Problem 1 – Arrays and Functions (25 points)

Suppose we have a 2D array which is used to record grocery item prices. Each row represents an item and each column represents a daily price. Notice that different rows may have different number of columns. Write a method to do statistics for these items. The method takes the aforementioned 2D array as input and returns another 2D array. Specifically, in the returned 2D array, each row represents the same item with the corresponding input 2D array and each row has exactly 3 columns where the first column is to store the average price, the second column is to store the maximum price and the last column is to store the minimum price. The method signature is given below:

```
public static double[][] stat(double[][] prices)
```

For example, if the method parameter is {{1,2,3}, {2,3}, {3,4,5,6}}, then the output would be a 3 by 3 2D array which has the following values:

```
2.0    3.0    1.0
2.5    3.0    2.0
4.5    6.0    3.0
```

Problem 2 – Recursion (25 points)

1. **(4 points)** Select the output of the `RecursionProblem1` program when executed.

```java
public class RecursionProblem1
{
    public static void recTest(int n)
    {
        if (n <= 0) return;
        recTest(n-4);
        recTest(n-2);
        StdOut.print(n + " ");
    }

    public static void main(String[] args)
    {
        recTest(6);
    }
}
```

a) 2 4
b) 2 2 4 8
c) 2 4 4 2
d) 2 2 4 6

2. **(9 points)** Given the RecursionProblem2 program below.

```java
public class RecursionProblem2
{
    public static int recCheck(int x)
    {
        if (x <= 0)
        {
            return 0;
        }
        else
        {
            StdOut.print(x + ":");
            return (recCheck(x/2));
        }
    }

    public static void main(String[] args)
    {
        StdOut.print(recCheck(1));
    }
}
```

a) **(2 points)** What is the base case for `recCheck`?

b) **(2 points)** What is the reduction/recursive step?

c) **(4 points)** What is the output of `recCheck(300)`?

d) **(1 point)** What is the output of `recCheck(1)`?

3. **(12 points)** Given the following `Rabithole` program.

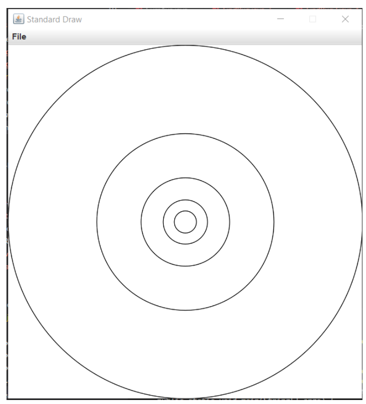
```
public class Rabbithole {

    // draw an order n Rabbithole, centered on (x, y)
    public static void draw(int n, double x, double y, double rad) {
        if (n == 0)
        {
            return;
        }
        else
        {
            // INSERT CODE HERE
        }
    }

    // reads an integer command-line argument n and creates concentric circles down.
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);

        double x = 0.5, y = 0.5;   // center of circle
        double size = 0.5;         // radius of circle
        draw(n, x, y, size);
    }
}
```

Insert code (where shown) to create a recursive program that draws smaller circles (circles with a radius half that of the circle outside of it) inside the larger ones. When the code is run for 5 levels ("`java Rabbithole 5`" at a command line) it looks like this:



Problem 3 – Object Oriented Programming (40 points)

A gardening supply center sells many varieties of plants and must keep an adequate amount of each variety available for customers to purchase. This problem involves writing methods in a `PurchaseOrder` class. A `PurchaseOrder` is an order that holds multiple `PlantOrders`.
Each `PlantOrder` has its own unique `orderID`. The IDs are assigned to each `PlantOrder` in the `PlantOrder` constructor. The first `orderID` assigned is 100. The second `orderID` assigned is 101, etc.

a. **(4 points) Refer to the `PlantOrder` class below.** Explain how you must modify the `PlantOrder` class so that when a `PlantOrder` is created, a unique `orderID` is assigned. This `orderID` is determined by incrementing the last assigned `orderID` by 1.

PurchaseOrder class

```java
import java.util.ArrayList;

public class PurchaseOrder{

    // The list of all plant orders
    private ArrayList<PlantOrder> masterOrder;

    //Constructs a new PuchaseOrder object.
    public PurchaseOrder() {
        //to be inoplemented in part b
    }

    // adds a new PlantOrder to the masterOrder
    public void addOrder(PlantOrder order) {
        masterOrder.add(order);
    }

    /* returns the sum of the number of plants of all of the plant orders
       on the master order
    */
    public int getTotalPlants() {
        //to be implemented in part c
    }

    /* returns total plants of specified variety in MasterOrder.
     */
    public int getPlants(String variety) {
        //to be implemented in part d
    }

    /** Removes all orders from the master order that have the same variety of
        plant as the parameter, variety, and returns the total number of plants
        that were removed.
    */
    public int removeVariety(String variety) {
        //to be implemented in part e
    }

    /*
      for appropriate printing of masterOrder contents
    */
    public String toString(){
        return masterOrder.toString();
    }
}
```

Consider the following statements in a client program.

```java
PurchaseOrder plantDepot = new PurchaseOrder();
plantDepot.addOrder(new PlantOrder("tulips",1000));
plantDepot.addOrder(new PlantOrder("roses",100));
plantDepot.addOrder(new PlantOrder("lilies",200));
plantDepot.addOrder(new PlantOrder("daisies",100));
plantDepot.addOrder(new PlantOrder("roses",50));
plantDepot.addOrder(new PlantOrder("daffodils",60));
```

The resulting `PurchaseOrder` would hold the `PlantOrder`s below:

plantDepot

100 **tulips** **1000**	**101** **roses** **100**	**102** **lilies** **200**	**103** **daisies** **100**	**104** **roses** **50**	**105** **daffodils** **60**

Consider further, the following statements in a client program:

```
System.out.println(plantDepot);
System.out.println("Total plants ordered = " + plantDepot.getTotalPlants());
System.out.println("Total roses ordered = " + plantDepot.getPlants("roses"));
System.out.println("Total mums ordered = " + plantDepot.getPlants("mums"));
System.out.println(plantDepot.removeVariety("roses") + " roses removed." ) ;
System.out.println(plantDepot);
```

The result of executing the above would print:

[100 tulips: 1000 ordered, 101 roses: 100 ordered, 102 lilies: 200 ordered, 103 daisies: 100 ordered, 104 roses: 50 ordered, 105 daffodils: 60 ordered]
Total plants ordered = 1510
Total roses ordered = 150
Total mums ordered = 0
150 roses removed.
[100 tulips: 1000 ordered, 102 lilies: 200 ordered, 103 daisies: 100 ordered, 105 daffodils: 60 ordered]

b. **(6 points)** Implement `PurchaseOrder()`

```
//Constructs a new PuchaseOrder object.
public PurchaseOrder() {
    //to be inoplemented in part b
}
```

c. **(8 points)** Implement `getTotalPlants()`

```
/* returns the sum of the number of plants of all of the plant orders
   on the master order
*/
public int getTotalPlants() {
    //to be implemented in part c
}
```

d. **(10 points)** Implement `getPlants()`

```
/* returns total plants of specified value in MasterOrder.
 */
public int getPlants(String variety) {
    //to be implemented in part d
}
```

e. **(12 points)** Implement `removeVariety()`

```
/** Removes all orders from the master order that have the same variety of
    plant as the parameter, variety, and returns the total number of plants
    that were removed.
*/
public int removeVariety(String variety) {
    //to be implemented in part e
}
```

Problem 4 – Searching and Sorting (20 points)

a) **(12 points)** Search for the character **F** using the **binary search** algorithm on the following array of characters:

B	C	F	K	N	O	P	T	U
0	1	2	3	4	5	6	7	8

For each iteration of binary search use the table below to list: (a) the left index and (b) the right index of the array that denote the region of the array that is still being searched, (c) the middle point index of the array, and (d) the number of character-to-character comparisons made during the search.

iteration	left	right	middle	#compares
1				
2				
3				

b) **(8 points)** Given an unsorted array of *n* elements. Using one of the sorting algorithms you have learned, describe the fastest algorithm that would modify the input array to have the smallest *k* elements in the array in the first *k* positions in sorted order. The remaining values can be in any order. Assume 0 < *k* <= *n*. The algorithm is expected to run in O(n).

For example:

- If the array is [**5, 12, 9, 8, 1, 7, 15**] and **k = 2** the algorithm would return [**1, 5**, 9, 8, 12, 7, 15], notice that the first 2 positions have the 2 smallest values in sorted order.
- If the array is [**5, 12, 9, 8, 1, 7, 15**] and **k = 3** the algorithm would return [**1, 5, 7**, 8, 12, 9, 15], notice that the first 3 positions have the 3 smallest values in sorted order.

Problem 5 – Complexity Analysis (20 points)

1. (2 points) (True or False) In a doubling experiment we double the time it takes to run the experiment.

2. (2 points) When considering an algorithm's performance we consider time and ?
   a. cost
   b. memory
   c. power
   d. elegance

3. (2 points) In order to provide a performance guarantee for an algorithm we take a conservative view and examine the running time of :
   a. all cases
   b. the worst case
   c. the best case
   d. a random sample of cases

4. (2 points) The Big O (order of growth) for the code fragment below is:

```
for (int i = 0; i < n; i++)
{
    for (int j = i+1; j < n; j++)
    {
        StdOut.println(i + " " + j);
    }
}
```

   a. $O(n^2)$
   b. O(n)
   c. $O(n^3)$
   d. O(1)
   e. O(log n)
   f. O(n log n)

5. (2 points) The Big O (order of growth) for the code fragment below is:

```
StdOut.println(n);
```

a. $O(n^2)$
b. O(n)
c. $O(n^3)$
d. O(1)
e. O(log n)
f. O(n log n)

6. (2 points) The Big O (order of growth) for the code fragment below is:

```
for (int i = 0; i < n; i++)
{
    StdOut.println(i);
}
```

a. $O(n^2)$
b. O(n)
c. $O(n^3)$
d. O(1)
e. O(log n)
f. O(n log n)

7. (2 points) The Big O (order of growth) for the code fragment below is:

```
for (int i = n; i > 0; i /= 2)
{
    StdOut.println(i);
}
```

a. $O(n^2)$
b. O(n)
c. $O(n^3)$
d. O(1)
e. O(log n)
f. O(n log n)

8. (2 points) The Big O (order of growth) for the code fragment below is:

```
// a is an array of size n
int n = a.length;
    for (int i = 0; i < n; i++) {
        for (int j = i+1; j < n; j++) {
            for (int k = j+1; k < n; k++) {
                if (a[i] + a[j] + a[k] == 0) {
                    StdOut.println(a[i] + " " + a[j] + " " + a[k]);
                }
            }
        }
    }
```

a. $O(n^2)$
b. O(n)
c. $O(n^3)$
d. O(1)
e. O(log n)
f. O(n log n)

9. (4 points) Consider the snippet of code below.

```
public class counting
{
    Run | Debug
    public static void main(String[] args)
    {

    int n = Integer.parseInt(args[0]);
    int a[] = new int[n];
    for (int i = 0; i < n; i++) a[i] = i;

    int b = 1;
    int clicker = 0;

    while (b < a.length)
    {
        for (int i = 0; i < b; i++)
        {
            clicker += 1;
        }
        b++;
    }

StdOut.println(clicker);
```

9.1 – (2 points) What is the Big O (order of growth) for the above snippet of code?

9.2 – (2 points) What is the value of the variable “clicker” after the snippet is run for n=5?