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Technology and Engineering

Introduction to Computer Science II (ITI 1121)
Final Examination

Instructor: Marcel Turcotte

April 2008, duration: 3 hours

Identification

Student name: ______________________________

Student number: ______________ Signature: ______________________

Instructions

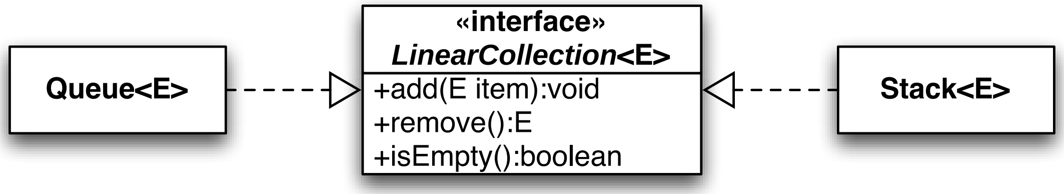
1. This is a closed book examination;
2. No calculators or other aids are permitted;
3. Write comments and assumptions to get partial points;
4. Beware, poor hand writing can affect grades;
5. **Do not remove the staple holding the examination pages together**;
6. Write your answers in the space provided. Use the backs of pages if necessary. There are two blank pages at the end. You may **not** hand in additional pages.

Marking scheme

Question	Points	Score
1	10	
2	15	
3	15	
4	10	
5	5	
6	10	
7	15	
8	10	
Total	**90**	

Question 1 (10 points)

For this question, the classes **Queue** and **Stack** both implement the interface **LinearCollection**.



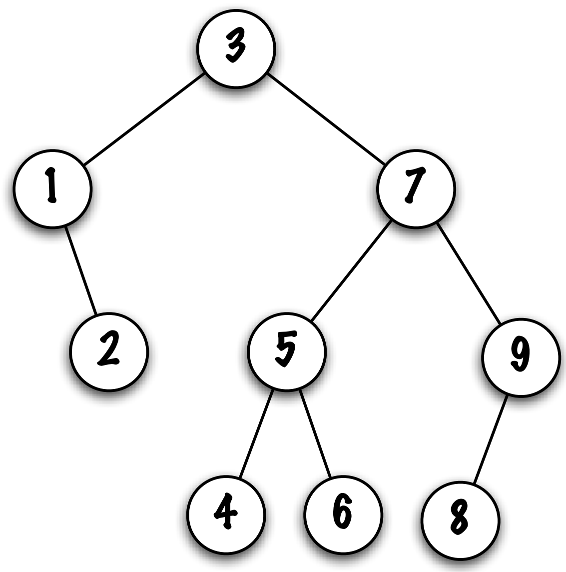
Queue, as all the other implementations of a queue, is such that the method **add** enqueues the **item** at the rear of the queue, the method **remove** dequeues the front element, and the method **isEmpty** returns **true** if this queue contains no elements.

Stack, as all the other implementations of a stack, is such that the method **add** pushes the **item** onto the top of the stack, the method **remove** pops (removes and returns) the top element, and the method **isEmpty** returns **true** if this stack contains no elements.

A **BinarySearchTree** was created by adding elements in the order that follows; the resulting tree is shown to the right.

```
BinarySearchTree<Integer> t;
t = new BinarySearchTree<Integer>();

t.add( 3 );
t.add( 1 );
t.add( 7 );
t.add( 9 );
t.add( 5 );
t.add( 4 );
t.add( 6 );
t.add( 2 );
t.add( 8 );
```



A. Circle the answer that corresponds to the following method call:

```
t.traverse( new Queue< Node<Integer> >() );
```

- **A.** 1 2 3 4 5 6 7 8 9
- **B.** 2 1 4 6 5 8 9 7 3
- **C.** 2 3 4 5 5 8 9 7 3
- **D.** 3 1 7 2 5 9 4 6 8
- **E.** 3 1 2 7 5 4 6 9 8
- **F.** 3 7 1 9 5 2 8 6 4
- **G.** 3 7 9 8 5 6 4 1 2
- **H.** 8 6 4 9 5 2 7 1 3
- **I.** 9 8 7 6 5 4 3 2 1

B. Circle the answer that corresponds to the following method call:

```
t.traverse( new Stack< Node<Integer> >() );
```

- **A.** 1 2 3 4 5 6 7 8 9
- **B.** 2 1 4 6 5 8 9 7 3
- **C.** 2 3 4 5 5 8 9 7 3
- **D.** 3 1 7 2 5 9 4 6 8
- **E.** 3 1 2 7 5 4 6 9 8
- **F.** 3 7 1 9 5 2 8 6 4
- **G.** 3 7 9 8 5 6 4 1 2
- **H.** 8 6 4 9 5 2 7 1 3
- **I.** 9 8 7 6 5 4 3 2 1

The source code for the method **traverse** can be found on the next page.

```
public class BinarySearchTree< E extends Comparable<E> > {

    private static class Node<T> {
        private T value;
        private Node<T> left = null;
        private Node<T> right = null;
        private Node( T value ) {
            this.value = value;
        }
    }

    private Node<E> root = null;

    public void traverse( LinearCollection< Node<E> > store ) {

        if ( root != null ) {

            store.add( root );

            while ( ! store.isEmpty() ) {

                Node<E> current = store.remove();

                System.out.print( " " + current.value );

                if ( current.left != null ) {
                    store.add( current.left );
                }

                if ( current.right != null ) {
                    store.add( current.right );
                }

            }

            System.out.println();
        }

    }

    public boolean add( E obj ) { ... }

}
```

Question 2 (15 points)

The abstract data type **Deque** — pronounced "deck" — combines features of both a queue and a stack. In particular, a **Deque** ("Double-Ended QUEue") allows for

- efficient insertions at the front or rear;
- efficient deletions at the front or the rear.

Below, you will find a complete implementation of the class **Deque** that uses a circular array to store its elements, and has an instance variable, **size**, to keep track of the number of elements. Here are the descriptions of the four main methods of this class.

boolean offerFirst(E item): adds an item at the **front** of this **Deque**, returns **true** if the item was successfully added;

boolean offerLast(E item): adds an item at the **rear** of this **Deque**, returns **true** if the item was sucessfully added;

E pollFirst(): removes and returns the **front** item of this **Deque**, returns **null** if this **Deque** was empty;

E pollLast(): removes and returns the **rear** item of this **Deque**, returns **null** if this **Deque** was empty.

```
public class Deque<E> {

    private E[] elems;
    private int size = 0, front, rear, capacity;

    public Deque( int capacity ) {
        this.capacity = capacity;
        elems = (E[]) new Object[ capacity ];
        front = 0;
        rear  = capacity-1;
    }

    public int size() {
        return size;
    }

    public boolean isEmpty() {
        return size == 0;
    }

    public boolean isFull() {
        return size == capacity;
    }

    // continues on the next page...
```

```
// ... continues

public boolean offerFirst( E obj ) {
    boolean added = false;
    if ( size < capacity ) {
        front = ( front + ( capacity - 1 ) ) % capacity;
        elems[ front ] = obj;
        added = true;
        size++;
    }
    return added;
}

public boolean offerLast( E obj ) {
    boolean added = false;
    if ( size < capacity ) {
        rear = (rear + 1) % capacity;
        elems[ rear ] = obj;
        added = true;
        size++;
    }
    return added;
}

public E pollFirst() {
    E obj = null;
    if ( size > 0 ) {
        obj = elems[ front ];
        elems[ front ] = null;
        front = (front + 1) % capacity;
        size--;
    }
    return obj;
}

public E pollLast() {
    E obj = null;
    if ( size > 0 ) {
        obj = elems[ rear ];
        elems[ rear ] = null;
        rear = ( rear + ( capacity - 1 ) ) % capacity;
        size--;
    }
    return obj;
}

// continues on the next page...
```

```
    // ... continues

    public void dump() {

        System.out.println( "front = " + front );
        System.out.println( "rear = " + rear );

        for ( int i=0; i<elems.length; i++ ) {
            System.out.print( "  elems[" + i + "] = " );
            if ( elems[ i ] == null ) {
                System.out.println( "null" );
            } else {
                System.out.println( elems[ i ] );
            }
        }

        System.out.println();
    }

    public static void main( String[] args ) {
        // ...
    }
} // End of Deque
```

For each of the following (5) blocks of code, give the result of the call to the method d.dump(). Write your answers in the boxes.

```
// Block 1

int n = 6; int num=1;

Deque<String> d = new Deque<String>( n );

for ( int i=0; i<4; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<2; i++ ) {
    d.pollFirst();
}

for ( int i=0; i<2; i++ ) {
    d.offerLast( "item-" + num++ );
}

System.out.println( d );
d.dump();
```

```
// Block 2

int n = 4; int num = 1;

d = new Deque<String>( n );

for ( int i=0; i<4; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<3; i++ ) {
    d.pollFirst();
}

for ( int i=0; i<2; i++ ) {
    d.offerLast( "item-" + num++ );
}

System.out.println( d );
d.dump();
```

```
// Block 3

int n = 4; int num = 1;

d = new Deque<String>( n );

for ( int i=0; i<4; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<3; i++ ) {
    d.pollLast();
}

for ( int i=0; i<2; i++ ) {
    d.offerFirst( "item-" + num++ );
}

System.out.println( d );
d.dump();
```

```
// Block 4

int n = 4; int num = 1;

d = new Deque<String>( n );

for ( int i=0; i<4; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<3; i++ ) {
    d.pollFirst();
}

for ( int i=0; i<2; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<2; i++ ) {
    d.pollFirst();
}

System.out.println( d );
d.dump();
```

```
// Block 5

int n = 4; int num = 1;

d = new Deque<String>( n );

for ( int i=0; i<6; i++ ) {
    d.offerLast( "item-" + num++ );
}

for ( int i=0; i<3; i++ ) {
    d.pollLast();
}

for ( int i=0; i<2; i++ ) {
    d.offerFirst( "item-" + num++ );
}

for ( int i=0; i<2; i++ ) {
    d.pollLast();
}

System.out.println( d );
d.dump();
```

Question 3 (15 points)

Complete the implementation of the instance method **void insertAfter(E obj, LinkedList<E> other)**. The method inserts the content of **other** after the leftmost occurrence of **obj** in this list, the elements are removed from **other**.

An exception, **IllegalArgumentException**, is thrown if **obj** is **null**, or the parameter **obj** is not found in this list. The implementation of **LinkedList** has the following characteristics.

- An instance always starts off with a dummy node, which serves as a marker for the start of the list. The dummy node is never used to store data. The empty list consists of the dummy node only;
- In the implementation for this question, the nodes of the list are doubly linked;
- In this implementation, the list is circular, i.e. the reference **next** of the last node of the list is pointing at the dummy node, the reference **previous** of the dummy node is pointing at the last element of the list. In the empty list, the dummy node is the first and last node of the list, its references **previous** and **next** are pointing at the node itself;
- Since the last node is easily accessed, because it is always the previous node of the dummy node, the header of the list does not have (need) a tail pointer.

Example: **xs** contains [**a,b,c,f**], **ys** contains [**d,e**], after the call: **xs.insertAfter("c", ys)**, **xs** contains [**a,b,c,d,e,f**], and **ys** is empty.

Write your answer in the class **LinkedList** on the next page. **You cannot use the methods of the class LinkedList. In particular, you cannot use the methods add() or remove().**

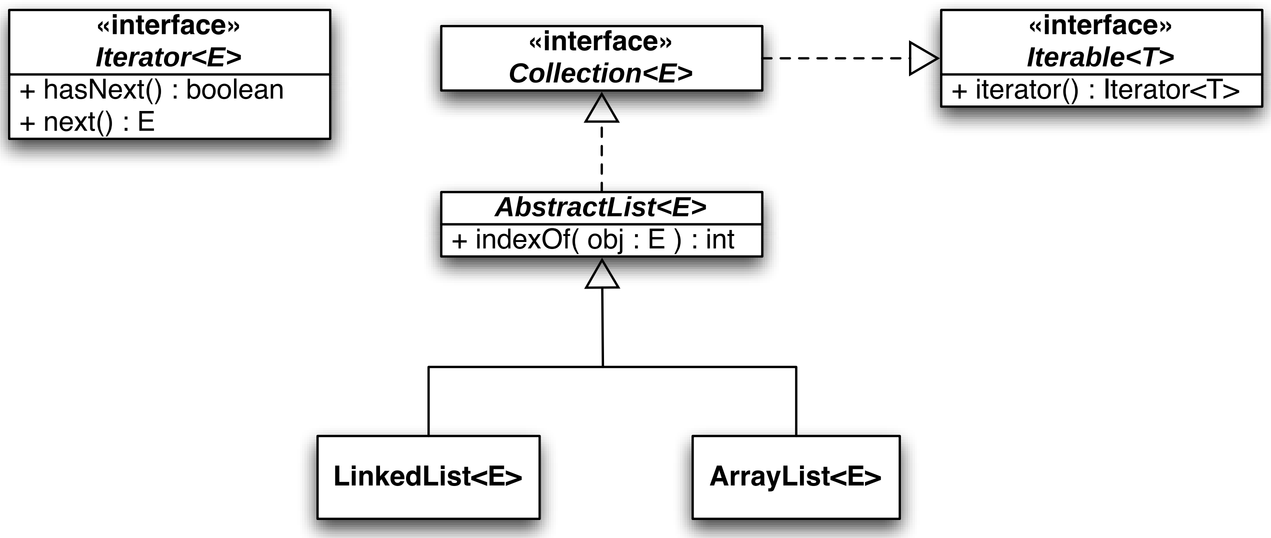
Hint: draw detailed memory diagrams.

```
public class LinkedList<E> {
    private static class Node<T> { // implementation of the doubly linked nodes
        private T value;
        private Node<T> previous;
        private Node<T> next;
        private Node( T value, Node<T> previous, Node<T> next ) {
            this.value = value;
            this.previous = previous;
            this.next = next;
        }
    }
    private Node<E> head;
    private int size;
    public LinkedList() {
        head = new Node<E>( null, null, null );
        head.next = head.previous = head;
        size = 0;
    }

    public void insertAfter( E obj, LinkedList<E> other ) {
```

```
    } // End of insertAfter
} // End of LinkedList
```

Question 4 (10 points)



A. In the abstract class **AbstractList**, implement the instance method **int indexOf(E obj)**. The known information about the class **AbstractList** is summarized in the above UML diagram.

The method **int indexOf(E obj)** returns the index of the leftmost occurrence of the specified element in this list, or -1 if this list does not contain the element.

B. Make **all** the necessary changes so that **Iterator** and **LinkedList** declare and implement the instance method **int nextIndex()**.

The method **int nextIndex()** returns the index of the element that would be returned by a subsequent call to **next**, or the size of the list if the iterator is at end of list.

You may add new instance variables to the class **LinkedListIterator** if you wish so, but not to the class **LinkedList**.

The class **LinkedList** implements a singly linked list. There are **no** dummy nodes.

A. You don't need to write the class declaration, write only the implementation of the method **indexOf**. Write your answer in the space below.

B. Implement the method **int nextIndex()**, additional space is available on the next page.

```
public interface Iterator<T> {
    public abstract boolean hasNext();
    public abstract T next();
}
```

```
import java.util.NoSuchElementException;

public class LinkedList<E> extends AbstractList<E> {

    private static class Node<T> {

        private T value;
        private Node<T> next;

        private Node( T value, Node<T> next ) {
            this.value = value;
            this.next = next;
        }
    }

    private Node<E> first = null;

    private class LinkedListIterator implements Iterator<E> {

        private Node<E> current = null;

        public boolean hasNext() {
            return ( ( ( current == null ) && ( first != null ) ) ||
                     ( ( current != null ) && ( current.next != null ) ) );
        }

        public E next() {

            if ( current == null ) {
                current = first;
            } else {
                current = current.next;
            }

            if ( current == null ) {
                throw new NoSuchElementException();
            }

            return current.value;
        }

    } // End of LinkedListIterator

    public Iterator<E> iterator() {
        return new LinkedListIterator();
    }

    // The other methods of the class LinkedList would be here

} // End of LinkedList
```

(**Question 4 continues**)

Question 5 (5 points)

Which of these statements characterizes the execution of the main method of the following program.

A. Prints []
B. Prints [a,c,e]
C. Prints [e,c,a]
D. Prints [a,b,c,d,e]
E. Prints [e,d,c,b,a]
F. Prints [a,a,a,a,a]
G. Prints [e,e,e,e,e]
H. Prints [a,a,b,b,c,c,d,d,e,e]
I. Prints [e,e,d,d,c,c,b,b,a,a]
J. Causes a stack overflow exception
K. None of the above

```
public class LinkedList< E > {
    private static class Node<T> { // singly linked nodes
        private T value;
        private Node<T> next;
        private Node( T value, Node<T> next ) {
            this.value = value;
            this.next  = next;
        }
    }

    private Node<E> first; // instance variable

    public void addFirst( E item ) {
        first = new Node<E>( item, first );
    }

    public static void main( String[] args ) {

        LinkedList<String> xs = new LinkedList<String>();

        xs.addFirst( "e" );
        xs.addFirst( "d" );
        xs.addFirst( "c" );
        xs.addFirst( "b" );
        xs.addFirst( "a" );

        xs.f();

        System.out.println( xs );
    }

    // continues on the next page
```

```
    public void f() {
        f( true, first );
    }

    private void f( boolean predicate, Node<E> current ) {

        if ( current == null ) {
           return;
        }

        if ( predicate ) {
            current.next = new Node<E>( current.value, current.next );
        }

        f( ! predicate, current.next );

        return;
    }

    public String toString() {

        StringBuffer answer = new StringBuffer( "[" );

        Node p = first;

        while ( p != null ) {

            if ( p != first ) {
                answer.append( "," );
            }

            answer.append( p.value );

            p = p.next;
        }

        answer.append( "]" );

        return answer.toString();
    }

}
```

Question 6 (10 points)

Complete the implementation of the method **removeAll(Sequence<E> l, E obj)**. It removes all the occurrences of **obj** in **l**. Its implementation **must be recursive**. The class **Sequence** is a linked list with additional methods to write efficient recursive list processing methods outside of the implementation of the list. Here are the characteristics of the class **Sequence**. The methods of the class **Sequence** include.

- **boolean isEmpty()**; returns **true** if and only if **this** list is empty;
- **E head()**; returns a reference to the object stored in the first node of **this** list;
- **Sequence<E> split()**; returns the tail of **this** sequence, **this** sequence now contains a single element. It throws **IllegalStateException** if the **Sequence** was empty when the call was made;
- **void join(Sequence<E> other)**; appends **other** at the end of **this** sequence, **other** is now empty.

```
public class Q6 {
    public static <E> void removeAll( Sequence<E> l, E obj ) {











    // End of removeAll
// End of Q6
```

Question 7 (15 points)

For the partial implementation of the class **BinarySearchTree** below, implement the methods **isLeaf** and **getHeight**.

A. **boolean isLeaf(E obj)**: this instance method returns **true** if the node containing **obj** is a leaf, and **false** otherwise. The method throws **IllegalArgumentException** if **obj** is **null**. The method throws **NoSuchElementException** if **obj** is not found in this tree. (8 points)

B. **int getHeight()**: this instance method returns the height of this tree. Do not add any new instance variable. (7 points)

```
import java.util.NoSuchElementException;

public class BinarySearchTree< E extends Comparable<E> > {

    private static class Node<T> {
        private T value;
        private Node<T> left = null;
        private Node<T> right = null;
        private Node( T value ) {
            this.value = value;
        }
    }

    private Node<E> root = null;
```

(Question 7 continues)

Question 8 (10 points)

A. Which of these statements best characterizes the following block of code. (3 points)

(a) Prints “c = 0”;

(b) Prints “c = Infinity”;

(c) Prints “** caught ArithmeticException **”, “c = 3”;

(d) Prints “** caught Exception **”, “c = 2”;

(e) Does not compile: “exception java.lang.ArithmeticException has already been caught”;

(f) Produces a run time error, with a stack trace.

```
int a = 1, b = 0, c = 0;
try {
    c = a/b;
} catch ( Exception e ) {
    System.err.println( "** caught Exception **" );
    c = 2;
} catch ( ArithmeticException ae ) {
    System.err.println( "** caught ArithmeticException **" );
    c = 3;
}
System.out.println( "c = " + c );
```

B. Create a new checked exception type called **MyException**. (3 points)

C. Modify the following program so that it will compile. (4 points)

```
import java.io.*;

public class Q8 {

    public static String cat( String fileName ) {

        FileInputStream fin = new FileInputStream( fileName );

        BufferedReader input = new BufferedReader( new InputStreamReader( fin ) );

        StringBuffer buffer = new StringBuffer();

        String line = null;

        while ( ( line = input.readLine() ) != null ) {

            line = line.replaceAll( "\\s+", " " );

            buffer.append( line );

        }

        fin.close();

        return buffer.toString();

    } // End of cat

    public static void main( String[] args ) {

        System.out.println( cat( args[ 0 ] ) );

    }
}
```

where

- **FileInputStream(name)** throws **FileNotFoundException** (a checked exception) if the file does not exist, is a directory rather than a regular file, or for some other reason cannot be opened for reading;
- **readLine()** throws **IOException** (a checked exception) if an I/O error occurs;
- **line.replaceAll(expression, replacement)**, here, this replaces consecutive white space characters by a single white space. It throws **PatternSyntaxException** (an unchecked exception) if the syntax of the first parameter (a regular expression) is not valid;
- **close()** throws **IOException** (a checked exception) if an I/O error occurs.

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