

Unit-3

Queues

- Introduction and Definition
- Representation
- Operation on Queues
- Types of Queues: Dequeue, Circular Queue, Priority Queue
- Applications of Queue

Queue Introduction

- Queues can be easily represented using linear arrays.
- Every queue has front and rear variables that point to the position from where deletions and insertions can be done.

12	9	7	18	14	36				
0	1	2	3	4	5	6	7	8	9

Figure 8.1 Queue

12	9	7	18	14	36	45			
0	1	2	3	4	5	6	7	8	9

Figure 8.2 Queue after insertion of a new element

	9	7	18	14	36	45			
0	1	2	3	4	5	6	7	8	9

Figure 8.3 Queue after deletion of an element

Insert Array Element

```
Step 1: IF REAR = MAX-1
        Write OVERFLOW
        Goto step 4
    [END OF IF]
Step 2: IF FRONT = -1 and REAR = -1
        SET FRONT = REAR = 0
    ELSE
        SET REAR = REAR + 1
    [END OF IF]
Step 3: SET QUEUE[REAR] = NUM
Step 4: EXIT
```

- For ex. front = 0 and rear = 5.
- Add =45
- Rear=Rear+1
- Front=0 and rear=6
- Every time a new element has to be added, we repeat the same procedure

12	9	7	18	14	36	45			
0	1	2	3	4	5	6	7	8	9

Deletion in Queue

```
Step 1: IF FRONT = -1 OR FRONT > REAR
        Write UNDERFLOW
    ELSE
        SET VAL = QUEUE[FRONT]
        SET FRONT = FRONT + 1
    [END OF IF]
Step 2: EXIT
```

Deletions are done from front end of the queue.

Front=front+1

front = 1 and rear = 6.

Before inserting an element in a queue, we must check for overflow/underflow conditions.

An overflow →

Insert an element into a queue that is already full.

When rear = MaX - 1, where MaX is the size of the queue

An underflow→

Delete an element from a queue that

is already empty. If front = -1 and rear = -1, it means there is no element in the queue

	9	7	18	14	36	45			
0	1	2	3	4	5	6	7	8	9

Types of Queue

- A queue data structure can be classified into the following types:
 1. Circular Queue
 2. Deque
 3. Priority Queue

Circular Queue

1. Efficient Memory Utilization

- **Linear Queue Problem:** Once the rear reaches the end of the array, no more elements can be added—even if there's space at the front due to dequeued elements.
- **Circular Queue Solution:** The rear wraps around to the front, using up that freed space.

Example:

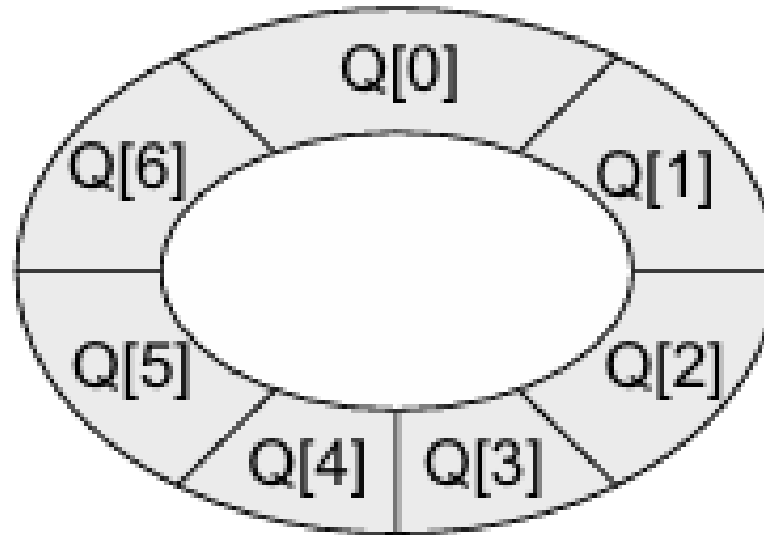
- After enqueue: [10, 20, 30, 40, 50]
- After dequeue two elements: [_, _, 30, 40, 50]
- In a **linear queue**, rear is at index 4, so no more insertions.
- In a **circular queue**, rear wraps to index 0, allowing insertion at freed spots.

2. Better Performance for Continuous Operations

Circular queues are ideal for systems where data is constantly added and removed—like streaming buffers, CPU scheduling, or network routers.

3. No Need to Shift Elements

- In a linear queue, after multiple dequeues, you may need to shift elements to the front to make space.
- Circular queues eliminate this overhead.



Circular insert Algorithm

Step 1: IF (FRONT == 0 AND REAR == MAX - 1) OR (FRONT == REAR + 1)

 PRINT "OVERFLOW"

 GOTO Step 5

 [END OF IF]

Step 2: IF FRONT == -1

 SET FRONT = REAR = 0

ELSE IF REAR == MAX - 1

 SET REAR = 0

ELSE

 SET REAR = REAR + 1

 [END OF IF]

Step 3: SET QUEUE[REAR] = NUM

Step 4: PRINT "Element Inserted"

Step 5: EXIT

MAX = 5

QUEUE = [10, 20, 30, _, _]

FRONT = 0, REAR = 2

Insert 40:

- REAR = 3, insert at index 3 → QUEUE = [10, 20, 30, 40, _]

Insert 50:

- REAR = 4, insert at index 4 → QUEUE = [10, 20, 30, 40, 50]

Insert 60:

- Now REAR = 4, FRONT = 0 → next REAR = 0 (wrap around)
- Insert at index 0 → QUEUE = [60, 20, 30, 40, 50]
- FRONT == REAR + 1, so next insert will cause **overflow**

Circular Delete Algorithm

```
Step 1: IF FRONT == -1
    WRITE "UNDERFLOW"
    GOTO Step 4
[END OF IF]
Step 2: SET VAL = QUEUE[FRONT]
Step 3: IF FRONT == REAR
    SET FRONT = REAR = -1
ELSE IF FRONT == MAX - 1
    SET FRONT = 0
ELSE
    SET FRONT = FRONT + 1
[END OF IF]
Step 4: EXIT
```

```
- MAX = 5
- QUEUE = [10, 20, 30, _, _]
- FRONT = 0, REAR = 2
First Deletion
- VAL = QUEUE[FRONT] = 10
- FRONT = 1
- Queue becomes: [_, 20, 30, _, _]
Second Deletion
- VAL = 20
- FRONT = 2
- Queue becomes: [_, _, 30, _, _]
Third Deletion
- Now FRONT == REAR == 2 → only one element left
- VAL = 30
- Set FRONT = REAR = -1 → queue is now empty
- Queue becomes: [_, _, _, _, _]
Fourth Deletion (Underflow)
- FRONT == -1 → queue is empty
- Output: "UNDERFLOW"
```

Deque

- A deque is a linear data structure that supports:
 - Insertions at both ends
 - Deletions at both ends
- Unlike a regular queue (which follows FIFO: First In First Out), a deque gives you more flexibility. It can behave like a queue or a stack, depending on how you use it.
- Two variants of a double-ended queue.
 1. Input restricted deque In this deque, insertions can be done only at one of the ends, while deletions can be done from both ends.
 2. Output restricted deque In this deque, deletions can be done only at one of the ends, while insertions can be done on both ends.

Deque: Insert

Insert at Rear

Step 1: IF (FRONT == 0 AND REAR == MAX - 1) OR (FRONT == REAR + 1)

 WRITE "OVERFLOW"

 EXIT

Step 2: IF FRONT == -1

 SET FRONT = REAR = 0

 ELSE IF REAR == MAX - 1

 SET REAR = 0

 ELSE

 SET REAR = REAR + 1

Step 3: SET DEQUE[REAR] = VALUE

Step 4: EXIT

Insert at Front

Step 1: IF (FRONT == 0 AND REAR == MAX - 1) OR (FRONT == REAR + 1)

 WRITE "OVERFLOW"

 EXIT

Step 2: IF FRONT == -1

 SET FRONT = REAR = 0

 ELSE IF FRONT == 0

 SET FRONT = MAX - 1

 ELSE

 SET FRONT = FRONT - 1

Step 3: SET DEQUE[FRONT] = VALUE

Step 4: EXIT

Deque :Deletion

Delete from Front

Step 1: IF FRONT == -1

 WRITE "UNDERFLOW"

 EXIT

Step 2: SET VALUE =
 DEQUE[FRONT]

Step 3: IF FRONT == REAR

 SET FRONT = REAR = -1

 ELSE IF FRONT == MAX - 1

 SET FRONT = 0

 ELSE

 SET FRONT = FRONT + 1

Step 4: EXIT

Delete from Rear

Step 1: IF FRONT == -1

 WRITE "UNDERFLOW"

 EXIT

Step 2: SET VALUE = DEQUE[REAR]

Step 3: IF FRONT == REAR

 SET FRONT = REAR = -1

 ELSE IF REAR == 0

 SET REAR = MAX - 1

 ELSE

 SET REAR = REAR - 1

Step 4: EXIT

Examples

Index: [0] [1] [2] [3] [4]

Deque: [_] [_] [_] [_] [_]
 ↑ ↑
 FRONT REAR

Insert 10 at rear:

Deque: [10] [_] [_] [_] [_]
 ↑ ↑
 FRONT REAR

Insert 20 at rear:

Deque: [10] [20] [_] [_] [_]
 ↑ ↑
 FRONT REAR

Insert 5 at front:

Deque: [10] [20] [_] [_] [5]
 ↑ ↑
 FRONT REAR

Delete 5:

Deque: [10] [20] [_] [_] [_]
 ↑ ↑
 FRONT REAR

Delete 20:

Deque: [10] [_] [_] [_] [_]
 ↑ ↑
 FRONT REAR

Priority Queue

- Special type of queue where each element is assigned a **priority**, and elements are served based on their priority—not just their order of arrival.

Each element has:

- A value
- A priority level

Operations include:

- `insert(value, priority)` → Adds an element with a given priority
- `remove()` → Removes the element with the highest priority
- `peek()` → Views the highest-priority element without removing it

Example

```
insert("Task A", priority = 3)  
insert("Task B", priority = 1)  
insert("Task C", priority = 2)
```

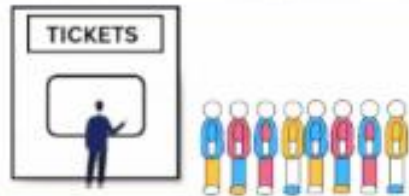
max-priority queue (higher number = higher priority)

- Task A (priority 3)
- Task C (priority 2)
- Task B (priority 1)

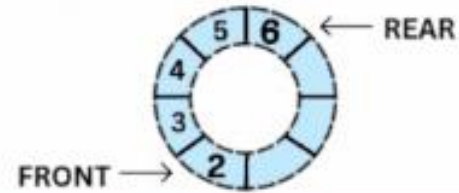
min-priority queue (lower number = higher priority)

- Task B (priority 1)
- Task C (priority 2)
- Task A (priority 3)

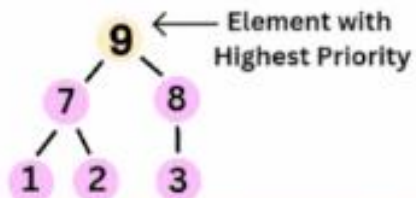
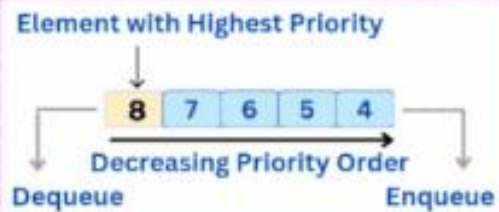
Simple FIFO Queue



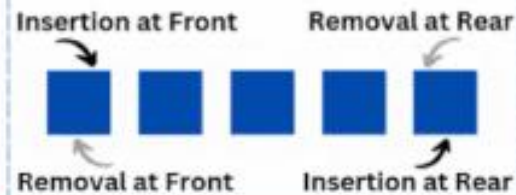
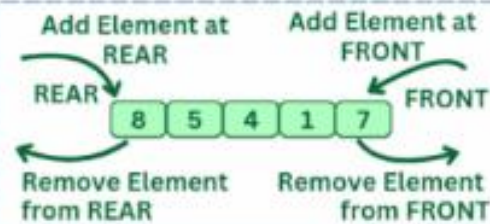
Circular Queue



Priority Queue



Deque

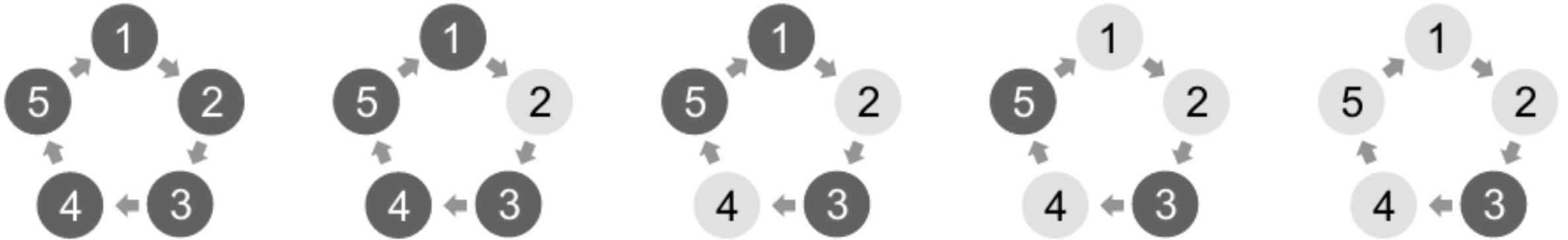


Application of Queue

- Queues are widely used as waiting lists for a single shared resource like printer, disk, CPU.
- Queues are used to transfer data asynchronously (data not necessarily received at same rate as sent) between two processes (IO buffers), e.g., pipes, file IO, sockets.
- Queues are used as buffers on MP3 players and portable CD players, iPod playlist.
- Queues are used in Playlist for jukebox to add songs to the end, play from the front of the list.
- Queues are used in operating system for handling interrupts. When programming a real-time system that can be interrupted, for example, by a mouse click, it is necessary to process the interrupts immediately, before proceeding with the current job. If the interrupts have to be handled in the order of arrival, then a FIFO queue is the appropriate data structure.

Queue Application: Josephus Problem

- In Josephus problem, n people stand in a circle waiting to be executed.
- The counting starts at some point in the circle and proceeds in a specific direction around the circle.
- In each step, a certain number of people are skipped and the next person is executed (or eliminated).
- The elimination of people makes the circle smaller and smaller. At the last step, only one person remains who is declared the 'winner'.
- If there are n number of people and a number k which indicates that $k-1$ people are skipped and k -th person in the circle is eliminated, then the problem is to choose a position in the initial circle so that the given person becomes the winner.



For example, if there are 5 (n) people and every second (k) person is eliminated, then first the person at position 2 is eliminated followed by the person at position 4 followed by person at position 1 and finally the person at position 5 is eliminated. Therefore, the person at position 3 becomes the winner.