Unit-1(ADS) search with ➔*for new topics*

➔*Data Structures:-*

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 specific 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.

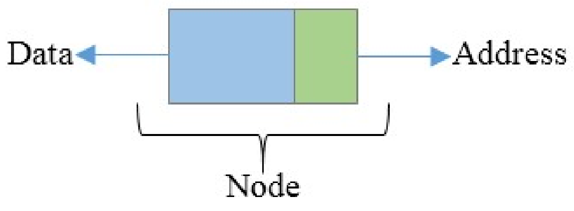
Simple Linked List − Item navigation is forward only.

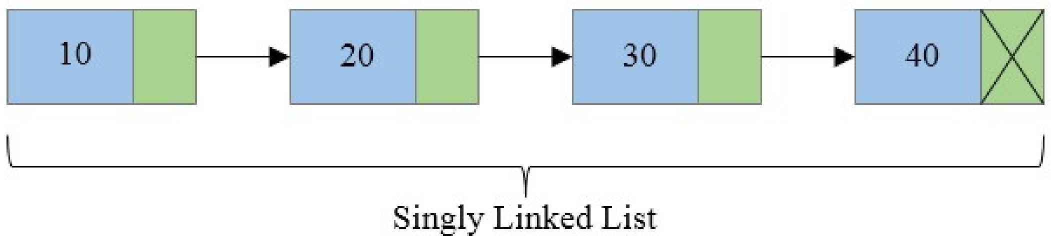
Doubly Linked List − Items can be navigated forward and backward.

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.

➔*Singly Linked Lists*

Singly linked list is a basic linked list type. Singly linked list is a collection of nodes linked together in a sequential way where each node of singly linked list contains a data field and an address field which contains the reference of the next node. Singly linked list can contain multiple data fields but should contain at least single address field pointing to its connected next node.





To perform any operation on a linked list we must keep track/reference of the first node which may be referred by head pointer variable. In singly linked list address field of last node must contain a NULL value specifying end of the list.

Basic structure of a singly linked list

Each node of a singly linked list follows a common basic structure. In a node we can store more than one data fields but we need at least single address field to store the address of next connected node.

```
struct node {
   int data;          // Data
   struct node * next; // Address
};
```

Advantages of Singly linked list

There are several points about singly linked list that makes it an important data structure.

- Singly linked list is probably the most easiest data structure to implement.
- Insertion and deletion of element can be done easily.
- Insertion and deletion of elements doesn't requires movement of all elements when compared to an array.
- Requires less memory when compared to doubly, circular or doubly circular linked list.
- Can allocate or deallocate memory easily when required during its execution.
- It is one of most efficient data structure to implement when traversing in one direction is required.

Disadvantages of Singly linked list

After seeing the advantages of singly linked list. Singly linked list also has some disadvantages over other data structures.

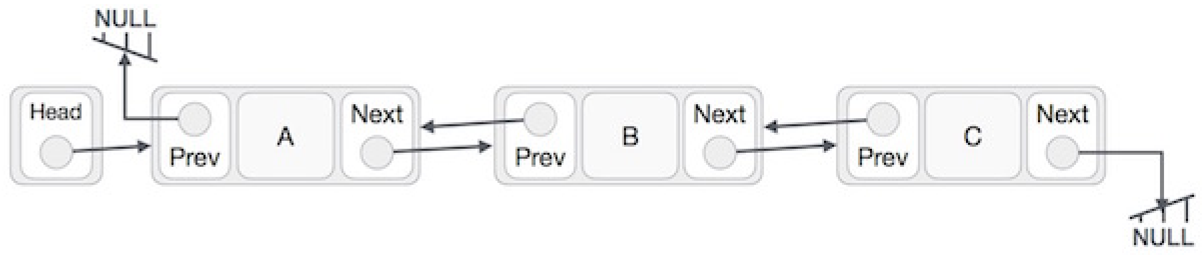
- It uses more memory when compared to an array.
- Since elements are not stored sequentially hence requires more time to access each elements of list.
- Traversing in reverse is not possible in case of Singly linked list when compared to Doubly linked list.
- Requires O(n) time on appending a new node to end. Which is relatively very high when compared to array or other linked list.

➔*Doubly Linked Lists*

Doubly Linked List is a variation of Linked list in which navigation is possible in both ways, either forward and backward easily as compared to Single Linked List. Following are the important terms to understand the concept of doubly 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.
- **Prev** − Each link of a linked list contains a link to the previous link called Prev.
- **LinkedList** − A Linked List contains the connection link to the first link called First and to the last link called Last.

Doubly Linked List Representation



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

- Doubly Linked List contains a link element called first and last.
- Each link carries a data field(s) and two link fields called next and prev.
- Each link is linked with its next link using its next link.
- Each link is linked with its previous link using its previous link.
- The last link carries a link as null to mark the end of the list.

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.
- **Insert Last** − Adds an element at the end of the list.
- **Delete Last** − Deletes an element from the end of the list.
- **Insert After** − Adds an element after an item of the list.
- **Delete** − Deletes an element from the list using the key.
- **Display forward** − Displays the complete list in a forward manner.
- **Display backward** − Displays the complete list in a backward manner.

Insertion Operation

Following code demonstrates the insertion operation at the beginning of a doubly linked list.

Example

```
//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;

  if(isEmpty()) {
    //make it the last link
    last = link;
  } else {
    //update first prev link
    head->prev = link;
  }

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

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

Deletion Operation

Following code demonstrates the deletion operation at the beginning of a doubly linked list.

Example

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

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

  //if only one link
  if(head->next == NULL) {
    last = NULL;
  } else {
    head->next->prev = NULL;
  }

  head = head->next;
```

```
   //return the deleted link
   return tempLink;
}
```

Insertion at the End of an Operation

Following code demonstrates the insertion operation at the last position of a doubly linked list.

Example

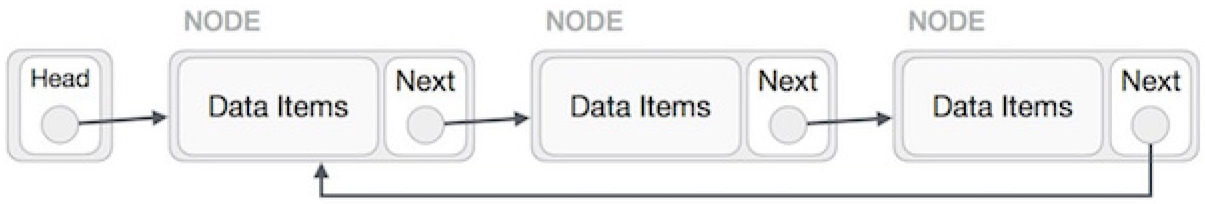
```
//insert link at the last location
void insertLast(int key, int data) {

   //create a link
   struct node *link = (struct node*) malloc(sizeof(struct node));
   link->key = key;
   link->data = data;

   if(isEmpty()) {
      //make it the last link
      last = link;
   } else {
      //make link a new last link
      last->next = link;

      //mark old last node as prev of new link
      link->prev = last;
   }

   //point last to new last node
   last = link;
}
```

➔*Circular Lists*

Circular Linked List is a variation of Linked list in which the first element points to the last element and the last element points to the first element. Both Singly Linked List and Doubly Linked List can be made into a circular linked list.

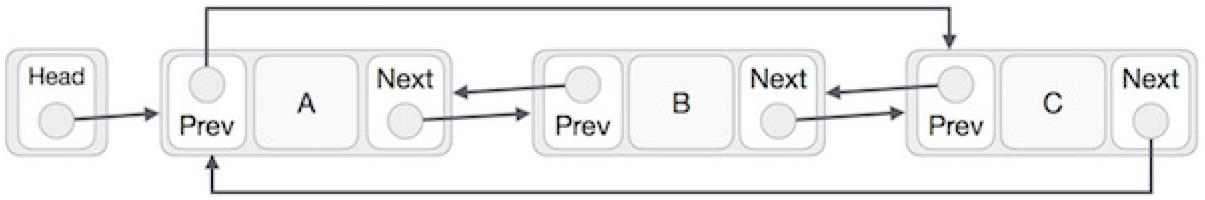
Singly Linked List as Circular

In singly linked list, the next pointer of the last node points to the first node.



Doubly Linked List as Circular

In doubly linked list, the next pointer of the last node points to the first node and the previous pointer of the first node points to the last node making the circular in both directions.



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

- The last link's next points to the first link of the list in both cases of singly as well as doubly linked list.
- The first link's previous points to the last of the list in case of doubly linked list.

Basic Operations

Following are the important operations supported by a circular list.

- **insert** − Inserts an element at the start of the list.
- **delete** − Deletes an element from the start of the list.
- **display** − Displays the list.

Insertion Operation

Following code demonstrates the insertion operation in a circular linked list based on single linked list.

Example

```
insertFirst(data):
Begin
  create a new node
  node -> data := data
  if the list is empty, then
    head := node
    next of node = head
  else
    temp := head
    while next of temp is not head, do
    temp := next of temp
    done
    next of node := head
    next of temp := node
    head := node
  end if
End
```

Deletion Operation

Following code demonstrates the deletion operation in a circular linked list based on single linked list.

```
deleteFirst():
Begin
  if head is null, then
    it is Underflow and return
  else if next of head = head, then
    head := null
    deallocate head
  else
    ptr := head
    while next of ptr is not head, do
      ptr := next of ptr
    next of ptr = next of head
    deallocate head
    head := next of ptr
  end if
End
```

Display List Operation

Following code demonstrates the display list operation in a circular linked list.

```
display():
Begin
  if head is null, then
    Nothing to print and return
  else
    ptr := head
    while next of ptr is not head, do
      display data of ptr
      ptr := next of ptr
    display data of ptr
  end if
End
```

➔*Stacks*

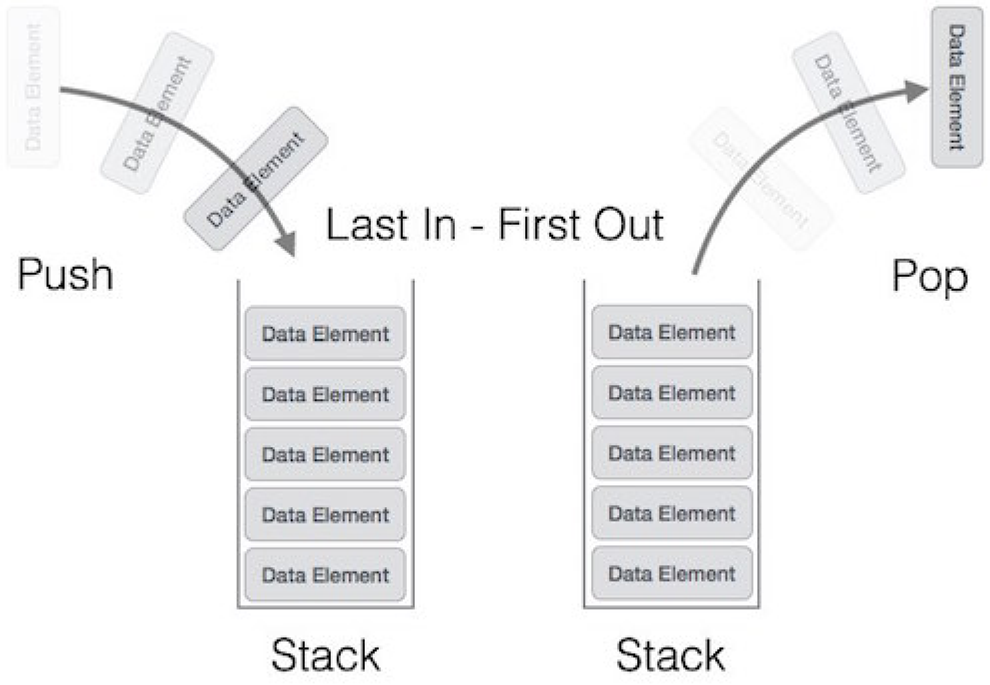
A stack is an Abstract Data Type (ADT), commonly used in most programming languages. It is named stack as it behaves like a real-world stack, for example – a deck of cards or a pile of plates, etc.

A real-world stack allows operations at one end only. For 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]
end procedure
```

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
  endif

end procedure
```

Implementation of isfull() function in C programming language −

Example

```
bool isfull() {
  if(top == MAXSIZE)
    return true;
  else
    return false;
}
```

isempty()

Algorithm of isempty() function −

```
begin procedure isempty

  if top less than 1
    return true
  else
    return false
  endif

end procedure
```

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

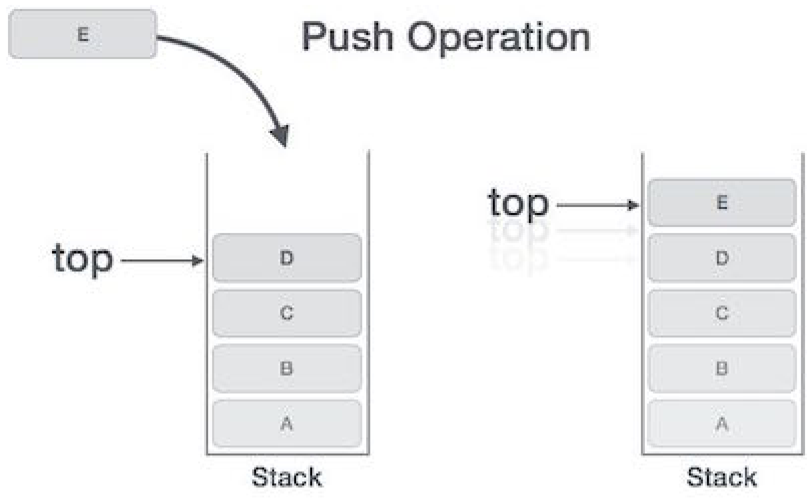
```
bool isempty() {
  if(top == -1)
    return true;
  else
    return false;
}
```

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

  if stack is full
    return null
  endif

  top ← top + 1
  stack[top] ← data

end procedure
```

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

Example

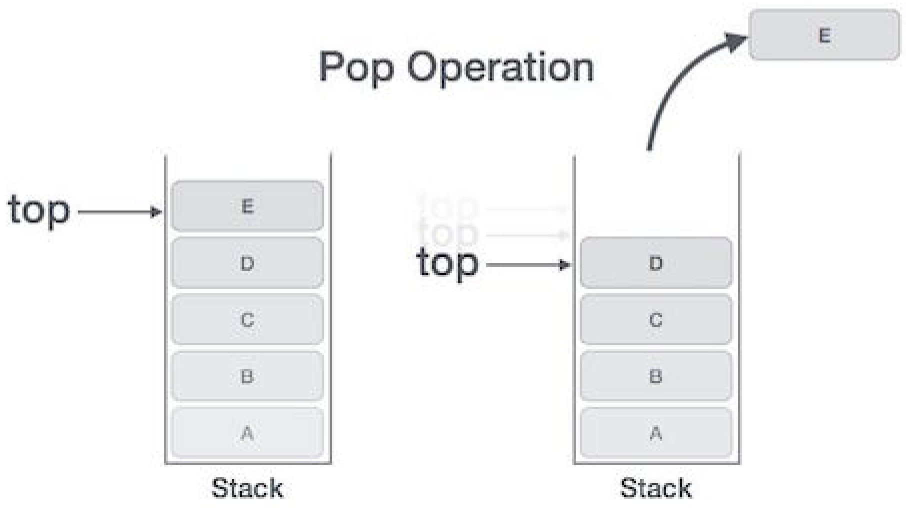
```
void push(int data) {
  if(!isFull()) {
    top = top + 1;
    stack[top] = data;
  } else {
    printf("Could not insert data, Stack is full.\n");
  }
}
```

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]
  top ← top - 1
  return data

end procedure
```

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 {
    printf("Could not retrieve data, Stack is empty.\n");
  }
}
```

➔*Queues*

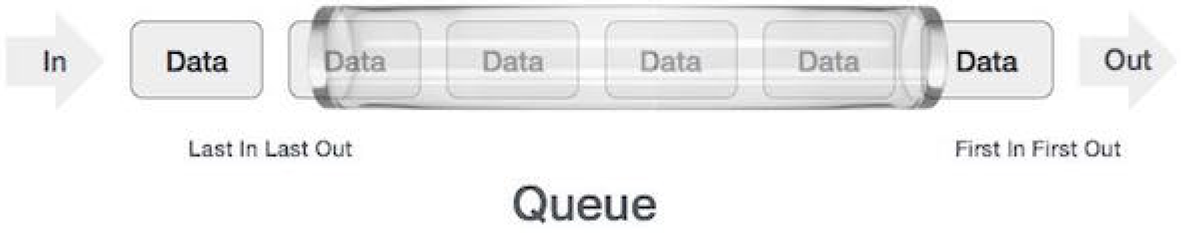
Queue is an abstract data structure, somewhat similar to Stacks. Unlike stacks, a queue is open at both its ends. One end is always used to insert data (enqueue) and the other is used to remove data (dequeue). Queue follows First-In-First-Out methodology, i.e., the data item stored first will be accessed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

LAST IN
LAST OUT
ONE WAY
FIRST IN
FIRST OUT

A real-world example of queue can be a single-lane one-way road, where the vehicle enters 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
  endif

end procedure
```

Implementation of isfull() function in C programming language −

Example

```
bool isfull() {
  if(rear == MAXSIZE - 1)
    return true;
  else
    return false;
}
```

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

end procedure
```

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

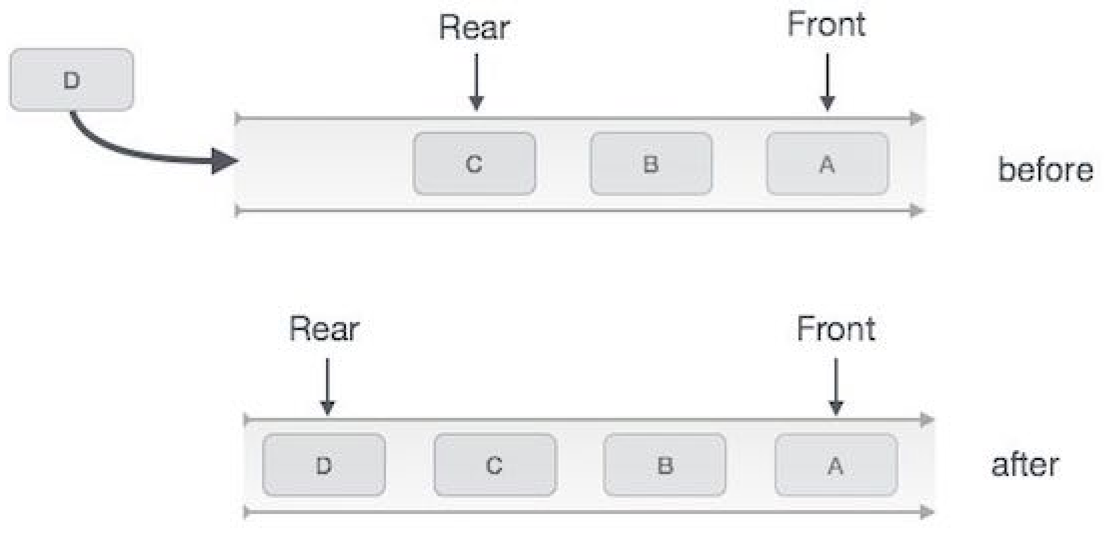
```
bool isempty() {
  if(front < 0 || front > rear)
    return true;
  else
    return false;
}
```

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)

  if queue is full
    return overflow
  endif

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

end procedure
```

Implementation of enqueue() in C programming language −

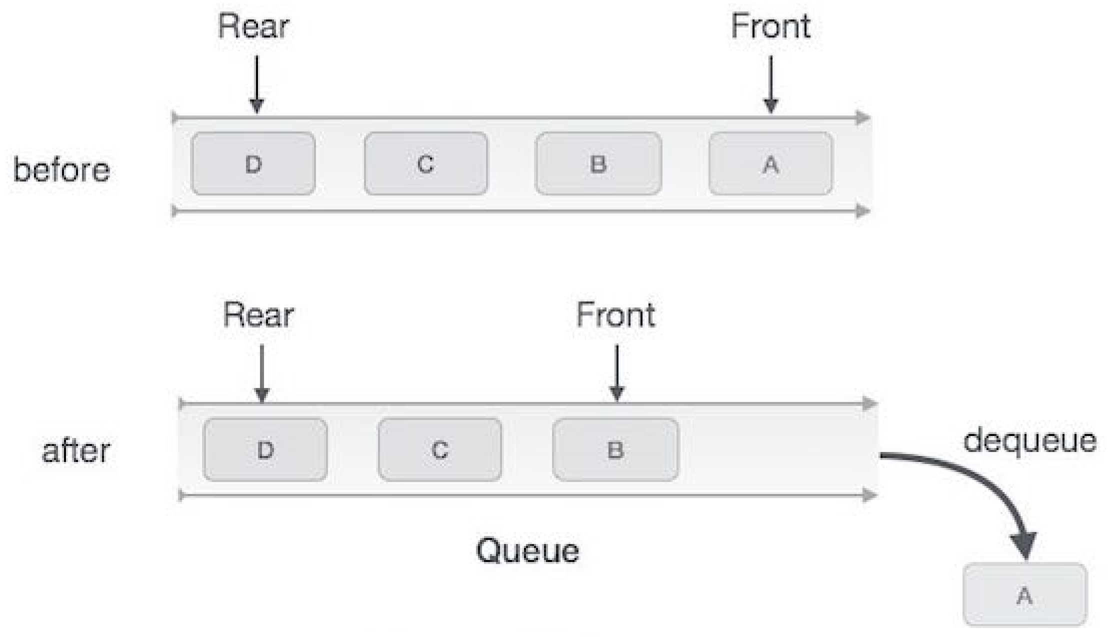
Example

```
int enqueue(int data)
  if(isfull())
    return 0;

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

  return 1;
end procedure
```

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

end procedure
```

Implementation of dequeue() in C programming language −

Example

```
int dequeue() {
  if(isempty())
    return 0;

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

  return data;
}
```