# Midterm 1: Compsci 201

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October 2, 2013

Print your name and NetID legibly in ALL CAPITAL letters. Make sure that we can clearly determine L vs. 1 and S vs. 5. It will effect your grade if you do not follow these instructions or we cannot read your name or netID.

Name: _____

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Honor code acknowledgment (signature) _____

This test has 15 pages (with a help page and APT at the end), be sure your test has them all. Do NOT spend too much time on one question — remember that this class lasts 75 minutes.

In writing code you do not need to worry about specifying the proper `import statements`. Don't worry about getting function or method names exactly right. Assume that all libraries and packages are imported in any code you write.

| | value | grade |
|---|---|---|
| Problem 1 | 18 pts. | |
| Problem 2 | 12 pts. | |
| Problem 3 | 8 pts. | |
| Problem 4 | 14 pts. | |
| Problem 5 | 8 pts. | |
| Problem 6 | 20 pts. | |
| TOTAL: | 80 pts. | |

**PROBLEM 1 : (*The sorting hat: 18 points*)**

You are to implement a class `Student` to satisfy several criteria. You'll implement a constructor, you'll override `.equals` and `.hashCode`, and you'll implement `compareTo` since `Student` implements the `Comparable` interface.

Each `Student` object stores a student's name (String), a student's courage (int), and a student's determination (int). A code example of how `Student` objects are used is shown below. For those of you who have read or seen any *Harry Potter* books or movies you can think of the `Student` class as facilitating sorting as done by the Sorting Hat to determine which student wizards are placed in Gryffindor house. But knowledge of Harry Potter isn't necessary to understand this question.

- Two `Student` objects are equal if they have the same name, the same courage value, and the same determination value.
- You should be sure your `.hashCode` method is implemented according to best principles of correctness and performance.
- When sorting, courage values are most important, high courage values come first when `Student` objects are sorted. When courage values are equal, higher determination values come first, and if both courage and determination values are equal, `Student` objects should be sorted in alphabetical order.
- Assume that `Student.toString` has been implemented, you don't need to implement it.

The coding example below shows how `Student` objects should work when constructing and sorting `Student` objects. In the function `sortStudents` parameter `name` is an array of student names, parameter `courage` is an array of student courage values (0 is none, 10 is extremely high), and parameter `determine` is an array of student determination, again on a scale of 0-10. The name at `name[i]` has a courage value given by `courage[i]` and a determination given by `determine[i]`.

**Example:**

Input:

`name` = `["Potter, Harry", "Granger, Hermione", "Malfoy, Draco", "Lovegood, Luna"]`

`courage` = `[10, 10, 4, 7]`

`determine` = `[10, 10, 9, 8]`

Output:

`"Granger, Hermione", "Potter, Harry", "Lovegood, Luna", "Malfoy, Draco"`

**Code: sortStudents**

```
public void sortStudents(String[] name, int[] courage[], int[] determine){
    ArrayList<Student> list = new ArrayList<Student>();
    for(int i = 0; i < name.length; i++)
        list.add(new Student(name[i], courage[i], determine[i]));
    Collections.sort(list);
    for(Student s: list)
        System.out.println(s.toString());
}
```

*Question continues on the next page.*

**Instance variables and constructor: 6 points** Complete the implementation of class `Student` by adding instance variables and completing the constructor so that the class `Student` will work with the code given above.

```
public class Student implements Comparable<Student>{
    // add your instance variable(s) here

    String myName;
    int myCourage;
    int myDetermine;









    // complete the constructor definition and don't forget to define parameters
    public Student( String name, int courage, int determine){
        myName = name;
        myCourage = courage;
        myDetermine = determine;
    }
```

**Equals and hash code: 6 points**

Complete the hashCode and equals methods below.

```
    public int hashCode(){

    return myName.hashCode() + 17*myCourage + 13*myDetermine;


    }
```

*Question continues on the next page.*

```
public boolean equals(Object obj){
    if (obj == this) {
        return true;
    }
    if (obj == null || obj.getClass() != this.getClass()) {
        return false;
    }

    Student temp = (Student) obj;

    if(this.myName.equals(temp.myName)
            && this.myCourage == temp.myCourage
            && this.myDetermine == temp.myDetermine)
        return true;

    return false;

}
```

**compareTo: 6 points**

Complete the compareTo method below.

```
public int compareTo(Student arg0) {

    int courage = this.myCourage - arg0.myCourage;

    if(courage == 0){
        int determine = this.myDetermine = arg0.myDetermine;
        if(determine == 0)
            return this.myName.compareTo(arg0.myName);
        else
            return determine;
    }
    else
        return courage;
}
```

**PROBLEM 2 : (*Big-Oh: 12 points*)**

For each of the following, give the running time in terms of the parameter `n` in big-Oh notation. You must justify your answer. (2 points for each running time, and 1 point for each justification)

```
public int numberOne(int n){
    int answer = 1;
    for(int i = 0; i < n*n; i+=2)
        for(int j = 0; j < 2*n; j++)
            answer++;
    return answer;
}
```

Big-Oh: $O(N^3)$ Justification: Outer loop is $N^2$, inner loop is $2N$. $N^2 \times 2N = 2N^3 = O(N^3)$

---

```
public int numberTwo(int n){
    int answer = 1;
    for(int i = 0; i < n; i++)
        answer++;
    for(int i = 0; i < 10000; i++)
        for(int j = 0; j < 10000; j++)
            answer++;
    return answer;
}
```

Big-Oh: O(N) Justification: First loop is N, nested-for-loop is constant.

---

```
public int numberThree(int n){
    int answer = 1;
    for(int i = 1; i <= n; i=i*2)
        answer++;
    return answer;
}
```

Big-Oh: $O(logN)$ Justification:$log_2(N) = x$ where $2^x = N$ The loop will run $log_2(N)$ times.

---

```
public int numberFour(int n){
    int answer = 1;
    for(int i = 1; i <= n; i++)
        for(int j = 0; j < i; j++)
            answer++;
    return answer;
}
```

Big-Oh: $O(N^2)$ Justification: $\sum_{i=1}^{N} i = 1 + 2 + 3 + ...N = \frac{N^2+N}{2} = O(N^2)$

**PROBLEM 3 : (*BB-Queue: 8 points*)**

Your friend Sammy really wants to understand queues and has decided to implement a queue from scratch rather than rely on the Java implementation provided in the `java.util` package.

Explain to Sammy how a queue works (**2 points**)

A queue is a list of data items that work like a line, the first one in is the first one out. FIFO.

Sammy has decided to use an `ArrayList` for the queue implementation. Explain why using an `ArrayList` may not be the best idea. Make sure to talk about efficiency. (**3 points**)

For a queue you will be adding elements to the end of the Arraylist O(1), but removing from the front of the ArrayList O(N). Since the remove is expensive it is better to not use an ArrayList.

Give Sammy some advice as to what data structure would be better for implementing a queue. Explain why and make sure to talk about efficiency. (**3 points**)

A LinkedList would be a better data structure. Adding at the end (assuming a back pointer) costs O(1) and removing from the beginning is O(1). This is much more efficient than an ArrayList.

**PROBLEM 4 : (*Corned Hash: 14 points*)**

Sammy wants to write a class, Person, with instance variables `String myName` and `int myAge`, the person's name and age respectively. Sammy has written the following code to override `.hashCode` and `.equals`.

```
public boolean equals(Object obj){
    if (obj == this) {
        return true;
    }
    if (obj == null || obj.getClass() != this.getClass()) {
        return false;
    }
    Person temp = (Person) obj;
    return myName.equals(temp.myName) && myAge == temp.myAge;
}

public int hashCode(){
    return myAge;
}
```

You want to convince Sammy that this may not be the best code. You come up with an example where $n$ Persons, each with different names, but with all with the same age are added to a hash table.

Based on the `.equals` and `.hashCode` methods above, what is the running time to determine if the hash table that stores $n$ objects `contains` a *Person* object? (**3 points**)

Running time: O(N) Explain your answer.

All Person objects with the same age are based to the same location. To search through the names will be linear time.

Based on the hashCode method above, what is the running time to `add` $n$ Persons with different names but the same age to an initially empty hash table? (**3 points**)

Running time: $O(N^2)$ Explain your answer.

Each add will cost the length of the list. Repeat this N times.

$\sum_{i=1}^{N} i = 1 + 2 + 3 + ...N = \frac{N^2+N}{2} = O(N^2)$

Improve Sammy's hashCode method by rewriting the code here. (**2 points**).

```
public int hashCode(){
    return myName.hashCode() + myAge;
}
```

Based on your hashCode method, what is the running time to determine if the hash table that stores $n$ objects `contains` a *Person*? object (**3 points**)

Running time: O(1) Explain your answer.

People with different names and ages will be given different hashCodes and should has to different locations in the table. This should prevent collisions and make the runtime constant.

Based on your hashCode method above, what is the running time to `add` $n$ Persons with different names but the same ages to your hash table? (**3 points**)

Running time: O(N) Explain your answer.

Each add should be constant. Repeat this N times.

**PROBLEM 5 : (*Anonymous: 8 points*)**

An almost complete solution to the Anonymous APT is below. Complete the method `makeMap` so that the APT tester returns all green! You can find the Anonymous APT writeup at the end of the exam. **Do not modify** any code in `howMany`.

```
public class Anonymous {
    public int howMany(String[] headlines, String[] messages) {
        int count = 0;
        HashMap<Character, Integer> headmap = new HashMap<Character, Integer>();

        for(String s: headlines){
            makeMap(headmap, s);
        }

        for(String s: messages){
            HashMap<Character, Integer> m = new HashMap<Character, Integer>();
            makeMap(m, s);
            boolean works = true;
            for(Character c: m.keySet()){

                if(headmap.containsKey(c)){
                    if(m.get(c) > headmap.get(c)){
                        works = false;  break;
                    }
                }
                else{
                    works = false;  break;
                }
            }
            if(works)
                count++;
        }
        return count;
    }

    public void makeMap(HashMap<Character, Integer> map, String s){

        s = s.toLowerCase();
        for(int i = 0; i < s.length(); i++){
            char c = s.charAt(i);
            if(c != ' '){
                if(map.containsKey(c))
                    map.put(c, map.get(c)+1);
                else
                    map.put(c, 1);
            }

    }
}
```

**PROBLEM 6 : (*Linked lists: 20 points*)**

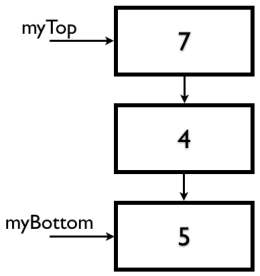
Complete the code below to implement a Stack using linked lists. Your stack will use the `Node` class below.

```
public class Node{
    public Node myNext;
    public int myData;

    public Node(int data, Node next){
        myNext = next;
        myData = data;
    }
}
```

**Part A: 4 points**

The stack below stores the values (5, 4, 7) where 5 was added first to the stack, then 4, and then 7. The node `myTop` points to the top of the stack where elements are pushed (added) and popped (removed), and `myBottom` points to the bottom of the stack.




Draw the stack that results after a `pop` (remove) is called from the stack diagrammed above. Be sure to include labels for both `myBottom` and `myTop`

Based on your previous drawing, draw the resulting stack after `push(2)` (add a node with the value 2) is called. Make sure to diagram all relevant pointers.

**Part B: 6 points**

Below is a partially completed integer stack with both top and bottom pointers, `myTop` and `myBottom`. The number of elements in the stack is held in `mySize`. This code uses the Node class on the previous page.

```
public class IntStack {
    public Node myTop;
    public Node myBottom;
    public int mySize;


    public IntStack() {
        myTop = null;
        myBottom = null;
        mySize = 0;
    }
    public boolean isEmpty() {
        return mySize == 0;
    }
```

**Complete** `pop`**.**

```
   // Pop a node from the stack. Code has been added for you to throw
   // an exception if the stack is empty.

    public int pop(){

        if (isEmpty()) throw new java.util.NoSuchElementException();

        // add code here
        int data = myTop.myData;
        myFront = myTop.myNext;
        mySize--;
        return data;
    }
```

**Part C: 4 points**

Complete `push` which pushes a node onto a stack

```
        // push a node onto the stack
        public void push(int data){

        Node newTop = new Node(data, myTop);
        myTop = newTop;
        mySize++;


    }
```

**Part D: 6 points**

It is possible to implement a queue using two stacks (and no other containers – no ArrayLists, no arrays). Making calls to `push`, `pop` and `isEmpty`, from above, complete the method `dequeue`, that removes an element from a queue and returns the value. The method `enqueue` has been completed for you.

```
public class TwoStackQueue extends IntStack{
    private IntStack stackA;
    private IntStack stackB;

    public void enqueue(int i){
        stackA.push(i);
    }

    // removes the first item in the queue and returns its value.
    // note that if queue is empty an exception is thrown
    public int dequeue(){

        if (stackA.empty()) throw new java.util.NoSuchElementException();

        while(stackA.mySize > 0){
            stackB.push(stackA.pop());
        }
        if(stackB.mySize > 0)
            return stackB.pop();

        while(stackB.mySize() > 0)
            stackA.push(stackB.pop();


    }
}
```

# APT: Anonymous

## Problem Statement

**Class**

```
public class Anonymous {
   public int howMany(String[] headlines, String[] messages) {
         // fill in code here
   }
}
```

If you want to write a message anonymously, one way to do it is to cut out letters from headlines in a newspaper and paste them onto a blank piece of paper to form the message you want to write. Given several headlines that you have cut out, determine how many messages from a list you can write using the letters from the headlines. You should only consider each message by itself and not in conjunction with the others, see example 2.

Write the method `howMany` which takes as parameters a `String[] headlines` containing the headlines which you have cut out as well as a `String[] messages` with the messages you may want to write, and returns an int which is the total number of messages you can write.

## Constraints

- All letters that you cut out can be used both as upper or lower case in a message.
- Spaces should be ignored in elements in both headlines and messages.
- `headlines` will contain between 1 and 50 elements, inclusive.
- `messages` will contain between 1 and 50 elements, inclusive.
- The length of each element in `headlines` will be between 1 and 50 characters, inclusive.
- The length of each element in `messages` will be between 1 and 50 characters, inclusive.
- Each element in `headlines` will only contain the letters 'A'-'Z', 'a'-'z' and space.
- Each element in `messages` will only contain the letters 'A'-'Z', 'a'-'z' and space.

---

`String`

- `.length()` Get the length of the `String`. $O(1)$.
- `.charAt(i)` Get the `char` at index `i`. $O(1)$.
- `.split(" ")` Split a string by spaces and store it in a string[].
- `.substring(i, j)` Get the substring between indices `i` and `j`. Index `i` is *inclusive*, and index `j` is *exclusive*. $O(1)$. For example:

```
String x = "abcdefg";
String y = x.substring(2, 4);
// y now has the value "cd"
```

`ArrayList<T>  // Where T is a type, like String or Integer`

- `.add(i, X)` Add element `X` to the list at index `i`. If no `i` is provided, add an element to the end of the list. Adding to the end runs in $O(1)$.
- `.get(i)` Get the element at position `i`. Runs in $O(1)$.
- `.set(i, X)` Set the element at position `i` to the value `X`. $O(1)$.
- `.size()` Get the number of elements. $O(1)$.

`HashSet<T>  // Where T is a type, like String or Integer`

- `.size()` Compute the size. $O(1)$.
- `.add(X)` Add the value `X` to the set. If it's already in the set, do nothing. $O(1)$.
- `.contains(X)` Return a `boolean` indicating if `X` is in the set. $O(1)$.
- `.remove(X)` Remove `X` from the set. If `X` was not in the set, do nothing. $O(1)$.

`HashMap<K, V>  // Where K and V are the key and value types, respectively.`

- `.size()` Compute the size. $O(1)$.
- `.containsKey(X)` Determines if the map contains a value for the key `X`. To get that value, use `.get()`. $O(1)$.
- `.get(X)` Gets the value for the key `X`. If `X` is not in the map, return `null`. $O(1)$.
- `.put(k, v)` Map the key `k` to the value `v`. If there was already a value for `k`, replace it. $O(1)$.
- `.keySet()` Return a `Set` containing the keys in the map. Useful for iterating over. $O(1)$.

To iterate over a `HashSet<T>`, use

```
for (T v : nameOfSet) {
  // v is the current element of the set.
}
```

This can be combined with `HashMap`'s `.keySet()` to iterate over a `HashMap`.