Arc cosine of x
asin(x)	Arc sine of x
atan(x)	Arc tangent of x
atan 2(x,y)	Arc tangent of x/y
cos(x)	Cosine of x
sin(x)	Sine of x
tan(x)	Tangent of x
Hyperbolic	
cosh(x)	Hyperbolic cosine of x
sinh(x)	Hyperbolic sine of x
tanh(x)	Hyperbolic tangent of x
Other functions	
ceil(x)	x rounded up to the nearest integer
exp(x)	e to the x power (e^x)
fabs(x)	Absolute value of x.
floor(x)	x rounded down to the nearest integer
fmod(x,y)	Remainder of x/y
log(x)	Natural log of x, x > 0
log10(x)	Base 10 log of x, x > 0
pow(x,y)	x to the power y (x^y)
sqrt(x)	Square root of x, x >= 0

Note: 1. **x** and **y** should be declared as **double**.
2. In trigonometric and hyperbolic functions, **x** and **y** are in radians.
3. All the functions return a **double**.

4. C99 has added **float** and **long double** versions of these fuctions.
5. C99 has added many more mathematical functions.
6. See the Appendix "C99 Features" for details.

As pointed out earlier in Chapter 1, to use any of these functions in a program, we should include the line:

#include <math.h>

in the beginning of the program.

Just Remember

- Use *decrement* and *increment* operators carefully. Understand the difference between **postfix** and **prefix** operations before using them.
- Add parentheses wherever you feel they would help to make the evaluation order clear.
- Be aware of side effects produced by some expressions.
- Avoid any attempt to divide by zero. It is normally undefined. It will either result in a fatal error or in incorrect results.
- Do not forget a semicolon at the end of an expression.
- Understand clearly the precedence of operators in an expression. Use parentheses, if necessary.
- Associativity is applied when more than one operator of the same precedence are used in an expression. Understand which operators associate from right to left and which associate from left to right.
- Do not use *increment* or *decrement* operators with any expression other than a *variable identifier*.
- It is illegal to apply modules operator % with anything other than integers.
- Do not use a variable in an expression before it has been assigned a value.
- Integer division always truncates the decimal part of the result. Use it carefully. Use casting where necessary.
- The result of an expression is converted to the type of the variable on the left of the assignment before assigning the value to it. Be careful about the loss of information during the conversion.
- All mathematical functions implement *double* type parameters and return *double* type values.
- It is an error if any space appears between the two symbols of the operators ==, !=, <= and >=.
- It is an error if the two symbols of the operators !=, <= and >= are reversed.
- Use spaces on either side of binary operator to improve the readability of the code.
- Do not use increment and decrement operators to floating point variables.
- Do not confuse the equality operator == with the assignment operator =.

Case Studies

1. Salesman's Salary

A computer manufacturing company has the following monthly compensation policy to their sales-persons:

Minimum base salary : 1500.00
Bonus for every computer sold : 200.00
Commission on the total monthly sales : 2 per cent

Since the prices of computers are changing, the sales price of each computer is fixed at the beginning of every month. A program to compute a sales-person's gross salary is given in Fig. 3.9.

```
Program
    #define BASE_SALAR          1500.00
    #define BONUS_RATE          200.00
    #define COMMISSION          0.02
    main()
    {
        int quantity ;
        float gross_salary, price ;
        float bonus, commission ;
        printf("Input number sold and price\n") ;
        scanf("%d %f", &quantity, &price) ;
        bonus           = BONUS_RATE * quantity ;
        commission      = COMMISSION * quantity * price ;
        gross_salary    = BASE_SALARY + bonus + commission ;
        printf("\n");
        printf("Bonus          = %6.2f\n", bonus) ;
        printf("Commission     = %6.2f\n", commission) ;
        printf("Gross salary   = %6.2f\n", gross_salary) ;
    }
Output
    Input number sold and price
    5 20450.00
    Bonus           = 1000.00
    Commission      = 2045.00
    Gross salary    = 4545.00
```

Fig. 3.9 *Program of salesman's salary*

Given the base salary, bonus, and commission rate, the inputs necessary to calculate the gross salary are, the price of each computer and the number sold during the month.

The gross salary is given by the equation:

Gross salary = base salary + (quantity * bonus rate)
+ (quantity * Price) * commission rate

2. Solution of the quadratic equation

An equation of the form

$$ax^2 + bx + c = 0$$

is known as the *quadratic equation*. The values of x that satisfy the equation are known as the *roots* of the equation. A quadratic equation has two roots which are given by the following two formulae:

$$\text{root 1} = \frac{-b + \text{sqrt}(b^2 - 4ac)}{2a}$$

$$\text{root 2} = \frac{-b - \text{sqrt}(b^2 - 4ac)}{2a}$$

A program to evaluate these roots is given in Fig. 3.10. The program requests the user to input the values of **a**, **b** and **c** and outputs **root 1** and **root 2**.

Program

```
#include <math.h>
main()
{
     float a, b, c, discriminant,
           root1, root2;
     printf("Input values of a, b, and c\n");
     scanf("%f %f %f", &a, &b, &c);
     discriminant = b*b - 4*a*c ;
     if(discriminant < 0)
        printf("\n\nROOTS ARE IMAGINARY\n");
     else
     {
        root1 = (-b + sqrt(discriminant))/(2.0*a);
        root2 = (-b - sqrt(discriminant))/(2.0*a);
        printf("\n\nRoot1 = %5.2f\n\nRoot2 = %5.2f\n",
               root1,root2 );
     }
}
```

Output

```
Input values of a, b, and c
2 4 -16
Root1 = 2.00
Root2 = -4.00
Input values of a, b, and c
1 2 3
ROOTS ARE IMAGINARY
```

Fig. 3.10 *Solution of a quadratic equation*

The term (b^2–4ac) is called the *discriminant*. If the discriminant is less than zero, its square roots cannot be evaluated. In such cases, the roots are said to be imaginary numbers and the program outputs an appropriate message.

Review Questions

3.1 State whether the following statements are *true* or *false*.
   (a) All arithmetic operators have the same level of precedence.
   (b) The modulus operator % can be used only with integers.
   (c) The operators <=, >= and != all enjoy the same level of priority.
   (d) During modulo division, the sign of the result is positive, if both the operands are of the same sign.
   (e) In C, if a data item is zero, it is considered false.
   (f) The expression *!(x<=y)* is same as the expression *x>y*.
   (g) A unary expression consists of only one operand with no operators.
   (h) Associativity is used to decide which of several different expressions is evaluated first.
   (i) An expression statement is terminated with a period.
   (j) During the evaluation of mixed expressions, an implicit cast is generated automatically.
   (k) An explicit cast can be used to change the expression.
   (l) Parentheses can be used to change the order of evaluation expressions.

3.2 Fill in the blanks with appropriate words.
   (a) The expression containing all the integer operands is called_______ expression.
   (b) The operator ________cannot be used with real operands.
   (c) C supports as many as ______relational operators.
   (d) An expression that combines two or more relational expressions is termed as _________expression.
   (e) The __________operator returns the number of bytes the operand occupies.
   (f) The order of evaluation can be changed by using _____ in an expression.
   (g) The use of _______ on a variable can change its type in the memory.
   (h) _________is used to determine the order in which different operators in an expression are evaluated.

3.3 Given the statement
   int a = 10, b = 20, c;
   determine whether each of the following statements are true or false.
   (a) The statement a = + 10, is valid.
   (b) The expression a + 4/6 * 6/2 evaluates to 11.
   (c) The expression b + 3/2 * 2/3 evaluates to 20.
   (d) The statement a + = b; gives the values 30 to a and 20 to b.
   (e) The statement ++a++; gives the value 12 to a
   (f) The statement a = 1/b; assigns the value 0.5 to a

3.4 Declared **a** as *int* and **b** as *float*, state whether the following statements are true or false.

(a) The statement a = 1/3 + 1/3 + 1/3; assigns the value 1 to a.
(b) The statement b = 1.0/3.0 + 1.0/3.0 + 1.0/3.0; assigns a value 1.0 to b.
(c) The statement b = 1.0/3.0 * 3.0 gives a value 1.0 to b.
(d) The statement b = 1.0/3.0 + 2.0/3.0 assigns a value 1.0 to b.
(e) The statement a = 15/10.0 + 3/2; assigns a value 3 to a.

3.5 Which of the following expressions are true?
(a) !(5 + 5 >=10)
(b) 5 + 5 = = 10 || 1 + 3 = = 5
(c) 5 > 10 || 10 < 20 && 3 < 5
(d) 10 ! = 15 && !(10<20) || 15 > 30

3.6 Which of the following arithmetic expressions are valid ? If valid, give the value of the expression; otherwise give reason.
(a) 25/3 % 2
(b) +9/4 + 5
(c) 7.5 % 3
(d) 14 % 3 + 7 % 2
(e) −14 % 3
(f) 15.25 + − 5.0
(g) (5/3) * 3 + 5 % 3
(h) 21 % (int)4.5

3.7 Write C assignment statements to evaluate the following equations:
(a) $\text{Area} = \pi r^2 + 2\pi rh$

(b) $\text{Torque} = \dfrac{2m_1m_2}{m_1 + m_2} \cdot g$

(c) $\text{Side} = \sqrt{a^2+b^2-2ab\cos(x)}$

(d) $\text{Energy} = \text{mass}\left[\text{acceleration} \times \text{height} + \dfrac{(\text{velocity})^2}{2}\right]$

3.8 Identify unnecessary parentheses in the following arithmetic expressions.
(a) ((x−(y/5)+z)%8) + 25
(b) ((x−y) * p)+q
(c) (m*n) + (−x/y)
(d) x/(3*y)

3.9 Find errors, if any, in the following assignment statements and rectify them.
(a) `x = y = z = 0.5, 2.0. -5.75;`
(b) `m = ++a * 5;`
(c) `y = sqrt(100);`
(d) `p * = x/y;`
(e) `s = /5;`
(f) `a = b++ -c*2`

3.10 Determine the value of each of the following logical expressions if a = 5, b = 10 and c = −6
(a) a > b && a < c
(b) a < b && a > c
(c) a == c || b > a
(d) b > 15 && c < 0 || a > 0
(e) (a/2.0 == 0.0 && b/2.0 != 0.0) || c < 0.0

3.11 What is the output of the following program?

```
main ( )
{
        char x;
        int y;
        x = 100;
        y = 125;
        printf ("%c\n", x) ;
        printf ("%c\n", y) ;
        printf ("%d\n", x) ;
}
```

3.12 Find the output of the following program?

```
main ( )
{
        int x = 100;
        printf("%d/n", 10 + x++);
        printf("%d/n", 10 + ++x);
}
```

3.13 What is printed by the following program?

```
main
{
        int x = 5, y = 10, z = 10 ;
        x = y == z;
        printf("%d",x ) ;
}
```

3.14 What is the output of the following program?

```
main ( )
{
        int x = 100, y = 200;
        printf ("%d", (x > y)? x : y);
}
```

3.15 What is the output of the following program?

```
main ( )
{
        unsigned x = 1 ;
        signed char y = -1 ;
        if(x > y)
                printf(" x > y");
        else
                printf("x<= y") ;
}
```

Did you expect this output? Explain.

3.16 What is the output of the following program? Explain the output.

```
main ( )
{
        int x = 10 ;
        if(x = 20) printf("TRUE") ;
        else printf("FALSE") ;
}
```

3.17 What is the error in each of the following statements?

(a) if (m == 1 & n ! = 0)
printf("OK");

(b) if (x = < 5)
printf ("Jump");

3.18 What is the error, if any, in the following segment?

```
int x = 10 ;
float y = 4.25 ;
x = y%x ;
```

3.19 What is printed when the following is executed?

```
for (m = 0; m <3; ++m)
printf("%d/n", (m%2) ? m: m+2);
```

3.20 What is the output of the following segment when executed?

```
int m = - 14, n = 3;
printf("%d\n", m/n * 10) ;
n = -n;
printf("%d\n", m/n * 10);
```

Programming Exercises

3.1 Given the values of the variables x, y and z, write a program to rotate their values such that x has the value of y, y has the value of z, and z has the value of x.

3.2 Write a program that reads a floating-point number and then displays the right-most digit of the integral part of the number.

3.3 Modify the above program to display the two right-most digits of the integral part of the number.

3.4 Write a program that will obtain the length and width of a rectangle from the user and compute its area and perimeter.

3.5 Given an integer number, write a program that displays the number as follows:

First line : all digits
Second line : all except first digit
Third line : all except first two digits
....
Last line : The last digit

For example, the number 5678 will be displayed as:

```
5 6 7 8
6 7 8
7 8
8
```

3.6 The straight-line method of computing the yearly depreciation of the value of an item is given by

$$\text{Depreciation} = \frac{\text{Purchase Price} - \text{Salvage Value}}{\text{Years of Service}}$$

Write a program to determine the salvage value of an item when the purchase price, years of service, and the annual depreciation are given.

3.7 Write a program that will read a real number from the keyboard and print the following output in one line:

Smallest integer not less than the number	The given number	Largest integer not greater than the number

3.8 The total distance travelled by a vehicle in t seconds is given by

$$\text{distance} = ut + (at^2)/2$$

Where u is the initial velocity (metres per second), a is the acceleration (metres per second ^{2}). Write a program to evaluate the distance travelled at regular intervals of time, given the values of u and a. The program should provide the flexibility to the user to select his own time intervals and repeat the calculations for different values of u and a.

3.9 In inventory management, the Economic Order Quantity for a single item is given by

$$\text{EOQ} = \sqrt{\frac{2 \times \text{demand rate} \times \text{setup costs}}{\text{holding cost per item per unit time}}}$$

and the optimal Time Between Orders

$$\text{TBO} = \sqrt{\frac{2 \times \text{setup costs}}{\text{demand rate} \times \text{holding cost per item per unit time}}}$$

Write a program to compute EOQ and TBO, given demand rate (items per unit time), setup costs (per order), and the holding cost (per item per unit time).

3.10 For a certain electrical circuit with an inductance L and resistance R, the damped natural frequency is given by

$$\text{Frequency} = \sqrt{\frac{1}{LC} - \frac{R^2}{4C^2}}$$

It is desired to study the variation of this frequency with C (capacitance). Write a program to calculate the frequency for different values of C starting from 0.01 to 0.1 in steps of 0.01.

3.11 Write a program to read a four digit integer and print the sum of its digits.
Hint: Use / and % operators.

3.12 Write a program to print the size of various data types in C.

3.13 Given three values, write a program to read three values from keyboard and print out the largest of them without using **if** statement.

3.14 Write a program to read two integer values m and n and to decide and print whether m is a multiple of n.

3.15 Write a program to read three values using **scanf** statement and print the following results:
(a) Sum of the values
(b) Average of the three values
(c) Largest of the three
(d) Smallest of the three

3.16 The cost of one type of mobile service is Rs. 250 plus Rs. 1.25 for each call made over and above 100 calls. Write a program to read customer codes and calls made and print the bill for each customer.

3.17 Write a program to print a table of **sin** and **cos** functions for the interval from 0 to 180 degrees in increments of 15 as shown below.

x (degrees)	*sin (x)*	*cos (x)*
0	......	......
15	......	......
...		
...		
180	......	......

3.18 Write a program to compute the values of square-roots and squares of the numbers 0 to 100 in steps 10 and print the output in a tabular form as shown below.

Number	*Square-root*	*Square*
0	0	0
100	10	10000

3.19 Write a program that determines whether a given integer is odd or even and displays the number and description on the same line.

3.20 Write a program to illustrate the use of cast operator in a real life situation.