Goal The purpose of this project is to implement elementary data structures using arrays and linked lists, and to introduce you to generics and iterators.

Problem 1. (*Deque*) A double-ended queue or deque (pronounced "deck") is a generalization of a stack and a queue that supports adding and removing items from either the front or the back of the data structure. Create a generic, iterable data type called `LinkedDeque` that uses a doubly-linked list to implement the following deque API:

`LinkedDeque`

`LinkedDeque()`	constructs an empty deque
`boolean isEmpty()`	returns `true` if this deque empty, and `false` otherwise
`int size()`	returns the number of items on this deque
`void addFirst(Item item)`	adds `item` to the front of this deque
`void addLast(Item item)`	adds `item` to the back of this deque
`Item peekFirst()`	returns the item at the front of this deque
`Item removeFirst()`	removes and returns the item at the front of this deque
`Item peekLast()`	returns the item at the back of this deque
`Item removeLast()`	removes and returns the item at the back of this deque
`Iterator<Item> iterator()`	returns an iterator to iterate over the items in this deque from front to back
`String toString()`	returns a string representation of this deque

Corner Cases

- The `add*()` methods should throw a `NullPointerException("item is null")` if *item* is `null`.
- The `peek*()` and `remove*()` methods should throw a `NoSuchElementException("Deque is empty")` if the deque is empty.
- The `next()` method in the deque iterator shoud throw a `NoSuchElementException("Iterator is empty")` if there are no more items to iterate.

Performance Requirements

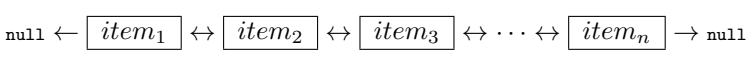
- The constructor and methods in `LinkedDeque` and `DequeIterator` should run in time $T(n) \sim 1$.

`>_ ~/workspace/project2`

```
$ java LinkedDeque
Filling the deque...
The deque (364 characters): There is grandeur in this view of life, with its several powers, having been originally
breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law
of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being,
evolved. ~ Charles Darwin, The Origin of Species
Emptying the deque...
deque.isEmpty()? true
```

Directions:

- Use a doubly-linked list `Node` to implement the API — each node in the list stores a generic `item`, and references `next` and `prev` to the next and previous nodes in the list



- Instance variables:
  - Reference to the front of the deque, `Node first`.
  - Reference to the back of the deque, `Node last`.
  - Size of the deque, `int n`.

- `LinkedDeque()`
  - Initialize instance variables to appropriate values.
- `boolean isEmpty()`
  - Return whether the deque is empty or not.
- `int size()`
  - Return the size of the deque.
- `void addFirst(Item item)`
  - Add the given item to the front of the deque.
  - Increment `n` by one.
  - If this is the first item that is being added, both `first` and `last` must point to the same node.
- `void addLast(Item item)`
  - Add the given item to the back of the deque.
  - Increment `n` by one.
  - If this is the first item that is being added, both `first` and `last` must point to the same node.
- `Item peekFirst()`
  - Return the item at the front of the deque.
- `Item removeFirst()`
  - Remove and return the item at the front of the deque.
  - Decrement `n` by one.
  - If this is the last item that is being removed, both `first` and `last` must point to `null`.
- `Item peekLast()`
  - Return the item at the back of the deque.
- `Item removeLast()`
  - Remove and return the item at the back of the deque.
  - Decrement `n` by one.
  - If this is the last item that is being removed, both `first` and `last` must point to `null`.
- `Iterator<Item> iterator()`
  - Return an object of type `DequeIterator`.
- `LinkedDeque :: DequeIterator.`
  - Instance variable:
    - Reference to current node in the iterator, `Node current`.
  - `DequeIterator()`
    - Initialize instance variable appropriately.
  - `boolean hasNext()`
    - Return whether the iterator has more items to iterate or not.
  - `Item next()`

* Return the item in `current` and advance `current` to the next node.

Problem 2. (*Sorting Strings*) Implement a program called `Sort.java` that accepts strings from standard input, stores them in a `LinkedDeque` data structure, sorts the deque, and writes the sorted strings to standard output.

Performance Requirements

- The program should run in time $T(n) \sim n^2$, where n is the number of input strings.

```
>_ ~/workspace/project2
$ java Sort
A B R A C A D A B R A
<ctrl-d>
A
A
A
A
A
B
B
C
D
R
R
```

Directions:

- Create a queue `d`.
- For each word `w` read from standard input
  - Add `w` to the front of `d` if it is less† than the first word in `d`.
  - Add `w` to the back of `d` if it is greater† than the last word in `d`.
  - Otherwise, remove words that are less than `w` from the front of `d` and store them in a temporary stack `s`; add `w` to the front of `d`; and add words from `s` also to the front of `d`.
- Write the words from `d` to standard output.

† Use the helper method `boolean less(String v, String w)` to test if a string `v` is less than a string `w`.

Problem 3. (*Random Queue*) A random queue is similar to a stack or queue, except that the item removed is chosen uniformly at random from items in the data structure. Create a generic, iterable data type called `ResizingArrayRandomQueue` that uses a resizing array to implement the following random queue API:

ResizingArrayRandomQueue	
`ResizingArrayRandomQueue()`	constructs an empty random queue
`boolean isEmpty()`	returns `true` if this queue is empty, and `false` otherwise
`int size()`	returns the number of items in this queue
`void enqueue(Item item)`	adds *item* to the end of this queue
`Item sample()`	returns a random item from this queue
`Item dequeue()`	removes and returns a random item from this queue
`Iterator<Item> iterator()`	returns an independent† iterator to iterate over the items in this queue in random order
`String toString()`	returns a string representation of this queue

† The order of two or more iterators on the same randomized queue must be mutually independent, ie, each iterator must maintain its own random order.

Corner Cases

- The `enqueue()` method should throw a `NullPointerException("item is null")` if *item* is `null`.
- The `sample()` and `dequeue()` methods should throw a `NoSuchElementException("Random queue is empty")` if the random queue is empty.
- The `next()` method in the random queue iterator shoud throw a `NoSuchElementException("Iterator is empty")` if there are no more items to iterate.

Performance Requirements

- The constructor and methods in `ResizingArrayRandomQueue` should run in time $T(n) \sim 1$.
- The constructor in `RandomQueueIterator` should run in time $T(n) \sim n$.
- The methods in `RandomQueueIterator` should run in time $T(n) \sim 1$.

```
>_ ~/workspace/project2
$ java ResizingArrayRandomQueue
sum       = 5081434
iterSumQ  = 5081434
dequeSumQ = 5081434
iterSumQ + dequeSumQ == 2 * sum? true
```

Directions:

- Use a resizing array to implement the API
- Instance variables:
  - Array to store the items of queue, `Item[] q`.
  - Size of the queue, `int n`.
- `ResizingArrayRandomQueue()`
  - Initialize instance variables appropriately — create `q` with an initial capacity of 2.
- `boolean isEmpty()`
  - Return whether the queue is empty or not.
- `int size()`
  - Return the size of the queue.
- `void enqueue(Item item)`
  - If `q` is at full capacity, resize it to twice its current capacity.
  - Insert the given item in `q` at index `n`.
  - Increment `n` by one.
- `Item sample()`
  - Return `q[r]`, where `r` is a random integer from the interval `[0, n)`.
- `Item dequeue()`
  - Save `q[r]` in `item`, where `r` is a random integer from the interval `[0, n)`.
  - Set `q[r]` to `q[n - 1]` and `q[n - 1]` to `null`.
  - Decrement `n` by one.
  - If `q` is at quarter capacity, resize it to half its current capacity.
  - Return `item`.

- `Iterator<Item> iterator()`
  - Return an object of type `RandomQueueIterator`.
- `ResizingArrayRandomQueue :: RandomQueueIterator()`
  - Instance variables:
    - Array to store the items of `q`, `Item[] items`.
    - Index of the current item in `items`, `int current`.
  - `RandomQueueIterator()`
    - Create `items` with capacity `n`.
    - Copy the `n` items from `q` into `items`.
    - Shuffle `items`.
    - Initialize `current` appropriately.
  - `boolean hasNext()`
    - Return whether the iterator has more items to iterate or not.
  - `Item next()`
    - Return the item in `items` at index `current` and advance `current` by one.

Problem 4. (*Sampling Integers*) Implement a program called `Sample.java` that accepts *lo* (int), *hi* (int), *k* (int), and *mode* (String) as command-line arguments, uses a random queue to sample *k* integers from the interval $[lo, hi]$, and writes the samples to standard output. The sampling must be done with replacement if *mode* is "+", and without replacement if *mode* is "-". You may assume that $k \leq hi - lo + 1$.

Corner Cases

- The program should throw an `IllegalArgumentException("Illegal mode")` if *mode* is different from "+" or "-".

Performance Requirements

- The program should run in time $T(k, n) \sim kn$ in the worst case (sampling without replacement), where k is the sample size and n is the length of the sampling interval.

```
>_ ~/workspace/project2
$ java Sample 1 5 5 +
3
3
5
4
1
$ java Sample 1 5 5 -
2
3
1
4
5
```

Directions:

- Accept *lo* (int), *hi* (int), *k* (int), and *mode* (String) as command-line arguments.
- Create a random queue *q* containing integers from the interval $[lo, hi]$.
- If *mode* is "+" (sampling with replacement), sample and write *k* integers from *q* to standard output.
- If *mode* is "-" (sampling without replacement), dequeue and write *k* integers from *q* to standard. output

Acknowledgements This project is an adaptation of the Deques and Randomized Queues assignment developed at Princeton University by Kevin Wayne.

Files to Submit

1. `LinkedDeque.java`
2. `Sort.java`
3. `ResizingArrayRandomQueue.java`
4. `Sample.java`
5. `notes.txt`

Before you submit your files, make sure:

- You do not use concepts outside of what has been taught in class.
- Your code is adequately commented, follows good programming principles, and meets any specific requirements such as corner cases and running times.
- You edit the sections (`#1` mandatory, `#2` if applicable, and `#3` optional) in the given `notes.txt` file as appropriate. Section `#1` must provide a clear high-level description of the project in no more than 200 words.