Programming Assignment 2: Deques and Randomized Queues

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 adding 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)          // add the item to the front
   public void addLast(Item item)           // add the item to the end
   public Item removeFirst()                // remove and return the item from the front
   public Item removeLast()                 // remove and return the item from 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 (optional)
}
```

Corner cases. Throw the specified exception for the following corner cases:

- Throw a `java.lang.IllegalArgumentException` if the client calls either `addFirst()` or `addLast()` with a `null` argument.
- Throw a `java.util.NoSuchElementException` if the client calls either `removeFirst()` or `removeLast` when the deque is empty.
- Throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator when there are no more items to return.
- Throw a `java.lang.UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

Performance requirements. Your deque implementation must support each deque operation (including construction) in *constant worst-case time*. A deque containing n items must use at most $48n + 192$ bytes of memory and use space proportional to the number of items *currently* in the deque. Additionally, your iterator implementation must support each operation (including construction) in *constant worst-case time*.

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 randomized queue empty?
   public int size()                        // return the number of items on the randomized queue
   public void enqueue(Item item)           // add the item
   public Item dequeue()                    // remove and return a random item
   public Item sample()                     // return a random item (but do not remove it)
   public Iterator<Item> iterator()         // return an independent iterator over items in random order
   public static void main(String[] args)   // unit testing (optional)
}
```

Iterator. Each iterator must return the items in uniformly random order. The order of two or more iterators to the same randomized queue must be *mutually independent*; each iterator must maintain its own random order.

Corner cases. Throw the specified exception for the following corner cases:

- Throw a `java.lang.IllegalArgumentException` if the client calls `enqueue()` with a `null` argument.
- Throw a `java.util.NoSuchElementException` if the client calls either `sample()` or `dequeue()` when the randomized queue is empty.
- Throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator when there are no more items to return.
- Throw a `java.lang.UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

Performance requirements. Your randomized queue implementation must support each randomized queue operation (besides creating an iterator) in *constant amortized time*. That is, any sequence of m randomized queue operations (starting from an empty queue) must take at most cm steps in the worst case, for some constant c. A randomized queue containing n items must use at most $48n + 192$ bytes of memory. Additionally, your iterator implementation must support operations `next()` and `hasNext()` in *constant worst-case time*; and construction in *linear time*; you may (and will need to) use a linear amount of extra memory per iterator.

Client. Write a client program `Permutation.java` that takes an integer *k* as a command-line argument; reads in a sequence of strings from standard input using `StdIn.readString()`; and prints exactly *k* of them, uniformly at random. Print each item from the sequence at most once.

```
% more distinct.txt                     % more duplicates.txt
A B C D E F G H I                       AA BB BB BB BB BB CC CC

% java-algs4 Permutation 3 < distinct.txt   % java-algs4 Permutation 8 < duplicates.txt
C                                          BB
G                                          AA
A                                          BB
                                           CC
% java-algs4 Permutation 3 < distinct.txt  BB
E                                          BB
F                                          CC
G                                          BB
```

Your program must implement the following API:

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

Command-line input. You may assume that $0 \le k \le n$, where *n* is the number of string on standard input.

Performance requirements. The running time of `Permutation` 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*. (For an extra challenge, use only one `Deque` or `RandomizedQueue` object of maximum size at most *k*.)

Deliverables. Submit the programs `RandomizedQueue.java`, `Deque.java`, and `Permutation.java`. Your submission may not call library functions except those in `StdIn`, `StdOut`, `StdRandom`, `java.lang`, `java.util.Iterator`, and `java.util.NoSuchElementException`. In particular, do not use either `java.util.LinkedList` or `java.util.ArrayList`.

This assignment was developed by Kevin Wayne.