Queues

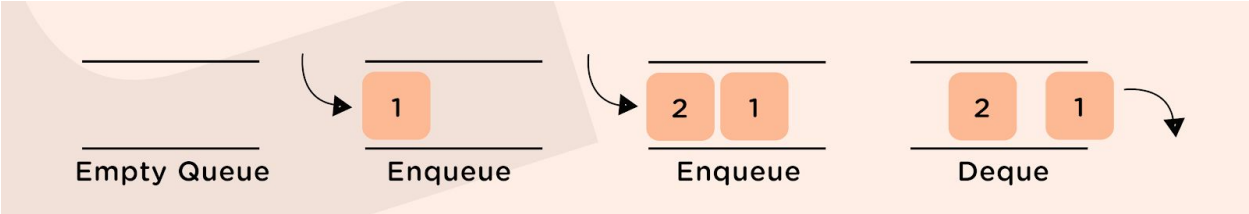
Introduction

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)**, a principle that queue data structure follows

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".

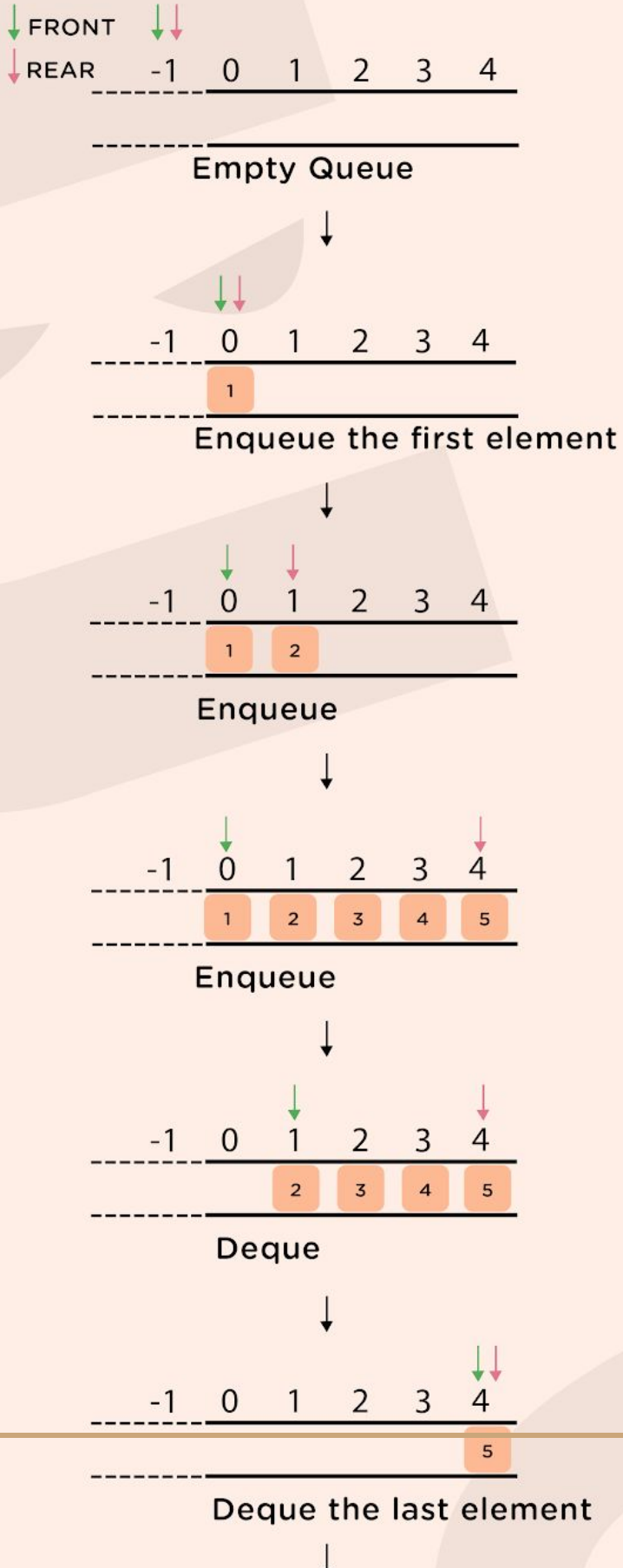


How does the queue work?

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.

Refer to the pictorial representation below:


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

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.

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.

Implementation of queue using array

Follow up the code along with the comments below:

```
template <typename T>                          // Generalised using templates
class QueueUsingArray {
        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;
        }

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

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

        void enqueue(T element) {              // Function for insertion
                if(size == capacity) {         // To check if the queue is already full
                        cout << "Queue Full ! " << endl;
                        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
        }
```

```
        T front() {                                 //  To return the element at front position
                if(isEmpty()) {                     // To check if the queue was initially empty
                        cout << "Queue is empty ! " << endl;
                        return 0;
                }
                return data[firstIndex];    // otherwise returned the element
        }

        T dequeue() {                               // Function for deletion
                if(isEmpty()) {                     // To check if the queue was empty
                        cout << "Queue is empty ! " << endl;
                        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;
        }
};
```

Like stack, we can also make dynamic queues (discussed in the further sections)..

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. 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.

```
template <typename T>

class QueueUsingArray {
        T *data;
        int nextIndex;
        int firstIndex;
        int size;
        int capacity;

        public :
        QueueUsingArray(int s) {
                data = new T[s];
                nextIndex = 0;
                firstIndex = -1;
                size = 0;
                capacity = s;
        }

        int getSize() {
                return size;
        }

        bool isEmpty() {
                return size == 0;
        }

        void enqueue(T element) {
                if(size == capacity) {                          // When size becomes 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++;
                        }
                        delete [] data;
                        data = newData;
```

```
                firstIndex = 0;
                nextIndex = capacity;
                capacity *= 2;                  // Updated here as well
                //cout << "Queue Full ! " << endl;
                // return;
        }
        data[nextIndex] = element;
        nextIndex = (nextIndex + 1) % capacity ;
        if(firstIndex == -1) {
                firstIndex = 0;
        }
        size++;
    }

    T front() {
        if(isEmpty()) {
                cout << "Queue is empty ! " << endl;
                return 0;
        }
        return data[firstIndex];
    }

    T dequeue() {
        if(isEmpty()) {
                cout << "Queue is empty ! " << endl;
                return 0;
        }
        T ans = data[firstIndex];
        firstIndex = (firstIndex + 1) % capacity;
        size--;
        if(size == 0) {
                firstIndex = -1;
                nextIndex = 0;
        }
        return ans;
    }
};
```

The STL queues in C++ are implemented in a similar fashion.

We can also implement the queues with the help of linked lists.

Queues using LL

Check the function description below and try to implement it yourselves.

```
template <typename T>
class Node {                                    // Node class for linked list, no change needed
        public :
                T data;
                Node<T> *next;
                Node(T data) {
                        this -> data = data;
                        next = NULL;
                }
};
template <typename T>
class Queue {
        Nod<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
        }

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

        }

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

        }

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

        }

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

        T dequeue() {                   // moves the head pointer one position ahead
                                        // and deletes the head pointer. Also decrease the
```

```
        }                                   // size by 1
};
```

In-built queue

C++ provides the in-built queue in it's **standard temporary library (STL)** which can be used instead of creating/writing a queue class each time.

Header file used:

```
#include <queue>
```

Syntax for declaration of queue:

```
queue <datatype> name_of_queue
```

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
- **.empty()** : Returns TRUE if the queue is empty and vice versa
-

Let us now consider an example to implement queue using STL:

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.

Solution: Check the code for the above stated...

```
#include <iostream>
#include <queue>                        // Header file for using in-built queue
using namespace std;

int main() {
        queue<int> q;                   // queue declared of type int with name q
        q.push(10);                     // Now inserted elements using .push()
        q.push(20);                     // Part 1
        q.push(30);
        q.push(40);
        q.push(50);
        q.push(60);

        cout << q.front() << endl;      // Part 2
        q.pop();                        // Part 3
        cout << q.front() << endl;      // Part 3
        cout << q.size() << endl;       // Part 4
        cout << q.empty() << endl;          // prints 1 for TRUE and 0 for FALSE(Part 4)

        while(!q.empty()) {                 // prints all the elements until the queue
                                            // is empty (Part 5)
                cout << q.front() << endl;
                q.pop();
        }
}
```

Output of the following code is:

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

Practice problems:

- https://www.spoj.com/problems/ADAQUEUE/
- https://www.hackerearth.com/practice/data-structures/queues/basics-of-queues/practice-problems/algorithm/number-recovery-0b988eb2/
- https://www.codechef.com/problems/SAVJEW
- https://www.hackerrank.com/challenges/down-to-zero-ii/problem