Queues

What is a queue?

- First-in first-out data structure (FIFO)
- New objects are placed at rear
- Removal restricted to front
- Examples?

Queue ADT Operations

- **enqueue**(o): Insert o at rear of queue
  - Input: Object; Output: None
- **dequeue**(): Remove object at front; error if empty
  - Input: None; Output: Object removed
- **size**(): Return number of objects in queue
  - Input: None; Output: Integer
- **isEmpty**(): Return a boolean indicating queue empty
  - Input: None; Output: Boolean
- **first**(): Return object at front without removing; error if empty
  - Input: None; Output: Object

Example

- enqueue(5)
- enqueue(3)
- dequeue()
- enqueue(7)
- dequeue()
- front()
- dequeue()
- dequeue()
- isEmpty()
- enqueue(9)
- enqueue(7)
- size()
- enqueue(3)
- enqueue(5)
- dequeue()

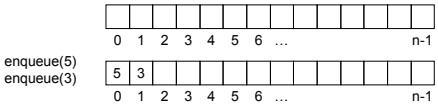
Queue Interface

```
int size();

bool isEmpty();

Object front() throws QueueEmptyException;

void enqueue(Object obj);

Object dequeue() throws QueueEmptyException;
```

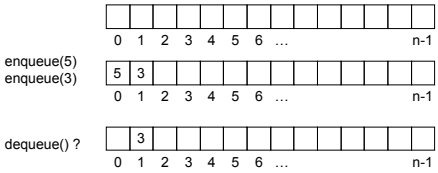
Underlying Representation

- Array versus Linked List
  - Pros and cons?
- Running time?
  - size
  - isEmpty
  - enqueue
  - dequeue
  - front

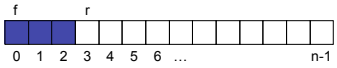
Array Implementation



Array Implementation

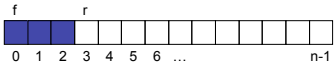


Circular Array



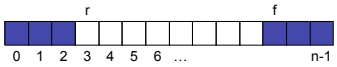
- *f* – stores index of cell which stores first element of queue
- *r* – stores index of next available cell in queue
- Initially, f = r = 0
- How do you add a new element?
- How do you remove an element?

Circular Array



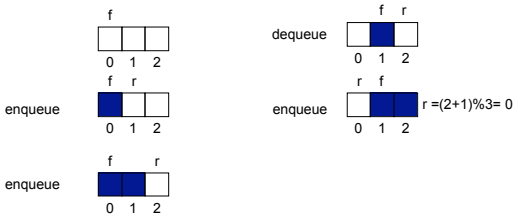
- How do you add a new element?
  - insert at array[r]
  - increment r
- How do you remove an element?
  - return array[f]
  - increment f
- What happens when r >= n-1?

Circular Array



- Need to be able to wrap around
- Modulo – %
  - increment f using (f+1)%n
  - increment r using (r+1)%n

Circular Array



Algorithms

- size
  - return (N-f+r) mod N
- isEmpty
  - return (f == r)
- front
  - if isEmpty then throw QueueEmptyException
  - return array[f]
- dequeue
  - if isEmpty then throw QueueEmptyException
  - temp = array[f]
  - f = (f+1)%N
  - return temp
- enqueue
  - if size == N-1 then throw QueueFullException SIZE MUST BE < N-1
  - array[r] = object
  - r = (r+1)%N

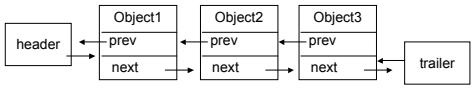
Deque

- Double-ended queue
  - insertFirst
  - insertLast
  - removeFirst
  - removeLast
  - first
  - last
  - size
  - isEmpty

Example

- insertFirst(3)
- insertFirst(5)
- first()
- removeFirst()
- insertLast(7)
- last()
- removeFirst()
- removeLast()

Doubly Linked List



- Algorithms
  - insertFirst
  - removeLast