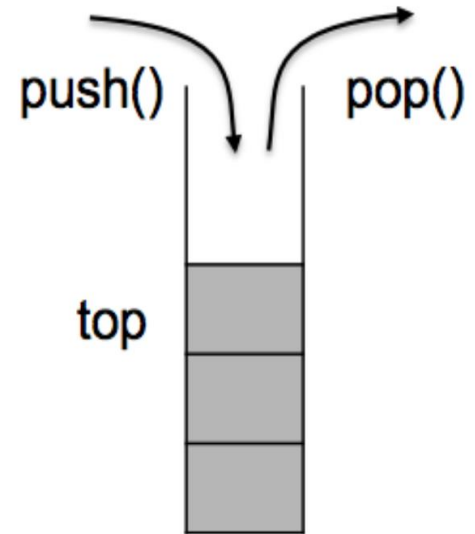


CMSC 132: Object-Oriented Programming II

Stack and Queue

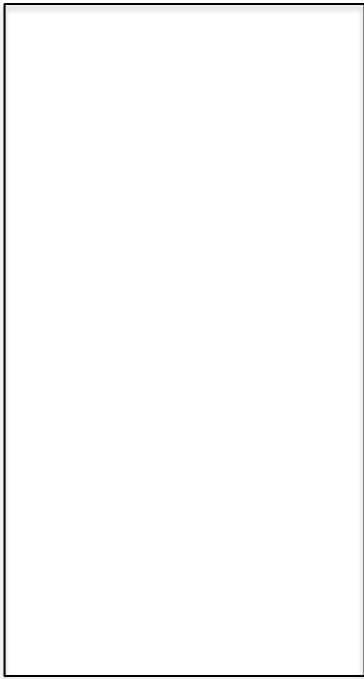
Stack

- ▶ Allows access to only the last item inserted.
- ▶ An item is inserted or removed from the stack from one end called the “top” of the stack.
- ▶ This mechanism is called Last-In-First-Out (LIFO).



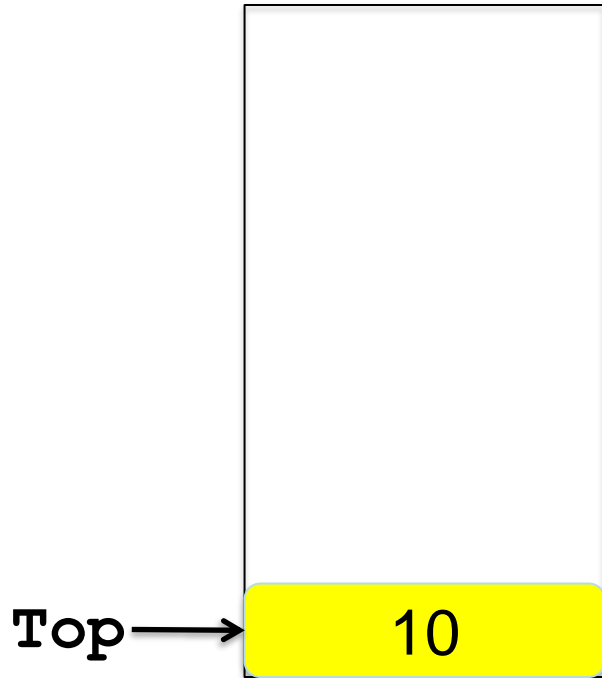
Stack Example

- ▶ Empty Stack



Stack Example

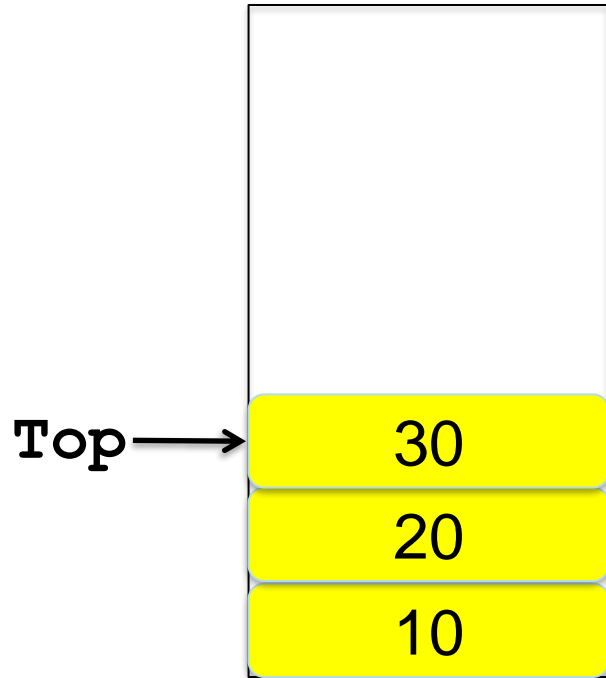
- ▶ Stack



Push 10

Stack Example

- ▶ Stack



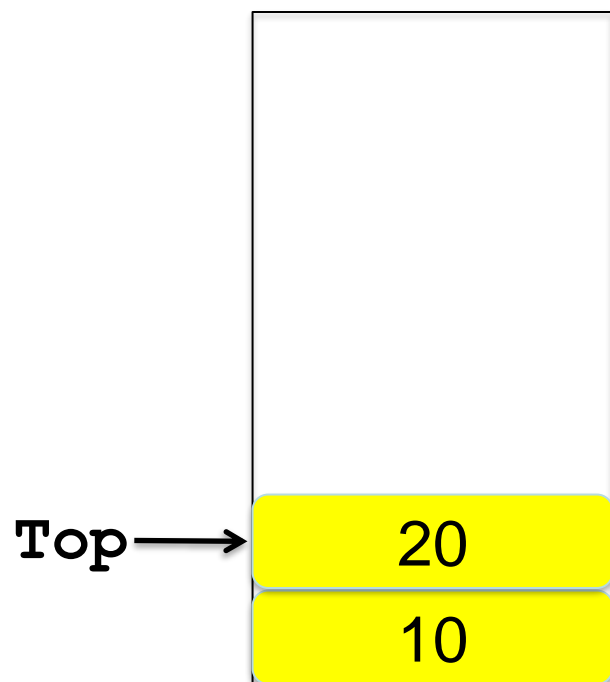
Push 10

Push 20

Push 30

Stack Example

- ▶ Stack



Push 10

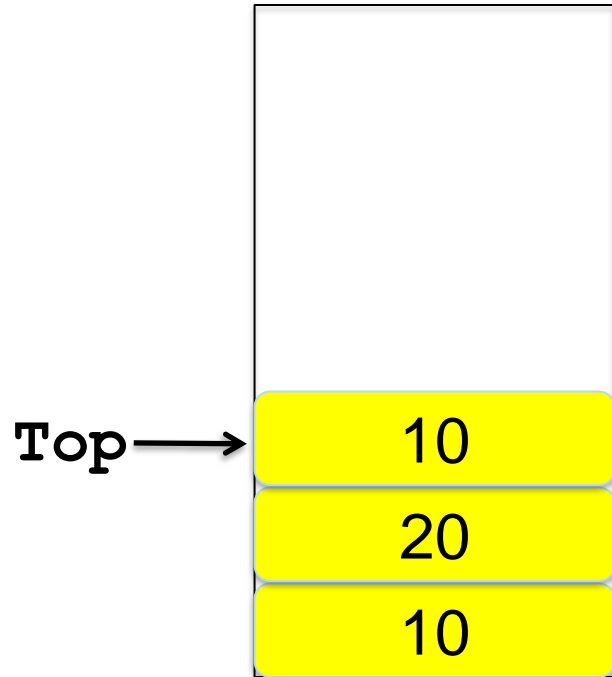
Push 20

Push 30

Pop

Stack Example

- ▶ Stack



Push 10

Push 20

Push 30

Pop

Push 10

Applications

- ▶ JVM stack machine
- ▶ Function Call
- ▶ Expression Evaluation
- ▶ Pushdown Automata
- ▶ Recursive \rightarrow Iterative Function Conversion

Stack Interface

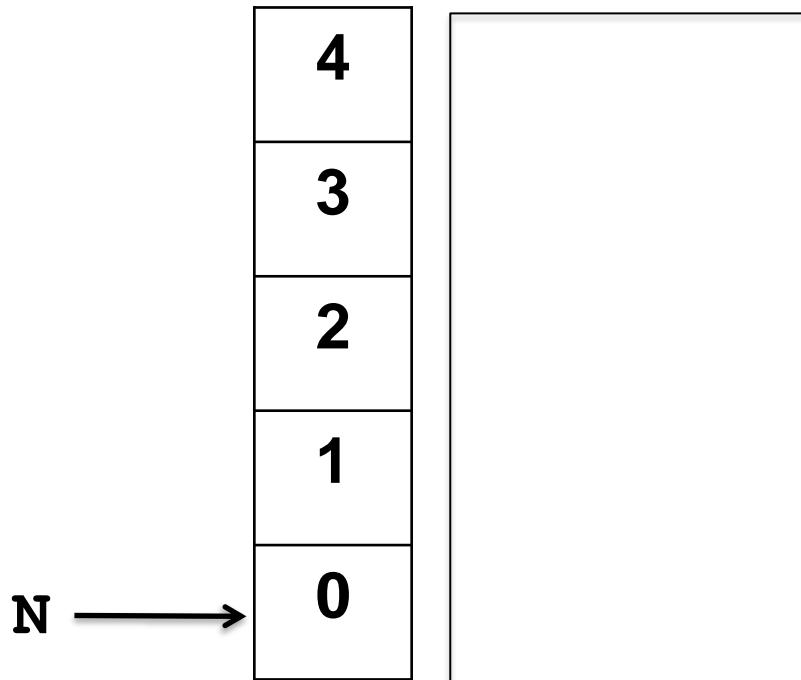
```
public interface Stack<T> extends Iterable<T>{
    void push(T t);
    T pop(); // throws EmptyStackException;
    T peek() ; //throws EmptyStackException;
    boolean isEmpty();
    int size();
}
```

Implement Stack Using an Array

```
public class ArrayStack<T> implements Stack<T> {
    private T[] items;
    private int N; // number of elements in the stack
    public ArrayStack(){
        items = (T[])new Object[2];
    }
}
```

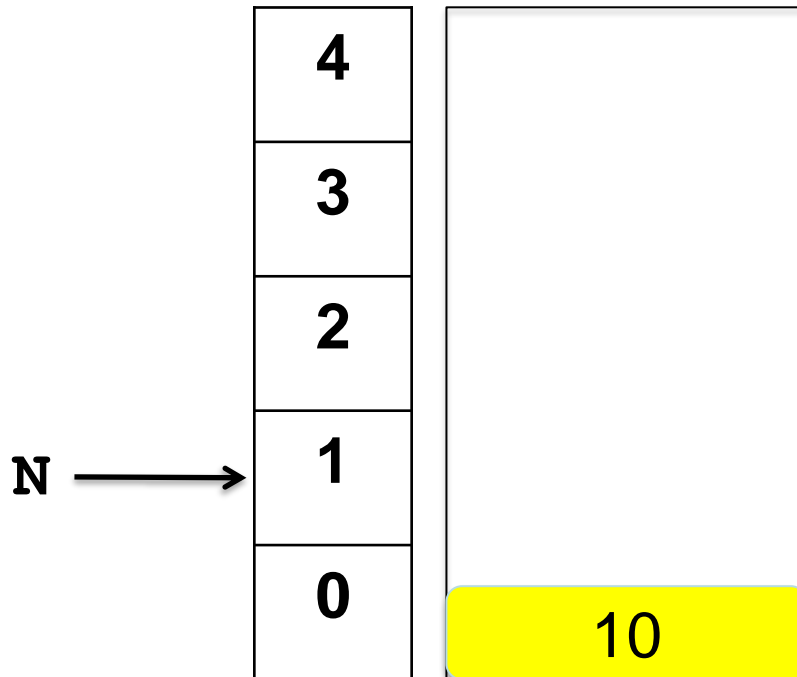
Stack Example

- ▶ Empty Stack

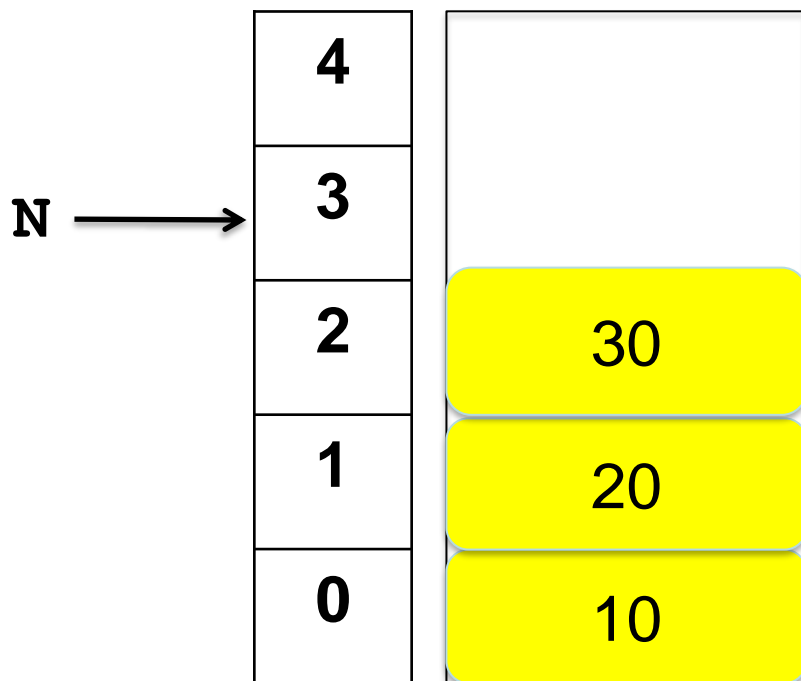


Pushing an item

Push 10



Pushing more items



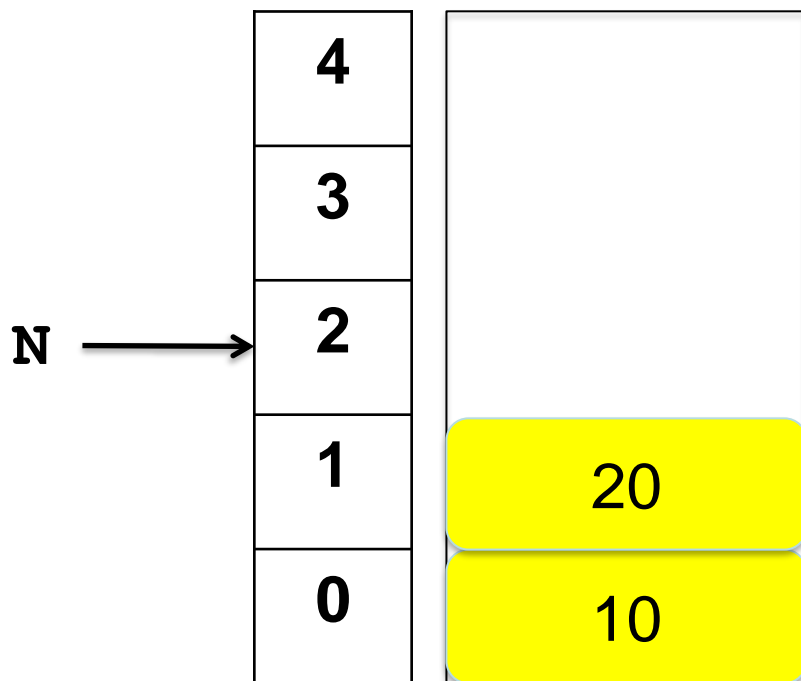
Push 10

Push 20

Push 30

What if
the array
is full?

Removing an item



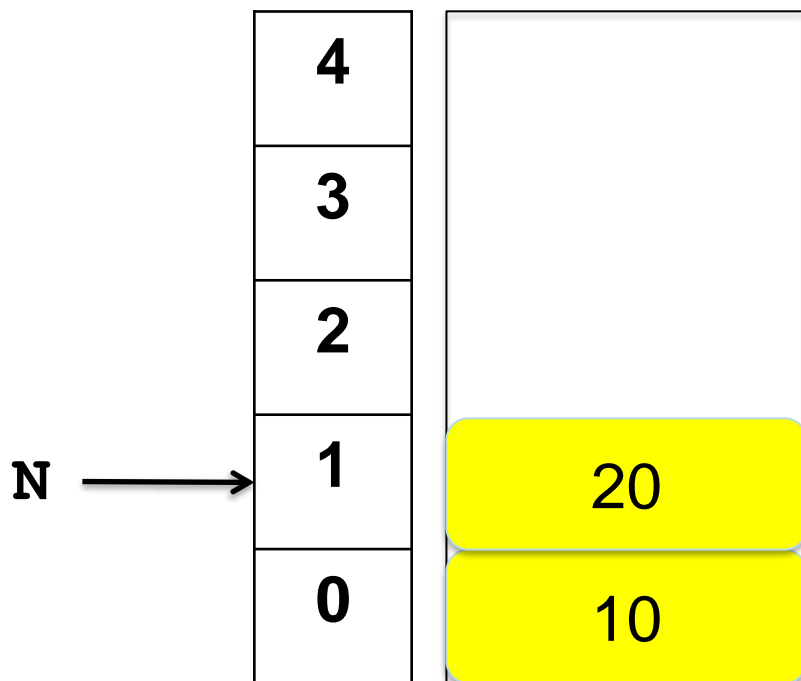
Push 10

Push 20

Push 30

Pop

Removing an item



Push 10

Push 20

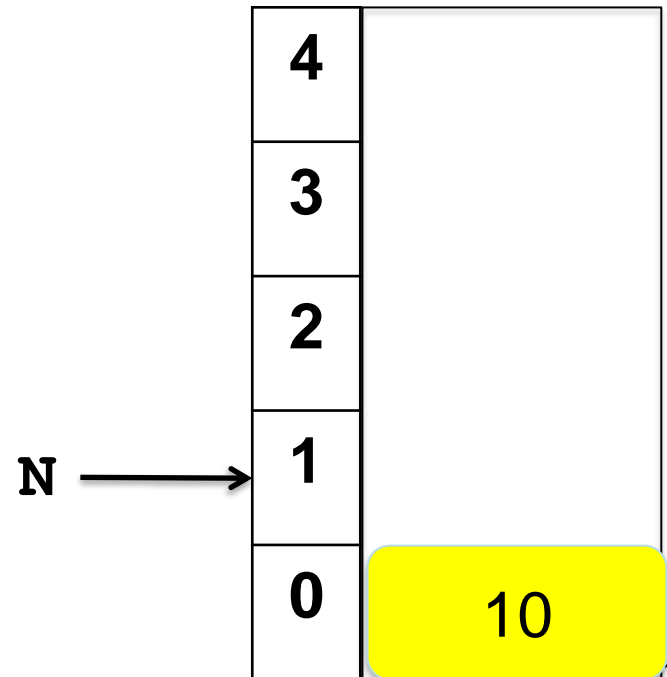
Push 30

Pop

Pop

Array Implementation: push

```
public void push(T item) {  
    if(N == items.length) {  
        resize(2 * items.length);  
    }  
    items[N++] = item;  
}
```



Array Implementation: pop

```
public T pop() {  
    if(isEmpty()) throw new NoSuchElementException();  
    T item = items[--N];  
    items[N] = null;  
    return item;  
}
```



Why?

Array Implementation: peek

```
public T peek() {  
    if (isEmpty())  
        throw new NoSuchElementException("Stack Underflow");  
    return items[N-1];  
}
```

Implement Stack Using a Linked List

```
public class LinkedStack<T> implements Stack<T> {
    private int N;
    private Node first;

    private class Node{
        private T data;
        private Node next;
        Node(T item) {
            data = item;
        }
    }
}
```

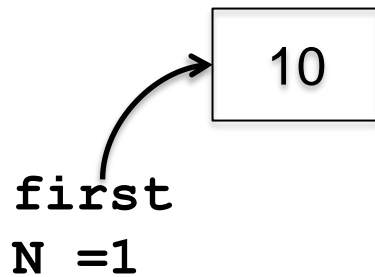
Stack Example

- ▶ Empty Stack

```
first = null  
N = 0
```

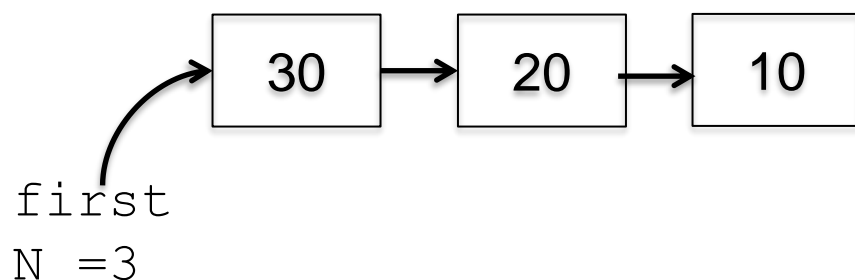
Pushing an item

Push 10



```
public void push(T item) {  
    Node old = first;  
    first = new Node(item);  
    first.next = old;  
    N++;  
}
```

Pushing more items



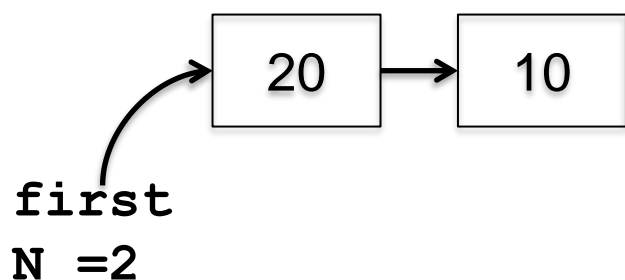
Push 10

Push 20

Push 30

```
public void push(T item) {  
    Node old = first;  
    first = new Node(item);  
    first.next = old;  
    N++;  
}
```

Pushing more items



Push 10

Push 20

Push 30

Pop

```
public T pop() {  
    if (isEmpty()) {  
        throw new NoSuchElementException();  
    }  
    T item = first.data;  
    first = first.next;  
    N--;  
    return item;  
}
```

Other methods

Peek

```
public T peek() {  
    if (isEmpty()) { throw new NoSuchElementException(); }  
    return first.data;  
}
```

size

```
public int size() {  
    return N;  
}
```

isEmpty

```
public boolean isEmpty() {  
    return first == null;  
}
```


Testing the Stack

```
public static void main(String [] args) {
    LinkedStack<Integer> ls = new LinkedStack ();
    for(int i = 1; i <= 7; i++){
        ls.push(i);
    }
    System.out.println("size:" + ls.size());
    System.out.println("\n");
    while (!ls.isEmpty()) {
        System.out.print(ls.peek()+",");
        System.out.print(ls.pop()+",");
    }
}
```

Size:7

7,7,6,6,5,5,4,4,3,3,2,2,1,1

Queue

- ▶ Queue is an ADT data structure similar to stack, except that the first item to be inserted is the first one to be removed.
- ▶ This mechanism is called First-In-First-Out (FIFO).
- ▶ Placing an item in a queue: enqueue.
- ▶ Removing an item from a queue: dequeue
- ▶ Applications: printer queue, keystroke queue, etc.

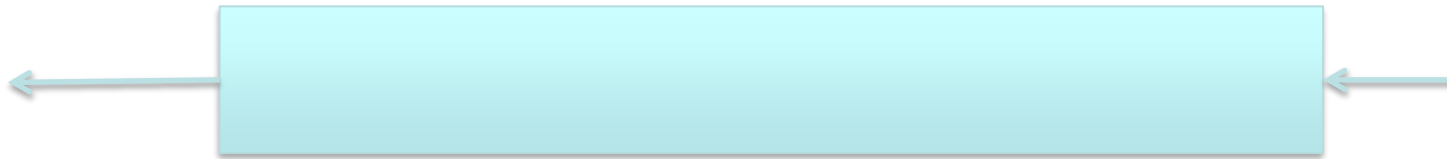
Queue



```
public interface Queue<T> extends Iterable<T> {  
    void enqueue(T t);  
    T dequeue(); // throws EmptyStackException;  
    T peek(); // throws EmptyStackException;  
    boolean isEmpty();  
    int size();  
}
```

Queue Example

Empty Queue



Adding an item

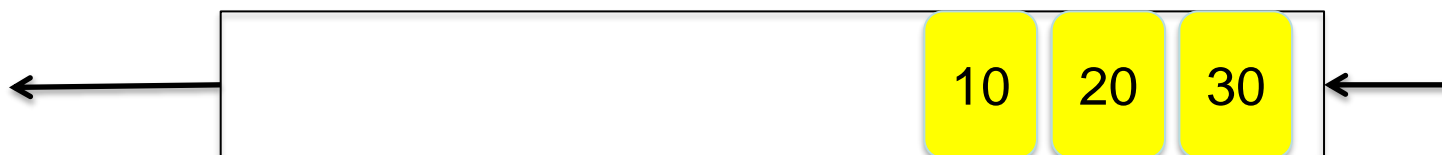
Empty Queue



`enqueue 10`

Adding more items

Empty Queue



`enqueue 10`

`enqueue 20`

`enqueue 30`

Adding more items

Empty Queue



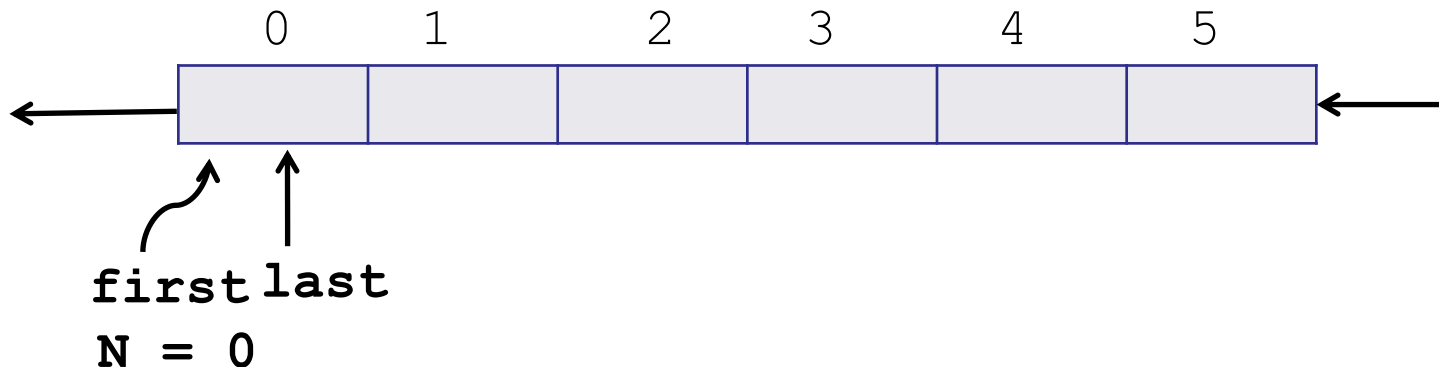
`enqueue 10`

`enqueue 20`

`enqueue 30`

`dequeue`

Circular Array Implementation



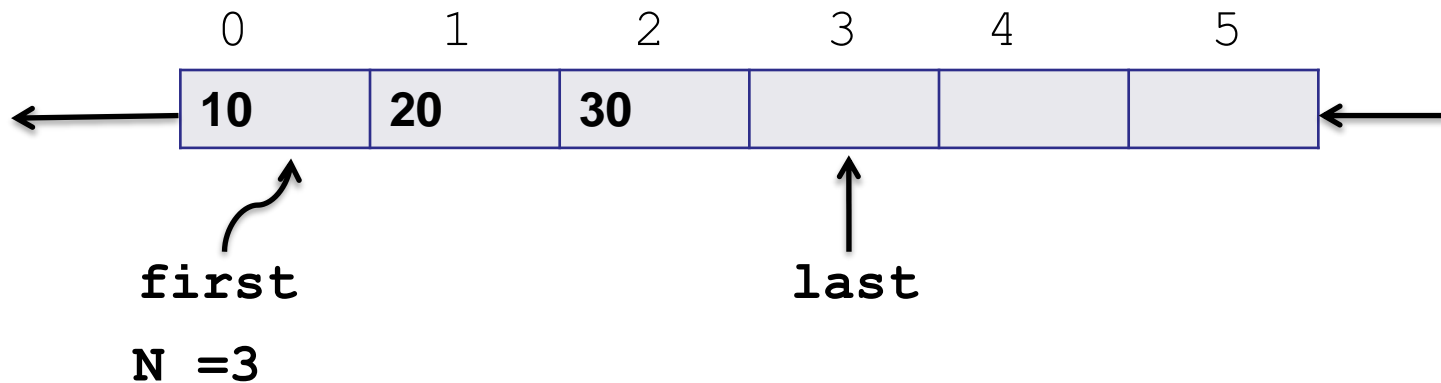
Enqueue:

```
q[last++] = item;  
if (last == q.length) last = 0; //wrap-around
```

Dequeue:

```
first++;  
if (first == q.length) first = 0; // wrap-around
```


Circular Array Implementation

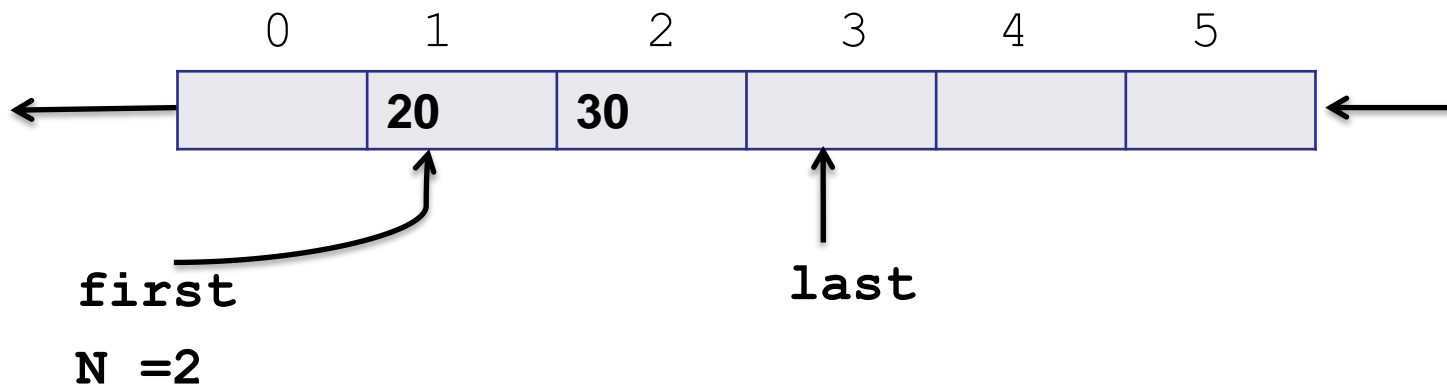


enqueue 10

enqueue 20

enqueue 30

Circular Array Implementation



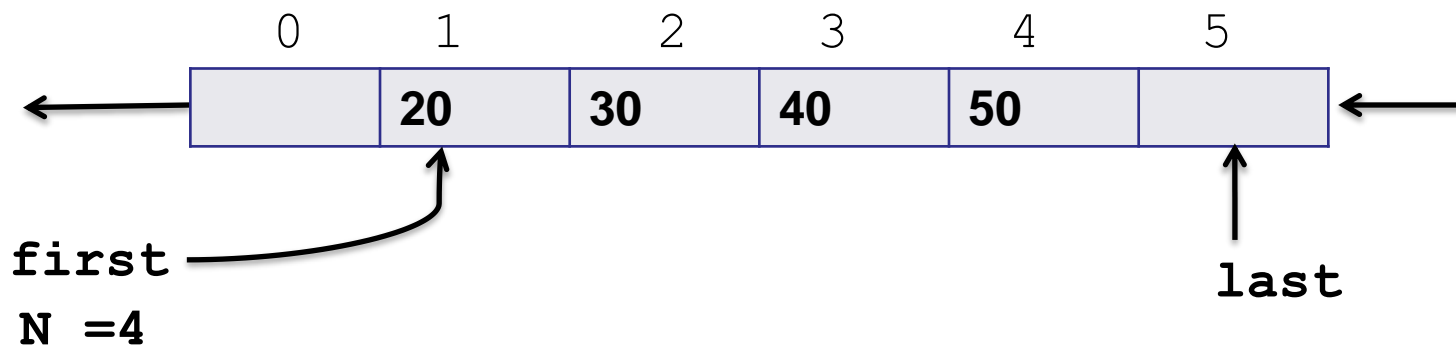
enqueue 10

dequeue

enqueue 20

enqueue 30

Circular Array Implementation



`enqueue 10`

`enqueue 20`

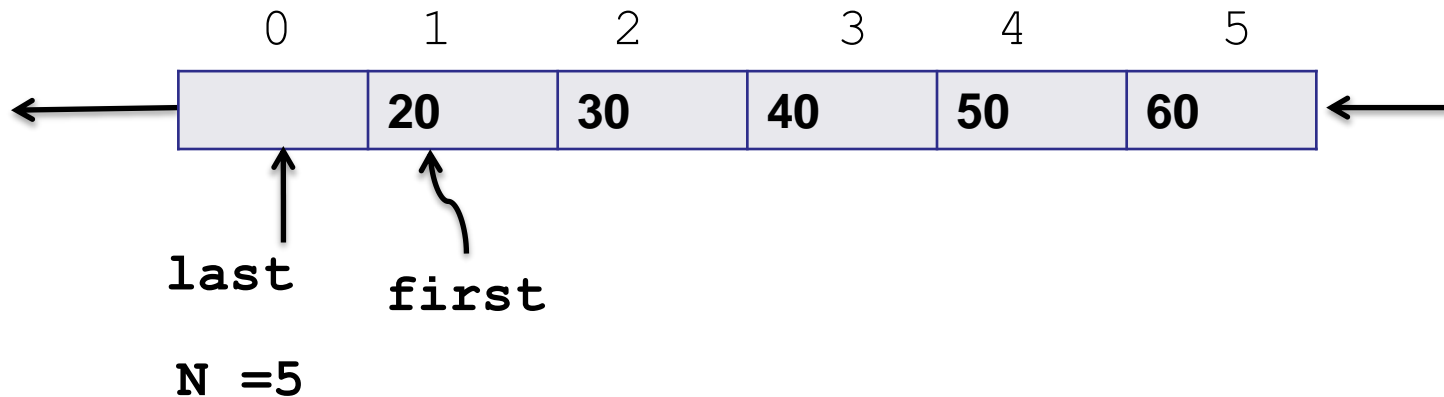
`enqueue 30`

`dequeue`

`enqueue 40`

`enqueue 50`

Circular Array Implementation



enqueue 10

enqueue 20

enqueue 30

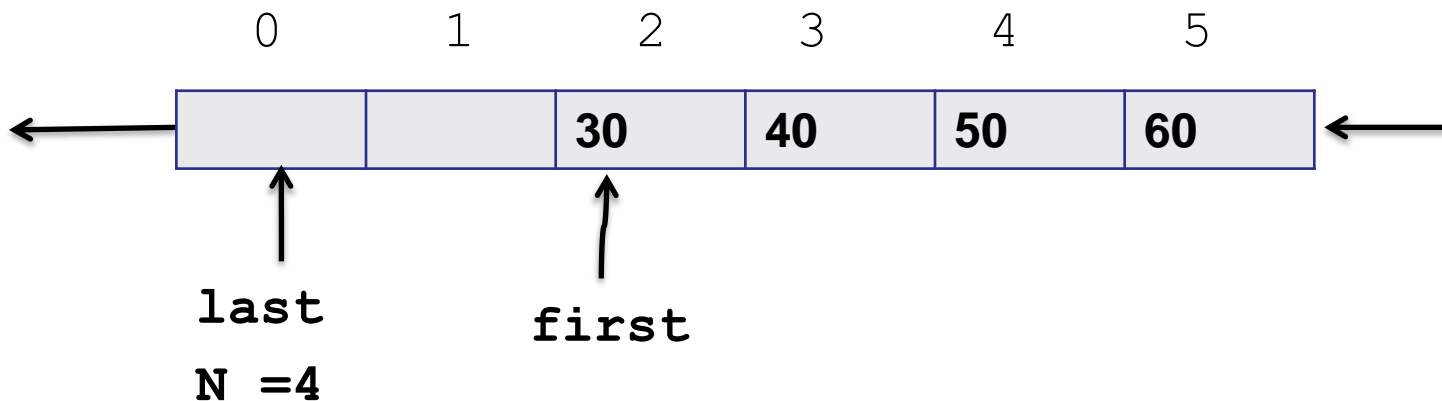
dequeue

enqueue 40

enqueue 50

enqueue 60

Circular Array Implementation



enqueue 10

enqueue 20

enqueue 30

dequeue

enqueue 40

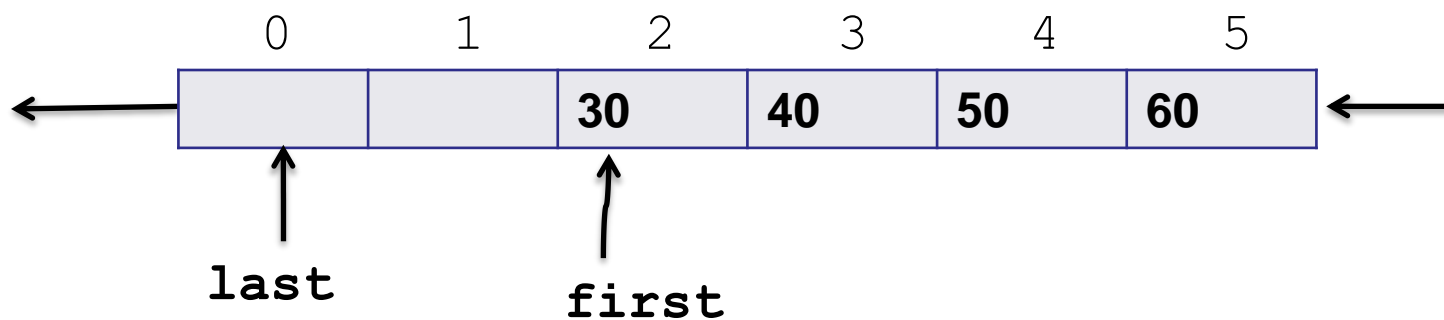
enqueue 50

enqueue 60

dequeue

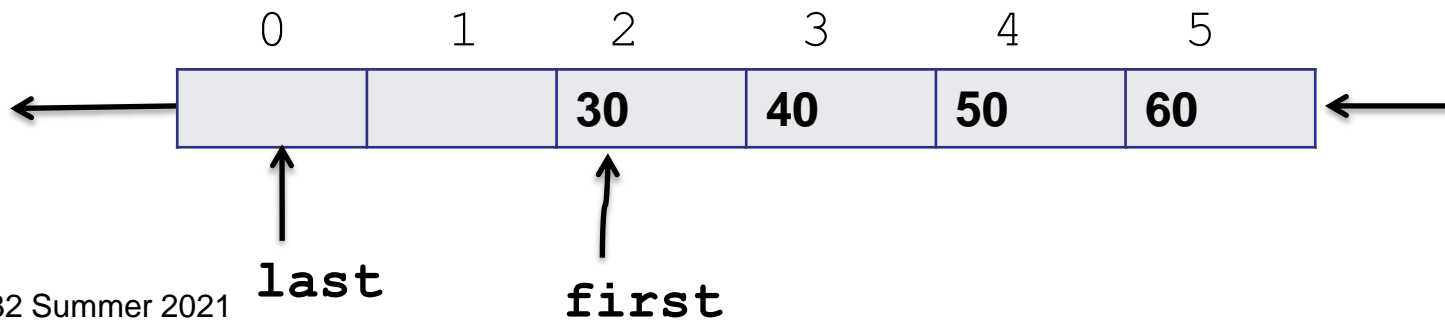
Implementing push (enqueue)

```
public void enqueue(E item) {  
    if (N == q.length) resize(2*q.length);  
    q[last++] = item;  
    if (last == q.length) last = 0; //wrap-around  
    N++;  
}
```



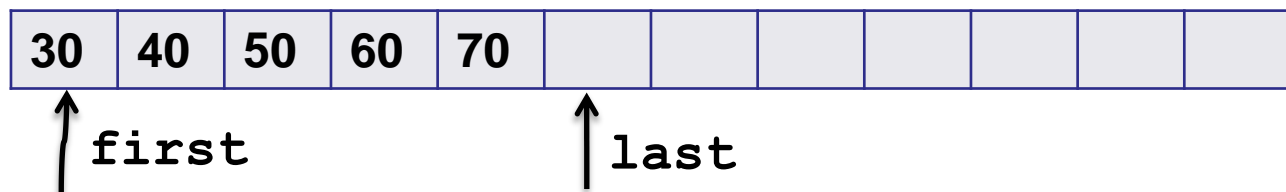
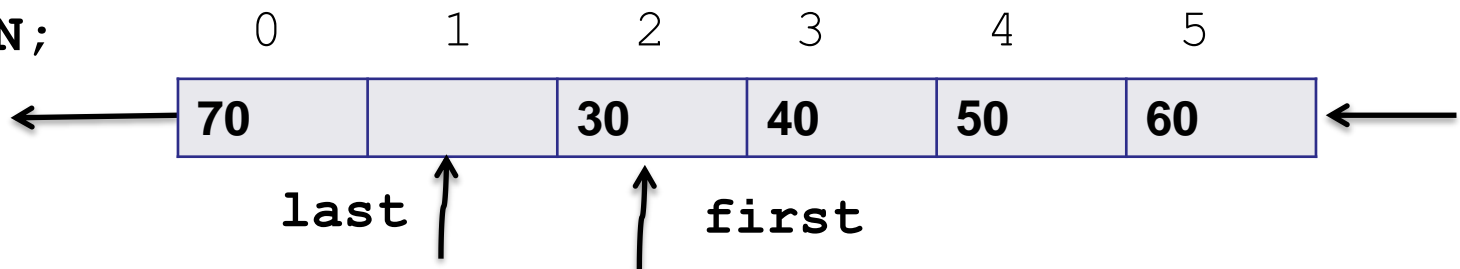
Implementing pop (dequeue)

```
public E dequeue() {  
    if(isEmpty()) throw  
        new NoSuchElementException("Queue underflow");  
    E item = q[first];  
    q[first] = null;  
    N--;  
    first++;  
    if (first == q.length) first = 0; // wrap-around  
    // shrink size of array if necessary  
    if (N > 0 && N == q.length/4)  
        resize(q.length/2);  
    return item;  
}
```

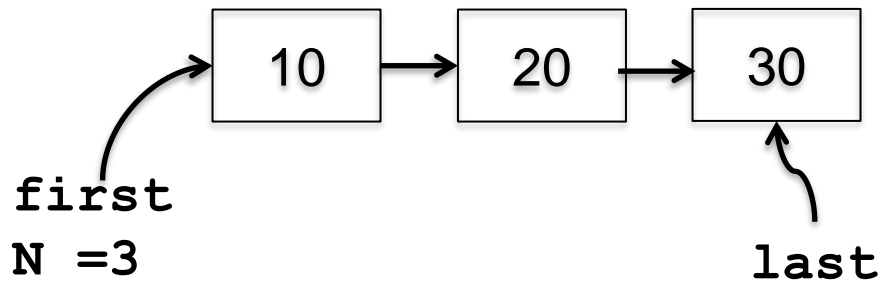


Implementing resize

```
private void resize(int max) {  
    assert max >= N;  
    E[] temp = (E[]) new Object[max];  
    for (int i = 0; i < N; i++) {  
        temp[i] = q[(first + i) % q.length];  
    }  
    q = temp;  
    first = 0;  
    last = N;  
}
```



Linked List Queue



- Add a new item
 - New node is added to tail (`last.next`)
- Remove an item
 - Remove the first node (`first = first.next`)

Linked Queue Implementation

```
public class LinkedQueue<E> implements Queue<E> {
    private int N;           // number of elements on queue
    private Node first;     // beginning of queue
    private Node last;     // end of queue

    // helper linked list class
    private class Node {
        private E item;
        private Node next;
    }
}
```

Enqueue

```
public void enqueue(E item) {
    Node oldlast = last;
    last = new Node();
    last.item = item;
    last.next = null;
    if (isEmpty()) first = last;
    else          oldlast.next = last;
    N++;
}
```

Deque

```
public E dequeue() {
    if (isEmpty())
        throw new NoSuchElementException("Queue underflow");
    E item = first.item;
    first = first.next;
    N--;
    if (isEmpty()) last = null;    // to avoid loitering
    return item;
}
```

Peek, isEmpty, and Size

```
public boolean isEmpty() {  
    return first == null;  
}
```

```
public int size() {  
    return N;  
}
```

```
public E peek() {  
    if (isEmpty()) throw new NoSuchElementException  
                    ("Queue underflow");  
    return first.item;  
}
```