Object Inheritance and Reusability

- In OOPs, the mechanism of deriving new class from old one is called inheritance.
- The old class is referred to as (base class /parent class/super class) and new class is called as (derived class/child class /sub class).
- The derived class inherits some or all of the data and functions from base class so that so that we can reuse the already written and tested code in our program.
  Example:
  The properties of class named Person like name, age, address, phone number can be reusable in Class Employee. So, inheritance supports reusability and minimizes coding redundancy.

Visibility Modifier (Access Specifier):

Visibility Modifier (Access Specifier)	Accessible from own class	Accessible from derived class	Accessible from objects outside class
public	yes	yes	yes
private	yes	no	no
protected	yes	yes	no

Defining Derived Class (Specifying Derived Class):

General syntax :

```
class derived_class_name : visibility_mode base_class_name
{
//members of derived class
} ;
```

- The colon (:) indicates that the derived_class_name is derived from the base_class_name.
- The visibility_mode is optional, if present, may be either private or public.
  The default visibility mode is private.
- Visibility mode specifies whether the features of the base class are privately derived or publicly derived or derived on protected.

Base Class Visibility	Derived Class Visibility		
	Public derivation	Private derivation	Protected derivation
Private	Not inherited	Not inherited	Not inherited
Protected	Protected	Private	Protected
Public	Public	Private	Protected

```
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
};
```

While any derived_class is inherited from a base_class, following things should be understood:

1. When a base class is privately inherited by a derived class, only the public and protected members of base class can be accessed by the member functions of derived class. This means no private member of the base class can be accessed by the objects of the derived class. Public and protected member of base class becomes private in derived class.
2. When a base class is publicly inherited by a derived class the private members are not inherited, the public and protected are inherited. The public members of base class becomes public in derived class whereas protected members of base class becomes protected in derived class.
3. When a base class is protectedly inherited by a derived class, then public members of base class becomes protected in derived class ; protected members of base class becomes protected in the derived class, the private members of the base class are not inherited to derived class but note that we can access private member through inherited member function of the base class.

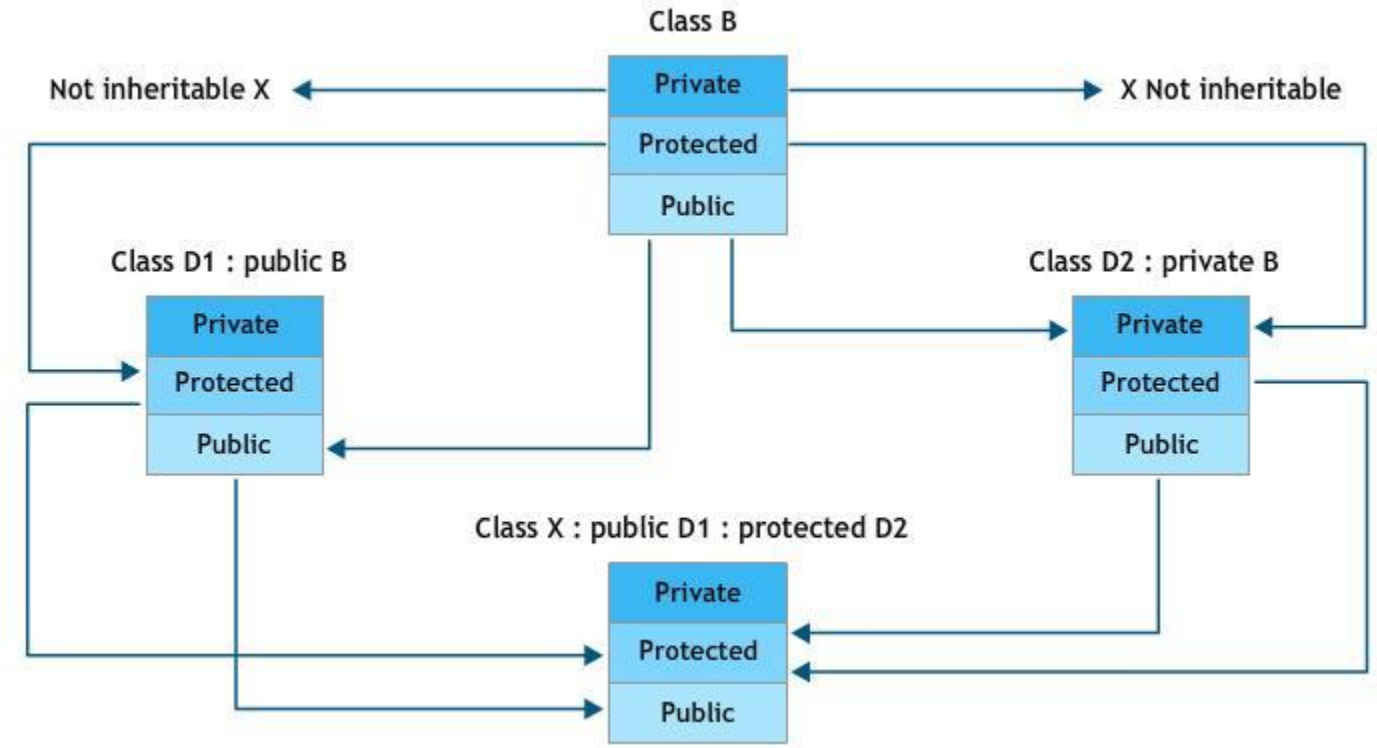


Fig: Effect of inheritance on visibility of members

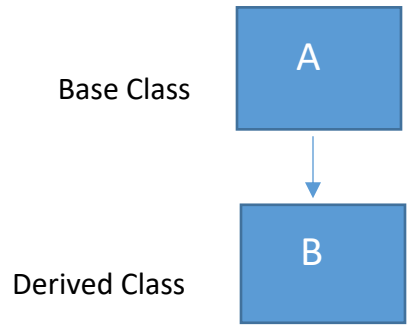
Types of Inheritance:

There are five types of inheritance:

1) Single Inheritance
2) Multiple inheritance
3) Hierarchical Inheritance
4) Multilevel Inheritance
5) Hybrid Inheritance

1) Single Inheritance

When a class is derived from only one base class, then it is called single inheritance.



General form:

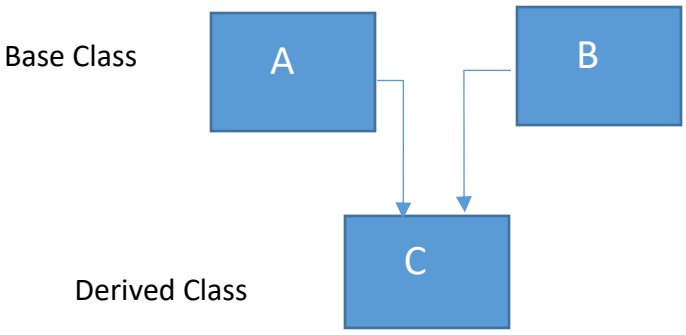
```
class A                    // base class
{
. . . . . .
};
class B : public A         // derived class B
{
. . . . . .
};
```

Here in, Single Inheritance

- One base class and one derived class only involved
- Class A is base class.
- B is derived class.
- B is not used as base class again
- No further extension of derived class
- All data members in protected and public of class A can be accessed using object of class B.

2) Multiple Inheritance

When a class is derived from two or more base classes, it is called multiple inheritance.

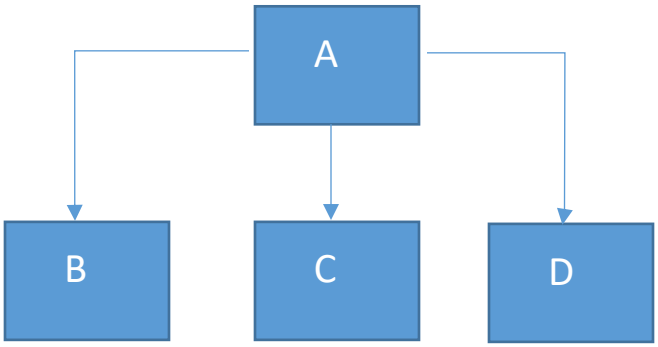


General form

```
class A
{

};
Class B
{

};
class C:public A, public B
{

};
```

In General form there are 3 classes A, B and C. Class A and B are base classes and C is derived class.
All data members in protected and public of class A & B can be accessed using object of class C.
Here two base classes A and B have been created and a derived class C is created from both base classes.

3) **Hierarchical Inheritance**: When two or more than two classes are derived from one base class, it is called hierarchical inheritance.

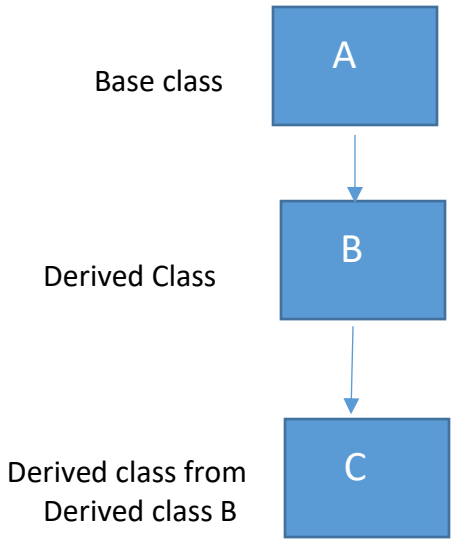


General form

```
class A
{

};
Class B: public A
{

};
Class C: public A
{

};
Class D: public A
{

};
```

In General form three classes B and C and D are derived from same base class A. All data members in protected and public of class A can be accessed using object of classes B, C, D.

4) **Multilevel Inheritance:** The mechanism for deriving a class from another derived class is known as multilevel inheritance.

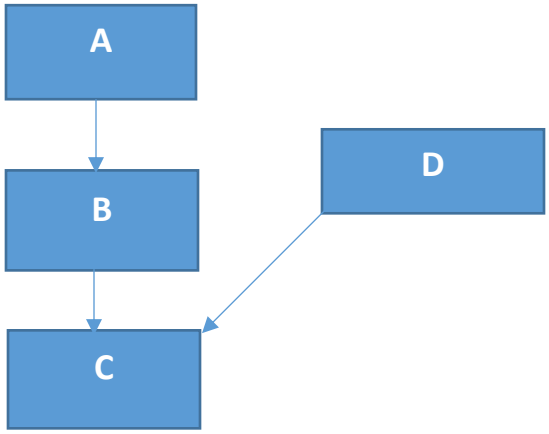


General form

```
Class A
{
. . . . . .
};
Class B: public A
{
. . . . . .
};
Class C: public B
{
. . . . . .
};
```

In General form there are 3 classes A,B and C. Class A is base class and Class B is derived class from Class A and class C is derived class from class B. All data members in protected and public of class A can be accessed using object of classes B, C and of class B can be accessed by class C.

5) **Hybrid Inheritance:**
Combination of one or more types of inheritance is known as hybrid inheritance.




```
Class A
{


};
Class D
{


};
Class B: public A
{


};
Class C: public B, Public D
{


};
```

Description: In General form there are 4 classes A, B, C and D. Classes A & D are base classes and Class B is derived class from Class A and class C is derived class from classes B & D. All data members in protected and public of class A can be accessed using object of classes B, C and of classes B&D can be accessed by class C.

Program:

Single Inheritance: Public

```
#include<iostream>
using namespace std;
class A
{
private:
int x;
protected:
int y;
public:
int z;
void get_xyz()
{
        cout<<"Enter the value of x,y,z"<<endl;
        cin>>x>>y>>z;
}
void show_xyz()
{
        cout<<"x="<<x<<"y="<<y<<"z="<<z<<endl;
}
};
class B:public A
{
private:
int k,sum;
public:
void get_k()
{
cout<<"Enter the value of k"<<endl;
cin>>k;
}
void show_k()
{
cout<<"k="<<k<<endl;
}
void addition()
{
        sum=y+z+k;
}
```

```
void display()
{
cout<<"Sum="<<sum<<endl;
}
};

int main()
{
B b1;
b1.get_xyz();
b1.get_k();
b1.show_xyz();
b1.show_k();
b1.addition();
b1.display();
}
```

Single Inheritance: Private

```
#include<iostream>
using namespace std;
class A
{
private:
int x;
protected:
int y;
public:
int z;
void get_xyz()
{
        cout<<"Enter the value of x,y,z"<<endl;
        cin>>x>>y>>z;
}
void show_xyz()
{
        cout<<"x="<<x<<"y="<<y<<"z="<<z<<endl;
}
};
class B:private A
{
private:
int k,sum;
public:
```

```
void getdata()
{
get_xyz();
cout<<"Enter the value of k"<<endl;
cin>>k;
}
void showdata()
{
show_xyz();
cout<<"k="<<k<<endl;
}
void addition()
{
        sum=y+z+k;
}
void display()
{
cout<<"y+z+k="<<sum<<endl;
}
};

int main()
{
B b1;
b1.getdata();
b1.showdata();
b1.addition();
b1.display();
}
```

Example of Multiple Inheritance:

```
#include<iostream>
using namespace std;
class M
{
	protected:
		int m;
	public:
		void get_m(int x)
		{
			m=x;
		}
};
class N
{
protected:
int n;
public:
	void get_n(int y)
	{
		n=y;
	}
};

class P:public M,public N
{
	public:
		void display()
		{
		cout<<"m= "<<m<<endl;
		cout<<"n= "<<n<<endl;
		cout<<"m*n="<<m*n<<endl;
		}
};
int main()
{
P p;
p.get_m(10);
p.get_n(20);
p.display();
return 0;
}
```

Example of multilevel Inheritance

```
#include<iostream>
using namespace std;
class student
{
protected:
int roll;
public:
void getnum(int x)
{
 roll=x;
}

void putnum()
{
cout<<"Roll number="<<roll<<endl;
}
};
class test:public student
{
protected:
float sub1,sub2;
public:
void getmarks(float x,float y)
{
sub1=x;
sub2=y;
}

void putmarks()
{
 cout<<"Marks in sub1="<<sub1<<endl;
 cout<<"Marks in sub2="<<sub2<<endl;
}
};
```

```
class result:public test
{
        private:
        float total;
        public:
        void display()
        {
        total=sub1+sub2;
        putnum();
        putmarks();
        cout<<"Total="<<total<<endl;
   }
};
int main()
{
        result r;
        r.getnum(10);
        r.getmarks(75.5,80);
        r.display();
        return 0;
}
```

Example of Hierarchical Inheritance

```
#include<iostream>
using namespace std;
class A
{
protected:
int x,y;
public:
void init()
{
x=20;y=10;
}
};
```

```
class B:public A
{
private:
int sum ;
public:
void add( )
{
sum=x+y ;
cout<< "x+y="<<sum<<endl;
}
};
class C: public A
{
int diff;
public:
void sub()
{
diff=x-y;
cout<< "x-y="<<diff<<endl;
}
};
class D: public A
{
int m;
public:
void mul( )
{
m=x*y ;
cout<<"x*y="<<m<<endl;
}};
int main()
{
B b1;
C c1;
D d1;
b1.init();
b1.add();
c1.init();
c1.sub() ;
d1.init();
d1.mul();
return 0;
}
```

Example of Hybrid Inheritance

```
#include<iostream>
using namespace std;
class A
{
protected:
int x;
public:
void assignx( )
{
x=20;
}
};
class B: public A
{
protected:
int y ;
public:
void assigny()
{
y=40;
}
};
class C :public B
{
protected:
int z;
public:
void assignz( )
{
z=60;
}
};
class D
{
protected :
int k ;
public:
void assignk( )
{
k=80;
}
};
```

```
class E :public D, public C
{
private:
int total;
public:
void output()
{
total=x+y+z+k;
cout<< "x+y+z+k="<<total<<endl;
}
};
int main( )
{
E e1;
e1.assignx();
e1.assigny();
e1.assignz();
e1.assignk();
e1.output();
return 0;
}
```

Ambiguity in Multiple inheritance

When two or more than two base classes have a function of identical name and when class inherits from multiple base classes then ambiguity occurs.

Let us consider the following case:

```
class M
{
public:
void display()
{
cout<<"Class M"<<endl;
}
};
class N
{
        public:
        void display()
        {
         cout<<"Class N"<<endl;
        }
};
```

Which display function is used by the derived class when we inherit these two classes?
We can solve this problem by redefining the member in the derived class using **resolution operator** with the function as shown below.

```
class P:public M,public N
{
public:
void display()
{
 M::display();
}
};
```

Now we can use the derived class as follows:

```
int main()
{
P p;
p.display();
return 0;
}
```

Output:

```
Class M
```

Ambiguity in single Inheritance

Ambiguity may also arise in single inheritance applications. For example, Let us consider the following situation.

```
class A
{
public:
void display()
{
cout<<"class A"<<endl;
}
};

class B:public A
{
public:
void display()
{
cout<<"class B"<<endl;
}
};
```

In this case, the function in the derived class overrides the inherited function and therefore simple call to display() by B type object will invoke function defined in B only. However, we may invoke the function defined in A by using the scope resolution operator to specify the class.

```
int main()
{
B b;
b.display();      //derived class object
b.A::display();  //invokes display() in A
b.B::display();  //invokes display() in B
return 0;
}
```

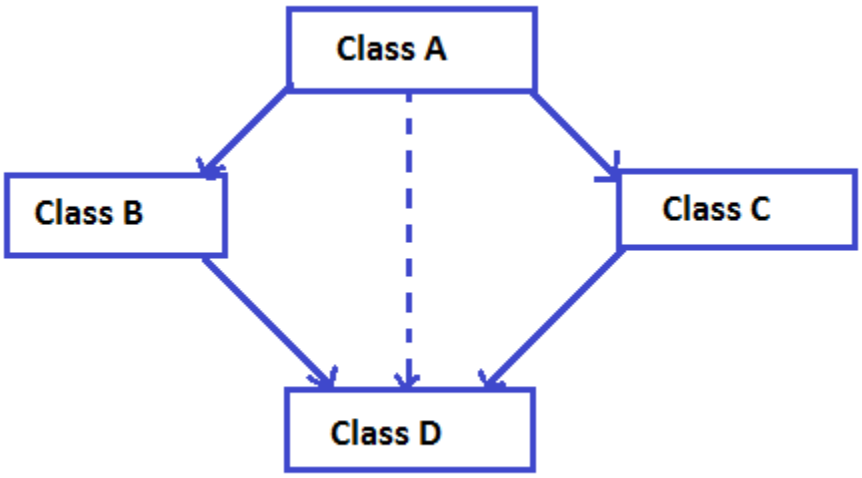
Output:

```
Class B
Class A
Class B
```

Virtual Base class

- *During the time of hybrid inheritance when there is a hierarchical inheritance at the upper level and multiple inheritance at lower level, ambiguity occurs due to the duplication of data from multiple path at the grand child class. How this kind of ambiguity is resolved? Explain with suitable example.**[PU:2013 fall]***
- *Does ambiguity occurs in hybrid inheritance .If yes? How can you remove this? Explain with example.**[PU:2018 fall]***
- *Under what condition virtual base class is created? Explain it with suitable example .**[PU:2017 fall]***

Let us consider the following situation:



In the above example, both Class B and Class C inherit properties of Class A, they both have single copy of Class A. However Class D inherit both Class B and Class C, therefore Class D have two copies of Class A, one from Class B and another from Class C. This introduces ambiguity and should be avoided..

The duplication of inherited members due to these multiple paths can be avoided by making common base class as virtual class while declaring the direct or intermediate base classes.

By making a class virtual only one copy of that class is inherited though we may have many inheritance paths between the virtual base class and a derived class .we can specify a base class inheritance by using the keyword virtual.

To remove multiple copies of Class A from Class D, we must inherit Class A in Class Band Class C as virtual class.

```
class A
{
----------------------
};
class B:virtual public A
{
//parent1
----------------------
};
class C:public virtual A
{
//parent2
----------------------
};
class D:public B, public C{
//child
----------------------
};
```

Program

```
#include<iostream>
using namespace std;
class A
{
   public:
   int a;
};
class B : virtual public A
{
   public:
   int b;
};
class C : virtual public A
{
   public:
   int c;
};

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

int  main()
{

D obj;
obj.a = 10;      //value of obj.a is replaced by 100 due to only one copy of data member of class A
obj.a = 100;     // is available in class D
obj.b = 20;
obj.c = 30;
obj.d = 40;
cout<< "A="<<obj.a<<endl;
cout<< "B="<<obj.b<<endl;
cout<< "C="<<obj.c<<endl;
cout<< "D="<<obj.d<<endl;
return 0;
}
```

Constructor and Destructor in Inheritance

- Compiler automatically calls constructer of base class and derived class automatically when derived class object is created.
- If we declare derived class object in inheritance constructor of base class is executed first and then constructor of derived class.
- If derived class object goes out of scope or deleted by programmer the derived class destructor is executed first and then base class destructor

Illustration of when base and derived class constructor and destructor functions are executed

```
#include <iostream>
using namespace std;
class A
{
public:
A( )
{
cout<< "Constructor in base class"<<endl ;
}
~A( )
{
cout<< "Destructor  in  base class"<<endl ;
}
} ;
class B:public A
{
public:
B()
{
cout<< "Constructor in derived class"<<endl ;
}
~B( )
{
cout<< "Destructor in  derived class"<<endl ;
}
};
int main( )
{
        B obj;
        return 0;
}
```

In Above Program Class A is base class with one constructor and destructor, Class B is derived from class A having a constructor and destructor. In **main()** Object of derived class i.e. class B is declared. When class B's object is declared constructor of base class is executed followed by derived class constructor. At end of program destructor of derived class is executed first followed by base class destructor

Output:

```
Constructor in base Class
Constructor in derived class
Destructor in derived Class
Destructor in base class
```

Constructor in derived class

- If the **base class does not have any constructors taking arguments** (parameterized constructors), the **derived class need not have a constructor** function.
- If the **base class contains a constructor with one or more arguments** then it is **mandatory for the derived class to have a constructor** and pass the arguments to the base class constructors.
- When both the **derived and base classes contain constructors** then the **base class constructors is execute first** and then the constructor in the derived class is executed.
- In case of **Multiple Inheritance**
  - The **base classes are constructed in the order** in which they appear in the declaration of the derived class
- In case of **Multilevel Inheritance**
  - The constructors will be executed **in the order of inheritance**
- The constructors for virtual base classes are invoked before any non-virtual base classes.

Method of inheritance	Order of Execution
Class B:public A{ };	A(); base constructor (first) B(); derived constructor(second)
Class A:public B, public C{ }	B(); base constructor (first) C(); base constructor(second) A();derived (last)
Class A: public B, virtual public C{ }	C(); virtual base (first) B(); ordinary base constructor(second) A();derived (last)

Argument passing mechanism for supplying initial values to the bases classes constructors:

- The **constructor of the derived class receives the entire list of values as its arguments and passed them to the base class constructors** in the order in which they are declared in the base class.
- The **base class constructors are called and executed first** before executing the statements in the body of the derived constructor.

General form of defining a derived constructor:

Derived-constructor(Arglist1, Arglist2,……ArglistN, ArglistD):

base1(Arglist1),

base2(arglist2)

. . . . . .

baseN(arglistN)

{

//Body of the derived constructor

}

The header line of derived constructor function contains two parts separated by a colon (:)
The first part provide the declaration of arguments that are passed to the derived constructor and the second part lists the function calls to the base constructors

Here, base1(Arglist1), base2(Arglist2)….. baseN (ArglistN) are function calls to base class constructors and Arglist1, Arglist2…… ArglistN are the actual parameters that are passed to the base constructors . Here, ArglistD provides the parameters that are necessary to initialize the members of the derived class itself.

Example:

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

```
class alpha
{
int x;
public:
alpha(int a)
{
x=a;
cout<<"Alpha is initialized"<<endl;
}
void showa()
{
cout<<"x="<<x<<endl;
}
};
class beta
{
int y;
public:
beta(int b)
{
y=b;
cout<<"Beta is initialized"<<endl;
}
void showb()
{
cout<<"y="<<y<<endl;
}
};
class gamma:public beta,public alpha
{
int z;
public:
gamma(int a,int b,int c):alpha(a),beta(b)
{
          z=c;
   cout<<"Gamma is initialized"<<endl;
}

void showg()
{
cout<<"z="<<z<<endl;
}
};
```

```
int main()
{
gamma g(5,10,15);
g.showa();
g.showb();
g.showg();
return 0;
}
```

Output:

```
Beta is initialized
Alpha is initialized
Gamma is initialized
```

Here, **beta** is initialized first although it appears second in the derived constructor *as it has been* declared first in the derived class header line

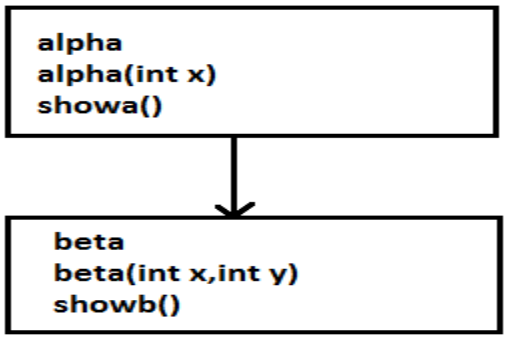
```
class gamma: public beta, public alpha
{

}
```

If we change the order *to*

```
class gamma: public alpha, public beta
{
}
```

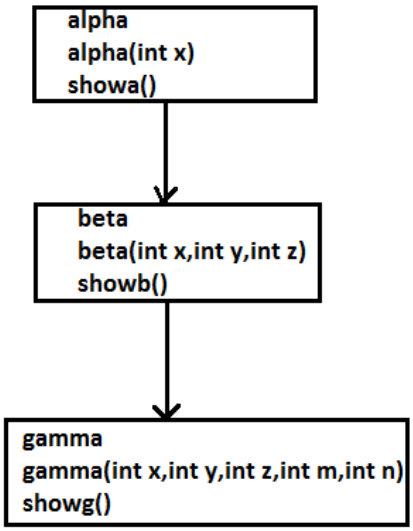
then alpha will be initialized first

1. **Write a complete program with reference to given below.**



```
#include<iostream>
using namespace std;
class alpha
{
private:
int a;
public:
alpha(int x)
{
a=x;
}
void showa()
{
cout<<"value of a="<<a<<endl;
}
};
class beta:public alpha
{
private:
int b;
public:
beta(int x,int y):alpha(x)
{
b=y;
}
void showb()
{
cout<<"value of b="<<b<<endl;
}
};

int main()
{
beta b1(3,4);
b1.showa();
b1.showb();
return 0;
}
```

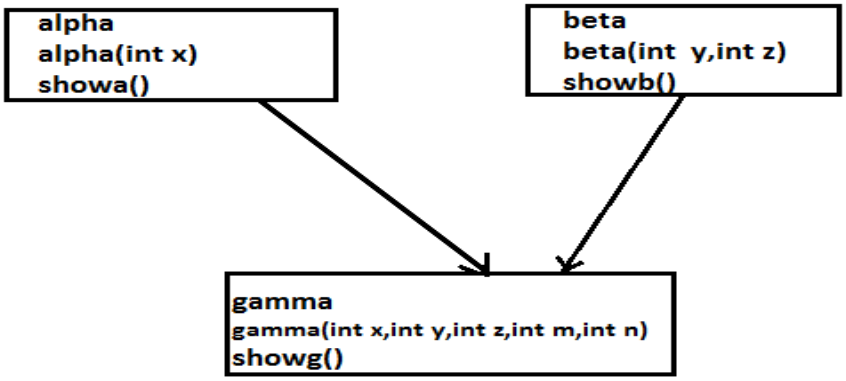
2. **Write a complete program with reference to given below.**




```
#include<iostream>
using namespace std;
class alpha
{
private:
int a;
public:
alpha(int x)
{
a=x;
}
void showa()
{
cout<<"value of a="<<a<<endl;
}
};
```

```
class beta:public alpha
{
private:
int b,c;
public:
beta(int x,int y,int z):alpha(x)
{
b=y;
c=z;
}
void showb()
{
cout<<"value of b="<<b<<endl;
cout<<"value of c="<<c<<endl;
}
};
class gamma:public beta
{
private:
int d,e;
public:
gamma(int x,int y,int z,int m,int n):beta(x,y,z)
{
d=m;
e=n      ;
}
void showc()
{
cout<<"value of d="<<d<<endl;
cout<<"value of e="<<e<<endl;
}
};

int main()
{
gamma g1(5,6,7,10,20);
g1.showa();
g1.showb();
g1.showc();
return 0;
}
```

3. **Write a complete program with reference to given below.**




```
#include<iostream>
using namespace std;
class alpha
{
private:
int a;
public:
alpha(int x)
{
a=x;
}
void showa()
{
cout<<"value of a="<<a<<endl;
}
};
class beta
{
private:
int b,c ;
public:
beta(int y,int z)
{
b=y;
c=z;
}
```

```
void showb()
{
cout<<"value of b="<<b<<endl;
cout<<"value of c="<<c<<endl;
}
};
class gamma:public alpha,public beta
{
private:
int d,e;
public:
gamma(int x,int y,int z,int m,int n):alpha(x),beta(y,z)
{
d=m;
e=n      ;
}
void showc()
{
cout<<"value of d="<<d<<endl;
cout<<"value of e="<<e<<endl;
}
};

int main()
{
gamma g1(5,6,7,10,20);
g1.showa();
g1.showb();
g1.showc();
return 0;
}
```

Initialization list in constructors

C++ supports another method of initializing the class objects .This method uses what is known as initialization list in the constructor function. This takes the following form.

```
constructor (arglist):initialization- section
{
assignment-section
}
```

- **assignment-section:** It is body of the constructor function and used to initialize value to its data members.
- **Initialization-section:** This section is used to provide initial value to the base constructors and also initialize its own class member.
- We can use either of the section to initialize the data members of constructor in class.
- The initialization section basically contains a list of initializations separated by commas. This list is known as initialization list.

Consider the simple example:

```
class alpha
{
int a;
int b;
public:
alpha(int x,int y):a(x),b(2*y)
{
}
};
int main()
{
alpha a1(2,3);
}
```

This program will initialize a to 2 and b to 6. Now data members are initialized ,just by using the variable name followed by initialization value enclosed in the parenthesis(like a function call.

Any of the parameters of the argument list may be used as the initialization value and the item list may be in any order.

```
alpha(int x,int y):b(x),a(x+y)

{ }
```

In this case a will be initialized to 5 and b to 2.

Data members are initialized in the order of the declaration, independent of the order of the initialization list.

alpha(int x,int y):a(x),b(a*y){}

Here the data member a has been declared first so value of a is initialized first and its value is used to initialize b.

However, the following will not work:

alpha(int x,int y):b(x),a(b*y)

{

}

Because the value of b is not available to which is to be initialized first.

The following statements are also valid:

```
alpha(int x,int y):a(x)
{
b=y
}
```
OR
```
alpha(int x,int y)
{
a=x;
b=y:
}
```

Program:

```
#include<iostream>
using namespace std;
class alpha
{
private:
int a,b,c;
public:
alpha(int x,int y,int z):a(x),b(2*y)
{
c=z;
}
void showa()
{
cout<<"a="<<a<<endl;
cout<<"b="<<b<<endl;
cout<<"c="<<c<<endl;
}
};

class beta:public alpha
{
private:
int d,e;
public:
beta(int x,int y,int z,int m,int n):alpha(x,y,z),d(2+m)
{
e=n;
}
void showb()
{
cout<<"d="<<d<<endl;
cout<<"e="<<e<<endl;
}
};
int main()
{
beta b1(5,10,15,20,25);
b1.showa();
b1.showb();
return 0;
}
```

Subclass, Subtype and Principle of Substitutability

If we consider the relationship of a data type associated with a parent class to the data type associated with a child class, the following observations can be made.

- Instances of the child class must possess all data members associated with the parent class.
- Instances of the child class must implement, through inheritance as least (if not explicitly overridden), all functionality defined for parent class. (*They can also define new functionality*)
- The instance of a child class can mimic the behavior of parent class and should be indistinguishable from an instance of parent class if substituted in similar situation.

The Principal of Substitutability

It states that "If we have two classes A and B such that class B is a subclass of A, it should be possible to substitute instances of class B for instances of class A in any situation with no observable effect"

The term subtype is used to refer to a subclass relationship in which the principle of substitutability is maintained to distinguish such forms from the general subclass relationship, we may or may not satisfy this principle.

In the example below the class B object is replaced by the object of class A without any error. This is achieved when a child class is inherited from a base class publicly. In the same example, if the mode of inheritance is made private the base class object **'a'** can't be replaced by the parent class object **'a'.**

EXAMPLE:

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

class A
{
public:
void display()
{
cout <<"class A";
}
};
```

```
class B : public A
{
public:
void display()
{
cout <<"class B";
}
};
void test(A a)
{
a.display();
}
int main()
{
B b;
test(b);// b substituted for object of A.
return 0;
}
```

Containership/Composition

When a class contains object of another class as its member data, it is termed as containership. The class which contains the object is called container class. Containership is also termed as “class within class”.

```
class A
{
……
……
};
class B
{
…..
A obj1;
…..
};
```

Here, class B contains object of class A. so that B is the container class.

Program to illustrate the concept of containership

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

class Employee
{
int eid;
float salary;
public:
void getdata()
{
cout<<"Enter id and salary of employee"<<endl;
cin>>eid>>salary;
}
void display()
{
cout<<"Emp ID:"<<eid<<endl;
cout<<"Salary:"<<salary<<endl;
}
};
class Company
{
char cname[20];
char department[20];
Employee e;
public:
void getdata()
{
e.getdata();
cout<<"Enter company name and Deparment:"<<endl;
cin>>cname>>department;
}
void display()
{
e.display();
cout<<"Company name:"<<cname<<endl;
cout<<"Department:"<<department<<endl;
}
};
```

```
int main()
{
Company c;
c.getdata();
c.display();
return 0;
}
```

In above example class company contains the object of another class employee. As we know "company **has a** employee" sounds logical .so there exits has a relationship between company and employee.

IS A RULE/HAS A RULE *OR (IS A /HAS A RELATIONSHIP)*

As we know, One of the advantages of an Object Oriented programming language is code reuse, however, There are two ways we can do code reuse either by the implementation of inheritance (IS-A relationship), or object composition (HAS-A relationship).

IS A Relationship	**HAS A relationship**
1. If the first concept is a specialized instance of the second one then there exists an "*is-a"* relationship between them.	1. If the second concept is a component of the first and the two are not in any sense the same thing then there exists a "has a" relationship between them.
2. Example: Car is a vehicle	**2. Example:** car has a engine.
3. "**IS A**" Relationship refers to Inheritance.	**3. "HAS A"** Relationship refers to composition.
4. 'Is-a' relationship asserts the instance of the subclass must be more specialized form of the superclass.	*4.* In 'has-a' relationship class contains object of another class as its member data to make it as a whole.

5. class Vehicle
{
 	
};
class Car: Public Vehicle
{
};
class Bus: Public Vehicle
{
 	
};
	5. class engine{
	};
	class car {
	engine e; // a car is composed of an engine
	};

Inheritance VS. composition

Inheritance	Composition
1. In Inheritance derived classes inherit attributes and methods from their parent class.	**1.** In composition a class contains object of another class as its member data.
2. It exhibits "is-a" relationship.	2. It exhibits "has-a" relationship.
3. Example: Car **is a** vehicle	3. Example: Car **has a** engine

4. class Vehicle
{
};
class Car: Public Vehicle
{
};
class Bus: Public Vehicle
{
 	
}
	4. class engine
	{
	};
	class car
	{
	engine e;
	// a car is composed of an engine
	};

5. Inheritance leads tight coupling between superclass and subclass. 6. So it is harder to maintain in future.	***5.*** In Composition relationship between class can be decoupled easily .so it is can be easily maintained in future**.**
7. Inheritance permits polymorphism	6. Composition does not permit polymorphism.

Program to illustrate concept of inheritance
#include<iostream>
using namespace std;
class first
{
private:
int a;
public:
void geta()
{
cout<<"Enter value of a"<<endl;
cin>>a;
}
void puta()
{
cout<<"a="<<a<<endl;
}
};
	Program to illustrate concept of composition
	#include<iostream>
	using namespace std;
	class first
	{
	private:
	int a;
	public:
	void geta()
	{
	cout<<"Enter value of a"<<endl;
	cin>>a;
	}
	void puta()
	{
	cout<<"a="<<a<<endl;
	}
	};

```
class second:public first
{
        private:
        int b;
        public:
        void getb()
        {
         cout<<"Enter value of b"<<endl;
         cin>>b;
        }
        void putb()
        {
        cout<<"b="<<b<<endl;
        }
};
int main()
{
second s;
s.geta();
s.getb();
s.puta();
s.putb();
return 0;
}
```

```
class second
{
        private:
        int b;
        first f;
        public:
        void getb()
        {
         f.geta();
         cout<<"Enter value of b"<<endl;
         cin>>b;
        }
        void putb()
        {
        f.puta();
        cout<<"b="<<b<<endl;
        }
};
int main()
{
second s;
s.getb();
s.putb();
return 0;
}
```

Software reusability

Software reusability is the practice of using existing code for a new software. But in order to reuse code, that code needs to be high-quality. And that means it should be safe, secure, reliable, efficient and maintainable.

In OOP, the concept of inheritance provide the idea of reusability. This means that we can add additional features to an existing class without modifying it. This is possible by deriving a new class from the existing one. The new class will have the combined features of both the classes.

Reusability can be provided through the concept of composition also. In composition one class contains the object of another classes to make it as a whole.

Advantages of reusability.

• Re usability enhanced reliability.
•Re usability saves the programmer time and effort.
•As the existing code is reused, it leads to less development and maintenance costs.
•Extensibility as we can extend the already made classes by adding some new features.
•Inheritance makes the sub classes follow a standard interface.

Difficulty in software reusability

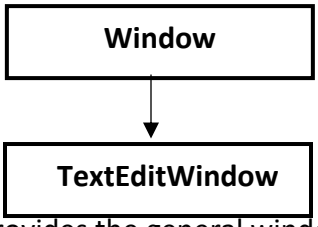
•As the number of projects and developers increases, it becomes harder to reuse software. It's a challenge to effectively communicate the details and requirements for code reuse.

•As the number of projects and developers grows, it's difficult to share libraries of reusable code.

Forms of Inheritance

1. **Subclassing for specialization**

   The new class is a specialized form of the parent class but satisfies the specifications of the parent class in all relevant aspects.
   Example:

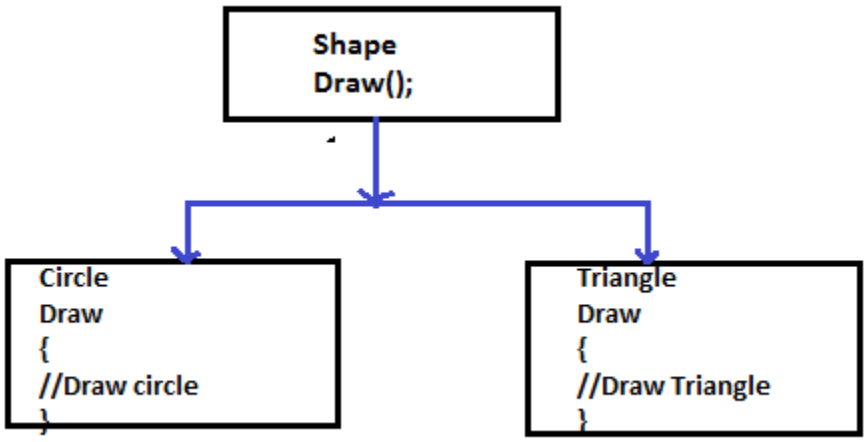


- Window class provides the general windowing operations (moving, resizing, iconification and so on).
- The specialized subclass TextEditWindow inherits the window operations and in addition provides the facilities that allow window to display textual material and user to edit the text values.

2. **Subclassing for specification**

   - Here class maintains the common interface (they implement the same methods).
   - The parent class can be a combination of implemented operations and operations that are deferred to the child classes.
   - There is no interface change as the child implements the behavior described but not implemented in parent.

Example:



3. **Subclassing for Construction**

   Here a class can often inherit almost all of its desired functionality from a parent class, perhaps changing only names of the methods used to interface to the class or modifying the arguments in a certain fashion.

4. **Subclassing for Generalization**

   - It is opposite to the subclassing for specialization.
   - Subclass extends the behavior of parent class to create more general kind of object.
   - It is applicable when we build on a base of existing classes that we do not wish to or cannot modify.

   Consider a graphics display system in which a class Window has been defined for displaying on a simple black-and-white background. We could create a subtype ColoredWindow that lets the background color to be something other than white by adding an additional field to store the color and overriding the inherited window display code that specifies the background be drawn in that color.

5. **Subclassing for extension**

   - The child class adds the new functionality to the parent class but does not change any inherited behavior.
   - Subclassing for generalization modifies or expands on the existing functionality of an object whereas subclassing for extension add totally new abilities.

6. Subclassing for limitation

- The child class restricts the use of some of the behaviors inherited from the parent class.
- Subclassing for limitation occurs when the behavior of subclass is smaller or more restrictive than the behavior of the parent class.

For example ,an existing class library provides the double-ended queue or **deque,** data structure. Elements cab be added or removed form either end of the **deque,** but a programmer wishes to write stack class, enforcing the property that elements can be added to removed from only one end of the stack.

7. Subclassing for variance

Subclassing for variance is employed when two or more classes have similar implementations but do not seem to posses any hierarchical relationships between the abstract concept represented by the classes.

Example

Code required to control the mouse may be nearly identical to the code required to control the graphics tablet. Conceptually there is no reason why class mouse should be made the subclass of class GraphicsTablet.

A better alternative is to factor out the common code into an abstract class, say PointingDevice and to have both classes inherit from this parent classes.

8 .**Subclassing for Combination**

Here, the subclass represents the combination of features from two or more parent classes .Eg. A teaching assistant may have characteristic of both teacher and student. This is multiple inheritance.

SUMMARY OF FORMS OF INHERITANCE

Inheritance is used in variety ways according to user's requirements. The Following are forms of inheritance.

1) **Sub classing for specialization:** The child class is the special case of the parent class; in other words the child class is a subtype of parent class.
2) **Sub classing for specification:** The parent class defines behavior that is implemented in child class but not in parent class.
3) **Sub classing for construction:** The child class makes use of behavior provided by the parent class but is not a subtype of parent class.
4) **Sub classing for generalization:** The child class modifies or overrides some of the methods of the parent class but is not a subtype of parent class.
5) **Sub classing for extension**: The child class adds new functionality to the parent class but does not change any inherited behavior.
6) **Sub classing for limitation:** The child class restricts the use of some of the behavior inherited from parent class.
7) **Sub classing for variance:** The child class and parent class are variants of each other and the class-subclass relationship is arbitrary.
8) **Sub classing for combination**: The child class inherits features from more than one parent class. This is multiple inheritance.

Advantages and Disadvantages of Inheritance

Advantages (Pros /Merits)

1) Inheritance strongly supports reusability. The data members and member functions that are defined at parent class can be reused in base class. So, there is no need to define the member again.
2) Reusability enhanced reliability. The base class code will be already tested and debugged.
3) Base class logic can be extend as per business logic of the derived class.
4) Eliminates duplication of code.
5) Reduces development and maintenance costs as well saves time and efforts.
6) Program structure is short and concise which is more reliable.
7) Codes are easy to debug. Inheritance allows the program to capture the bugs easily
8) With inheritance, we will be able to override the methods of the base class so that meaningful implementation of the base class method can be designed in the derived class.
9) It is easy to partition the work in a project based on objects.
10) Object oriented systems can be easily upgraded from small to large system.
11) Software complexity can be easily managed.

Disadvantages (Cons/Demerits)

1) Main disadvantage of using inheritance is that the two classes (base and inherited class) get tightly coupled. This means one cannot be used independent of each other.
2) A change in base class will affect all the child classes.
3) It increases the time and efforts take to jump through different levels of the inheritance.so it reduces execution speed.
4) Often, data members in the base class are left unused which may lead to memory wastage.
5) Inappropriate usage of inheritance will cause complexity in program
6) If the methods in the super class are deleted then it is very difficult to maintain the functionality of the child class which has implemented the super class's method.
7) Also with time, during maintenance adding new features both base as well as derived classes are required to be changed. If a method signature is changed then we will be affected in both cases (inheritance & composition)

1) **WAP to concatenate two strings (name and address of a person) using the concept of containership.[2014 fall]**

```
#include<iostream>
#include<string.h>
using namespace std;
class first
{
char name[20];
public:
void setn(char n[])
{
 strcpy(name,n);
}
char* getn()
{
return (name);
}
};

class second
{
char address[20];
public:
void seta(char a[])
{
 strcpy(address,a);
}
char* geta()
{
return (address);
}
};
class concat
{
private:
first f;
second s;
public:
void getinfo(char n[],char a[])
{
f.setn(n);
s.seta(a);
}
```

```
void join()
{
strcat(f.getn(),s.geta());
cout<<"name+address:"<<f.getn();
}
};

int main()
{
concat c;
c.getinfo("Ram","kathmandu");
c.join();
return 0;
}
```

Alternative solution:

```
#include<iostream>
#include<string.h>
using namespace std;
class first
{
string name;
public:
void setn(string n)
{
 name=n;
}
string getn()
{
return (name);
}
};
```

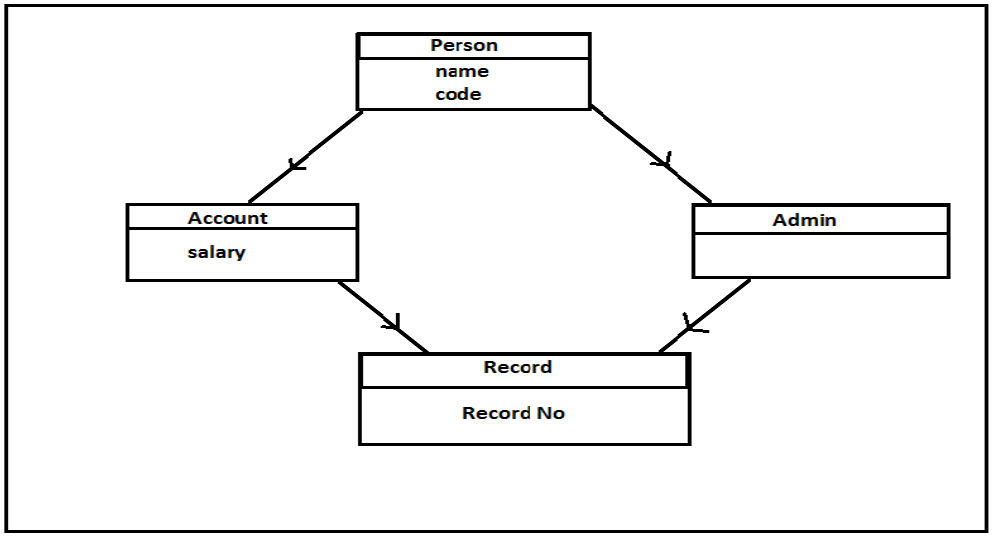
```
class second
{
string address;
public:
void seta(string a)
{
 address=a;
}
string geta()
{
return (address);
}
};

class concat
{
private:
string tn,ta;
first f;
second s;
public:
void getinfo( string a,string b)
{
f.setn(a);
s.seta(b);
}
void join()
{
tn=f.getn();
ta=s.geta();
tn=tn+ta;
cout<<"name+address:"<<tn;
}
};

int main()
{
concat c;
c.getinfo("Ram","Kathmandu");
c.join();
return 0;
}
```

2) Create a class person with data members name, age and address. Create another class teacher with data members Qualification and department .Also create another class Student with data members program and semester. Both class are inherited from class person. Every class has at least one constructor which uses base class constructor. Create member function showdata() in each to display the information of the class member.[PU:2018 fall,2014 spring]

```
#include<iostream>
#include<string.h>
using namespace std;
class Person
{
private:
char name[20];
int age;
char address[20];
public:
Person(char n[],int a,char addr[])
{
        strcpy(name,n);
        age=a;
        strcpy(address,addr);
}
void showdata()
{
cout<<"Name:"<<name<<endl;
cout<<"Age:"<<age<<endl;
cout<<"Address:"<<address<<endl;
}
};
class Teacher:public Person
{
char qualification[20];
char department[20]  ;
public:
Teacher(char n[],int a,char addr[],char q[],char d[]):Person(n,a,addr)
{
strcpy(qualification,q);
strcpy(department,d);
}
```

```
void showdata()
{
cout<<"Qualification:"<<qualification<<endl;
cout<<"Department:"<<department<<endl;
}
};
class Student:public Person
{
private:
char program[20];
int sem;
public:
        Student(char n[],int a,char addr[],char p[],int s):Person(n,a,addr)

        {
                strcpy(program,p);
                sem=s;
        }
        void showdata()
        {
         cout<<"Program:"<<program<<endl;
         cout<<"Semester:"<<sem<<endl;
        }
};
int main()
{
Teacher t("Hari",32,"Kathmandu","Master","Civil");
Student s("Ram",24,"Pokhara","Computer",2);
cout<<"Information of Teacher is"<<endl;
t.Person::showdata();
t.showdata();
cout<<"Information of Student is"<<endl;
s.Person::showdata();
s.showdata();
return 0;
}
```

3) Consider the class network of the following figure:



The class Record derives the information from both Account and Admin classes and in turn derive information from the class Person .Define all the four classes with at least one parameterixed constructor and 'void display' method in each class.In main() function create a object of class 'Record' and initialize all data members and display them.[PU:2015 spring]

```
#include<iostream>
#include<string.h>
using namespace std;
class Person
{
private:
char name[20];
int code;
public:
Person(char n[],int c)
{
strcpy(name,n);
code=c;
}
void display()
{
cout<<"Name="<<name<<endl;
cout<<"Code="<<code<<endl;
}
};
```

```
class Account: virtual public Person
{
private:
float salary;
public:
Account(char n[],int c,float s):Person(n,c)
{
salary=s;
}
void display()
{
cout<<"salary="<<salary<<endl;
}
};
class Admin:virtual public Person
{
private:
int year;
public:
Admin(char n[],int c,int y):Person(n,c)
{
year=y;
}

void display()
{
cout<<"No of experience year="<<year<<endl;
}
};
class Record:public Account,public Admin
{
private:
int recno;
public:
Record(char n[],int c,float s,int y,int r):Account(n,c,s),Admin(n,c,y),Person(n,c)
{
recno=r;
}
void display()
{
cout<<"Record no="<<recno<<endl;
}
};
```

```
int main()
{
char name[20];
int code,year,recno;
float salary;
cout<<"Enter person name and code"<<endl;
cin>>name>>code;
cout<<"Enter salary"<<endl;
cin>>salary;
cout<<"Enter number of year of experience"<<endl;
cin>>year;
cout<<"Eneter Record no"<<endl;
cin>>recno;
Record r1(name,code,salary,year,recno);
r1.Person::display();
r1.Account::display();
r1.Admin::display();
r1.display();
return 0;
}
```

4) **Write a base class that ask the user to enter time(hour,minute and second) and derived class adds the time of its own with the base.Finally make third class that is friend of derived and calculate the difference of base time and is own time.[PU:2017 fall]**

```
#include<iostream>
using namespace std;
class time1
{
protected:
int hr1,min1,sec1;
public:
void getdata1()
{
cout<<"Enter hour,minute and second for base class"<<endl;
cin>>hr1>>min1>>sec1;
}
void display1()
{
cout<<hr1<<"hours"<<min1<<"minutes"<<sec1<<"seconds"<<endl;
}
};
```

```
class time2:public time1
{
private:
int hr2,min2,sec2;
int hr,min,sec;
public:
void getdata2()
{
cout<<"Enter hour,minute and second for derived class"<<endl;
cin>>hr2>>min2>>sec2;
}
void display2()
{
cout<<hr2<<"hours"<<min2<<"minutes"<<sec2<<"seconds"<<endl;
}
void addtime()
{
sec=sec1+sec2;
min=sec/60;
sec=sec%60;
min=min+min1+min2;
hr=min/60;
min=min%60;
hr=hr+hr1+hr2;
cout<<"sum of time:";
cout<<hr<<"hours"<<min<<"minutes"<<sec<<"seconds"<<endl;
}
friend class time3;
};
class time3
{
private:
int hr,min,sec;
int hr3,min3,sec3;
public:
void getdata3()
{
cout<<"Enter hour,minute and second for friend class"<<endl;
cin>>hr3>>min3>>sec3;
}
```

```
void timediff(time2 t)
{
if(sec3>t.sec1)
{
--t.min1;
t.sec1=t.sec1+ 60;
}
sec = t.sec1-sec3;
if(min3> t.min1)
{
--t.hr1;
t.min1=t.min1+ 60;
}
min = t.min1-min3;
hr = t.hr1-hr3;
if(hr<0)
{
hr=hr*(-1);
}
cout<<"Time Difference:";
cout<<hr<<"hours"<<min<<"minutes"<<sec<<"seconds"<<endl;
}
};
int main()
{
time2 t2;
time3 t3;
t2.getdata1();
t2.getdata2();
cout<<"Time in base class:";
t2.display1();
cout<<"Time in derived class:";
t2.display2();
t2.addtime();
t3.getdata3();
t3.timediff(t2);
return 0;
}
```

IMPORTANT QUESTIONS FROM THIS CHAPTER

INHERITANCE

1. "Inheritance allows us to create a hierarchy of classes. Justify this statement. Discuss private and public inheritance.[PU:2016 spring]
2. How does visibility mode control the access of members in the derived class? Explain with an example.[PU 2017 spring]
3. Explain hybrid inheritance with example.[2009 spring]
4. What is hybrid Inheritance. Explain any three pros and three cons of inheritance. [PU: 2010 fall]
5. How inheritance support reusability features of OOP? Explain with example.[PU:2010 spring]
6. When base class and derived class have the same function name what happens when derived class object calls the function?[PU 2017 fall]
7. Explain how inheritance support Reusability? Describe the syntax of multiple and multilevel inheritance?[PU:2015 fall]
8. Inheritance supports characteristic of OOP. Justify your answer. Explain ambiguity that occurs in multiple inheritance.[PU:2017 spring]
9. "Ambiguity is essential evil" ",Explain by example how it can effectively solve in complex programming?[PU: 2015 spring]
10. Explain why multiple inheritance is dangerous?
11. During the time of hybrid inheritance when there is hierarchical inheritance at the upper level and multiple inheritance at lower level, ambiguity occurs due to the duplication of data from multiple path at the grand child class. How this kind of ambiguity is resolved? Explain with suitable example?
12. Does ambiguity occurs in hybrid inheritance? If yes, how can you remove this? Explain with an example.[PU 2018 fall]
13. Under what condition virtual base class is created? Explain with suitable example.[PU:2017 fall,2019 fall,2014 fall]
14. How are arguments are sent to base constructors in multiple inheritance ?Who is responsibility of it.[PU:2013 spring]
15. How does inheritance influence working of constructors and destructors? Class 'Y' has been derived from class 'X' .The class 'Y' does not contain any data members of its own. Does the class 'Y' require constructors? If yes why.[PU:2013 spring]
16. What is containership? How does it differ from inheritance, describe how an object of a class that contain object of another classes are created.[PU:2013 fall]
17. How composition differs from inheritance?
18. Explain how composition provide reusability?[PU:2018 fall]
19. Compare and contrast composition and inheritance?[PU:2015 fall]

20. Distinguish between subclass and subtype in light of principle of substitutability. Support your answer with suitable example.[PU:2006 spring,2016 spring]
21. Differentiate between

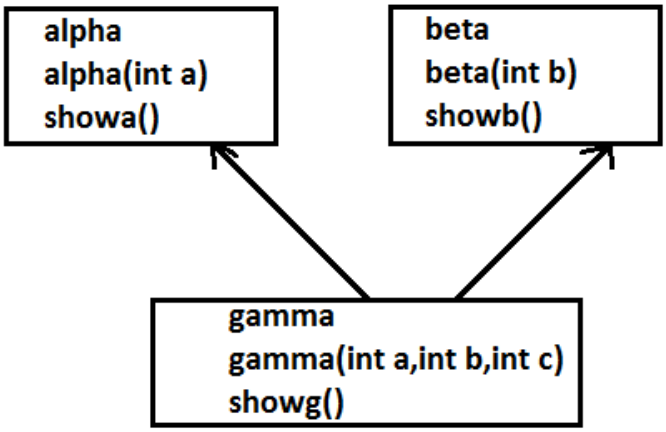
- subclass and subtype.
- Is a rule and has a rule

22. State principle of substitutability .Explain sub-classing for specialization, generalization. List out disadvantages of inheritance.[PU:2016 fall]
23. What is inheritance? What are the different forms of inheritance? [PU: 2016 spring,PU:2015 spring]
24. Differentiate between is a rule and has a rule with suitable example. [PU:2015 fall,2014 spring]
25. **Write a short notes on:**

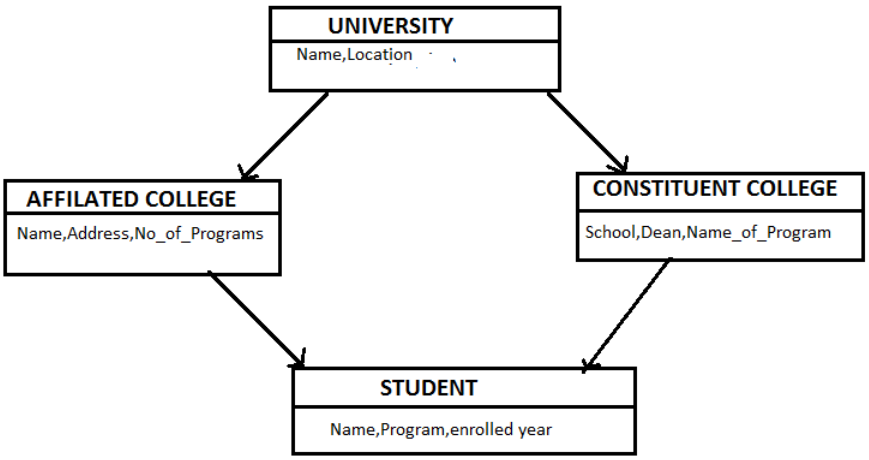
- Containership[PU:2010 fall]
- Subclass-subtype
- Software reusability[PU:2005 fall]
- Is a rule and has a rule[PU:2009 fall,2016 fall, 2016 spring,2015 spring]
- Hybrid inheritance[PU:2006 spring]ii
- Inheritance and substitutability
- Generalization[PU:2013 spring]

Programming Questions:

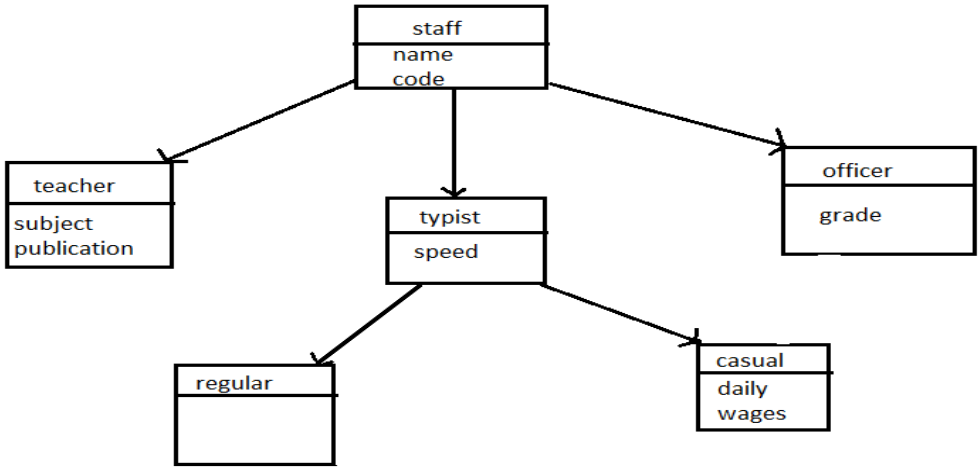
1) WAP to enter information of n students and then display is using the concept multiple inheritance**,[PU: 2015 fall]**
2) Write a complete program with reference to the given figure.



3) The following figure shows the minimum information required for each class. Write a progam by realizing the necessary member functions to read and display information of individual object. Every class should contain at least one constructor and should be inherited from other classes as well.[PU:2019 fall]

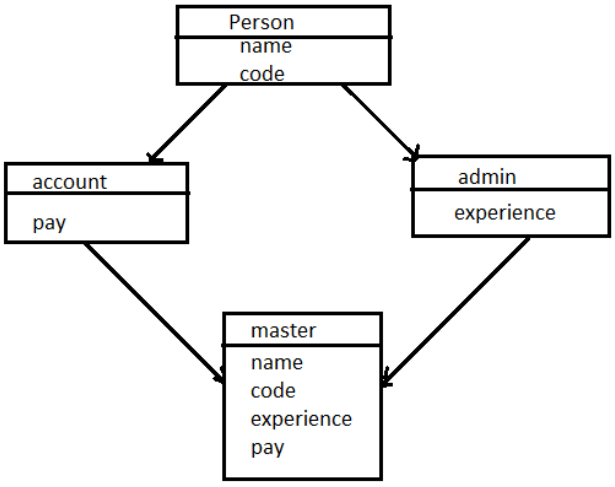


4) An educational institution wishes to maintain a database of its employees. The database is divided into a number of classes whose hierarchical relationship are shown below. The figure also shows minimum information requires for each class. Specify all the classes and define functions to create database and retrieve individual information when required.



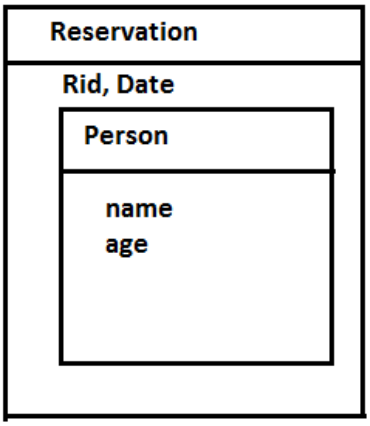
5) The following figure shows minimum information required for each class.

i) Write a Program to realize the above program with necessary member functions to create the database and retrieve individual information

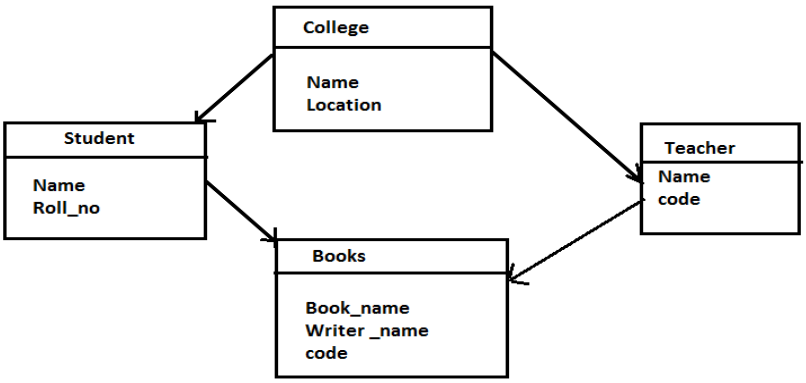


ii) Rewrite the above program using constructor on each class to initialize the data members.

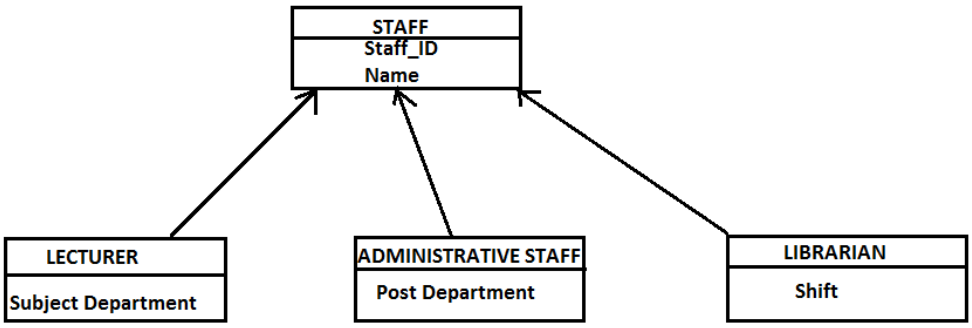
6) Write a program that allow you to book a ticket for person and use two classes PERSON, RESERVATION. Class RESERVATION is composite class/ container class.



7) The following figure shows the minimum information required for each class. Write a program to realize the above program with necessary member functions to create the database and retrieve individual information .Every class should contain at least one constructor and should be inherited to other classes as well.[PU:2010 spring][PU 2009 fall]



8) Develop a complete program for an institution, which wishes to maintain a database of its staff. The database is divided into number of classes whose hierarchical relationship is shown in the following diagram. specify all classes and define constructors and functions to create database and retrieve the individual information as per requirements.



9) Develop a complete program for an institution which wishes to maintain a database of its staff. Declare a base class STAFF which include staff_id and name.Now develop a records for the following staffs with the given information below.

i. Lecturer(subject,department)

ii. Administrative staff (Post,department)