Class: SYBBA-CA **Subject: Object Oriented Programming using "C"**
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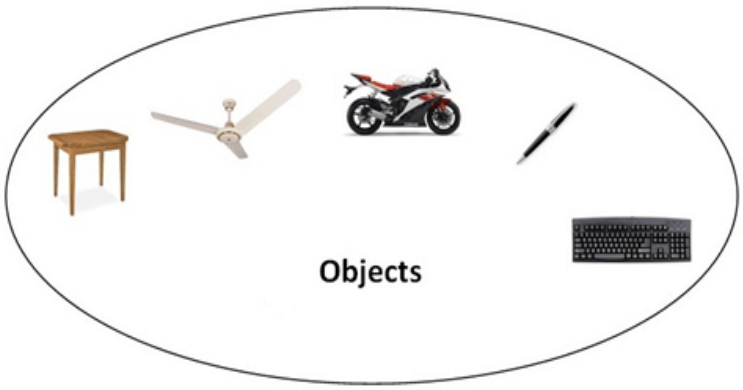
Unit 1-Introduction to C++

OOPs (Object Oriented Programming)

Object means a real word entity such as pen, chair, table etc. **Object-Oriented Programming** is a methodology or paradigm to design a program using classes and objects. It simplifies the software development and maintenance by providing some concepts:



- Object
- Class
- Inheritance
- Polymorphism
- Abstraction
- Encapsulation

Object

Any entity that has state and behavior is known as an object. For example: chair, pen, table, keyboard, bike etc. It can be physical and logical. An Object is an identifiable entity with some characteristics and behaviour. An Object is an instance of a Class. When a class is defined, no memory is allocated but when it is instantiated (i.e. an object is created) memory is allocated.

Class

Collection of objects is called class. It is a logical entity.For Example: Consider the Class of Cars. There may be many cars with different names and brand but all of them will share some common properties like all of them will have 4 wheels, Speed Limit, Mileage range etc. So here, Car is the class and wheels, speed limits, mileage are their properties.

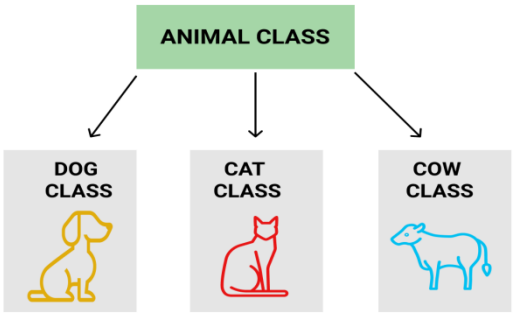
- A Class is a user-defined data-type which has data members and member functions.
- Data members are the data variables and member functions are the functions used to manipulate these variables and together these data members and member functions define the properties and behaviour of the objects in a Class.
- In the above example of class Car, the data member will be speed limit, mileage etc and member functions can apply brakes, increase speed etc.

Inheritance

When one object acquires all the properties and behaviours of parent object i.e. known as inheritance. It provides code reusability. It is used to achieve runtime polymorphism.

- **Sub Class**: The class that inherits properties from another class is called Sub class or Derived Class.
- **Super Class**:The class whose properties are inherited by sub class is called Base Class or Super class.
- **Reusability**: Inheritance supports the concept of "reusability", i.e. when we want to create a new class and there is already a class that includes some of the code that we want, we can derive our new class from the existing class. By doing this, we are reusing the fields and methods of the existing class.

Example: Dog, Cat, Cow can be Derived Class of Animal Base Class.



Polymorphism

When **one task is performed by different ways** i.e. known as polymorphism. For example: to convince the customer differently, to draw something e.g. shape or rectangle etc.

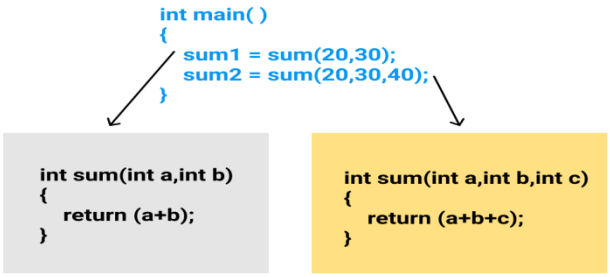
A person at the same time can have different characteristic. Like a man at the same time is a father, a husband, an employee. So the same person posses different behaviour in different situations. This is called polymorphism.

An operation may exhibit different behaviours in different instances. The behaviour depends upon the types of data used in the operation.

C++ supports operator overloading and function overloading.

- *Operator Overloading*: The process of making an operator to exhibit different behaviours in different instances is known as operator overloading.
- *Function Overloading*: Function overloading is using a single function name to perform different types of tasks.
  Polymorphism is extensively used in implementing inheritance.

Example: Suppose we have to write a function to add some integers, some times there are 2 integers, some times there are 3 integers. We can write the Addition Method with the same name having different parameters, the concerned method will be called according to parameters.



Abstraction

Hiding internal details and showing functionality is known as abstraction. For example: phone call, we don't know the internal processing.

Consider a real-life example of a man driving a car. The man only knows that pressing the accelerators will increase the speed of the car or applying brakes will stop the car but he does not know about how on pressing accelerator the speed is actually increasing, he does not know about the inner mechanism of the car or the implementation of accelerator, brakes etc in the car. This is what abstraction is.

- *Abstraction using Classes*: We can implement Abstraction in C++ using classes. The class helps us to group data members and member functions using available access specifiers. A Class can decide which data member will be visible to the outside world and which is not.
- *Abstraction in Header files*: One more type of abstraction in C++ can be header files. For example, consider the pow() method present in math.h header file. Whenever we need to calculate the power of a number, we simply call the function pow() present in the math.h header file and pass the numbers as arguments without knowing the underlying algorithm according to which the function is actually calculating the power of numbers.

Encapsulation

Binding (or wrapping) code and data together into a single unit is known as encapsulation. For example: capsule, it is wrapped with different medicines.

Consider a real-life example of encapsulation, in a company, there are different sections like the accounts section, finance section, sales section etc. The finance section handles all the financial transactions and keeps records of all the data related to finance. Similarly, the sales section handles all the sales-related activities and keeps records of all the sales. Now there may arise a situation when for some reason an official from the finance section needs all the data about sales in a particular month. In this case, he is not allowed to directly access the data of the sales section. He will first have to contact some other officer in the sales section and then request him to give the particular data. This is what encapsulation is. Here the data of the sales section and the employees that can manipulate them are wrapped under a single name "sales section".

Advantage of OOPs over Procedure-oriented programming language

1. OOPs makes development and maintenance easier where as in Procedure-oriented programming language it is not easy to manage if code grows as project size grows.
2. OOPs provide data hiding whereas in Procedure-oriented programming language a global data can be accessed from anywhere.
3. OOPs provide ability to simulate real-world event much more effectively. We can provide the solution of real word problem if we are using the Object-Oriented Programming language.

Introduction to CPP

C++ is a general-purpose programming language that was developed as an enhancement of the C language to include object-oriented paradigm. It is an imperative and a **compiled** language.

C++ is a statically typed, compiled, general-purpose, case-sensitive, free-form programming language that supports procedural, object-oriented, and generic programming.

C++ is regarded as a **middle-level** language, as it comprises a combination of both high-level and low-level language features.

C++ was developed by Bjarne Stroustrup starting in 1979 at Bell Labs in Murray Hill, New Jersey, as an enhancement to the C language and originally named C with Classes but later it was renamed C++ in 1983.

C++ is a superset of C, and that virtually any legal C program is a legal C++ program.

Features of CPP

features & key-points to note about the programming language are as follows:

- **Simple**: It is a simple language in the sense that programs can be broken down into logical units and parts, has a rich libray support and a variety of data-types.
- **Machine Independent but Platform Dependent**: A C++ executable is not platform-independent (compiled programs on Linux won't run on Windows), however they are machine independent.
- **Mid-level language**: It is a mid-level language as we can do both systems-programming (drivers, kernels, networking etc.) and build large-scale user applications (Media Players, Photoshop, Game Engines etc.)

- **Rich library support**: Has a rich library support (Both standard ~ built-in data structures, algorithms etc.) as well 3rd party libraries (e.g. Boost libraries) for fast and rapid development.
- **Speed of execution**: C++ programs excel in execution speed. Since, it is a compiled language, and also hugely procedural. Newer languages have extra in-built default features such as grabage-collection, dynamic typing etc. which slow the execution of the program overall. Since there is no additional processing overhead like this in C++, it is blazing fast.
- **Pointer and direct Memory-Access**: C++ provides pointer support which aids users to directly manipulate storage address. This helps in doing low-level programming (where one might need to have explicit control on the storage of variables).
- **Object-Oriented**: One of the strongest points of the language which sets it apart from C. Object-Oriented support helps C++ to make maintainable and extensible programs. i.e. Large-scale applications can be built. Procedural code becomes difficult to maintain as code-size grows.
- **Compiled Language**: C++ is a compiled language, contributing to its speed.

Applications of C++:

C++ finds varied usage in applications such as:

- **Application Software Development** - C++ programming has been used in developing almost all the major Operating Systems like Windows, Mac OSX and Linux. Apart from the operating systems, the core part of many browsers like Mozilla Firefox and Chrome have been written using C++. C++ also has been used in developing the most popular database system called MySQL.
- **Programming Languages Development** - C++ has been used extensively in developing new programming languages like C#, Java, JavaScript, Perl, UNIX's C Shell, PHP and Python, and Verilog etc.
- **Computation Programming** - C++ is the best friends of scientists because of fast speed and computational efficiencies.
- **Games Development** - C++ is extremely fast which allows programmers to do procedural programming for CPU intensive functions and provides greater control over hardware, because of which it has been widely used in development of gaming engines.
- **Embedded System** - C++ is being heavily used in developing Medical and Engineering Applications like softwares for MRI machines, high-end CAD/CAM systems etc.

C++ Basic Input/Output

The C++ standard libraries provide an extensive set of input/output capabilities which we will see in subsequent chapters. This chapter will discuss very basic and most common I/O operations required for C++ programming.

C++ I/O occurs in streams, which are sequences of bytes. If bytes flow from a device like a keyboard, a disk drive, or a network connection etc. to main memory, this is called **input operation** and if bytes flow from main memory to a device like a display screen, a printer, a disk drive, or a network connection, etc., this is called **output operation**.

I/O Library Header Files

There are following header files important to C++ programs −

Sr.No	Header File & Function and Description
1	**<iostream>** This file defines the **cin, cout, cerr** and **clog** objects, which correspond to the standard input stream, the standard output stream, the un-buffered standard error stream and the buffered standard error stream, respectively.
2	**<iomanip>** This file declares services useful for performing formatted I/O with so-called parameterized stream manipulators, such as **setw** and **setprecision**.
3	**<fstream>** This file declares services for user-controlled file processing. We will discuss about it in detail in File and Stream related chapter.

The Standard Output Stream (cout)

The predefined object **cout** is an instance of **ostream** class. The cout object is said to be "connected to" the standard output device, which usually is the display screen. The **cout** is used in conjunction with the stream insertion operator, which is written as << which are two less than signs as shown in the following example.

```
#include <iostream>

using namespace std;

int main() {
   char str[] = "Hello C++";

   cout << "Value of str is : " << str << endl;
}
```

When the above code is compiled and executed, it produces the following result −

Output-> Value of str is : Hello C++

The C++ compiler also determines the data type of variable to be output and selects the appropriate stream insertion operator to display the value. The << operator is overloaded to output data items of built-in types integer, float, double, strings and pointer values.

The insertion operator << may be used more than once in a single statement as shown above and **endl** is used to add a new-line at the end of the line.

The Standard Input Stream (cin)

The predefined object **cin** is an instance of **istream** class. The cin object is said to be attached to the standard input device, which usually is the keyboard. The **cin** is used in conjunction with the stream extraction operator, which is written as >> which are two greater than signs as shown in the following example.

```
#include <iostream>

using namespace std;

int main() {
  char name[50];

  cout << "Please enter your name: ";
  cin >> name;
  cout << "Your name is: " << name << endl;

}
```

When the above code is compiled and executed, it will prompt you to enter a name. You enter a value and then hit enter to see the following result −

Please enter your name: cplusplus
Your name is: cplusplus

The C++ compiler also determines the data type of the entered value and selects the appropriate stream extraction operator to extract the value and store it in the given variables.

The stream extraction operator >> may be used more than once in a single statement. To request more than one datum you can use the following −

cin >> name >> age;

This will be equivalent to the following two statements −

cin >> name;
cin >> age;

C++ Program Structure

Let us look at a simple code that would print the words *Hello World*.

```
#include <iostream>
using namespace std;

// main() is where program execution begins.
int main() {
   cout << "Hello World"; // prints Hello World
   return 0;
}
```

Let us look at the various parts of the above program −

- The C++ language defines several headers, which contain information that is either necessary or useful to your program. For this program, the header **<iostream>** is needed.
- The line **using namespace std;** tells the compiler to use the std namespace. Namespaces are a relatively recent addition to C++.
- The next line '**// main() is where program execution begins.**' is a single-line comment available in C++. Single-line comments begin with // and stop at the end of the line.
- The line **int main()** is the main function where program execution begins.
- The next line **cout << "Hello World";** causes the message "Hello World" to be displayed on the screen.
- The next line **return 0;** terminates main( )function and causes it to return the value 0 to the calling process.

Unit-2 Beginning with CPP

C++ Data Types

While writing program in any language, you need to use various variables to store various information. Variables are nothing but reserved memory locations to store values. This means that when you create a variable you reserve some space in memory.

You may like to store information of various data types like character, wide character, integer, floating point, double floating point, boolean etc. Based on the data type of a variable, the operating system allocates memory and decides what can be stored in the reserved memory.

Primitive Built-in Types

C++ offers the programmer a rich assortment of built-in as well as user defined data types. Following table lists down seven basic C++ data types –

Type	Keyword
Boolean	bool
Character	char
Integer	int
Floating point	float
Double floating point	double
Valueless	void
Wide character	wchar_t

Several of the basic types can be modified using one or more of these type modifiers −

- signed
- unsigned
- short
- long

The following table shows the variable type, how much memory it takes to store the value in memory, and what is maximum and minimum value which can be stored in such type of variables.

Type	Typical Bit Width	Typical Range
char	1byte	-127 to 127 or 0 to 255
unsigned char	1byte	0 to 255
signed char	1byte	-127 to 127
int	4bytes	-2147483648 to 2147483647
unsigned int	4bytes	0 to 4294967295
signed int	4bytes	-2147483648 to 2147483647
short int	2bytes	-32768 to 32767
unsigned short int	2bytes	0 to 65,535
signed short int	2bytes	-32768 to 32767
long int	8bytes	-2,147,483,648 to 2,147,483,647
signed long int	8bytes	same as long int
unsigned long int	8bytes	0 to 4,294,967,295
long long int	8bytes	-(2^63) to (2^63)-1
unsigned long long int	8bytes	0 to 18,446,744,073,709,551,615

float	4bytes	
double	8bytes	
long double	12bytes	
wchar_t	2 or 4 bytes	1 wide character

The size of variables might be different from those shown in the above table, depending on the compiler and the computer you are using.

Following is the example, which will produce correct size of various data types on your computer.

```
#include <iostream>
using namespace std;

int main() {
  cout << "Size of char : " << sizeof(char) << endl;
  cout << "Size of int : " << sizeof(int) << endl;
  cout << "Size of short int : " << sizeof(short int) << endl;
  cout << "Size of long int : " << sizeof(long int) << endl;
  cout << "Size of float : " << sizeof(float) << endl;
  cout << "Size of double : " << sizeof(double) << endl;
  cout << "Size of wchar_t : " << sizeof(wchar_t) << endl;

  return 0;
}
```

This example uses **endl**, which inserts a new-line character after every line and << operator is being used to pass multiple values out to the screen. We are also using **sizeof()** operator to get size of various data types.

When the above code is compiled and executed, it produces the following result which can vary from machine to machine −

```
Size of char : 1
Size of int : 4
Size of short int : 2
Size of long int : 4
Size of float : 4
Size of double : 8
Size of wchar_t : 4
```

typedef Declarations

You can create a new name for an existing type using **typedef**. Following is the simple syntax to define a new type using typedef −

typedef type newname;

For example, the following tells the compiler that feet is another name for int −

typedef int feet;

Now, the following declaration is perfectly legal and creates an integer variable called distance −

feet distance;

Enumerated Types

An enumerated type declares an optional type name and a set of zero or more identifiers that can be used as values of the type. Each enumerator is a constant whose type is the enumeration.

Creating an enumeration requires the use of the keyword **enum**. The general form of an enumeration type is −

enum enum-name { list of names } var-list;

Here, the enum-name is the enumeration's type name. The list of names is comma separated.

For example, the following code defines an enumeration of colors called colors and the variable c of type color. Finally, c is assigned the value "blue".

```
enum color { red, green, blue } c;
c = blue;
```

By default, the value of the first name is 0, the second name has the value 1, and the third has the value 2, and so on. But you can give a name, a specific value by adding an initializer. For example, in the following enumeration, **green** will have the value 5.

enum color { red, green = 5, blue };

Here, **blue** will have a value of 6 because each name will be one greater than the one that precedes it.

C++ Keywords

The following list shows the reserved words in C++. These reserved words may not be used as constant or variable or any other identifier names.

asm	else	new	this
auto	enum	operator	throw
bool	explicit	private	true
break	export	protected	try

case	extern	public	typedef
catch	false	register	typeid
char	float	reinterpret_cast	typename
class	for	return	union
const	friend	short	unsigned
const_cast	goto	signed	using
continue	if	sizeof	virtual
default	inline	static	void
delete	int	static_cast	volatile
do	long	struct	wchar_t
double	mutable	switch	while
dynamic_cast	namespace	template	

C++ Variable Types

A variable provides us with named storage that our programs can manipulate. Each variable in C++ has a specific type, which determines the size and layout of the variable's memory; the range of values that can be stored within that memory; and the set of operations that can be applied to the variable.

The name of a variable can be composed of letters, digits, and the underscore character. It must begin with either a letter or an underscore. Upper and lowercase letters are distinct because C++ is case-sensitive −

Variable Definition in C++

A variable definition tells the compiler where and how much storage to create for the variable. A variable definition specifies a data type, and contains a list of one or more variables of that type as follows −

type variable_list;

Here, **type** must be a valid C++ data type including char, w_char, int, float, double, bool or any user-defined object, etc., and **variable_list** may consist of one or more identifier names separated by commas. Some valid declarations are shown here −

```
int    i, j, k;
char   c, ch;
float  f, salary;
double d;
```

The line **int i, j, k;** both declares and defines the variables i, j and k; which instructs the compiler to create variables named i, j and k of type int.

Variables can be initialized (assigned an initial value) in their declaration. The initializer consists of an equal sign followed by a constant expression as follows −

type variable_name = value;

Some examples are −

```
extern int d = 3, f = 5;    // declaration of d and f.
int d = 3, f = 5;           // definition and initializing d and f.
byte z = 22;                // definition and initializes z.
char x = 'x';               // the variable x has the value 'x'.
```

For definition without an initializer: variables with static storage duration are implicitly initialized with NULL (all bytes have the value 0); the initial value of all other variables is undefined.

Variable Declaration in C++

A variable declaration provides assurance to the compiler that there is one variable existing with the given type and name so that compiler proceed for further compilation without needing complete detail about the variable. A variable declaration has its meaning at the time of compilation only, compiler needs actual variable definition at the time of linking of the program.

A variable declaration is useful when you are using multiple files and you define your variable in one of the files which will be available at the time of linking of the program. You will use **extern** keyword to declare a variable at any place. Though you can declare a variable multiple times in your C++ program, but it can be defined only once in a file, a function or a block of code.

Example

Try the following example where a variable has been declared at the top, but it has been defined inside the main function −

```
#include <iostream>
using namespace std;
```

```
// Variable declaration:
extern int a, b;
extern int c;
extern float f;

int main () {
  // Variable definition:
  int a, b;
  int c;
  float f;

  // actual initialization
  a = 10;
  b = 20;
  c = a + b;

  cout << c << endl ;

  f = 70.0/3.0;
  cout << f << endl ;

  return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
30
23.3333
```

Same concept applies on function declaration where you provide a function name at the time of its declaration and its actual definition can be given anywhere else. For example −

```
// function declaration
int func();
int main() {
  // function call
  int i = func();
}

// function definition
int func() {
  return 0;
}
```

Variable Scope in C++

A scope is a region of the program and broadly speaking there are three places, where variables can be declared −

- Inside a function or a block which is called local variables,
- In the definition of function parameters which is called formal parameters.

- Outside of all functions which is called global variables.

We will learn what is a function and it's parameter in subsequent chapters. Here let us explain what are local and global variables.

Local Variables

Variables that are declared inside a function or block are local variables. They can be used only by statements that are inside that function or block of code. Local variables are not known to functions outside their own. Following is the example using local variables −

```
#include <iostream>
using namespace std;

int main () {
  // Local variable declaration:
  int a, b;
  int c;

  // actual initialization
  a = 10;
  b = 20;
  c = a + b;

  cout << c;

  return 0;
}
```

Global Variables

Global variables are defined outside of all the functions, usually on top of the program. The global variables will hold their value throughout the life-time of your program.

A global variable can be accessed by any function. That is, a global variable is available for use throughout your entire program after its declaration. Following is the example using global and local variables −

```
#include <iostream>
using namespace std;

// Global variable declaration:
int g;

int main () {
  // Local variable declaration:
  int a, b;

  // actual initialization
  a = 10;
  b = 20;
```

```
   g = a + b;

   cout << g;

   return 0;
}
```

A program can have same name for local and global variables but value of local variable inside a function will take preference. For example −

```
#include <iostream>
using namespace std;

// Global variable declaration:
int g = 20;

int main () {
   // Local variable declaration:
   int g = 10;

   cout << g;

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

10

Operators in C++

An operator is a symbol that tells the compiler to perform specific mathematical or logical manipulations. C++ is rich in built-in operators and provide the following types of operators

- Arithmetic Operators
- Relational Operators
- Logical Operators
- Bitwise Operators
- Assignment Operators
- Misc Operators

This chapter will examine the arithmetic, relational, logical, bitwise, assignment and other operators one by one.

Arithmetic Operators

There are following arithmetic operators supported by C++ language −

Assume variable A holds 10 and variable B holds 20, then −

Show Examples

Operator	Description	Example
+	Adds two operands	A + B will give 30
-	Subtracts second operand from the first	A - B will give -10
*	Multiplies both operands	A * B will give 200
/	Divides numerator by de-numerator	B / A will give 2
%	Modulus Operator and remainder of after an integer division	B % A will give 0
++	Increment operator, increases integer value by one	A++ will give 11
--	Decrement operator, decreases integer value by one	A-- will give 9

Relational Operators

There are following relational operators supported by C++ language

Assume variable A holds 10 and variable B holds 20, then −

Show Examples

Operator	Description	Example
==	Checks if the values of two operands are equal or not, if yes then condition becomes true.	(A == B) is not true.
!=	Checks if the values of two operands are equal or not, if values are not equal then condition becomes true.	(A != B) is true.

>	Checks if the value of left operand is greater than the value of right operand, if yes then condition becomes true.	(A > B) is not true.
<	Checks if the value of left operand is less than the value of right operand, if yes then condition becomes true.	(A < B) is true.
>=	Checks if the value of left operand is greater than or equal to the value of right operand, if yes then condition becomes true.	(A >= B) is not true.
<=	Checks if the value of left operand is less than or equal to the value of right operand, if yes then condition becomes true.	(A <= B) is true.

Logical Operators

There are following logical operators supported by C++ language.

Assume variable A holds 1 and variable B holds 0, then −

Show Examples

Operator	Description	Example
&&	Called Logical AND operator. If both the operands are non-zero, then condition becomes true.	(A && B) is false.
||	Called Logical OR Operator. If any of the two operands is non-zero, then condition becomes true.	(A || B) is true.

!	Called Logical NOT Operator. Use to reverses the logical state of its operand. If a condition is true, then Logical NOT operator will make false.	!(A && B) is true.

Bitwise Operators

Bitwise operator works on bits and perform bit-by-bit operation. The truth tables for &, |, and ^ are as follows −

p	q	p & q	p | q	p ^ q
0	0	0	0	0
0	1	0	1	1
1	1	1	1	0
1	0	0	1	1

Assume if A = 60; and B = 13; now in binary format they will be as follows −

A = 0011 1100

B = 0000 1101

A&B = 0000 1100

A|B = 0011 1101

A^B = 0011 0001

~A = 1100 0011

The Bitwise operators supported by C++ language are listed in the following table. Assume variable A holds 60 and variable B holds 13, then −

Show Examples

Operator	Description	Example

&	Binary AND Operator copies a bit to the result if it exists in both operands.	(A & B) will give 12 which is 0000 1100
|	Binary OR Operator copies a bit if it exists in either operand.	(A | B) will give 61 which is 0011 1101
^	Binary XOR Operator copies the bit if it is set in one operand but not both.	(A ^ B) will give 49 which is 0011 0001
~	Binary Ones Complement Operator is unary and has the effect of 'flipping' bits.	(~A) will give -61 which is 1100 0011 in 2's complement form due to a signed binary number.
<<	Binary Left Shift Operator. The left operands value is moved left by the number of bits specified by the right operand.	A << 2 will give 240 which is 1111 0000
>>	Binary Right Shift Operator. The left operands value is moved right by the number of bits specified by the right operand.	A >> 2 will give 15 which is 0000 1111

Assignment Operators

There are following assignment operators supported by C++ language −

Show Examples

Operator	Description	Example
=	Simple assignment operator, Assigns values from right side operands to left side operand.	C = A + B will assign value of A + B into C

+=	Add AND assignment operator, It adds right operand to the left operand and assign the result to left operand.	C += A is equivalent to C = C + A
-=	Subtract AND assignment operator, It subtracts right operand from the left operand and assign the result to left operand.	C -= A is equivalent to C = C - A
*=	Multiply AND assignment operator, It multiplies right operand with the left operand and assign the result to left operand.	C *= A is equivalent to C = C * A
/=	Divide AND assignment operator, It divides left operand with the right operand and assign the result to left operand.	C /= A is equivalent to C = C / A
%=	Modulus AND assignment operator, It takes modulus using two operands and assign the result to left operand.	C %= A is equivalent to C = C % A
<<=	Left shift AND assignment operator.	C <<= 2 is same as C = C << 2
>>=	Right shift AND assignment operator.	C >>= 2 is same as C = C >> 2
&=	Bitwise AND assignment operator.	C &= 2 is same as C = C & 2
^=	Bitwise exclusive OR and assignment operator.	C ^= 2 is same as C = C ^ 2
|=	Bitwise inclusive OR and assignment operator.	C |= 2 is same as C = C | 2

Misc Operators

The following table lists some other operators that C++ supports.

Sr.No	Operator & Description
1	**sizeof** sizeof operator returns the size of a variable. For example, sizeof(a), where 'a' is integer, and will return 4.
2	**Condition ? X : Y** Conditional operator (?). If Condition is true then it returns value of X otherwise returns value of Y.
3	**,** Comma operator causes a sequence of operations to be performed. The value of the entire comma expression is the value of the last expression of the comma-separated list.
4	**. (dot) and -> (arrow)** Member operators are used to reference individual members of classes, structures, and unions.
5	**Cast** Casting operators convert one data type to another. For example, int(2.2000) would return 2.
6	**&** Pointer operator & returns the address of a variable. For example &a; will give actual address of the variable.
7	*** Pointer operator * is pointer to a variable. For example *var; will pointer to a variable var.

Operators Precedence in C++

Operator precedence determines the grouping of terms in an expression. This affects how an expression is evaluated. Certain operators have higher precedence than others; for example, the multiplication operator has higher precedence than the addition operator −

For example x = 7 + 3 * 2; here, x is assigned 13, not 20 because operator * has higher precedence than +, so it first gets multiplied with 3*2 and then adds into 7.

Here, operators with the highest precedence appear at the top of the table, those with the lowest appear at the bottom. Within an expression, higher precedence operators will be evaluated first.

Show Examples

Category	Operator	Associativity
Postfix	() [] -> . ++ - -	Left to right
Unary	+ - ! ~ ++ - - (type)* & sizeof	Right to left
Multiplicative	* / %	Left to right
Additive	+ -	Left to right
Shift	<< >>	Left to right
Relational	< <= > >=	Left to right
Equality	== !=	Left to right
Bitwise AND	&	Left to right
Bitwise XOR	^	Left to right
Bitwise OR	|	Left to right
Logical AND	&&	Left to right
Logical OR	||	Left to right

Conditional	?:	Right to left
Assignment	= += -= *= /= %=>>= <<= &= ^= |=	Right to left
Comma	,	Left to right

Memory Management Operators

In C language, we use the malloc() or calloc() functions to allocate the memory dynamically at run time, and free() function is used to deallocate the dynamically allocated memory. C++ also supports these functions, but C++ also defines unary operators such as new and delete to perform the same tasks, i.e., allocating and freeing the memory.

New operator

A **new** operator is used to create the object while a **delete** operator is used to delete the object. When the object is created by using the new operator, then the object will exist until we explicitly use the delete operator to delete the object. Therefore, we can say that the lifetime of the object is not related to the block structure of the program.

Syntax

1. pointer_variable = **new** data-type

The above syntax is used to create the object using the new operator. In the above syntax, '**pointer_variable**' is the name of the pointer variable, '**new**' is the operator, and '**data-type**' defines the type of the data.

Example 1:

```
1. int *p;
2. p = new int;
```

In the above example, 'p' is a pointer of type int.

Delete operator

When memory is no longer required, then it needs to be deallocated so that the memory can be used for another purpose. This can be achieved by using the delete operator, as shown below:

1. **delete** pointer_variable;

In the above statement, **'delete'** is the operator used to delete the existing object, and **'pointer_variable'** is the name of the pointer variable.

In the previous case, we have created two pointers 'p' and 'q' by using the new operator, and can be deleted by using the following statements:

1. **delete** p;

C++ Functions

A function is a group of statements that together perform a task. Every C++ program has at least one function, which is **main()**, and all the most trivial programs can define additional functions.

You can divide up your code into separate functions. How you divide up your code among different functions is up to you, but logically the division usually is such that each function performs a specific task.

A function **declaration** tells the compiler about a function's name, return type, and parameters. A function **definition** provides the actual body of the function.

The C++ standard library provides numerous built-in functions that your program can call. For example, function **strcat()** to concatenate two strings, function **memcpy()** to copy one memory location to another location and many more functions.

A function is known with various names like a method or a sub-routine or a procedure etc.

Defining a Function

The general form of a C++ function definition is as follows −

```
return_type function_name( parameter list ) {
   body of the function
}
```

A C++ function definition consists of a function header and a function body. Here are all the parts of a function −

- **Return Type** − A function may return a value. The **return_type** is the data type of the value the function returns. Some functions perform the desired operations without returning a value. In this case, the return_type is the keyword **void**.
- **Function Name** − This is the actual name of the function. The function name and the parameter list together constitute the function signature.
- **Parameters** − A parameter is like a placeholder. When a function is invoked, you pass a value to the parameter. This value is referred to as actual parameter or argument. The parameter list refers to the type, order, and number of the parameters of a function. Parameters are optional; that is, a function may contain no parameters.
- **Function Body** − The function body contains a collection of statements that define what the function does.

Example

Following is the source code for a function called **max()**. This function takes two parameters num1 and num2 and return the biggest of both −

```
// function returning the max between two numbers

int max(int num1, int num2) {
  // local variable declaration
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Function Declarations

A function **declaration** tells the compiler about a function name and how to call the function. The actual body of the function can be defined separately.

A function declaration has the following parts −

```
return_type function_name( parameter list );
```

For the above defined function max(), following is the function declaration −

```
int max(int num1, int num2);
```

Parameter names are not important in function declaration only their type is required, so following is also valid declaration −

```
int max(int, int);
```

Function declaration is required when you define a function in one source file and you call that function in another file. In such case, you should declare the function at the top of the file calling the function.

Calling a Function

While creating a C++ function, you give a definition of what the function has to do. To use a function, you will have to call or invoke that function.

When a program calls a function, program control is transferred to the called function. A called function performs defined task and when it's return statement is executed or when its function-ending closing brace is reached, it returns program control back to the main program.

To call a function, you simply need to pass the required parameters along with function name, and if function returns a value, then you can store returned value. For example −

```
#include <iostream>
```

```
using namespace std;

// function declaration
int max(int num1, int num2);

int main () {
  // local variable declaration:
  int a = 100;
  int b = 200;
  int ret;

  // calling a function to get max value.
  ret = max(a, b);
  cout << "Max value is : " << ret << endl;

  return 0;
}

// function returning the max between two numbers
int max(int num1, int num2) {
  // local variable declaration
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

I kept max() function along with main() function and compiled the source code. While running final executable, it would produce the following result −

Max value is : 200

Function Arguments

If a function is to use arguments, it must declare variables that accept the values of the arguments. These variables are called the **formal parameters** of the function.

Sr.No	Call Type & Description
1	Call by Value This method copies the actual value of an argument into the formal parameter of the function. In this case, changes made to the parameter inside the function have no effect on the argument.

2	Call by Pointer This method copies the address of an argument into the formal parameter. Inside the function, the address is used to access the actual argument used in the call. This means that changes made to the parameter affect the argument.
3	Call by Reference This method copies the reference of an argument into the formal parameter. Inside the function, the reference is used to access the actual argument used in the call. This means that changes made to the parameter affect the argument.

The formal parameters behave like other local variables inside the function and are created upon entry into the function and destroyed upon exit.

While calling a function, there are two ways that arguments can be passed to a function −

By default, C++ uses **call by value** to pass arguments. In general, this means that code within a function cannot alter the arguments used to call the function and above mentioned example while calling max() function used the same method.

Default Values for Parameters

When you define a function, you can specify a default value for each of the last parameters. This value will be used if the corresponding argument is left blank when calling to the function.

This is done by using the assignment operator and assigning values for the arguments in the function definition. If a value for that parameter is not passed when the function is called, the default given value is used, but if a value is specified, this default value is ignored and the passed value is used instead. Consider the following example −

```
#include <iostream>
using namespace std;

int sum(int a, int b = 20) {
  int result;
  result = a + b;

  return (result);
}
int main () {
  // local variable declaration:
  int a = 100;
  int b = 200;
  int result;

  // calling a function to add the values.
  result = sum(a, b);
  cout << "Total value is :" << result << endl;
```

```
   // calling a function again as follows.
   result = sum(a);
   cout << "Total value is :" << result << endl;

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Total value is :300
Total value is :120
```

Unit 3
C++ Classes and Objects

The main purpose of C++ programming is to add object orientation to the C programming language and classes are the central feature of C++ that supports object-oriented programming and are often called user-defined types.

A class is used to specify the form of an object and it combines data representation and methods for manipulating that data into one neat package. The data and functions within a class are called members of the class.

C++ Class Definitions

When you define a class, you define a blueprint for a data type. This doesn't actually define any data, but it does define what the class name means, that is, what an object of the class will consist of and what operations can be performed on such an object.

A class definition starts with the keyword **class** followed by the class name; and the class body, enclosed by a pair of curly braces. A class definition must be followed either by a semicolon or a list of declarations. For example, we defined the Box data type using the keyword **class** as follows −

```
class Box {
   public:
      double length;   // Length of a box
      double breadth;  // Breadth of a box
      double height;   // Height of a box
};
```

The keyword **public** determines the access attributes of the members of the class that follows it. A public member can be accessed from outside the class anywhere within the scope of the class object. You can also specify the members of a class as **private** or **protected** which we will discuss in a sub-section.

Define C++ Objects

A class provides the blueprints for objects, so basically an object is created from a class. We declare objects of a class with exactly the same sort of declaration that we declare variables of basic types. Following statements declare two objects of class Box −

```
Box Box1;        // Declare Box1 of type Box
Box Box2;        // Declare Box2 of type Box
```

Both of the objects Box1 and Box2 will have their own copy of data members.

Accessing the Data Members

The public data members of objects of a class can be accessed using the direct member access operator (.). Let us try the following example to make the things clear −

```
#include <iostream>

using namespace std;

class Box {
  public:
     double length;   // Length of a box
     double breadth;  // Breadth of a box
     double height;   // Height of a box
};

int main() {
  Box Box1;        // Declare Box1 of type Box
  Box Box2;        // Declare Box2 of type Box
  double volume = 0.0;     // Store the volume of a box here

  // box 1 specification
  Box1.height = 5.0;
  Box1.length = 6.0;
  Box1.breadth = 7.0;

  // box 2 specification
  Box2.height = 10.0;
  Box2.length = 12.0;
  Box2.breadth = 13.0;

  // volume of box 1
  volume = Box1.height * Box1.length * Box1.breadth;
  cout << "Volume of Box1 : " << volume <<endl;

  // volume of box 2
  volume = Box2.height * Box2.length * Box2.breadth;
  cout << "Volume of Box2 : " << volume <<endl;
  return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Volume of Box1 : 210
```

Volume of Box2 : 1560

It is important to note that private and protected members can not be accessed directly using direct member access operator (.). We will learn how private and protected members can be accessed.

Classes and Objects in Detail

So far, you have got very basic idea about C++ Classes and Objects. There are further interesting concepts related to C++ Classes and Objects which we will discuss in various sub-sections listed below −

Sr.No	Concept & Description
1	Class Member Functions A member function of a class is a function that has its definition or its prototype within the class definition like any other variable.
2	Class Access Modifiers A class member can be defined as public, private or protected. By default members would be assumed as private.
3	Constructor & Destructor A class constructor is a special function in a class that is called when a new object of the class is created. A destructor is also a special function which is called when created object is deleted.
4	Copy Constructor The copy constructor is a constructor which creates an object by initializing it with an object of the same class, which has been created previously.
5	Friend Functions A **friend** function is permitted full access to private and protected members of a class.
6	Inline Functions With an inline function, the compiler tries to expand the code in the body of the function in place of a call to the function.

7	this Pointer Every object has a special pointer **this** which points to the object itself.
8	Pointer to C++ Classes A pointer to a class is done exactly the same way a pointer to a structure is. In fact a class is really just a structure with functions in it.
9	Static Members of a Class Both data members and function members of a class can be declared as static.

Access Specifiers

By now, you are quite familiar with the `public` keyword that appears in all of our class examples:

Example

```
class MyClass {  // The class
  public:       // Access specifier
    // class members goes here
};
```

The `public` keyword is an **access specifier.** Access specifiers define how the members (attributes and methods) of a class can be accessed. In the example above, the members are `public` - which means that they can be accessed and modified from outside the code.

However, what if we want members to be private and hidden from the outside world?

In C++, there are three access specifiers:

- public - members are accessible from outside the class
- private - members cannot be accessed (or viewed) from outside the class
- protected - members cannot be accessed from outside the class, however, they can be accessed in inherited classes. You will learn more about Inheritance later.

In the following example, we demonstrate the differences between `public` and `private` members:

Example

```
class MyClass {
  public:    // Public access specifier
```

```
  int x;   // Public attribute
 private:   // Private access specifier
  int y;   // Private attribute
};

int main() {
 MyClass myObj;
 myObj.x = 25;  // Allowed (public)
 myObj.y = 50;  // Not allowed (private)
 return 0;
}
```

If you try to access a private member, an error occurs:

error: y is private

Class Methods

Methods are **functions** that belongs to the class.

There are two ways to define functions that belongs to a class:

- Inside class definition
- Outside class definition

In the following example, we define a function inside the class, and we name it "`myMethod`".

Note: You access methods just like you access attributes; by creating an object of the class and by using the dot syntax (`.`):

Inside Example

```
class MyClass {        // The class
 public:             // Access specifier
  void myMethod() {  // Method/function defined inside the class
   cout << "Hello World!";
  }
};

int main() {
 MyClass myObj;     // Create an object of MyClass
 myObj.myMethod();  // Call the method
 return 0;
}
```

To define a function outside the class definition, you have to declare it inside the class and then define it outside of the class. This is done by specifiying the name of the class, followed the scope resolution `::` operator, followed by the name of the function:

Outside Example

```
class MyClass {        // The class
  public:              // Access specifier
    void myMethod();   // Method/function declaration
};

// Method/function definition outside the class
void MyClass::myMethod() {
  cout << "Hello World!";
}

int main() {
  MyClass myObj;     // Create an object of MyClass
  myObj.myMethod();  // Call the method
  return 0;
}
```

Example

```
#include <iostream>
using namespace std;

class Car {
  public:
    int speed(int maxSpeed);
};

int Car::speed(int maxSpeed) {
  return maxSpeed;
}

int main() {
  Car myObj; // Create an object of Car
  cout << myObj.speed(200); // Call the method with an argument
  return 0;
}
```

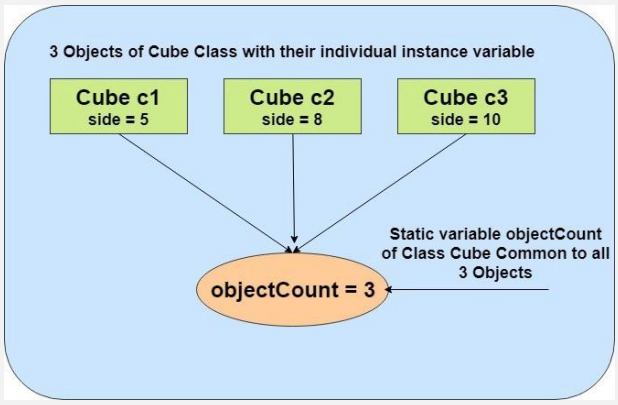
Static Data Member & Member Function in C++

Static Data Member

A data member of a class can be qualified as static. The properties of a static member variable are similar to that of Cs static variable. A static data member has certain special characteristics. They are:-

- It is initialized to zero when the first object of its class is created. No other initialization is permitted.
- Only one copy of that member is created for the entire class and is shared by all the objects of that class, no matter how many objects are created.
- It is visible only within the class, but its lifetime is the entire program.

A static variable is normally used to maintain value common to the entire class. For e.g, to hold the count of objects created. Note that the type and scope of each static member variable must be declared outside the class definition. This is necessary because the static data members are stored separately rather than as a part of an object.



Declaration

```
static data_type member_name;
```

Defining the static data member

It should be defined outside of the class following this syntax:

```
data_type class_name :: member_name =value;
```

If you are calling a static data member within a member function, member function should be declared as static (i.e. a static member function can access the static data members)

Let's see a simple example

```
#include <iostream>
using namespace std;
class Demo
{
        public:
                static int ABC;
};

//defining
int Demo :: ABC =10;


int main()
{

        cout<<"\nValue of ABC: "<<Demo::ABC;
        return 0;
}
```

Output

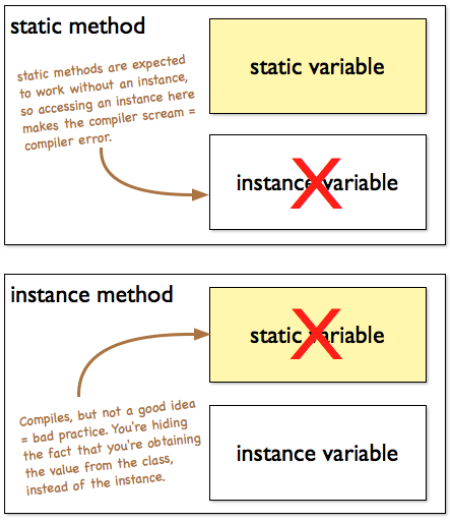
```
Value of ABC: 10
```

Static Member Function

like a static member variable, we can also have static member functions. A member function that is declared static has the following properties:-

- A static function can have access to only other static members (function or variable) declared in the same class.
- A static member function can be called using the class name (instead of its object) as follows-

Class_name::Function_name();



Consider the example, here static data member is accessing through the static member function:

```
#include <iostream>
using namespace std;class Demo
{
        private:
                static int X;          public:
                static void fun()
                {
                        cout <<"Value of X: " << X << endl;
                }
};//defining
int Demo :: X =10;
int main()
{
        Demo X; X.fun();

        return 0;
}
```

Output

Value of X: 10

Friend Class in C++

Friend Class A friend class can access private and protected members of other class in which it is declared as friend. It is sometimes useful to allow a particular class to access private members of other class. For example a LinkedList class may be allowed to access private members of Node.

```
class Node {
private:
    int key;
    Node* next;
    /* Other members of Node Class */

    // Now class  LinkedList can
    // access private members of Node
    friend class LinkedList;

};
```

Friend Functions in C++

A friend function of a class is defined outside that class' scope but it has the right to access all private and protected members of the class. Even though the prototypes for friend functions appear in the class definition, friends are not member functions.

A friend can be a function, function template, or member function, or a class or class template, in which case the entire class and all of its members are friends.

To declare a function as a friend of a class, precede the function prototype in the class definition with keyword **friend** as follows −

```
class Box {
   double width;

   public:
      double length;
      friend void printWidth( Box box );
      void setWidth( double wid );
};
```

To declare all member functions of class ClassTwo as friends of class ClassOne, place a following declaration in the definition of class ClassOne −

```
friend class ClassTwo;
```

Consider the following program −

```
#include <iostream>

using namespace std;

class Box {
   double width;

   public:
      friend void printWidth( Box box );
      void setWidth( double wid );
};

// Member function definition
void Box::setWidth( double wid ) {
   width = wid;
}

// Note: printWidth() is not a member function of any class.
void printWidth( Box box ) {
   /* Because printWidth() is a friend of Box, it can
   directly access any member of this class */
   cout << "Width of box : " << box.width <<endl;
}

// Main function for the program
int main() {
   Box box;

   // set box width without member function
   box.setWidth(10.0);

   // Use friend function to print the wdith.
   printWidth( box );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

Width of box : 10

Unit 4

Constructors and Destructors

Constructors and Destructors in C++

Constructors are special class functions which performs initialization of every object. The Compiler calls the Constructor whenever an object is created. Constructors initialize values to object members after storage is allocated to the object.

Whereas, Destructor on the other hand is used to destroy the class object.

Let's start with Constructors first, following is the syntax of defining a constructor function in a class:

```
class A
{
   public:
   int x;
   // constructor
   A()
   {
      // object initialization
   }
};
```

While defining a contructor you must remeber that the **name of constructor** will be same as the **name of the class**, and contructors will never have a return type.

Constructors can be defined either inside the class definition or outside class definition using class name and scope resolution :: operator.

```
class A
{
   public:
   int i;
   A(); // constructor declared
};

// constructor definition
A::A()
{
   i = 1;
}
```

Types of Constructors in C++

Constructors are of three types:

1. Default Constructor
2. Parametrized Constructor
3. Copy COnstructor

Default Constructors

Default constructor is the constructor which doesn't take any argument. It has no parameter.

Syntax:

```
class_name(parameter1, parameter2, ...)
{
   // constructor Definition
}
```

For example:

```
class Cube
{
   public:
   int side;
   Cube()
   {
      side = 10;
   }
};

int main()
{
   Cube c;
   cout << c.side;
}
```

10

In this case, as soon as the object is created the constructor is called which initializes its data members.

A default constructor is so important for initialization of object members, that even if we do not define a constructor explicitly, the compiler will provide a default constructor implicitly.

```
class Cube

{

   public:

   int side;
```

```
};

int main()

{

   Cube c;

   cout << c.side;

}
```

0 or any random value

In this case, default constructor provided by the compiler will be called which will initialize the object data members to default value, that will be 0 or any random integer value in this case.

Parameterized Constructors

These are the constructors with parameter. Using this Constructor you can provide different values to data members of different objects, by passing the appropriate values as argument.

For example:

```
class Cube
{
   public:
   int side;
   Cube(int x)
   {
      side=x;
   }
};
int main()
{
   Cube c1(10);
   Cube c2(20);
   Cube c3(30);
   cout << c1.side;
   cout << c2.side;
   cout << c3.side;
}
```

```
Output-

10

20

30
```

By using parameterized construcor in above case, we have initialized 3 objects with user defined values. We can have any number of parameters in a constructor.

Copy Constructors

These are special type of Constructors which takes an object as argument, and is used to copy values of data members of one object into other object. We will study copy constructors in detail later.

Constructor Overloading in C++

Just like other member functions, constructors can also be overloaded. Infact when you have both default and parameterized constructors defined in your class you are having Overloaded Constructors, one with no parameter and other with parameter.

You can have any number of Constructors in a class that differ in parameter list.

```
class Student
{
   public:
   int rollno;
   string name;
   // first constructor
   Student(int x)
   {
      rollno = x;
      name = "None";
   }
   // second constructor
   Student(int x, string str)
   {
      rollno = x;
      name = str;
   }
};
int main()
```

```
{
   // student A initialized with roll no 10 and name None
   Student A(10);

   // student B initialized with roll no 11 and name John
   Student B(11, "John");
}
```
In above case we have defined two constructors with different parameters, hence overloading the constructors.

One more important thing, if you define any constructor explicitly, then the compiler will not provide default constructor and you will have to define it yourself.

In the above case if we write `Student S;` in **main()**, it will lead to a compile time error, because we haven't defined default constructor, and compiler will not provide its default constructor because we have defined other parameterized constructors.

Destructors in C++

Destructor is a special class function which destroys the object as soon as the scope of object ends. The destructor is called automatically by the compiler when the object goes out of scope.

The syntax for destructor is same as that for the constructor, the class name is used for the name of destructor, with a **tilde** `~` sign as prefix to it.

```
class A
{
   public:
   // defining destructor for class
   ~A()
   {
      // statement
   }
};
```
Destructors will never have any arguments.

Example to see how Constructor and Destructor are called

Below we have a simple class `A` with a constructor and destructor. We will create object of the class and see when a constructor is called and when a destructor gets called.

```
class A
```

```
{
   // constructor
   A()
   {
      cout << "Constructor called";
   }

   // destructor
   ~A()
   {
      cout << "Destructor called";
   }
};
int main()
{
   A obj1;   // Constructor Called
   int x = 1
   if(x)
   {
      A obj2;  // Constructor Called
   }   // Destructor Called for obj2
} //  Destructor called for obj1
```

```
Constructor called

Constructor called

Destructor called

Destructor called
```

When an object is created the constructor of that class is called. The object reference is destroyed when its scope ends, which is generally after the closing curly bracket `}` for the code block in which it is created.

The object `obj2` is destroyed when the `if` block ends because it was created inside the `if` block. And the object `obj1` is destroyed when the `main()` function ends.

Single Definition for both Default and Parameterized Constructor

In this example we will use **default argument** to have a single definition for both defualt and parameterized constructor.

```
class Dual
{
   public:
```

```
    int a;
    Dual(int x=0)
    {
        a = x;
    }
};
int main()
{
    Dual obj1;
    Dual obj2(10);
}
```

Here, in this program, a single Constructor definition will take care for both these object initializations. We don't need separate default and parameterized constructors.

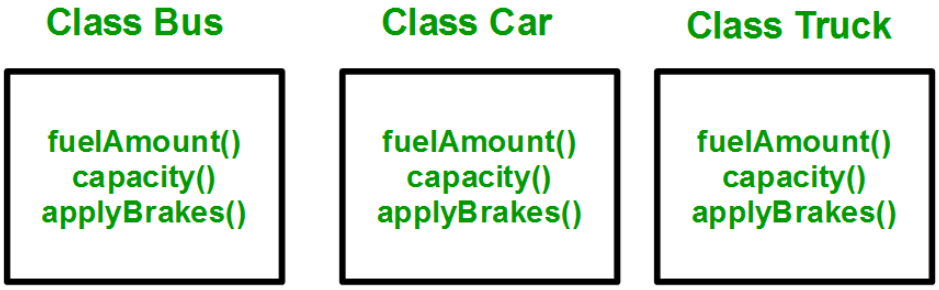
Unit 5
Inheritance in C++

The capability of a class to derive properties and characteristics from another class is called **Inheritance**. Inheritance is one of the most important feature of Object Oriented Programming.

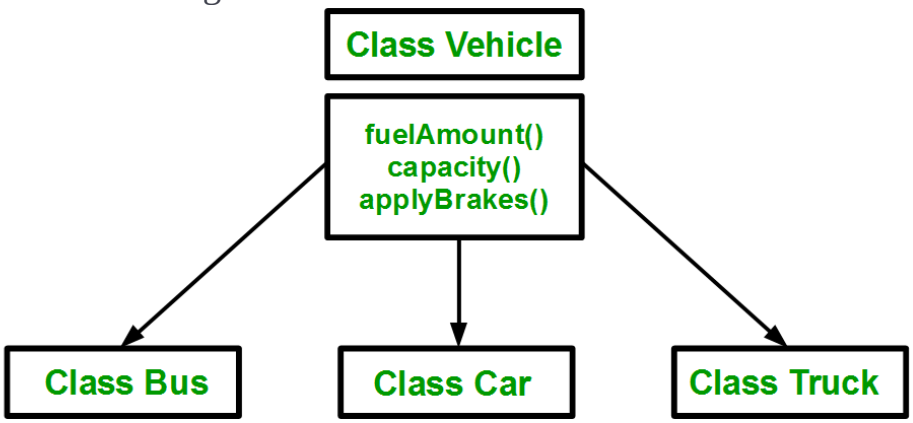
Sub Class: The class that inherits properties from another class is called Sub class or Derived Class.

Super Class: The class whose properties are inherited by sub class is called Base Class or Super class.

Why and when to use inheritance?
Consider a group of vehicles. You need to create classes for Bus, Car and Truck. The methods fuelAmount(), capacity(), applyBrakes() will be same for all of the three classes. If we create these classes avoiding inheritance then we have to write all of these functions in each of the three classes as shown in below figure:



You can clearly see that above process results in duplication of same code 3 times. This increases the chances of error and data redundancy. To avoid this type of situation, inheritance is used. If we create a class Vehicle and write these three functions in it and inherit the rest of the classes from the vehicle class, then we can simply avoid the duplication of data and increase re-usability. Look at the below diagram in which the three classes are inherited from vehicle class:



Using inheritance, we have to write the functions only one time instead of three times as we have inherited rest of the three classes from base class(Vehicle).

Implementing inheritance in C++: For creating a sub-class which is inherited from the base class we have to follow the below syntax.
Syntax:

```
class subclass_name : access_mode base_class_name
{
  //body of subclass
```

};

Here, **subclass_name** is the name of the sub class, **access_mode** is the mode in which you want to inherit this sub class for example: public, private etc. and **base_class_name** is the name of the base class from which you want to inherit the sub class.
Note: A derived class doesn't inherit ***access*** to private data members. However, it does inherit a full parent object, which contains any private members which that class declares.

```
// C++ program to demonstrate implementation
// of Inheritance
#include <bits/stdc++.h>
using namespace std;
//Base class
class Parent
{
   public:
     int id_p;
};
// Sub class inheriting from Base Class(Parent)
class Child : public Parent
{
   public:
     int id_c;
};
//main function
int main()
  {
      Child obj1;
      // An object of class child has all data members
      // and member functions of class parent
      obj1.id_c = 7;
      obj1.id_p = 91;
      cout << "Child id is " <<  obj1.id_c << endl;
      cout << "Parent id is " <<  obj1.id_p << endl;
 return 0;
  }
```

Output:

Child id is 7
Parent id is 91

In the above program the 'Child' class is publicly inherited from the 'Parent' class so the public data members of the class 'Parent' will also be inherited by the class 'Child'.

Modes of Inheritance

1. **Public mode**: If we derive a sub class from a public base class. Then the public member of the base class will become public in the derived class and protected members of the base class will become protected in derived class.
2. **Protected mode**: If we derive a sub class from a Protected base class. Then both public member and protected members of the base class will become protected in derived class.
3. **Private mode**: If we derive a sub class from a Private base class. Then both public member and protected members of the base class will become Private in derived class.

Note : The private members in the base class cannot be directly accessed in the derived class, while protected members can be directly accessed. For example, Classes B, C and D all contain the variables x, y and z in below example. It is just question of access.

```
// C++ Implementation to show that a derived class
// doesn’t inherit access to private data members.
// However, it does inherit a full parent object
class A
{
public:
   int x;
protected:
   int y;
private:
   int z;
};
class B : public A
{
   // x is public
   // y is protected
   // z is not accessible from B
};

class C : protected A
{
   // x is protected
   // y is protected
   // z is not accessible from C
};
class D : private A    // 'private' is default for classes
{
   // x is private
   // y is private
```

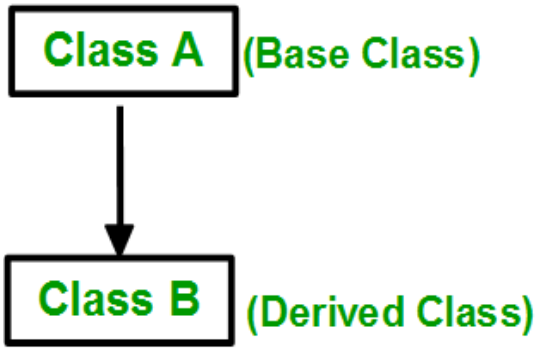
```
    // z is not accessible from D
};
```

The below table summarizes the above three modes and shows the access specifier of the members of base class in the sub class when derived in public, protected and private modes:

Base class member access specifier	Type of Inheritence		
	Public	Protected	Private
Public	Public	Protected	Private
Protected	Protected	Protected	Private
Private	Not accessible (Hidden)	Not accessible (Hidden)	Not accessible (Hidden)

Types of Inheritance in C++

1. **Single Inheritance**: In single inheritance, a class is allowed to inherit from only one class. i.e. one sub class is inherited by one base class only.



Syntax:

```
class subclass_name : access_mode base_class
{
  //body of subclass
};
```

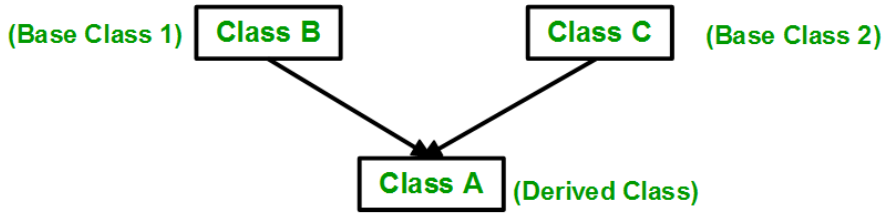
Example

```
// C++ program to explain
// Single inheritance
#include <iostream>
using namespace std;

// base class
class Vehicle {
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};
// sub class derived from two base classes
class Car: public Vehicle{ };
// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base classes
    Car obj;
    return 0;
}
```

Output:

This is a vehicle

2. **Multiple Inheritance:** Multiple Inheritance is a feature of C++ where a class can inherit from more than one classes. i.e one **sub class** is inherited from more than one **base classes**.



Syntax:

class subclass_name : access_mode base_class1, access_mode base_class2, ...

{

//body of subclass

};

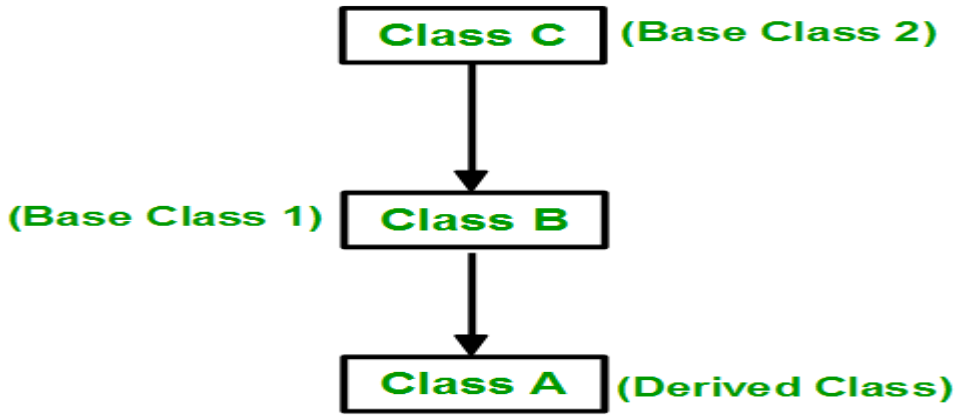
Here, the number of base classes will be separated by a comma (‘, ‘) and access mode for every base class must be specified.

```
// C++ program to explain
// multiple inheritance
#include <iostream>
using namespace std;
// first base class
class Vehicle {
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};

// second base class
class FourWheeler {
  public:
    FourWheeler()
    {
      cout << "This is a 4 wheeler Vehicle" << endl;
    }
};
// sub class derived from two base classes
class Car: public Vehicle, public FourWheeler {};
// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base classes
    Car obj;
    return 0;
}
```

Output:

This is a Vehicle
This is a 4 wheeler Vehicle

3. **Multilevel Inheritance**: In this type of inheritance, a derived class is created from another derived class.



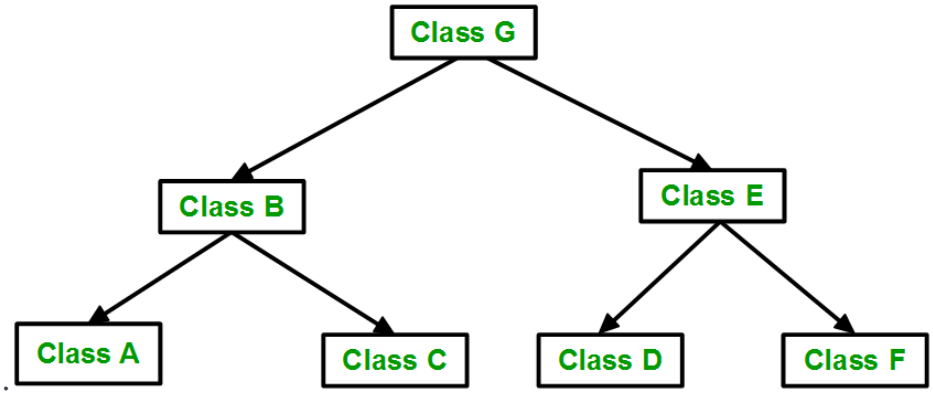
Example

```
// C++ program to implement
// Multilevel Inheritance
#include <iostream>
using namespace std;
// base class
class Vehicle
{
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};
class fourWheeler: public Vehicle
{  public:
    fourWheeler()
    {
      cout<<"Objects with 4 wheels are vehicles"<<endl;
    }
};
// sub class derived from two base classes
class Car: public fourWheeler{
   public:
     car()
     {
       cout<<"Car has 4 Wheels"<<endl;
     }
};

// main function
int main()
{
    //creating object of sub class will
    //invoke the constructor of base classes
    Car obj;
    return 0;
}
```

output:

This is a Vehicle
Objects with 4 wheels are vehicles
Car has 4 Wheels

4. **Hierarchical Inheritance**: In this type of inheritance, more than one sub class is inherited from a single base class. i.e. more than one derived class is created from a single base class




```
// C++ program to implement
// Hierarchical Inheritance
#include <iostream>
using namespace std;

// base class
class Vehicle
{
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};


// first sub class
class Car: public Vehicle
{

};

// second sub class
class Bus: public Vehicle
{

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base class
    Car obj1;
    Bus obj2;
    return 0;
```

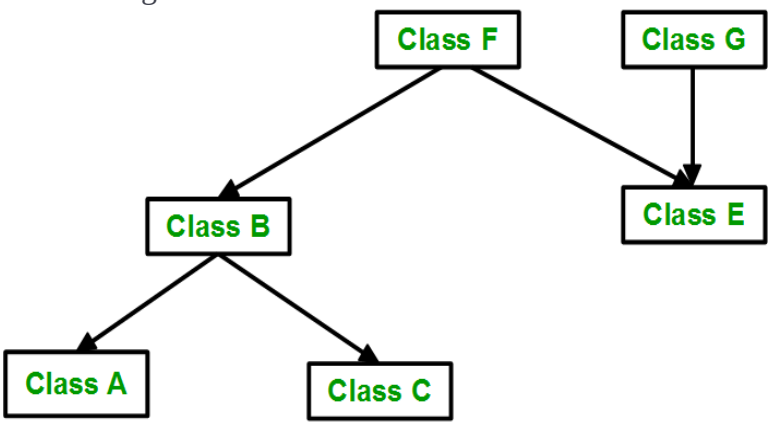
}

Output:

This is a Vehicle

This is a Vehicle

5. **Hybrid (Virtual) Inheritance**: Hybrid Inheritance is implemented by combining more than one type of inheritance. For example: Combining Hierarchical inheritance and Multiple Inheritance.
Below image shows the combination of hierarchical and multiple inheritance:




```
// C++ program for Hybrid Inheritance

#include <iostream>
using namespace std;

// base class
class Vehicle
{
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};

//base class
class Fare
{
    public:
    Fare()
    {
        cout<<"Fare of Vehicle\n";
    }
};
```

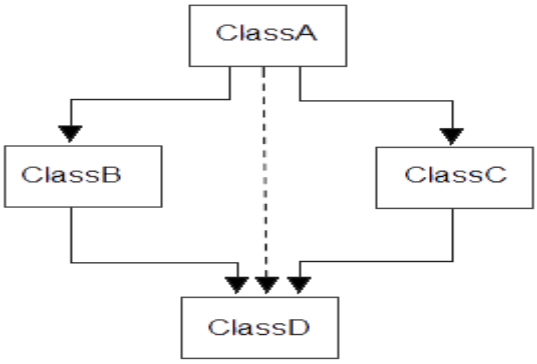
```
// first sub class
class Car: public Vehicle
{

};

// second sub class
class Bus: public Vehicle, public Fare
{

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base class
    Bus obj2;
    return 0;
}
```

Output:

This is a Vehicle

Fare of Vehicle

A special case of hybrid inheritance : Multipath inheritance:
A derived class with two base classes and these two base classes have one common base class is called multipath inheritance. An ambiguity can arrise in this type of inheritance.



Consider the following program:

// C++ program demonstrating ambiguity in Multipath Inheritance

```
#include<iostream.h>
#include<conio.h>
class ClassA
    {
        public:
        int a;
    };

    class ClassB : public ClassA
    {
        public:
        int b;
    };
    class ClassC : public ClassA
    {
        public:
        int c;
    };

    class ClassD : public ClassB, public ClassC
    {
        public:
        int d;
    };

    void main()
    {

        ClassD obj;

        //obj.a = 10;           //Statement 1, Error
        //obj.a = 100;          //Statement 2, Error

        obj.ClassB::a = 10;     //Statement 3
        obj.ClassC::a = 100;    //Statement 4

        obj.b = 20;
        obj.c = 30;
        obj.d = 40;

        cout<< "\n A from ClassB  : "<< obj.ClassB::a;
        cout<< "\n A from ClassC  : "<< obj.ClassC::a;

        cout<< "\n B : "<< obj.b;
        cout<< "\n C : "<< obj.c;
        cout<< "\n D : "<< obj.d;
```

```
}
```

Output:

```
A from ClassB  : 10
A from ClassC  : 100
B : 20
C : 30
D : 40
```

In the above example, both Class B & Class C inherit Class A, they both have single copy of Class A. However Class D inherit both Class B & Class C, therefore Class D have two copies of Class A, one from Class B and another from Class C.
If we need to access the data member a of Class A through the object of Class D, we must specify the path from which a will be accessed, whether it is from Class B or Class C, bco'z compiler can't differentiate between two copies of Class A in Class D.

There are 2 ways to avoid this ambiguity:

1. **Use scope resolution operator**
2. **Use virtual base class**

Avoiding ambiguity using scope resolution operator:
Using scope resolution operator we can manually specify the path from which data member a will be accessed, as shown in statement 3 and 4, in the above example.

```
obj.ClassB::a = 10;      //Statement 3
obj.ClassC::a = 100;     //Statement 4
```

Note : Still, there are two copies of Class A in Class D.

```
#include<iostream.h>
    #include<conio.h>

    class Class A
    {
          public:
          int a;
    };

    class Class B : virtual public Class A
    {
          public:
          int b;
    };
    class Class C : virtual public Class A
    {
          public:
          int c;
    };

    class Class D : public Class B, public Class C
    {
          public:
          int d;
    };

    void main()
    {

          Class D obj;

          obj.a = 10;       //Statement 3
          obj.a = 100;      //Statement 4
          obj.b = 20;
          obj.c = 30;
          obj.d = 40;
          cout<< "\n A : "<< obj.a;
          cout<< "\n B : "<< obj.b;
          cout<< "\n C : "<< obj.c;
          cout<< "\n D : "<< obj.d;

    }
```

Output:

A : 100

B : 20
C : 30
D : 40
According to the above example, ClassD has only one copy of ClassA, therefore, statement 4 will overwrite the value of a, given at statement 3.

Unit 6

Polymorphism

The word **polymorphism** means having many forms. Typically, polymorphism occurs when there is a hierarchy of classes and they are related by inheritance.

C++ polymorphism means that a call to a member function will cause a different function to be executed depending on the type of object that invokes the function.

Consider the following example where a base class has been derived by other two classes −

```
#include <iostream>
using namespace std;

class Shape {
  protected:
    int width, height;

  public:
    Shape( int a = 0, int b = 0){
      width = a;
      height = b;
    }
    int area() {
      cout << "Parent class area :" <<endl;
      return 0;
    }
};
class Rectangle: public Shape {
  public:
    Rectangle( int a = 0, int b = 0):Shape(a, b) { }

    int area () {
      cout << "Rectangle class area :" <<endl;
      return (width * height);
    }
};

class Triangle: public Shape {
  public:
    Triangle( int a = 0, int b = 0):Shape(a, b) { }
```

```
    int area () {
      cout << "Triangle class area :" <<endl;
      return (width * height / 2);
    }
};

// Main function for the program
int main() {
  Shape *shape;
  Rectangle rec(10,7);
  Triangle  tri(10,5);

  // store the address of Rectangle
  shape = &rec;

  // call rectangle area.
  shape->area();

  // store the address of Triangle
  shape = &tri;

  // call triangle area.
  shape->area();

  return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Parent class area :
Parent class area :
```

The reason for the incorrect output is that the call of the function area() is being set once by the compiler as the version defined in the base class. This is called **static resolution** of the function call, or **static linkage** - the function call is fixed before the program is executed. This is also sometimes called **early binding** because the area() function is set during the compilation of the program.

But now, let's make a slight modification in our program and precede the declaration of area() in the Shape class with the keyword **virtual** so that it looks like this −

```
class Shape {
  protected:
    int width, height;

  public:
    Shape( int a = 0, int b = 0) {
      width = a;
      height = b;
    }
    virtual int area() {
      cout << "Parent class area :" <<endl;
      return 0;
```

```
    }
};
```

After this slight modification, when the previous example code is compiled and executed, it produces the following result −

```
Rectangle class area
Triangle class area
```

This time, the compiler looks at the contents of the pointer instead of it's type. Hence, since addresses of objects of tri and rec classes are stored in *shape the respective area() function is called.

As you can see, each of the child classes has a separate implementation for the function area(). This is how **polymorphism** is generally used. You have different classes with a function of the same name, and even the same parameters, but with different implementations.

Virtual Function

A **virtual** function is a function in a base class that is declared using the keyword **virtual**. Defining in a base class a virtual function, with another version in a derived class, signals to the compiler that we don't want static linkage for this function.

What we do want is the selection of the function to be called at any given point in the program to be based on the kind of object for which it is called. This sort of operation is referred to as **dynamic linkage**, or **late binding**.

Pure Virtual Functions

It is possible that you want to include a virtual function in a base class so that it may be redefined in a derived class to suit the objects of that class, but that there is no meaningful definition you could give for the function in the base class.

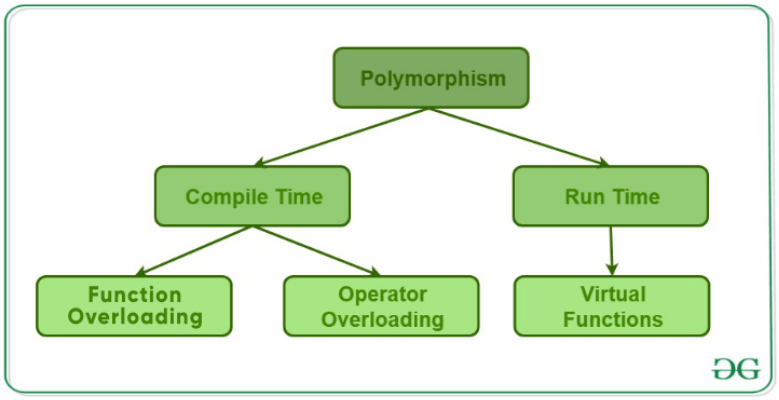
We can change the virtual function area() in the base class to the following −

```
class Shape {
  protected:
    int width, height;

  public:
    Shape(int a = 0, int b = 0) {
      width = a;
      height = b;
    }

    // pure virtual function
    virtual int area() = 0;
};
```

The = 0 tells the compiler that the function has no body and above virtual function will be called **pure virtual function**.

In C++ polymorphism is mainly divided into two types:

- Compile time Polymorphism
- Runtime Polymorphism



1. **Compile time polymorphism:** This type of polymorphism is achieved by function overloading or operator overloading.

   - Function Overloading: When there are multiple functions with same name but different parameters then these functions are said to be **overloaded**. Functions can be overloaded by **change in number of arguments** or/and **change in type of arguments**.
     Rules of Function Overloading
     filter_none
     edit
     play_arrow
     brightness_4

```
// C++ program for function overloading
#include <bits/stdc++.h>

using namespace std;
class Geeks
{
   public:

   // function with 1 int parameter
   void func(int x)
   {
      cout << "value of x is " << x << endl;
   }

   // function with same name but 1 double parameter
   void func(double x)
   {
      cout << "value of x is " << x << endl;
   }
```

```
    // function with same name and 2 int parameters
    void func(int x, int y)
    {
        cout << "value of x and y is " << x << ", " << y << endl;
    }
};

int main() {

    Geeks obj1;

    // Which function is called will depend on the parameters passed
    // The first 'func' is called
    obj1.func(7);

    // The second 'func' is called
    obj1.func(9.132);

    // The third 'func' is called
    obj1.func(85,64);
    return 0;
}
```

Output:
value of x is 7
value of x is 9.132
value of x and y is 85, 64
In the above example, a single function named *func* acts differently in three different situations which is the property of polymorphism.

- Operator Overloading: C++ also provide option to overload operators. For example, we can make the operator ('+') for string class to concatenate two strings. We know that this is the addition operator whose task is to add two operands. So a single operator '+' when placed between integer operands , adds them and when placed between string operands, concatenates them.
  Example:

```
// CPP program to illustrate
// Operator Overloading
#include<iostream>
using namespace std;

class Complex {
private:
    int real, imag;
public:
    Complex(int r = 0, int i =0)  {real = r;   imag = i;}
```

```
    // This is automatically called when '+' is used with
    // between two Complex objects
    Complex operator + (Complex const &obj) {
        Complex res;
        res.real = real + obj.real;
        res.imag = imag + obj.imag;
        return res;
    }
    void print() { cout << real << " + i" << imag << endl; }
};

int main()
{
    Complex c1(10, 5), c2(2, 4);
    Complex c3 = c1 + c2; // An example call to "operator+"
    c3.print();
}
```

Output:
12 + i9
In the above example the operator '+' is overloaded. The operator '+' is an addition operator and can add two numbers(integers or floating point) but here the operator is made to perform addition of two imaginary or complex numbers.

Runtime polymorphism: This type of polymorphism is achieved by Function Overriding.

- Function overriding on the other hand occurs when a derived class has a definition for one of the member functions of the base class. That base function is said to be **overridden**.

filter_none
edit
play_arrow
brightness_4

```
// C++ program for function overriding

#include <bits/stdc++.h>
using namespace std;

class base
{
public:
   virtual void print ()
   { cout<< "print base class" <<endl; }

   void show ()
   { cout<< "show base class" <<endl; }
};

class derived:public base
{
public:
   void print () //print () is already virtual function in derived class, we could also declared as
virtual void print () explicitly
   { cout<< "print derived class" <<endl; }

   void show ()
   { cout<< "show derived class" <<endl; }
};

//main function
int main()
{
   base *bptr;
   derived d;
   bptr = &d;

   //virtual function, binded at runtime (Runtime polymorphism)
   bptr->print();

   // Non-virtual function, binded at compile time
   bptr->show();

   return 0;
}
```

Output:
print derived class
show base class

Operator Overloading in C++

- Operator overloading is a type of polymorphism in which an operator is overloaded to give user defined meaning to it.
- The main purpose of operator overloading is to perform operation on user defined data type. **For eg.** The '+' operator can be overloaded to perform addition on various data types.
- Operator overloading is used by the programmer to make a program clearer.
- It is an important concept in C++.
  Syntax:

```
Return_type Classname :: Operator OperatorSymbol (Argument_List)
{
    //Statements;
}
```

- The **operator** keyword is used for overloading the operators.
  There are a few operators which cannot be overloaded are follows,

i. Scope resolution operator (::)
ii. sizeof
iii. member selector (.)
iv. member pointer selector (*)
v. ternary operator (? :)

There are some restrictions considered while implementing the operator overloading,

1. The number of operands cannot be changed. Unary operator remains unary, binary remains binary etc.
2. Only existing operators can be overloaded.
3. The precedence and associativity of an operator cannot be changed.
4. Cannot redefine the meaning of a procedure.

Overloadable Operators

Following is the list of operators which can be overloaded:

+	-	*	/	%	^
&	|	~	!	,	=
<	>	<=	>=	++	-

<<	>>	==	!=	&&	||
+=	-=	/=	%=	^=	&=
|=	*=	<<=	>>=	[ ]	( )
→	→*	new	new[]	delete	delete[]

Unary Operator Overloading

Unary operator works with one operand and therefore the user defined data types, operand becomes the caller and hence no arguments are required.

Example : Program demonstrating the Unary Increment & Decrement Operator Overloading

```
#include<iostream>
using namespace std;
//Increment and Decrement overloading

class IncreDecre
{
    private:
        int cnt ;
    public:
        IncreDecre() //Default constructor
        {
            cnt = 0 ;
        }
        IncreDecre(int C)  // Constructor with Argument
        {
            cnt = C ;
        }
        IncreDecre operator ++ ()     // Operator Function Definition for prefix
        {
            return IncreDecre(++cnt);
        }
        IncreDecre operator ++ (int)       // Operator Function Definition with dummy
```

```
argument for postfix
        {
            return IncreDecre(cnt++);
        }
        IncreDecre operator -- ()       // Operator Function Definition for prefix
        {
            return IncreDecre(--cnt);
        }
        IncreDecre operator -- (int)       // Operator Function Definition with dummy argument
for postfix
        {
            return IncreDecre(cnt--);
        }
        void show()
        {
            cout << cnt << endl ;
        }
};
int main()
{
    IncreDecre a, b(5), c, d, e(2), f(5);
    cout<<"Unary Increment Operator : "<<endl;
    cout << "Before using the operator ++()\n";
    cout << "a = ";
    a.show();
    cout << "b = ";
    b.show();

    ++a;
    b++;

    cout << "After using the operator ++()\n";
    cout << "a = ";
    a.show();
    cout << "b = ";
```

```
b.show();

c = ++a;
d = b++;

cout << "Result prefix (on a) and postfix (on b)\n";
cout << "c = ";
c.show();
cout << "d = ";
d.show();
cout<<"\n Unary Decrement Operator : "<<endl;
cout << "Before using the operator --()\n";
cout << "e = ";
e.show();
cout << "f = ";
f.show();

--e;
f--;

cout << "After using the operator --()\n";
cout << "e = ";
e.show();
cout << "f = ";
f.show();

c = --e;
d = f--;

cout << "Result prefix (on e) and postfix (on f)\n";
cout << "c = ";
c.show();
cout << "d = ";
d.show();
```

```
    return 0;
}
```

Output:

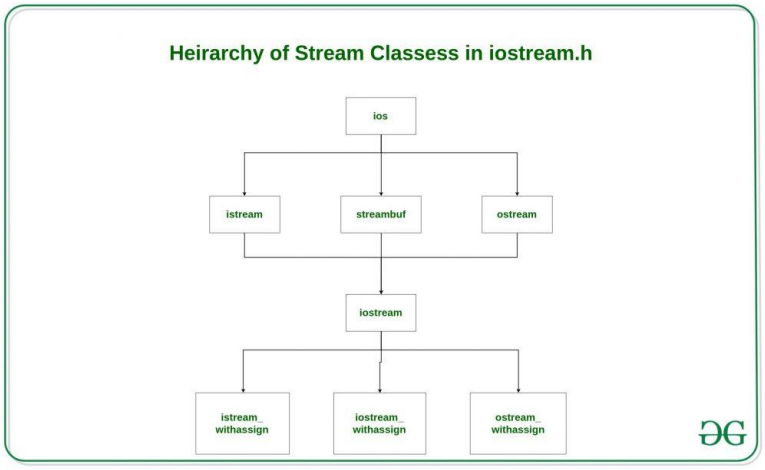
```
Unary Increment Operator :
Before using the operator ++()
a = 0
b = 5
After using the operator ++()
a = 1
b = 6
Result prefix (on a) and postfix (on b)
c = 2
d = 6

Unary Decrement Operator :
Before using the operator --()
e = 2
f = 5
After using the operator --()
e = 1
f = 4
Result prefix (on e) and postfix (on f)
c = 0
d = 4
```

In the above program, **int** is a **dummy argument** to redefine the functions for the unary **increment (++)** and **decrement (– –)** overloaded operators. Remember one thing **int is not an Integer, it is just a dummy argument.** It is a signal to compiler to create the postfix notation of the operator. **Bjarne Stroustrup** has **introduced the concept of dummy argument,** so it becomes function overloading for the operator overloaded functions.

Unit 7
Managing console I/O operations

C++ Stream Classes Structure

In C++ there are number of stream classes for defining various streams related with files and for doing input-output operations. All these classes are defined in the file **iostream.h**. Figure given below shows the hierarchy of these classes.



1. **ios class** is topmost class in the stream classes hierarchy. It is the base class for **istream, ostream,** and **streambuf** class.

2. **istream** and **ostream** serves the base classes for **iostream** class. The class **istream** is used for input and **ostream** for the output.

3. Class **ios** is indirectly inherited to **iostream** class using **istream** and **ostream**. To avoid the duplicity of data and member functions of **ios** class, it is declared as virtual base class when inheriting in **istream** and **ostream** as

```
class istream: virtual public ios
{
};
class ostream: virtual public ios
{
};
```

The **_withassign classes** are provided with extra functionality for the assignment operations that's why **_withassign** classes.

Facilities provided by these stream classes.

1. **The ios class:** The ios class is responsible for providing all input and output facilities to all other stream classes.

2. **The istream class:** This class is responsible for handling input stream. It provides number of function for handling chars, strings and objects such as **get, getline, read, ignore, putback** etc..
   Example:

```
#include <iostream>
using namespace std;

int main()
{
   char x;

   // used to scan a single char
   cin.get(x);

   cout << x;
}
```

Input:

```
g
```

Output:

```
g
```

The ostream class: This class is responsible for handling output stream. It provides number of function for handling chars, strings and objects such as **write, put** etc..
Example:

```
#include <iostream>
using namespace std;

int main()
{
   char x;

   // used to scan a single char
   cin.get(x);

   // used to put a single char onto the screen.
   cout.put(x);
}
```

1. **Input:**

g
Output:

g

The iostream: This class is responsible for handling both input and output stream as both **istream class** and o**stream class** is inherited into it. It provides function of both **istream class** and o**stream class** for handling chars, strings and objects such as **get, getline, read, ignore, putback, put, write** etc..
Example:

```
#include <iostream>
using namespace std;

int main()
{

   // this function display
   // ncount character from array
   cout.write("geeksforgeeks", 5);
}
```

Output:

geeks

istream_withassign class: This class is variant of **istream** that allows object assigment. The predefined object **cin** is an object of this class and thus may be reassigned at run time to a different **istream** object.
Example: To show that **cin** is object of **istream** class.

```
#include <iostream>
using namespace std;

class demo {
public:
   int dx, dy;

   // operator overloading using friend function
   friend void operator>>(demo& d, istream& mycin)
   {
      // cin assigned to another object mycin
      mycin >> d.dx >> d.dy;
   }
```

```
};

int main()
{
   demo d;
   cout << "Enter two numbers dx and dy\n";

   // calls operator >> function and
   // pass d and cin as reference
   d >> cin; // can also be written as operator >> (d, cin) ;

   cout << "dx = " << d.dx << "\tdy = " << d.dy;
}
```

Input:

```
4 5
```

Output:

```
Enter two numbers dx and dy
4 5
dx = 4  dy = 5
```

ostream_withassign class: This class is variant of **ostream** that allows object assigment. The predefined objects **cout, cerr, clog** are objects of this class and thus may be reassigned at run time to a different **ostream** object.
Example: To show that **cout** is object of **ostream** class.

```
#include <iostream>
using namespace std;

class demo {
public:
   int dx, dy;

   demo()
   {
      dx = 4;
      dy = 5;
   }

   // operator overloading using friend function
   friend void operator<<(demo& d, ostream& mycout)
   {
      // cout assigned to another object mycout
      mycout << "Value of dx and dy are \n";
      mycout << d.dx << " " << d.dy;
```

```
    }
};

int main()
{
    demo d; // default constructor is called

    // calls operator << function and
    // pass d and cout as reference
    d << cout; // can also be written as operator << (d, cout) ;
}
```

Output:

```
Value of dx and dy are
4 5
```

Unit 8
Working with Files

C++ Files and Streams

So far, we have been using the **iostream** standard library, which provides **cin** and **cout** methods for reading from standard input and writing to standard output respectively.

This tutorial will teach you how to read and write from a file. This requires another standard C++ library called **fstream**, which defines three new data types −

Sr.No	Data Type & Description
1	**ofstream** This data type represents the output file stream and is used to create files and to write information to files.
2	**ifstream** This data type represents the input file stream and is used to read information from files.

3	**fstream** This data type represents the file stream generally, and has the capabilities of both ofstream and ifstream which means it can create files, write information to files, and read information from files.

To perform file processing in C++, header files <iostream> and <fstream> must be included in your C++ source file.

Opening a File

A file must be opened before you can read from it or write to it. Either **ofstream** or **fstream** object may be used to open a file for writing. And ifstream object is used to open a file for reading purpose only.

Following is the standard syntax for open() function, which is a member of fstream, ifstream, and ofstream objects.

```
void open(const char *filename, ios::openmode mode);
```

Here, the first argument specifies the name and location of the file to be opened and the second argument of the **open()** member function defines the mode in which the file should be opened.

Sr.No	Mode Flag & Description
1	**ios::app** Append mode. All output to that file to be appended to the end.
2	**ios::ate** Open a file for output and move the read/write control to the end of the file.
3	**ios::in** Open a file for reading.
4	**ios::out** Open a file for writing.
5	**ios::trunc** If the file already exists, its contents will be truncated before opening the file.

You can combine two or more of these values by **OR**ing them together. For example if you want to open a file in write mode and want to truncate it in case that already exists, following will be the syntax −

```
ofstream outfile;
outfile.open("file.dat", ios::out | ios::trunc );
```

Similar way, you can open a file for reading and writing purpose as follows −

```
fstream  afile;
afile.open("file.dat", ios::out | ios::in );
```

Closing a File

When a C++ program terminates it automatically flushes all the streams, release all the allocated memory and close all the opened files. But it is always a good practice that a programmer should close all the opened files before program termination.

Following is the standard syntax for close() function, which is a member of fstream, ifstream, and ofstream objects.

```
void close();
```

Writing to a File

While doing C++ programming, you write information to a file from your program using the stream insertion operator (<<) just as you use that operator to output information to the screen. The only difference is that you use an **ofstream** or **fstream** object instead of the **cout** object.

Reading from a File

You read information from a file into your program using the stream extraction operator (>>) just as you use that operator to input information from the keyboard. The only difference is that you use an **ifstream** or **fstream** object instead of the **cin** object.

Read and Write Example

Following is the C++ program which opens a file in reading and writing mode. After writing information entered by the user to a file named afile.dat, the program reads information from the file and outputs it onto the screen −

```
#include <fstream>
#include <iostream>
using namespace std;

int main () {
  char data[100];

  // open a file in write mode.
  ofstream outfile;
```

```
   outfile.open("afile.dat");

   cout << "Writing to the file" << endl;
   cout << "Enter your name: ";
   cin.getline(data, 100);

   // write inputted data into the file.
   outfile << data << endl;

   cout << "Enter your age: ";
   cin >> data;
   cin.ignore();

   // again write inputted data into the file.
   outfile << data << endl;

   // close the opened file.
   outfile.close();

   // open a file in read mode.
   ifstream infile;
   infile.open("afile.dat");

   cout << "Reading from the file" << endl;
   infile >> data;

   // write the data at the screen.
   cout << data << endl;

   // again read the data from the file and display it.
   infile >> data;
   cout << data << endl;

   // close the opened file.
   infile.close();

   return 0;
}
```

When the above code is compiled and executed, it produces the following sample input and output −

```
$./a.out
Writing to the file
Enter your name: Zara
Enter your age: 9
Reading from the file
Zara
9
```

Above examples make use of additional functions from cin object, like getline() function to read the line from outside and ignore() function to ignore the extra characters left by previous read statement.

File Position Pointers

Both **istream** and **ostream** provide member functions for repositioning the file-position pointer. These member functions are **seekg** ("seek get") for istream and **seekp** ("seek put") for ostream.

The argument to seekg and seekp normally is a long integer. A second argument can be specified to indicate the seek direction. The seek direction can be **ios::beg** (the default) for positioning relative to the beginning of a stream, **ios::cur** for positioning relative to the current position in a stream or **ios::end** for positioning relative to the end of a stream.

The file-position pointer is an integer value that specifies the location in the file as a number of bytes from the file's starting location. Some examples of positioning the "get" file-position pointer are −

```
// position to the nth byte of fileObject (assumes ios::beg)
fileObject.seekg( n );

// position n bytes forward in fileObject
fileObject.seekg( n, ios::cur );

// position n bytes back from end of fileObject
fileObject.seekg( n, ios::end );

// position at end of fileObject
fileObject.seekg( 0, ios::end );
```

C++ Exception Handling

An exception is a problem that arises during the execution of a program. A C++ exception is a response to an exceptional circumstance that arises while a program is running, such as an attempt to divide by zero.

Exceptions provide a way to transfer control from one part of a program to another. C++ exception handling is built upon three keywords: **try, catch,** and **throw**.

- **throw** − A program throws an exception when a problem shows up. This is done using a **throw** keyword.
- **catch** − A program catches an exception with an exception handler at the place in a program where you want to handle the problem. The **catch** keyword indicates the catching of an exception.
- **try** − A **try** block identifies a block of code for which particular exceptions will be activated. It's followed by one or more catch blocks.

Assuming a block will raise an exception, a method catches an exception using a combination of the **try** and **catch** keywords. A try/catch block is placed around the code that

might generate an exception. Code within a try/catch block is referred to as protected code, and the syntax for using try/catch as follows −

```
try {
   // protected code
} catch( ExceptionName e1 ) {
   // catch block
} catch( ExceptionName e2 ) {
   // catch block
} catch( ExceptionName eN ) {
   // catch block
}
```

You can list down multiple **catch** statements to catch different type of exceptions in case your **try** block raises more than one exception in different situations.

Throwing Exceptions

Exceptions can be thrown anywhere within a code block using **throw** statement. The operand of the throw statement determines a type for the exception and can be any expression and the type of the result of the expression determines the type of exception thrown.

Following is an example of throwing an exception when dividing by zero condition occurs −

```
double division(int a, int b) {
   if( b == 0 ) {
      throw "Division by zero condition!";
   }
   return (a/b);
}
```

Catching Exceptions

The **catch** block following the **try** block catches any exception. You can specify what type of exception you want to catch and this is determined by the exception declaration that appears in parentheses following the keyword catch.

```
try {
   // protected code
} catch( ExceptionName e ) {
  // code to handle ExceptionName exception
}
```

Above code will catch an exception of **ExceptionName** type. If you want to specify that a catch block should handle any type of exception that is thrown in a try block, you must put an ellipsis, ..., between the parentheses enclosing the exception declaration as follows −

```
try {
   // protected code
} catch(...) {
  // code to handle any exception
}
```

The following is an example, which throws a division by zero exception and we catch it in catch block.

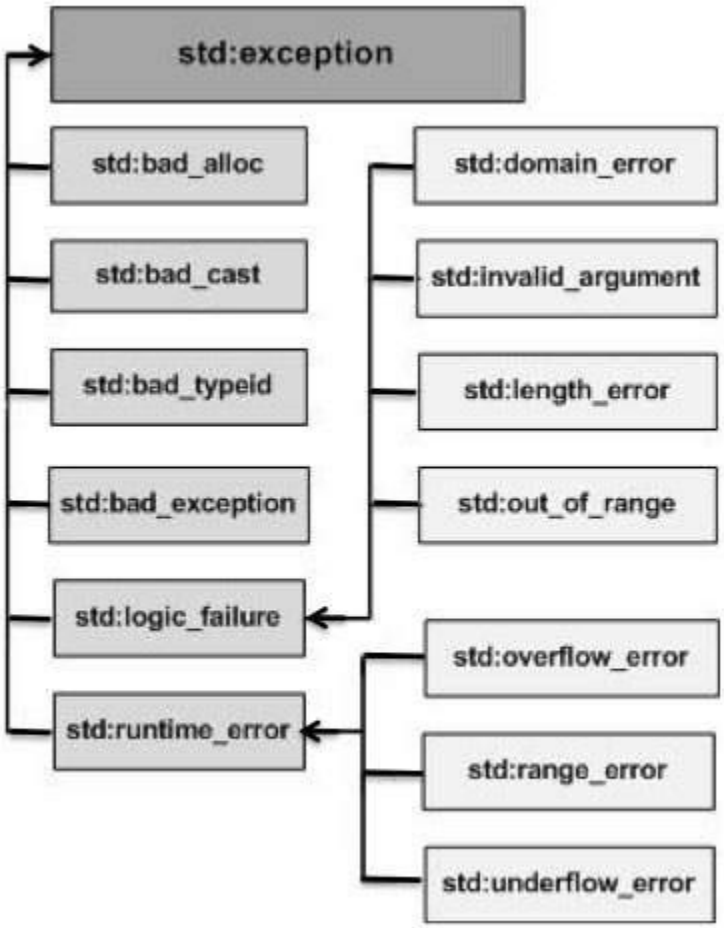
```
#include <iostream>
using namespace std;

double division(int a, int b) {
  if( b == 0 ) {
     throw "Division by zero condition!";
  }
  return (a/b);
}

int main () {
  int x = 50;
  int y = 0;
  double z = 0;

  try {
     z = division(x, y);
     cout << z << endl;
  } catch (const char* msg) {
    cerr << msg << endl;
  }

  return 0;
}
```

Because we are raising an exception of type **const char***, so while catching this exception, we have to use const char* in catch block. If we compile and run above code, this would produce the following result −

Division by zero condition!

C++ Standard Exceptions

C++ provides a list of standard exceptions defined in **<exception>** which we can use in our programs. These are arranged in a parent-child class hierarchy shown below −



Here is the small description of each exception mentioned in the above hierarchy −

Sr.No	Exception & Description
1	**std::exception** An exception and parent class of all the standard C++ exceptions.
2	**std::bad_alloc** This can be thrown by **new**.
3	**std::bad_cast** This can be thrown by **dynamic_cast**.
4	**std::bad_exception** This is useful device to handle unexpected exceptions in a C++ program.

5	**std::bad_typeid** This can be thrown by **typeid**.
6	**std::logic_error** An exception that theoretically can be detected by reading the code.
7	**std::domain_error** This is an exception thrown when a mathematically invalid domain is used.
8	**std::invalid_argument** This is thrown due to invalid arguments.
9	**std::length_error** This is thrown when a too big std::string is created.
10	**std::out_of_range** This can be thrown by the 'at' method, for example a std::vector and std::bitset<>::operator[]().
11	**std::runtime_error** An exception that theoretically cannot be detected by reading the code.
12	**std::overflow_error** This is thrown if a mathematical overflow occurs.
13	**std::range_error** This is occurred when you try to store a value which is out of range.
14	**std::underflow_error** This is thrown if a mathematical underflow occurs.

Define New Exceptions

You can define your own exceptions by inheriting and overriding **exception** class functionality. Following is the example, which shows how you can use std::exception class to implement your own exception in standard way −

```
#include <iostream>
#include <exception>
using namespace std;

struct MyException : public exception {
  const char * what () const throw () {
    return "C++ Exception";
  }
};

int main() {
  try {
    throw MyException();
  } catch(MyException& e) {
    std::cout << "MyException caught" << std::endl;
    std::cout << e.what() << std::endl;
  } catch(std::exception& e) {
    //Other errors
  }
}
```

This would produce the following result −

```
MyException caught
C++ Exception
```

Here, **what()** is a public method provided by exception class and it has been overridden by all the child exception classes. This returns the cause of an exception.

Unit 9- Templates

Templates are the foundation of generic programming, which involves writing code in a way that is independent of any particular type.

A template is a blueprint or formula for creating a generic class or a function. The library containers like iterators and algorithms are examples of generic programming and have been developed using template concept.

There is a single definition of each container, such as **vector**, but we can define many different kinds of vectors for example, **vector <int>** or **vector <string>**.

You can use templates to define functions as well as classes, let us see how they work −

Function Template

The general form of a template function definition is shown here −

```
template <class type> ret-type func-name(parameter list) {
   // body of function
}
```

Here, type is a placeholder name for a data type used by the function. This name can be used within the function definition.

The following is the example of a function template that returns the maximum of two values −

```
#include <iostream>
#include <string>

using namespace std;

template <typename T>
inline T const& Max (T const& a, T const& b) {
   return a < b ? b:a;
}

int main () {
   int i = 39;
   int j = 20;
   cout << "Max(i, j): " << Max(i, j) << endl;

   double f1 = 13.5;
   double f2 = 20.7;
   cout << "Max(f1, f2): " << Max(f1, f2) << endl;

   string s1 = "Hello";
   string s2 = "World";
   cout << "Max(s1, s2): " << Max(s1, s2) << endl;

   return 0;
}
```

If we compile and run above code, this would produce the following result −

```
Max(i, j): 39
Max(f1, f2): 20.7
Max(s1, s2): World
```

Class Template

Just as we can define function templates, we can also define class templates. The general form of a generic class declaration is shown here −

```
template <class type> class class-name {
  .
  .
  .
}
```

Here, **type** is the placeholder type name, which will be specified when a class is instantiated. You can define more than one generic data type by using a comma-separated list.

Following is the example to define class Stack<> and implement generic methods to push and pop the elements from the stack −

```
#include <iostream>
#include <vector>
#include <cstdlib>
#include <string>
#include <stdexcept>

using namespace std;

template <class T>
class Stack {
  private:
    vector<T> elems;    // elements

  public:
    void push(T const&);  // push element
    void pop();               // pop element
    T top() const;            // return top element

    bool empty() const {      // return true if empty.
      return elems.empty();
    }
};

template <class T>
void Stack<T>::push (T const& elem) {
  // append copy of passed element
  elems.push_back(elem);
}

template <class T>
```

```
void Stack<T>::pop () {
  if (elems.empty()) {
    throw out_of_range("Stack<>::pop(): empty stack");
  }

  // remove last element
  elems.pop_back();
}

template <class T>
T Stack<T>::top () const {
  if (elems.empty()) {
    throw out_of_range("Stack<>::top(): empty stack");
  }

  // return copy of last element
  return elems.back();
}

int main() {
  try {
    Stack<int>         intStack;  // stack of ints
    Stack<string> stringStack;    // stack of strings

    // manipulate int stack
    intStack.push(7);
    cout << intStack.top() <<endl;

    // manipulate string stack
    stringStack.push("hello");
    cout << stringStack.top() << std::endl;
    stringStack.pop();
    stringStack.pop();
  } catch (exception const& ex) {
    cerr << "Exception: " << ex.what() <<endl;
    return -1;
  }
}
```

If we compile and run above code, this would produce the following result −

```
7
hello
Exception: Stack<>::pop(): empty stack
```