

Queues

- Linear list.
- One end is called **front**.
- Other end is called **rear**.
- Additions are done at the **rear** only.
- Removals are made from the **front** only.

Bus Stop Queue



Bus Stop Queue



front



rear



Bus Stop Queue



front



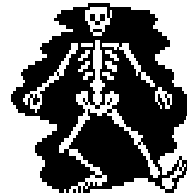
rear



Bus Stop Queue



front



rear





The Interface Queue

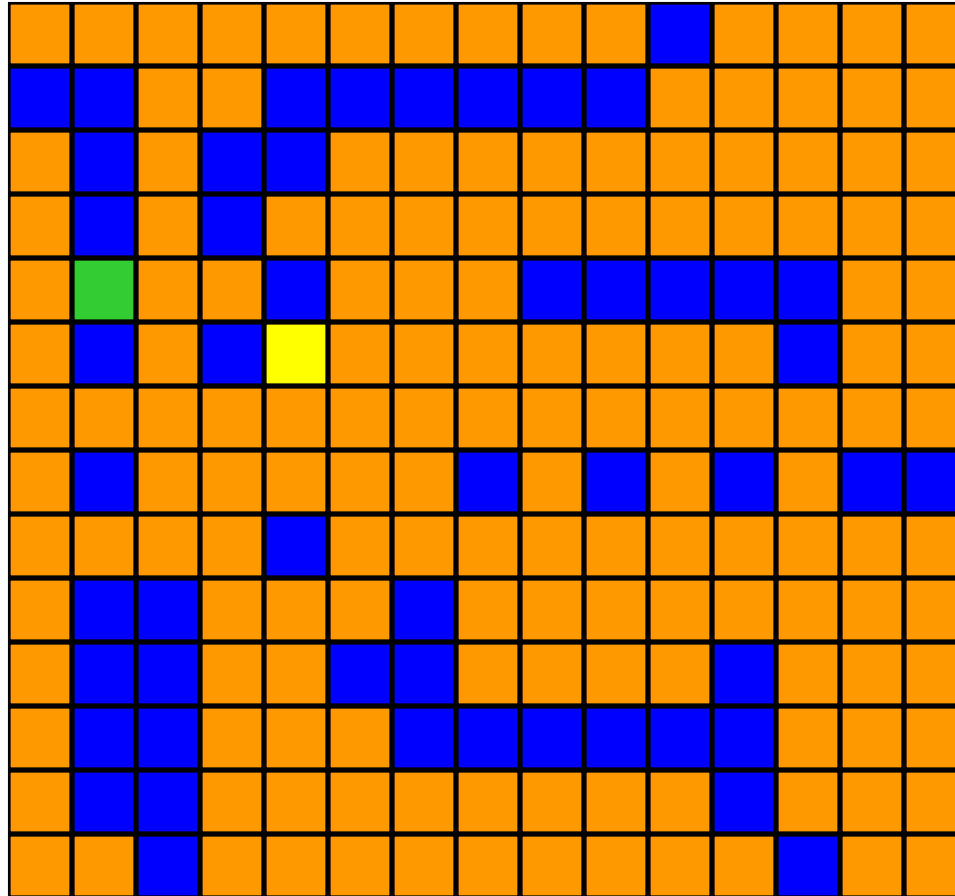
```
public interface Queue
{
    public boolean isEmpty();
    public Object getFrontEelement();
    public Object getRearEelement();
    public void put(Object theObject);
    public Object remove();
}
```

Revisit Of Stack Applications

- Applications in which the stack cannot be replaced with a queue.
 - Parentheses matching.
 - Towers of Hanoi.
 - Method invocation and return.
 - Try-catch-throw implementation.
- Application in which the stack may be replaced with a queue.
 - Rat in a maze.
 - Results in finding shortest path to exit.



Lee's Wire Router

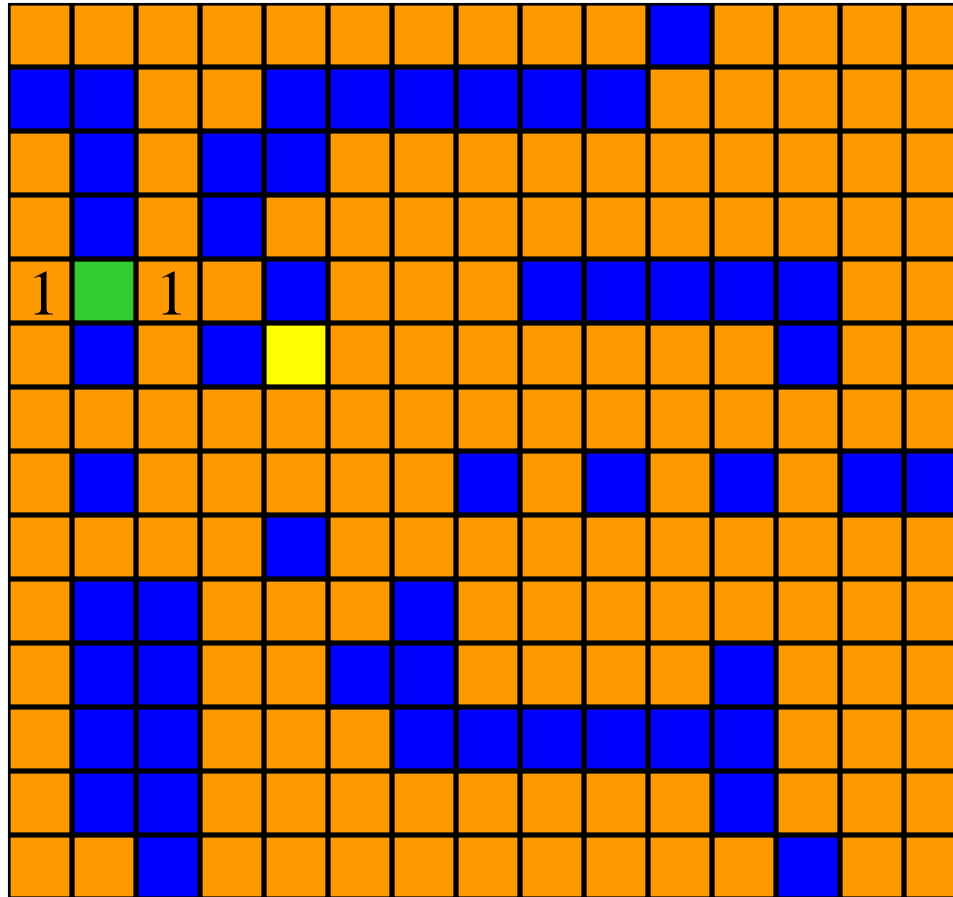
 start pin
 end pin



Label all reachable squares **1** unit from start.

Lee's Wire Router

 start pin
 end pin

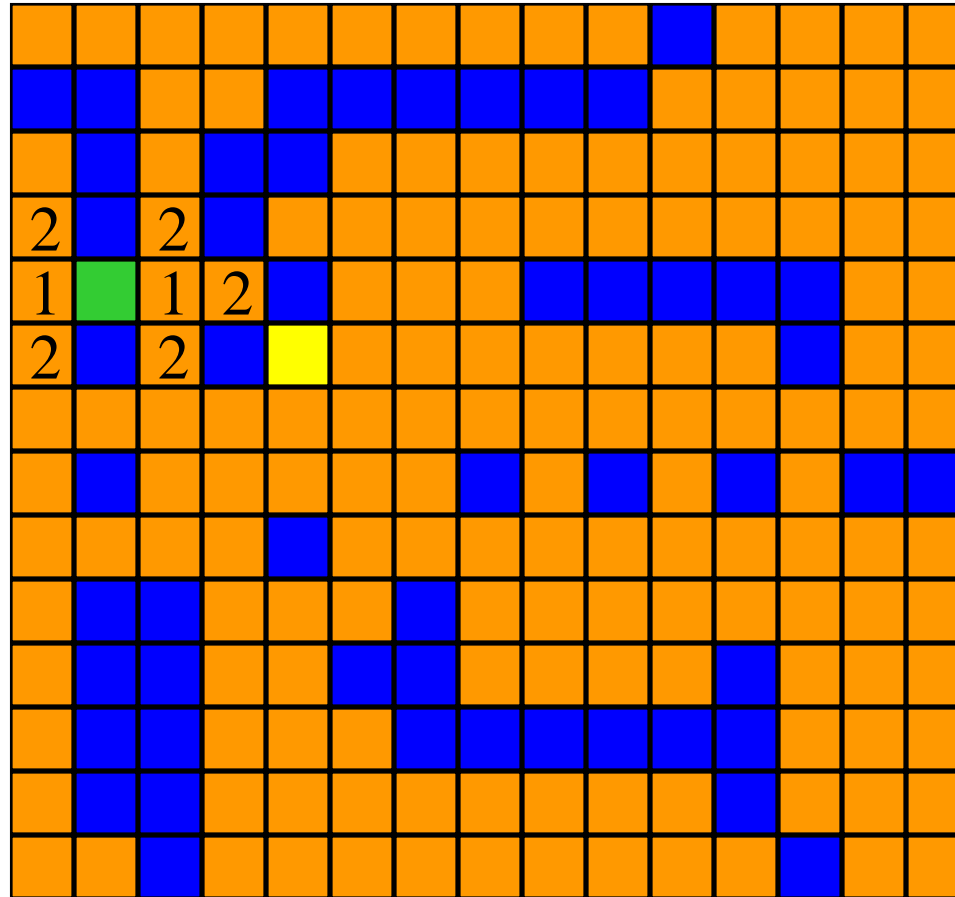


Label all reachable unlabeled squares **2** units from start.

Lee's Wire Router



 start pin

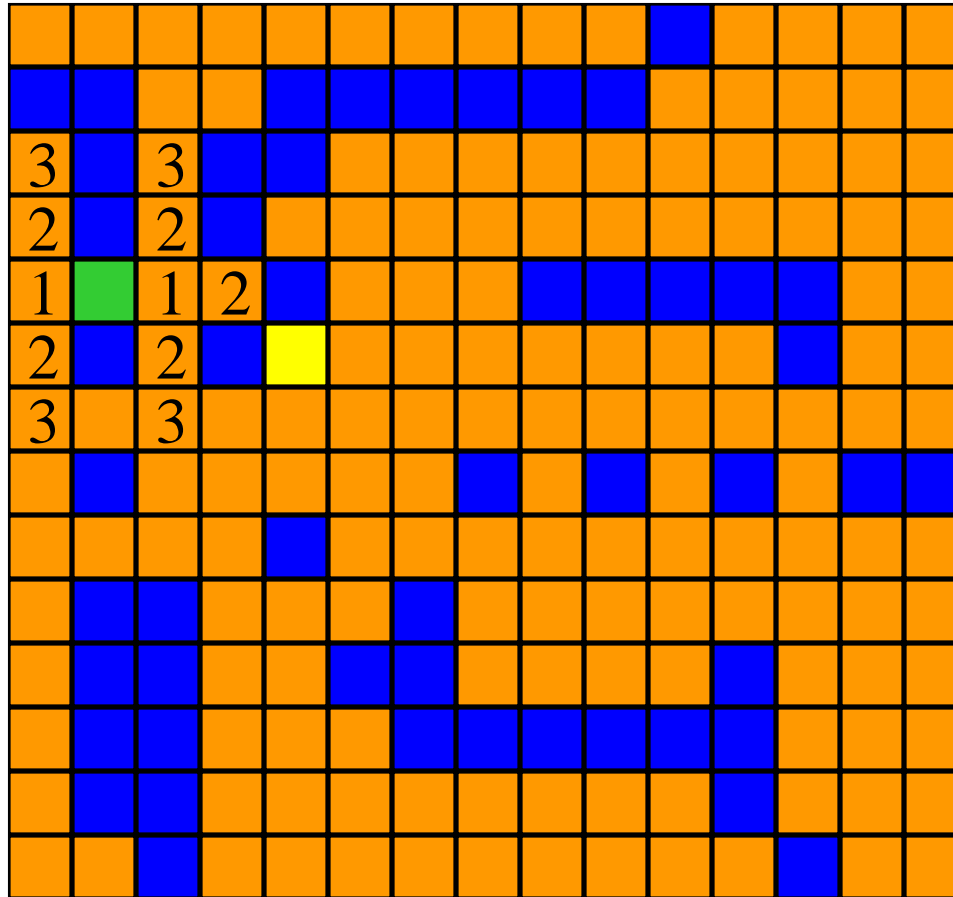
 end pin



Label all reachable unlabeled squares 3 units from start.



Lee's Wire Router

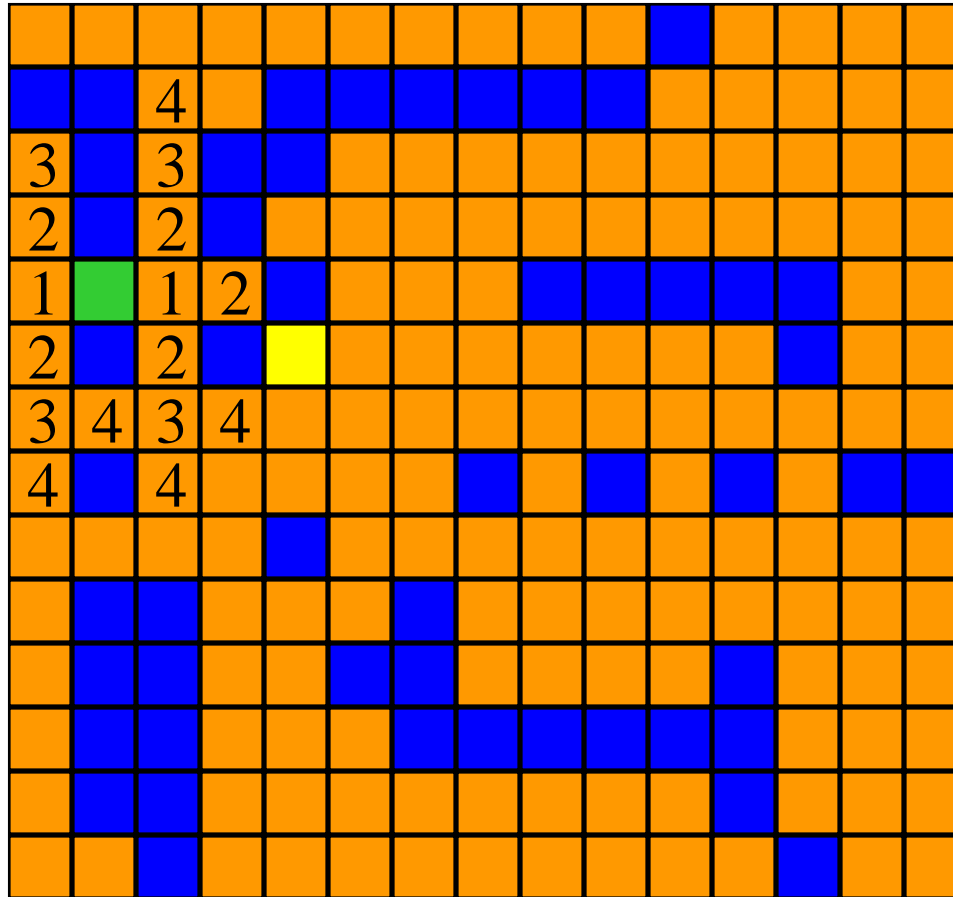
 start pin
 end pin



Label all reachable unlabeled squares 4 units from start.

Lee's Wire Router

 start pin
 end pin

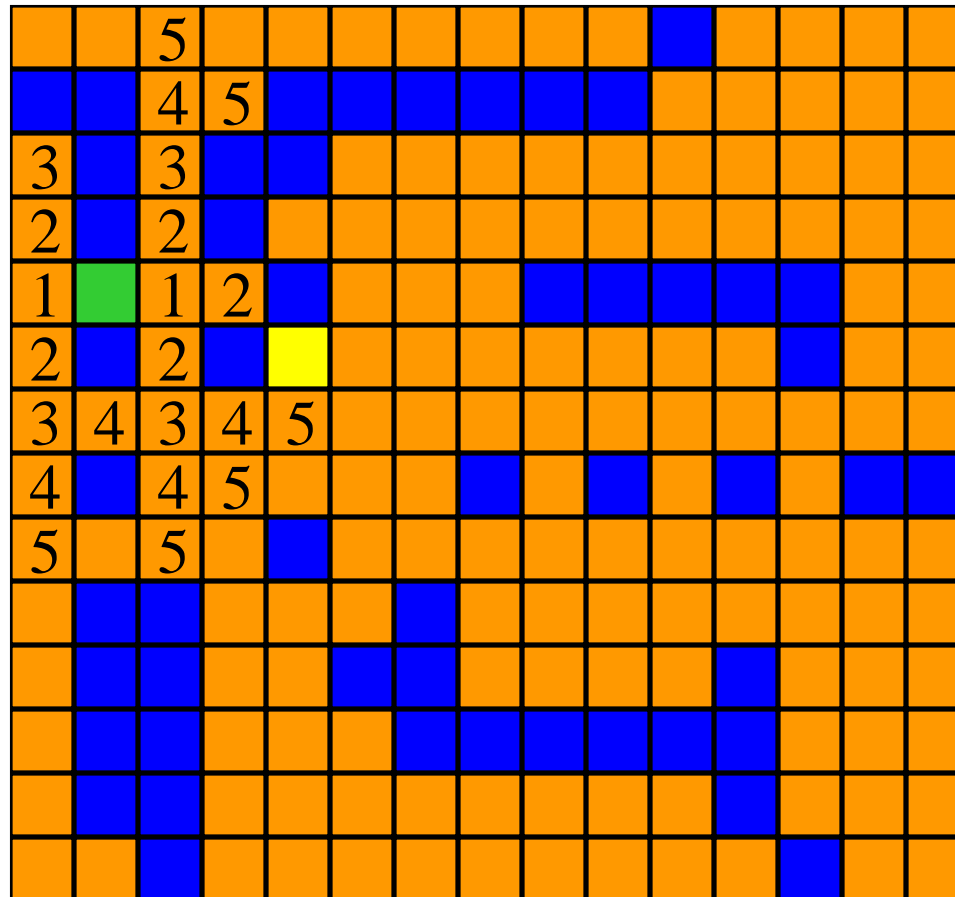


Label all reachable unlabeled squares **5** units from start.

Lee's Wire Router



 start pin

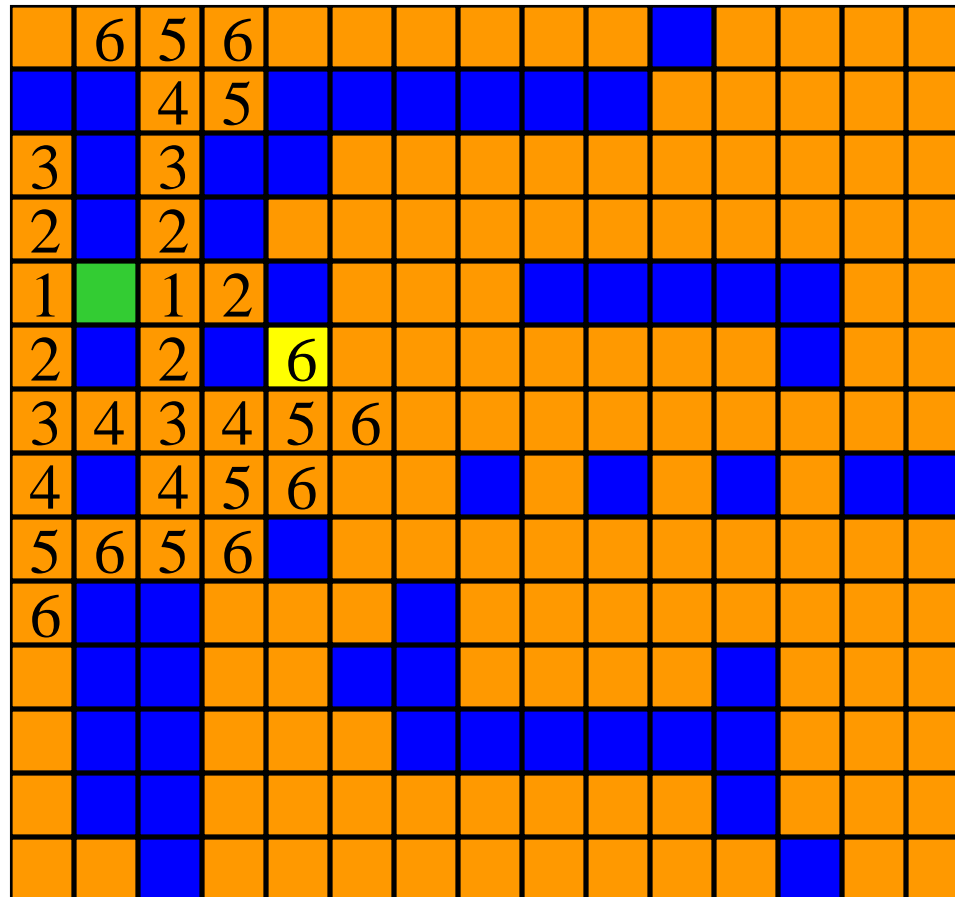
 end pin



Label all reachable unlabeled squares 6 units from start.



Lee's Wire Router

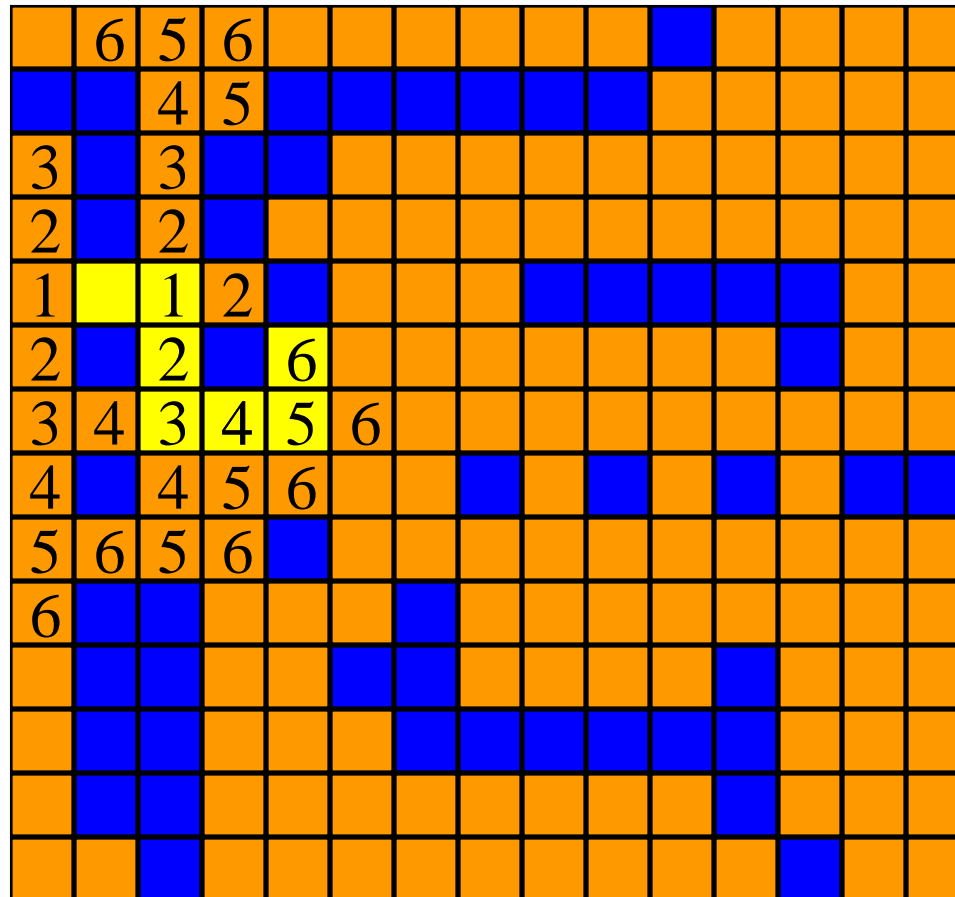
 start pin
 end pin



End pin reached. Traceback.

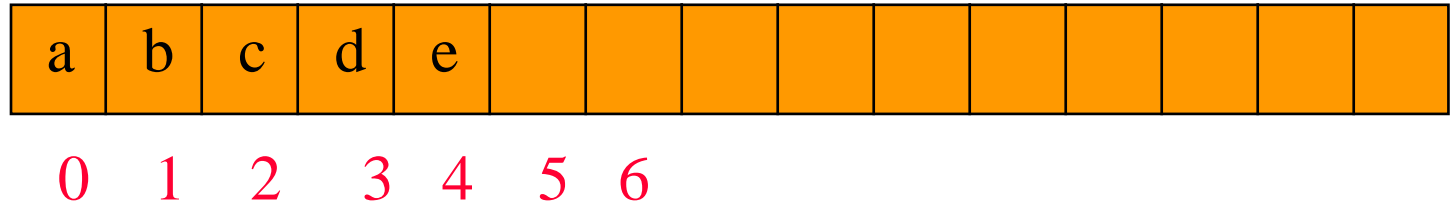
Lee's Wire Router

 start pin
 end pin



End pin reached. Traceback.

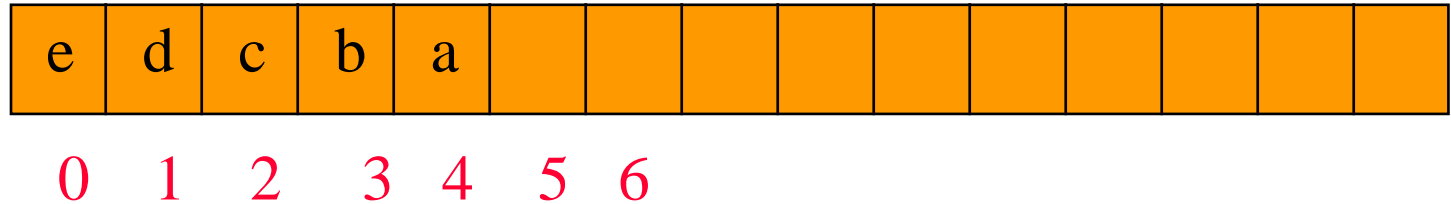
Derive From ArrayList



➤ when front is left end of list and rear is right end

- `Queue.isEmpty() => super.isEmpty()`
 - $O(1)$ time
- `getFrontElement() => get(0)`
 - $O(1)$ time
- `getRearElement() => get(size() - 1)`
 - $O(1)$ time
- `put(theObject) => add(size(), theObject)`
 - $O(1)$ time
- `remove() => remove(0)`
 - $O(\text{size})$ time

Derive From ArrayList

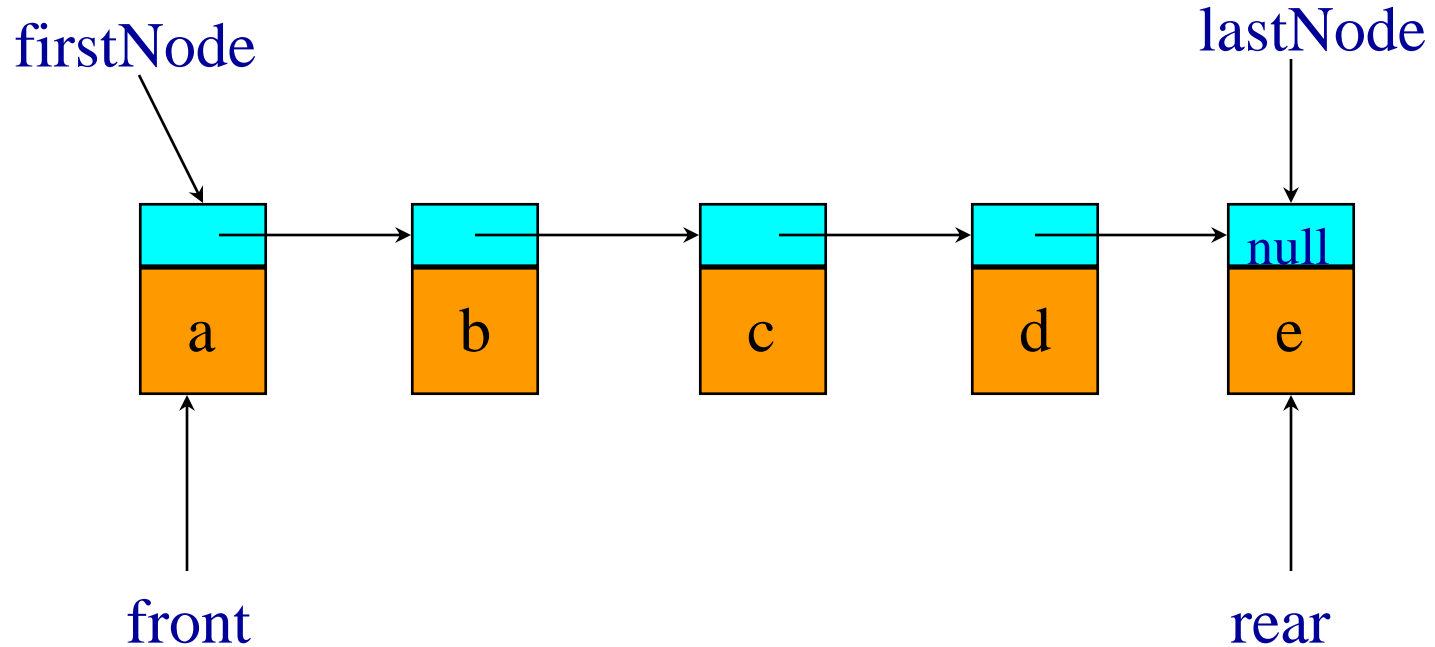


- when rear is left end of list and front is right end
 - `Queue.isEmpty() => super.isEmpty()`
 - $O(1)$ time
 - `getFrontElement() => get(size() - 1)`
 - $O(1)$ time
 - `getRearElement() => get(0)`
 - $O(1)$ time
 - `put(theObject) => add(0, theObject)`
 - $O(\text{size})$ time
 - `remove() => remove(size() - 1)`
 - $O(1)$ time

Derive From ArrayList

- to perform each operation in $O(1)$ time (excluding array doubling), we need a customized array representation.

Derive From Linked List



➤ when front is left end of list and rear is right end

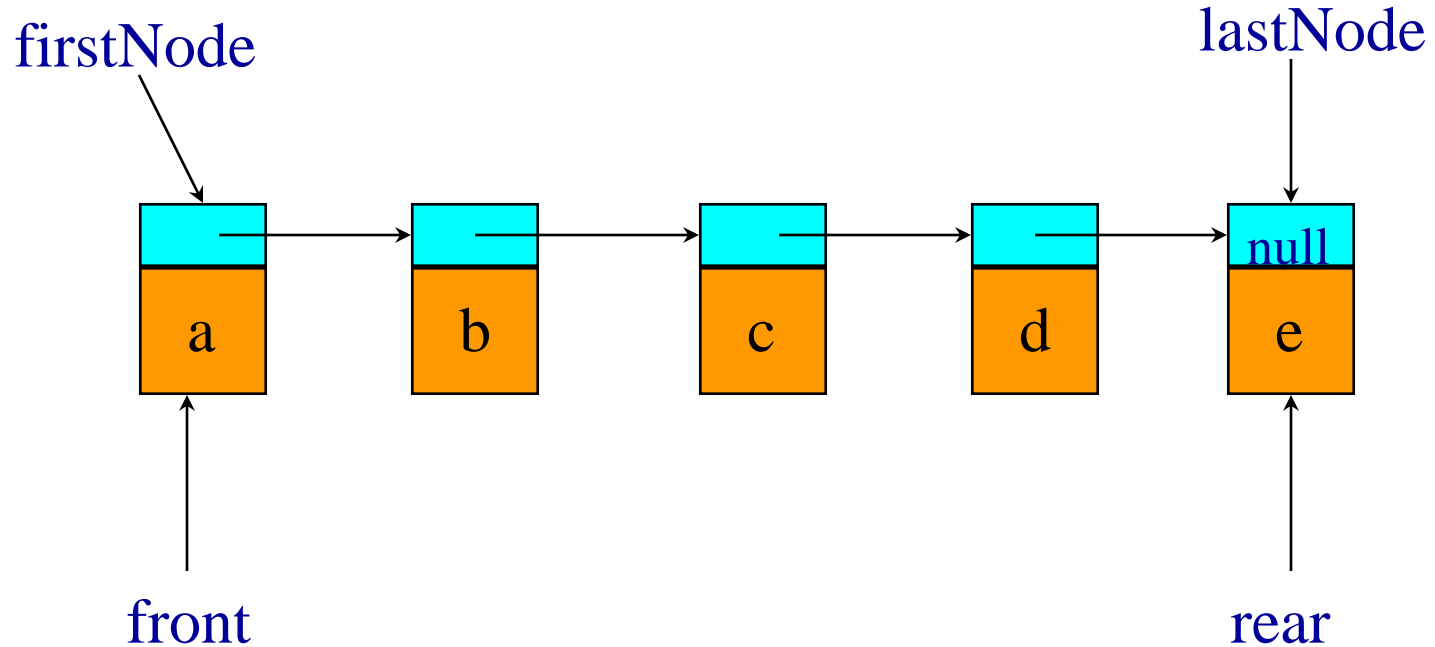
- `Queue.isEmpty()` \Rightarrow `super.isEmpty()`

- $O(1)$ time

- `getFrontElement()` \Rightarrow `get(0)`

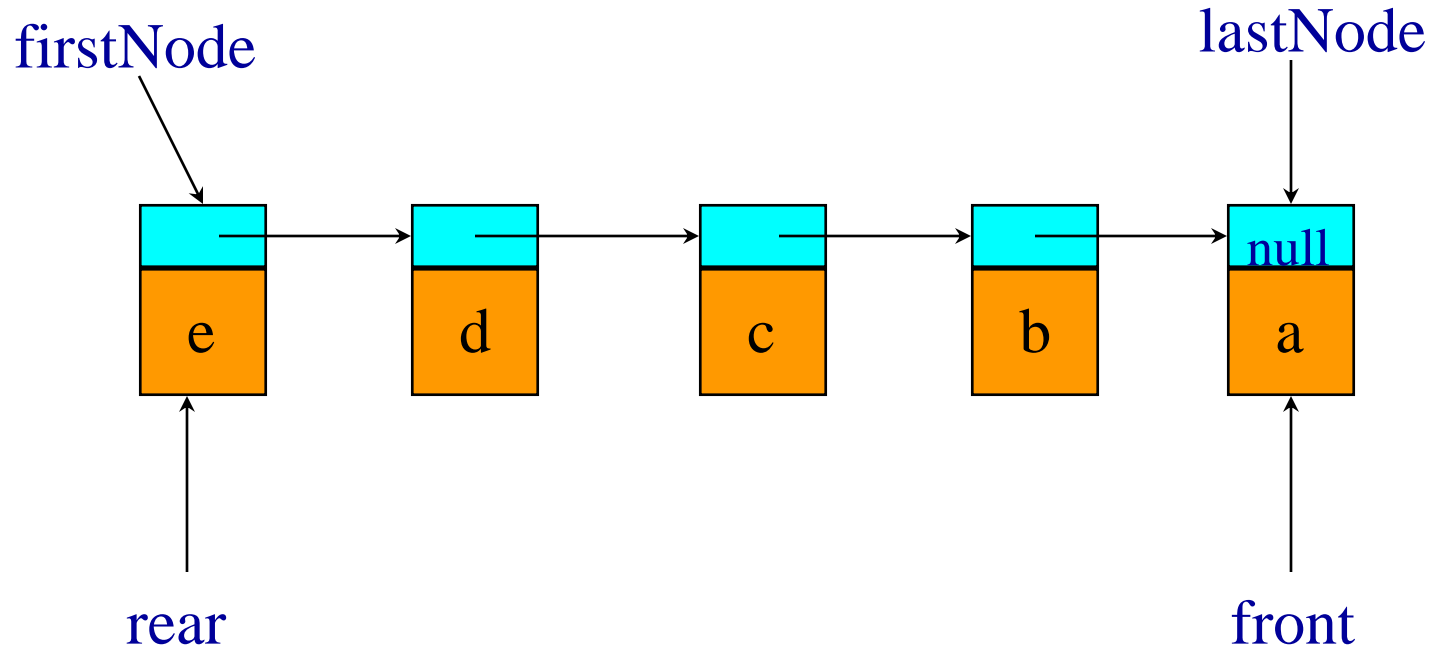
- $O(1)$ time

Derive From Linked List



- `getRearElement()` => `getLast()` ... new method
 - $O(1)$ time
- `put(theObject)` => `append(theObject)`
 - $O(1)$ time
- `remove()` => `remove(0)`
 - $O(1)$ time

Derive From Linked List



➤ when front is right end of list and rear is left end

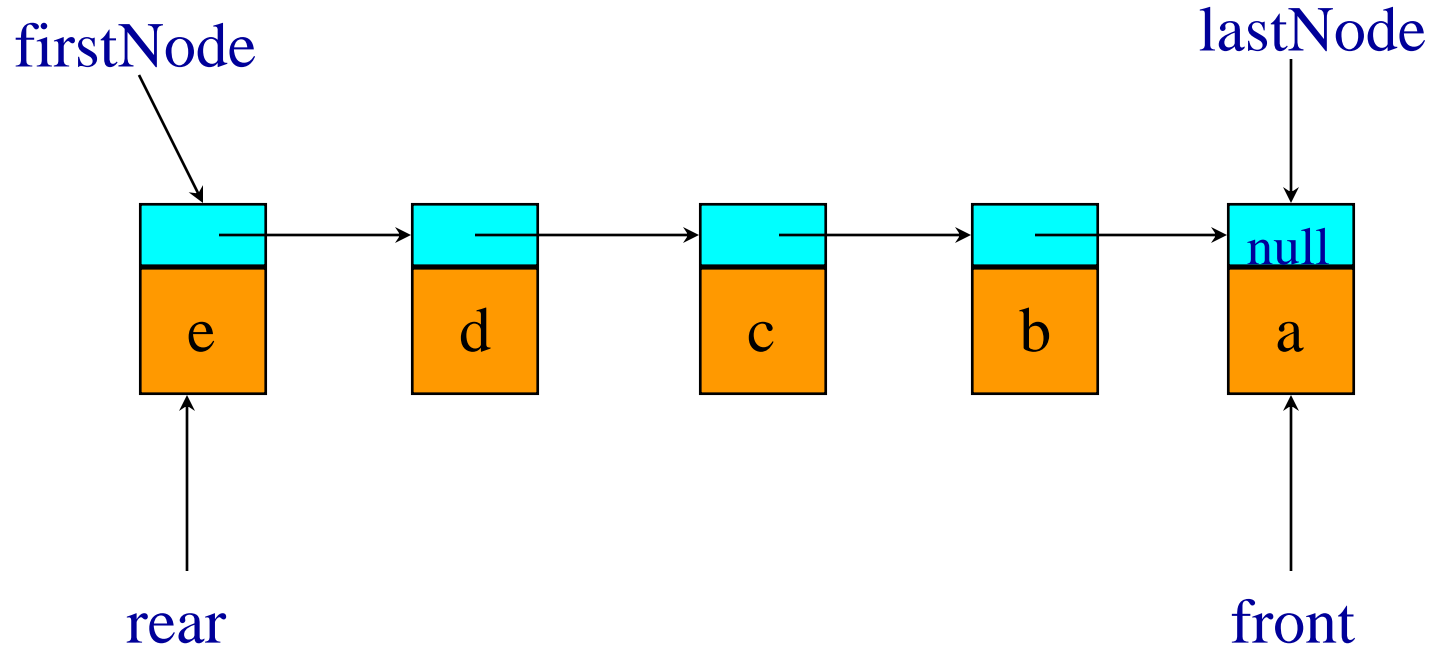
- `Queue.isEmpty() => super.isEmpty()`

- $O(1)$ time

- `getFrontElement() => getLast()`

- $O(1)$ time

Derive From Linked List



- `getRearElement()` \Rightarrow `get(0)`
 - $O(1)$ time
- `put(theObject)` \Rightarrow `add(0, theObject)`
 - $O(1)$ time
- `remove()` \Rightarrow `remove(size-1)`
 - $O(\text{size})$ time

Custom Linked Code

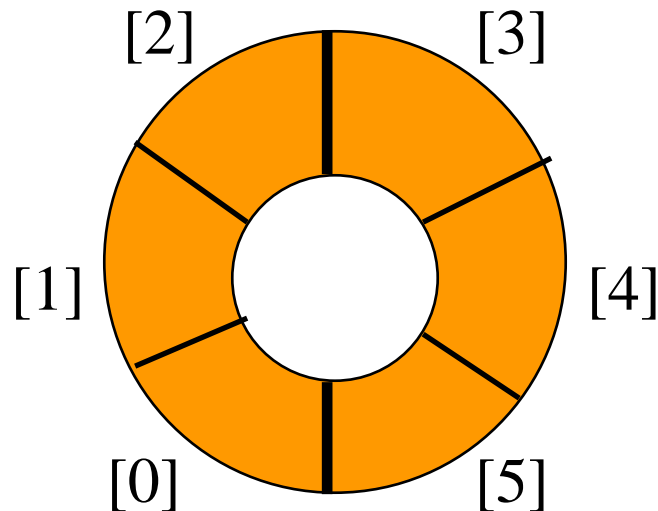
- Develop a linked class for **Queue** from scratch to get better performance than obtainable by deriving from **Linked List**.

Custom Array Queue

- Use a 1D array `queue`.

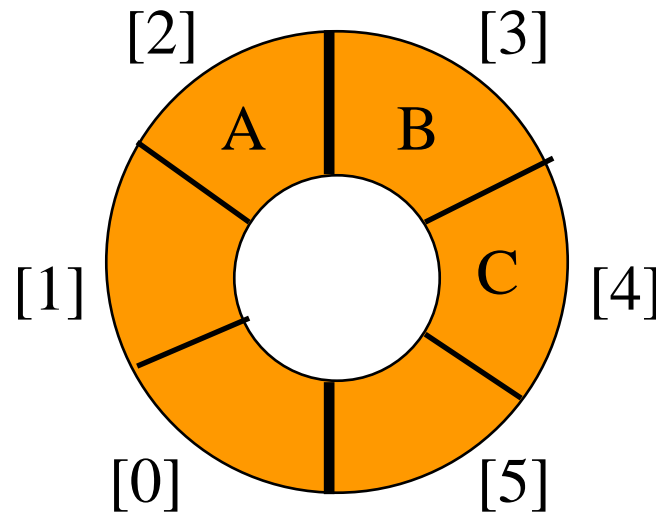
`queue[]` 

- Circular view of array.



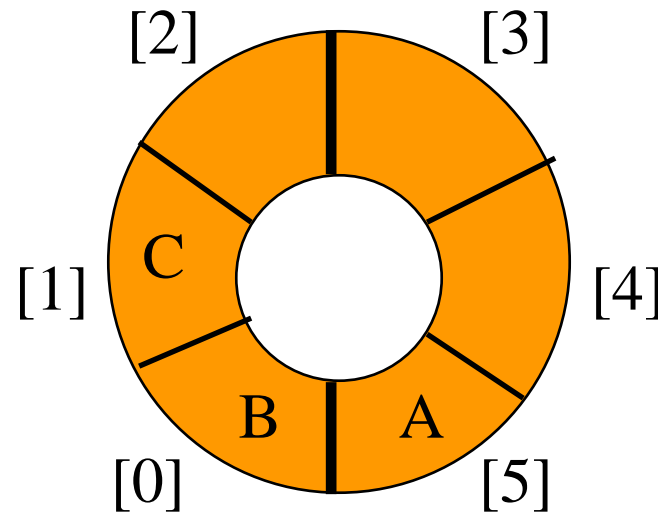
Custom Array Queue

- Possible configuration with 3 elements.



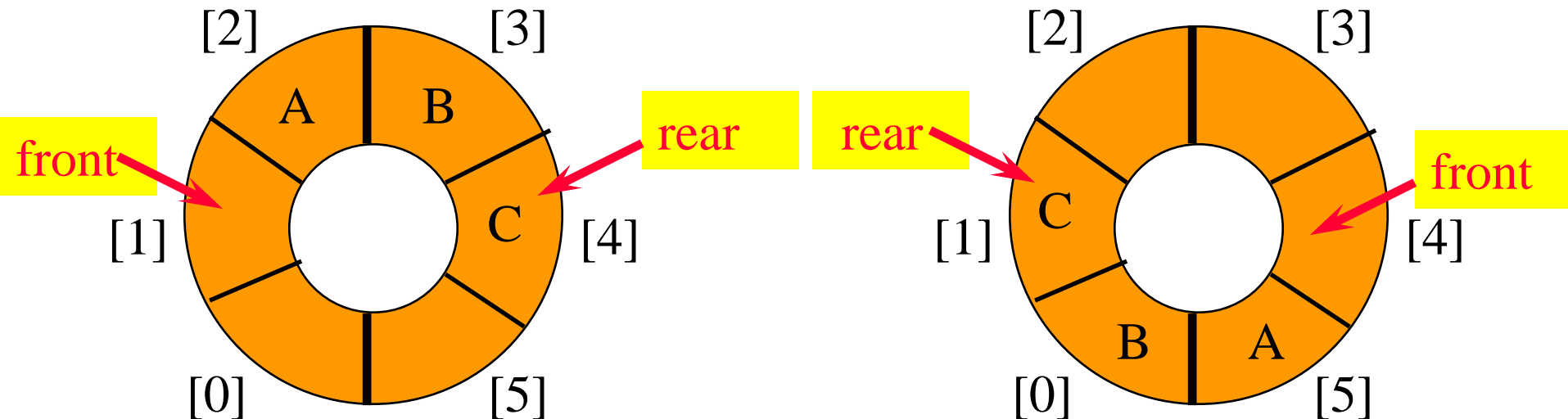
Custom Array Queue

- Another possible configuration with 3 elements.



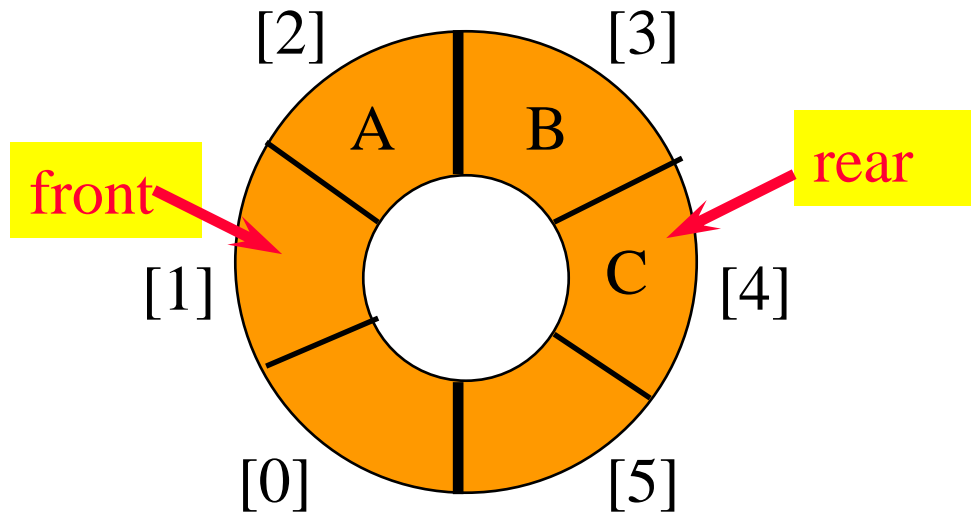
Custom Array Queue

- Use integer variables **front** and **rear**.
 - **front** is one position counterclockwise from first element
 - **rear** gives position of last element



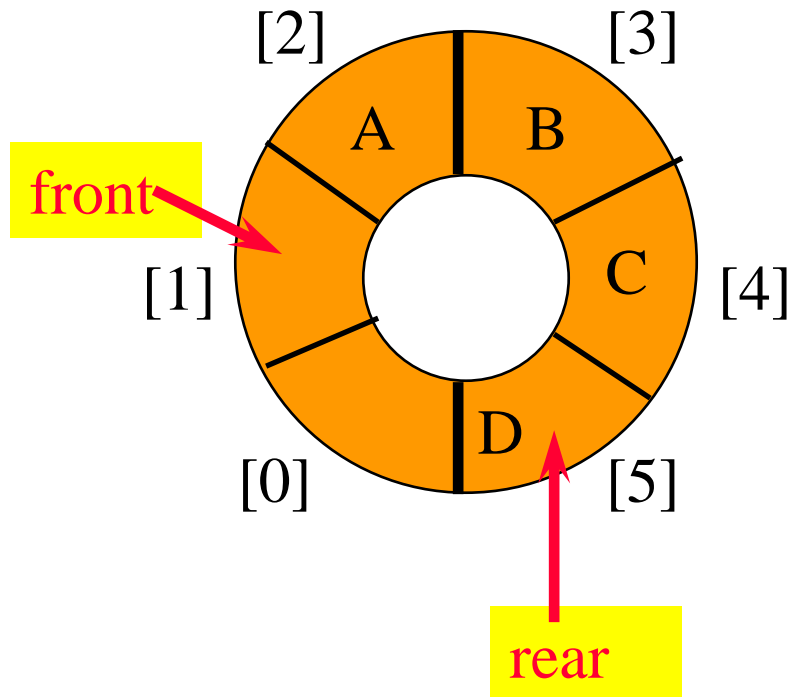
Add An Element

- Move **rear** one clockwise.



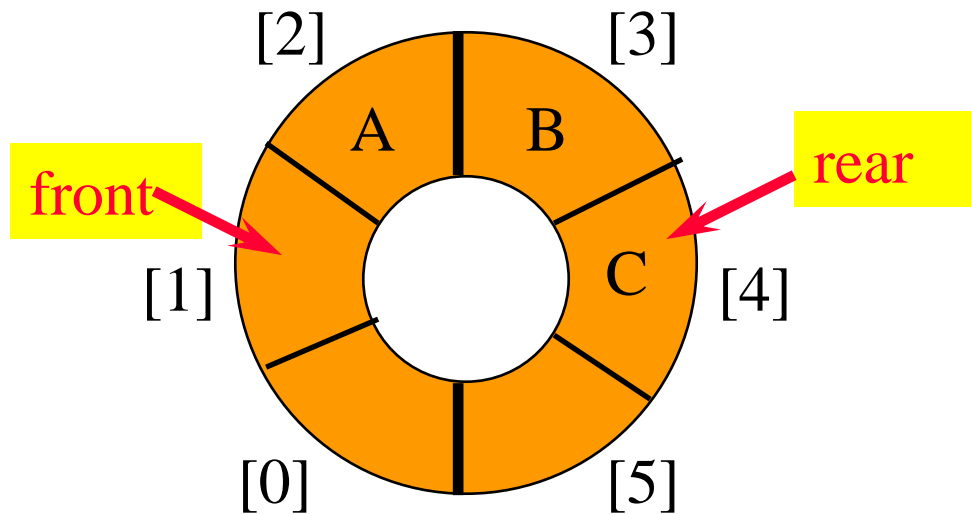
Add An Element

- Move **rear** one clockwise.
- Then put into **queue[rear]**.



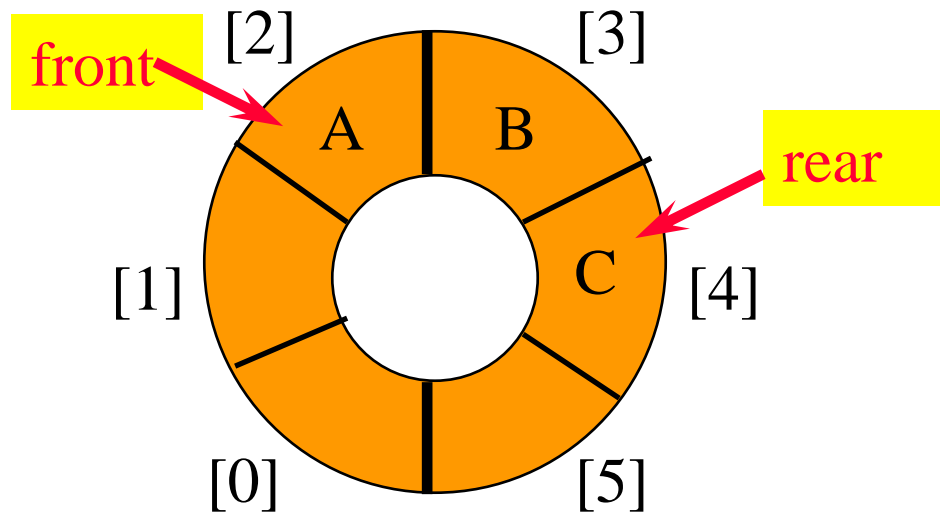
Remove An Element

- Move **front** one clockwise.



Remove An Element

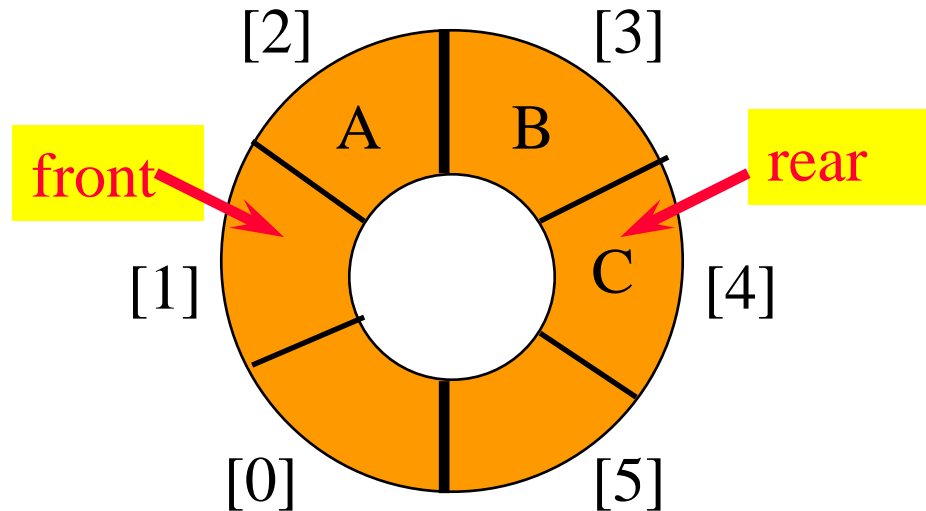
- Move **front** one clockwise.
- Then extract from **queue[front]**.



Moving rear Clockwise

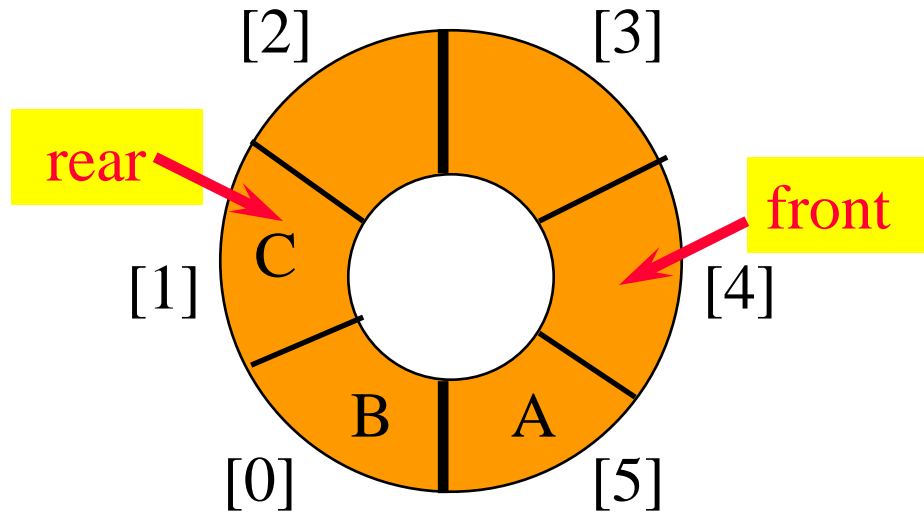
- `rear++;`

`if (rear == queue.length) rear = 0;`

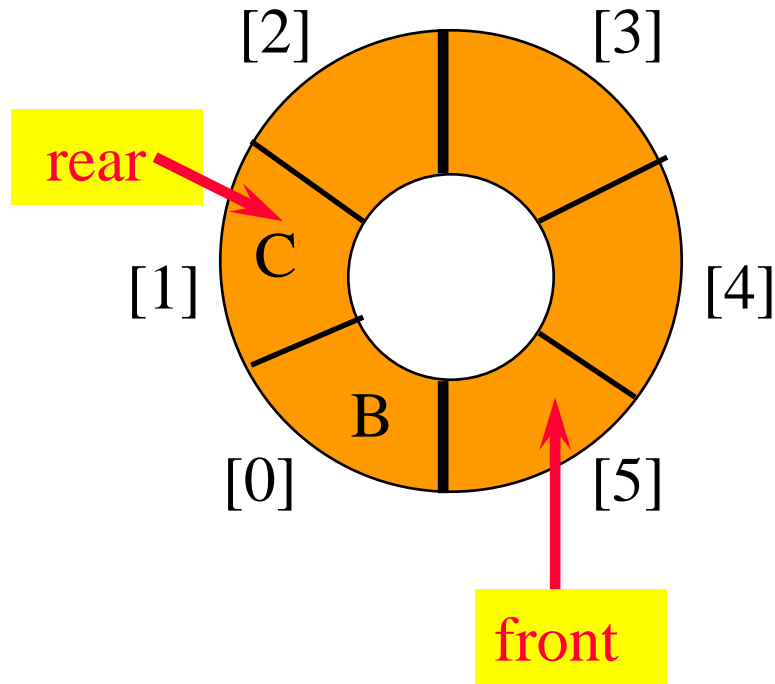


- `rear = (rear + 1) % queue.length;`

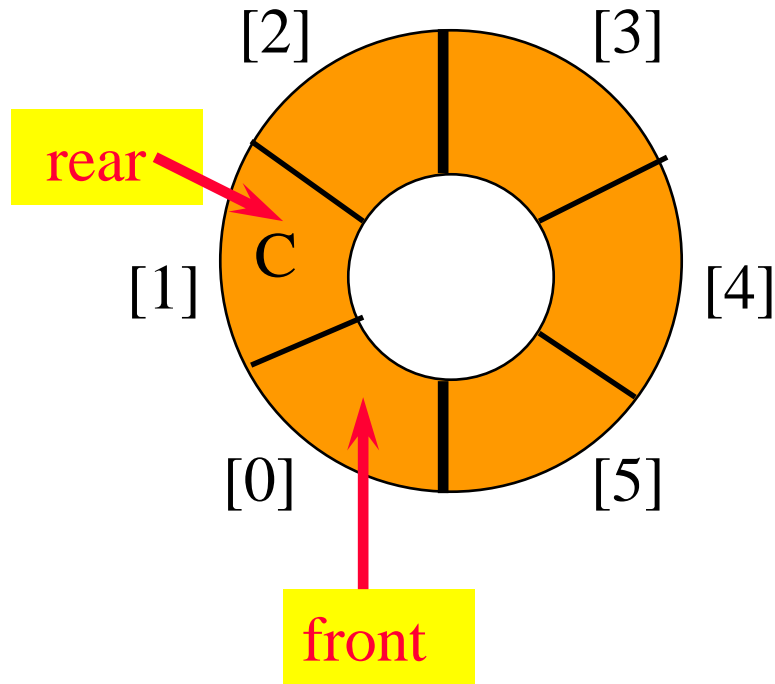
Empty That Queue



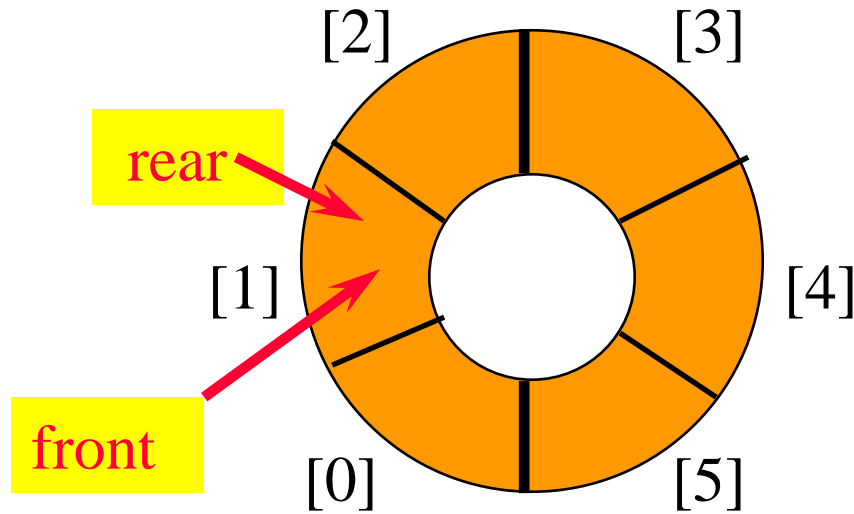
Empty That Queue



Empty That Queue

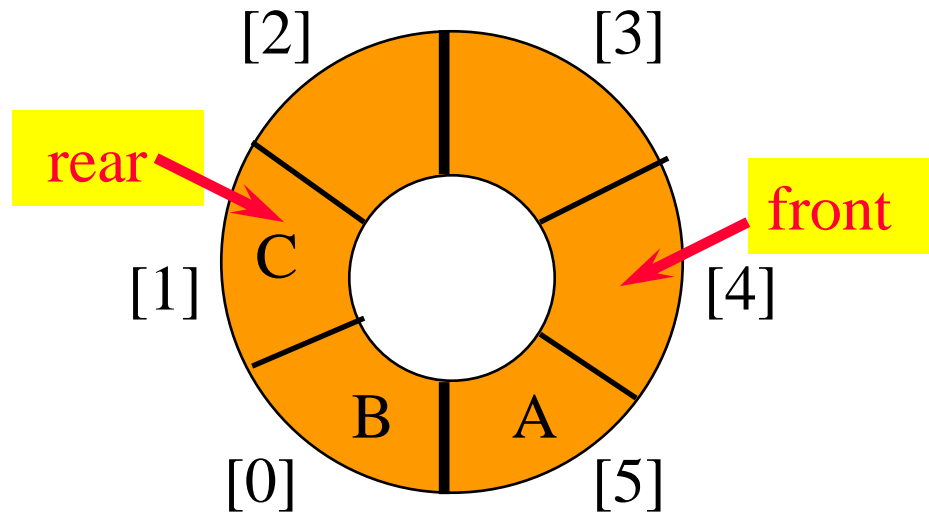


Empty That Queue

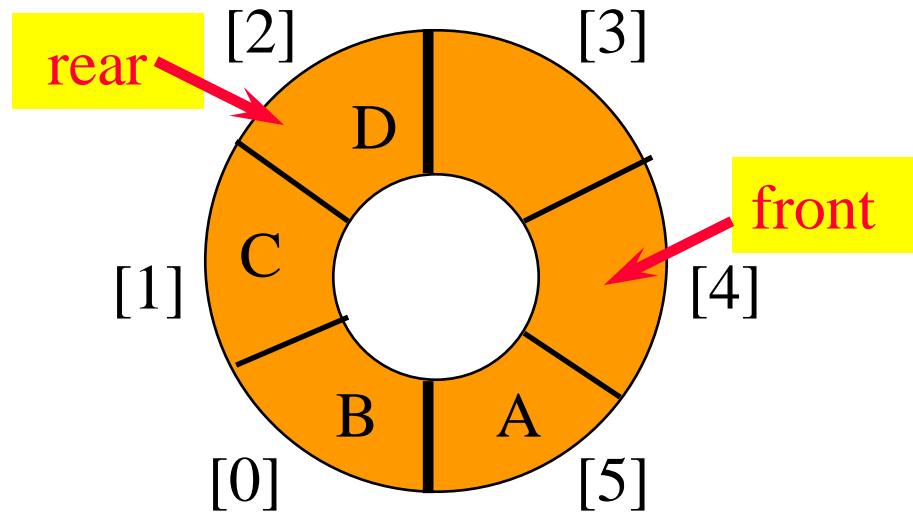


- When a series of removes causes the queue to become empty, **front = rear**.
- When a queue is constructed, it is empty.
- So initialize **front = rear = 0**.

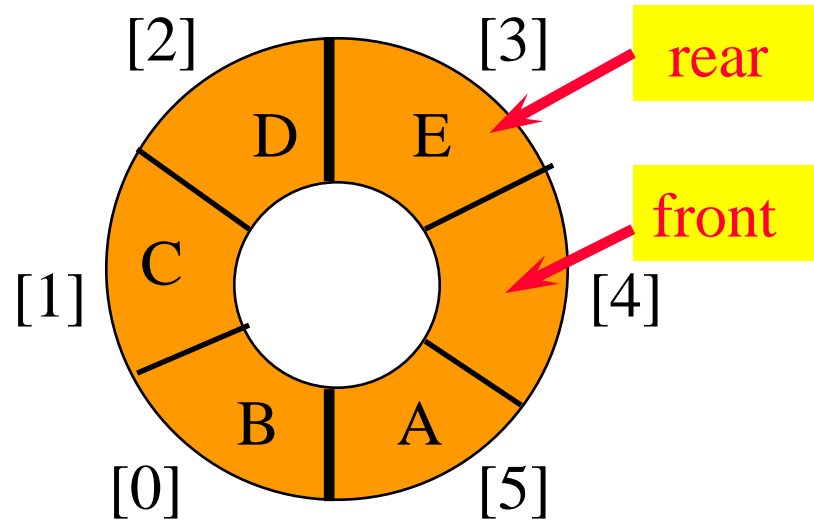
A Full Tank Please



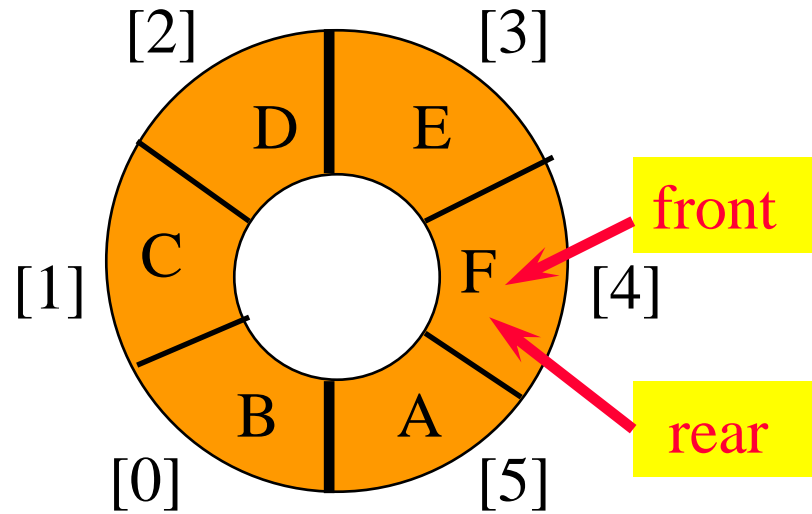
A Full Tank Please



A Full Tank Please



A Full Tank Please



- When a series of adds causes the queue to become full, **front = rear**.
- So we cannot distinguish between a full queue and an empty queue!

Ouch!!!!

- Remedies.
 - Don't let the queue get full.
 - When the addition of an element will cause the queue to be full, increase array size.
 - This is what the text does.
 - Define a boolean variable **lastOperationIsPut**.
 - Following each **put** set this variable to **true**.
 - Following each **remove** set to **false**.
 - Queue is empty iff **(front == rear) && !lastOperationIsPut**
 - Queue is full iff **(front == rear) && lastOperationIsPut**

Ouch!!!!

- Remedies (continued).
 - Define an integer variable `size`.
 - Following each `put` do `size++`.
 - Following each `remove` do `size--`.
 - Queue is empty iff `(size == 0)`
 - Queue is full iff `(size == queue.length)`
 - Performance is slightly better when first strategy is used.