Design of Data Structure

INDEX

UNIT -1

Introduction:

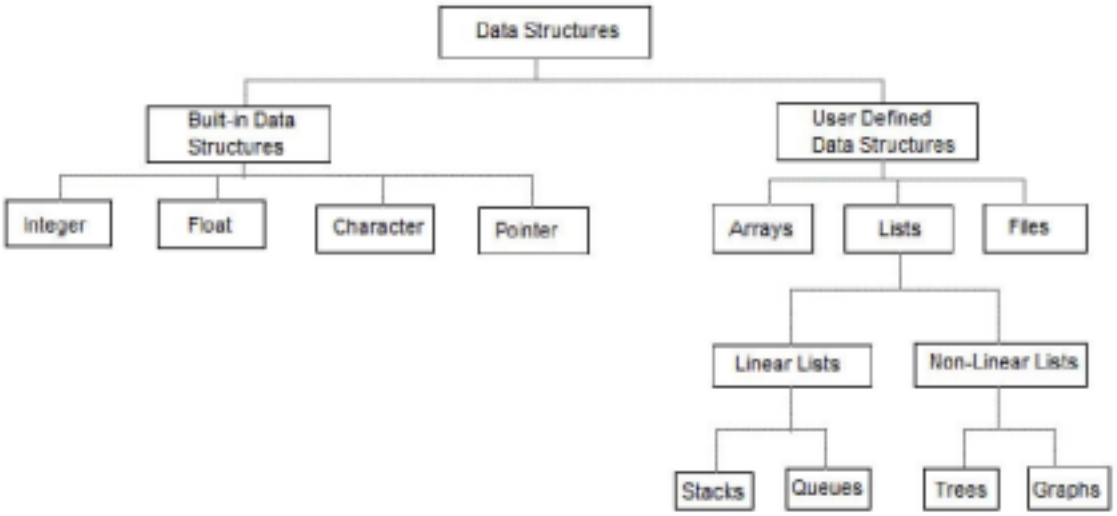
Abstract data types, **Singly linked list**: Definition, operations: Traversing, Searching, Insertion and deletion, **Doubly linked list**: Definition, operations: Traversing, Searching, Insertion and deletion, **Circular Linked List**: Definition, operations: Traversing, Searching, Insertion and deletion

Data structure A data structure is a specialized format for organizing and storing data. General data structure types include the array, the file, the record, the table, the tree, and so on. Any data structure is designed to organize data to suit a specific purpose so that it can be accessed and worked with in appropriate ways

Abstract Data Type

In computer science, an abstract data type (ADT) is a mathematical model for data types where a data type is defined by its behavior (semantics) from the point of view of a user of the data, specifically in terms of possible values, possible operations on data of this type, and the behavior of these operations. When a class is used as a type, it is an abstract type that refers to a hidden representation. In this model an ADT is typically implemented as a class, and each instance of the ADT is usually a n object of that class.

In ADT all the implementation details are hidden



• Linear data structures are the data structures in which data is arranged in a list or in a sequence.

• Non linear data structures are the data structures in which data may be arranged in a hierarchic al manner

LIST ADT

List is basically the collection of elements arrange d in a sequential manner. In memory we can store the list in two ways: one way is we can store the elements in sequential memory locations. That means we can store the list in arrays.

The other way is we can use pointers or links to associate elements sequentially. This is known as linked list.

LINKED LISTS

The linked list is very different type of collection from an array. Using such lists, we can store collections of information limited only by the total amount of memory that the OS will

allow us to use.Further more, there is no need to specify our needs in advance. The linked list is very flexible dynamic data structure : items may be added to it or deleted from it at will. A programmer need not worry about how many items a program will have to accommodate in advance. This allows us to write robust programs which require much less maintenance.

The linked allocation has the following draw backs:

1. No direct access to a particular element.
2. Additional memory required for pointers.

Linked list are of 3 types:

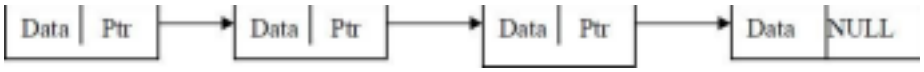
1. Singly Linked List
2. Doubly Linked List
3. Circularly Linked List

SINGLY LINKED LIST

A singly linked list, or simply a linked list, is a linear collection of data items. The linear order is given

by means of POINTERS. These types of lists are often referred to as **linear linked list**. * Each item in the list is called a node.
* Each node of the list has two fields:
1. Information- contains the item being stored in the list.
2. Next address- contains the address of the next item in the list.
* The last node in the list contains NULL pointer to indicate that it is the end of the list. Conceptual

view of Singly Linked List



Operations on Singly linked list:

- ➢ Insertion of a node
- ➢ Deletions of a node
- ➢ Traversing the list

Structure of a node:

Method -1:

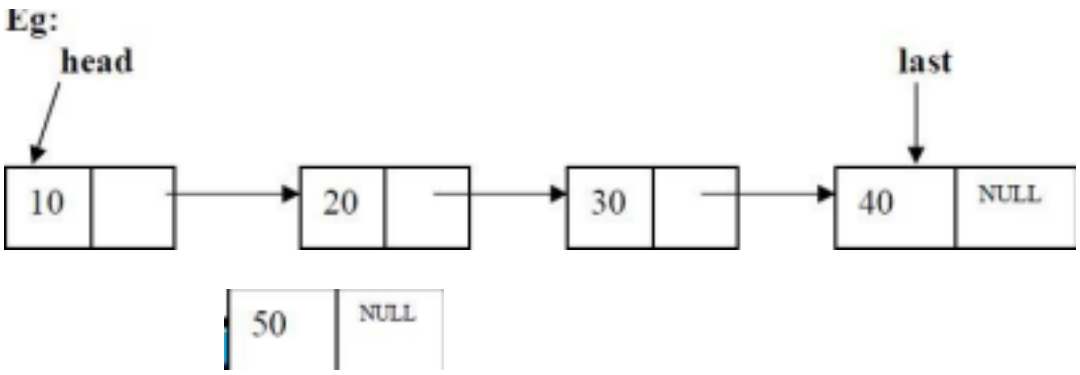

```
struct node
{
        int data;
         struct node *link;
};
```

Method -2:


```
class node
{ public:
        int data;
node *link; };
```

Insertions: To place an elements in the list there are 3 cases :
1. At the beginning
2. End of the list
3. At a given position

case 1:Insert at the beginning



head is the pointer variable which contains address of the first node and **temp** contains address of new node to be inserted then sample code is

temp->link=head;

head=temp;

After insertion:

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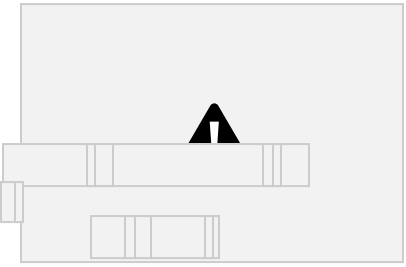
Code for insert front:-

```
template <class T> void
list<T>::insert_front()
{
struct node <T>*t,*temp;
        cout<<"Enter data into node:"; cin>>item;
        temp=create_node(item);
        if(head==NULL) head=temp;
        else
        { temp->link=head;
                head=temp;
        }
}
```

case 2: Inserting end of the list

temp

head is the pointer variable which contains address of the first node and **temp** contains address of new node to be inserted then sample code is



```
t=head;



while(t->link!=NULL
) {
        t=t->link;
}
t->link=temp;
```

After insertion the linked list is

Code for insert End:-

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```
template <class T> void
list<T>::insert_end()
{
struct node<T> *t,*temp; int n;
cout<<"Enter data into node:";
cin>>n; temp=create_node(n);
if(head==NULL) head=temp;
        else
        { t=head;
                while(t->link!=NULL) t=t-
```

```
        >link;
    t->link=temp;
  }
}
```

case 3: Insert at a position

insert node at position 3

head is the pointer variable which contains address of the first node and **temp** contains address of new node to be inserted then sample code is

```
c=1;
while(c<pos)
{
        prev=cur;
        cur=cur->link;
       c++;
}
prev->link=temp;
temp->link=cur;
```

Code for inserting a node at a given position: -

```
template <class T> void
 list<T>::Insert_at_pos(int pos)
 {struct node<T>*cur,*prev,*temp;
int c=1; cout<<"Enter data into node:";
            cin>>item
            temp=create_node(item);
             if(head==NULL) head=temp;
              else
              { prev=cur=head;
                        if(pos==1)
                        { temp->link=head;



                                  head=temp;
                        } else {
                        while(c<pos)
                        { c++;
                                  prev=cur; cur=cur->link;
                        }
                        prev->link=temp;
                        temp->link=cur;
                        }
            }
}
```

Deletions: Removing an element from the list, without destroying the integrity of the list itself.
To place an element from the list there are 3 cases :

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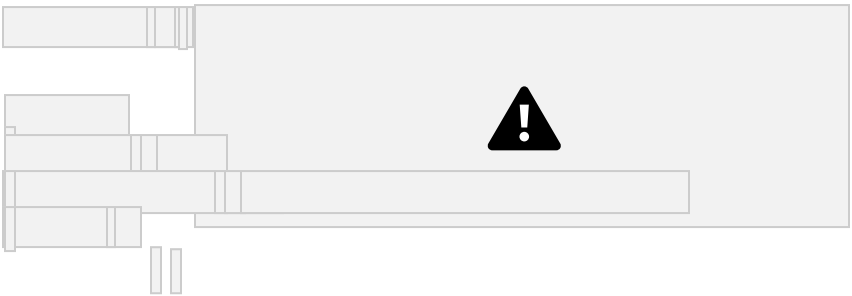
1. Delete a node at beginning of the list
2. Delete a node at end of the list
3. Delete a node at a given position

Case 1: Delete a node at beginning of the list head

head is the pointer variable which contains address of the first node



sample code is

```
t=head;
head=head->link;
cout<<"node "<<t->data<<" Deletion is sucess";
delete(t);
```

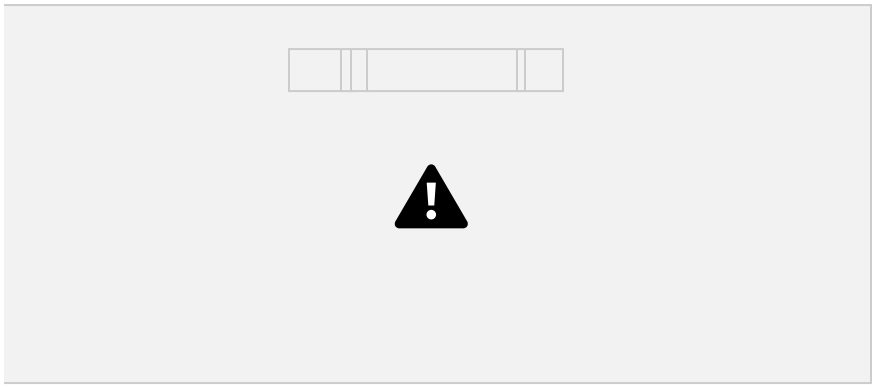

code for deleting a node at front

```
template <class T> void
 list<T>::delete_front()
 {
 struct node<T>*t; if(head==NULL)
          cout<<"List is Empty\n";
          else
          { t=head;


                  head=head->link;
                    cout<<"node "<<t->data<<" Deletion is sucess";
                  delete(t);
          }
}
```

Case 2. Delete a node at end of the list

head

To delete last node , find the node using following code



```
struct node<T>*cur,*prev;
cur=prev=head;
while(cur->link!=NULL)
{
prev=cur;
cur=cur->link;
}
prev->link=NULL;
cout<<"node "<<cur->data<<" Deletion is sucess";
free(cur);
```

head

code

fordeleting a node at end of the list

```
template <class T>
void list<T>::delete_end()
{
struct node<T>*cur,*prev;
        cur=prev=head;
        if(head==NULL) cout<<"List is
        Empty\n";
        else
        { cur=prev=head;
                if(head->link==NULL)
                  { cout<<"node "<<cur->data<<" Deletion is sucess";
                        free(cur);
                       head=NULL;
                }
```

```
        else
        { while(cur->link!=NULL)
                { prev=cur;
                        cur=cur->link;
                }
               prev->link=NULL;
                 cout<<"node "<<cur->data<<" Deletion is sucess";
                free(cur);
        }
}
```



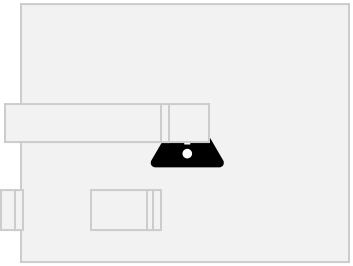
```
}
```

CASE 3. Delete a node at a given position

head

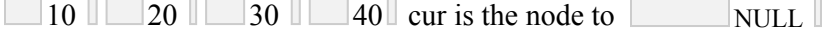
Delete node at position 3 **head** is the pointer variable which contains address of the first node. Node to be deleted is node containing value 30.

Finding node at position 3



```
c=1;

while(c<pos)

{ c++;
        prev=cur;
        cur=cur->link;
}
```


prev cur


10 20 30 40 cur is the node to NULL

be deleted . before deleting update links

```
                                prev->link=cur->link;
                                cout<<cur->data <<"is deleted
                                successfully";          delete cur;
```

code to update

links

prev

cur

10 20 30 40

NULL

Traversing the list: Assuming we are given the pointer to the head of the list, how do we get the end of the list.

```
template <class T> void
list<T>:: display()
 { struct node<T>*t;
```



```
                if(head==NULL)
                 { cout<<"List is Empty\n";
                 }
                 else
                 { t=head;
                        while(t!=NULL)
                            { cout<<t->data<<"->";
                                t=t->link;
                        }
                 }
        }
```


Dynamic Implementation of list ADT

```
#include<iostream.h>
#include<stdlib.h>
template <class T>
struct node
{
        T data;
        struct node<T> *link;
```

```
};
template <class T> class
 list
 {
        int item; struct
        node<T>*head;
        public: list();
        void display();
        struct node<T>*create_node(int n);
        void insert_end(); void
         insert_front(); void
         Insert_at_pos(int pos); void
         delete_end(); void
         delete_front(); void
        Delete_at_pos(int pos); void
        Node_count();
};
```

```
template <class T>
 list<T>::list()
        {
                head=NULL;
        }
```



```
template <class T> void
 list<T>:: display()
 { struct node<T>*t;

        if(head==NULL)
         { cout<<"List is Empty\n";
         }
         else
         { t=head;
                while(t!=NULL)
                 { cout<<t->data<<"->";
                        t=t->link;
                 }
         }
}

template <class T>
 struct node<T>* list<T>::create_node(int n)
```

```
{struct node<T> *t; t=new
        struct node<T>;
        t->data=n;
        t->link=NULL;
return t;
}

template <class T> void
list<T>::insert_end()
{struct node<T>
*t,*temp;
int n; cout<<"Enter data into node:";
        cin>>n; temp=create_node(n);
        if(head==NULL) head=temp;
        else
        { t=head;
                while(t->link!=NULL) t=t-
                        >link;
                t->link=temp;
        }
}




template <class T> void
list<T>::insert_front()
```



```
{
struct node <T>*t,*temp;
        cout<<"Enter data into
        node:"; cin>>item;
        temp=create_node(item);
        if(head==NULL) head=temp;
        else
        { temp->link=head;
                head=temp;
        }
}

template <class T> void
list<T>::delete_end()
{
struct node<T>*cur,*prev;
        cur=prev=head;
        if(head==NULL) cout<<"List is
        Empty\n";
        else
        { cur=prev=head;
```

```
                if(head->link==NULL)
                {
                        cout<<"node "<<cur->data<<" Deletion is sucess";
                        free(cur);
                        head=NULL;
                } else
                { while(cur->link!=NULL)
                        { prev=cur;
                                cur=cur->link;
                        }
                        prev->link=NULL;
                        cout<<"node "<<cur->data<<" Deletion is sucess";
                        free(cur);
                }
        }
}

template <class T> void
 list<T>::delete_front()
 {
struct node<T>*t; if(head==NULL)
        cout<<"List is Empty\n";
        else
         { t=head;
                head=head->link;
```



```
                cout<<"node "<<t->data<<" Deletion is sucess";
                delete(t);
        }
}

template <class T> void
 list<T>::Node_count()
 {
struct node<T>*t; int
c=0; t=head;
if(head==NULL)
            { cout<<"List is Empty\n";

            } else
          { while(t!=NULL)
                { c++;
                        t=t->link;
                }
```

```
                cout<<"Node Count="<<c<<endl;
            }
        }

        template <class T> void
        list<T>::Insert_at_pos(int pos) {struct
        node<T>*cur,*prev,*temp; int c=1;
        cout<<"Enter data into node:";
                            cin>>item
                            temp=create_node(item);
                    if(head==NULL)
                        head=temp;
                     else
                     { prev=cur=head; if(pos==1) {
        temp->link=head; head=temp;
                        } else {
                        while(c<pos
                        )
                        { c++;
                            prev=cur; cur=cur->link;
                        }
                        prev->link=temp;
                        temp->link=cur;
                        }



                    }
```



```
        }

        template <class T>
        void list<T>::Delete_at_pos(int pos)
        {
        struct node<T>*cur,*prev,*temp;
        int c=1;

                    if(head==NULL)
                    { cout<<"List is Empty\n";
                        } else
                      { prev=cur=head;
                        if(pos==1)
                        {
                        head=head->link;
                        cout<<cur->data <<"is deleted sucesfully";
                        delete cur;
                        } else
                        { while(c<pos)
                            { c++;
```

```
                    prev=cur; cur=cur-
                    >link;
                }
                prev->link=cur->link;
                cout<<cur->data <<"is deleted sucesfully";
                delete cur;
            }
        }
}

int main() {
int ncount,ch,pos;
list <int> L;
while(1)
    { cout<<"\n ***Operations on Linked List***"<<endl;
        cout<<"\n1.Insert node at End"<<endl;
        cout<<"2.Insert node at Front"<<endl;
        cout<<"3.Delete node at END"<<endl;
        cout<<"4.Delete node at Front"<<endl;
        cout<<"5.Insert at a position "<<endl;
        cout<<"6.Delete at a position "<<endl;
        cout<<"7.Node Count"<<endl; cout<<"8.Display
        nodes "<<endl; cout<<"9.Clear Screen "<<endl;
```



```
        cout<<"10.Exit "<<endl;
        cout<<"Enter Your choice:";
        cin>>ch; switch(ch)
        { case 1: L.insert_end();
                    break;
          case 2: L.insert_front();
                    break;
          case 3:L.delete_end();
                    break;
          case 4:L.delete_front();
                    break;
         case 5: cout<<"Enter position to insert";
                    cin>>pos;
                      L.Insert_at_pos(pos);
                    break;
         case 6: cout<<"Enter position to insert";
                    cin>>pos;
                      L.Delete_at_pos(pos);
                    break;
```

```
                case 7: L.Node_count();
                        break;
                case 8: L.display();
                        break;
                case 9:system("cls");
                        break;
                case 10:exit(0);


                default:cout<<"Invalid choice"; }
        }
}
```

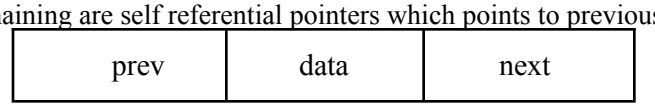
DOUBLY LINKED LIST

A singly linked list has the disadvantage that we can only traverse it in one direction. Many applications require searching backwards and forwards through sections of a list. A useful refinement that can be made to the singly linked list is to create a doubly linked list. The distinction made between the two list types is that while singly linked list have pointers going in one direction, doubly linked list have pointer both to the next and to the previous element in the list. The main advantage of a doubly linked list is that, they permit traversing or searching of the list in both directions.

In this linked list each node contains three fields.

a) One to store data

b) Remaining are self referential pointers which points to previous and next nodes in the list



UNIT -1

Implementation of node using structure

Method -1:

```
struct node
{
        int data; struct
        node *prev; struct
        node * next;
};
```

Implementation of node using class

Method -2:

```
class node
{ public:
```

```
        int data;
        node *prev;
        node * next;
};
```

Operations on Doubly linked list: ➢
Insertion of a node
➢ Deletions of a node
➢ Traversing the list

Doubly linked list ADT:

```
template <class T>
class dlist
{
        int data;
        struct dnode<T>*head;
public:
        dlist()
        {
                head=NULL;
        } void
        display();
        struct dnode<T>*create_dnode(int n);
        void insert_end();
        void insert_front();
        void delete_end();
```

void Insert_at_pos(int pos);
void Delete_at_pos(int pos); };

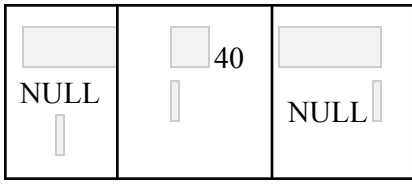
Insertions: To place an elements in the list there are 3 cases

➢ 1. At the beginning
➢ 2. End of the list
➢ 3. At a given position

case 1:Insert at the beginning

head

NULL 10 20 30 NULL



temp

head is the pointer variable which contains address of the first node and **temp** contains address of new node to be

s

temp->next=head;
head->prev=temp;
head=temp;

head
void delete_front();
void dnode_count();

40 10 20 30 NULL

Code for insert front:-

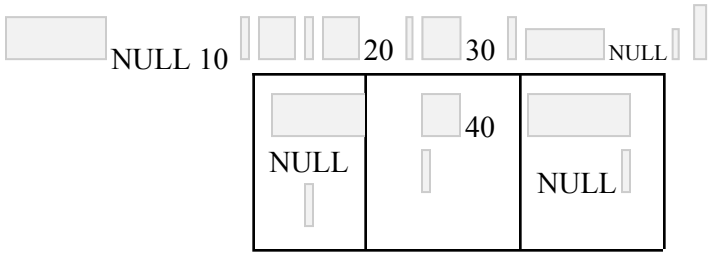
```
template <class T>
void DLL<T>::insert_front()
 {
 struct dnode <T>*t,*temp;
        cout<<"Enter data into node:";
        cin>>data;
        temp=create_dnode(data);
        if(head==NULL)
```

head=temp; else

{ temp->next=head; head>prev=temp;
head=temp;
}
}

case 2: Inserting end of the list

head



temp

head is the pointer variable which contains address of the first node and temp contains address of new node to be inserted then sample code is

LL) t=t->next;

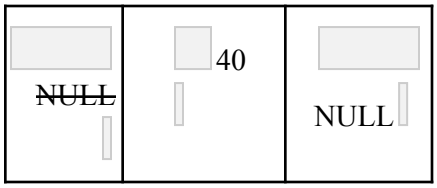
t->next=temp;

temp->prev=t;

t=head;

while(t->next!=NU

NULL 10 20 30 ~~NULL~~



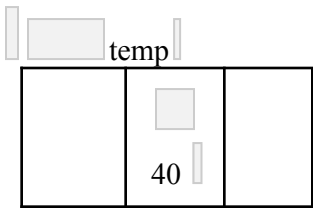
Code to insert a node at End:-

```
template <class T> void
DLL<T>::insert_end()
{
struct dnode<T> *t,*temp;
```



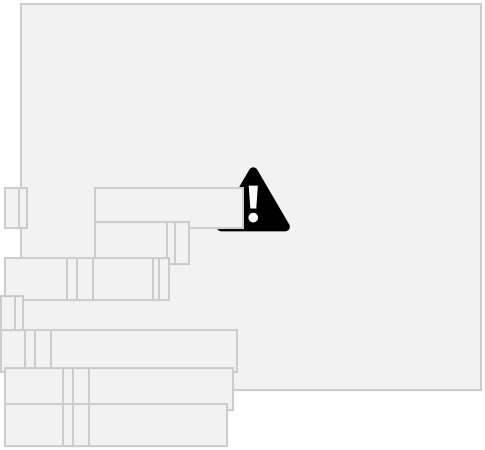
```
int n; cout<<"Enter data into dnode:";
        cin>>n;
        temp=create_dnode(n);
        if(head==NULL)
        head=temp;
        else
        { t=head;
                while(t->next!=NULL) t=t-
                        >next;



                t->next=temp; temp-
                >prev=t;
        }
}
```

case 3: Inserting at a give position



insert 40 at position 2

head is the pointer variable which contains address of the first node and **temp** contains address of new node to be inserted then sample code is



```
while(count<pos)
    { count++;
        pr=cr;
        cr=cr->next;
}
pr->next=temp;
temp->prev=pr;
temp->next=cr;
cr->prev=temp;
```


head pr cr

NULL 10 20 30 NULL

NULL ~~NULL~~ 40

temp

Code to insert a node at a position

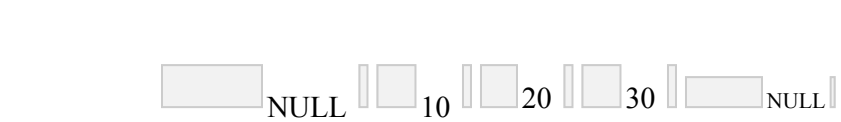
```
template <class T>
void dlist<T>::Insert_at_pos(int pos)
{
struct dnode<T>*cr,*pr,*temp;
int count=1; cout<<"Enter data into
        dnode:"; cin>>data;
        temp=create_dnode(data);
        display();
        if(head==NULL)
        {//when list is empty
                head=temp;
        } else
         { pr=cr=head;
                if(pos==1)
                { //inserting at pos=1 temp-
                        >next=head;
                        head=temp;
                }
                  else
                {
                        while(count<pos)
                         { count++;
                                pr=cr; cr=cr-
                                >next;
                         } pr->next=temp;
                         temp->prev=pr;
```



```
                        temp->next=cr;
                        cr->prev=temp;
                }
        }
}
```

Deletions: Removing an element from the list, without destroying the integrity of the list itself.
To place an element from the list there are 3 cases :
1. Delete a node at beginning of the list
2. Delete a node at end of the list
3. Delete a node at a given position

Case 1: Delete a node at beginning of the list



head is the pointer variable which contains address of the first node sample

code is

t=head;

head

head=head->next;

head->prev=NULL;
cout<<"dnode "<<t->data<<"

Deletion is sucess";

delete(t);

NULL 10 NULL 20 30 NULL

code for deleting a node at front

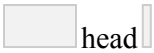
template <class T>


```
void dlist<T>:: delete_front()
{struct dnode<T>*t; if(head==NULL)
        cout<<"List is Empty\n";
        else
        { t=head;
                head=head->next; head-
                >prev=NULL;
                cout<<"dnode "<<t->data<<" Deletion is sucess";
                delete(t);
        }
}
```

Case 2. Delete a node at end of the list

To deleted the last node find the last node. find the node using following code

```
struct dnode<T>*pr,*cr;
pr=cr=head;
while(cr->next!=NULL)
{ pr=cr;
cr=cr->next;
}
pr->next=NULL;
cout<<"dnode "<<cr->data<<" Deletion is sucess";
delete(cr);
```



code for deleting a node at end of the list

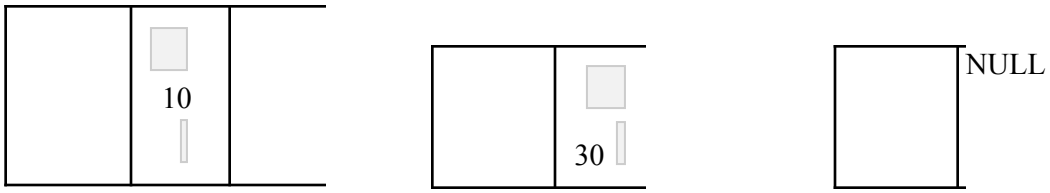
```
template <class T> void
dlist<T>::delete_end()
{
struct dnode<T>*pr,*cr; pr=cr=head;
        if(head==NULL) cout<<"List is
        Empty\n";
        else
         { cr=pr=head;
                if(head->next==NULL)
                {
                        cout<<"dnode "<<cr->data<<" Deletion is sucess";
```



```
                        delete(cr);
                        head=NULL;
                } else
                { while(cr->next!=NULL)
                        { pr=cr;
                                cr=cr->next;
                        }
                        pr->next=NULL;
```

```
                cout<<"dnode "<<cr->data<<" Deletion is sucess";
                delete(cr);
            }
        }
}
```

CASE 3. Delete a node at a given position head



Delete node at position 2 **head** is the pointer variable which contains address of the first node. Node to be deleted is node containing value 30. Finding node at position 2.

```
                cr=cr->next;
                count++;
                }
pr->next=cr->next;
                cr->next->prev=pr;
```

```
while(count<pos)
{ pr=cr;
```

code for deleting a node at a position

```
template <class T>
void dlist<T>::Delete_at_pos(int pos)
```

```
{
struct dnode<T>*cr,*pr,*temp;
int count=1;
        display();
         if(head==NULL)
         { cout<<"List is Empty\n";
                } else
         { pr=cr=head; if(pos==1) {
head=head->next; head-
>prev=NULL;
                        cout<<cr->data <<"is deleted sucesfully";
                         delete cr;
                }
                else
                {
                         while(count<pos)
                         { count++;
                                 pr=cr; cr=cr-
                                 >next;
                         }
                        pr->next=cr->next; cr->next->prev=pr;
                        cout<<cr->data <<"is deleted sucesfully";
                        delete cr;
                }
         }
}
```

Dynamic Implementation of Doubly linked list ADT

```
#include<iostream.h>
template <class T>
struct dnode
{ T data; struct
dnode<T> *prev;
struct dnode<T> *next;
};
template <class T>
class dlist
{
         int data;
        struct dnode<T>*head;
public:
         dlist();
        struct dnode<T>*create_dnode(int n);
void insert_front(); void
```

insert_end(); void Insert_at_pos(int pos);

UNIT -1

```
        void delete_front(); void
delete_end(); void Delete_at_pos(int
pos);
                void dnode_count();
                void display();
        };

        template <class T>
         dlist<T>::dlist()
                {
                        head=NULL;
                }

        template <class T>
        struct dnode<T>*dlist<T>::create_dnode(int n)
        {
        struct dnode<T> *t; t=new
                struct dnode<T>;
                t->data=n; t-
                >next=NULL;
                t-
        >prev=NULL; return t;
        }
        template <class T> void
        dlist<T>::insert_front()
        {
        struct dnode <T>*t,*temp;
                cout<<"Enter data into dnode:";


                cin>>data;
                temp=create_dnode(data);
                if(head==NULL)
                head=temp; else
                { temp->next=head; head>prev=temp;
                        head=temp;
                } } template <class
        T> void
        dlist<T>::insert_end()
        {
        struct dnode<T> *t,*temp;
        int n; cout<<"Enter data into dnode:";
                cin>>n; temp=create_dnode(n);
                if(head==NULL) head=temp;
                else
```

```
        { t=head;
```



```
                while(t->next!=NULL) t=t-
                        >next;
                t->next=temp; temp-
                >prev=t;
        }
}


template <class T>
void dlist<T>::Insert_at_pos(int pos)
{
struct dnode<T>*cr,*pr,*temp;
int count=1; cout<<"Enter data into
        dnode:"; cin>>data;
        temp=create_dnode(data);
        display();
        if(head==NULL)
        {//when list is empty
                head=temp;
        } else
         { pr=cr=head;
                if(pos==1)
                { //inserting at pos=1 temp-
                        >next=head; head=temp;
                } else



                { while(count<pos)
                        { count++;
                                pr=cr; cr=cr-
                                >next;
                        } pr->next=temp;
                        temp->prev=pr;
                        temp->next=cr;
                        cr->prev=temp;
                }
        }
}

template <class T>
void dlist<T>:: delete_front()
{struct dnode<T>*t; if(head==NULL)
        cout<<"List is Empty\n";
        else
        { display();
```

```
                t=head; head=head-
                >next; head-
                >prev=NULL;
                cout<<"dnode "<<t->data<<" Deletion is sucess";
                delete(t);
        } }
template <class T> void
 dlist<T>::delete_end()
 {
struct dnode<T>*pr,*cr; pr=cr=head;
        if(head==NULL) cout<<"List is
        Empty\n";
        else
         { cr=pr=head;
                if(head->next==NULL)
                {
cout<<"dnode "<<cr->data<<" Deletion is sucess"; delete(cr);
                        head=NULL;
                }
                else
                { while(cr->next!=NULL)
                        { pr=cr;
                                cr=cr->next;
                        }
                        pr->next=NULL;
                          cout<<"dnode "<<cr->data<<" Deletion is sucess";
                        delete(cr);



                }
        } }
template <class T>
void dlist<T>::Delete_at_pos(int pos)
 {
struct dnode<T>*cr,*pr,*temp;
int count=1;
        display();
         if(head==NULL)
         { cout<<"List is Empty\n";
                 } else
         { pr=cr=head; if(pos==1) {
head=head->next;
                        head->prev=NULL;
                       cout<<cr->data <<"is deleted sucesfully";
                        delete cr;
```

```
                }
                else
                {
                        while(count<pos)
                        { count++;
                                pr=cr; cr=cr-
                                >next;
                        }
                        pr->next=cr->next; cr->next->prev=pr;
                        cout<<cr->data <<"is deleted sucesfully";
                        delete cr;
                }
        } }
template <class T>
void dlist<T>::dnode_count()
{
struct dnode<T>*t;
int count=0;
display();
        t=head;
         if(head==NULL) cout<<"List
                is Empty\n";
         else
         { while(t!=NULL)
                { count++;
                        t=t->next;
                }
                cout<<"node count is "<<count;



        } }
template <class T> void
 dlist<T>::display()
 { struct dnode<T>*t;
        if(head==NULL)
         { cout<<"List is Empty\n";
         } else
         { cout<<"Nodes in the linked list are
                ...\n"; t=head; while(t!=NULL)
                { cout<<t->data<<"<=>";
                        t=t->next;
                }
         } } int
main() { int
ch,pos; dlist
<int> DL;
while(1)
        { cout<<"\n ***Operations on Doubly List***"<<endl;
                cout<<"\n1.Insert dnode at End"<<endl;
```

```
cout<<"2.Insert dnode at Front"<<endl;
cout<<"3.Delete dnode at END"<<endl;
cout<<"4.Delete dnode at Front"<<endl;
```



```
cout<<"5.Display nodes "<<endl; cout<<"6.Count
Nodes"<<endl; cout<<"7.Insert at a position
"<<endl; cout<<"8.Delete at a position "<<endl;
cout<<"9.Exit "<<endl; cout<<"10.Clear Screen
"<<endl; cout<<"Enter Your choice:"; cin>>ch;
switch(ch)
 { case 1: DL.insert_end();
          break;
          case 2: DL.insert_front();
                        break;
          case 3:DL.delete_end();
                        break;
          case 4:DL.delete_front(); break;
          case 5://display contents
                        DL.display();
                        break;



          case 6: DL.dnode_count();
                        break;
         case 7: cout<<"Enter position to insert";
                        cin>>pos;
                          DL.Insert_at_pos(pos);
                        break;
         case 8: cout<<"Enter position to Delete";
                        cin>>pos;
                         DL.Delete_at_pos(pos);
                        break;
          case 9:exit(0); case
          10:system("cls");
                        break;
          default:cout<<"Invalid choice"; }
        }
}
```

CIRCULARLY LINKED LIST

A circularly linked list, or simply circular list, is a linked list in which the last node is always points to the first node. This type of list can be build just by replacing the NULL pointer at the end of the list with a pointer which points to the first node. There is no first or last node in the circular list.

Advantages:

- ➢ Any node can be traversed starting from any other node in the list.
- ➢ There is no need of NULL pointer to signal the end of the list and hence, all pointers contain valid addresses.

➢ In contrast to singly linked list, deletion operation in circular list is simplified as the search for the previous node of an element to be deleted can be started from that item itself.

head

Dynamic

Implementation of Circular linked list ADT

```
#include<iostream.h>
#include<stdlib.h>
template <class T>
struct cnode
{ T
data;
struct cnode<T> *link;
};
//Code fot circular linked List ADT template
<class T>



class clist
{
        int data; struct
        cnode<T>*head;
        public:
                clist();
                struct cnode<T>* create_cnode(int n);
                void display();
                void insert_end();
                void insert_front();
                void delete_end();
                void delete_front();
                void cnode_count();

};
//code for defaut constructor
template <class T>
clist<T>::clist()
        {
                head=NULL;
        }
```

```
//code to display elements in the list
template <class T> void
clist<T>::display()
```



```
{ struct cnode<T>*t;
        if(head==NULL)
         { cout<<"clist is Empty\n";
         }
         else
         { t=head;
                if(t->link==head) cout<<t-
                >data<<"->"; else
                { cout<<t->data<<"->";
                        t=t->link;
                        while(t!=head)
                         { cout<<t->data<<"->";
                                t=t->link;
                         }
                }
         }
}

//Code to create node
template <class T>
struct cnode<T>* clist<T>::create_cnode(int n)


{
struct cnode<T> *t; t=new
        struct cnode<T>;
        t->data=n;
        t->link=NULL;
return t;
}
//Code to insert node at the end
template <class T> void
clist<T>::insert_end()
{
struct cnode<T>*t;
struct cnode<T>*temp;
int n; cout<<"Enter data into cnode:";
        cin>>n;
        temp=create_cnode(n);
        if(head==NULL)
        {
```

```
                head=temp;
                temp->link=temp;
        }
        else
        {
                t=head;
```



```
                if(t->link==head)// list containing only one node {
t->link=temp; temp->link=t;
                }
                else
                {
                        while(t->link!=head)
                        { t=t->link;
                        } t->link=temp;
                        temp-
                        >link=head;
                }
        }
        cout<<"Node inerted"<<endl; }


//Code to insert node at front
template <class T> void
clist<T>::insert_front()
{ struct cnode <T>*t; struct
cnode<T>*temp; cout<<"Enter data
into cnode:"; cin>>data;



        temp=create_cnode(data);
        if(head==NULL)
        {
                head=temp;
                temp->link=temp;
        }
        else
        {
                t=head; if(t-
                >link==head) {
t- >link=temp; temp->link=t;
                }
                else
                {
                        //code to find last node while(t-
                        >link!=head)
                        { t=t->link;
                        }
                       t->link=temp; //linking last and first node
                        temp->link=head;
```

```
                    head=temp;


                }
        } cout<<"Node
inserted \n";
```



```
}

//Code to delete node at end
template <class T> void
clist<T>::delete_end()
{
struct cnode<T>*cur,*prev;
        cur=prev=head;
        if(head==NULL) cout<<"clist is
        Empty\n";
        else
        { cur=prev=head;
                if(cur->link==head) {
                        cout<<"cnode "<<cur->data<<" Deletion is sucess";
                        free(cur);
                        head=NULL;
                } else
                { while(cur->link!=head)
                        { prev=cur;
                                cur=cur->link;
                        }


                        //prev=cur; //cur=cur->link;
                        prev->link=head;//points to head
                          cout<<"cnode "<<cur->data<<" Deletion is sucess";
                        free(cur);
                }
        }
}
//Code to delete node at front
template <class T> void
clist<T>::delete_front()
{
struct cnode<T>*t,*temp;
        if(head==NULL)
                cout<<"circular list is Empty\n";
        else
        { t=head;
                //head=head->link;
                if(t->link==head)
```

```
                    {
                            head=NULL;
                             cout<<"cnode "<<t->data<<" Deletion is sucess";
                            delete(t);
                    } else
                    {
```



```
                    //code to find last node while(t-
                            >link!=head)
                            { t=t->link;
                            }
                            temp=head;
                                t->link=head->link; //linking last and first node
                        cout<<"cnode "<<temp->data<<" Deletion is
                        sucess"; head=head->link; delete(temp);
                        }
                }
        }
        //Code to count nodes in the circular linked list
        template <class T> void
        clist<T>::cnode_count()
        {
        struct cnode<T>*t; int
        c=0; t=head;
        if(head==NULL)
                        {
                        cout<<"circular list is Empty\n";

                        }


                else
                { t=t->link;
                        c++;
                        while(t!=head)
                        { c++;
                                t=t->link;
                        }
                cout<<"Node Count="<<c;

                }

        } int main() {
        int ch,pos; clist
        <int> L;
        while(1)
                { cout<<"\n ***Operations on Circular Linked clist***"<<endl;
                        cout<<"\n1.Insert cnode at End"<<endl; cout<<"2.Insert
```

```
Cnode at Front"<<endl; cout<<"3.Delete Cnode at
END"<<endl; cout<<"4.Delete Cnode at Front"<<endl;
cout<<"5.Display Nodes "<<endl; cout<<"6.Cnode
Count"<<endl; cout<<"7.Exit "<<endl; cout<<"8.Clear Screen
"<<endl; cout<<"Enter Your choice:"; cin>>ch; switch(ch)
{ case 1: L.insert_end();
                    break;
```



```
                    case 2: L.insert_front();
                                break;
                    case 3:L.delete_end();
                                break;
                    case 4:L.delete_front();
                                break;
                    case 5://display contents
                                L.display();
                                break;
                    case 6: L.cnode_count();
                                break;
                    case 7:exit(0); case
                    8:system("cls");
                    break;
                    default:cout<<"Invalid choice"; }
        }
}
```

Stack: Stack ADT, array and linked list implementation, Applications- expression conversion and evaluation. **Queue:** Types of Queue: Simple Queue, Circular Queue, Queue ADT - array and linked list implementation. Priority Queue, heaps.

STACK ADT:- A Stack is a linear data structure where insertion and deletion of items takes place at one end called top of the stack. A Stack is defined as a data structure which operates on a last-in first-out basis. So it is also is referred as Last-in First-out(LIFO).

Stack uses a single index or pointer to keep track of the information in the stack. The basic operations associated with the stack are:

a) push(insert) an item onto the stack.
b) pop(remove) an item from the stack.

The general terminology associated with the stack is as follows:

A stack pointer keeps track of the current position on the stack. When an element is placed on the stack, it is said to be **pushed** on the stack. When an object is removed from the stack, it is said to be **popped** off the stack. Two additional terms almost always used with stacks are **overflow**, which occurs when we try to push more information on a stack that it can hold, and **underflow**, which occurs when we try to pop an item off a stack which is empty.

Pushing items onto the stack:

Assume that the array elements begin at 0 (because the array subscript starts from 0) and the maximum elements that can be placed in stack is max. The stack pointer, **top**, is considered to be pointing to the top element of the stack. A push operation thus involves adjusting the stack pointer to point to next free slot and then copying data into that slot of the stack. Initially the top is initialized to -1.

```
//code to push an element on to stack;
template<class T> void
 stack<T>::push()
 { if(top==max-1) cout<<"Stack
          Overflow...\n";
          else
           {
cout<<"Enter an element to be pushed:"; top++;
                    cin>>data;
                    stk[top]=data;
                    cout<<"Pushed Sucesfully .... \n";
          }
}
```


Popping an element from stack:

To remove an item, first extract the data from top position in the stack and then decrement the stack pointer, top.

```
//code to remove an element from
 stack template<class T> void
 stack<T>::pop()
 { if(top= =-1) cout<<"Stack is Underflow";
          else
           {
                    data=stk[top];
                    top--;
                   cout<<data<<" is poped Sucesfully ....\n";
```

```
        }
    }
```

Static implementation of Stack ADT

```
#include<stdlib.h>
#include<iostream.h
> #define max 4
template<class T>
class stack
{
private:
        int top;
        T stk[max],data;
public:
        stack();
void push(); void pop();
        void display();
};
template<class T>
stack<T>::stack()
{ top=-1;
```



```
}
//code to push an element on to stack;
template<class T> void
stack<T>::push()
{ if(top==max-1) cout<<"Stack
        Overflow...\n";
        else
        {
cout<<"Enter an element to be pushed:"; top++;
                cin>>data;
                stk[top]=data;
                cout<<"Pushed Sucesfully .... \n";
        }
}
//code to remove an element from
stack template<class T> void
stack<T>::pop()
{ if(top==-1) cout<<"Stack is Underflow";
        else
        {
                data=stk[top];
```

```
                top--;
                cout<<data<<" is poped Sucesfully ....\n";
        }
}
//code to display stack elements
template<class T> void
stack<T>::display()
{ if(top==-1) cout<<"Stack Under Flow";
        else
        { cout<<"Elements in the Stack are .... \n";
                for(int i=top;i>-1;i--)
                { cout<<<<<stk[i]<<"\n";
                }
        }
} int main() {
int choice;
stack <int>st;
while(1)
        { cout<<"\n*****Menu for Stack operations*****\n";
                cout<<"1.PUSH\n2.POP\n3.DISPLAY\n4.EXIT\n";




                cout<<"Enter Choice:";
                cin>>choice;
                switch(choice)


                { case 1: st.push();
                                        break;
                        case 2: st.pop();
                                        break;
                        case 3: st.display();
                                        break;
                        case 4: exit(0);
                          default:cout<<"Invalid choice...Try again...\n";
                }
        }
} output:
*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY 4. EXIT
Enter Choice:1
Enter an element to be pushed:11
Pushed Sucesfully....
*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY
4.EXIT
Enter Choice:1
Enter an element to be pushed:22
```

Pushed Sucesfully....

*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY 4. EXIT
Enter Choice:1
Enter an element to be pushed:44
Pushed Sucesfully....

*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY 4. EXIT
Enter Choice:1
Enter Choice:1
Enter an item to be pushed:55
Pushed Sucesfully....

*****Menu for Stack operations*****
1.PUSH
2.POP

3.DISPLAY
4.EXIT
Enter Choice:1
Stack Overflow...

*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY 4. EXIT
Enter Choice:2
55 is poped Sucesfully....

*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY 4. EXIT
Enter Choice:3
Elements in the Stack are....
44
22
11

*****Menu for Stack operations*****
1.PUSH
2.POP
3.DISPLAY

4.EXIT
Enter Choice:4

Dynamic implementation of Stack ADT

```
#include<iostream.h
> template <class T>
struct node { T data;
struct node<T> *link;
};
template <class T> class
stack
{
        int data; struct
        node<T>*top;



        public:
        stack()


        {
                top=NULL;
        } void
        display();
        void push();
        void pop();
};
template <class T> void
stack<T>::display()
{ struct node<T>*t;

        if(top==NULL)
        {
                        cout<<"stack is Empty\n";
                } else
        { t=top;
                while(t!=NULL)
                { cout<<"|"<<t->data<<"|"<<endl;
                        t=t->link;
                }
        }
}

template <class T> void
stack<T>::push()
```

```
{
struct node <T>*t,*temp;
        cout<<"Enter data into node:";
        cin>>data;
        temp=new struct
        node<T>; temp-
        >data=data; temp-
        >link=NULL;
        if(top==NULL) top=temp;
        else
        { temp->link=top;
                top=temp;
        }
}


template <class T> void
stack<T>::pop()
{
struct node<T>*t; if(top==NULL)
        cout<<"stack is Empty\n";



        else



        { t=top;
                top=top->link;
                 cout<<"node "<<t->data<<" Deletion is sucess";
                delete(t);
        }
}

int main() { int
ch; stack <int>
st; while(1)
          { cout<<"\n ***Operations on Dynamic stack***"<<endl;
                cout<<"\n1.PUSH"<<endl; cout<<"2.POP"<<endl;
                cout<<"3.Display "<<endl; cout<<"4.Exit "<<endl;
                cout<<"Enter Your choice:"; cin>>ch; switch(ch)
                { case 1: st.push();
                                        break;
                        case 2: st.pop();
                                        break;
                         case 3:st.display();;
                                         break;
                        case 4:exit(0);
                         default:cout<<"Invalid choice"; }
        }
}
```

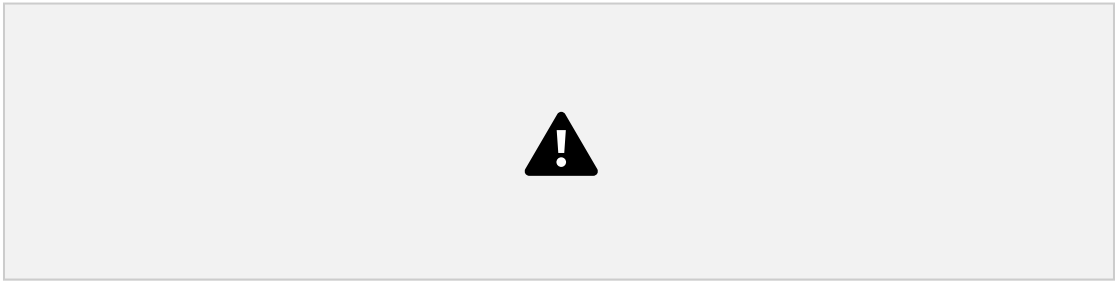
Applications of Stack:

1. Stacks are used in conversion of infix to postfix expression.
2. Stacks are also used in evaluation of postfix expression.
3. Stacks are used to implement recursive procedures.
4. Stacks are used in compilers.
5. Reverse String

An arithmetic expression can be written in three different but equivalent notations, i.e., without changing the essence or output of an expression. These notations are − 1. Infix Notation 2. Prefix (Polish) Notation

3. Postfix (Reverse-Polish) Notation

Conversion of Infix Expressions to Prefix and Postfix



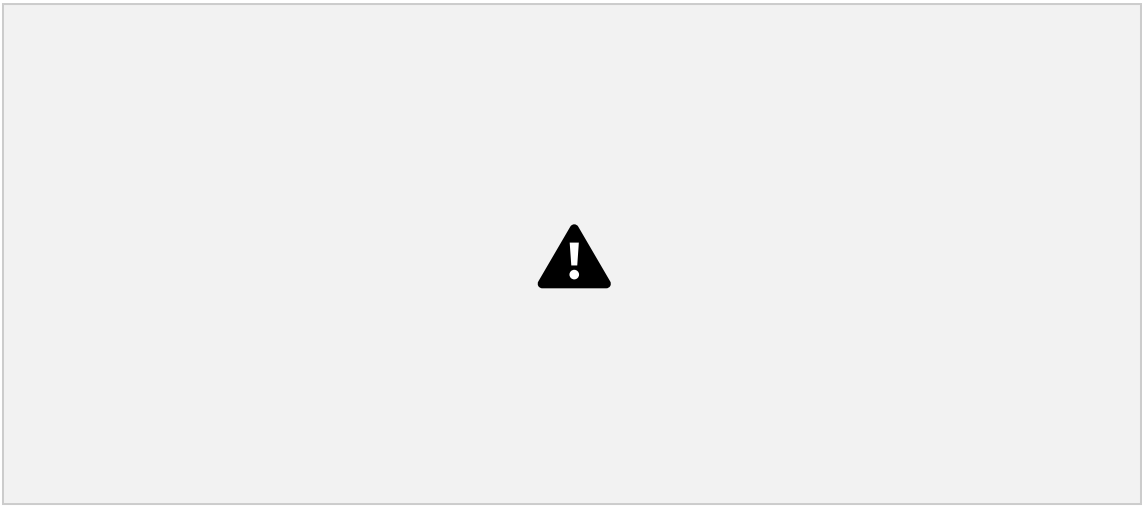
Convert following infix expression to prefix and postfix

(A + B) * C - (D - E) * (F + G)

The Tower of Hanoi (also called the Tower of Brahma or Lucas' Tower,[1] and sometimes pluralized) is a mathematical game or puzzle. It consists of three rods, and a number of disks of different sizes which can slide onto any rod. The puzzle starts with the disks in a neat stack in ascending order of size on one rod, the smallest at the top, thus making a conical shape.

The objective of the puzzle is to move the entire stack to another rod, obeying the following simple rules:

1. Only one disk can be moved at a time.
2. Each move consists of taking the upper disk from one of the stacks and placing it on top of another stack i.e. a disk can only be moved if it is the uppermost disk on a stack.
3. No disk may be placed on top of a smaller disk.



QUEUE ADT

A queue is an ordered collection of data such that the data is inserted at one end and deleted from another end. The key difference when compared stacks is that in a queue the information stored is processed first in first-out or FIFO. In other words the information receive from a queue comes in the same order that it was placed on the queue.

Representing a Queue:

One of the most common way to implement a queue is using array. An easy way to do so is to define an array Queue, and two additional variables front and rear. The rules for manipulating these variables are simple:

- ➢ Each time information is added to the queue, increment rear.
- ➢ Each time information is taken from the queue, increment front.
- ➢ Whenever **front >rear or front=rear=-1** the queue is empty.

Array implementation of a Queue do have drawbacks. The maximum queue size has to be set at compile time, rather than at run time. Space can be wasted, if we do not use the full capacity of the array.

Operations on Queue:

A queue have two basic operations: a)
adding new item to the queue
b) removing items from queue.

The operation of adding new item on the queue occurs only at one end of the queue called the **rea**r or back.

The operation of removing items of the queue occurs at the other end called the **front.**

For insertion and deletion of an element from a queue, the array elements begin at 0 and the maximum elements of the array is **maxSize.** The variable front will hold the index of the item that is considered the front of the queue, while the rear variable will hold the index of the last item in the queue.

Assume that initially the front and rear variables are initialized to -1. Like stacks, underflow and overflow conditions are to be checked before operations in a queue.

Queue empty or underflow condition is

if((front>rear)||front= =-1) cout<"Queue is empty";

Queue Full or overflow condition is

if((rear==max)

cout<"Queue is full";

Static implementation of Queue ADT

```
#include<stdlib.h>
#include<iostream.h>
#define max 4
template <class T>
class queue
{
        T q[max],item; int
          front,rear;
public: queue(); void
          insert_q(); void
          delete_q(); void
          display_q();
};
template <class T>
queue<T>::queue()
{ front=rear=-1;
}
//code to insert an item into queue;
template <class T> void
queue<T> ::insert_q()
```



```
{ if(front>rear) front=rear=-1;
        if(rear==max-1) cout<<"queue
          Overflow...\n";
        else
        { if(front==-1)
                        front=0;
          rear++;
          cout<<"Enter an item to be inserted:";
          cin>>item; q[rear]=item;
          cout<<"inserted Sucesfully..into queue..\n"; }
}
template <class T>
void queue<T>::delete_q()
{
        if((front==-1&&rear==-1)||front>rear)
        { front=rear=-1;
          cout<<"queue is Empty .. \n";
        } else
        { item=q[front];
          front++;
          cout<<item<<" is deleted Sucesfully ... \n"; }
}
template <class T>
void queue<T>::display_q()
{
        if((front==-1&&rear==-1)||front>rear)
        { front=rear=-1;
          cout<<"queue is Empty .. \n";
        } else
        {
          for(int i=front;i<=rear;i++)
                cout<<"|"<<q[i]<<"|<--";
```

```
                }
} int main() { int
choice; queue<int> q;
while(1)
                {
                cout<<"\n\n*****Menu for operations on QUEUE*****\n\n";
                cout<<"1.INSERT\n2.DELETE\n3.DISPLAY\n4.EXIT\n";



                cout<<"Enter Choice:";
                cin>>choice; switch(choice)
                    { case 1: q.insert_q(); break;
                              case 2: q.delete_q(); break;
                               case 3: cout<<"Elements in the queue are ... \n";
                                            q.display_q(); break;
                              case 4: exit(0);
                                default: cout<<"Invalid choice...Try again...\n"; }
                }
}
```


Dynamic implementation of Queue ADT #include<stdlib.h>

```
#include<iostream.h>
template <class T>
struct node
{
                T data;
struct node<T>*next;
};
template <class T> class
queue
{ private:
                 T item;
                node<T> *front,*rear;
public:
                    queue();
void insert_q(); void delete_q();
                    void display_q();
};
template <class T>
queue<T>::queue()
{ front=rear=NULL;
}
//code to insert an item into queue;
template <class T> void
queue<T>::insert_q()
{
node<T>*p;
```

```
                cout<<"Enter an element to be inserted:";



                cin>>item; p=new
                node<T>; p-
                >data=item; p-
                >next=NULL;
                if(front==NULL)
                { rear=front=p;
                } else
                { rear->next=p;
                   rear=p;
                }
                cout<<"\nInserted into Queue Sucesfully ... \n"; }
//code to delete an elementfrom queue template
<class T>
void queue<T>::delete_q()
{
```



```
node<T>*t; if(front==NULL) cout<<"\nQueue is
                Underflow"; else
                { item=front->data;
                   t=front;
                   front=front-
                   >next;
                   cout<<"\n"<<item<<" is deleted from Queue ... \n";
                } delete(t);
}
//code to display elements in queue template
<class T>
void queue<T>::display_q()
{
node<T>*t; if(front==NULL) cout<<"\nQueue
                Under Flow";
                else
                { cout<<"\nElements in the Queue are ... \n";
                   t=front;
                   while(t!=NULL)
                   {
                            cout<<"|"<<t->data<<"|<-";
                            t=t->next;
                   }
                }
} int main() {
int choice;
queue<int>q1;



                while(1)
                {
                cout<<"\n\n***Menu for operations on Queue***\n\n";
                cout<<"1.Insert\n2.Delete\n3.DISPLAY\n4.EXIT\n";
                cout<<"Enter Choice:"; cin>>choice; switch(choice)
                { case 1: q1.insert_q();
```

```
                    break;
                    case 2: q1.delete_q(); break;
                    case 3: q1.display_q();
                                    break;
                    case 4: exit(0);
                    default: cout<<"Invalid choice...Try again...\n";
                }
                }
}
```

Application of Queue:

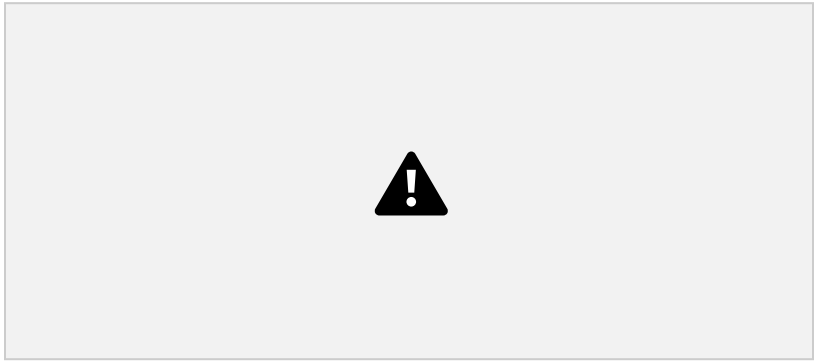
Queue, as the name suggests is used whenever we need to have any group of objects in an order in which the first one coming in, also gets out first while the others wait for there turn, like in the following scenarios :

1. Serving requests on a single shared resource, like a printer, CPU task scheduling etc.

2. In real life, Call Center phone systems will use Queues, to hold people calling them in an order, until a service representative is free.
3. Handling of interrupts in real-time systems. The interrupts are handled in the same order as they arrive, First come first served.

CIRCULAR QUEUE

Once the queue gets filled up, no more elements can be added to it even if any element is removed from it consequently. This is because during deletion, rear pointer is not adjusted.



When the queue contains very few items and the rear pointer points to last element. i.e. rear=maxSize-1, we cannot insert any more items into queue because the overflow condition satisfies. That means a lot of space is wasted

.Frequent reshuffling of elements is time consuming. One solution to this is arranging all elements in a circular fashion. Such structures are often referred to as **Circular Queues.**

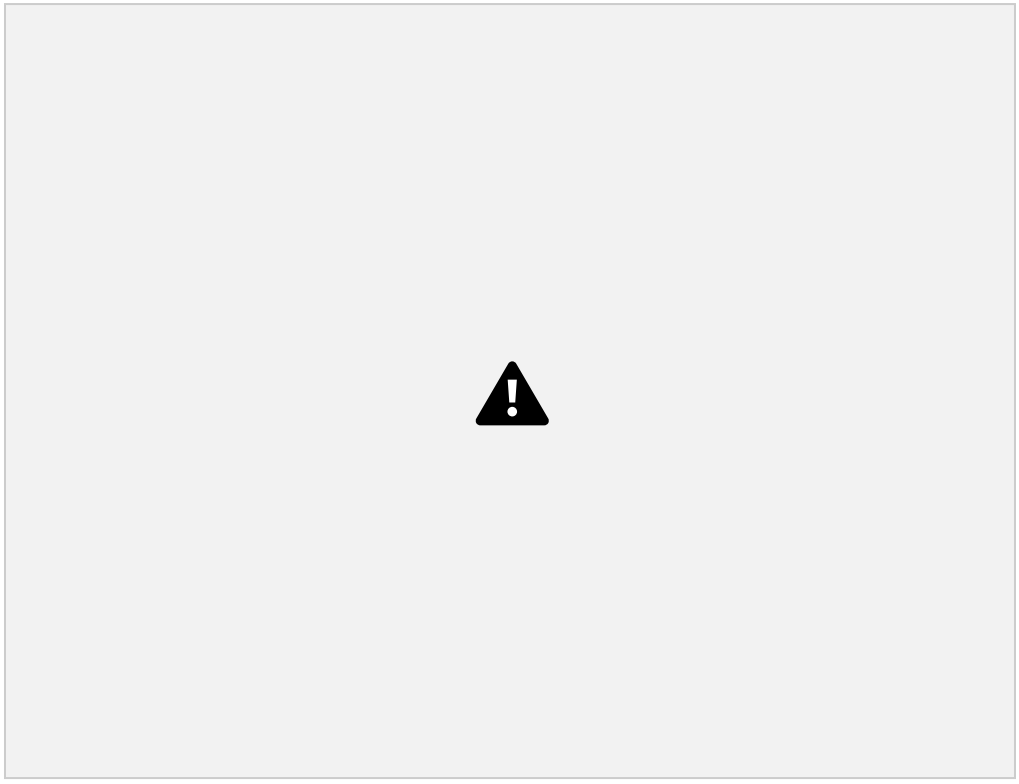
A circular queue is a queue in which all locations are treated as circular such that the first location CQ[0] follows the last location CQ[max-1].

Circular Queue empty or underflow condition is

```
if(front==-1)
  cout<<"Queue is empty";
```

Circular Queue Full or overflow condition is

```
if(front==(rear+1)%max)
{
  cout<<"Circular Queue is full \n";
}
```

Insertion into a Circular Queue:

Algorithm CQueueInsertion(Q,maxSize,Front,Rear,item)
Step 1: If Rear = maxSize-1 then
Rear = 0 else

```
                Rear=Rear+1
Step 2: If Front = Rear then print
        "Queue Overflow" Return
Step 3: Q[Rear] = item



Step 4: If Front = 0 then Front
        = 1
Step 5: Return
```

Deletion from Circular Queue:

```
Algorithm CQueueDeletion(Q,maxSize,Front,Rear,item)
Step 1: If Front = 0 then
        print "Queue Underflow" Return
Step 2: K=Q[Front]
Step 3: If Front = Rear then begin
                Front = -1
                Rear = -1
          end else
          If Front = maxSize-1 then
                Front = 0 else
                Front = Front + 1
Step 4: Return K
```


Static implementation of Circular Queue ADT

```
#include<iostream.h>
#define max 4
template <class T>
class CircularQ {
                T cq[max];
                int front,rear;
        public:
CircularQ(); void insertQ();
void deleteQ();
                void displayQ();
};
template <class T> CircularQ<T>::CircularQ()
{ front=rear=-1;
}
template <class T>
void CircularQ<T>:: insertQ()
{ int num;
if(front==(rear+1)%max)
        { cout<<"Circular Queue is full\n"; }
```

```
        else
                {
                        cout<<"Enter an element";
                        cin>>num; if(front==-1)
                        rear=front=0; else
                        rear=(rear+1)%max;
                        cq[rear]=num;
                        cout<<num <<" is inserted ...";
                        }
}
template <class T>
void CircularQ<T>::deleteQ()
{ int num; if(front==-1) cout<<"Queue is
empty";
        else
        {
                num=cq[front];
                cout<<"Deleted item is "<< num;
                if(front==rear)
                                front=rear=-1;
                else
                        front=(front+1)%max;
        } }
template <class T>
void CircularQ<T>::displayQ()
{ int
i;
```



```
        if(front==-1) cout<<"Queue is
                empty";
        else
        { cout<<"Queue elements are\n";
                for(i=front;i<=rear;i++) cout<<cq[i]<<"\t";
        }
        if(front>rear)
        { for(i=front;i<max;i++)
                cout<<cq[i]<<"\t";
                for(i=0;i<=rear;i++)
cout<<cq[i]<<"\t"; } } int main()
{
CircularQ<int> obj;
int choice; while(1)
        { cout<<"\n*** Circular Queue Operations***\n";


                cout<<"\n1.insert Element into CircularQ";
                cout<<"\n2.Delete Element from CircularQ";
                cout<<"\n3.Display Elements in CircularQ";
                cout<<"\n4.Exit "; cout<<"\nEnter Choice:";
                cin>>choice; switch(choice)
                { case 1:
                                        obj.insertQ(
                                        ); break;
                        case 2: obj.deleteQ(); break;
                        case 3: obj.displayQ();
```

```
                                        break;
                                case 4: exit(0);
                        }
                }
        }
```

Priority Queue

DEFINITION:

A priority queue is a collection of zero or more elements. Each element has a priority or value. Unlike the queues, which are FIFO structures, the order of deleting from a priority queue is determined by the element priority. Elements are removed/deleted either in increasing or decreasing order of priority rather than in the order in which they arrived in the queue.

There are two types of priority queues:

- Min priority queue
- Max priority queue

Min priority queue: Collection of elements in which the items can be inserted arbitrarily, but only smallest element can be removed.

Max priority queue: Collection of elements in which insertion of items can be in any order but only largest element can be removed.

In priority queue, the elements are arranged in any order and out of which only the smallest or largest element allowed to delete each time.

The implementation of priority queue can be done using arrays or linked list. The data structure **heap** is used to implement the priority queue effectively.

APPLICATIONS:

1. The typical example of priority queue is scheduling the jobs in operating system. Typically OS allocates priority to jobs. The jobs are placed in the queue and position of the job in priority queue determines their priority. In OS there are 3 jobs- real time jobs, foreground jobs and background jobs. The OS always schedules the real time jobs first. If there is no real time jobs pending then it schedules foreground jobs. Lastly if no real time and foreground jobs are pending then OS schedules the background jobs.
2. In network communication, the manage limited bandwidth for transmission the priority queue is used. 3. In simulation modeling to manage the discrete events the priority queue is used.

Various operations that can be performed on priority queue are- 1. Find an element

2. Insert a new element
3. Remove or delete an element

The abstract data type specification for a max priority queue is given below. The specification for a min priority queue is the same as ordinary queue except while deletion, find and remove the element with minimum priority

ABSTRACT DATA TYPE(ADT):

Abstract data type maxPriorityQueue

{

Instances

Finite collection of elements, each has a priority

Operations empty():return true iff the queue is empty size()

:return number of elements in the queue top() :return

element with maximum priority

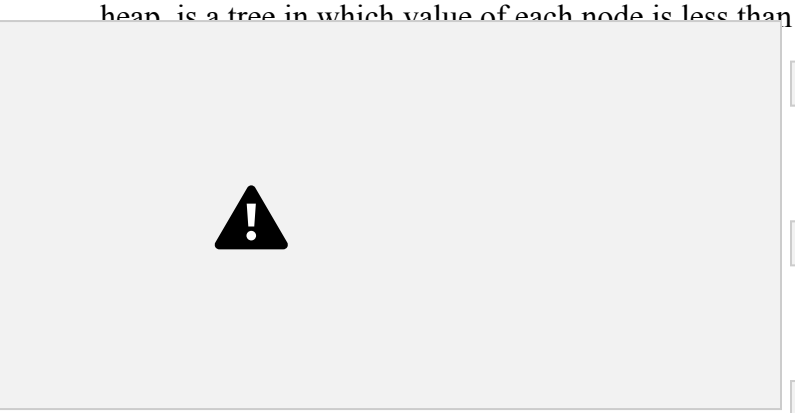
del() :remove the element with largest priority from the queue

insert(x): insert the element x into the queue

}

HEAPS

Heap is a tree data structure denoted by either a max heap or a min heap.
A max heap is a tree in which value of each node is greater than or equal to value of its children nodes. A min heap is a tree in which value of each node is less than or equal to value of its children nodes.

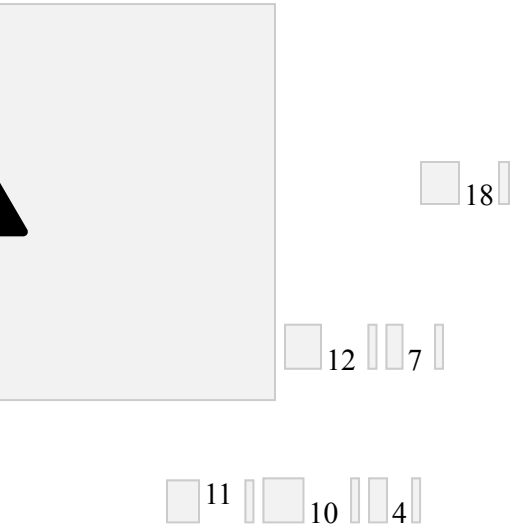


Max heap Min heap

Insertion of element in the Heap:

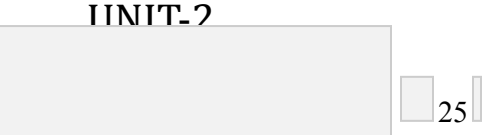
Consider a max heap as given below:

Now if we want to insert 7. We cannot insert 7 as left child of 4. This is because the max heap has a property that value of any node is always greater than the parent nodes. Hence 7 will bubble up 4 will be left child of 7. Note: When a new node is to be inserted in complete binary tree we start from bottom and from left child on the current level. The heap is always a complete binary tree.



inserted!

If we want to insert node 25, then as 25 is greatest element it should be the root. Hence 25 will bubble up and 18 will move down.



inserted!

The insertion strategy just outlined makes a single bubbling pass from a leaf toward the root. At each level we do (1) work, so we should be able to implement the strategy to have complexity O(height) = O(log n).

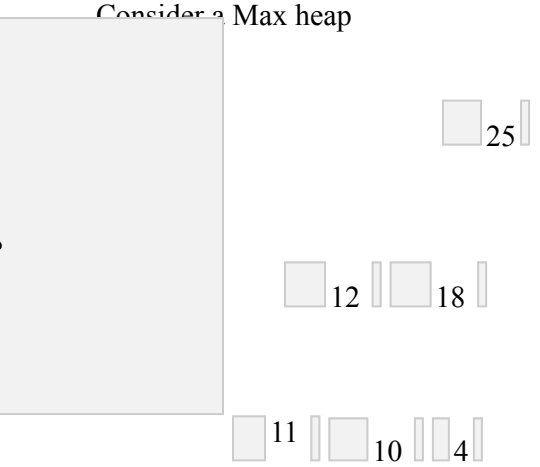
```
void Heap::insert(int item)
{ int temp; //temp node starts at leaf and moves up.
        temp=++size;
        while(temp!=1 && heap[temp/2]<item) //moving element down
        {
                H[temp] = H[temp/2]; temp=temp/2;
                //finding the parent
        }
        H[temp]=item;
}
```

Deletion of element from the heap:

For deletion operation always the maximum element is deleted from heap. In Max heap the maximum

element is always present at root. And if root element is deleted then we need to reheapify the tree.

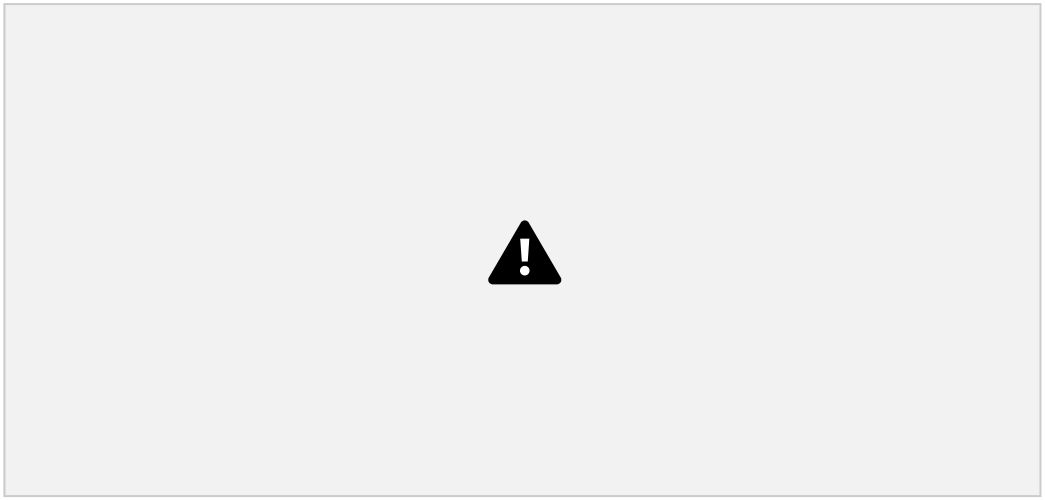
Consider a Max heap



Delete root element:25, Now we cannot put either 12 or 18 as root node and that should be greater than all its children elements.

Now we cannot put 4 at the root as it will not satisfy the heap property. Hence we will bubble up 18 and place 18 at root, and 4 at position of 18.

If 18 gets deleted then 12 becomes root and 11 becomes parent node of 10.



Thus deletion operation can be performed. The time complexity of deletion operation is O(log n). 1. Remove the maximum element which is present at the root. Then a hole is created at the root.

2. Now reheapify the tree. Start moving from root to children nodes. If any maximum element is found then place it at root. Ensure that the tree is satisfying the heap property or not.
3. Repeat the step 1 and 2 if any more elements are to be deleted.

```
void heap::delet(int item)
{
int item, temp; if(size==0)
cout<<"Heap is empty\n"; else {
//remove the last elemnt and reheapify item=H[size--];
//item is placed at root temp=1; child=2;
while(child<=size)
{
if(child<size && H[child]<H[child+1])
child++; if(item>=H[child]) break;
H[temp]=H[child];
temp=child;
child=child*2;
}
//pl;ace the largest item at root
H[temp]=item;
}
```

Applications Of Heap:

1. Heap is used in sorting algorithms. One such algorithm using heap is known as heap sort.

2. In priority queue implementation the heap is used.

HEAP SORT

Heap sort is a method in which a binary tree is used. In this method first the heap is created using binary tree and then heap is sorted using priority queue.

Eg:

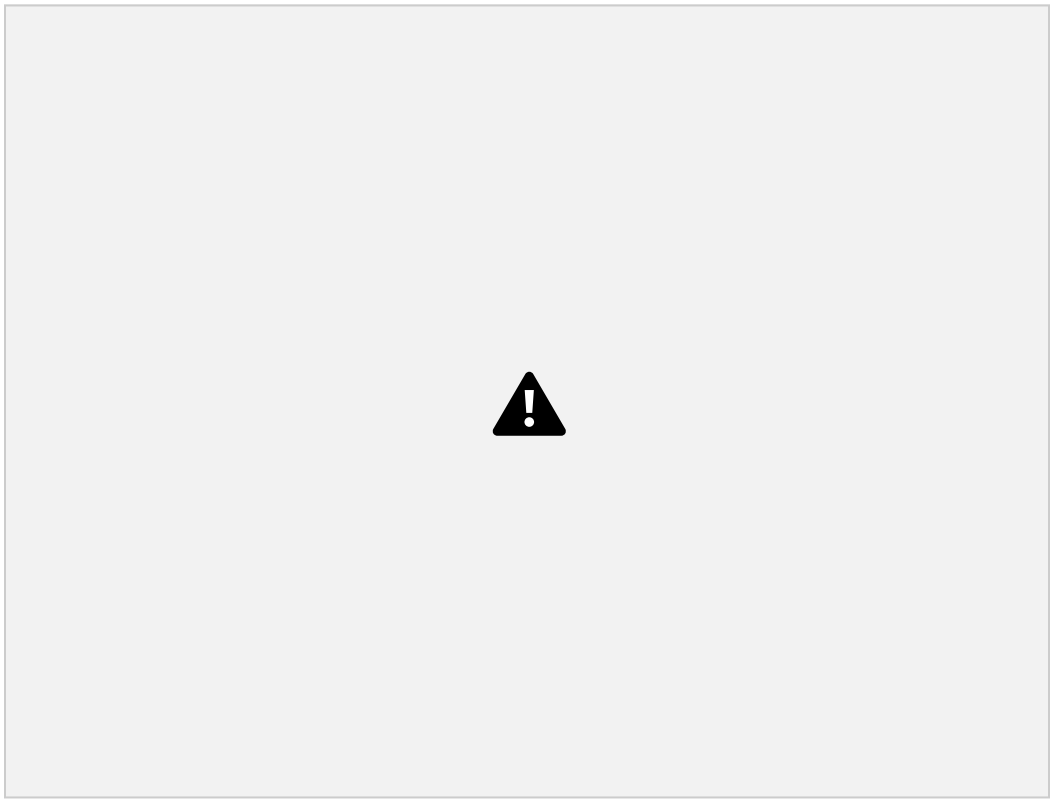
25 57 48 38 10 91 84 33

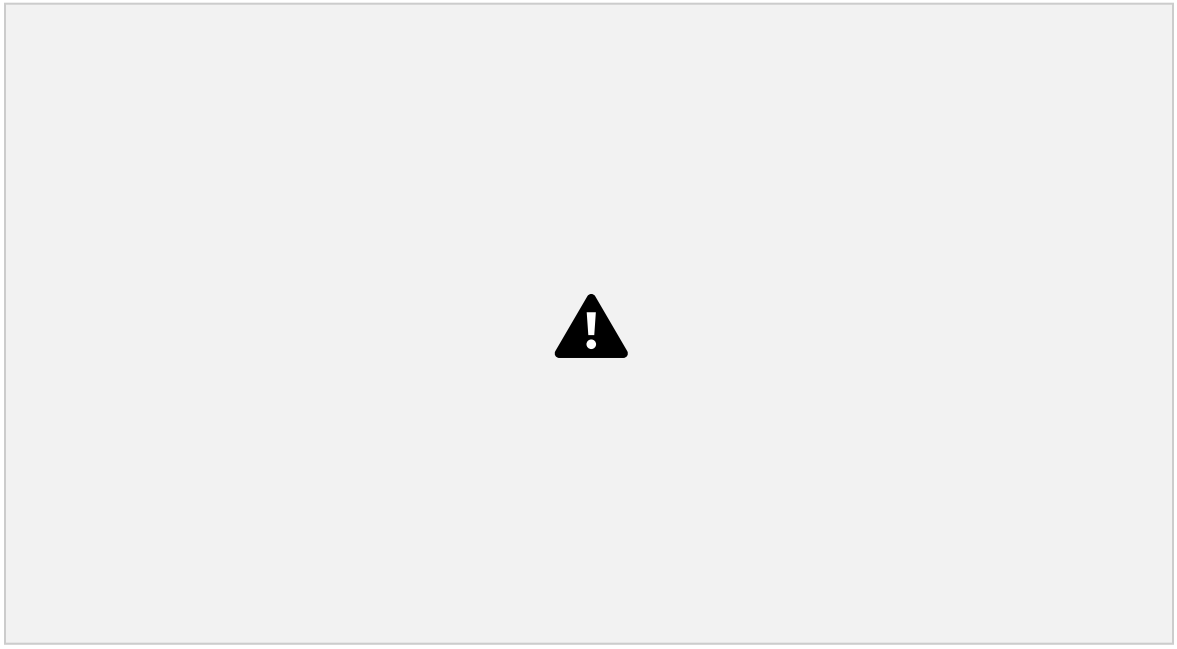
In the heap sort method we first take all these elements in the array “A”

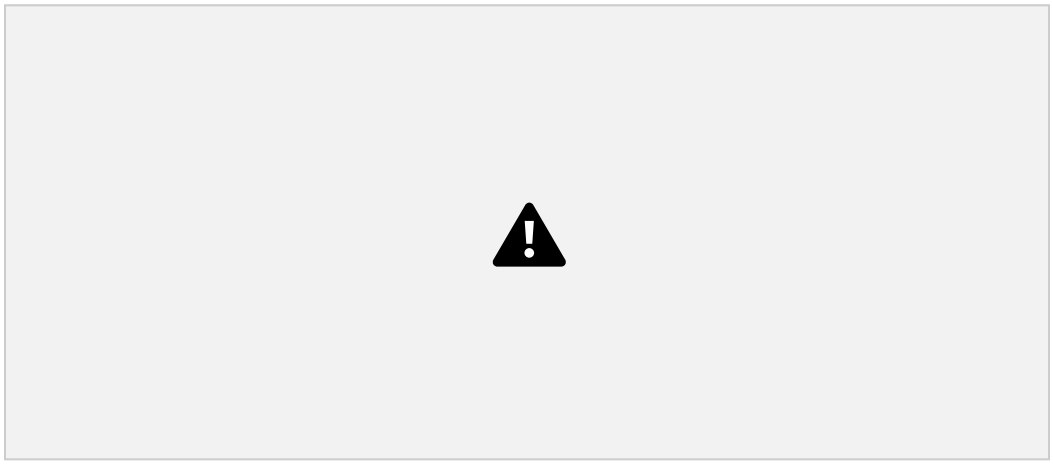
A[0]	A[1]	A[2]	A[3]	A[4]	A[5]	A[6]	A[7]
25	57	48	38	10	91	84	33

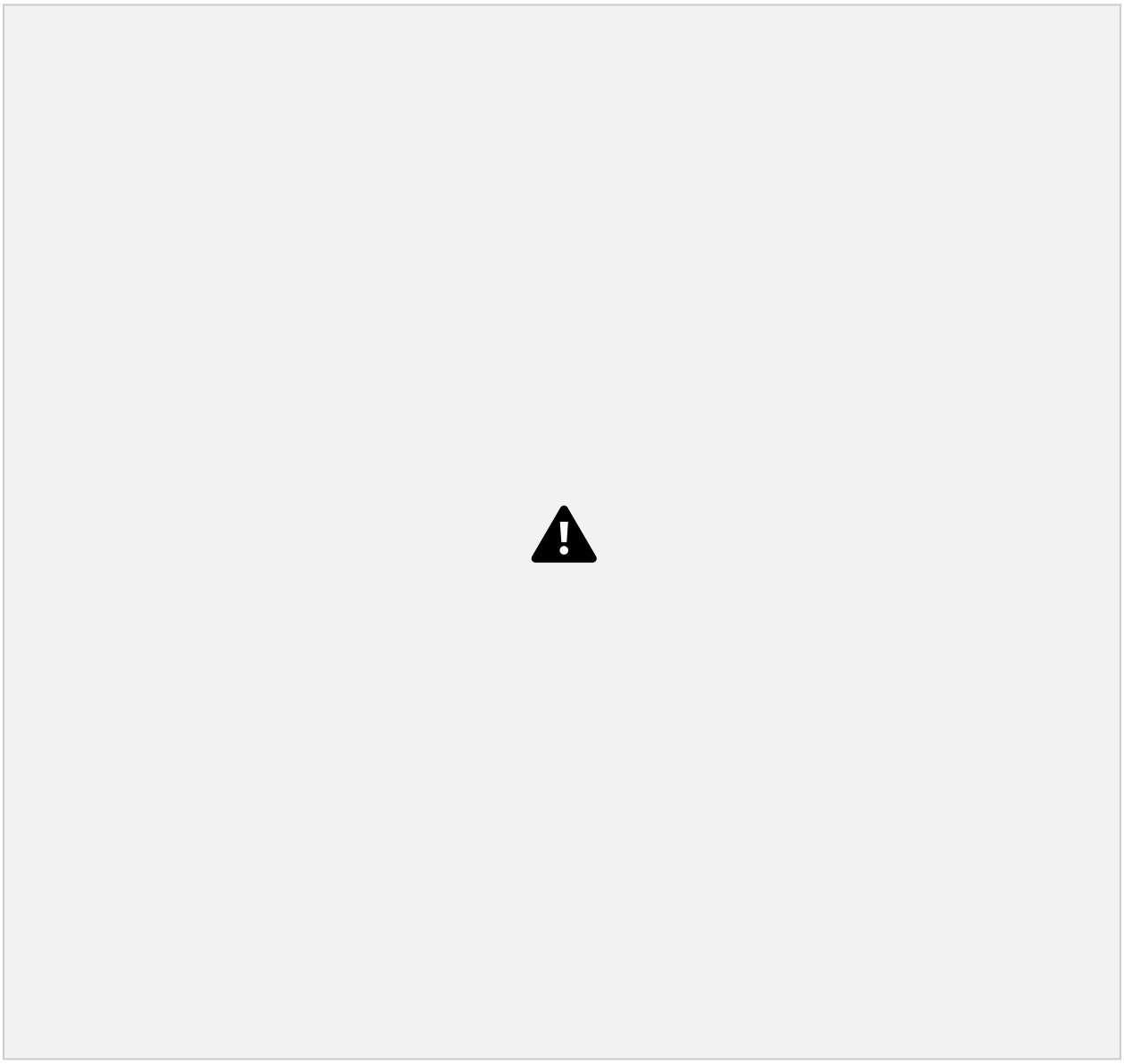
Now start building the heap structure. In forming the heap the key point is build heap in such a way that the highest value in the array will always be a root.

Insert 25

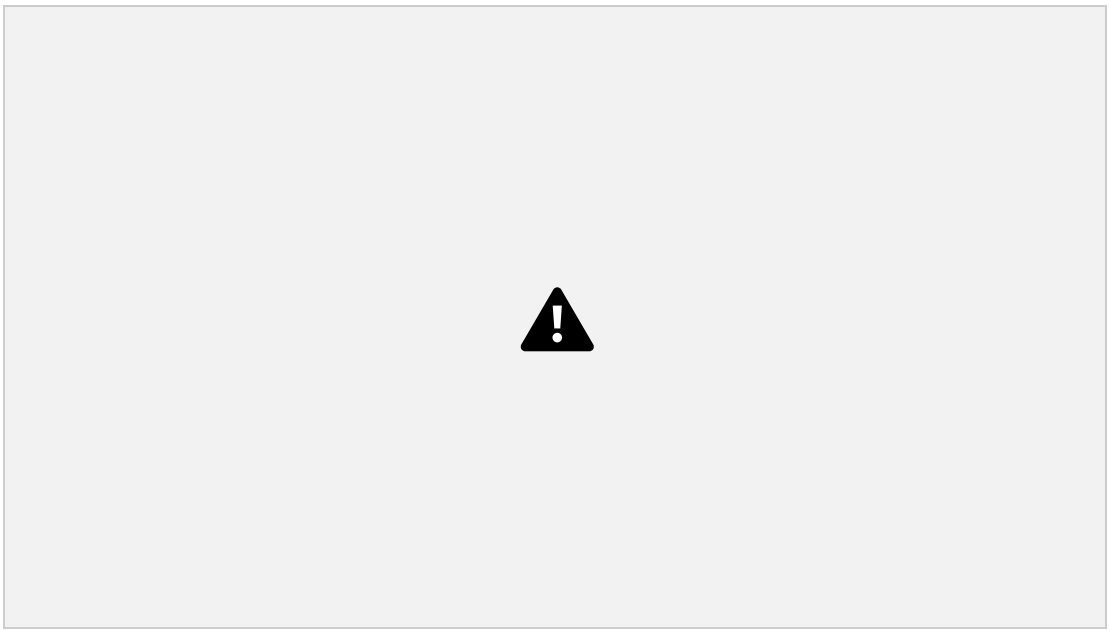






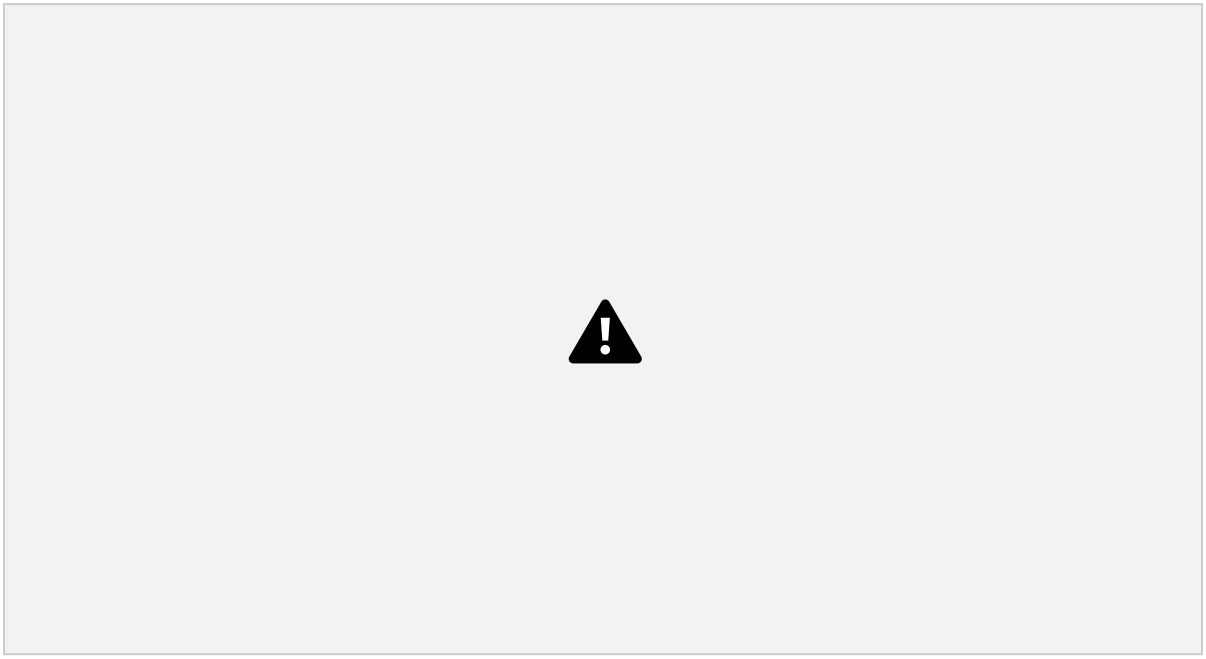


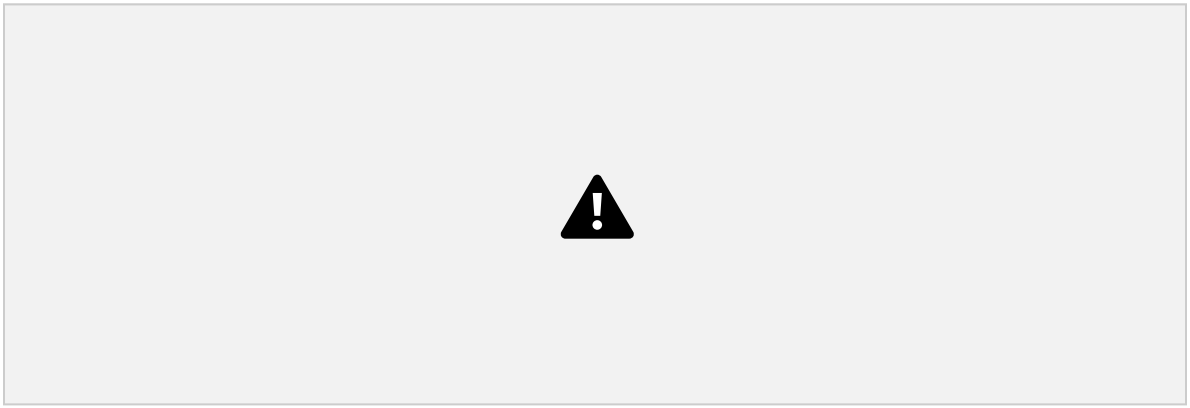
The next element is 84, which 91>84>57 the middle element. So 84 will be the parent of 57. For making the complete binary tree 57 will be attached as right of 84.

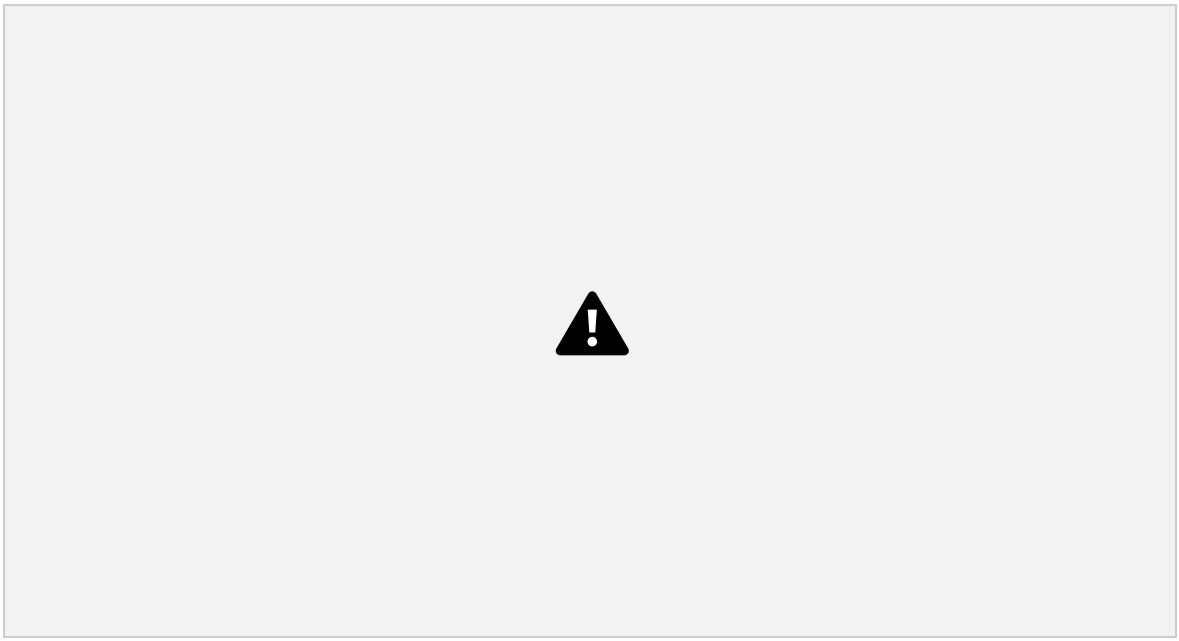


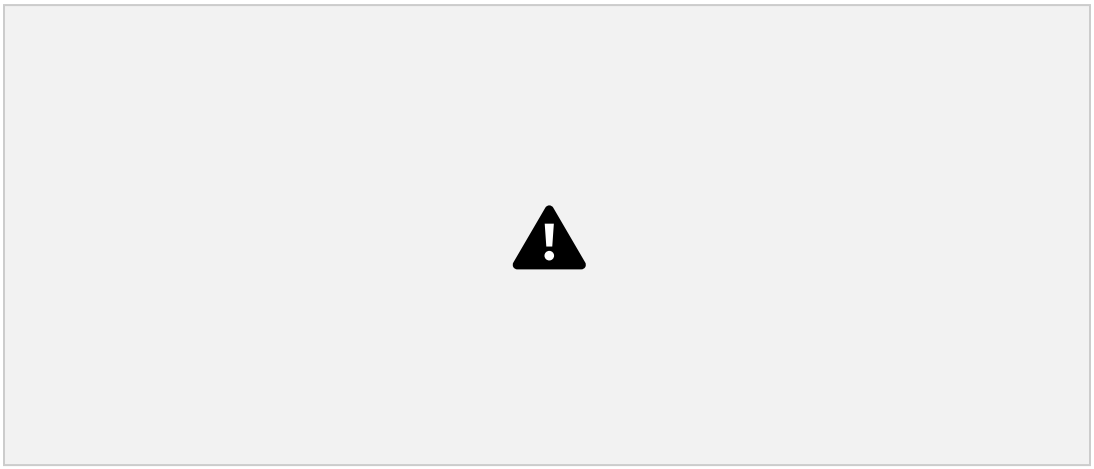
Now the heap is formed. Let us sort it. For sorting the heap remember two main th ings the first thing is that the binary tree form of the heap should not be distributed at all. For the complete sorting binary tree should be remained. And the second thing is that we will start sorting the higher elements at the end of array in sorted manner i.e.. A[7]=91, A[6]=84 and so on..

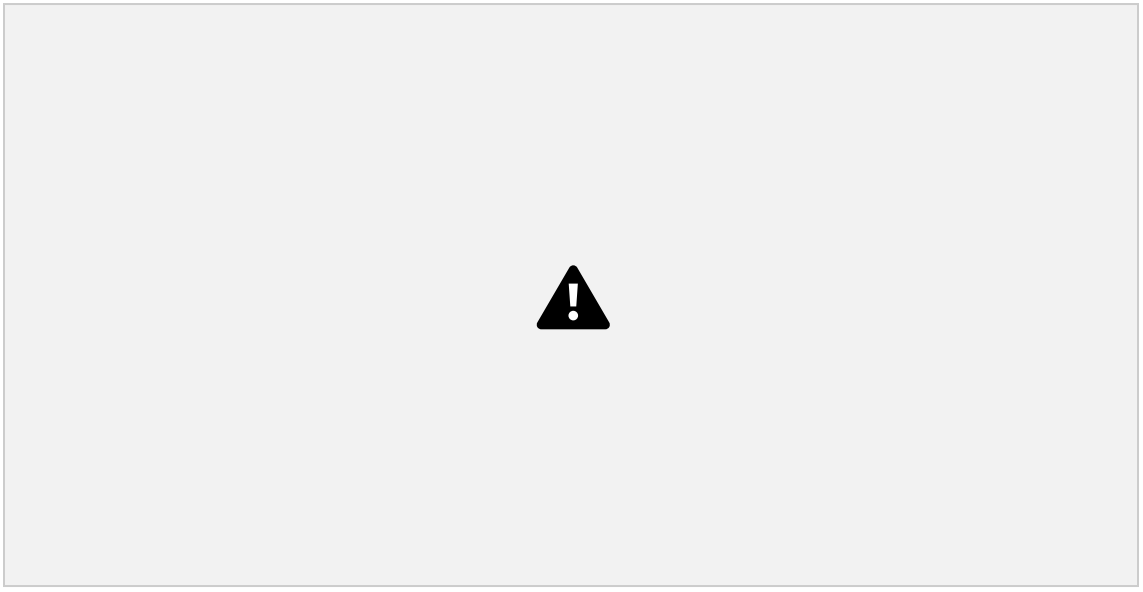
Step 1:- Exchange A[0] with A[7]

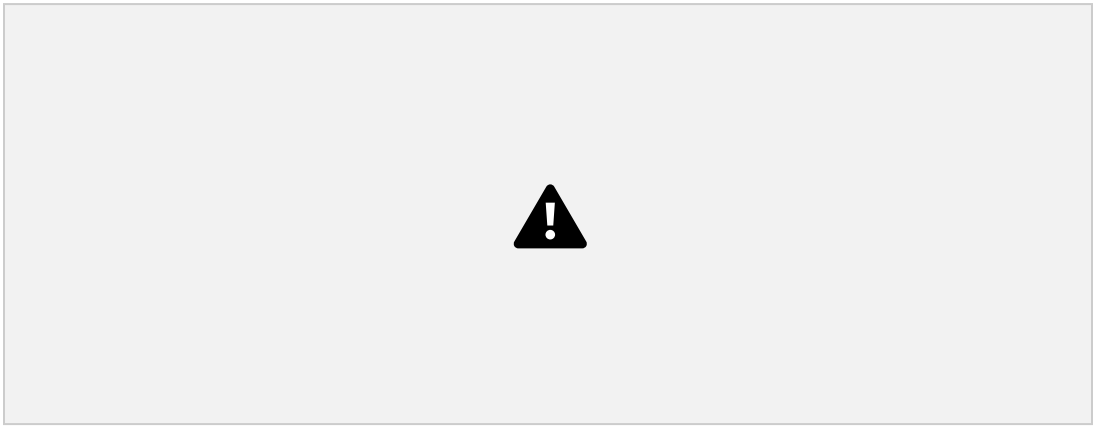


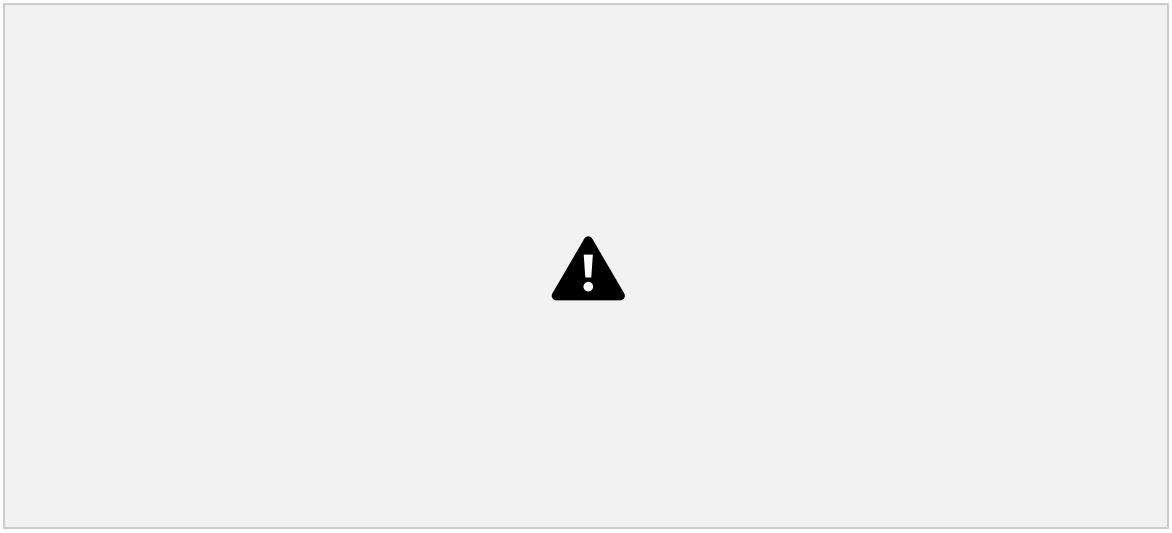


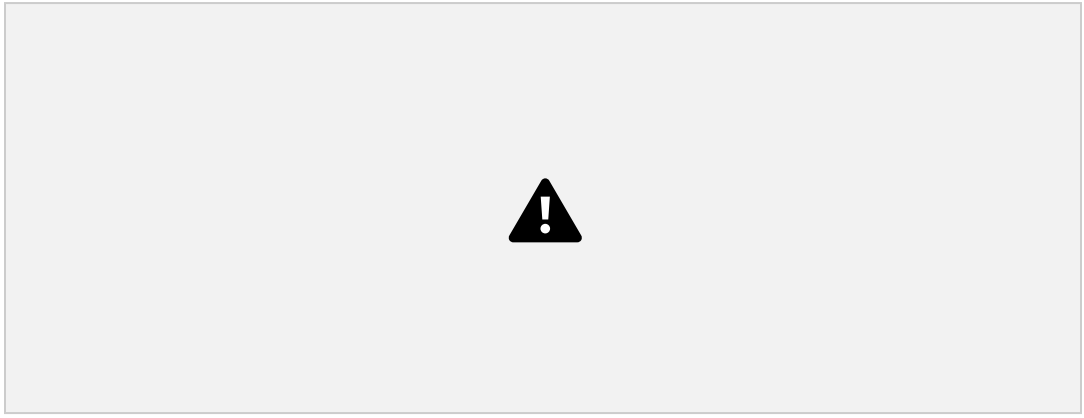


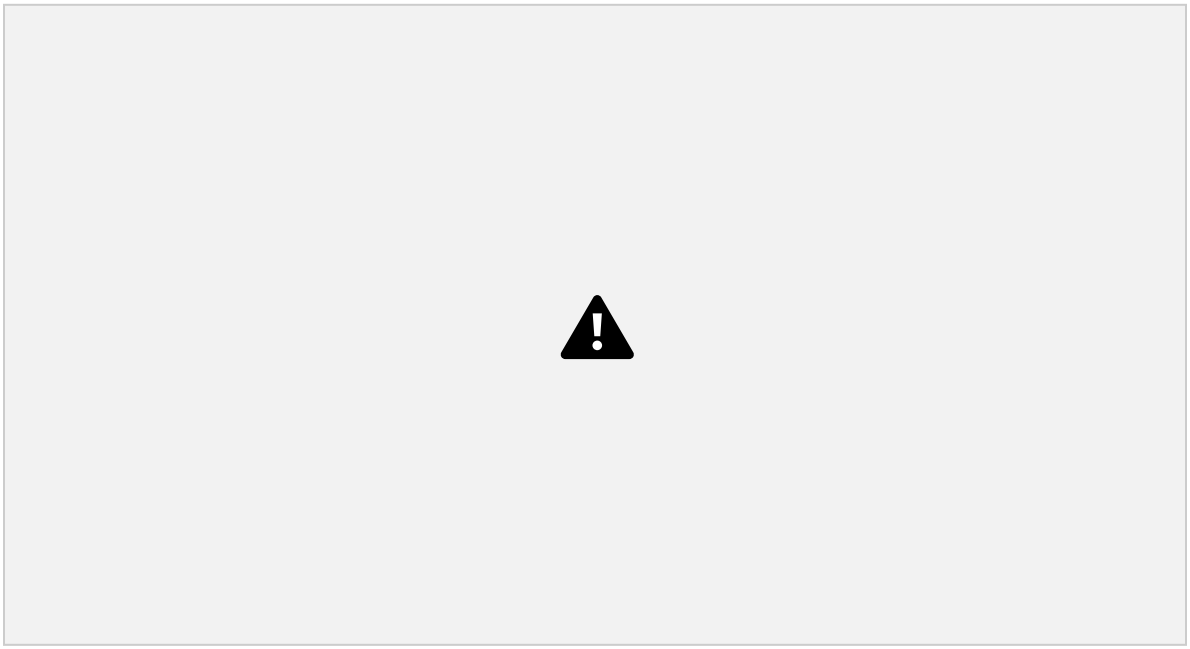


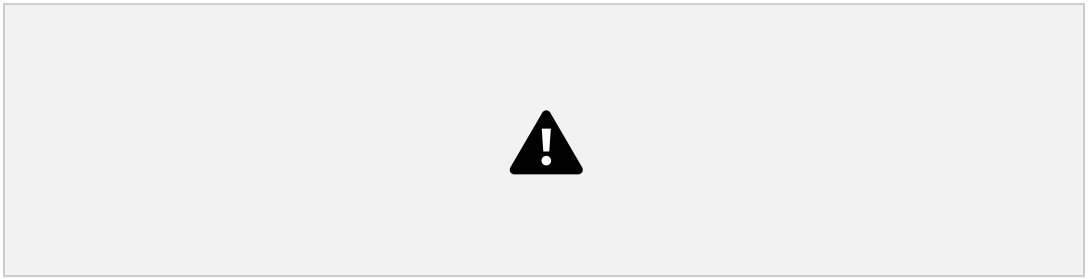






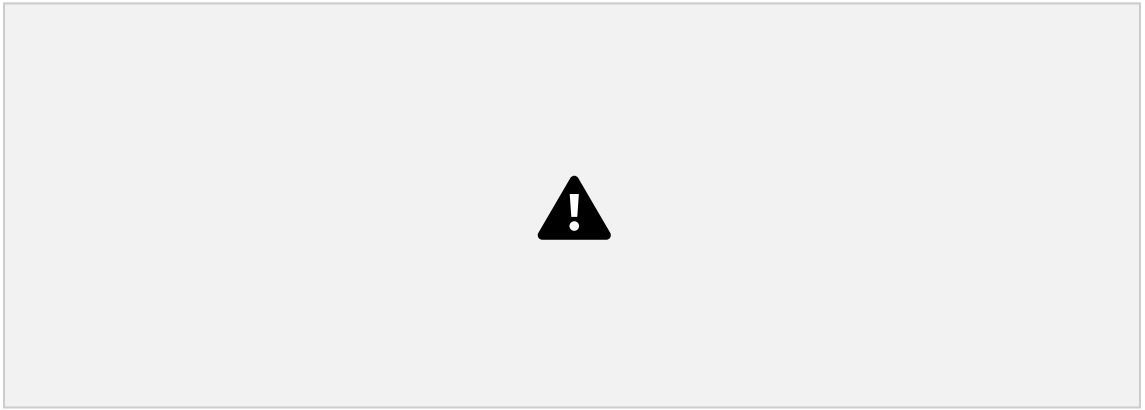


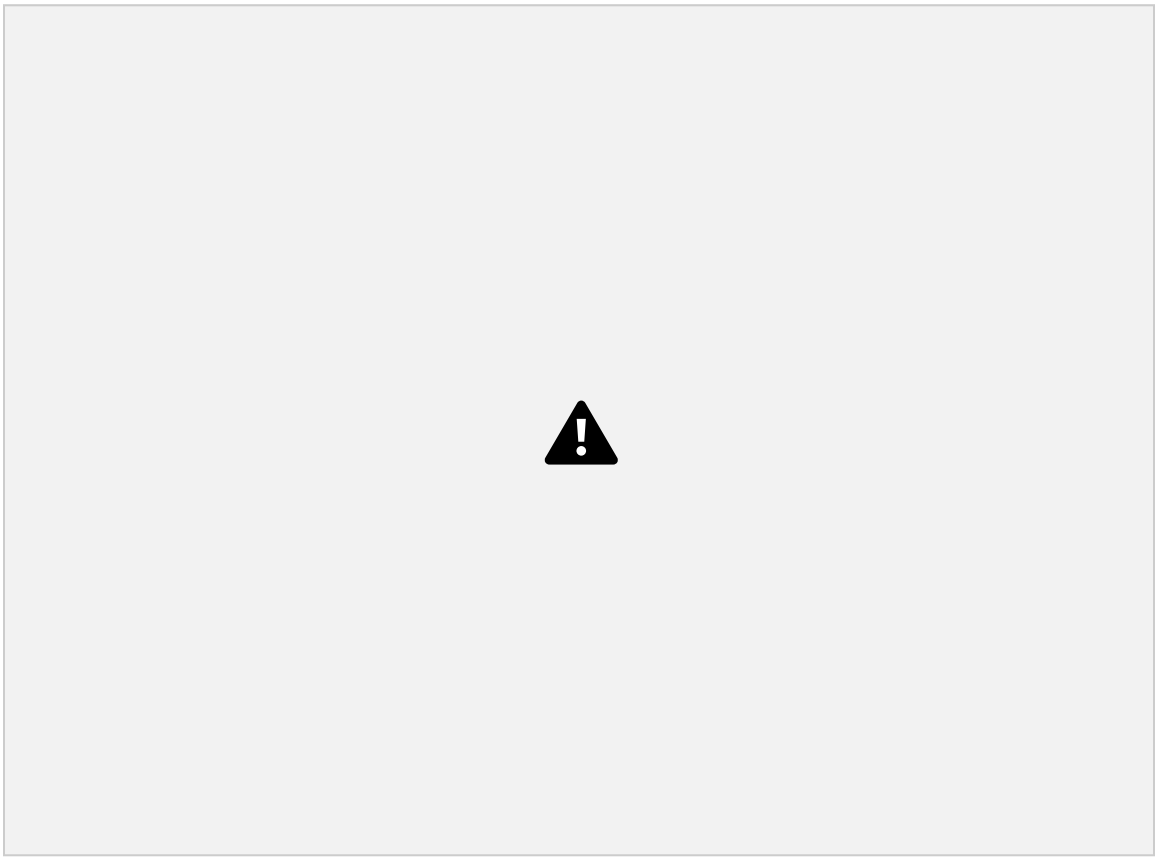




Step 5:-Exchane A[0] with A[2]

UNIT-2





Write a program to implement heap sort

```
#include<iostream.h> void
swap(int *a,int *b)
{
```



```
int t; t=*a;
        *a=*b;
        *b=t;
}
void heapify(int arr[], int n, int i)
{ int largest = i; // Initialize largest as root
   int l = 2*i + 1; // left = 2*i + 1 int r =
   2*i + 2; // right = 2*i + 2

   // If left child is larger than root
   if (l<n &&(arr[l] > arr[largest]))
   largest = l;

   // If right child is larger than largest so
```

```
    far if (r < n &&( arr[r] > arr[largest]))
    largest = r;
```



```
    // If largest is not root
    if (largest != i)
    { swap(&arr[i], &arr[largest]);

        // Recursively heapify the affected sub-tree
        heapify(arr, n, largest);
    }
}

// function to do heap sort void
heapSort(int arr[], int n)
{ int i;
    // Build heap (rearrange array)
    for ( i = n / 2 - 1; i >= 0; i--)
    heapify(arr, n, i);

    // One by one extract an element from heap
```

```
    for ( i=n-1; i>=0; i--)
    {
          // Move current root to end
          swap(&arr[0], &arr[i]);

          // call max heapify on the reduced heap
          heapify(arr, i, 0);
    }
}
/* A utility function to print array of size n */ void
printArray(int arr[], int n)
{ for (int i=0; i<n; ++i) cout
   << arr[i] << " ";
    cout << "\n";
} int main() {
int n,i;
int list[30]; cout<<"enter no of
          elements\n"; cin>>n;
          cout<<"enter "<<n<<" numbers ";
          for(i=0;i<n;i++) cin>>list[i];
          heapSort(list, n); cout << "Sorted
          array is \n";
   printArray(list, n);
return 0;
}
```


Searching: Linear and binary search methods.
Sorting: Bubble sort, selection sort, Insertion sort, Quick sort, Merge sort, Heap sort. Time complexities.
Graphs: Basic terminology, representation of graphs, graph traversal methods DFS, BFS.

ALGORITHMS

Definition: An Algorithm is a method of representing the step-by-step procedure for solving a problem. It is a method of finding the right answer to a problem or to a different problem by breaking the problem into simple cases.

It must possess the following properties:

1. **Finiteness:** An algorithm should terminate in a finite number of steps.
2. **Definiteness:** Each step of the algorithm must be precisely (clearly) stated.
3. **Effectiveness:** Each step must be effective.i.e; it should be easily convertible into program statement and can be performed exactly in a finite amount of time.

4. **Generality:** Algorithm should be complete in itself, so that it can be used to solve all problems of given type for any input data.

5. **Input/Output:** Each algorithm must take zero, one or more quantities as input data and gives one of more output values.

An algorithm can be written in English like sentences or in any standard representations. The algorithm written in English language is called Pseudo code.

Example: To find the average of 3 numbers, the algorithm is as shown below.

Step1: Read the numbers a, b, c, and d. Step2:
Compute the sum of a, b, and c.
Step3: Divide the sum by 3.
Step4: Store the result in variable of d. Step5:
End the program.

Searching: Searching is the technique of finding desired data items that has been stored within some data structure. Data structures can include linked lists, arrays, search trees, hash tables, or various other storage methods. The appropriate search algorithm often depends on the data structure being searched.

Search algorithms can be classified based on their mechanism of searching. They are •
Linear searching
• Binary searching

UNIT -3

Linear or Sequential searching: Linear Search is the most natural searching method and It is very simple but very poor in performance at times .In this method, the searching begins with

searching every element of the list till the required record is found. The elements in the list may be in any order. i.e. sorted or unsorted.

We begin search by comparing the first element of the list with the target element. If it matches, the search ends and position of the element is returned. Otherwise, we will move to next element and compare. In this way, the target element is compared with all the elements until a match occurs. If the match do not occur and there are no more elements to be compared, we conclude that target element is absent in the list by returning position as -1.

For example consider the following list of elements.

55 95 75 85 11 25 65 45

Suppose we want to search for element 11(i.e. Target element = 11). We first compare the target element with first element in list i.e. 55. Since both are not matching we move on the next elements in the list and compare. Finally we will find the match after 5 comparisons at position 4 starting from position 0.

Linear search can be implemented in two ways.i)Non recursive ii)recursive

Algorithm for Linear search

```
Linear_Search (A[ ], N, val , pos )
Step 1 : Set pos = -1 and k = 0
Step 2 : Repeat while k < N
          Begin
 Step 3 : if A[ k ] = val Set
                pos = k
                print pos
                Goto step 5
          End while
Step 4 : print "Value is not present" Step
5 : Exit
```

Non recursive C++ program for Linear search

```
#include<iostream>
using namespace std;
int Lsearch(int list[ ],int n,int key);
int main() {
int n,i,key,list[25],pos; cout<<"enter no
        of elements\n"; cin>>n;
        cout<<"enter "<<n<<" elements ";
        for(i=0;i<n;i++)
```



```
                cin>>list[i];
        cout<<"enter key to search";
        cin>>key;
        pos= Lsearch (list,n,key); if(pos==-
         1) cout<<"\nelement not found"; else


                cout<<"\n element found at index "<<pos;
}
/*function for linear search*/ int
Lsearch(int list[ ],int n,int key)
 { int i,pos=-1;
for(i=0;i<n;i++)
if(key==list[i]) {
pos=i; break;
                }
return pos;
}
```

Run 1:

enter no of elements 5 enter
5 elements 99 88 7 2 4 enter
key to search 7 element
found at index 2

Run 2: enter no of elements
5 enter 5 elements 99 88 7 2
4 enter key to search 88
element not found

Recursive C++ program for Linear search

```
#include<iostream>
using namespace std;
int Rec_Lsearch(int list[ ],int n,int
key); int main() {
int n,i,key,list[25],pos; cout<<"enter no
        of elements\n"; cin>>n;
        cout<<"enter "<<n<<" elements ";
        for(i=0;i<n;i++)
                cin>>list[i];
        cout<<"enter key to search";
        cin>>key;
```