



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> {

    // construct an empty deque
    public Deque()

    // is the deque empty?
    public boolean isEmpty()

    // return the number of items on the deque
    public int size()

    // add the item to the front
    public void addFirst(Item item)

    // add the item to the back
    public void addLast(Item item)

    // remove and return the item from the front
    public Item removeFirst()

    // remove and return the item from the back
    public Item removeLast()

    // return an iterator over items in order from front to back
    public Iterator<Item> iterator()

    // unit testing (required)
    public static void main(String[] args)

}
```

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

- Throw an `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 an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

*Unit testing.* Your `main()` method must call directly every public constructor and method to help verify that they work as prescribed (e.g., by printing results to standard output).

*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. 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 among items in the data structure. Create a generic data type `RandomizedQueue` that implements the following API:

```

public class RandomizedQueue<Item> implements Iterable<Item> {

    // construct an empty randomized queue
    public RandomizedQueue()

    // is the randomized queue empty?
    public boolean isEmpty()

    // return the number of items on the randomized queue
    public int size()

    // add the item
    public void enqueue(Item item)

    // remove and return a random item
    public Item dequeue()

    // return a random item (but do not remove it)
    public Item sample()

    // return an independent iterator over items in random order
    public Iterator<Item> iterator()

    // unit testing (required)
    public static void main(String[] args)

}

```

**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 an `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 an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

**Unit testing.** Your `main()` method must call directly every public constructor and method to verify that they work as prescribed (e.g., by printing results to standard output).

**Performance requirements.** Your randomized queue implementation must support each randomized queue operation (besides creating an iterator) in *constant amortized time*. That is, any intermixed 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 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.

```
~/Desktop/queues> cat distinct.txt
A B C D E F G H I

~/Desktop/queues> java Permutation 3 < distinct.txt
C
G
A

~/Desktop/queues> java Permutation 3 < distinct.txt
E
F
G
```

```
~/Desktop/queues> cat duplicates.txt
AA BB BB BB BB BB CC CC

~/Desktop/queues> java Permutation 8 < duplicates.txt
BB
AA
BB
CC
BB
BB
CC
BB
```

Your program must implement the following API:

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

*Command-line argument.* You may assume that  $0 \leq k \leq n$ , where  $n$  is the number of string on standard input. Note that you are not given  $n$ .

*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 and a small amount of extra credit, use only one `Deque` or `RandomizedQueue` object of maximum size at most  $k$ .)

**Web submission.** Submit a .zip file containing only `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 Bob Sedgewick and Kevin Wayne.  
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