Name: ______________________________________

Email address (UWNetID): ______________________________________

CSE 332 Autumn 2017 Final Exam

(closed book, closed notes, no calculators)

Instructions: Read the directions for each question carefully before answering. We may give partial credit based on the work you **write down**, so show your work! Use only the data structures and algorithms we have discussed in class so far. Writing after time has been called will result in a loss of points on your exam.

Note: For questions where you are drawing pictures, please circle your final answer.

You have 1 hour and 50 minutes, work quickly and good luck!

Total: Time: 1 hr and 50 minutes.

Question	**Max Points**	**Score**
1	11	
2	10	
3	9	
4	10	
5	14	
6	13	
7	6	
8	16	
9	11	
Total	100	

1) [11 points total] Hash Tables

For a) and b) below, insert the following elements in this order: 19, 48, 8, 27, 97, 7. For each table, TableSize = 10, and you should use the primary hash function h(k) = k%10. If an item cannot be inserted into the table, please indicate this and continue inserting the remaining values.

a) Separate chaining hash table – use a sorted linked list for each bucket where the values are ordered by **increasing value**

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

b) Quadratic probing hash table

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

c) What is the load factor in Table a)?

d) Would you implement lazy deletion on Table a)? In 1-2 sentences describe why or why not. Be specific.

e) In 1-2 sentences (or pseudo code) describe how you would implement re-hashing on Table b). Be specific.

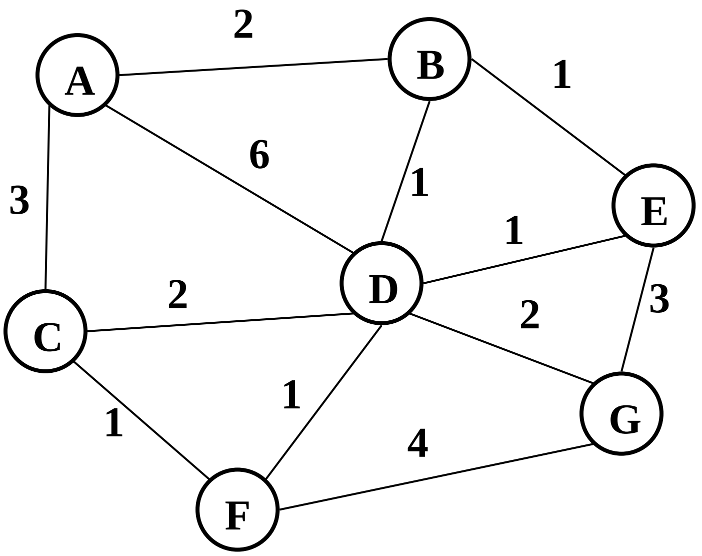
f) What is the big-O worst case runtime of an Insert in a hash table like Table a) containing N elements? _______

g) What is the big-O worst case runtime of determining what the maximum value is in a hash table like Table b) containing N elements? _______

2) [10 points total] Graphs!

a) [2 points] What is the big-O running time of Prim's algorithm (assuming an adjacency list representation) if a priority queue is used?

b) [2 points] Give a Minimum Spanning Tree (MST) of the graph below, by highlighting the edges that would be part of the MST.



c) [4 points] Kruskal's

(i) What is the worst case running time of Kruskal's algorithm as described in lecture (assuming an adjacency list representation is used)?

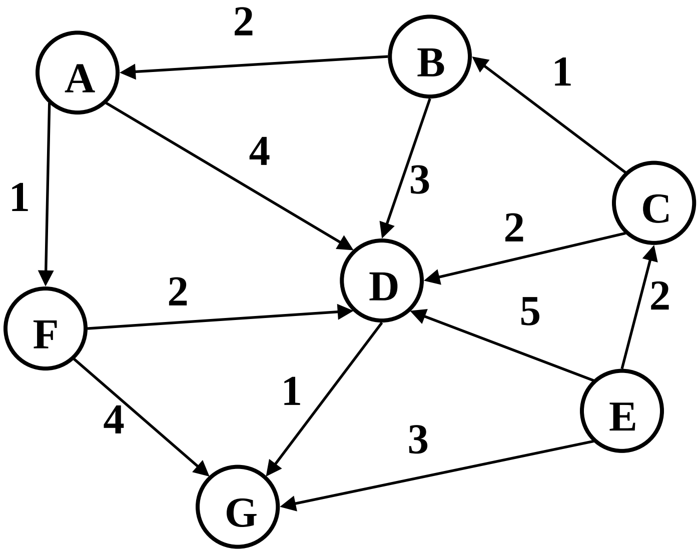
(ii) You try using a new implementation of union-find that claims to have better data locality. `find`() in this new implementation has a worst case running time of O(V^2) and `union`() has a running time of O(V). What is the worst case running time of your modified Kruskal's algorithm that uses this new implementation of union-find?

d) [2 points] What is the worst case running time to determine whether an edge exists from vertex x to vertex y.

(i) Given an adjacency matrix representation:

(ii) Given an adjacency list representation:

3) [9 points total] More Graphs!   Use the following graph for this problem:



a) [2 points] List a valid **topological ordering** of the nodes in the graph above (if there are no valid orderings, state why not).

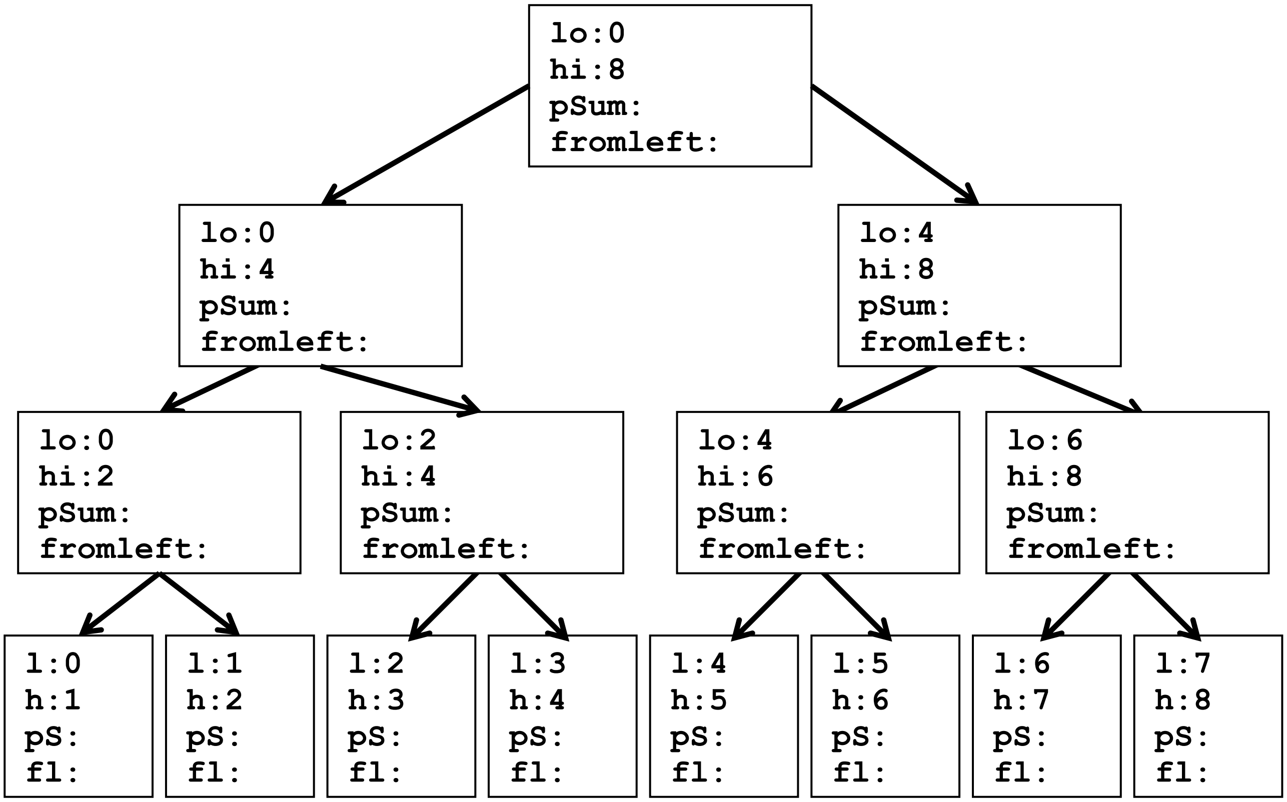
b) [3 points] In lecture we described an optimization to the topological sorting algorithm that used a queue. Your partner proposes that you use a priority queue instead of a FIFO queue. What would be the worst case running time of this new version of topological sort (assuming an adjacency list representation of the graph is used)? **For any credit, briefly describe your answer with pseudo code or in a couple of sentences.**

c) [2 points] ASSUMING the edges above are undirected, give a valid breadth first search of this graph, starting at vertex A, **using the algorithm described in lecture**.

d) [2 points] ASSUMING the edges above are undirected, give a valid depth first search of this graph, starting at vertex A, **using the non-recursive algorithm described in lecture**.

4) [10 points] Parallel Prefix Sum of Positives:

a) Given the following array as input, perform the parallel prefix algorithm to fill the **output** array with the sum of **only the positive values contained in all of the cells to the left** (including the value contained in that cell) in the input array. Negative values in the input array should not contribute to the sum. Fill in the values for: **`pSum`,** and **`fromLeft`** in the tree below. The output array has been filled in for you. Do not use a sequential cutoff.



Index	0	1	2	3	4	5	6	7
`Input`	**-1**	**5**	**-5**	**-2**	**2**	**-6**	**9**	**-3**
`Output`	**0**	**5**	**5**	**5**	**7**	**7**	**16**	**16**

b) How is the **`fromLeft`** value computed for the left and right children of a node in the tree. Give a formula where p is a reference to the current tree node.

`p.left.fromLeft` =

`p.right.fromLeft` =

c) How is **`output[i]`** computed? Give a formula assuming **`leaves[i]`** refers to the leaf node in the tree visible just above the corresponding location in the **`input`** and **`output`** arrays in the picture above.

`output[i] =`

5) [14 points] In Java using the ForkJoin Framework, write code to solve the following problem:

- **Input**: An array of ints
- **Output**: the array index of the rightmost number greater than zero in the Input array.

For example, if input array is {-3, 2, 5, -2, 7, 0, -4}, the output would be 4, since that is the index of the value 7. If there are no values greater than 0 in the array then -1 should be returned.

- Do **not** employ a sequential cut-off: **the base case should process one element**. (You can assume the input array will contain at least one element.)
- Give a class definition, `RightmostPosTask`, **along with any other code or classes needed**.
- Fill in the function `findRightmostPos` **below.**

You may not use any global data structures or synchronization primitives (locks).

```
import java.util.concurrent.ForkJoinPool;
import java.util.concurrent.RecursiveTask;
import java.util.concurrent.RecursiveAction;


class Main{
     public static final ForkJoinPool fjPool = new ForkJoinPool();

     // Returns the index of the rightmost positive value
     // in the array input. Returns -1 if no values > 0 in input.
     public static int findRightmostPos (int[] input) {
```

Please fill in the function above and write your class on the next page.

5) (Continued) Write your class on this page.

6) [13 points] Concurrency: The following class implements a Bank account containing both a savings and a checking balance.

```
public class BankAccount {
      private int savings;
      private int checking;
      private Object savLock = new Object();
      private Object chkLock = new Object();

      void depositToSavings(int amount){
            synchronized(savLock) {
                  savings += amount;
            }
      }

      void withdrawFromChecking(int amount){
            synchronized(chkLock) {
                  if (amount > checking)
                        throw new WithdawTooLargeException();
                  checking -= amount;
            }
      }

      void transferSavingsToChecking(int amount) {
            synchronized(savLock) {
                  synchronized(chkLock) {
                        if (amount > savings)
                              throw new WithdawTooLargeException();
                        savings -= amount;
                        checking += amount;
                  }
            }
      }
}
```

a) Does the `BankAccount` class above have (circle all that apply):

a race condition, potential for deadlock, a data race, none of these

If there are any problems, describe them in 1-2 sentences.

b) Does the code above provide any more concurrency than having one lock on the entire `BankAccount` object? **<u>In 1-2 sentences explain why or why not.</u>**

c) You decide to add one more method to the `BankAccount` class:

```
void transferCheckingToSavings(int amount) {
     synchronized(savLock) {
          synchronized(chkLock) {
               if (amount > checking)
                    throw new WithdawTooLargeException();
               checking -= amount;
               savings += amount;
          }
     }
}
```

Does adding this method to the `BankAccount` class **cause any new** (circle all that apply):

a race condition,   potential for deadlock,   a data race,   none of these

If there are any problems, describe them in 1-2 sentences.

d) **Circle** the critical section guarded by `chkLock` in the method above in part c).

e) **Instead of** adding in the method above in part c), you add this method to the `BankAccount` class:

```
int getOverallBalance() {
     return savings + checking;
}
```

Does adding this method to the `BankAccount` class **cause any new** (circle all that apply):

a race condition,   potential for deadlock,   a data race,   none of these

If there are any problems, describe them in 1-2 sentences.

7) [6 points] Speedup

What ***fraction of a program must be parallelizable*** in order to get 10x speedup on 20 processors?

You must show your work for any credit. For full credit give your answer as a number or a simplified fraction (not a formula).

8) [16 points] Sorting

a) **[3 points]** Give the ***recurrence*** for Quicksort (parallel sort & sequential partition) – best case span: (Note: We are NOT asking for the closed form.)

b) **[5 points]** Give the big-O runtimes requested below. For parallel sorts, give the span.

__________ A) Selection Sort – best case

__________ B) Quicksort (sequential) – best case

__________ C) Insertion Sort – best case

__________ D) Quicksort (parallel sort & parallel partition) – worst case span

__________ E) Quicksort (sequential) – worst case

c) **[5 points]** Fill in the blanks.

In class we discussed a Ω (______________) bound on ______________________ sorting.

Yet we came up with other sorts like ____________________ (name of sorting algorithm)

that had better worst case running times of Θ(_______________).

Describe in 1-2 sentences why it was possible to come up with these faster algorithms.

d) **[1 point]** Is radix sort in-place?

YES NO

e) **[2 points]** In 1-2 sentences, describe what it means for a sort to be in-place?

9) **[11 points] P, NP, NP-Complete**

a) **[2 points]** “NP” stands for ____

b) **[2 points]** What should you do if you **suspect** (but are not sure) a problem you are given is NP-complete?

c) **[5 points]** For the following problems, circle **ALL** the sets they belong to:

Finding the shortest path from one vertex to every other vertex in a directed weighted graph	NP-complete	P	NP	None of these
Finding a cycle that visits each edge in a graph exactly once	NP-complete	P	NP	None of these
Determining if a program will ever halt	NP-complete	P	NP	None of these
Determining if a chess move is the best move on an N x N board	NP-complete	P	NP	None of these
Finding a cycle in a weighted graph that visits every vertex exactly once and has a total cost < k.	NP-complete	P	NP	None of these

d) **[1 point]** If there exists a polynomial time algorithm to solve **SAT**, then there exists a polynomial time algorithm to solve **Hamiltonian Circuit**.

TRUE FALSE

e) **[1 point]** If there exists a polynomial time algorithm to solve **Euler Circuit** then any NP-complete problem can be solved by some polynomial time algorithm.

TRUE FALSE