**CIS 110 — Introduction to Computer Programming**
**Summer 2018 — Final**

Name: _____

Recitation # (e.g., 201): _____

Pennkey (e.g., paulmcb): _____

My signature below certifies that I have complied with the University of Pennsylvania's Code of Academic Integrity in completing this examination.

_____ _____

Signature Date

**Instructions:**

- **Do not open this exam until told by the proctor**. You will have exactly 120 minutes to finish it.
- **Make sure your phone is turned OFF (not to vibrate!) before the exam starts.**
- Food, gum, and drink are strictly forbidden.
- **You may not use your phone or open your bag for <u>any</u> reason**, including to retrieve or put away pens or pencils, until you have left the exam room.
- This exam is *closed-book, closed-notes, and closed-computational devices*.
- If you get stuck on a problem, it may be to your benefit to move on to another question and come back later.
- All code must be written out in proper java format, including all curly braces and semicolons.
- **<u>Do not separate the pages.</u>** You may tear off the one scratch page at the end of the exam. This scratch paper must be turned in or you lose 3 points.
- Turn in all scratch paper to your exam. Do not take any sheets of paper with you.
- If you require extra paper, please use the backs of the exam pages or the extra pages provided at the end of the exam. **Only answers on the FRONT of pages will be grading. The back is for scratch work only.**
- Use a pencil, or blue or black pen to complete the exam.
- If you have any questions, raise your hand and a proctor will come to answer them.
- When you turn in your exam, you may be required to show ID. **If you forgot to bring your ID, talk to an exam proctor <u>immediately</u>.**
- We wish you the best of luck.

**Scores:** [For instructor use only]

| | | |
|---|---|---|
| Question 0 | | 1 pt |
| Question 1 | | 11 pts |
| Question 2 | | 8 pts |
| Question 3 | | 16 pts |
| Question 4 | | 10 pts |
| Question 5 | | 11 pts |
| Question 6 | | 23 pts |
| **Total:** | | **80 pts** |

**0) (1 point)** The Easy One:

- Check that your exam has all 15 pages (excluding the cover sheet).
- Write your name, recitation number, and PennKey (username) on the front of the exam.
- Sign the certification that you comply with the Penn Academic Integrity Code.

## 1.) RECURSION (11 pts total)

### 1.1) Exponents

**(4 points)** Fill in the blank below for a recursive function that finds the value of x / y using integer division (i.e., dropping the remainder/decimal). You can assume x and y are POSTIVE (non-zero, non-negative) integers.

```
public static int division(int x, int y) {
    if (x < y) {
        return _______;
    }
    return ____________________________________________________;
}
```

### 1.2) Counting an Array

Consider the function `countArray(int[] array, int value, int start)` below that finds the number of times `value` appears in the array. This is done by finding, for each index `start` of the array, the number of times `value` appears between `start` and the end of the array.

Thus, countArray([4,2,1,2,2,0], 2, 0) would return 3 (There are 3 twos in the array starting from zero) while countArray([4,2,1,2,2,0], 2, 3) would be 2 (Since we only starting counting at index 3, so the first two is not counted).

This function is recursive in nature.

a) **(2 points)** Give an example **base case** input to the function (i.e., the values of array, value, and start) AND what it would return.

b) **(5 points)** Using the same recursive function above.

```
public static int countArray(int[] array, int count, int start){
    if (start < 0 || start > array.length) { //Error
        throw new RuntimeException("ERROR");

    if (start == _____________________________________) {

           return _____________________________________;

    } else {

           if (_____________________________________) {

                return 1 + _____________________________________________;
           } else {

                return _____________________________________________;
           }
    }
}
```

**2) RECURSION TRACING (8 points total)**

Below is a mystery recursion function. Do not try to work out WHAT it's doing, as the functionality is completely made up. It does nothing useful.

```
public static int mystery(int a, int b)
{
    if (a == 0 || b > 12) {
        System.out.println(a + "," + b);
        return 0;
    } else if (b % 2 == 0) {
        System.out.println(a + "," + b);
        return mystery(a - 1, b + 1) + 3;
    } else if (a % 2 == 0) {
        System.out.println(a + "," + b);
        return mystery(a - 1, b + 2) + 2;
    } else {
        System.out.println(a + "," + b);
        return mystery(a - 1, 2 * a) - 3;
    }
}
```

In the boxes below, write whatever prints when the function is called with the given arguments in order. At the bottom of each box, say what the function call ultimate returns.

a) mystery(3,3)

Returns:

b) mystery(4,2)

Returns:

**3) USING OBJECTS (16 points total)**

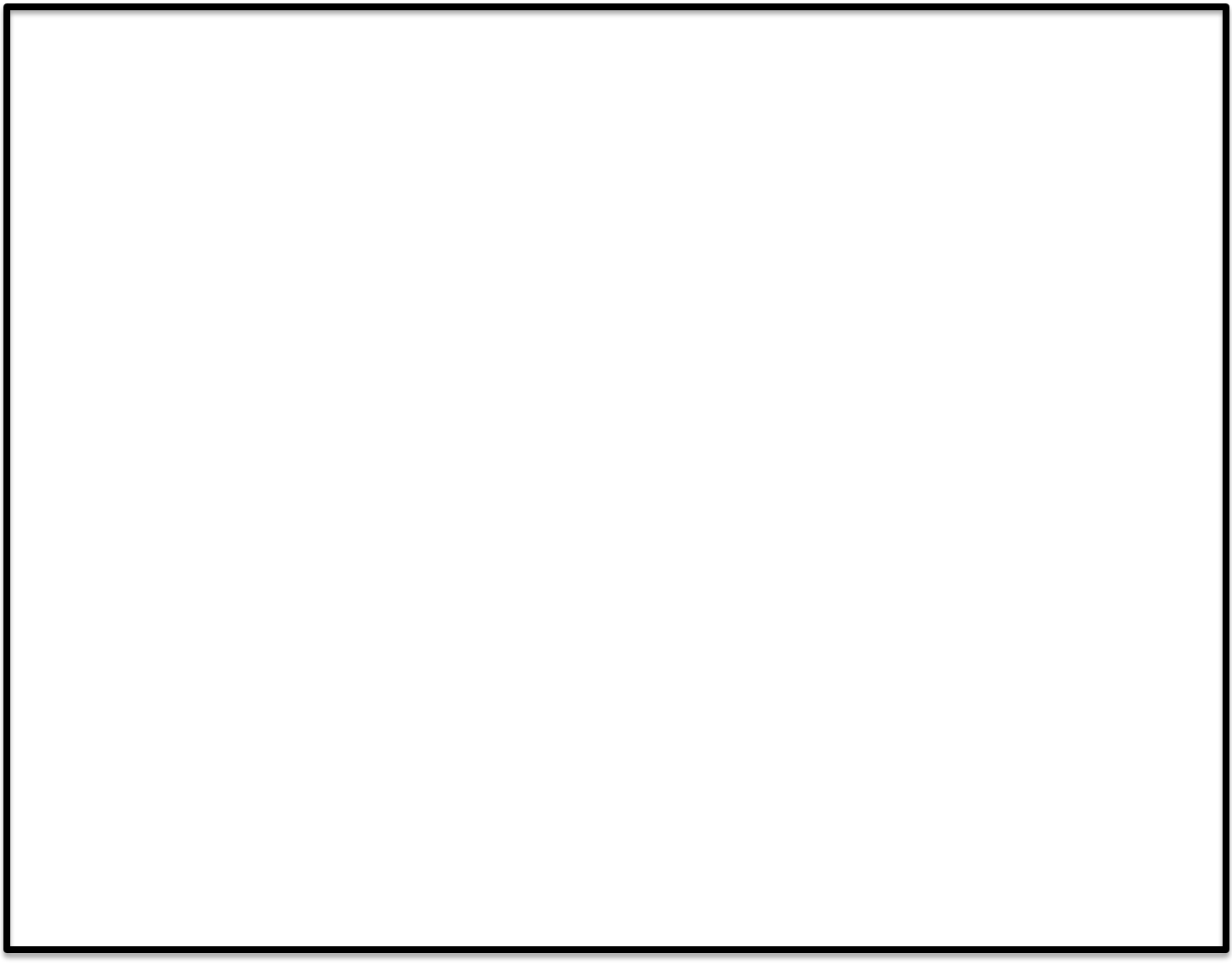
In this problem, you will be using the card class below. In Klondike Solitaire, as well as Freecell Solitaire, a player can move around the traditional French playing cards into columns. The rule is that each card can be placed under a card exactly **ONE RANK** higher, and of the opposite color (the colors are red and black). I.e., a **red 5** can be placed on a **black 6**, but it cannot be placed on a **red 6,** or any card of any other rank**.** This class is here to model this. Do not worry about specific suits (hearts, clubs, diamonds, spades), just worry about red/black.

```
public class Card {
    private char rank; //'A', or '2', or '3', etc.
    private boolean isRed; //true if card is red, false if it's black
    public final char[] ALL_RANKS =
             {'A','2','3','4','5','6','7','8','9','T','J','Q','K'};

    public Card(char rank, boolean isRed) {
        this.rank = rank;
        this.isRed = isRed;
    }

    public char getRank() {
        return rank;
    }

    public boolean isRed() {
        return isRed;
    }

    public int getRankIndex(char ch) {
        for (int i = 0; i < ALL_RANKS.length; i++) {
            if (ALL_RANKS[i] == ch) {
                return i;
            }
        }
        throw new RuntimeException("ERROR: Invalid rank");
    }
    /**
     * This method returns true if child can be placed on parent in
     * Klondike or Freecell Solitaire (i.e., true if parent is black 6 and
     * child is red 5
     */

    public boolean isValidParent(Card parent, Card child) {
        //TODO: SEE NEXT PAGE
    }
}
```

Write **one** (1) line of code to produce a red '5': **(2 points)**

To Complete the Method isValidParent, reorder all the lines of code below. Use **all** of the lines of code below **exactly once**. Do not use any line of code more than once, and **do not write any code not included below**. (You must rewrite the lines in their entiriety). **(8 points)**

```
}
}
}
}
}
}
} else {
childRank = i;
for (int i = 0; i < ALL_RANKS.length; i++) {
if (ALL_RANKS[i] == child.rank) {
if (ALL_RANKS[i] == parent.rank) {
if (childRank + 1 == parentRank) {
if (parent.isRed() == child.isRed()) {
int childRank = -1;
int parentRank = -1;
parentRank = i;
public boolean isValidParent(Card parent, Card child) {
return false;
return false;
return true;
```



In the space below, list the VARIABLE(S) (not methods) in Card that **should** be static. **(2 points)**

In the space below, list the METHOD(S) (not variables) in Card that **should** be static. **(2 points)**

Which attributes of a Card can you change **AFTER** calling the constructor from **outside** of the file? (*It's possible you can change **all** of them, **none** of them, or only certain ones.)* **(2 point)**

**4) Object Theory (10 points)**

1. How do you get a NullPointerException (you can either describe it or show a code example)? **(3 points)**

**2.** What function do you implement in order to make an object be printed as something other than "`ClassName@Address`" (write the entire method declaration, including visibility and return type) **(2 points)**

**3.** Give a reason you would want a private method in a class, or say why there no reason to ever make a method `private`. **(3 points)**

**4.** If a class is called `Exam` and you have exactly two instances (no more) of the class, `midterm` and `finalExam`, and there have a **`static`** `String` variable called `semester`, how should you change `semester` to "Summer 18" for both instances? **(2 points)**

**5) SORTING (11 points)**
Sort each array in **ascending** (smallest to largest) order using the specified technique. Show the state of the array after each iteration through the sorting loop, or after each merge.

a) Insertion sort – {8, 3, 4, 1, 5, 2, 5} **(4 points)**

b) Merge sort– {8, 3, 4, 1, 5, 2, 5} **(4 points)**

c) Which one of these sorts is recursive in nature? (don't say why, just name it) **(1 point)**

d) Which of the below is code for a **selection** sort? (circle the one that is a selection sort). Both pieces of code sort an `int[]` variable called **`array`**. Both use the swap function as covered in class (that swaps the location of two values in an array). Note that method declarations have been removed, and variable names obfuscated. **(1 point)**

```
for (int i = 1; i < array.lenth; i++) {
    for (int j = i; j > 0; j--) {
         if (array[j-1] > (array[j])) {
             swap(array, j - 1, j);
         }
    }
}
```

```
for(int i=0; i<array.length-1; i++){
    int a = array[i];
    int b = i;
    for(int j=i+1; j<array.length; j++){
        if(array[j] < a) {
            a = array[j];
            b = j;
        }
    }
    swap(array, i, b);
}
```

Below are two examples of a sorting algorithm on the same numbers. Which is a selection sort? **(1 point)**

```
8, 2, 6, 3, 6, 1
2, 6, 3, 6, 1, 8
2, 3, 6, 1, 6, 8
2, 3, 1, 6, 6, 8
2, 1, 3, 6, 6, 8
1, 2, 3, 6, 6, 8
```

```
8, 2, 6, 3, 6, 1
1, 2, 6, 3, 6, 8
1, 2, 6, 3, 6, 8
1, 2, 3, 6, 6, 8
1, 2, 3, 6, 6, 8
1, 2, 3, 6, 6, 8
```

**6) LINKED DATA STRUCTURES (23 points)**

Below is the class LinkedList which is a SINGLY Linked List. Fill in all the blanks below for the constructor and the methods `isEmpty` and `add`.

```
public class Node {
    public int value;
    public Node next;

    //Constructor that creates a node with the input value
    public Node(int value) {

        _____________________________________________________; //1 point
    }
}

public class LinkedList {
    public Node head; //first element of the list

    /**
     * returns true if the list is empty
     */
    public boolean isEmpty() {

        return _____________________________________________;//1 point
    }

    /**
     * Adds the integer x as a new node to the END of the List
     */
    public void add(int x) {

        Node newNode = _____________________________________;//1 point
        if (isEmpty()) {

            _____________________________________________;//1 point

        } else {

            Node t = _____________________________________; //1 point


             while (_____________________________________________) {//1 point


                 t = _____________________________________________;//1 point
            }

            t.next = newNode;
        }
    }
}
```

Write a function `addRecursive(int x)` that implements the same behavior as the existing add function, however does so recursively. You may need to write a helper function to do this.

Use comments to clearly identify your base case or base cases. There will be no partial credit for writing an iterative solution. If you use *either* `for` or `while` even once, you will get no credit. **(6 points)**

Using this implementation of LinkedList, write, on the next page, the function:

```
public boolean isSubList(LinkedList a, LinkedList b) {
```

This function returns true if **a** is a *sublist* of **b**. That is, if all of the elements a can be found inside of b and in the same order. For Example, if:

a = *5 → 3 → 1*

b = 7 → *5 → 3 → 1* → 2

Then a **is** a sublist of b (that is, your function should return true). However, if

a = 5 → 3 → 1

b = 7 → 5 → 3 → 2 → 1

A is **NOT** a sublist of b. This is because while every element of a is in B, they are not continuous. They are interrupted by the 2. Another example is:

a = 5 → 3 → 1

b = 7 → 1 → 3 → 5 → 2

This is another case where a is **NOT** a sublist of b, because the elements are not in the same order. Another case where a is **NOT** a sublist of b is when:

a = 7 → 5 → 3 → 1 → 2

b = 5 → 3 → 1

This is a case where a is **NOT** a sublist of b, but **b** is a sublist of A. Finally, if a and b are the *same* list, such as:

a = 5 → 3 → 1

b = 5 → 3 → 1

Then a **IS** a sublist of b (that is, return true). Be careful, however. For example, below, a **IS** a sublist of B. If you look, you can see why this case might be tricky.

a = *5 → 3 → 1*

b = 5 → 3 → 5 → *5 → 3 → 1* → 5

**DO NOT ATTEMPT TO USE RECURSION: IT WILL MAKE THIS A BILLION TIMES HARDER!!!!!!!! USE ITERATION!!!!!!!**

**10 points**

**EXTRA ANSWER SPACE: You may NOT rip this page off, but work written on the <u>FRONT</u> of this page may be graded.**

**SCRATCH PAPER: You may rip this page off, but must turn it in at the end of the exam.**
**If you take this page with you, you lose 3 points.**