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Faculty of Engineering

School of Information
Technology and Engineering

Introduction to Computer Science II (ITI 1121)
Midterm Examination

Instructor: Marcel Turcotte

February 2007, duration: 2 hours

Identification

Student name: _____

Student number: _____ Signature: _____

Instructions

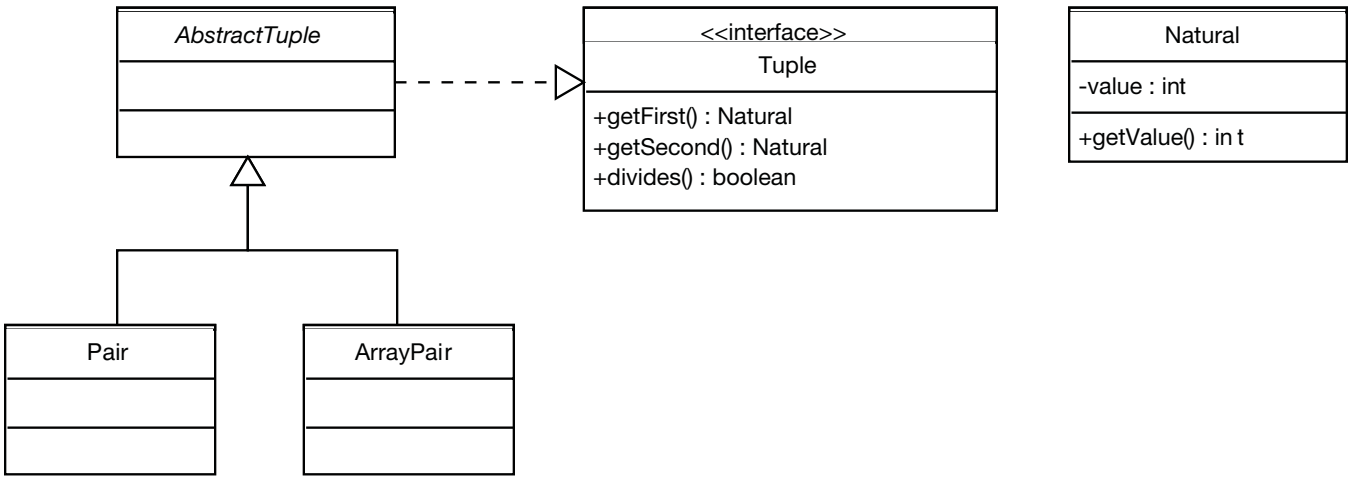
1. This is a closed book examination;
2. No calculators or other aids are permitted;
3. Write comments and assumptions to get partial marks;
4. Beware, poor hand writing can affect grades;
5. Do not remove the staple holding the examination pages together;
6. Write your answers in the space provided.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

Marking scheme

Question	Maximum	Result
1	36	
2	15	
3	15	
4	12	
5	22	
Total	**100**	

Question 1: (36 marks)

A tuple holds two **Natural** numbers (objects of the class **Natural**). All the tuples have a method **getFirst**, as well as a method **getSecond**, returning a reference to the first, and second, number of the tuple, respectively. A tuple has a method **divides** that returns **true** if the first element is a factor of the second element, and **false** otherwise.



For this question there is an interface named **Tuple**, an abstract class named **AbstractTuple**, and two concrete implementations, called **Pair** and **ArrayPair**. Their complete description can be found on the next pages. The implementation of the class **Natural** is given on page 18. The execution of the statements below produces the following output: `7 is a factor of 42`.

```
Natural n1, n2, n3;

n1 = new Natural( 7 );
n2 = new Natural( 17 );
n3 = new Natural( 42 );

Tuple t1, t2;

t1 = new Pair( n1, n2 );
t2 = new ArrayPair( n1, n3 );

if ( t1.divides() ) {
    System.out.println( t1.getFirst() + " is a factor of " + t1.getSecond() );
}

if ( t2.divides() ) {
    System.out.println( t2.getFirst() + " is a factor of " + t2.getSecond() );
}
```

Make sure to include the constructors and access methods that are necessary for the execution of the above statements.

A. Implement the interface **Tuple**. The interface declares 3 methods. There are two access methods, named **getFirst** and **getSecond**, and both return a reference to a **Natural** object. Finally, the interface also declares a method called **divides** that returns a **boolean** value. (8 marks)

B. Write the abstract class named **AbstractTuple**, which implements the interface **Tuple**. The class **AbstractTuple** has a concrete implementation of the method **divides**, which returns **true** if the first element of the tuple is a divisor of the second element, and **false** otherwise. A divisor of n is a number that divides n without leaving a remainder. (8 marks)

C. Write a concrete implementation of the class **AbstractTuple** called **Pair**. The implementation has two instance variables that are references to the first and second element of this tuple. Add all the necessary constructors and access methods. (10 marks)

D. Write a concrete implementation of the class **AbstractTuple** called **ArrayPair**. The implementation uses an array of size 2 to store references to the first and second element of this tuple. Add all the necessary constructors and access methods. (10 marks)

Question 2: (15 marks)

Complete the implementation of the static method **boolean isPalindrome(CharReader r)**. Let's define a **palindrome** as a word or a phrase that reads the same forward and backward if the punctuation symbols and spaces are ignored. Examples of palindromes include:

- i prefer pi
- never odd or even
- was it a cat i saw

For this question, the data is read using a **CharReader** object. Therefore, you don't know the actual size of the input and it is impossible to read it again, once read. Follow all the directives.

- **boolean isPalindrome(CharReader r)**. Write a stack-based algorithm that returns **true** if the whole word or phrase specified by the reader is a palindrome according to the above definition, and **false** otherwise;
- The parameter of the method is a **CharReader**. A **CharReader** has **exactly** two instance methods (and no public variables). Once the data has been read it is impossible to read it again.
  - **boolean hasMoreChars()**; returns **true** if the reader has more characters to return, that is if a call to **char nextChar()** would succeed, and **false** otherwise;
  - **char nextChar()**; returns the next character of the input.
- You cannot use arrays or strings to store the characters that are read from the input, you have to use implementations of a stack;
- Assume the existence of a class **StackImpl** that implements the interface **Stack**. For this question, a **Stack** stores characters.

```
public interface Stack {
    public abstract boolean isEmpty();
    public abstract char peek();
    public abstract char pop();
    public abstract void push( char element );
}
```

- **StackImpl** can store an arbitrarily large number of characters;
- **Character.isLetter(char ch)** determines if the specified character, **ch**, is a letter.

```
public static boolean isPalindrome( CharReader reader ) {




}
```

Question 3: (15 marks)

The class **DynamicArrayStack** below uses the technique seen in class, as well as in the assignment 3, to increase or decrease, its physical size according to the needs of the application.

- **DynamicArrayStack** uses an array to store the elements of this stack;
- The interface **Stack** and its implementation, **DynamicArrayStack**, have a formal parameter type (in other words, the implementation uses the concept of generics types, introduced in Java 1.5);
- The initial capacity of this array is given by the first parameter of the constructor;
- The physical size of the array is increased by a fixed amount (**increment**) when the method **void push(E elem)** is called and the array is full;
- The physical size of the array is decreased by a fixed amount (**increment**) during a call to the method **E pop()** if the number of free cells becomes **increment** or more;
- The **increment** is given by the second parameter of the constructor;
- The instance variable **top** designates the top element (i.e. the cell where the last element was inserted, or -1 if the stack is empty).

A. Correct at least 5 mistakes (compile-time or runtime errors) in the partial implementation. (5 marks)

B. Complete the partial implementation of the class **DynamicArrayStack** given the above information. (10 marks)

```
public class DynamicArrayStack<E> implements Stack<E> {

    // Instance variables
    private static E[] elems;    // Stores the elements of this stack
    private static int top = -1; // Designates the top element
    private final int capacity;  // Memorizes the initial capacity
    private final int increment; // Used to increase/decrease the size

    public DynamicArrayStack( int capacity, int increment ) {
        E[] elems = (E[]) new Object[ capacity ];
        this.capacity = capacity;
        this.increment = increment;
    }

    // Returns true if this stack is empty;
    public boolean isEmpty() {
        return top == 0;
    }

    // Continues on the next page ...
```

DynamicArrayStack (continued)

```
public void push( E element ) {

    if ( ___________________________ ) {
        increaseSize();
    }

    elems[ top ] = element;
    top++;
}

private void increaseSize() {

    E[] newElems;
    int newSize;

    newSize= elems.length + increment;

    newElems = new E[ newSize ];

    for ( int i=0; i<elems.length; i++ ) {
        newElems[ i ] = elems[ i ];
    }

    ______________________________;
}

// Continues on the next page ...
```

DynamicArrayStack (continued)

```
    public E peek() {

        return ______________________________;
    }

    // Complete the implementation of pop()

    public E pop() {


        E saved;
        saved = elems[ top ];


        elems[ top ] = ________________;


        top--;


        return saved;
    }


    private void decreaseSize() {

        E[] newElems;
        int newSize;

        newSize = elems.length - increment;

        if ( newSize < capacity ) {
            newSize = capacity;
        }

        ________________________________________;

        for ( int i=0; i<=top; i++ ) {
            newElems[ i ] = elems[ i ];
        }

        elems = newElems;
    }

} // End of DynamicArrayStack
```

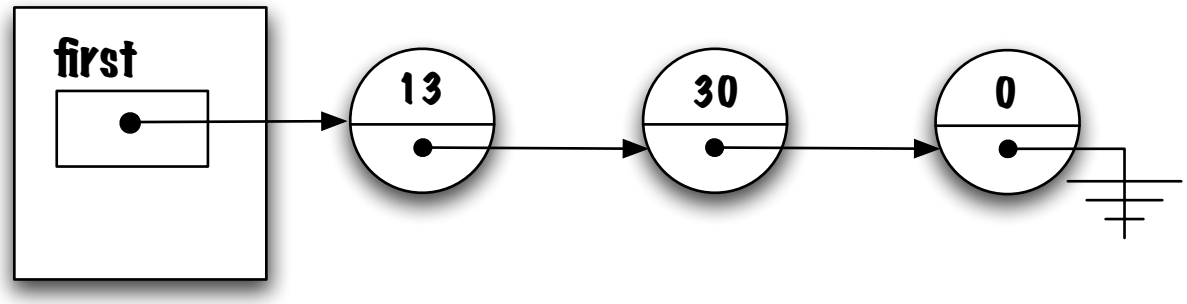
DynamicArrayStack (continued)

Complete the implementation of the method **main**. It declares a stack of Integer objects, creates a new stack of Integer objects, pushes 20 elements onto the stack, removes and prints those elements.

```
public class Test {

    public static void main( String[] args ) {

        // Declare a reference to a stak of Integer objects

        _____________ s;

        // Create an instance of DynamicStack to store Integer objects

        s = ______________________________________;

        for ( int i=0; i<20; i++ ) {
            s.push( new Integer( i ) );
        }

        while ( ! s.isEmpty() ) {
            // Declares an Integer

            _______________ elem;


            // Removes an element from the stack


            elem = _____________;

            System.out.println( elem );
        }
    }

} // End of Test
```

Question 4: (12 marks)

Complete the implementation of the class **Time** below. Linked elements are used to store the hours, minutes and seconds of this **Time** object. Specifically, the class **Time** has a single instance variable, called **first**. The variable **first** is a reference to an **Elem** object, which is used to store the hours of this **Time** value. The variable **next** of that element designates an **Elem** object, which is used to store the minutes. The variable next of that **Elem** object designates the last element, which is used to store the seconds of this **Time** value. For instance, the creation of this object: **new Time(13, 30, 0)**, has the following associated memory diagram.



Here, the values that are stored in the **Elem** objects are of type **int** (a primitive type).

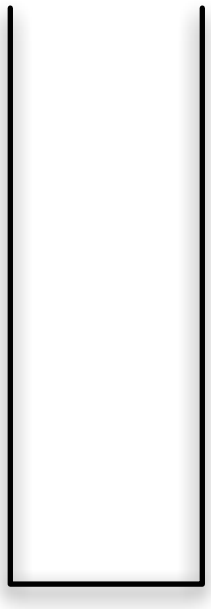
```
public class Time {
    private static class Elem {
        private int value;
        private Elem next;
        private Elem( int value, Elem next ) {
            this.value = value;
            this.next = next;
        }
    }
    private Elem first;

    public Time( int hours, int minutes, int seconds ) {









    }
```

```
    public int getHours() {









    }

    public int getMinutes() {









    }

    public int getSeconds() {









    }
} // End of Time ;-)
```

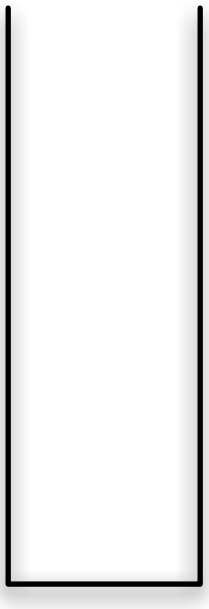
Question 5: (22 marks)

A. Use the stack-based algorithm seen in class to evaluate the following postfix (RPN) expression and show the content of the stack immediately before and after processing each operator. The notation $-_x$ is used to denote the first, second and third subtraction of the expression. (8 marks)

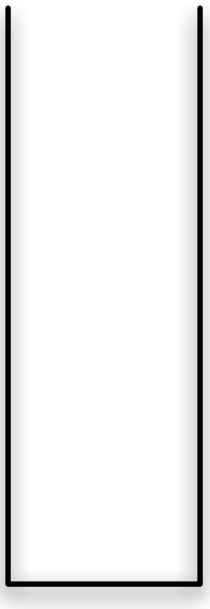
$$8 \quad 2 \quad -_a \quad 10 \quad 8 \quad 1 \quad -_b \quad -_c \quad /$$



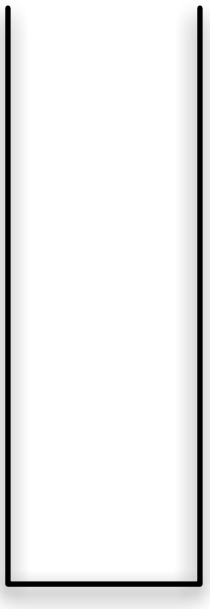
Before $-_a$



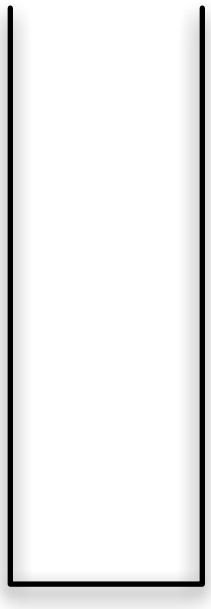
After $-_a$



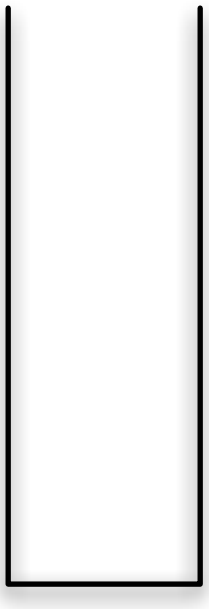
Before $-_b$



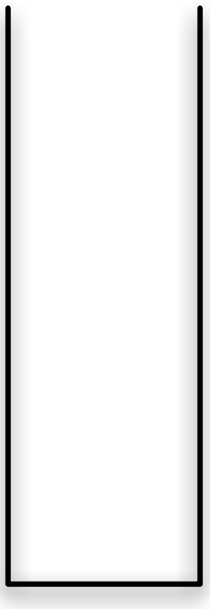
After $-_b$



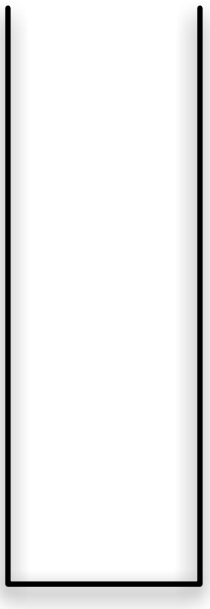
Before $-_c$



After $-_c$



Before /



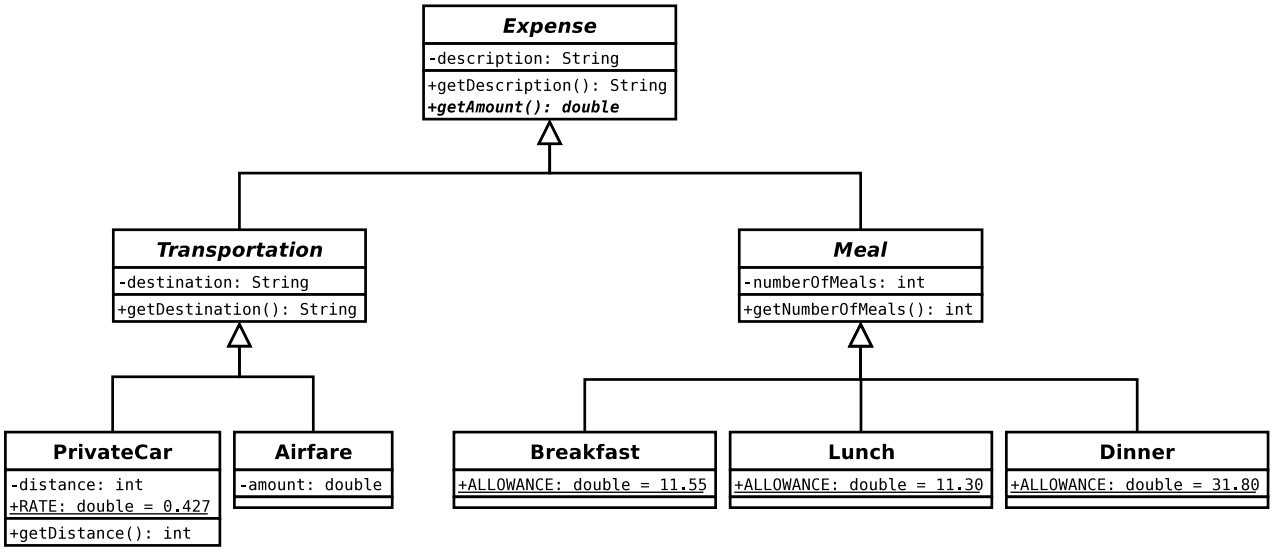
After /

B. Write the following infix expression in postfix (RPN) notation. (4 marks)

$$15 - 3 * 5 + 8/2$$

Solution:

C. The following class hierarchy is part of a software system for tracking professional expenses.



Specification:

- All expenses have a description (a character string);
- **Transportation** and **Meal** are sub-classes of **Expense**;
- **Expense**, **Transportation** and **Meal** are abstract classes;
- **PrivateCar** and **Airfare** are sub-classes of the class **Transportation**; **Breakfast**, **Lunch** and **Dinner** are sub-classes of the class **Meal**;
- All the transportation expenses have a destination (a character string);
- The class **Transportation** implements the interface **Taxable** (not shown in the above diagram);
- The interface **Taxable** declares the method **double getTax()**;
- A transportation expense using a private car has a distance (of type int);
- A transportation expense by air has a fixed amount (of type double) specified when a new transportation expense is created;
- All the meal expenses have an attribute which represents the number of meals;
- All the expenses have a method to calculate the amount represented by this expense:
  - The amount for a transportation expense using a private car is a fixed rate times the distance traveled;
  - The amount for a transportation expense by air is a fixed amount (specified when a new transportation expense is created);
  - The amount for a meal expense is the number of meals times a fixed rate. The rate depends on the kind of meal: Breakfast, Lunch or Dinner;

Which statements are valid? (10 marks)

(a) `Transportation t = new Transportation( "ISMB 2007", "San Fransisco" );`

(b) `Expense e = new Transportation( "ISMB 2007", "San Fransisco" );`

(c) `Taxable t = new Transportation( "ISMB 2007", "San Fransisco" );`

(d)
```
Expense e = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );
double a = e.getAmount();
```

(e) `Taxable t = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );`

(f)
```
Taxable t = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );
double x = t.getTax();
```

(g)
```
Expense e = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );
double x = e.getTax();
```

(h) **Taxable t = new Taxable(); double x = t.getTax();**

(i)
```
Expense e = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );
String s = e.getDestination();
```

(j)
```
Expense t = new Airfare( "ISMB 2007", "San Fransisco", 789.0 );
double x = t.getAmount();
```

A Natural

```
/* The Natural class wraps a value of the primitive type int in an
 * object. Furthermore, the value is greater than or equals to
 * zero. An object of type Natural contains a single field whose type
 * is int.
 */

public class Natural {

    private int value; // instance variable

    /* Constructs a newly allocated Natural object that represents
     * the specified int value. Throws IllegalArgumentException if the
     * specified value is negative.
     */

    public Natural( int value ) {
        if ( value < 0 ) {
            throw new IllegalArgumentException( "less than zero" );
        }
        this.value = value;
    }

    /* Returns the value of this Natural as an int.
     */

    public int getValue() {
        return value;
    }

    /* Returns a String representation of this Natural.
     */

    public String toString() {
        return Integer.toString( value );
    }
}
```