PNS SCHOOL OF ENGINEERING & TECHNOLOGY

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LAB MANUAL FOR

DATA STRUCTURE

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

3RD SEMESTER

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Introduction to Data Structure

<u>Experiment-01</u>

In computer terms, a data structure is a Specific way to store and organize data in a computer's memory so that these data can be used efficiently later. Data may be arranged in many different ways such as the logical or mathematical model for a particular organization of data is termed as a data structure. The variety of a particular data model depends on the two factors -

- Firstly, it must be loaded enough in structure to reflect the actual relationships of the data with the real world object.
- Secondly, the formation should be simple enough so that anyone can efficiently process the data each time it is necessary.

Categories of Data Structure:

The data structure can be sub divided into major types:

- Linear Data Structure
- Non-linear Data Structure

Linear Data Structure:

A data structure is said to be linear if its elements combine to form any specific order. There are basically two techniques of representing such linear structure within memory.

- First way is to provide the linear relationships among all the elements represented by means of linear memory location. These linear structures are termed as arrays.
- The second technique is to provide the linear relationship among all the elements represented by using the concept of pointers or links. These linear structures are termed as linked lists.

The common examples of linear data structure are:

- Arrays
- Queues
- Stacks
- Linked lists

Non linear Data Structure:

This structure is mostly used for representing data that contains a hierarchical relationship among various elements.

Examples of Non Linear Data Structures are listed below:

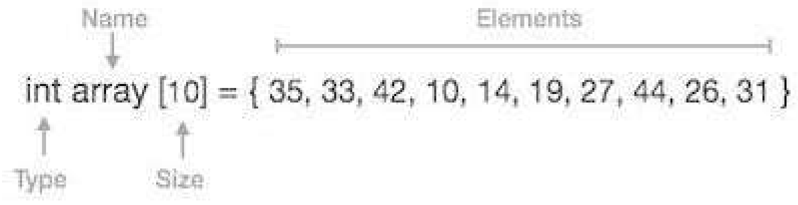
- Graphs
- family of trees and
- table of contents

Tree: In this case, data often contain a hierarchical relationship among various elements. The data structure that reflects this relationship is termed as rooted tree graph or a tree.

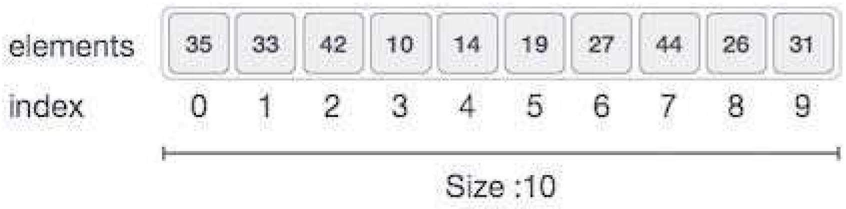
Graph: In this case, data sometimes hold a relationship between the pairs of elements which is not necessarily following the hierarchical structure. Such data structure is termed as a Graph.
Array is a container which can hold a fix number of items and these items should be of the same type. Most of the data structures make use of arrays to implement their algorithms. Following are the important terms to understand the concept of Array.

- **Element** − Each item stored in an array is called an element.
- **Index** − Each location of an element in an array has a numerical index, which is used to identify the element.

Array Representation:(Storage structure)
Arrays can be declared in various ways in different languages. For illustration, let's take C array declaration.



Arrays can be declared in various ways in different languages. For illustration, let's take C array declaration.



As per the above illustration, following are the important points to be considered.

- Index starts with 0.
- Array length is 10 which means it can store 10 elements.
- Each element can be accessed via its index. For example, we can fetch an element at index 6 as 9.

Basic Operations
Following are the basic operations supported by an array.

- **Traverse** − print all the array elements one by one.
- **Insertion** − Adds an element at the given index.
- **Deletion** − Deletes an element at the given index.
- **Search** − Searches an element using the given index or by the value.
- **Update** − Updates an element at the given index.

In C, when an array is initialized with size, then it assigns defaults values to its elements in following order.

Data Type	Default Value
bool	false

char	0
int	0
float	0.0
double	0.0f
void	
wchar_t	0

Insertion Operation

Insert operation is to insert one or more data elements into an array. Based on the requirement, a new element can be added at the beginning, end, or any given index of array.

Here, we see a practical implementation of insertion operation, where we add data at the end of the array −

Algorithm

Let **LA** be a Linear Array (unordered) with **N** elements and **K** is a positive integer such that **K<=N**. Following is the algorithm where ITEM is inserted into the K th position of LA

—

```
1. Start
2. Set J = N
3. Set N = N+1
4. Repeat steps 5 and 6 while J >= K
5. Set LA[J+1] = LA[J]
6. Set J = J-1
7. Set LA[K] = ITEM
8. Stop
```

Example

Following is the implementation of the above algorithm −

```
#include <stdio.h>

main() {
   int LA[] = {1,3,5,7,8};
   int item = 10, k = 3, n = 5;
   int i = 0, j = n;
   printf("The original array elements are :\n");
   for(i = 0; i<n; i++) {
      printf("LA[%d] = %d \n", i, LA[i]);
   }
   n = n + 1;
   while( j >= k) {
      LA[j+1] = LA[j];
      j = j - 1;
   }

   LA[k] = item;
   printf("The array elements after insertion :\n");
   for(i = 0; i<n; i++) {
      printf("LA[%d] = %d \n", i, LA[i]);
   }
```

When we compile and execute the above program, it produces the following result −

Output

```
The original array elements are :
LA[0] = 1
LA[1] = 3
LA[2] = 5
LA[3] = 7
LA[4] = 8
The array elements after insertion :
LA[0] = 1
LA[1] = 3
LA[2] = 5
LA[3] = 10
LA[4] = 7
LA[5] = 8
```

Deletion Operation

Deletion refers to removing an existing element from the array and re-organizing all elements of an array.

Algorithm

Consider **LA** is a linear array with **N** elements and **K** is a positive integer such that **K<=N**. Following is the algorithm to delete an element available at the Kth position of LA.

```
1. Start
2. Set J = K
3. Repeat steps 4 and 5 while J < N
4. Set LA[J] = LA[J + 1]
5. Set J = J+1
6. Set N = N-1
7. Stop
```

Following is the implementation of the above algorithm −

```
#include <stdio.h>

void main() {
  int LA[] = {1,3,5,7,8};
  int k = 3, n = 5;
  int i, j;
    printf("The original array elements are :\n");
  for(i = 0; i<n; i++) {
     printf("LA[%d] = %d \n", i, LA[i]);
  }


  j = k;
  while( j < n) {
     LA[j-1] = LA[j];
     j = j + 1;
  }

  n = n -1;
    printf("The array elements after deletion :\n");
  for(i = 0; i<n; i++) {
     printf("LA[%d] = %d \n", i, LA[i]);
  }
```

When we compile and execute the above program, it produces the following result −
Output

```
The original array elements are :
LA[0] = 1
LA[1] = 3
LA[2] = 5
LA[3] = 7
LA[4] = 8
The array elements after deletion :
LA[0] = 1
LA[1] = 3
LA[2] = 7
LA[3] = 8
```

Search Operation

You can perform a search for an array element based on its value or its index.

Algorithm

Consider **LA** is a linear array with **N** elements and **K** is a positive integer such that **K<=N**. Following is the algorithm to find an element with a value of ITEM using sequential search.

```
1. Start
2. Set J = 0
3. Repeat steps 4 and 5 while J < N
4. IF LA[J] is equal ITEM THEN GOTO STEP 6
5. Set J = J +1
6. PRINT J, ITEM
7. Stop
```

Example

Following is the implementation of the above algorithm −

```
#include <stdio.h>

void main() {
  int LA[] = {1,3,5,7,8};
  int item = 5, n = 5;
  int i = 0, j = 0;
    printf("The original array elements are :\n");
      for(i = 0; i<n; i++) {
    printf("LA[%d] = %d \n", i, LA[i]);
  }

    while( j < n){
     if( LA[j] == item ) {
        break;
     }

    j = j + 1;
  }
```

When we compile and execute the above program, it produces the following result −

Output

```
The original array elements are :
LA[0] = 1
LA[1] = 3
LA[2] = 5
```

```
LA[3] = 7
LA[4] = 8
Found element 5 at position 3
```

Update Operation

Update operation refers to updating an existing element from the array at a given index.

Algorithm

Consider **LA** is a linear array with **N** elements and **K** is a positive integer such that **K<=N**. Following is the algorithm to update an element available at the Kth position of LA.

```
1. Start
2. Set LA[K-1] = ITEM
3. Stop
```

Following is the implementation of the above algorithm −

```c
#include <stdio.h>

void main() {
   int LA[] = {1,3,5,7,8};
   int k = 3, n = 5, item = 10;
   int i, j;
     printf("The original array elements are :\n");
   for(i = 0; i<n; i++) {
      printf("LA[%d] = %d \n", i, LA[i]);
   }


   LA[k-1] = item;
  printf("The array elements after updation :\n");
   for(i = 0; i<n; i++) {
      printf("LA[%d] = %d \n", i, LA[i]);
   }
```

When we compile and execute the above program, it produces the following result −

Output

```
The original array elements are :
LA[0] = 1
LA[1] = 3
LA[2] = 5
LA[3] = 7
LA[4] = 8
```

```
The array elements after updation :
LA[0] = 1
LA[1] = 3
LA[2] = 10
LA[3] = 7
LA[4] = 8
```

Experiment-2

Linear Data Structures:

 Implement stack operations (push, pop, peek) using arrays and linked lists
 Develop programs for applications of stacks (e.g., infix-to-postfix conversion and postfix evaluation)
 Implement queue operations (enqueue, dequeue) using arrays and linked lists
 Write programs for types of queues: circular queues and dequeue

STACK

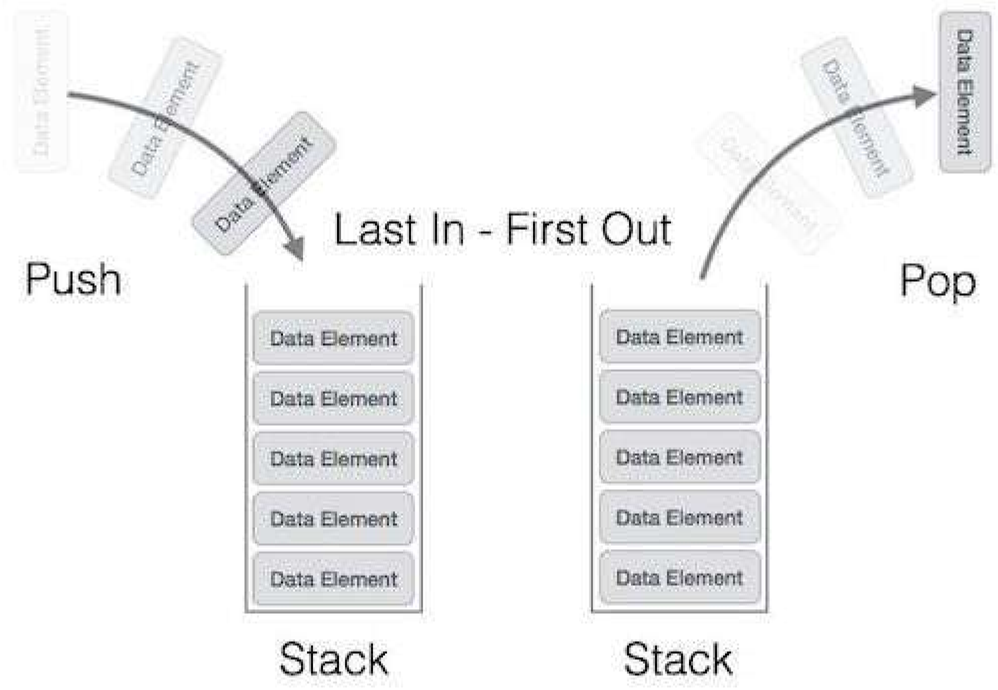
A stack is an Abstract Data Type (ADT), commonly used in most programming languages. It is named stack as it behaves like a real-world stack, for example — a deck of cards or a pile of plates, etc.

example, we can place or remove a card or plate from the top of the stack only. Likewise, Stack ADT allows all data operations at one end only. At any given time, we can only access the top element of a stack.

This feature makes it LIFO data structure. LIFO stands for Last-in-first-out. Here, the element which is placed (inserted or added) last, is accessed first. In stack terminology, insertion operation is called **PUSH** operation and removal operation is called **POP** operation.

Stack Representation

The following diagram depicts a stack and its operations −



A stack can be implemented by means of Array, Structure, Pointer, and Linked List. Stack can either be a fixed size one or it may have a sense of dynamic resizing. Here, we are going to implement stack using arrays, which makes it a fixed size stack implementation.

Basic Operations

Stack operations may involve initializing the stack, using it and then de-initializing it. Apart from these basic stuffs, a stack is used for the following two primary operations −

- **push()** − Pushing (storing) an element on the stack.

pop() − Removing (accessing) an element from the stack. When data is PUSHed onto stack.

To use a stack efficiently, we need to check the status of stack as well. For the same purpose, the following functionality is added to stacks −

- **peek()** − get the top data element of the stack, without removing it.
- **isFull()** − check if stack is full.
- **isEmpty()** − check if stack is empty.

At all times, we maintain a pointer to the last PUSHed data on the stack. As this pointer always represents the top of the stack, hence named **top**. The **top** pointer provides top value of the stack without actually removing it.

First we should learn about procedures to support stack functions −

peek()

Algorithm of peek() function −

```
begin procedure peek return
  stack[top]
```

Implementation of peek() function in C programming language −

Example

```
int peek() {

  return stack[top];
```

isfull()

Algorithm of isfull() function −

```
begin procedure isfull



  if top equals to MAXSIZE
    return true

  else

    return false
```

Implementation of isfull() function in C programming language −

Example

```
bool isfull() {

  if(top == MAXSIZE)
    return true;

  else
```

isempty()

Algorithm of isempty() function −

```
begin procedure isempty



  if top less than 1
     return true

  else

     return false
```

Implementation of isempty() function in C programming language is slightly different. We initialize top at -1, as the index in array starts from 0. So we check if the top is below zero or -1 to determine if the stack is empty. Here's the code −

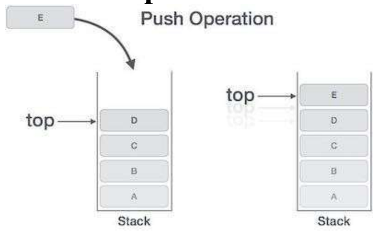
Example

```
bool isempty() {
  if(top == -1)

     return true; else

     return false;
```

Push Operation

The process of putting a new data element onto stack is known as a Push Operation. Push operation involves a series of steps −

- **Step 1** − Checks if the stack is full.
- **Step 2** − If the stack is full, produces an error and exit.
- **Step 3** − If the stack is not full, increments **top** to point next empty space.
- **Step 4** − Adds data element to the stack location, where top is pointing.
- **Step 5** − Returns success.



If the linked list is used to implement the stack, then in step 3, we need to allocate space dynamically.
Algorithm for PUSH Operation
A simple algorithm for Push operation can be derived as follows −

```
begin procedure push: stack, data

```

```
   return null
endif



top ← top + 1
stack[top] ← data
```

Implementation of this algorithm in C, is very easy. See the following code −

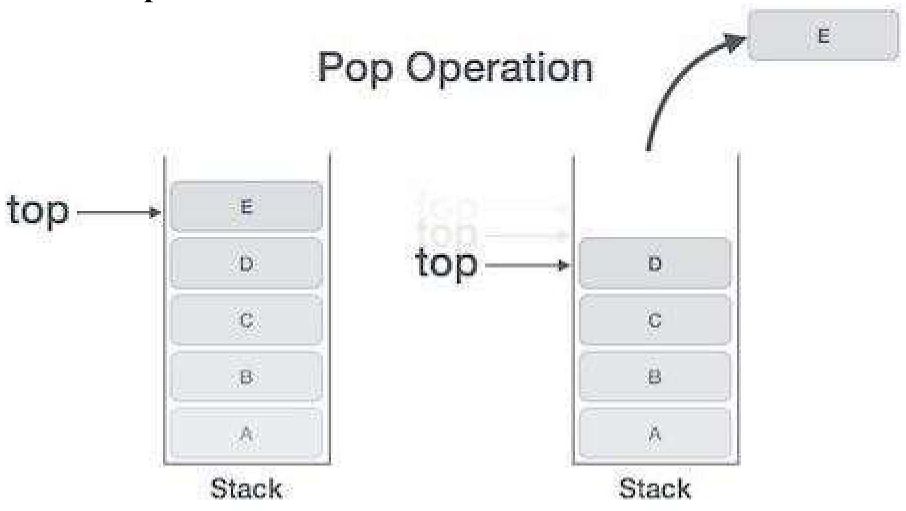
Example

```
void push(int data) {
   if(!isFull()) {

      top = top + 1;
      stack[top] = data;

   } else {

      printf("Could not insert data. Stack is full.\n");
```

Pop Operation

Accessing the content while removing it from the stack, is known as a Pop Operation. In an array implementation of pop() operation, the data element is not actually removed, instead **top** is decremented to a lower position in the stack to point to the next value. But in linked-list implementation, pop() actually removes data element and deallocates memory space. A Pop operation may involve the following steps −

- **Step 1** − Checks if the stack is empty.
- **Step 2** − If the stack is empty, produces an error and exit.
- **Step 3** − If the stack is not empty, accesses the data element at which **top** is pointing.
- **Step 4** − Decreases the value of top by 1.
- **Step 5** − Returns success.



Algorithm for Pop Operation

A simple algorithm for Pop operation can be derived as follows −

```
begin procedure pop: stack



 if stack is empty
    return null

 endif



 data ← stack[top]
```

Implementation of this algorithm in C, is as follows −

Example

```
int pop(int data) {



 if(!isempty()) {

    data = stack[top];
    top = top - 1; return
    data;

 } else {
```

Stack Applications

Three applications of stacks are presented here. These examples are central to many activities that a computer must do and deserve time spent with them.

1. Expression evaluation
2. Backtracking (game playing, finding paths, exhaustive searching)
3. Memory management, run-time environment for nested language features.

Expression evaluation

In particular we will consider arithmetic expressions. Understand that there are boolean and logical expressions that can be evaluated in the same way. Control structures can also be treated similarly in a compiler.

This study of arithmetic expression evaluation is an example of problem solving where you solve a simpler problem and then transform the actual problem to the simpler one.

Aside: *The NP-Complete problem*. There are a set of apparently intractable problems: finding the shortest route in a graph (Traveling Salesman Problem), bin packing, linear programming, etc. that are similar enough that if a polynomial solution is ever found (exponential solutions abound) for one of these problems, then the solution can be applied to all problems.

Infix, Prefix and Postfix Notation

We are accustomed to write arithmetic expressions with the operation between the two operands: a+b or c/d. If we write a+b*c, however, we have to apply precedence rules to avoid the ambiguous evaluation (add first or multiply first?).

There's no real reason to put the operation between the variables or values. They can just as well precede or follow the operands. You should note the advantage of prefix and postfix: the need for precedence rules and parentheses are eliminated.

Infix	Prefix	Postfix
a + b	+ a b	a b +
a + b * c	+ a * b c	a b c * +
(a + b) * (c - d)	* + a b - c d	a b + c d - *
b * b - 4 * a * c		
40 - 3 * 5 + 1		

Postfix expressions are easily evaluated with the aid of a stack.

Infix, Prefix and Postfix Notation KEY

Infix	Prefix	Postfix
a + b	+ a b	a b +
a + b * c	+ a * b c	a b c * +
(a + b) * (c - d)	* + a b - c d	a b + c d - *
b * b - 4 * a * c	*- * b b * * 4 a c*	*b b * 4 a * c * -*
40 - 3 * 5 + 1 = *26*	*+ - 40 * 3 5 1*	*40 3 5 * - 1 +*

Postfix Evaluation Algorithm

Assume we have a string of operands and operators, an informal, by hand process is

1. Scan the expression left to right
2. Skip values or variables (operands)
3. When an operator is found, apply the operation to the preceding two operands
4. Replace the two operands and operator with the calculated value (three symbols are replaced with one operand)
5. Continue scanning until only a value remains--the result of the expression

The time complexity is O(n) because each operand is scanned once, and each operation is performed once.

A more formal algorithm:

```
create a new stack
while(input  stream  is  not  empty){
   token  =  getNextToken();  if(token
   instanceof operand){
       push(token);
   } else if (token instance of operator) op2
       = pop();
       op1 = pop();
       result    =    calc(token,    op1,    op2);
       push(result);
   }

}

return pop();
```

Demonstration with 2 3 4 + * 5 -

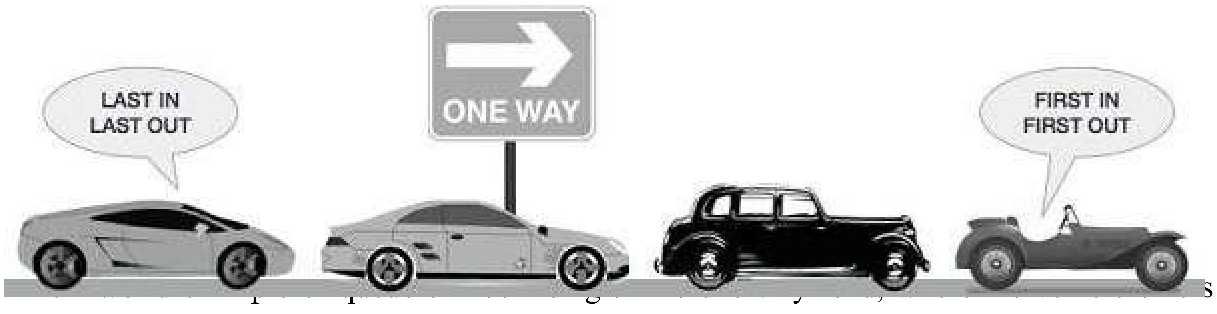
Infix transformation to Postfix

This process uses a stack as well. We have to hold information that's expressed inside parentheses while scanning to find the closing ')'. We also have to hold information on operations that are of lower precedence on the stack. The algorithm is:

1. Create an empty stack and an empty postfix output string/stream
2. Scan the infix input string/stream left to right
3. If the current input token is an operand, simply append it to the output string (note the examples above that the operands remain in the same order)
4. If the current input token is an operator, pop off all operators that have equal or higher

QUEUE

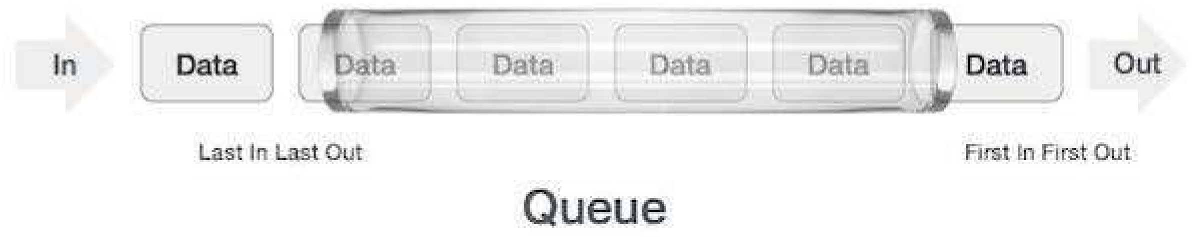
Queue is an abstract data structure, somewhat similar to Stacks. Unlike stacks, a queue is open at both its ends. One end is always used to insert data (enqueue) and the other is used to remove data (dequeue). Queue follows First-In-First-Out methodology, i.e., the data item stored first will be accessed first.



s first, exits first. More real-world examples can be seen as queues at the ticket windows and bus- stops.

Queue Representation

As we now understand that in queue, we access both ends for different reasons. The following diagram given below tries to explain queue representation as data structure −



As in stacks, a queue can also be implemented using Arrays, Linked-lists, Pointers and Structures. For the sake of simplicity, we shall implement queues using one-dimensional array. **Basic Operations**
Queue operations may involve initializing or defining the queue, utilizing it, and then completely erasing it from the memory. Here we shall try to understand the basic operations associated with queues −

- **enqueue()** − add (store) an item to the queue.
- **dequeue()** − remove (access) an item from the queue.

Few more functions are required to make the above-mentioned queue operation efficient. These are −

- **peek()** − Gets the element at the front of the queue without removing it.
- **isfull()** − Checks if the queue is full.
- **isempty()** − Checks if the queue is empty.

In queue, we always dequeue (or access) data, pointed by **front** pointer and while enqueing (or storing) data in the queue we take help of **rear** pointer.
Let's first learn about supportive functions of a queue −
peek()

This function helps to see the data at the **front** of the queue. The algorithm of peek() function is as follows −

Algorithm

```
begin procedure peek return
  queue[front]

end procedure
```

Implementation of peek() function in C programming language −

Example

```
int peek() {

  return queue[front];
```

isfull()

As we are using single dimension array to implement queue, we just check for the rear pointer to reach at MAXSIZE to determine that the queue is full. In case we maintain the queue in a circular linked-list, the algorithm will differ. Algorithm of isfull() function −

Algorithm

```
begin procedure isfull



  if rear equals to MAXSIZE return
    true

  else

    return false
```

Implementation of isfull() function in C programming language −

Example

```
bool isfull() {

  if(rear == MAXSIZE - 1)
    return true;

  else
```

isempty()

Algorithm of isempty() function −

Algorithm

```
begin procedure isempty


  if front is less than MIN  OR front is greater than rear return
    true
```

```
else

   return false
endif
```

If the value of **front** is less than MIN or 0, it tells that the queue is not yet initialized, hence empty. Here's the C programming code –

Example

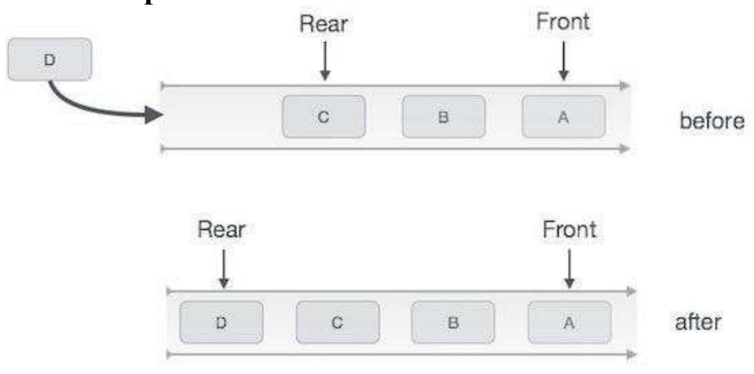
```
bool isempty() {

  if(front < 0 || front > rear)
     return true;

  else
```

Enqueue Operation

Queues maintain two data pointers, **front** and **rear**. Therefore, its operations are comparatively difficult to implement than that of stacks.

The following steps should be taken to enqueue (insert) data into a queue –

- **Step 1** – Check if the queue is full.
- **Step 2** – If the queue is full, produce overflow error and exit.
- **Step 3** – If the queue is not full, increment **rear** pointer to point the next empty space.
- **Step 4** – Add data element to the queue location, where the rear is pointing.
- **Step 5** – return success.



Queue Enqueue

Sometimes, we also check to see if a queue is initialized or not, to handle any unforeseen situations. Algorithm for enqueue operation

```
procedure enqueue(data)
```

```
  endif



  rear ← rear + 1
  queue[rear] ← data
  return true
```

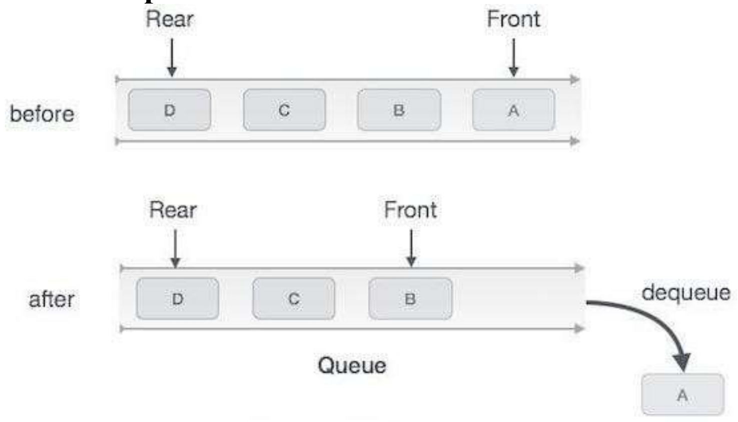
Implementation of enqueue() in C programming language –
Example

```
int enqueue(int data)
  if(isfull())

    return 0;



  rear = rear + 1; queue[rear]
  = data;
```

Dequeue Operation

Accessing data from the queue is a process of two tasks – access the data where **front** is pointing and remove the data after access. The following steps are taken to perform **dequeue** operation –

- **Step 1** – Check if the queue is empty.
- **Step 2** – If the queue is empty, produce underflow error and exit.
- **Step 3** – If the queue is not empty, access the data where **front** is pointing.
- **Step 4** – Increment **front** pointer to point to the next available data element.
- **Step 5** – Return success.



Queue Dequeue

Algorithm for dequeue operation

```
procedure dequeue
```

```
if queue is empty
   return underflow

end if



data = queue[front]
front ← front + 1
return true
```

Implementation of dequeue() in C programming language −
Example

```
int dequeue() {
   if(isempty())

      return 0;



   int data = queue[front];
   front = front + 1;
```

Experiment-3

Linked Lists:
□ **Implement singly linked list operations (insertion, deletion, traversal).**
□ **Write programs to create and manipulate circular and doubly linked lists**
□ **Implement stack and queue operations using linked lists.**

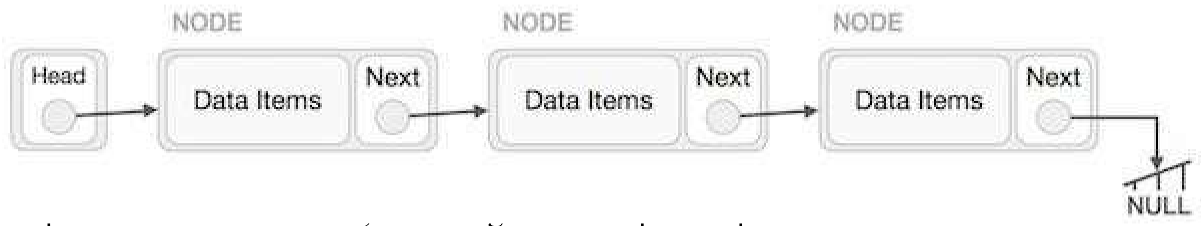
LINKED LIST

A linked list is a sequence of data structures, which are connected together via links. Linked List is a sequence of links which contains items. Each link contains a connection to another link. Linked list is the second most-used data structure after array. Following are the important terms to understand the concept of Linked List.

- **Link** − Each link of a linked list can store a data called an element.
- **Next** − Each link of a linked list contains a link to the next link called Next.
- **LinkedList** − A Linked List contains the connection link to the first link called First.

Linked List Representation

Linked list can be visualized as a chain of nodes, where every node points to the next node.



- Linked List contains a link element called first.

- Each link carries a data field(s) and a link field called next.
- Each link is linked with its next link using its next link.
- Last link carries a link as null to mark the end of the list.

Types of Linked List

Following are the various types of linked list.

- **Simple Linked List** − Item navigation is forward only.
- **Doubly Linked List** − Items can be navigated forward and backward.
- **Circular Linked List** − Last item contains link of the first element as next and the first element has a link to the last element as previous.

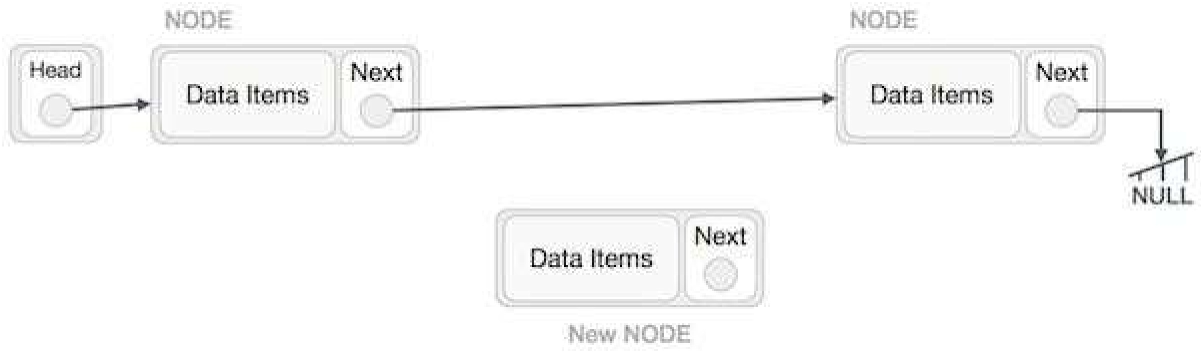
Basic Operations

Following are the basic operations supported by a list.

- **Insertion** − Adds an element at the beginning of the list.
- **Deletion** − Deletes an element at the beginning of the list.
- **Display** − Displays the complete list.
- **Search** − Searches an element using the given key.
- **Delete** − Deletes an element using the given key.

Insertion Operation

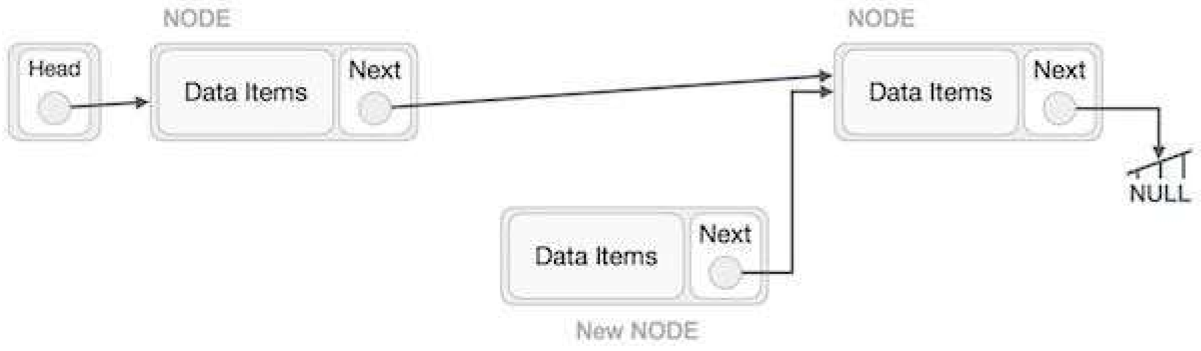
Adding a new node in linked list is a more than one step activity. We shall learn this with diagrams here. First, create a node using the same structure and find the location where it has to be inserted.



Imagine that we are inserting a node **B** (NewNode), between **A** (LeftNode) and **C** (RightNode). Then point B.next to C −

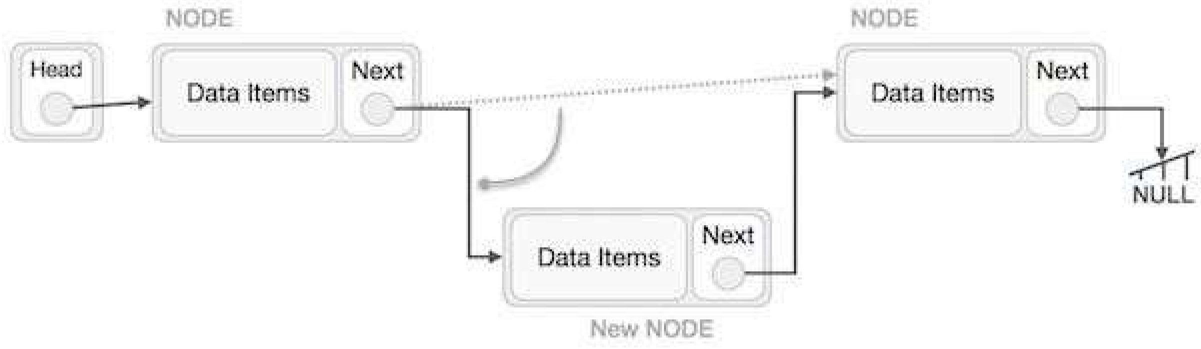
```
NewNode.next −> RightNode;
```

It should look like this −

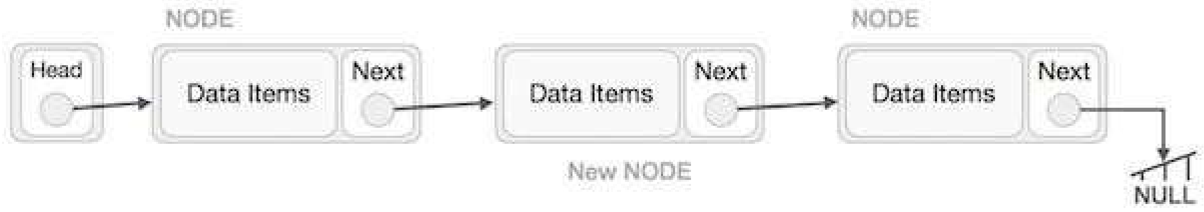


Now, the next node at the left should point to the new node.

```
LeftNode.next −> NewNode;
```



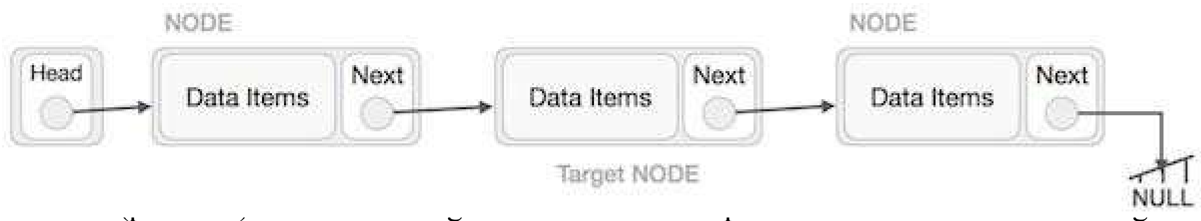
This will put the new node in the middle of the two. The new list should look like this −



Similar steps should be taken if the node is being inserted at the beginning of the list. While inserting it at the end, the second last node of the list should point to the new node and the new node will point to NULL.

Deletion Operation

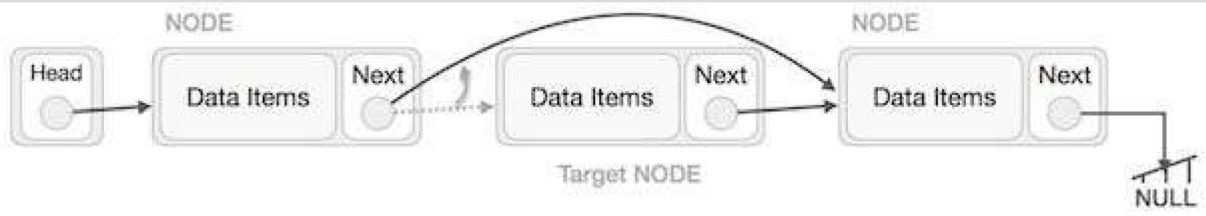
Deletion is also a more than one step process. We shall learn with pictorial representation. First, locate the target node to be removed, by using searching algorithms.



ode

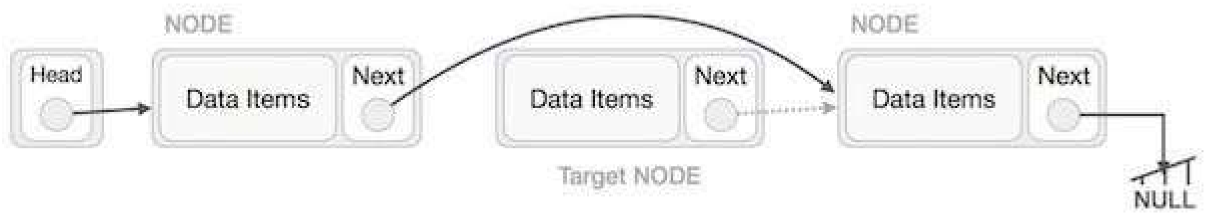
–

```
LeftNode.next −> TargetNode.next;
```

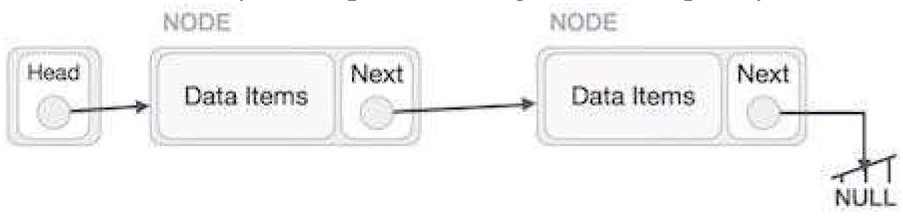


This will remove the link that was pointing to the target node. Now, using the following code,

```
TargetNode.next −> NULL;
```

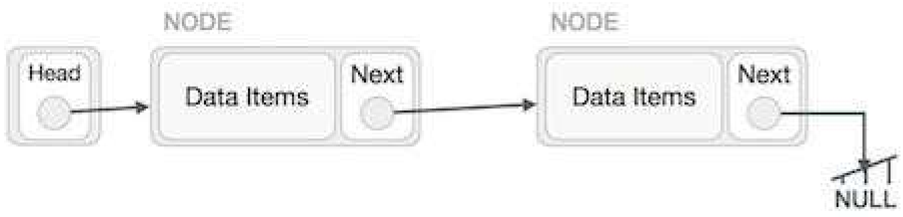


We need to use the deleted node. We can keep that in memory otherwise we can simply deallocate memory and wipe off the target node completely.

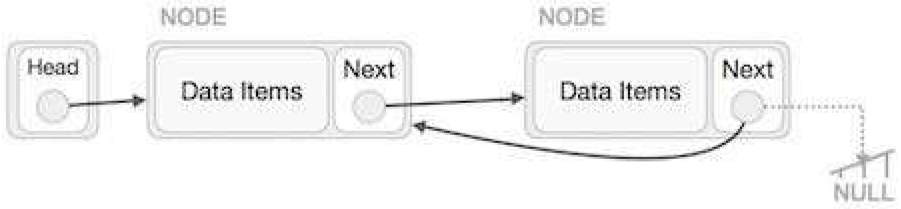


Reverse Operation

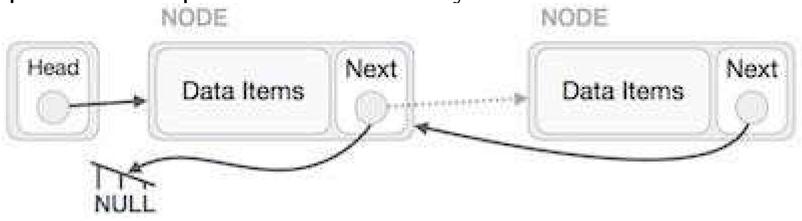
This operation is a thorough one. We need to make the last node to be pointed by the head node and reverse the whole linked list.



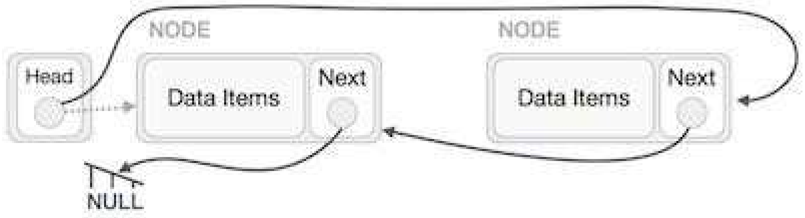
First, we traverse to the end of the list. It should be pointing to NULL. Now, we shall make it point to its previous node −



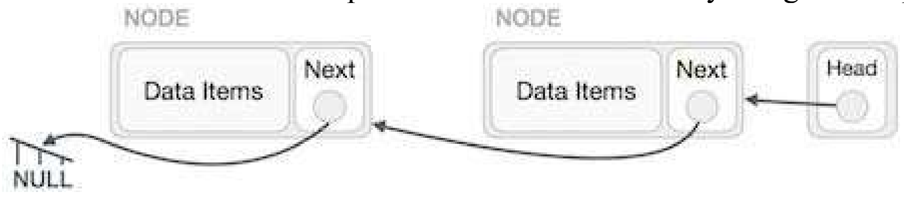
We have to make sure that the last node is not the lost node. So we'll have some temp node, which looks like the head node pointing to the last node. Now, we shall make all left side nodes point to their previous nodes one by one.



Except the node (first node) pointed by the head node, all nodes should point to their predecessor, making them their new successor. The first node will point to NULL.



We'll make the head node point to the new first node by using the temp node.



The linked list is now reversed.

Program:

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <stdbool.h>

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

```
struct node *head = NULL;
struct node *current = NULL;

//display the list
void printList() {
   struct node *ptr = head;
   printf("\n[ ");

   //start from the beginning
   while(ptr != NULL) {
      printf("(%d,%d)      ",ptr->key,ptr->data);
      ptr = ptr->next;
   }


   printf(" ]");
}


//insert link at the first location void
insertFirst(int key, int data) {
   //create a link
   struct node *link = (struct node*) malloc(sizeof(struct node));

   link->key = key;
   link->data = data;

   //point it to old first node
   link->next = head;

   //point first to new first node
   head = link;
}


//delete first item
struct node* deleteFirst() {

   //save reference to first link struct
   node *tempLink = head;

   //mark next to first link as first
   head = head->next;

   //return the deleted link
   return tempLink;
}


//is list empty bool
isEmpty() {
   return head == NULL;
}


int length() {
   int length = 0;
   struct node *current;

   for(current = head; current != NULL; current = current->next) {
      length++;
   }


   return length;
}


//find a link with given key struct
node* find(int key) {

   //start from the first link struct
   node* current = head;

   //if list is empty if(head
   == NULL) {
      return NULL;
   }


   //navigate      through      list
   while(current->key != key) {

      //if it is last node
      if(current->next == NULL) {
         return NULL;
      } else {
         //go to next link
         current = current->next;
      }

   }
   //if data found, return the current Link
   return current;
}

//delete a link with given key
struct node* delete(int key) {

   //start from the first link struct
   node* current = head;
   struct node* previous = NULL;

   //if list is empty if(head
   == NULL) {
      return NULL;
   }

   //navigate through list
   while(current->key != key) {

      //if it is last node
      if(current->next == NULL) {
         return NULL;
      } else {
         //store reference to current link
         previous = current;
         //move to next link current
         = current->next;
      }

   }

   //found a match, update the link if(current
   == head) {
      //change first to point to next link head
      = head->next;
   } else {
      //bypass the current link previous-
      >next = current->next;
   }

   return current;
}
```

```
void sort() {

   int  i,  j,  k,  tempKey,  tempData;
   struct node *current;
   struct node *next;

   int size = length(); k
   = size ;

   for  (  i  =  0  ;  i  <  size  -  1  ;  i++,  k--  )  {
      current = head;
      next = head->next;

      for ( j = 1 ; j < k ; j++ ) {

         if  (  current->data  >  next->data  )  {
            tempData       =       current->data;
            current->data  =  next->data;  next-
            >data = tempData;

            tempKey    =    current->key;
            current->key    =   next->key;
            next->key = tempKey;
         }


         current    =    current->next;
         next = next->next;
      }

   }

}


void   reverse(struct   node**   head_ref)   {
   struct node* prev   = NULL;
   struct node* current = *head_ref; struct
   node* next;

   while (current != NULL) {
      next     =     current->next;
      current->next     =     prev;
      prev = current;
      current = next;
   }
   *head_ref = prev;
}


void main() {
   insertFirst(1,10);
   insertFirst(2,20);
   insertFirst(3,30);
   insertFirst(4,1);
   insertFirst(5,40);
   insertFirst(6,56);

   printf("Original List: ");

   //print list
   printList();

   while(!isEmpty()) {
      struct node *temp = deleteFirst();
      printf("\nDeleted value:");
      printf("(%d,%d) ",temp->key,temp->data);
   }


   printf("\nList after deleting all items: ");
   printList();
   insertFirst(1,10);
   insertFirst(2,20);
   insertFirst(3,30);
   insertFirst(4,1);
   insertFirst(5,40);
   insertFirst(6,56);

   printf("\nRestored List: ");
   printList();
   printf("\n");

   struct node *foundLink = find(4);

   if(foundLink != NULL) {
      printf("Element found: ");
      printf("(%d,%d) ",foundLink->key,foundLink->data);
      printf("\n");
   } else {
      printf("Element not found.");
   }


   delete(4);
   printf("List after deleting an item: ");
   printList();
   printf("\n");
   foundLink = find(4);

   if(foundLink != NULL) {
      printf("Element found: ");
      printf("(%d,%d) ",foundLink->key,foundLink->data);
      printf("\n");
   } else {
      printf("Element not found.");
   }


   printf("\n");
   sort();

   printf("List after sorting the data: ");
   printList();

   reverse(&head);
   printf("\nList after reversing the data: ");
   printList();
```

If we compile and run the above program, it will produce the following result − Output

```
Original List:
[ (6,56) (5,40) (4,1) (3,30) (2,20) (1,10) ]
Deleted value:(6,56)
Deleted value:(5,40)
Deleted value:(4,1)
Deleted value:(3,30)
Deleted value:(2,20)
Deleted value:(1,10)
List after deleting all items:
[ ]

Restored List:
[ (6,56) (5,40) (4,1) (3,30) (2,20) (1,10) ]
```

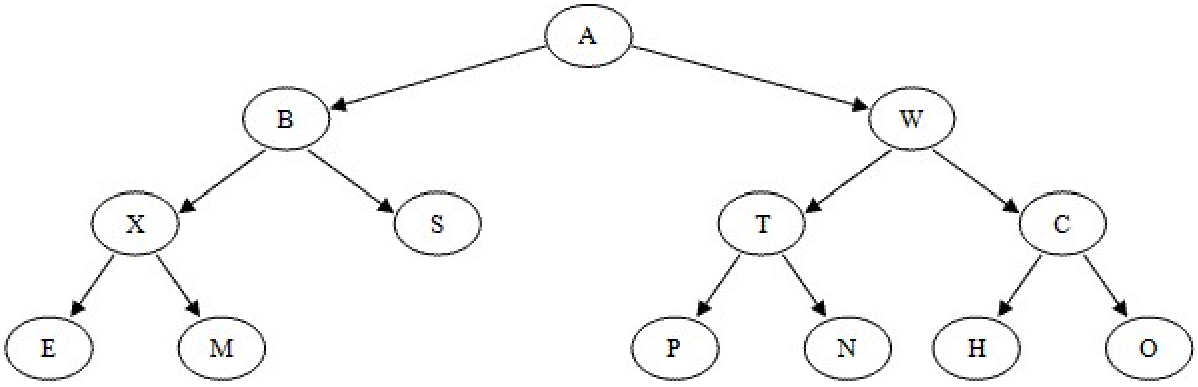
```
Element found: (4,1)
List after deleting an item:
[ (6,56) (5,40) (3,30) (2,20) (1,10) ]
Element not found.
List after sorting the data:
[ (1,10) (2,20) (3,30) (5,40) (6,56) ]
List after reversing the data:
[ (6,56) (5,40) (3,30) (2,20) (1,10) ]
```

Experiment-4
Non-Linear Data Structures:
 Implement binary tree operations (insertion, deletion, traversal)
 Develop programs for types of binary trees (binary search tree, AVL tree)

Binary Tree

A *binary tree* consists of a finite set of nodes that is either empty, or consists of one specially designated node called the *root* of the binary tree, and the elements of two disjoint binary trees called the *left subtree* and *right subtree* of the root.
Note that the definition above is recursive: we have defined a binary tree in terms of binary trees. This is appropriate since recursion is an innate characteristic of tree structures.

Diagram 1: A binary tree



Binary Tree Terminology

Tree terminology is generally derived from the terminology of family trees (specifically, the type of family tree called a *lineal chart*).

- Each root is said to be the *parent* of the roots of its subtrees.

- Two nodes with the same parent are said to be *siblings*; they are the *children* of their parent.
- The root node has no parent.
- A great deal of tree processing takes advantage of the relationship between a parent and its children, and we commonly say a *directed edge* (or simply an *edge*) extends from a parent to its children. Thus edges connect a root with the roots of each subtree. An *undirected edge* extends in both directions between a parent and a child.
- *Grandparent* and *grandchild* relations can be defined in a similar manner; we could also extend this terminology further if we wished (designating nodes as cousins, as an uncle or aunt, etc.).

Other Tree Terms

- The number of subtrees of a node is called the *degree* of the node. In a binary tree, all nodes have degree 0, 1, or 2.
- A node of degree zero is called a *terminal node* or *leaf node*.
- A non-leaf node is often called a *branch node*.
- The *degree of a tree* is the maximum degree of a node in the tree. A binary tree is degree 2.
- A *directed path* from node *n1* to *nk* is defined as a sequence of nodes *n1*, *n2*, ..., *nk* such that *ni* is the parent of *ni*+1 for 1 <= *i* < *k*. An *undirected path* is a similar sequence of undirected edges. The length of this path is the number of edges on the path, namely *k* — 1 (i.e., the number of nodes — 1). There is a path of length zero from every node to itself. Notice that in a binary tree there is exactly one path from the root to each node.
- The *level* or *depth* of a node with respect to a tree is defined recursively: the level of the root is zero; and the level of any other node is one higher than that of its parent. Or to put it another way, the level or depth of a node *ni* is the length of the unique path from the root to *ni*.
- The *height* of *ni* is the length of the longest path from *ni* to a leaf. Thus all leaves in the tree are at height 0.
- The *height of a tree* is equal to the height of the root. The *depth of a tree* is equal to the level or depth of the deepest leaf; this is always equal to the height of the tree.
- If there is a directed path from *n1* to *n2*, then *n1* is an ancestor of *n2* and *n2* is a

descendant of *n1*.

precedence and append them to the output string; push the operator onto the stack. The order of popping is the order in the output.

5. If the current input token is '(', push it onto the stack
6. If the current input token is ')', pop off all operators and append them to the output string until a '(' is popped; discard the '('.
7. If the end of the input string is found, pop all operators and append them to the output string.

This algorithm doesn't handle errors in the input, although careful analysis of parenthesis or lack of parenthesis could point to such error determination.

Apply the algorithm to the above expressions.

Binary Search Tree (BST)

A Binary Search Tree (BST) is a tree in which all the nodes follow the below-mentioned properties −

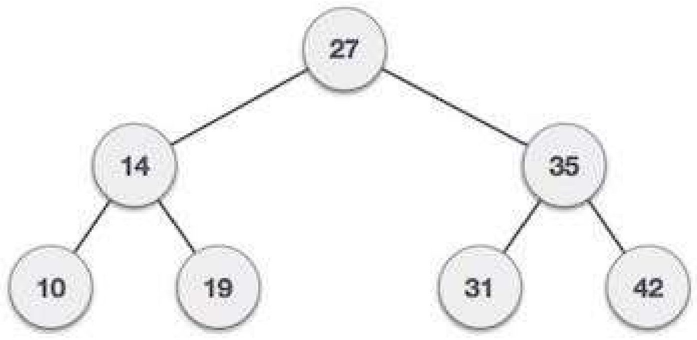
- The left sub-tree of a node has a key less than or equal to its parent node's key.
- The right sub-tree of a node has a key greater than to its parent node's key. Thus, BST divides all its sub-trees into two segments; the left sub-tree and the right sub-tree and can be defined as −

```
left_subtree (keys)  ≤  node (key)  ≤  right_subtree (keys)
```

Representation

BST is a collection of nodes arranged in a way where they maintain BST properties. Each node has a key and an associated value. While searching, the desired key is compared to the keys in BST and if found, the associated value is retrieved.

Following is a pictorial representation of BST −



We observe that the root node key (27) has all less-valued keys on the left sub-tree and the higher valued keys on the right sub-tree.

Basic Operations

Following are the basic operations of a tree −

- **Search** − Searches an element in a tree.
- **Insert** − Inserts an element in a tree.
- **Pre-order Traversal** − Traverses a tree in a pre-order manner.
- **In-order Traversal** − Traverses a tree in an in-order manner.
- **Post-order Traversal** − Traverses a tree in a post-order manner. Node

Define a node having some data, references to its left and right child nodes.

```
struct node {
   int data;
   struct node *leftChild;
   struct node *rightChild;
};
```

Search Operation

Whenever an element is to be searched, start searching from the root node. Then if the data is less than the key value, search for the element in the left subtree. Otherwise, search for the element in the right subtree. Follow the same algorithm for each node.

Algorithm

```
struct node* search(int data){
   struct node *current = root;
   printf("Visiting elements: ");

   while(current->data != data){

      if(current != NULL) {
         printf("%d ",current->data);

         //go to left tree
         if(current->data > data){
            current = current->leftChild;
         }  //else go to right tree
         else {
            current = current->rightChild;
         }


         //not found
         if(current == NULL){
            return NULL;
         }
      }
   }

   return current;
```

Insert Operation

Whenever an element is to be inserted, first locate its proper location. Start searching from the root node, then if the data is less than the key value, search for the empty location in the left subtree and insert the data. Otherwise, search for the empty location in the right subtree and insert the data.

Algorithm

```
void insert(int data) {
   struct node *tempNode = (struct node*) malloc(sizeof(struct node));
   struct node *current;
   struct node *parent;

   tempNode->data = data;
   tempNode->leftChild = NULL;
   tempNode->rightChild = NULL;

   //if tree is empty
   if(root == NULL) {
      root = tempNode;
   } else {
      current = root;
      parent = NULL;
   while(1) {
      parent = current;

      //go to left of the tree
      if(data < parent->data) {
         current = current->leftChild;
         //insert to the left

         if(current == NULL) {
            parent->leftChild = tempNode;
            return;
         }
      }  //go to right of the tree
      else {
         current = current->rightChild;

         //insert to the right
         if(current == NULL) {
            parent->rightChild = tempNode;
            return;
         }
      }
   }
}
```

Graphs Terminology
A **graph** consists of:

- A set, V, of **vertices** (nodes)
- A collection, E, of pairs of vertices from V called **edges** (arcs)

Edges, also called arcs, are represented by ***(u, v)*** and are either:

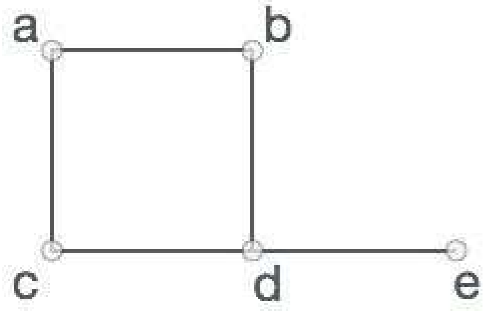
Directed if the pairs are ordered ***(u, v)***

u the **origin**

v the **destination**

Undirected if the pairs are unordered

A graph is a pictorial representation of a set of objects where some pairs of objects are connected by links. The interconnected objects are represented by points termed as **vertices**, and the links that connect the vertices are called **edges**.
Formally, a graph is a pair of sets **(V, E)**, where **V** is the set of vertices and **E**is the set of edges, connecting the pairs of vertices. Take a look at the following graph −



In the above graph, V
= {a, b, c, d, e}
E = {ab, ac, bd, cd, de}
Then a **graph** can be:
Directed graph (di-graph) if all the edges are directed **Undirected graph** (graph) if all the edges are undirected **Mixed graph** if edges are both directed or undirected **Illustrate terms on graphs**

End-vertices of an edge are the **endpoints** of the edge.

Two vertices are **adjacent** if they are endpoints of the same edge.
An edge is **incident** on a vertex if the vertex is an endpoint of the edge.
Outgoing edges of a vertex are directed edges that the vertex is the origin.
Incoming edges of a vertex are directed edges that the vertex is the destination.
Degree of a vertex, *v*, denoted *deg*(*v*) is the number of incident edges.
Out-degree, *outdeg*(*v*), is the number of outgoing edges.

In-degree, *indeg*(*v*), is the number of incoming edges.

Parallel edges or multiple edges are edges of the same type and end-vertices
Self-loop is an edge with the end vertices the same vertex

Simple graphs have **no** parallel edges or self-loops

Properties
If graph, G, has m edges **then** $\Sigma v \in G\ deg(v) = 2m$

If a di-graph, G, has m edges **then**

$\Sigma v \in G\ indeg(v) = m = \Sigma v \in G\ outdeg(v)$

If a **simple** graph, G, has m edges and n vertices:

If G is also directed **then** $m \leq n(n-1)$

If G is also undirected **then** $m \leq n(n-1)/2$

So a simple graph with n vertices has $O(n^2)$ edges at most
More Terminology
Path is a sequence of alternating vetches and edges such that each successive vertex is connected by the edge. Frequently only the vertices are listed especially if there are no parallel edges.
Cycle is a path that starts and end at the same vertex.
Simple path is a path with distinct vertices. **Directed path** is a path of only directed edges **Directed cycle** is a cycle of only directed edges. **Sub-graph** is a subset of vertices and edges.

Spanning sub-graph contains all the vertices.

Connected graph has all pairs of vertices connected by at least one path. **Connected component** is the maximal connected sub-graph of a unconnected graph. **Forest** is a graph without cycles.

Tree is a connected forest (previous type of trees are called rooted trees, these are free trees)
Spanning tree is a spanning subgraph that is also a tree.

More Properties
If G is an **undirected** graph with n vertices and m edges:

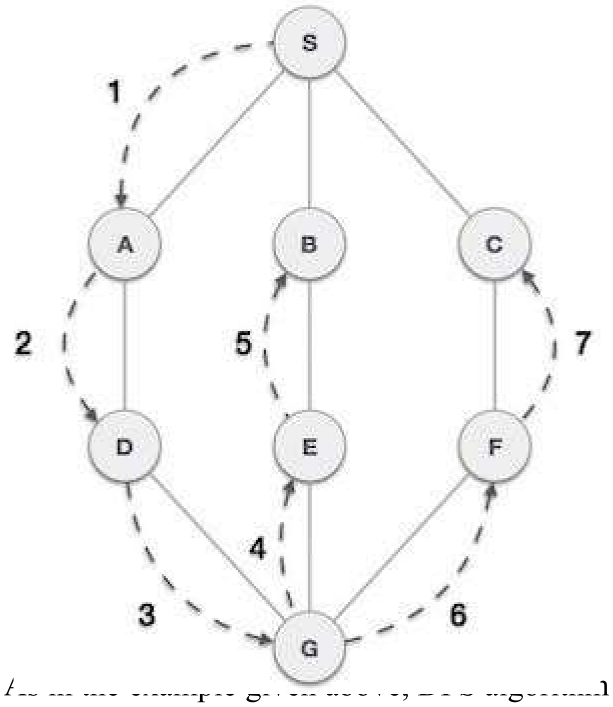
- **If** G is connected **then** $m \geq n - 1$
- **If** G is a tree **then** $m = n - 1$
- **If** G is a forest **then** $m \leq n — 1$

Graph Traversal:
1. Depth First Search
2. Breadth First Search

Lecture-20

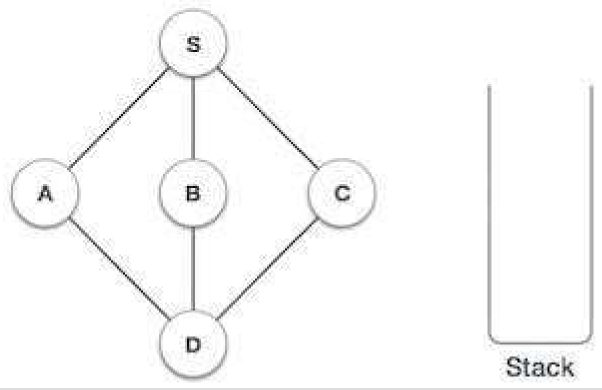
Depth First Search:

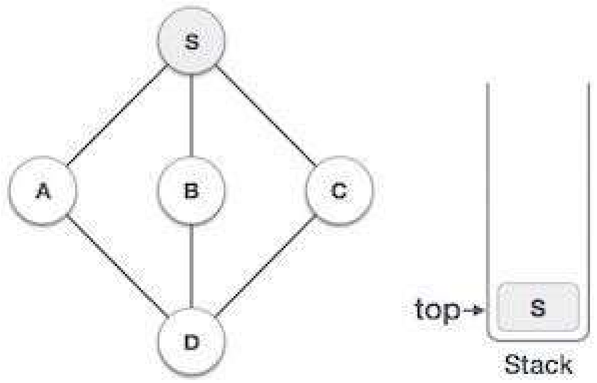
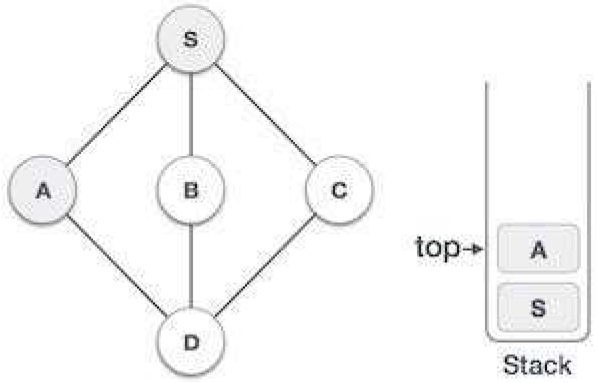
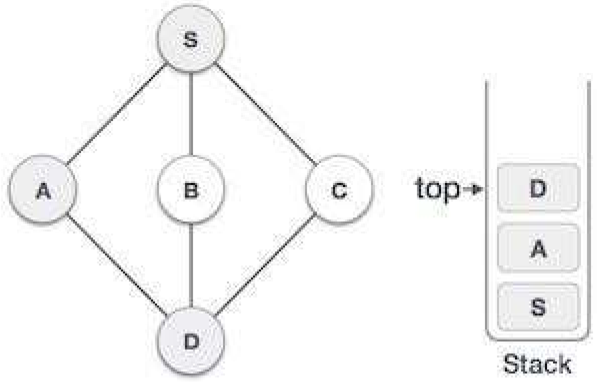
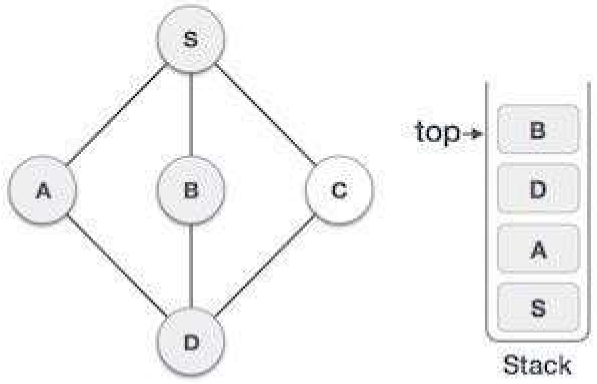
Depth First Search (DFS) algorithm traverses a graph in a depthward motion and uses a stack to remember to get the next vertex to start a search, when a dead end occurs in any iteration.

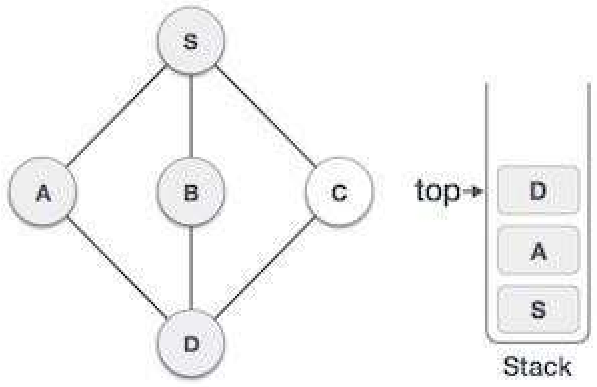
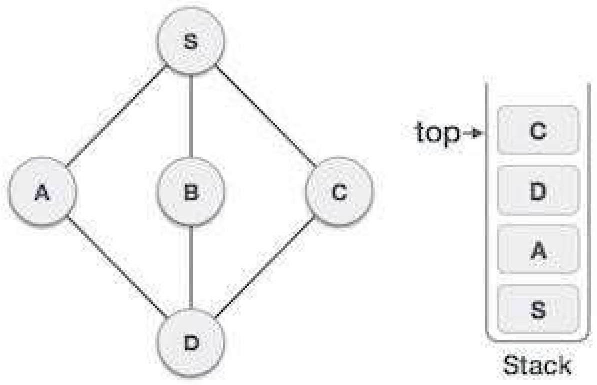


As in the example given above, DFS algorithm traverses from S to A to D to G to E to B first, then to F and lastly to C. It employs the following rules.

- **Rule 1** − Visit the adjacent unvisited vertex. Mark it as visited. Display it. Push it in a stack.
- **Rule 2** − If no adjacent vertex is found, pop up a vertex from the stack. (It will pop up all the vertices from the stack, which do not have adjacent vertices.)
- **Rule 3** − Repeat Rule 1 and Rule 2 until the stack is empty.

Step	Traversal	Description
1		Initialize the stack.

2		Mark **S** as visited and put it onto the stack. Explore any unvisited adjacent node from **S**. We have three nodes and we can pick any of them. For this example, we shall take the node in an alphabetical order.
3		Mark **A** as visited and put it onto the stack. Explore any unvisited adjacent node from A. Both **S**and **D** are adjacent to **A** but we are concerned for unvisited nodes only.
4		Visit **D** and mark it as visited and put onto the stack. Here, we have **B** and **C** nodes, which are adjacent to **D** and both are unvisited. However, we shall again choose in an alphabetical order.
5		We choose **B**, mark it as visited and put onto the stack. Here **B**does not have any unvisited adjacent node. So, we pop **B**from the stack.

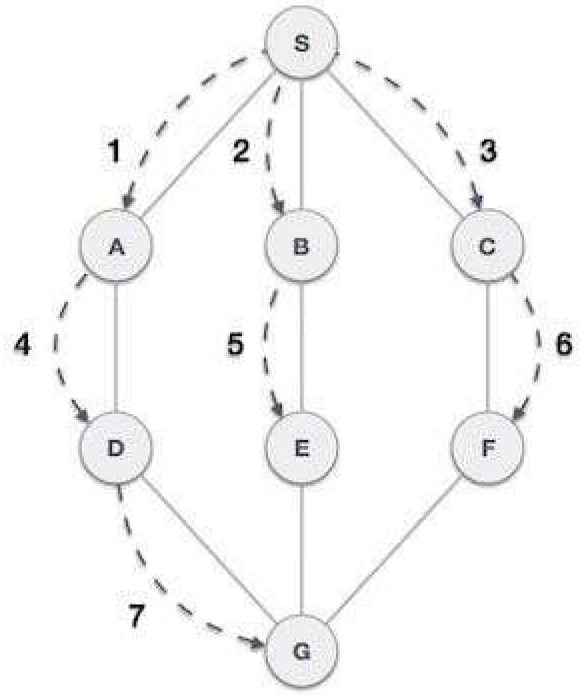
6		We check the stack top for return to the previous node and check if it has any unvisited nodes. Here, we find **D** to be on the top of the stack.
7		Only unvisited adjacent node is from **D** is **C** now. So we visit **C**, mark it as visited and put it onto the stack.

As **C** does not have any unvisited adjacent node so we keep popping the stack until we find a node that has an unvisited adjacent node. In this case, there's none and we keep popping until the stack is empty.

Lecture-21

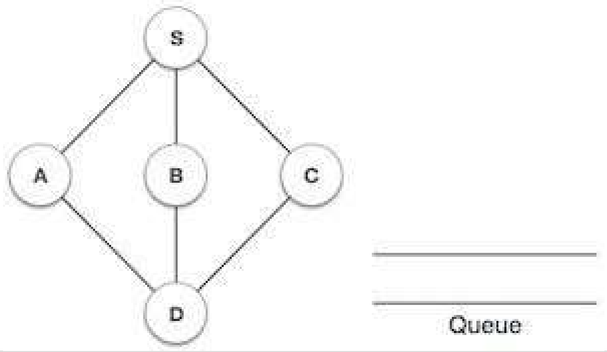
Breadth First Search

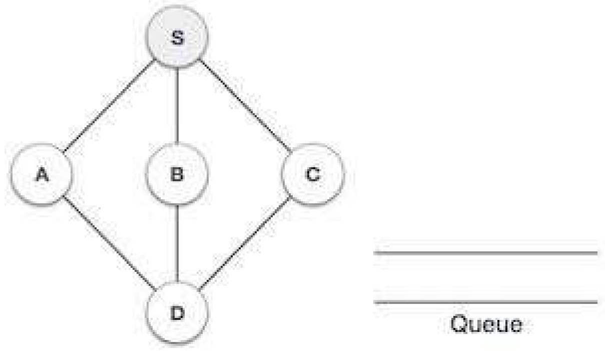
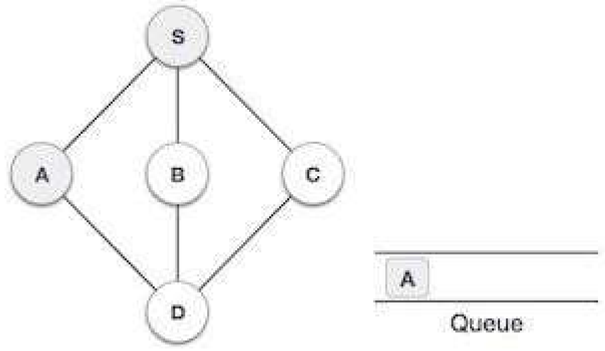
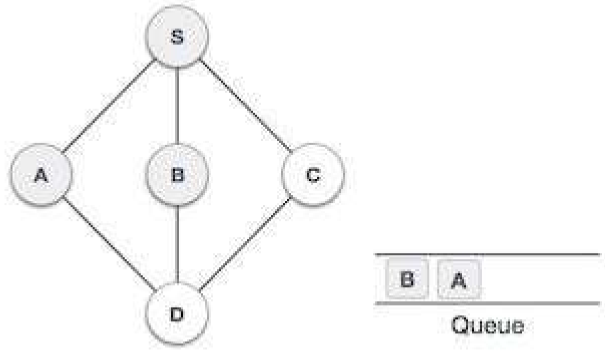
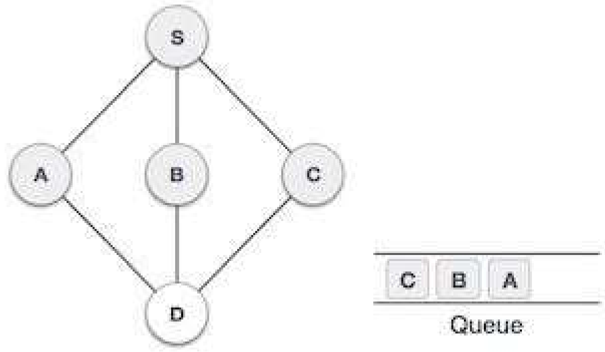
Breadth First Search (BFS) algorithm traverses a graph in a breadthward motion and uses a queue to remember to get the next vertex to start a search, when a dead end occurs in any iteration.

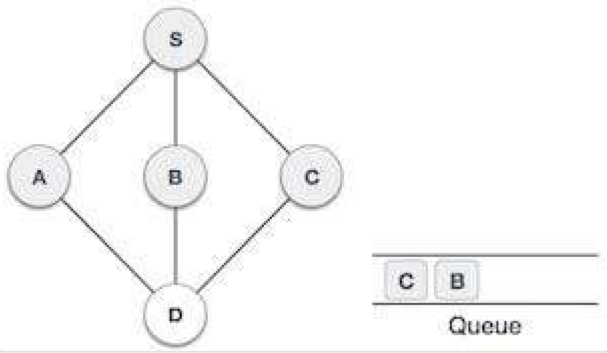
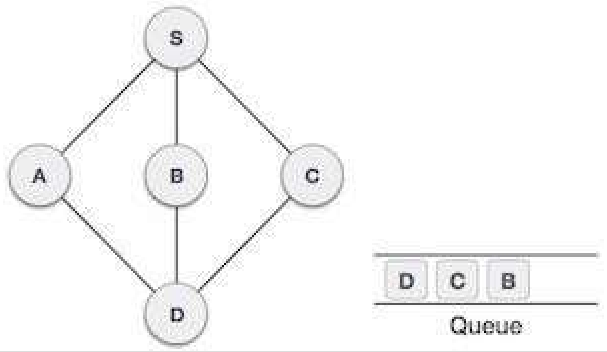


As in the example given above, BFS algorithm traverses from A to B to E to F first then to C and G lastly to D. It employs the following rules.

- **Rule 1** − Visit the adjacent unvisited vertex. Mark it as visited. Display it. Insert it in a queue.
- **Rule 2** − If no adjacent vertex is found, remove the first vertex from the queue.
- **Rule 3** − Repeat Rule 1 and Rule 2 until the queue is empty.

Step	Traversal	Description
1		Initialize the queue.

2		We start from visiting **S**(starting node), and mark it as visited.
3		We then see an unvisited adjacent node from **S**. In this example, we have three nodes but alphabetically we choose **A**, mark it as visited and enqueue it.
4		Next, the unvisited adjacent node from **S** is **B**. We mark it as visited and enqueue it.
5		Next, the unvisited adjacent node from **S** is **C**. We mark it as visited and enqueue it.

6		Now, **S** is left with no unvisited adjacent nodes. So, we dequeue and find **A**.
7		From **A** we have **D** as unvisited adjacent node. We mark it as visited and enqueue it.

At this stage, we are left with no unmarked (unvisited) nodes. But as per the algorithm we keep on dequeuing in order to get all unvisited nodes. When the queue gets emptied, the program is over.