SCJ2013 Data Structure & Algorithms

Queue

Nor Bahiah Hj Ahmad & Dayang Norhayati A. Jawawi

Course Objectives

At the end of the lesson students are expected to be able to:

- Understand queue concepts and applications.
- Understand queue structure and operations that can be done on queue.
- Understand and know how to implement queue using array and linked list : linear array, circular array, linear link list and circular list.

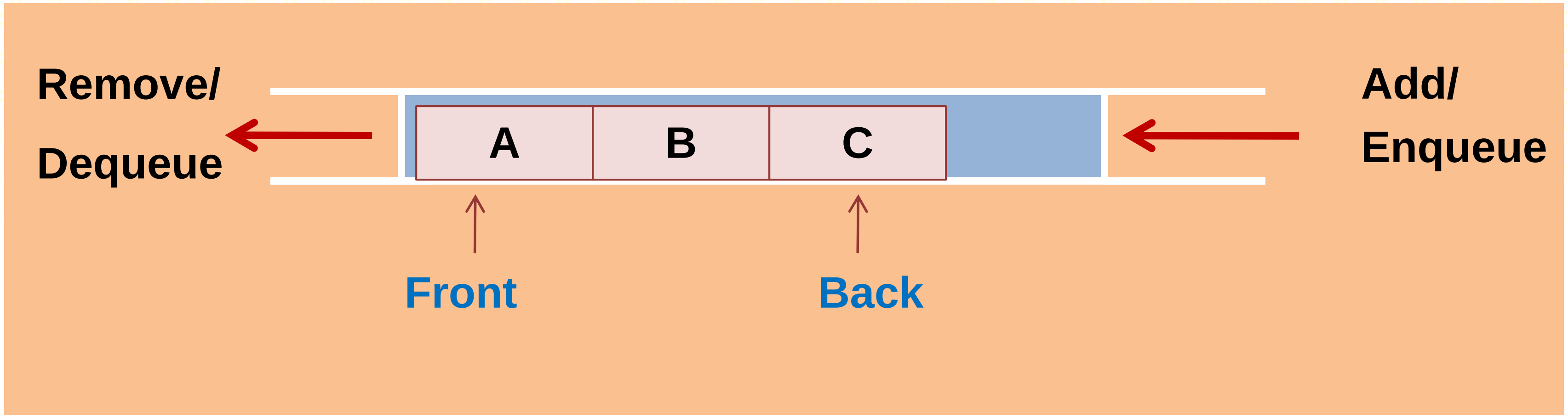
Introduction to Queue

- New items enter at the back of the queue.
- Items leave from the front queue.
- Implement First-in, first-out (FIFO) property.
  - The first item inserted into a queue is the first item to leave.
- Queue is important in simulation & analyzing the behavior of complex systems

Queue Applications

- Real-World Applications
  - Cashier lines in any store
  - Check out at a bookstore
  - Bank / ATM
  - Call an airline
- Computer Science Applications
  - Print lines of a document
  - Printer sharing between computers
  - Recognizing palindromes
  - Shared resource usage (CPU, memory access, …)
- Simulation
  - A study to see how to reduce the wait involved in an application

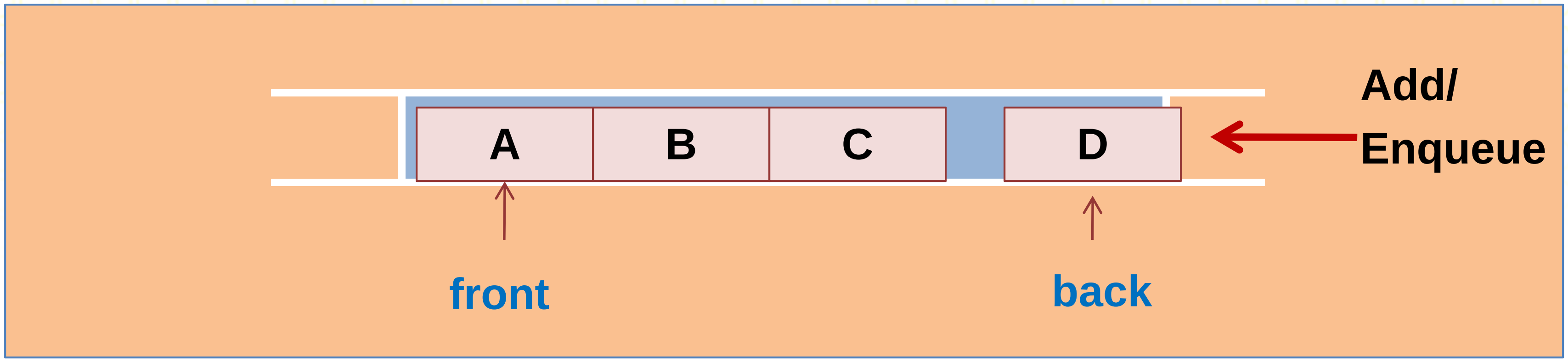
Queue Implementation



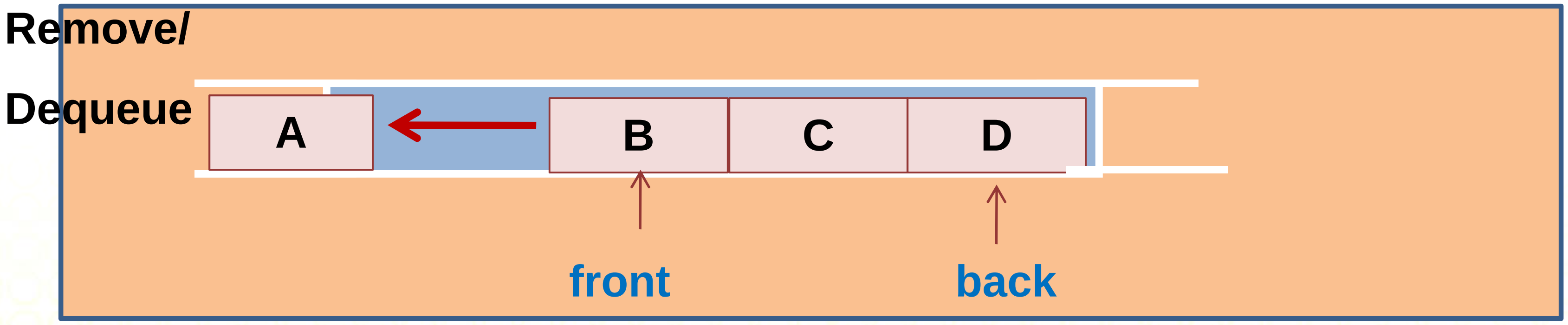
Basic Structure of a Queue:

- Data structure that hold the queue
- front
- back

Queue Implementation



Insert D into Queue (enQueue) : D is inserted at rear



Delete from Queue (deQueue) : A is removed

Queue Implementation

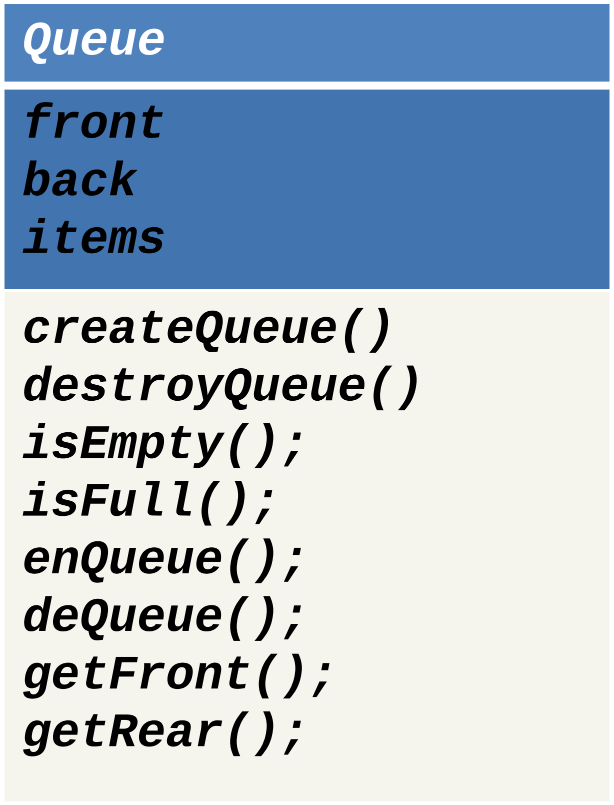
Implementation:

- Array-based
  - Linear
  - Circular
- Pointer-based : Link list
  - Linear
  - Circular

Queue: Linear Array Implementation

- Number of elements in Queue are fixed during declaration.
- Need **`isFull()`** operation to determine whether a queue is full or not.
- Queue structure need at least 3 elements:

1) Element to store items in Queue
2) Element to store index at front
3) Element to store index at back queue



```
Queue
front
back
items
createQueue()
destroyQueue()
isEmpty();
isFull();
enQueue();
deQueue();
getFront();
getRear();
```

Queue Abstract Data Type

ADT queue operations

- Create an empty queue
- Destroy a queue
- Determine whether a queue is empty
- Add a new item to the queue
- Remove the item that was added earliest
- Retrieve at Front
- Retrieve at Back

Queue Declaration

```
class Queue
{ private:
     int front; // index at front
     int back; // index at rear queue
     char items[size]; //store item in Q
  public:
    Queue(); // Constructor - create Q
   ~Queue(); // Destructor - destroy Q
    bool isEmpty(); // check Q empty
    bool isFull(); // check Q full
    void enQueue(char); // insert into Q
    void deQueue(); // remove item from Q
    char getFront(); // get item at Front
    char getRear(); // get item at back Q
};
```

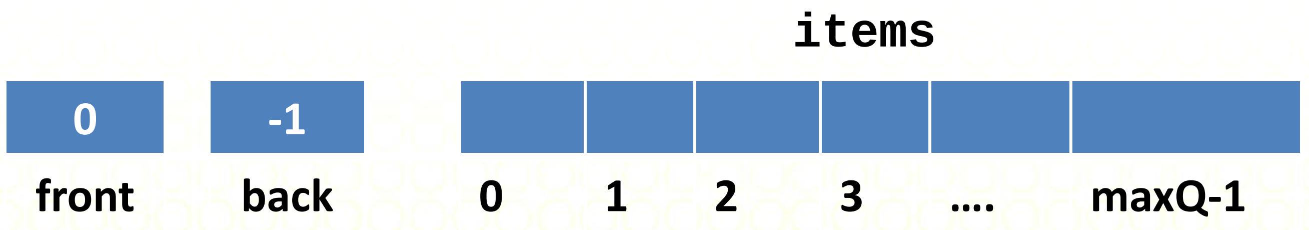
Queue
front *rear* *items*

createQueue()
destroyQueue()
isEmpty();
isFull();
enQueue();
deQueue();
getFront();
getRear();

CreateQueue() operation

- Linear Array implementation
- Constructor:
  - **`front`** and **`back`** are indexes in the array
  - Initial condition: **`front =0`** and **`back`** = -1

```
Queue::Queue()
{ front = 0;
  back = -1;
}
```



Initial state for a queue linear array

Queue Operations

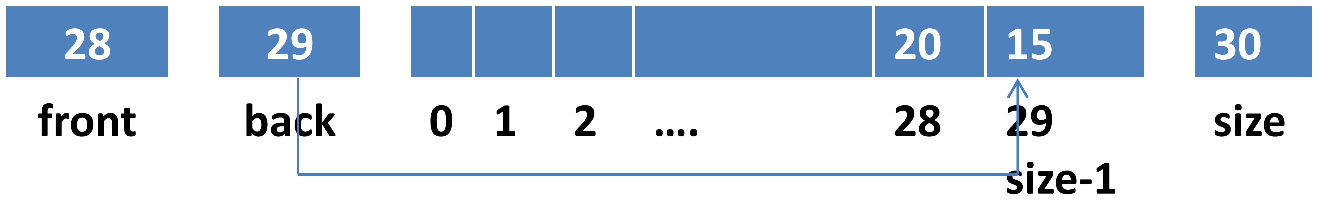
- Destroy Queue destructor : All elements in the queue will be disposed.

```
 queue::~queue()
{ delete [ ] items; }
```

- Check whether a queue is empty
  - Queue Empty Condition : back < front

```
bool queue::isEmpty()
{ return bool(back < front); }
```

Queue Operations



Check whether a queue is Full

- Queue Full Condition : back = size -1

```
bool queue::isFull()
{ return bool(back == size – 1); }
```

- Cannot insert any more item into a queue, when the queue is full.

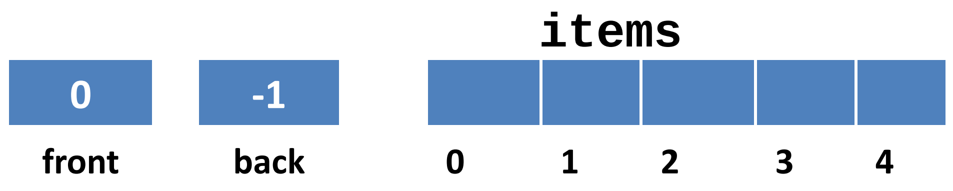
Queue Operations

- Insert into a queue (enQueue)
    - Increment back
    - Insert item in **`items[ back ]`**

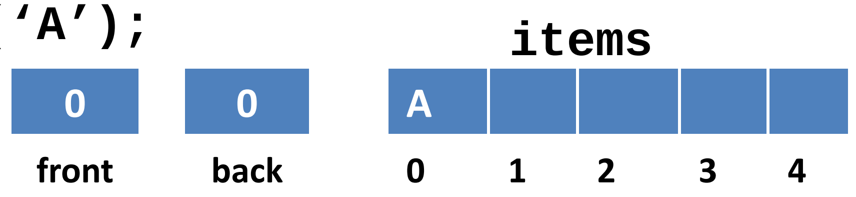
```
void queue::enQueue(char insertItem)
{ if (isFull())
       cout<< "\nCannot Insert. Queue is full!";
  else
  { //insert at back
    back++;
    items[back] = insertItem;
  } // end else if
}
```

enQueue operations for a queue with size = 5

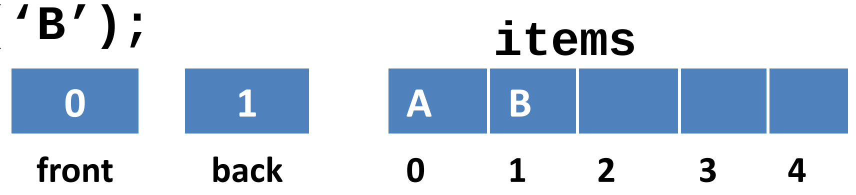
```
Queue myQueue;
```



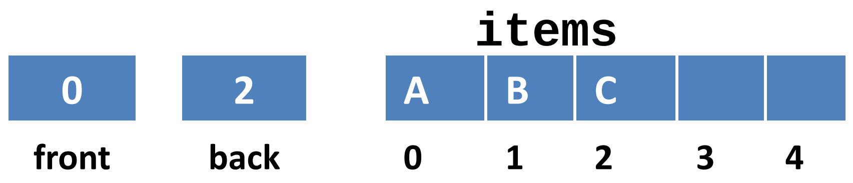
```
myQueue.enQueue('A');
```



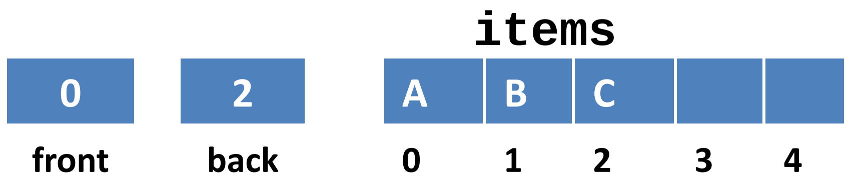
```
myQueue.enQueue('B');
```



```
myQueue.enQueue('C');
```



Queue operations



- **Item at front and back can be retrieved from queue**

```
char queue:: getFront() // get item at Front
{ return items[front] ; }
```

```
char queue::getRear() // get item at Back
{ return items[back] ; }
```

```
cout << myQueue.getFront(); //output is A
cout << myQueue.getRear(); // output is C
```

Queue operations

- Delete from a queue (deQueue)
  - Increment front

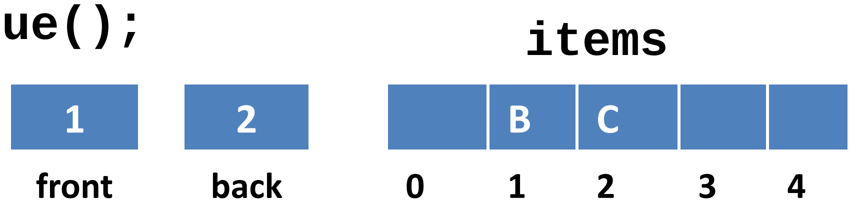
```
void queue::deQueue()
{ if (isEmpty())
      cout<< "\nCannot remove item. Empty Queue!";
   else
   { //retrieve item at front
      deletedItem = items[front];
      front++;
   } // end else if
}
```

deQueue operations

```
myQueue.deQueue();
```

deletedItem

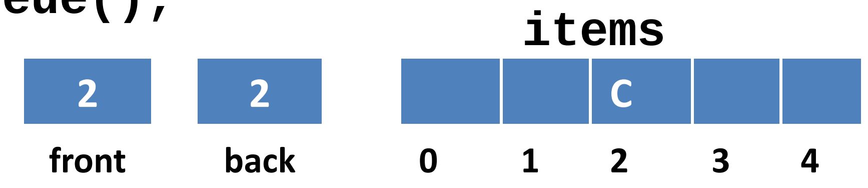
A



```
myQueue.deQueue();
```

deletedItem

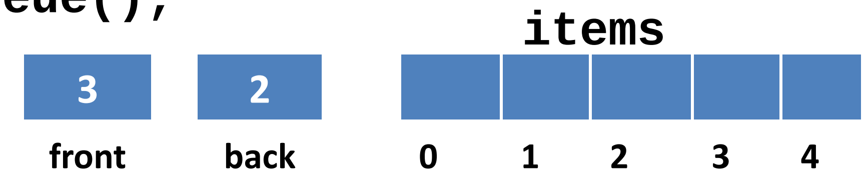
B



```
myQueue.deQueue();
```

deletedItem

C

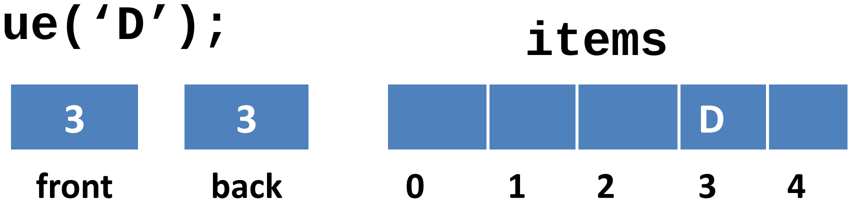


```
myQueue.deQueue();
```

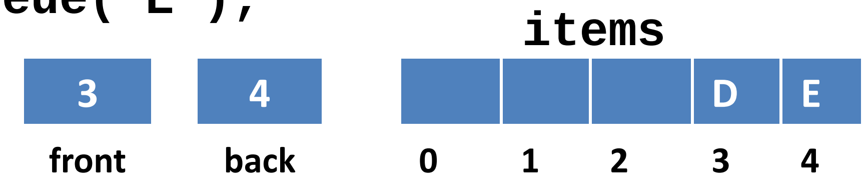
```
Cannot remove item.
Queue is Empty with back < front
```

Queue operations - enQueue

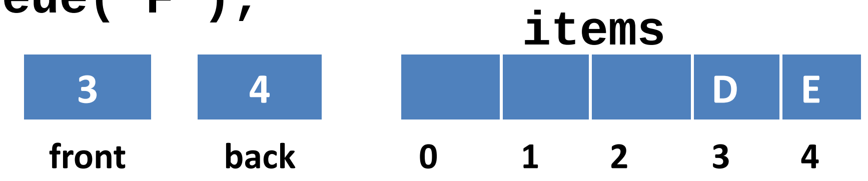
```
myQueue.enQueue('D');
```



```
myQueue.enQueue('E');
```



```
myQueue.enQueue('F');
```

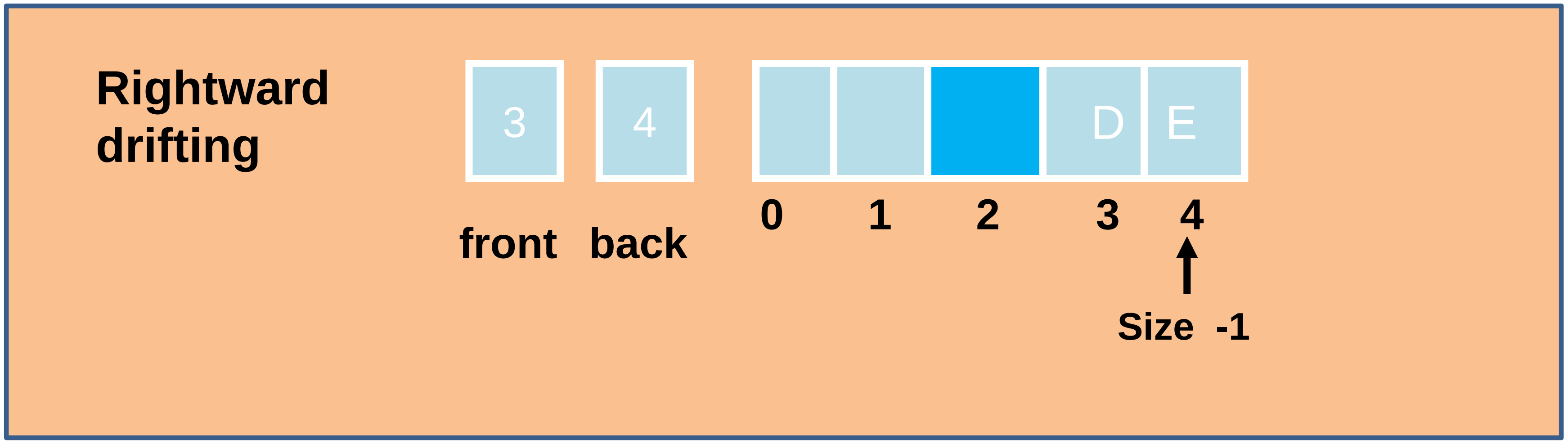


Cannot insert F, even though there are empty spaces in front of the queue array.
Currently, Queue is FULL with back == size – 1.

Linear Array Implementation - Drawback

Problem: Rightward-Drifting:

- After a sequence of additions and removals, items will drift towards the end of the array
- Even though, there are empty spaces in front of the queue array, enQueue operation cannot be performed on the queue, since back = size – 1.

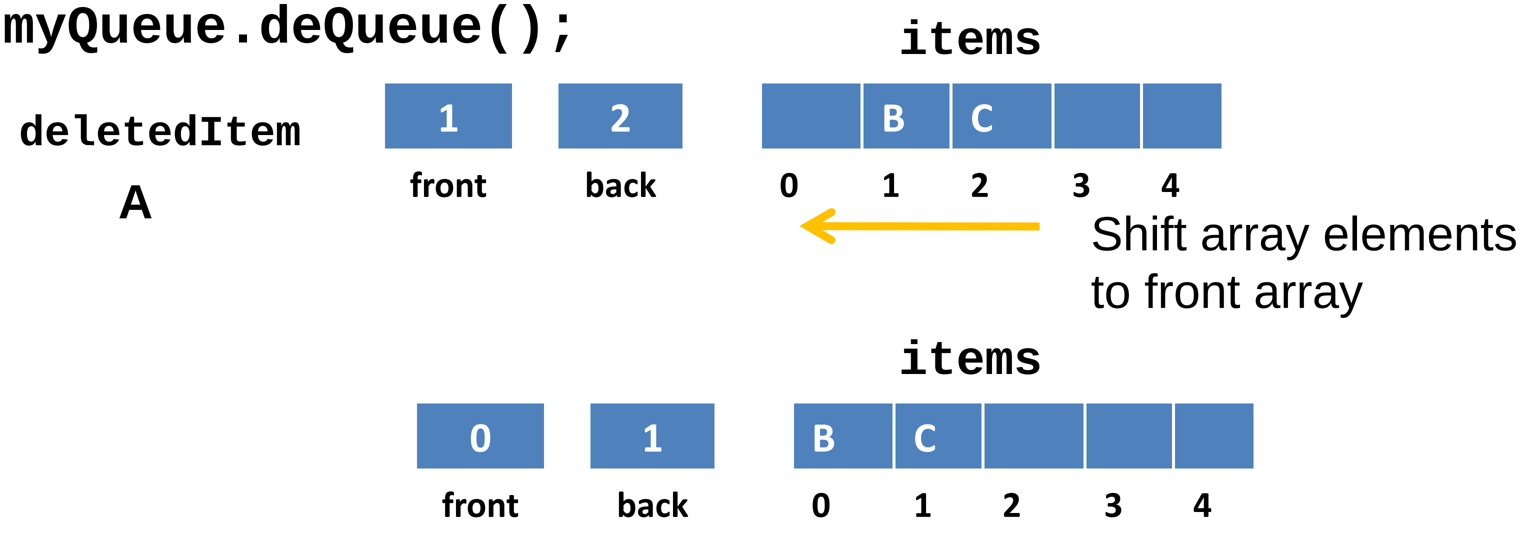


Rightward Drifting Solutions

To optimize space and to solve rightward drifting:

1. Shift array elements after each deletion.

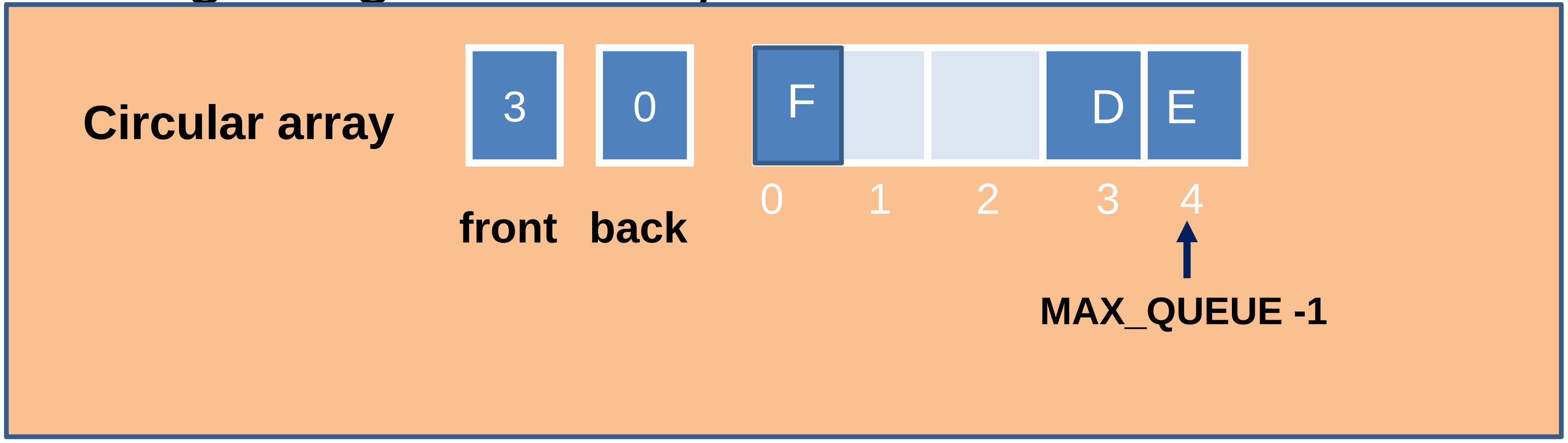
`myQueue.deQueue();`



However, shifting is not effective and dominates the cost of the implementation.

Rightward Drifting Solutions

2. Use a circular array: When front or back reach the end of the array, wrap them around to the beginning of the array.



In the figure, to insert F in the queue, F will be inserted at the front queue and restart again at index 0.

Queue Circular Array

- Problem:
  - front and back no longer can be used as condition to distinguish between queue-full and queue-empty
- Solution:
  - Use a counter, named count
  - count == 0 means empty queue
  - count == MAX_QUEUE means full queue
- Disadvantage
  - Overhead of maintaining a counter or flag

Circular Array Implementation

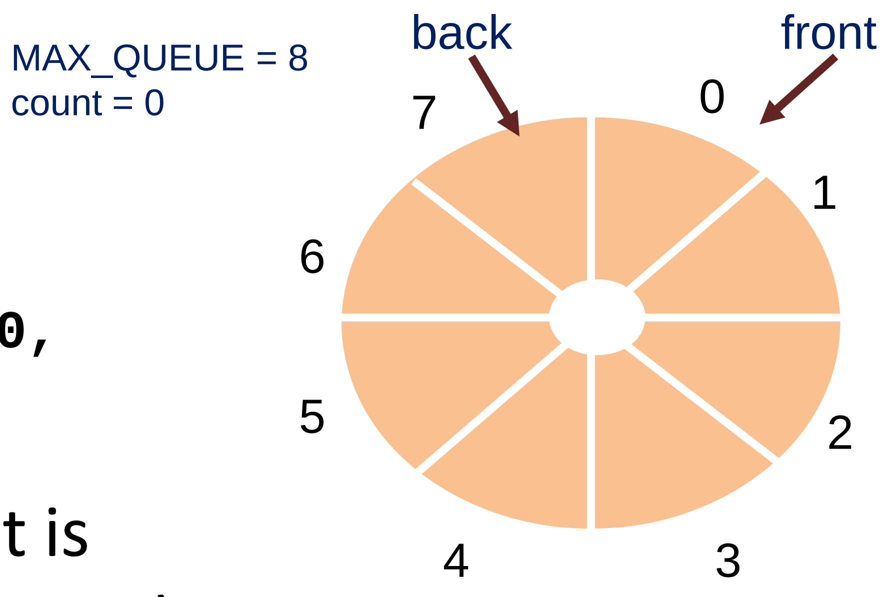
– Queue declarations

```
const int MAX_QUEUE = maximum-size-of-queue;
QueueItemType items [MAX_QUEUE];
int    front;
int    back;
int    count
```

– Initial condition:

- `count = 0, front = 0,`
- `back = MAX_QUEUE – 1`

– The Wrap-around effect is obtained by using modulo arithmetic (%-operator)



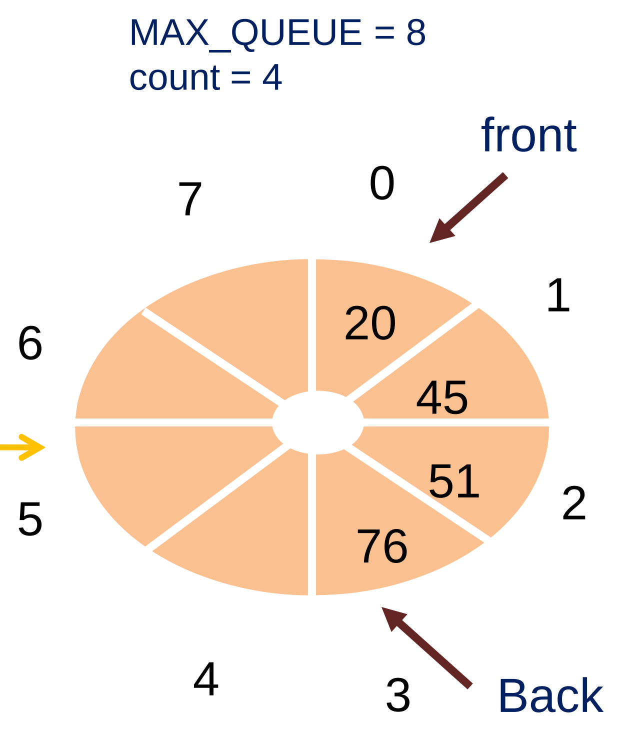
Empty circular queue.

Circular Arrays Implementation

– Insertion
  - Increment *back*, using modulo arithmetic
  - Insert item
  - Increment *count*

```
back = ( back + 1 ) % MAX_QUEUE;
items[back] = newItem;
++count;
```

After insert 20, 45, 51 and 76 sequentially into circular queue



Circular Arrays Implementation

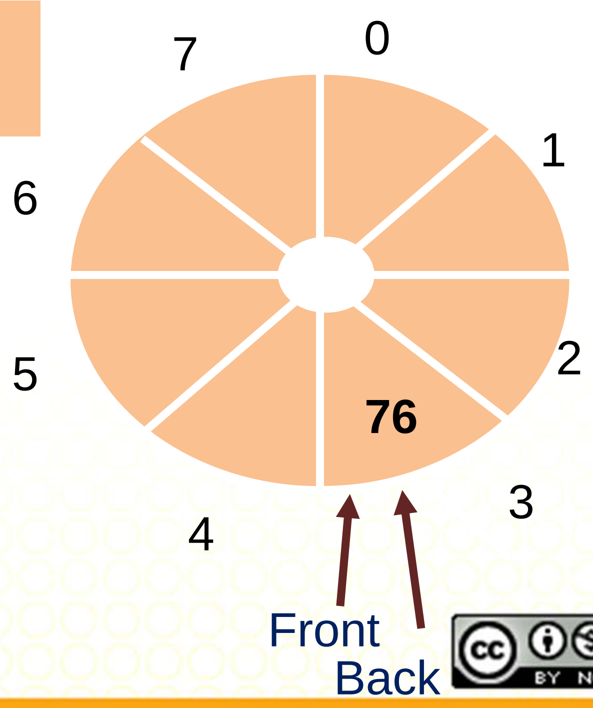
Deletion

Increment **`front`** using modulo arithmetic

```
front = ( front + 1 ) % MAX_QUEUE;
--count;
```

After delete 20, 45 and 51 sequentially from circular queue

MAX_QUEUE = 8
count = 1



Summary and Conclusion

- Queue can be implemented using linear array and circular array.
- Structure of queue linear array is the items that hold the array, front and back.
- Insertion happens at back, while deletion happens at front.
- Drawbacks of queue linear array is that it will lead to rightward drifting problem after sequence of deletion and insertion is performed on the queue.
- Queue circular array can be perform in order to solve the problem, whereby after front or back reach the end of the array, it will wrap around to the beginning of the array.
- The Wrap-around effect is obtained by using modulo arithmetic (%-operator)