Family Name:. . . . . **Other Names:** . . . .

Student ID:. . . . . **Signature**. . . . .

COMP 103 : Test 5

2021, Feb 5 ** WITH SOLUTIONS **

Instructions

- Time allowed: **50 minutes**
- Attempt **all** questions. There are 30 marks in total.
- Write your answers in this test paper and hand in all sheets.
- If you think some question is unclear, ask for clarification.
- Brief Java documentation is provided with the test
- This test contributes 10% of your final grade
- You may use dictionaries.
- You may write notes and working on this paper, but make sure your answers are clear.

Questions	**Marks**	
1. Graphs	[10]	
2. Binary Search	[10]	
2. Heaps	[10]	
	TOTAL:	

SPARE PAGE FOR EXTRA ANSWERS

Cross out rough working that you do not want marked.
Specify the question number for work that you do want marked.

Question 1. Traversing Graphs **[10 marks]**

You are writing a program to investigate interactions on a social media platform, such as Twitter. You are using a graph to keep track of the interactions between accounts.

Your program stores information about the accounts involved in a Set of TwitterAccount objects.

```
private List<TwitterAccount> allTwitterAccounts;  // all accounts being investigated
```

- Each TwitterAccount object contains a Set of other TwitterAccounts that it has interacted with.
- TwitterAccount is iterable, so you can iterate through all of an account's interactions with a for-each loop.
  - E.g. for(TwitterAccount interactions : account)
- You do not need to know about any of the other fields or methods in TwitterAccount.

(a) **[5 marks]** Complete the following countConnected method which is given a TwitterAccount and should count the total number of accounts that can be reached by following the graph of interactions.

The method should use the visited set to kep track of which accounts it has already processed.

```
public int countConnected(TwitterAccount account){
    Set<TwitterAccount> visited = new HashSet<TwitterAccount>();
    return countConnected(account, visited );
}

public int countConnected(TwitterAccount account, Set<TwitterAccount> visited){

    if(account == null || visited .contains(account)) return 0;

    visited .add(account);
    int count = 1;

    for(TwitterAccount ta : account) {
        count += countConnected(ta, visited);
    }

    return count;

}
```

(Question 1 continued on next page)

(Question 1 continued)

(b) **[2 marks]** Describe, in your own words, what it means for a graph to be disconnected.

If a graph is disconnected, there are parts of the graph that are unreachable from a given node. There are multiple components / subgraphs / etc.

(c) **[3 marks]** Complete the following isConnected(...) that checks to see if the graph of interactions is connected.

You may need to use the method you wrote above.

```
public boolean isConnected(TwitterAccount start){

    return countConnected(start) == allTwitterAccounts.size();

}
```

Question 2. Binary Search **[10 marks]**

This question concerns the binary search algorithm presented below.

```
public int indexOf ( String value , List < String > data ) {
    int low = 0;
    int hight = data . size () ;
    while ( low < high ) {
        int mid = ( low + high ) / 2;
        int comp = value . compareTo ( data . get ( mid ));

        // Found the item -- return the index
        if ( comp ==0) return mid ;

        if ( comp < 0) {
            // Check lower half
            high = mid ;
        } else {
            // Check upper half
            low = mid + 1;
        }
        return -1;
    }
}
```

(a) **[2 marks]** True or False: Binary Search works on both sorted and unsorted lists.

False: the list needs to be sorted.

(b) **[3 marks]** Explain why the binary search algorithm has a cost of **O(log n)**.

Each iteration cuts the search range in half, so the number of times the loop is executed is $\log_2(n)$
The rest of the algorithm is just O(1) operations.
Thus the total cost is O(log n)

(Question 2 continued on next page)

(Question 2 continued)

(c) **[5 marks]** Rewrite the method on the previous page so that instead of returning -1 if it can't find an item, it instead returns the index that item *would* exist at if it were in the list.

For example, if given the list below, findIndex("E", list) should return 4 (where "E" should be inserted), rather than -1.

"A"	"B"	"C"	"D"	"F"	"G"	"H"	"I"	"J"
0	1	2	3	4	5	6	7	8

```
public int findIndex(String value, List<String> data) {
    int low = 0;
    int high = data.size();
    while (low < high) {
        int mid = (low + high) / 2;
        if (value.compareTo(data.get(mid) > 0)
            low = mid + 1;
        else
            high = mid;
    }
    return low;
}
```

Question 3. Heaps **[10 marks]**

(a) **[2 marks]** What is the defining property of a partially ordered tree?

The children of a node must be less-than-or-equal-to the parent node.
OR: The parent node must be greater-than-or-equal-to both of its children.
OR (1 mark if the only property:) The root node is always the largest value

(b) **[2 marks]** A heap is a partially ordered tree stored in an array. If a node is stored at index 3, what are the indices of its left and right children (if they exist)?

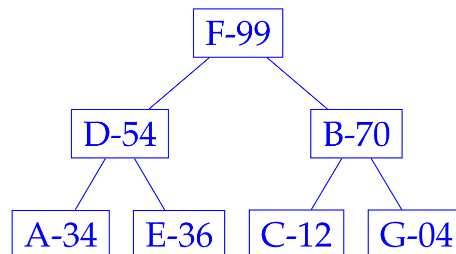
left $= 2n + 1 = 7$
right $= 2n + 2 = 8$.

(c) **[6 marks]** Suppose the values below were added, in the order shown, to a heap that is initially empty.

A-34, B-70, C-12, D-54, E-36, F-99, G-04

Draw the partially ordered tree that represents the heap after each value is added.

- The value of the item is represented by the number, so A has a value of 34, for example.
- The heap should be a **max** heap, so F-99 should end up as the root of the tree.



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Student ID: ....

SPARE PAGE FOR EXTRA ANSWERS

Cross out rough working that you do not want marked.
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Documentation

Brief, simplified specifications of some relevant Java collection types and classes.

Note: E stands for the type of the item in the collection.

```
interface Collection<E>
    public boolean isEmpty()                          // cost: O(1) for all standard collection classes
    public int size()                                 // cost: O(1) for all standard collection classes
    public void clear()
    public boolean add(E item)
    public boolean contains(Object item)
    public boolean remove(Object element)

interface List<E> extends Collection<E>
    // Implementations: ArrayList
    public boolean isEmpty()
    public int size()
    public void clear()
    public E get(int index)                           // cost: O(1)
    public E set(int index, E element)                // cost: O(1)
    public boolean contains(Object item)              // cost: O(n)
    public void add(int index, E element)             // cost: O(n) (unless index is close to the end.)
    public E remove(int index)                        // cost: O(n) (unless index is close to the end.)
    public boolean remove(Object element)             // cost: O(n)

interface Set extends Collection<E>
    // Implementations: HashSet, TreeSet
    public boolean isEmpty()
    public int size()
    public void clear()
    public boolean add(E item)                        // cost: O(1) for HashSet, O(log(n)) for TreeSet
    public boolean contains(Object item)              // cost: O(1) for HashSet, O(log(n)) for TreeSet
    public boolean remove(Object element)             // cost: O(1) for HashSet, O(log(n)) for TreeSet

interface Map<K, V>
    // Implementations: HashMap, TreeMap
    public V get(K key)                   // cost: O(1) for HashMap, O(log(n)) for TreeMap
    public V put(K key, V value)          // cost: O(1) for HashMap, O(log(n)) for TreeMap
    public V remove(K key)                // cost: O(1) for HashMap, O(log(n)) for TreeMap
    public boolean containsKey(K key)     // cost: O(1) for HashMap, O(log(n)) for TreeMap
    public Set<K> keySet()                // cost: O(1)
    public Collection<V> values()         // cost: O(1)
    // (get returns null if the key is not present)
    // (get put and remove return the old value, if any)
```

```
interface Queue<E> extends Collection<E>
    // Implementations: ArrayDeque, LinkedList, PriorityQueue
    public boolean isEmpty()
    public int size()
    public void clear()
    public E peek()                    // cost: O(1) for ArrayDeque, LinkedList,   O(1) for PriorityQueue
    public E poll()                    // cost: O(1) for ArrayDeque, LinkedList,   O(log(n)) for PriorityQueue
    public boolean offer(E element)    // cost: O(1) for ArrayDeque, LinkedList,   O(log(n)) for PriorityQueue
    // (peek and poll return null if the queue is empty)

class Stack<E> implements Collection<E>
    public boolean isEmpty()
    public int size()
    pubic void clear()
    public E peek()                    // cost: O(1)
    public E pop()                     // cost: O(1)
    public E push(E element)           // cost: O(1)
    // (peek and pop return null if the queue is empty)


class Collections
    public void sort(List<E> list);                           // cost = O(n log(n)), but O(n) if almost sorted
    public void sort(List<E> list, (E e1, E e2)->{...});      // cost = O(n log(n)), but O(n) if almost sorted
    public void swap(List<E> list, int i, int j);             // cost = O(1)
    public void reverse(List<E> list);                        // cost = O(n)
    public void shuffle(List<E> list);                        // cost = O(n)


interface Comparable<E> // All Comparable objects have a compareTo method:
    public int compareTo(E other);
            // returns
            //    -ve if this comes before other;
            //    +ve if this comes after other,
            //      0 if this and other are the same
```