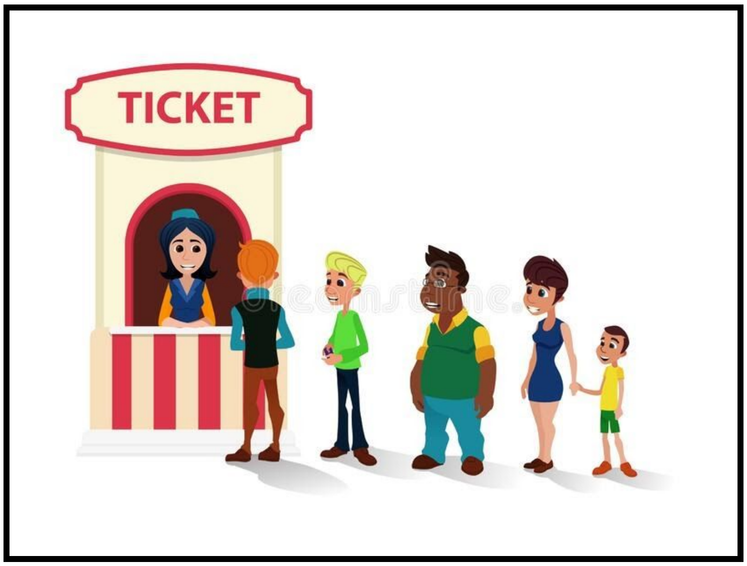
Queues

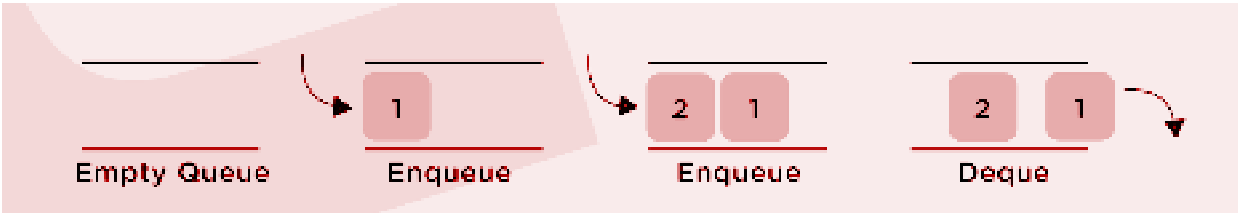
Introduction

- Like stack, the queue is also an abstract data type.
- As the name suggests, in queue elements are inserted at one end while deletion takes place at the other end.
- Queues are open at both ends, unlike stacks that are open at only one end(the top).

Let us consider a queue at a movie ticket counter:



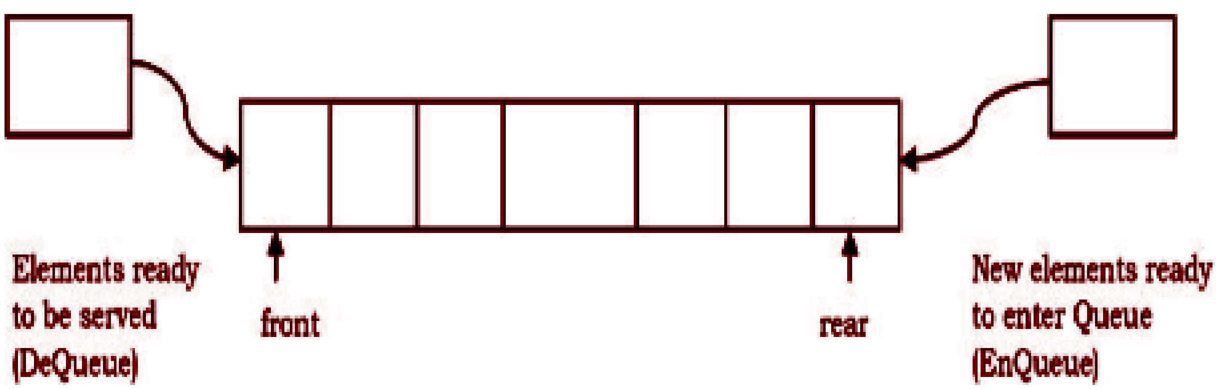
- Here, the person who comes first in the queue is served first with the ticket while the new seekers of tickets are added back in the line.
- This order is known as **First In First Out (FIFO)**.
- In programming terminology, the operation to add an item to the queue is called "enqueue", whereas removing an item from the queue is known as "dequeue".

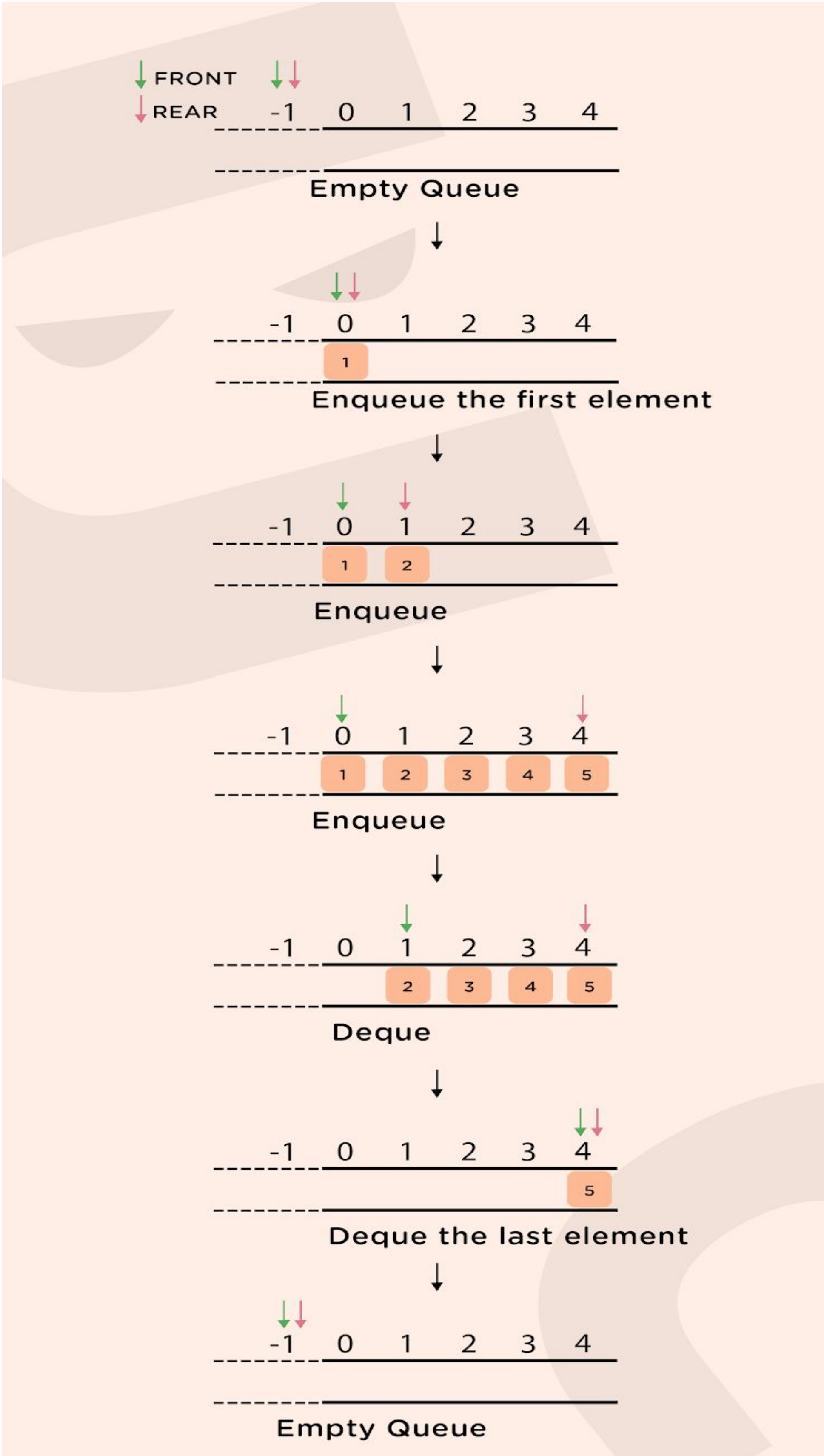


Working of A Queue

Queue operations work as follows:

1. Two pointers called **FRONT** and **REAR** are used to keep track of the first and last elements in the queue.
2. When initializing the queue, we set the value of FRONT and REAR to -1.
3. On **enqueuing** an element, we increase the value of the REAR index and place the new element in the position pointed to by REAR.
4. On **dequeuing** an element, we return the value pointed to by FRONT and increase the FRONT index.
5. Before enqueuing, we check if the queue is already full.
6. Before dequeuing, we check if the queue is already empty.
7. When enqueuing the first element, we set the value of FRONT to 0.
8. When dequeuing the last element, we reset the values of FRONT and REAR to -1.




FRONT
REAR
-1 0 1 2 3 4
Empty Queue
-1 0 1 2 3 4
1
Enqueue the first element
-1 0 1 2 3 4
1 2
Enqueue
-1 0 1 2 3 4
1 2 3 4 5
Enqueue
-1 0 1 2 3 4
2 3 4 5
Deque
-1 0 1 2 3 4
5
Deque the last element
-1 0 1 2 3 4
Empty Queue

Applications of queue

- CPU Scheduling, Disk Scheduling.
- When data is transferred asynchronously between two processesQueue is used for synchronization. eg: IO Buffers, pipes, file IO, etc.
- Handling of interrupts in real-time systems.
- Call Center phone systems use Queues to hold people in order of their calling.

Implementation of A Queue Using Array

Queue contains majorly these five functions that we will be implementing:

- **enqueue()**: Insertion of element
- **dequeue()**: Deletion of element
- **front()**: returns the element present in the front position
- **getSize()**: returns the total number of elements present at current stage
- **isEmpty()**: returns boolean value, TRUE for empty and FALSE for non-empty.

Now, let's implement these functions in our program.

NOTE: We will be using templates in the implementation, so that it can be generalised.

```
class QueueUsingArray <T> {
      T data;                                   // to store data
      int nextIndex;                            // to store next index
      int firstIndex;                           // to store the first index
      int size;                                 // to store the size
      int capacity;                         // to store the capacity it can hold

      public QueueUsingArray(int s) {   // Constructor to initialize values
            data = new T[s];
            nextIndex = 0;
            firstIndex = -1;
```

```
        size = 0;
        capacity = s;
    }

    public int getSize() {          // Returns number of elements present
        return size;
    }

    public bool isEmpty() {         // To check if queue is empty or not
        return size == 0;
    }

    public void enqueue(T element) {         // Function for insertion
        if(size == capacity) { // To check if the queue is already full
            System.out.println("Queue Full!");
            return;
        }
        data[nextIndex] = element;     // Otherwise added a new element
        nextIndex = (nextIndex + 1) % capacity ;    // in cyclic way
        if(firstIndex == -1) {           // Suppose if queue was empty
            firstIndex = 0;
        }
        size++;                    // Finally, incremented the size
    }




    public T front() {       //  To return the element at front position
        if(isEmpty()) {    // To check if the queue was initially empty
            System.out.println("Queue is Empty!");
            return 0;
        }
        return data[firstIndex];     // otherwise returned the element
    }

    public T dequeue() {                // Function for deletion
        if(isEmpty()) {       // To check if the queue was empty
            System.out.println("Queue is Empty!");
            return 0;
        }
        T ans = data[firstIndex];
        firstIndex = (firstIndex + 1) % capacity;
        size--;           // Decrementing the size by 1
        if(size == 0) {  // If queue becomes empty after deletion, then
            firstIndex = -1;    // resetting the original parameters
            nextIndex = 0;
```

```
        }
        return ans;
    }
}
```

Dynamic queue

In the dynamic queue. we will be preventing the condition where the queue becomes full and we were not able to insert any further elements in that.

As we all know that when the queue is full it means the internal array that we are using in the form of a queue has become full, we can resolve this problem by creating a new array of double the size of the previous one and copy pasting the elements of the previous array to the new one. Now this new array which has the double size will be considered as our queue. We will do this in insert function when we check for queue full (size==capacity), when this happens we will discard the previous array and create a new array of double size, copy pasting all the elements so that we don't lose the data. Let’s now check the implementation of the same.

Implementation is pretty similar to the static approach discussed above. A few minor changes are there which could be followed with the help of comments in the code below.

```
class QueueUsingArray <T> {
      T data;                                      // to store data
      int nextIndex;                              // to store next index
      int firstIndex;                            // to store the first index
      int size;                                 // to store the size
      int capacity;                          // to store the capacity it can hold

      public QueueUsingArray() {   // Constructor to initialize values
            data = new T[4];
            nextIndex = 0;
            firstIndex = -1;
            size = 0;
            capacity = 4;
```

```
    }

    public int getSize() {          // Returns number of elements present
          return size;
    }

    public boolean isEmpty() {  // To check if queue is empty or not
          return size == 0;
    }

    public void enqueue(T element) {         // Function for insertion
          if(size == capacity) { // To check if the queue is already full
                T *newData = new T[2 * capacity];// we simply doubled the
                                                 // capacity
                int j = 0;
                for(int i=firstIndex; i<capacity; i++) {// Now copied the
                                                        //Elements to new one
                      newData[j] = data[i];
                      j++;
                }
                for(int i=0; i<firstIndex; i++) {//Overcoming the initial
                                                 //  cyclic insertion by copying
                                                 //  the elements linearly
                      newData[j] = data[i];
                      j++;
                }
                data = newData;
                firstIndex = 0;
                nextIndex = capacity;
                capacity *= 2;          // Updated here as well
          }
          data[nextIndex] = element;     // Otherwise added a new element
          nextIndex = (nextIndex + 1) % capacity ;    // in cyclic way
          if(firstIndex == -1) {           // Suppose if queue was empty
                firstIndex = 0;
          }
          size++;                    // Finally, incremented the size
    }




    public T front() {       //  To return the element at front position
          if(isEmpty()) {    // To check if the queue was initially empty
                System.out.println("Queue is Empty!");
                return 0;
          }
```

```
            return data[firstIndex];     // otherwise returned the element
      }

      public T dequeue() {                    // Function for deletion
            if(isEmpty()) {       // To check if the queue was empty
                  System.out.println("Queue is Empty!");
                  return 0;
            }
            T ans = data[firstIndex];
            firstIndex = (firstIndex + 1) % capacity;
            size--;           // Decrementing the size by 1
            if(size == 0) {  // If queue becomes empty after deletion, then
                  firstIndex = -1;     // resetting the original parameters
                  nextIndex = 0;
            }
            return ans;
      }
}
```

Queues using Generic LL

Given below is an implementation of Queue using Linked List. This is similar to the way we wrote the LL Implementation for a Stack:

```
class Node <T> {       // Node class for linked list, no change needed
      T data;
      Node<T> next;
      Node(T data) {
            this -> data = data;
            next = NULL;
      }
}

class Queue <T> {
      Node<T> head;                    // for storing front of queue
      Node<T> tail;                   // for storing tail of queue
      int size;                       // number of elements in queue

      public Queue() {     // Constructor to initialise head, tail to NULL
                            // and size to 0
      }

      public int getSize() {      // just return the size of linked list
```

```java
    }

    public boolean isEmpty() {      // just check if head is NULL or not

    }

    public void enqueue(T element) {   // Simply insert the new node
                                       //at the tail of LL

    }

    public T front() { // Returns the head pointer of LL.
                       // Be careful for the case when size is 0
    }

    public T dequeue() {  // moves the head pointer one position ahead
                          // and deletes the head pointer.
    }                     // Also decrease the size by 1
}
```

In-built Queue in Java

Java provides the in-built queue in it's **library** which can be used instead of creating/writing a queue class each time. To use this queue, we need to use the import following file:

```java
import java.util.Queues;
import java.util.LinkedList;
```

Key functions of this in-built queue:

- **.push(element_value)** : Used to insert the element in the queue
- **.pop()** : Used to delete the element from the queue
- **.front()** : Returns the element at front of the queue

- **.size()** : Returns the total number of elements present in the queue
- **.isEmpty()** : Returns TRUE if the queue is empty and vice versa

Let us now consider an example to implement queue using inbuilt library:

Problem Statement: Implement the following parts using queue:

1. Declare a queue of integers and insert the following elements in the same order as mentioned: 10, 20, 30, 40, 50, 60.
2. Now tell the element that is present at the front position of the queue
3. Now delete an element from the front side of the queue and again tell the element present at the front position of the queue.
4. Print the size of the queue and also tell if the queue is empty or not.
5. Now, print all the elements that are present in the queue.

```
import java.util.Queues;
import java.util.LinkedList;

Class QueueTesting{
    public static void main(String[] args) {
         Queue<Integer> q = new LinkedList<>();
          q.push(10);      // part 1
          q.push(20);
          q.push(30);
          q.push(40);
          q.push(50);
          q.push(60);
          System.out.println(q.front());     // Part 2
          q.pop();                           // Part 3
          System.out.println(q.front());     // Part 3
          System.out.println(q.size());      // Part 4
          System.out.println(q.isEmpty());  // prints 1 for TRUE and 0 for
                                            // FALSE(Part 4)

          while(!q.isEmpty()) {  // prints all the elements until the queue
                                // is empty (Part 5)
                System.out.println(q.front());
                q.pop();
```

```
        }
    }
}
```

We get the following output:

```
10
20
5
0
20
30
40
50
60
```