

## 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 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  % java-algs4 Permutation 8 < duplicates.txt
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  $0 \leq k \leq n$ , 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.  
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