University of Western Ontario
Department of Computer Science
Computer Science 1027b Final Exam
3 hours, April 11th, 2014

PRINT YOUR NAME:

PRINT YOUR SECTION NUMBER:

PRINT YOUR STUDENT NUMBER:

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Instructions

- Fill in your name and student number above immediately.
- You have **3 hours** to complete the exam.
- For multiple choice questions, circle your answers on this exam paper.
- For other questions, write your answers in the spaces provided in this exam paper.
- The marks for each individual question are given.
- Several interfaces are at the back of the exam.
- There are also pages for rough work at the back of the exam. You may detach them if you wish, but hand them in with the rest of the exam paper.
- Calculators are not allowed!

Mark summary

1	2	3	4	5	6	7	8	9	10	total
/20	/10	/10	/15	/15	/25	/20	/10	/15	/30	/155

Problem 1: true/false (20 marks)

Choose **one** answer for each question.

1. (1 mark) Given the preorder and the inorder traversals of a tree it is possible to reconstruct the tree.
   (a) [✓ true]
   (b) false

2. (1 mark) Given the preorder and the postorder traversals of a tree it is possible to reconstruct the tree.
   (a) [✓ true]
   (b) false

3. (1 mark) Given the inorder and the postorder traversals of a tree it is possible to reconstruct the tree.
   (a) true
   (b) [✓ false]

4. (1 mark) Heap sort is O(n^2) is the worst case but O(n) is the best case.
   (a) true
   (b) [✓ false]

5. (1 mark) Bubble sort is O(n^2) is the worst case but O(n) is the best case.
   (a) [✓ true]
   (b) false

6. (1 mark) Search in a balanced binary tree is $O(\log_2 n)$ in the worst case.
   (a) [✓ true]
   (b) false

7. (1 mark) Search in a unbalanced binary tree is $O(n^2)$ in the worst case.
   (a) true
   (b) [✓ false]

8. (1 mark) Two or more methods with same name can be differentiated on the basis of their parameters data type and number of parameters. This is called **overriding**.
   (a) true
   (b) [✓ false]

9. (1 mark) A method in a subclass can have the same number and type of parameters as a method of the same name in a superclass?
   (a) [✓ true]
   (b) false

10. (1 mark) The **charAt()** method can be used to obtain a substring at specified index in a string?
    (a) true
    (b) [✓ false]

11. (1 mark) The more comments in a program, the faster the program runs.
    - (a) true
    - (b) [✓ false]

12. (1 mark) Garbage collection in Java is, when all references to an object are gone, the memory used by the object is automatically reclaimed.
    - (a) [✓ true]
    - (b) false

13. (1 mark) The following statement `mystery.thing(blab)` in a Java program that compiles and executes means that `thing` is a private variable?
    - (a) true
    - (b) [✓ false]

14. (1 mark) The `iterator()` is used to obtain an iterator to the start of the collection.
    - (a) [✓ true]
    - (b) false

15. (1 mark) Whenever a subclass needs to refer to its immediate super class it uses the keyword `super`.
    - (a) [✓ true]
    - (b) false

16. (1 mark) The private variables of a class can only be accessed by methods in that class
    - (a) [✓ true]
    - (b) false

17. (1 mark) The protected variables in a class can only be access by methods in that class or any of its super class.
    - (a) true
    - (b) [✓ false]

18. (1 mark) Interfaces can be used to fully abstract a class from its implementation.
    - (a) [✓ true]
    - (b) false

19. (1 mark) An infinite loop occurs when a recursive method does not have a base case.
    - (a) [✓ true]
    - (b) false

20. (1 mark) Janitors working for Sun MicroSystems are required to throw away any Microsoft documentation on Java found in the employees' offices.
    - (a) true
    - (b) [✓ false]

Problem 2 (10 marks)

In each of the following situations, use big-O notation to express the amount of work being done in terms of n.

1. (2 marks) We execute the following code segment

   ```
   for (int i = 1; i < n/2; i+=2)
     for (int j = 1; j < n/3; j+=3)
       System.out.println(i+j);
   ```

   Answer: $O(n^2)$

2. (2 marks) We execute the following code segment

   ```
   for (int i = 1; i < n/2; i*=2)
     for (int j = 1; j < n/3; j*=2)
       System.out.println(i+j);
   ```

   Answer: $O((\log_2(n))^2)$

3. (2 marks) We insert an integer into a sorted list of integers using binary search.

   Answer: $O(n)$ - integers may need to be shifted, on average $n/2$ shifts.

4. (2 marks) We visit each internal node in a binary search tree using a **preOrder** method.

   Answer: $O(n)$ - we need to visit each mode once and determine if it is a leaf or internal node

5. (2 marks) We visit each leaf node in a binary search tree using a **postOrder** method.

   Answer: $O(n)$ - we need to visit each mode once and determine if it is a leaf or internal node

Problem 3 (10 marks)

In all following cases, write a code segment whose running time is as required. Use a `System.out.println(1)` statement or something like that as the statement to be executed the required number of times.

1. (2 marks) $O((log_2 n)^2)$ using 2 nested loops:

   One possible answer:

   ```
   for(int i=0;i<n;i=i*2)
   for(int j=0;j<n;j=j*2)
       System.out.println(1)
   ```

2. (2 marks) $O(2^n)$, using a recursive method and no loop:

   One possible answer:

   ```
   static void func(int n){
     if (n <= 0)
       System.out.println(1);
     else{
       System.out.println(n);
       func(n-1)+func(n-2);
     }
   }
   ```

3. (2 marks) $O(n^2)$, using five nested loops.

   One possible answer:

   ```
   for (int i = 0; i < n; i++)
     for (int j = 0; j < n; j++)
       for (int k=0; k <100000; k++)
          for (int l=0; l <100000; l++)
              for (int m=0; m <100000; m++)
                    System.out.println(1);
   ```

4. (2 marks) $O(n^5)$, using a single loop.

   One possible answer:

   ```
   for(int i = 0; i < Math.pow(n,5);i++)
      System.out.println(1);
   ```

5. (2 marks) $O(n)$, using only a recursive function.

   ```
   static void func(int n){
     if (n <= 0)
       System.out.println(1);
     else{
       System.out.println(n);
       func(n-1);
     }
   }
   ```

Problem 4 (15 marks)

This question is related to this year's assignment 4. We wish to write a method to determine if one region is completely inside another. By this, we mean the second region is completely enclosed by the first region's boundary. We can check this using the **adjacent** method on assignment 4 by doing the following for region **r** and **this** region:

1. check if **r** and **this** region are adjacent and, if true,
2. check if every additional region **ri** that is adjacent to **this** region is NOT adjacent to region **r**.

The adjacent method to be used here is the one on assignment 4. That is, `r1.adjacent(r2)` is true is regions `r1` and `r2` are adjacent to each other and false otherwise. Write a Boolean Java method **insideRegion(r)** that does this. That is, `ri.insideRegion(r,regionQueue)` returns true if `r` is inside region `ri` and false otherwise. `regionQueue` is a list of all the regions found to date.

```
public Boolean insideRegion(Region r,QueueADT<Region> regionQueue) {

if(this.adjacent(r)==false) return false;

for(int i=0;i<regionQueue.size();i++)
   {
   Region reg=regionQueue.dequeue();
   regionQueue.enqueue(reg);
   if(r!=reg && this.adjacent(reg) && r.adjacent(reg)) return false;
   }
return true;
}
```

Problem 5 (15 marks)

Consider the following Java program:

```
class Problem5_2014 {

public static class A extends B {
    public void method2() {
        System.out.print("a 2  ");
        method1();
    }
}

public static class B extends C {

    public String toString() {
        return("b");
    }

    public void method2() {
    System.out.print("b 2  ");
    super.method2();
    }
}

public static class C {
    public String toString() {
        return "c";
    }

    public void method1() {
        System.out.print("c 1  ");
    }

    public void method2() {
        System.out.print("c 2  ");
    }
}

public static class D extends B {
    public void method1() {
       System.out.print("d 1  ");
       method2();
   }
}
public static void main(String[] args) {

C[] elements = {new A(), new B(), new C(), new D()};

for (int i = 0; i < elements.length; i++) {
System.out.println(elements[i]);
elements[i].method1();
System.out.println();
elements[i].method2();
System.out.println();
System.out.println();
}
}

} // Problem5_2014
```

Hand trace this program (show what is printed) below:

```
b
c 1
a 2  c 1

b
c 1
b 2  c 2

c
c 1
c 2

b
d 1  b 2  c 2
b 2  c 2
```

Problem 6 (25 marks)

We consider the *selection* sorting algorithm for `int`'s. We want to write a recursive implementation of it, using only arrays.

(6 marks) Write a method `public static void swap(int[] data, int i1, int i2)` that exchanges the contents of `data[i1]` and `data[i2]`. For instance, if array `data` is initially $(12, 43, 56, 87)$, `i1` is 3 and `i2` is 0, `data` should be $(87, 43, 56, 12)$ after calling the method. You can assume that `i1` and `i2` are not out of bounds.

```
public static void swap(int[] data, int i1, int i2){
  int tmp = data[i1];
  data[i1] = data[i2];
  data[i2] = tmp;
}
```

(9 marks) Write a method `public static int indexMinimum(int[] data, int start)` which returns the index of the smallest element among `data[start]`, `data[start+1]`, … `data[data.length-1]`. For instance, if `data` is $(12, 0, 35, 20)$ and `start` is 2, the result should be 3. You can assume that `start` is greater than or equal to 0, and less than `data.length`.

```
public static int indexMinimum(int[] data, int start){
  int index = start;
  for (int i = start+1; i < data.length; i++)
    if (data[i] < data[index])
      index = i;
  return index;
}
```

(7 marks) Write a recursive method `public static void sortRec(int[] data, int start)` that sorts the portion of `data` between indices `start` and `data.length-1` (inclusive). If `start` $\geq$ `data.length`, don't do anything. Otherwise, find the index of the minimum element between indices `start` and `data.length-1`, exchange it with `data[start]` and do a recursive call on the portion of `data` starting at `start+1`. Note: this method returns nothing; it modifies the array `data`. Use `indexMinimum` in your solution.

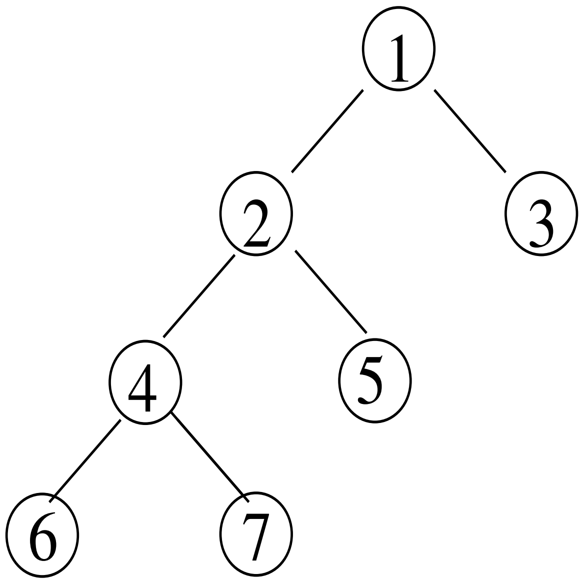
```
public static void sortRec(int[] data, int start){
  if (start >= data.length)
    return;
  int index = indexMinimum(data, start);
  swap(data, start, index);
  sortRec(data, start+1);
}
```

(3 marks) Write a method `public static void sort(int[] data)` that sorts the whole array, using `sortRec`.

```
public static void sort(int[] data){
  sortRec(data, 0);
}
```

Problem 7 (20 marks)

Consider the following binary tree:



(7a) (3%) Give the **inorder** traversal of this tree:

6472513

(7b) (3%) Give the **preorder** traversal of this tree:

1246753

(7c) (3%) Give the **postorder** traversal of this tree:

6745231

(7d) (3%) Give the **level order** traversal of this tree:

1234567

(7e) (8%) Consider the mystery traversal **6753**. Write a recursive method that produces this output

```
public static void mystery(BinaryTreeNode<Integer> node) {
  if (node == null)
    return;
  // a leaf node
  if (node.getLeft() == null && node.getRight() == null)
    System.out.print(node.getElement());
  else{
    mystery(node.getLeft());
    mystery(node.getRight());
  }
}
```

Problem 8 (10 marks)

Write a method `size` that gives the number of nodes in a `BinaryTreeNode` (you can only use the getters we give).

```
public static int size(BinaryTreeNode<Integer> node) {
  if (node == null)
    return 0;
  return 1 + size(node.getLeft()) + size(node.getRight());
}
```

Problem 9 (15 marks)

We say that a binary tree is *strict* if every node has either **0** or **2** children.

(3 marks) Is the tree of Problem 7 strict?

yes

(12 marks) Write a method `isStrict` that returns whether the input tree is strict (you can only use the getters we give).

```
public static boolean isStrict(BinaryTreeNode<Integer> node) {
  if (node == null)
    return true;
  if (node.getLeft() == null && node.getRight() != null)
    return false;
  if (node.getLeft() != null && node.getRight() == null)
    return false;
  return isStrict(node.getLeft()) && isStrict(node.getRight());
}
```

Problem 10 (15 + 15 marks)

Suppose we have a class `OrderedList` of `Integer`'s sorted in increasing order, with the following methods:

```
public class OrderedList{
  public OrderedList();
  public Integer getFirst();         // returns the first element, the list doesn't change
  public void removeFirst();         // removes the first element
  public void setFirst(Integer s);   // sets the first element, shifts all other elements
  public boolean isEmpty();
}
```

For instance, starting from the list $(2, 3, 7)$, `getFirst` would return 2, `removeFirst` would change the list to $(3, 7)$ and `setFirst(0)` would modify the list to make it $(0, 3, 7)$.

We want to insert an `Integer s` in an `OrderedList` called `list`, using *only* the methods above. We use the following algorithm. To insert `s` in `list`, we can suppose that `list` is not empty (if it is empty, just insert `s` in it). Then, we can extract the first element of `list`, call it `t`, and remove it from the list. If `s` ≤ `t`, set `t` as the first element of `list`, and then `s`. Otherwise, insert `s` in `list`, then set `t` as the first element.

(15 marks) Write a method `public static void insert(Integer s, OrderedList list)` that implements this algorithm. The algorithm must modify the input list. You can assume that `list` is not `null`.

```
  public static void insert(Integer s, OrderedList list){
    if (list.isEmpty()){
      list.setFirst(s);
      return;
    }

    Integer t = list.getFirst();
    list.removeFirst();

    if (s <= t){
      list.setFirst(t);
      list.setFirst(s);
    }
    else{
      insert(s, list);
      list.setFirst(t);
    }
  }
```

Bonus question (15 marks) We want to *merge* two `OrderedLists`, while maintaining the order. Suppose for instance that `list1` is $(0, 2, 3, 9)$ and `list2` is $(2, 4, 10)$; the output should be $(0, 2, 2, 3, 4, 9, 10)$. Write a recursive method for this. It may or may not modify the input lists.

```
public static OrderedList merge(OrderedList list1, OrderedList list2){
  if (list1.isEmpty())
    return list2;
  Integer t = list1.getFirst();
  list1.removeFirst();

  OrderedList list = merge(list1, list2);
  insert(t, list);
  return list;
}
```

Interfaces and classes

```
public interface StackADT<T>{
  // Adds one element to the top of this stack.
  public void push (T element);

  // Removes and returns the top element from this stack.
  public T pop();

  // Returns without removing the top element of this stack.
  public T peek();

  // Returns true if this stack contains no elements.
  public boolean isEmpty();

  // Returns the number of elements in this stack.
  public int size();

  // Returns a string representation of this stack.
  public String toString();
}

public interface QueueADT<T>{
   // Adds one element to the rear of this queue.
   public void enqueue (T element);

   // Removes and returns the element at the front of this queue.
   public T dequeue();

   // Returns without removing the element at the front of this queue.
   public T first();

   // Returns true if this queue contains no elements.
   public boolean isEmpty();

   // Returns the number of elements in this queue.
   public int size();

   // Returns a string representation of this queue
   Public String toString();
}
```

```
public interface ListADT<T> extends Iterable<T>{
  // Removes and returns the first element from this list.
  public T removeFirst();

  // Removes and returns the last element from this list.
  public T removeLast();

  // Removes and returns the specified element from this list.
  public T remove(T element);

  // Returns a reference to the first element in this list.
  public T first();

  // Returns a reference to the last element in this list.
  public T last();

  // Returns true if this list contains the specified target element.
  public boolean contains(T target);

  // Returns true if this list contains no elements.
  public boolean isEmpty();

  // Returns the number of elements in this list.
  public int size();

  // Returns an iterator for the elements in this list.
  public Iterator<T> iterator();

  // Returns a string representation of this list.
  public String toString();
}


public interface Iterator<T>{
  // Returns true if the iterator has more elements.
  boolean hasNext();

  // Returns the next element in the iterator.
  T next();
}


public class BinaryTreeNode<T>{
   protected T element;
   protected BinaryTreeNode<T> left, right;

   // the getters you will need
   public T getElement();
   public BinaryTreeNode<T> getLeft();
   public BinaryTreeNode<T> getRight();
}
```

Rough work 1/4

Rough work 2/4

Rough work 3/4

Rough work 4/4