

## 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.

**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 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 a `java.lang.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 a `java.lang.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.

*Performance requirements.* Your deque implementation must support each deque operation 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 queue empty?
    public int size()                // return the number of items on the queue
    public void enqueue(Item item)   // add the item
    public Item dequeue()            // remove and return a random item
    public Item sample()             // return (but do not remove) a random item
    public Iterator<Item> iterator() // return an independent iterator over items in random order
    public static void main(String[] args) // unit testing (optional)
}
```

*Corner cases.* The order of two or more iterators to the same randomized queue must be *mutually independent*; each iterator must maintain its own random order. Throw a `java.lang.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 a `java.lang.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.

*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) should 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.

**Permutation client.** Write a client program `Permutation.java` that takes a command-line integer  $k$ ; 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. You may assume that  $0 \leq k \leq n$ , where  $n$  is the number of string on standard input.

```
% more distinct.txt
A B C D E F G H I
```

```
% more duplicates.txt
AA BB BB BB BB BB CC CC
```

```
% java Permutation 3 < distinct.txt
C
G
A
```

```
% java Permutation 8 < duplicates.txt
```

```
BB
AA
BB
CC
BB
BB
CC
BB
```

```
% java Permutation 3 < distinct.txt
E
F
G
```

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  $k$ .) It must have the following API:

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

**Deliverables.** Submit only `Deque.java`, `RandomizedQueue.java`, and `Permutation.java`. We will supply `algs4.jar`. Do 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`.