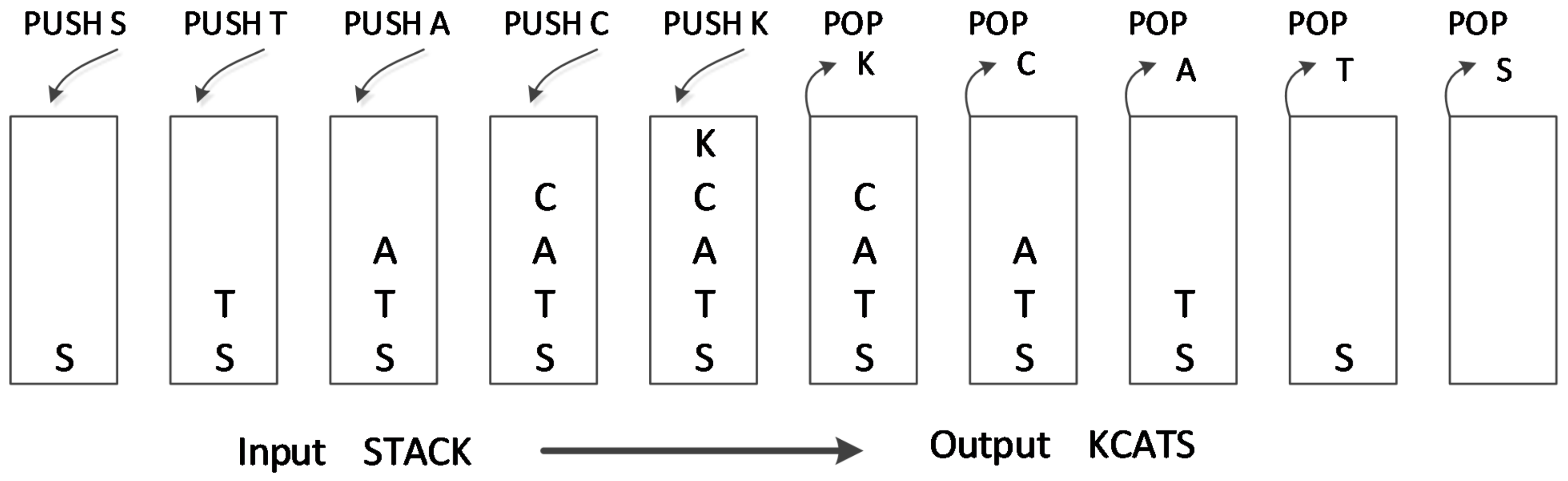
Data Structures and Algorithms

Chapter 6

Stacks

- Linear data structure
- Elements are added to and removed from one end called *top*.
- LIFO (last in first out)



Stacks

- Stack ADT supports the following operations:
  - push(*e*): Adds element *e* to the stack top.
  - pop( ): Removes and returns the top element from the stack. Returns null if the stack is empty.
  - top( ): Returns the top element of the stack without removing it. Returns null if the stack is empty.
  - size( ): Returns the number of elements in the stack.
  - isEmpty( ): Returns true if the stack is empty and false otherwise.

Stacks

- Illustration

Operation	Return Value	Stack Contents → top
push(10)	-	(10)
push(20)	-	(10, 20)
push(5)	-	(10, 20, 5)
size( )	3	(10, 20, 5)
top( )	5	(10, 20, 5)
pop( )	5	(10, 20)
push(30)	-	(10, 20, 30)
pop( )	30	(10, 20)
pop( )	20	(10)
pop( )	10	( )
isEmpty( )	true	( )
pop( )	null	( )

Stacks

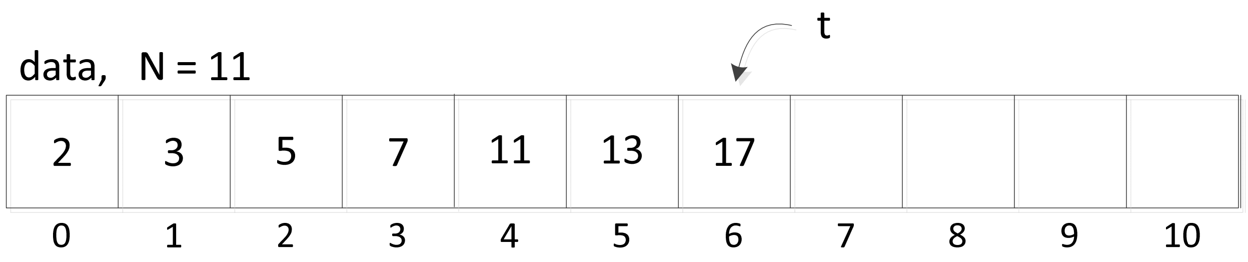
- Java’s stack (*java.util.Stack* class)

Stack ADT in Textbook	Class java.util.Stack
size( )	size( )
isEmpty( )	empty( )
push(e)	push(e)
pop( )	pop( )
top( )	peek( )

- JavaStackDemo.java

Stacks

- Array-based implementation
  - The bottom element is stored in *data*[0].
  - The top element is stored in *data*[*t*], $0 \le t < N$.
  - When the stack is empty, by convention, $t = -1$.



- ArrayStack.java

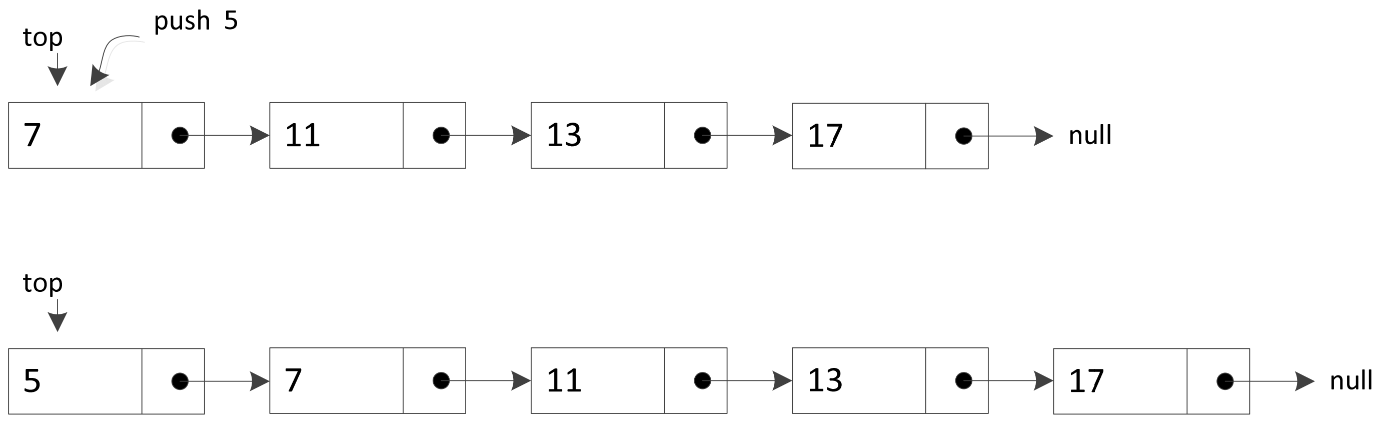
Stacks

- Running times of array-based implementation

Method	Running Time
size( )	O(1)
isEmpty( )	O(1)
push(e)	O(1)
pop( )	O(1)
top( )	O(1)

Stacks

- Stack implementation using singly-linked list.
  - Stack top element is stored at the head of a list.
  - All operations take $O(1)$.



- *LinkedStack.java*

Stacks

- Reversing array elements

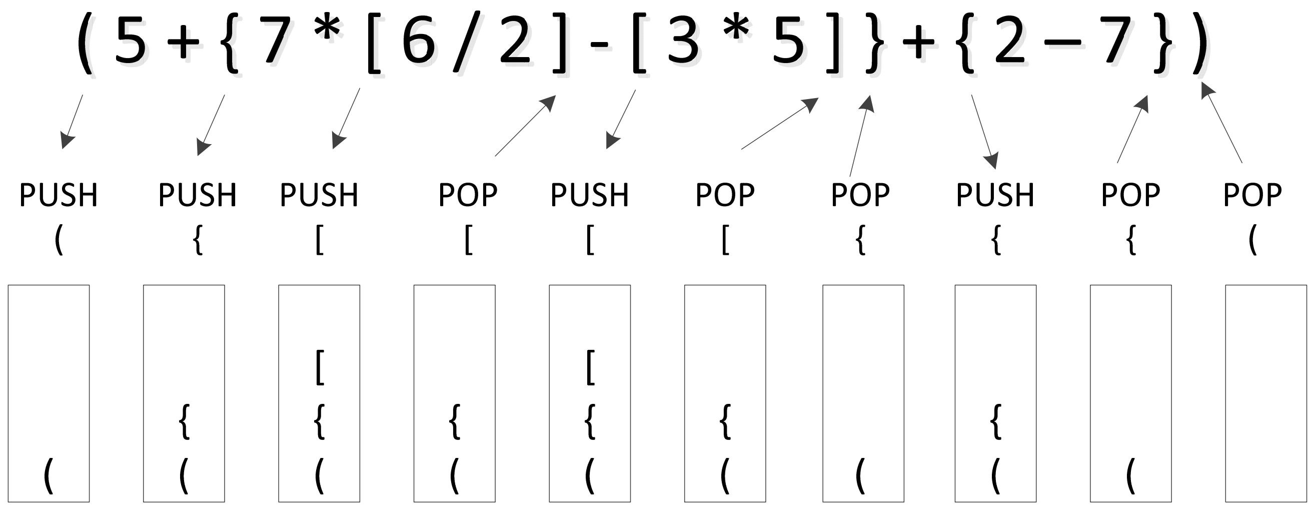
```
public static <E> void reverse(E[ ] a) {
  Stack<E> buffer = new ArrayStack<>(a.length);
  for (int i=0; i < a.length; i++)
    buffer.push(a[i]);
  for (int i=0; i < a.length; i++)
    a[i] = buffer.pop();
}
```

Stacks

- Matching parentheses
  - Scan the expression one character at a time from left to right
  - If the character is an opening delimiter, push it to the stack
  - If the character is a closing delimiter:
    - Pop a delimiter from the stack
    - Compare that with the closing delimiter being scanned
    - If they are a matching pair (for example, a left square bracket and a right square bracket), continue
    - Else, the expression is invalid

Stacks

- Matching parentheses (continued)

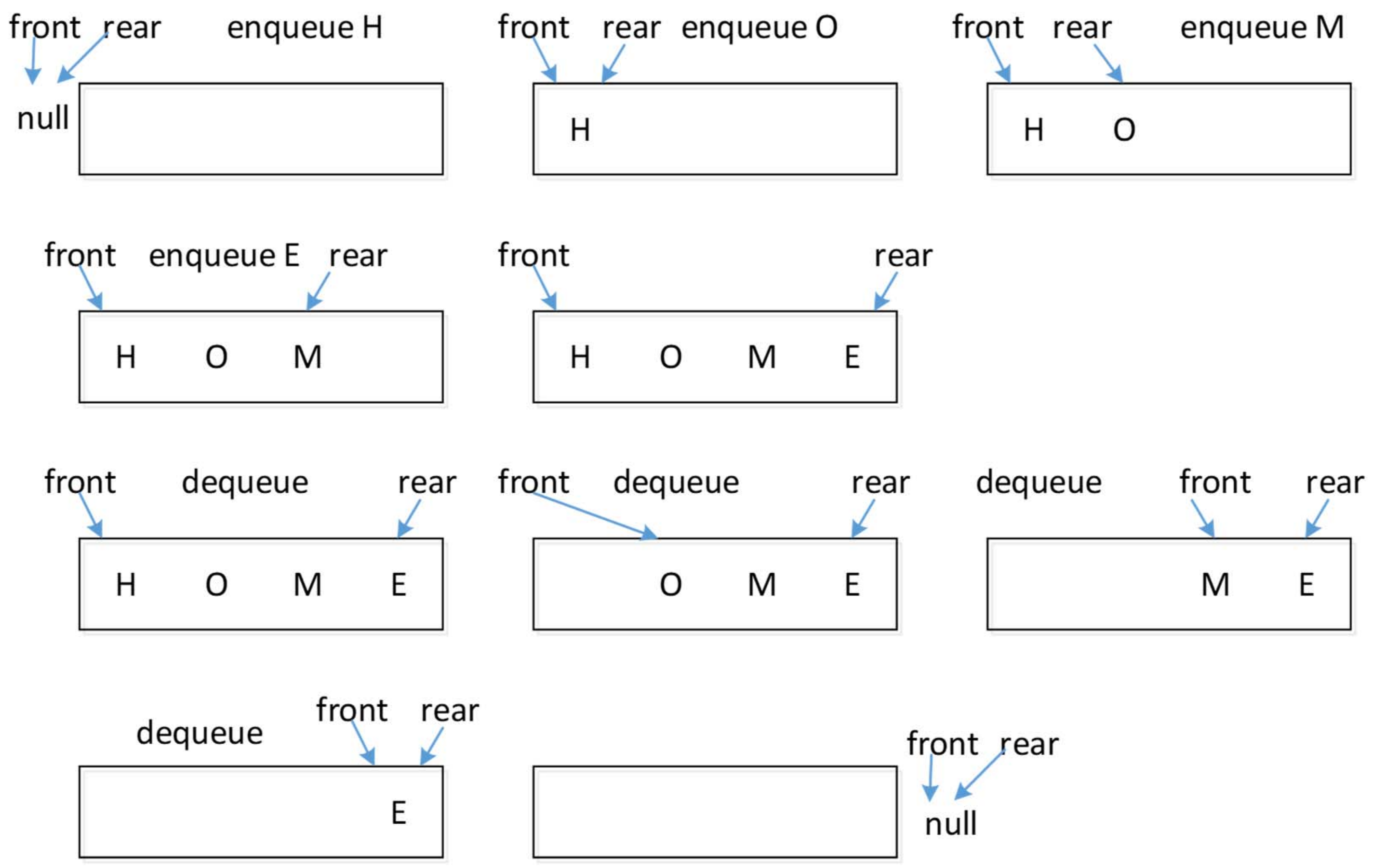


Queues

- A queue has a linear data structure (like stack)
- An object is added to one end called *rear*, and removed from the other end called *front*.
- FIFO (first in first out).
- Adding is called *enqueue*
- Removing is called *dequeue*

Queues

- Illustration



Queues

- Queue ADT operations:
  - enqueue(*e*): Adds element *e* to the back of queue.
  - dequeue( ): Remove and returns the first element from the queue. Returns null if the queue is empty.
  - first( ): Returns the first element of the queue, without removing it. Returns null if the queue is empty.
  - size( ): Returns the number of elements in the queue.
  - isEmpty( ): Returns true if the queue is empty and false otherwise.

Queues

- Illustration of operations:

Operation	Return Value	first ← Q ← last
enqueue(10)	-	(10)
enqueue(20)	-	(10, 20)
enqueue(5)	-	(10, 20, 5)
size( )	3	(10, 20, 5)
dequeue( )	10	(20, 5)
enqueue(30)	-	(20, 5, 30)
dequeue ( )	20	(5, 30)
dequeue ( )	5	(30)
dequeue ( )	30	( )
isEmpty( )	true	( )
dequeue( )	null	( )

Queues

- Java has the *java.util.Queue* interface.
- Java Queue interface operations:

Queue ADT	Interface java.util.Queue	
	throws exception	returns special value
enqueue(e)	add(e)	offer(e)
dequeue( )	remove( )	poll( )
first( )	element( )	peek( )
size( )	size( )	
isEmpty( )	isEmpty	

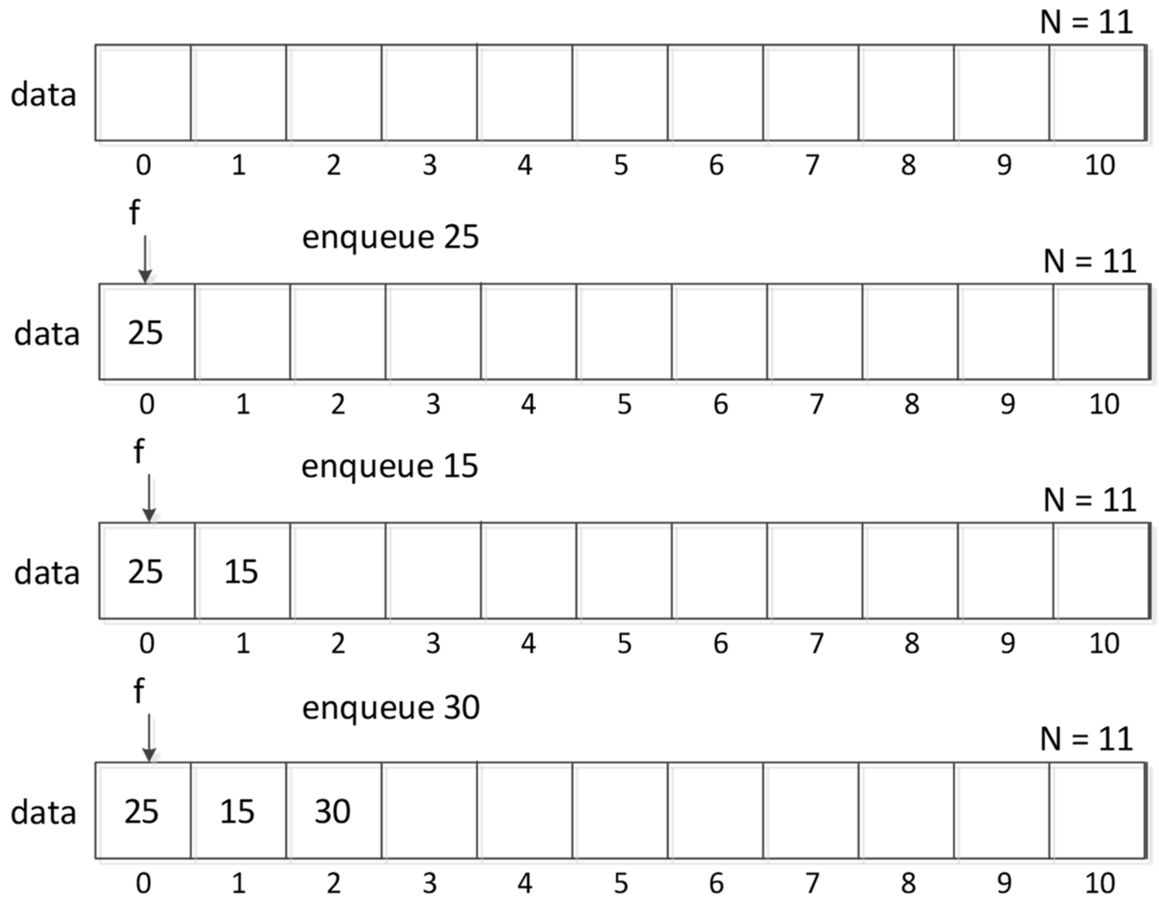
Queues

- In Java:
  - LinkedList class implements List and Deque interfaces.
  - Deque interface extends Queue interface.

- JavaQueueDemo.java

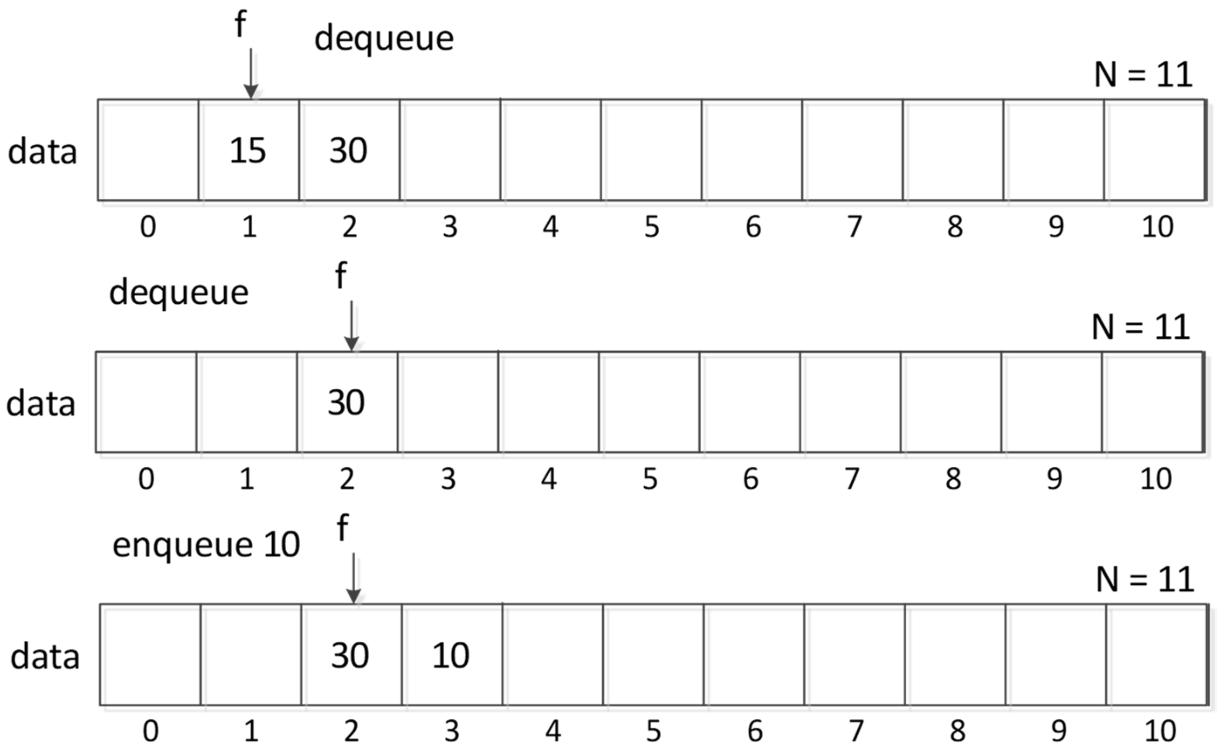
Queues

- Array-based implementation (*ArrayQueue.java*)



Queues

- Array-based implementation (continued)

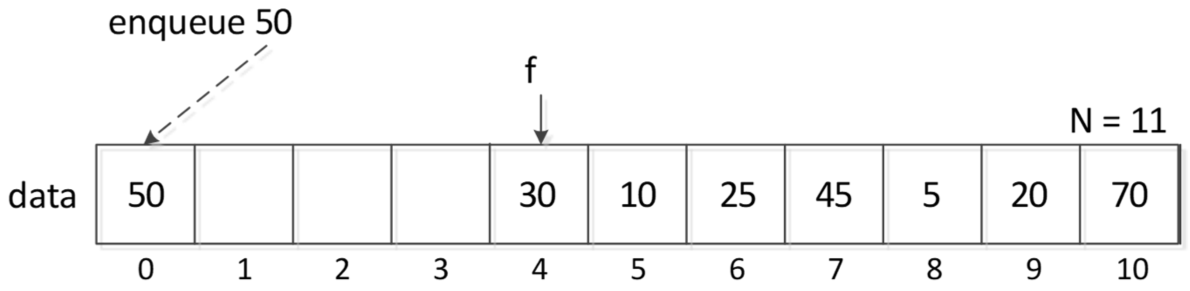


Queues

- Array-based implementation (continued)

- Elements are added in a wrap around manner:

```
public void enqueue(E e) throws IllegalStateException {
 if (sz == data.length)
     throw new IllegalStateException("Queue is full");
  int avail = (f + sz) % data.length;   // use modular arithmetic
  data[avail] = e;
  sz++;
}
```



Queues

- Singly linked list-based implementation

```
public class LinkedQueue<E> implements Queue<E> {
  private SinglyLinkedList<E> list = new SinglyLinkedList<>();
  public LinkedQueue() { }
  public int size() { return list.size(); }
  public boolean isEmpty() { return list.isEmpty(); }
  public void enqueue(E element) { list.addLast(element); }
  public E first() { return list.first(); }
  public E dequeue() { return list.removeFirst(); }
}
```

Queues

- Double-ended queue, called *deque* (pronounced “deck”).
  - Allows insertion and deletion at both ends.
  - Can be used as a stack or as a queue

- Queue and Deque (in Java)

Queue Method	**Equivalent Deque Method**
add(e)	addLast(e)
offer(e)	offerLast(e)
remove()	removeFirst()
poll()	pollFirst()
element()	getFirst()
peek()	peekFirst()

Queues

- Stack and Deque (in Java)

Stack Method	**Equivalent Deque Method**
push(e)	addFirst(e)
pop()	removeFirst()
peek()	peekFirst()

- *java.util.Deque* interface.
- *java.util.ArrayDeque* implements *Deque* interface.

References

- M.T. Goodrich, R. Tamassia, and M.H. Goldwasser, “Data Structures and Algorithms in Java,” Sixth Edition, Wiley, 2014.
- Oracle online documentation