# CSN 102: DATA STRUCTURES

Queue: Queue Fundamentals, Application of queue

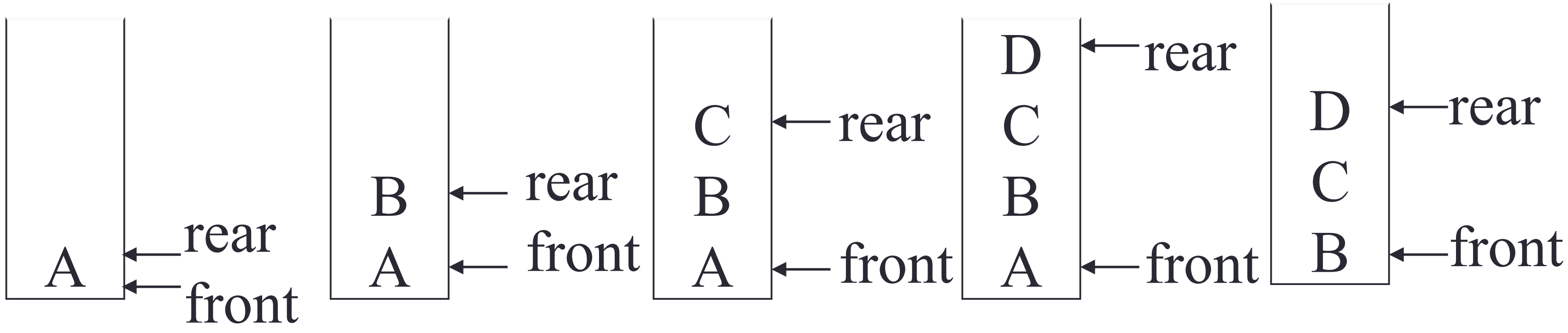
# Abstract Data Type (ADT)

- An Abstract Data Type is:
  - Set of values
  - Set of operations which can be uniformly applied to these values
  - Set of Axioms

# What is Queue?

- Stores the elements in particular way
- First In First Out (LIFO)
- Two pointers: Front and Rear
- enqueue(key): inserts the element key at Rear of queue
- dequeue(): deletes the element from front of the queue

# First In First Out (FIFO)



# Queue Abstract Data Type

- Queue ADT has:
  - Values based on what kind of data queue stores
  - Main operations:
    - new() : creates a new queue
    - enqueue(Q, key): inserts element key at top of queue Q
    - dequeue(Q): deletes element from top of queue Q
    - front(Q): returns the top element of queue Q without deleting it
  - Supported operations:
    - isEmpty(Q): checks whether queue Q is empty or not
    - isFull(Q):checks whether queue Q is full or not
    - size(Q): returns the number of objects in queue Q

# Queue Abstract Data Type

- Queue ADT has:
  - Axioms:
    - front( enqueue( new(), v)) = v
    - dequeue( enqueue( new(), v)) = new()
    - Front( enqueue( enqueue( Q, w), v)) = front(enqueue( Q, w))
    - Dequeue( enqueue( enqueue( Q, w), v)) = enqueue(dequeue(enqueue( Q, w)), v)

# Queue Operations

```
enqueue(Q, key)
    if (queue is not full)
        increase rear by 1
        insert key at rear

dequeue(Q)
    if (queue is not empty)
        key = delete element from front
        increase front by 1
        return (key)
```

# Queue application: Job Scheduling

- Single processor and more than one job wants to execute
- More jobs are entering the system while other executing
- Once a job/process is executed, no longer required to be stored
- Eg. Printing documents using a printer
- Some strategy is required to execute all the processes

# First Come First Serve (FCFS)

- The job which enters the system first, will be executed first
- Once finished execution, execute next job in the queue
- Eg. Print file1, then file2 and so on
- Implemented using a Queue

- Start executing the first job in Queue
- Insert new jobs to the end of Queue
- Once execution is done, get the next job from front and start execution of this job

# Job Scheduling: Example

| front | rear | Q[0] | Q[1] | Q[2] | Q[3] | Comments |
|---|---|---|---|---|---|---|
| -1 | -1 | | | | | Queue Q is empty |
| 0 | 0 | J1 | | | | Job J1 added to Q |
| 0 | 1 | J1 | J2 | | | Job J2 added to Q |
| 1 | 1 | | J2 | | | Job J1 deleted from Q |
| 1 | 2 | | J2 | J3 | | Job J3 added to Q |
| 1 | 3 | | J2 | J3 | J4 | Job J4 added to Q |
| 2 | 3 | | | J3 | J4 | Job J2 deleted from Q |

# Array implementation of Queue(1)

```
front ← -1;
rear ← -1;
isFull()
        if (rear = N-1)
                return true;
        else
                return false;
size()
        if (front = -1)
                return 0
        else
                return (rear + 1 – front)
isEmpty()
        if (!size() or front = rear + 1)
                return true;
        else
                return false;
```

# Array Implementation of Queue(2)

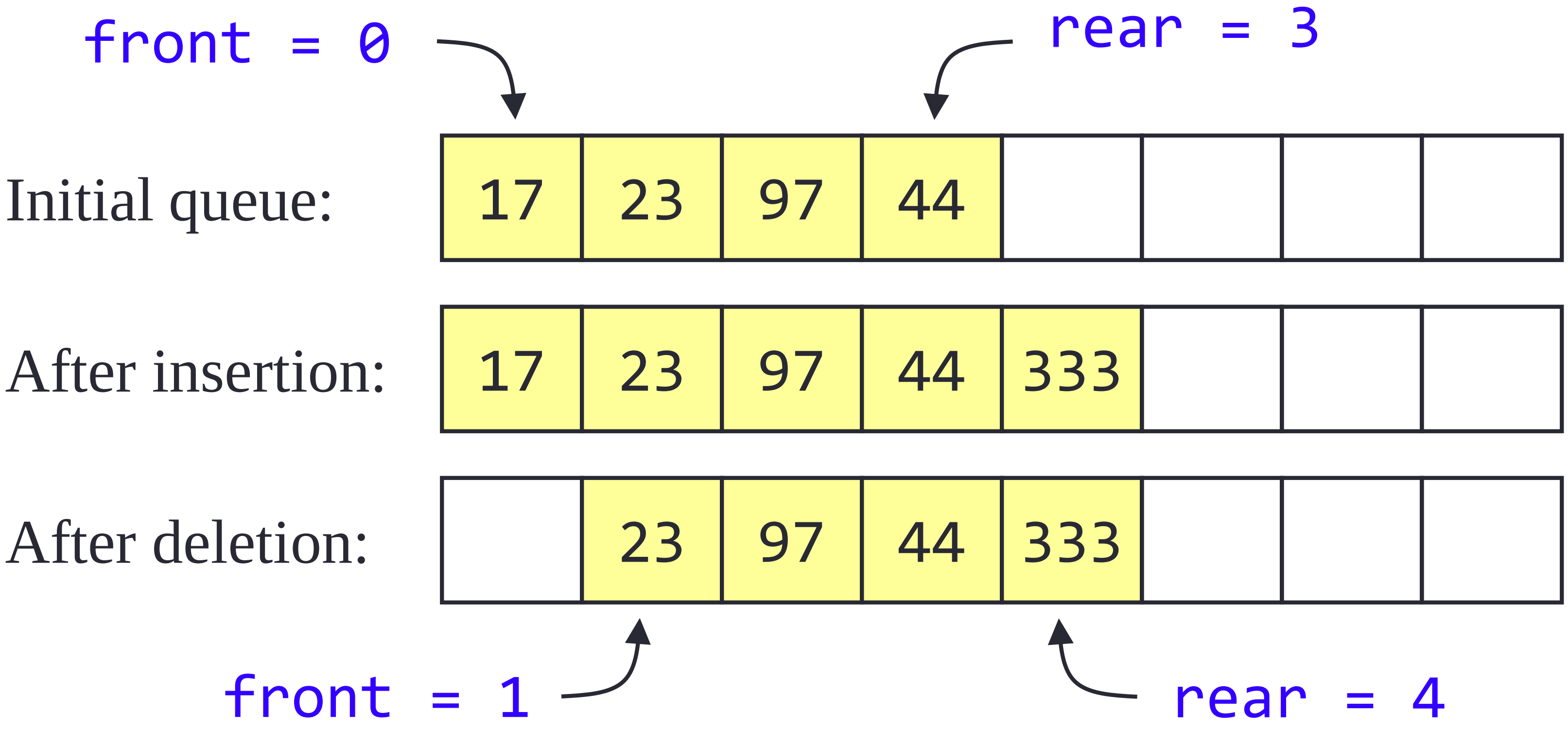
**enqueue(key)**

```
        if (isFull())
                "Queue is full"
        else if (front = -1)
                front ← 0;
                rear ← 0;
                Q[rear] ← key;
        else
                rear ← rear + 1;
                Q[rear] ← key;
```

# Array Implementation of Queue(3)

```
dequeue()
    if (isEmpty())
        “Queue is empty”
    else
        key ← Q[front]
        front ← front + 1;
        return key
```

# Sample



front = 0

rear = 3

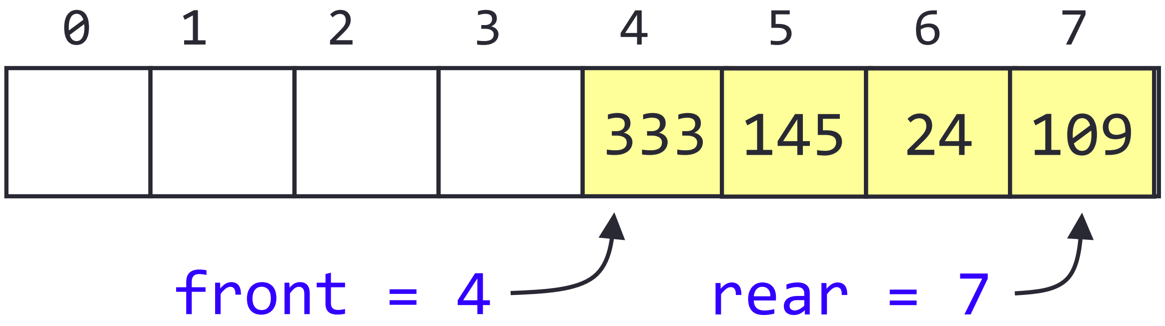
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Initial queue: | 17 | 23 | 97 | 44 | | | | |
| After insertion: | 17 | 23 | 97 | 44 | 333 | | | |
| After deletion: | | 23 | 97 | 44 | 333 | | | |

front = 1

rear = 4

# Issue with Implementation

After deletion:



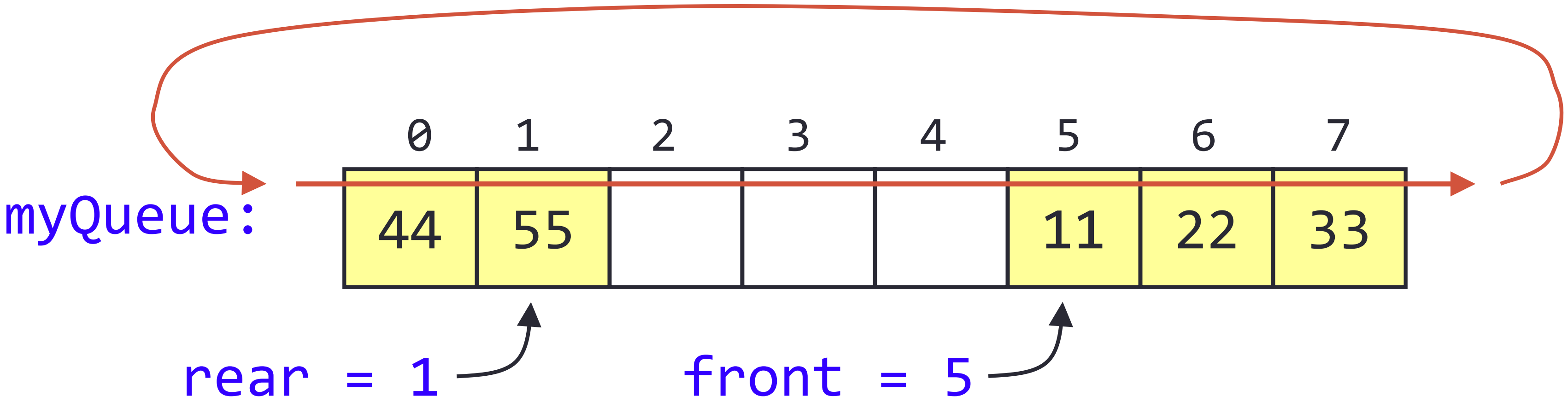
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | | | | 333 | 145 | 24 | 109 |

front = 4

rear = 7

- Problem: Even if space is available, can’t insert the objects in queue
- Solution: circular queue

# Circular Queue



`myQueue:`

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 44 | 55 |  |  |  | 11 | 22 | 33 |

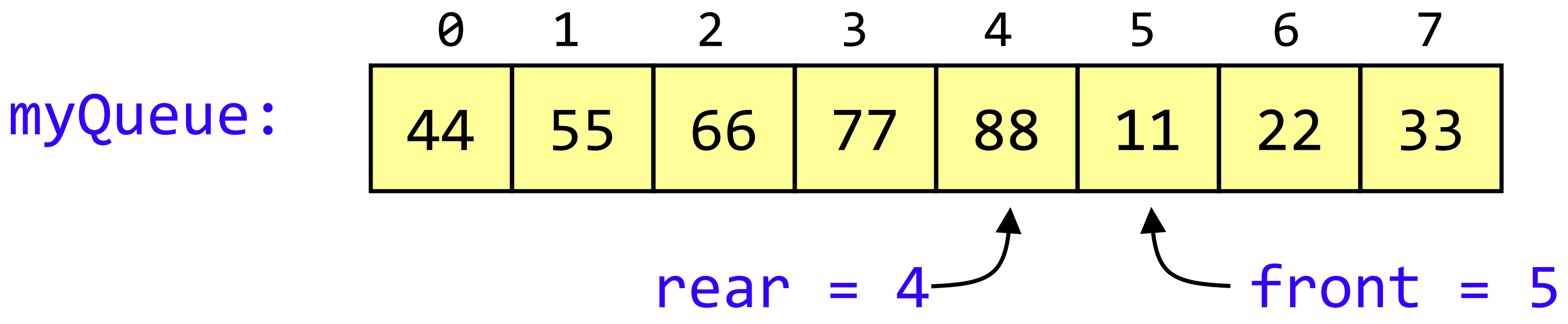
`rear = 1`

`front = 5`

- Once end of array is reached, start inserting/deleting from the beginning of array
- Updated dequeue: `front = (front + 1) % length;`
- updated enqueue: `rear = (rear + 1) % length;`

# Full and empty queues

- If the queue were to become completely full, it would look like this:



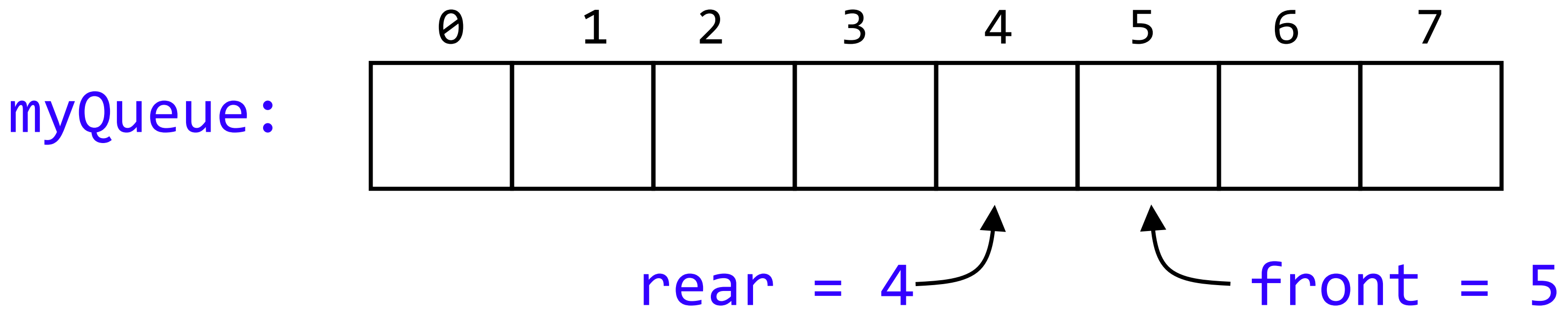
myQueue:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 44 | 55 | 66 | 77 | 88 | 11 | 22 | 33 |

rear = 4

front = 5

- If we were then to remove all eight elements, making the queue completely empty, it would look like this:



myQueue:

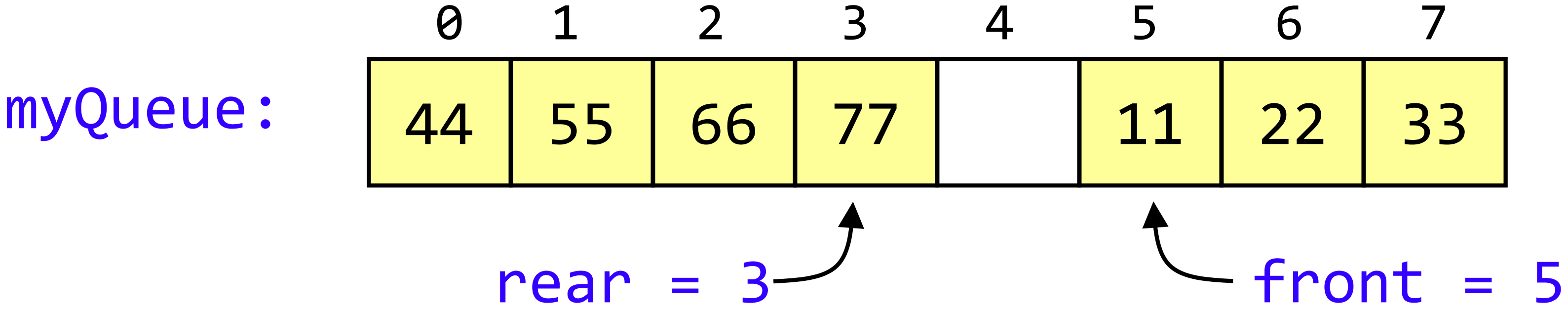
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |

rear = 4

front = 5

# Issue with Implementation

- Problem: Both full and empty queue has same front and rear values
- Solution: consider queue full when it has n-1 elements



myQueue:

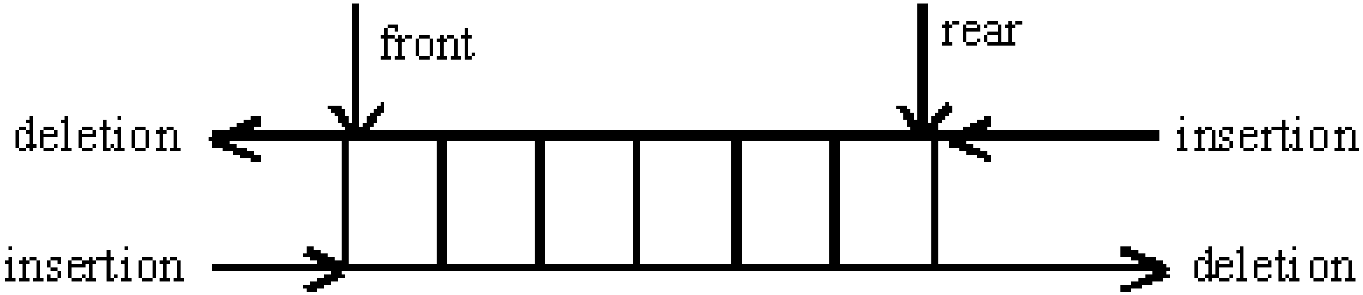
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 44 | 55 | 66 | 77 |  | 11 | 22 | 33 |

rear = 3

front = 5

# Double Ended Queue(Deque)

- Insertion and deletion can happen at both ends of the queue
- Separate function for insertion and deletion from front and rear



# Implementation of Deque

```
insert_F(queue Q, int data) {  //insert in front of queue
        if (Q is full)
                print (“overflow”);
        else
                front = front-1;
                Q[front] = data; }

delete_F(queue Q) {  //delete from front of queue
        if (Q is empty)
                print (“underflow”);
        else
                temp = Q[front];
                front = front +1;
                return temp; }
```

# Implementation of Deque

```
insert_R(queue Q, int data) {  //insert in rear of queue
        if (Q is full)
                print (“overflow”);
        else
                rear = rear + 1;
                Q[rear] = data; }

delete_R(queue Q) {  //delete from rear of queue
        if (Q is empty)
                print (“underflow”);
        else
                temp = Q[rear];
                rear = rear - 1;
                return temp; }
```

# Versions of Deque

- **Input restricted Deque:** deletion can be made from both ends, but insertion can be made at one end only.

- **Output restricted Deque:** insertion can be made at both ends, but deletion can be made from one end only.

# Application of Deque

- Undo-Redo operations
- Web Browsing History