Programming Assignment 2: Randomized Queues and Deques

Write a generic data type for a deque and a randomized queue. The goal of this assignment is to implement elementary data structures using arrays and linked lists, and to introduce you to generics and iterators.

Dequeue. A *double-ended queue* or *deque* (pronounced "deck") is a generalization of a stack and a queue that supports inserting and removing items from either the front or the back of the data structure. Create a generic data type `Deque` that implements the following API:

```
public class Deque<Item> implements Iterable<Item> {
   public Deque()                           // construct an empty deque
   public boolean isEmpty()                 // is the deque empty?
   public int size()                        // return the number of items on the deque
   public void addFirst(Item item)          // insert the item at the front
   public void addLast(Item item)           // insert the item at the end
   public Item removeFirst()                // delete and return the item at the front
   public Item removeLast()                 // delete and return the item at the end
   public Iterator<Item> iterator()         // return an iterator over items in order from front to end
   public static void main(String[] args)   // unit testing
}
```

Throw a `NullPointerException` if the client attempts to add a null item; throw a `java.util.NoSuchElementException` if the client attempts to remove an item from an empty deque; throw an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator; throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator and there are no more items to return.

Your deque implementation must support each deque operation in *constant worst-case time* and use space proportional to the number of items *currently* in the deque. Additionally, your iterator implementation must support the operations `next()` and `hasNext()` (plus construction) in constant worst-case time and use a constant amount of extra space per iterator.

Randomized queue. A *randomized 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 data type `RandomizedQueue` that implements the following API:

```
public class RandomizedQueue<Item> implements Iterable<Item> {
   public RandomizedQueue()                 // construct an empty randomized queue
   public boolean isEmpty()                 // is the queue empty?
   public int size()                        // return the number of items on the queue
   public void enqueue(Item item)           // add the item
   public Item dequeue()                    // delete and return a random item
   public Item sample()                     // return (but do not delete) a random item
   public Iterator<Item> iterator()         // return an independent iterator over items in random order
   public static void main(String[] args)   // unit testing
}
```

Throw a `NullPointerException` if the client attempts to add a null item; throw a `java.util.NoSuchElementException` if the client attempts to sample or dequeue an item from an empty randomized queue; throw an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator; throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator and there are no more items to return.

Your randomized queue implementation must support each randomized queue operation (besides creating an iterator) in *constant amortized time* and use space proportional to the number of items *currently* in the queue. That is, any sequence of M randomized queue operations (starting from an empty queue) should take at most cM steps in the worst case, for some constant c. Additionally, your iterator implementation must support construction in time linear in the number of items and it must support the operations `next()` and `hasNext()` in constant worst-case time; you may use a linear amount of extra memory per iterator. The order of two or more iterators to the same randomized queue should be *mutually independent*; each iterator must maintain its own random order.

Subset client. Write a client program `Subset.java` that takes a command-line integer k; reads in a sequence of N strings from standard input using `StdIn.readString()`; and prints out exactly k of them, uniformly at random. Each item from the sequence can be printed out at most once. You may assume that $k \geq 0$ and no greater than the number of string N on standard input.

```
% echo A B C D E F G H I | java Subset 3
C
G
A

% echo A B C D E F G H I | java Subset 3
E
F
G
```

```
% echo AA BB BB BB BB BB CC CC | java Subset 8
BB
AA
BB
CC
BB
BB
CC
BB
```

The running time of `Subset` must be linear in the size of the input. You may use only a constant amount of memory plus either one `Deque` or `RandomizedQueue` object of maximum size at most N, where N is the number of strings on standard input. (For an extra challenge, use only one `Deque` or `RandomizedQueue` object of maximum size at most k.) It should have the following API.

```
public class Subset {
   public static void main(String[] args)
```

```
}
```

Deliverables. Submit only `Deque.java`, `RandomizedQueue.java`, and `Subset.java`. We will supply `stdlib.jar`. You may not call any library functions other than those in `java.lang` and `stdlib.jar`.