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Introduction to Computer Science II (ITI 1121)

FINAL EXAMINATION: SOLUTIONS

Instructor: Marcel Turcotte

April 2008, duration: 3 hours

Identification

Student name: _____

Student number: _____ Signature: _____

Instructions

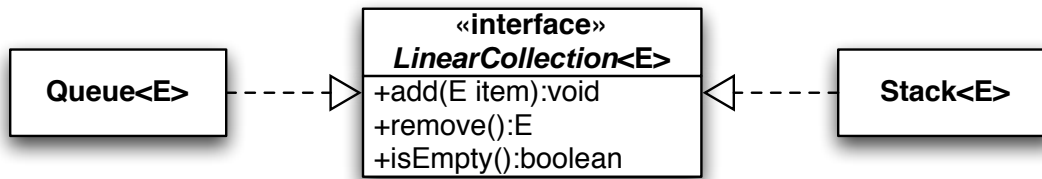
1. This is a closed book examination;
2. No calculators or other aids are permitted;
3. Write comments and assumptions to get partial points;
4. Beware, poor hand writing can affect grades;
5. **Do not remove the staple holding the examination pages together;**
6. Write your answers in the space provided. 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.

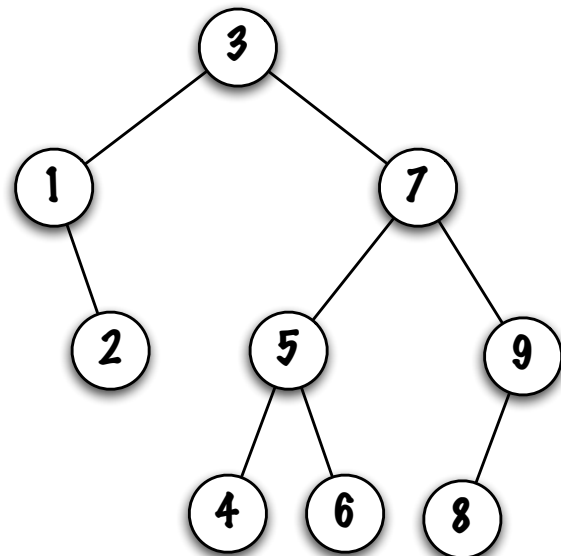
Stack, as all the other implementations of a stack, is such that the method **add** pushes the **item** onto the top of the stack, the method **remove** pops (removes and returns) the top element, and the method **isEmpty** returns **true** if this stack contains no elements.

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 successfully 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 `t.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();
```

SOLUTIONS:

```
front = 2
rear = 5
  elems[0] = null
  elems[1] = null
  elems[2] = item-3
  elems[3] = item-4
  elems[4] = item-5
  elems[5] = item-6
```

```
front = 3
rear = 1
  elems[0] = item-5
  elems[1] = item-6
  elems[2] = null
  elems[3] = item-4
```

```
front = 2
rear = 0
  elems[0] = item-1
  elems[1] = null
  elems[2] = item-6
  elems[3] = item-5
```

```
front = 1
rear = 1
  elems[0] = null
  elems[1] = item-6
  elems[2] = null
  elems[3] = null
```

```
front = 2
rear = 2
  elems[0] = null
  elems[1] = null
  elems[2] = item-6
  elems[3] = null
```

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 ) {
```

```
// MODEL:

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

    if ( obj == null || other == null ) {
        throw new IllegalArgumentException( "null" );
    }

    Node<E> p = head.next;

    while ( p != head && ( ! obj.equals( p.value ) ) ) {
        p = p.next;
    }

    if ( p == head ) {
        throw new IllegalArgumentException( "obj not found" );
    }

    Node<E> q = p.next;
    Node<E> otherFirst = other.head.next;
    Node<E> otherLast = other.head.previous;

    if ( otherFirst != otherLast ) {

        p.next = otherFirst;
        otherFirst.previous = p;

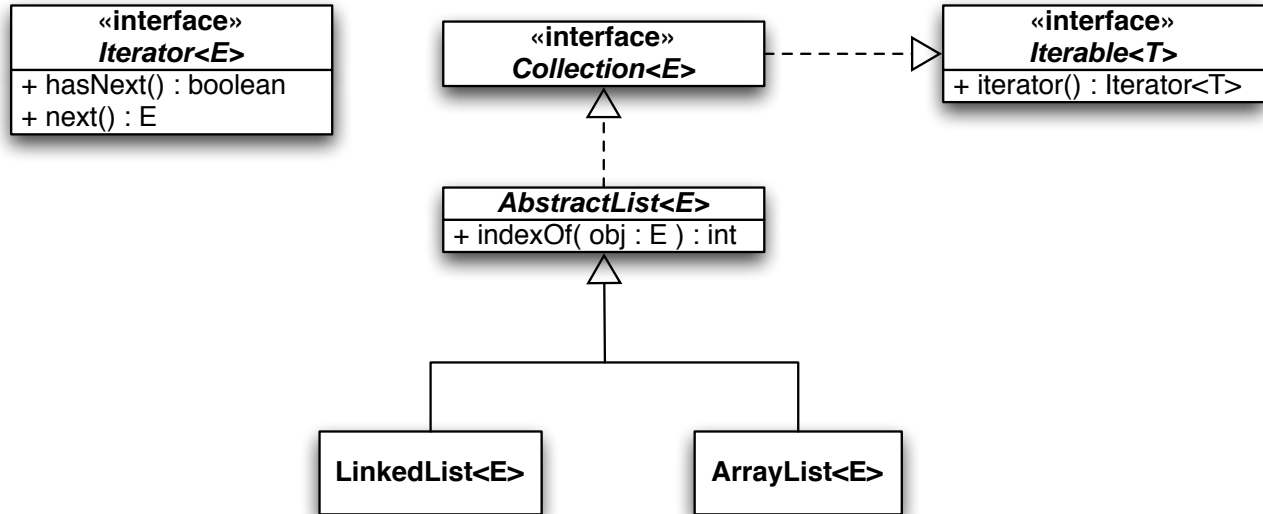
        otherLast.next = q;
        q.previous = otherLast;

        other.head.next = other.head;
        other.head.previous = other.head;

        size = size + other.size;
        other.size = 0;
    }

} // 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.

```
// MODEL:

public int indexOf(E obj) {

    int pos = 0;
    boolean found = false;

    Iterator<E> i = iterator();

    while (!found && i.hasNext()) {
        E elem = i.next();

        if (obj == null && elem == null) {
            found = true;
        } else if (obj != null && obj.equals(elem)) {
            found = true;
        } else {
            pos++;
        }
    }

    if (!found) {
        pos = -1;
    }

    return pos;
}
```

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

```
1 public interface Iterator<T> {
2     public abstract boolean hasNext();
3     public abstract T next();
4 }

1 import java.util.NoSuchElementException;
2
3 public class LinkedList<E> extends AbstractList<E> {
4
5     private static class Node<T> {
6
7         private T value;
8         private Node<T> next;
9
10        private Node( T value , Node<T> next ) {
11            this.value = value;
12            this.next = next;
13        }
14    }
15
16    private Node<E> first = null;
17
18    private class LinkedListIterator implements Iterator<E> {
19
20        private Node<E> current = null;
21
22        public boolean hasNext() {
23            return ( ( current == null ) && ( first != null ) ) ||
24                ( ( current != null ) && ( current.next != null ) );
25        }
26
27        public E next() {
28
29            if ( current == null ) {
30                current = first;
31            } else {
32                current = current.next;
33            }
34
35            if ( current == null ) {
36                throw new NoSuchElementException();
37            }
38
39            return current.value;
40        }
41    } // End of LinkedListIterator
42
43    public Iterator<E> iterator() {
44        return new LinkedListIterator();
45    }
46
47    // The other methods of the class LinkedList would be here
48
49 } // End of LinkedList
```

(Question 4 continues)

```
// MODEL:
public interface Iterator<T> {
    public abstract boolean hasNext();
    public abstract T next();
    public abstract int nextIndex(); // <-
}

private class LinkedListIterator implements Iterator<E> {

    private Node<E> current;
    private int nextIndex = 0; // <-

    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();
        }

        nextIndex++; // <-

        return current.value;
    }

    public int nextIndex() { // <-
        return nextIndex;
    }
}
```

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 {
    // MODEL:
    public static <E> void removeAll( Sequence<E> l, E obj ) {
        if ( ! l.isEmpty() ) {
            Sequence<E> t;
            t = l.split();
            removeAll( t, obj );
            if ( l.head().equals( obj ) ) {
                l.deleteFirst();
            }
            l.join( t );
        }
    }

    public static <E> void removeAll2( Sequence<E> l, E obj ) {
        if ( ! l.isEmpty() ) {
            Sequence<E> t;
            t = l.split();
            removeAll2( t, obj );
            if ( l.head().equals( obj ) ) {
                l.deleteFirst();
                // Hack removing the head element
                Sequence<E> dummy = new Sequence<E>();
                dummy.join( l );
            }
            l.join( t );
        }
    }
} // 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;

    // Sub-question B MODEL:

    public int getHeight() {
        return getHeight( root );
    }

    private static<E> int getHeight( Node<E> current ) {
        int answer;
        if ( current == null ) {
            answer = -1;
        } else {
            answer = 1 + Math.max( getHeight( current.left ), getHeight( current.right ) );
        }
        return answer;
    }
}
```

(Question 7 continues)

```
// Sub-question A MODEL (iterative)
public boolean isLeaf( E obj ) {
    if ( obj == null ) {
        throw new IllegalArgumentException( "null" );
    }
    boolean found = false;
    Node<E> current = root;
    while ( ! found && current != null ) {
        int test = obj.compareTo( current.value );
        if ( test == 0 ) {
            found = true;
        } else if ( test < 0 ) {
            current = current.left;
        } else {
            current = current.right;
        }
    }
    if ( current == null ) {
        throw new NoSuchElementException( obj.toString() );
    }
    return current.left == null && current.right == null;
}

// Sub-question A MODEL (recursive)
public boolean isLeaf2( E obj ) {
    if ( obj == null ) {
        throw new IllegalArgumentException( "null" );
    }
    return isLeaf2( root, obj );
}

private boolean isLeaf2( Node<E> current, E obj ) {
    if ( current == null ) {
        throw new NoSuchElementException( obj.toString() );
    }
    boolean answer;
    int test = obj.compareTo( current.value );
    if ( test == 0 ) {
        answer = current.left == null && current.right == null;
    } else if ( test < 0 ) {
        answer = isLeaf2( current.left, obj );
    } else {
        answer = isLeaf2( current.right, obj );
    }
    return answer;
}
}
```

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)

```
// MODEL:
public class MyException extends Exception {
    public MyException() {
        super();
    }
    public MyException( String message ) {
        super( message );
    }
}
```

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

```
1  import java.io.*;
2
3  public class Q8 {
4
5      public static String cat( String fileName ) {
6
7          FileInputStream fin = new FileInputStream( fileName );
8
9          BufferedReader input = new BufferedReader( new InputStreamReader( fin ) );
10
11         StringBuffer buffer = new StringBuffer();
12
13         String line = null;
14
15         while ( ( line = input.readLine() ) != null ) {
16
17             line = line.replaceAll( "\\s+", " " );
18
19             buffer.append( line );
20
21         }
22
23         fin.close();
24
25         return buffer.toString();
26
27     } // End of cat
28
29     public static void main( String[] args ) {
30
31         System.out.println( cat( args[ 0 ] ) );
32
33     }
34 }
```

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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```
// MODEL:
```

```
import java.io.*;
```

```
public class Q8b {
```

```
    public static String cat( String fileName )
        throws FileNotFoundException, IOException { // <-
        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+", " " ); // replaces mutiples spaces by one
            buffer.append( line );
        }
        fin.close();
        return buffer.toString();
```

```
    } // End of cat
```

```
    public static void main( String[] args )
        throws FileNotFoundException, IOException { // <-
        System.out.println( cat( args[ 0 ] ) );
```

```
    }
```

```
}
```

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