SMITH COLLEGE

FALL 2024 FINAL EXAM

Course Number and Section: CSC 210 - 02
Course Title: Data Structures
Instructor: Halie Rando
Exam Format: Limited Materials
Number of Blue Books per student: 1

STUDENT NAME: Answers

ID NUMBER:

CLASS YEAR:

EXAM DATE: **EXAM OUT:** **EXAM DUE:**

EXAM IN:

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Student Signature: _____

Note: All blue books, used or unused, must be returned with the exam.

EXAM INSTRUCTIONS

Please indicate materials allowed (if any), number of pages and questions in exam, and any other relevant information.

ALL ANSWERS SHOULD BE WRITTEN IN THE EXAM PACKET. YOU CAN USE THE BLUE BOOK FOR ADDITIONAL SCRATCH PAPER.

YOU MAY USE A CALCULATOR.

YOU MAY NOT USE NOTES, THE TEXTBOOK, A COMPUTER, OR ANY OTHER INFORMATION SOURCE.

THIS EXAM CONSISTS OF 17 PAGES WITH 5 QUESTIONS.

Name: _____

Question 1. Selecting Implementations (10 points)

For each of the following scenarios, first **circle** the solution that you would pick and then **explain why** below**.**

Please answer five out of the six questions below.

Example:

Keeping track of when students get to ask questions to a TAs during Tutoring Hours

i. Stack ii. Queue iii. Dequeue

Justification: Students should get to ask their questions in the order that they've been waiting, with students who have been waiting longer getting an opportunity first. FIFO is best implemented using a queue.

(A) Looking for a single element within an unordered collection

i. Linear search ii. Binary search

Justification: Binary search requires sorted

(B) Using binary search to identify an element within an ordered collection

i. Array ii. Linked List iii. Doesn't matter

Justification: index access makes this possible in log(n) time, LL would be much slower

(C) Storing a set of items sold in the Campus Center and their associated prices.

i. Hash Set ii. Lookup Table iii. Hash Map

Justification: Set: no associative map property Lookup Table requires enumerable keys and storage for every possible key Hash map balances storage w/ lookup speed

Name: _____

(D) Sort a massive collection of items, where only a small fraction of the items can be held in memory at the same time

i. Selection Sort ii. Merge Sort

Justification: Merge sort is more computationally efficient and though it requires secondary storage, allows you to "chunk" your data while still sorting efficiently

(E) Track friendships and friend-breakups among the first-year class

i. Array ii. Tree iii. Graph

Justification: Graph lets us store relationships between entities (people) via edges & nodes, respectively. Array & tree do not allow multiple relationships as easily (though you can represent a graph as an array of arrays.

(F) Organize data that you need search for several different things

i. Array ii. Linked List iii. Binary Search Tree

Justification: If you are planning to search repeatedly, storing in a BST will let you lookup & insert/delete efficiently, if you only want to search, binary search on an array will give similar performance

Reminder: You can skip one of the above problems. If you answer all 6, please indicate which one you would like to be excluded.

Name: _____

Question 2. (Flawed) Operations on Singly Linked Lists (12 points)

Consider the list methods implemented below. Each one has at least one bug. This can be either a general issue with the implementation or a special case that is not handled properly. It will not be a syntax error.

For each method below, you are asked to indicate what problem might arise from the implementation shown. Please see the example below.

Please answer four of the five questions below.

Example:

```
/** Inserts the given item at the head of the linked list */
public void addFirst(T item){
  head = new NodeSL<T>(item, new NodeSL<T>(head.getData(), null));
}
```

What's wrong? This method will create two new nodes. The previous head node is no longer part of the list. Instead, its data has been copied over into a new node.

(A) What else could go wrong with the method in the example above (think of special cases)?

If the list is empty, it will throw an exception b/c of head.getData() call

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Name: _____

(B)

```
65  /** Returns the last element in the linked list */
66  public NodeSL<T> getTail(){
67    NodeSL<T> current = head;
68    while(current.next.next != null){
69        current = current.next;
70    }
71    return current;
72  }
```

What is wrong with this method?

Stops at node before tail, not tail (current.next = null)

(C)

```
74  /* Calculate the size of the list by counting the nodes */
75  public int size(){
76    int size = 0;
77    if(!isEmpty()) {
78      NodeSL<T> node = this.head;
79      while (!(node.getNext() == null)){
80        size++;
81      }
82    }
83    return size;
84  }
```

What is wrong with this method?

Doesn't count the tail (stops once node.getNext()==null w/o incrementing

Name: _____

(D)

```
162   /**
163    * Removes the given item from the head of the list
164    * @return v item removed
165    */
166   public T removeFirst() {
167     T result = head.getData();
168     head = head.getNext();
169     return result;
170   }
```

What is wrong with this method?

Will throw an exception if list is empty

(E)

```
22  /** Copy constructor makes a deep copy of the list */
23  public SLL(SLL<T> orig) {
24    if (orig.head == null) {
25      // handle special case of an empty list
26      head = null;
27    } else {
28      head = orig.head;
29    }
30  }
```

What is wrong with this method?

This is a shallow copy, the head node is the same node object. None of the nodes were copied

Reminder: You can skip one of the above problems. If you answer all 5, please indicate which one you would like to be excluded.

Name: _____

Question 3. Iterative and Recursive Problem Solving (23 points)

This semester, we talked about both iterative and recursive strategies for solving problems. Imagine you have an array of integers of length *n* and you want to find the sum. Assume *n* is available as array1.size.

Here is an example array with n=7.

2	4	0	6	1	8	3

A. How would you take the sum of this array iteratively? Please provide pseudocode describing your approach.

int sum = 0
for index i from 0 to n
do
sum + array[i]
done

(return sum if method)

Name: _____

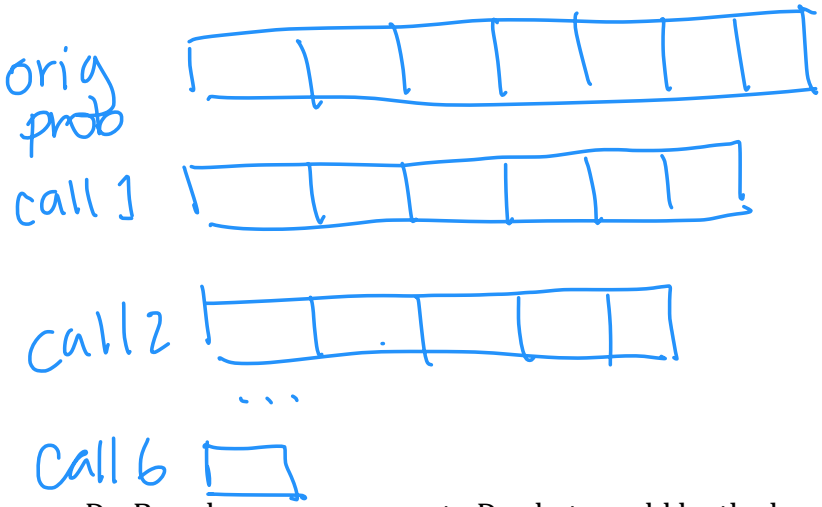
B. With an **iterative** approach, what is the computational complexity of taking the sum of all the elements in an **array**? Feel free to show your work, but please put your final answer in the brackets.

O(n)

1 op. per item in array

The next few questions will ask you to consider how to use recursion to take the sum of an array.

C. With each recursive call, how would the data you are looking at (e.g., the passed argument) change? It may help to think about whether this is a structural or generative recursive problem. You can answer in words or draw a picture.



Structural: call on smaller chunk each time

D. Based on your answer to D, what would be the base-case?

Base case: view of array len of 1 (or 0)

Name: _____

E. In pseudocode, sketch out a recursive function to calculate the sum of an array of length *n*. If you can't think of how to write it in pseudocode, just write out your logic and/or describe how you would approach the problem.

```
method recSum(array, index)
    if index == 0:
        return array[0]
    else:
        return array[index] +
               recSum(array, index - 1)
```

---

call w/ resSum(array, n)
to start

Name: _____

Question 4. Computational Complexity of Linked-List Operations (12 points)

Imagine you have a linked list containing integers as the data.

Outline **two** approaches that would allow you to find the ***k* lowest elements**. Indicate the **computational complexity** of each approach. Explain your approach using pseudocode, words, and/or drawings. Please provide a short name/title for each approach so that I know approach you are employing (e.g., "Calculate the sum while counting the length, divide sum/length" would be a way to find the average.)

Approach 1: Find min k times

How it works:

① Iterate over Linked List, tracking min element seen

② remove & return min

Do this k times

Computational complexity: $O(n \cdot k)$ or $O(n)$

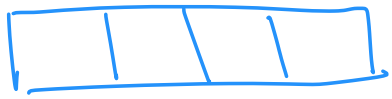
$k << n$

Name: _____

Approach 2: Track k min values seen

How it works:

Adapted insertion sort-type approach

k=4 

Iterate over linked list one time. Treat array above like "sorted" part of list, moving/copying el over just like in insertion sort. Done when reach end of linked list

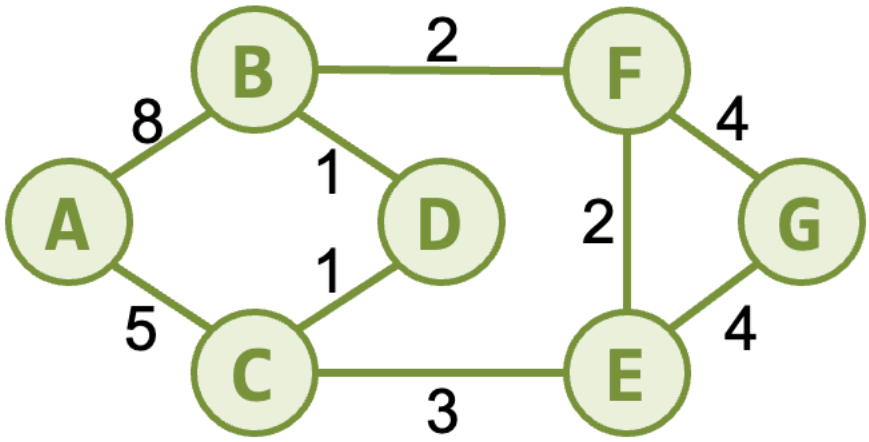
Computational complexity: O(n) if k << n

Name: _____

Question 5. Dissecting an Algorithm (28 points)

Dijkstra's algorithm gives us a way to find the shortest path between two nodes. We did not discuss it this semester, so **you are not expected to have any prior knowledge** of this algorithm**.** Instead, your goal is to figure out how you would implement Dijkstra's algorithm using what you've learned this semester.

We will consider a graph with weighted edges, like this:



Your goal is to find the cheapest path (in terms of the sum of the edges visited) to get from **Node A to Node G.** To do this, you will start at node A. When you **visit** Node A, you identify which nodes you can reach from A and what the associated cost of reaching them is.

There are a few things you need to keep track of, as described in **parts A-C** below. For each, propose a data structure that can be used for this goal, and explain why.

PART A: First, you want to **keep track of nodes that have not yet been visited**. Initially, you want track all of the nodes in your graph, as none of them have been visited yet. As you visit each node, you remove it from your Unvisited collection. The Unvisited nodes do not need to be stored in any particular order. Instead, you want to be able to find and remove them quickly.

i. The most efficient data structure for tracking Unvisited nodes is:

hash set

Name: _____

ii. Why?

Fast lookup/remove O(1)
All nodes should be unique

PART B: Next, you'll need to track the **cost** of the most efficient route you've found to get to each node from A. We would want to organize this information so that we can easily look up the lowest cost we have found so far.

Example: In the graph above:

1. You can get from A → B with a cost of 8.
2. You can get from A→ C with a cost of 5.
3. Next, you find you can get from A→ D with a cost of 9 (8 to get to B and 1 to get from B → D).
4. Later, you discover that you can get from A → D with a cost of 6 (5 + 1 additional from C→ D).
    a. Because 6 is less than 9, we would want to remove the value of 8 and instead store the cost of 6 to reach D from A.

Think about ways to store and access this information.

i. The most efficient data structure for tracking the minimum cost to reach each node is: priority queue or hashmap

ii. Why did you choose this data structure?

Associate node w/ min cost to reach it found (for both)

Name: _____

iii. What would you want to set the costs to initially, before you start visiting the graph? (Please explain why.)

∞ is a good choice so every real path is an improvement

PART C: We need to track not only the minimum cost we've found to reach a node (as in Part B) but also the path we took to get there. In particular, we want to know which neighbor we came from to get the lowest cost. This will allow us to retrace our steps later.

Example:

Continuing the example above:

1. We visited A to get to B.
2. We visited A to get to C.
3. We visited B to get to D.
4. Now we found we can get to D via a cheaper route, so we want to replace B with C.

i. The most efficient data structure for tracking the neighbor that led to the lowest-cost route to each node is:

Hash map

ii. Why?

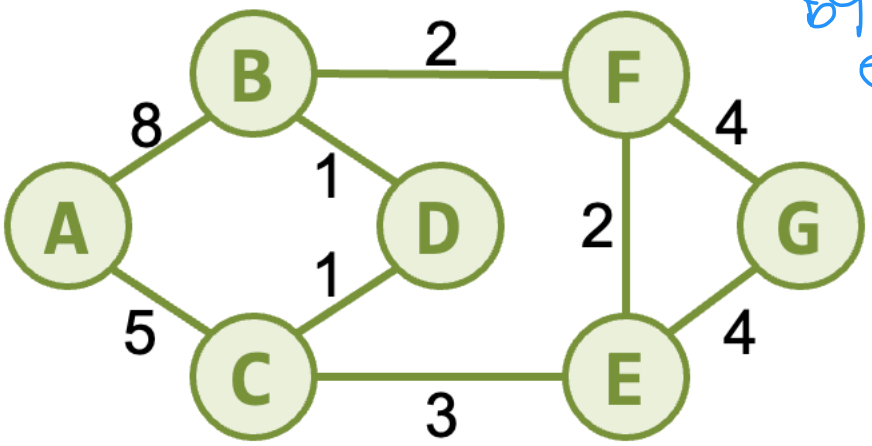
This would be the easiest way to track the paths w/o adding a field to the nodes of the priority queue (which would depend on implementation)

Name: _____

PART D: What is the lowest-cost path you can find from A to G? Please show all of your work. (You are not expected to execute this perfectly on the first time, so show your logic clearly—there will be lots of partial credit given). You can traverse the nodes however you like. The main goal is to show how you would apply your answers to A-C to solving this problem.

If you feel stuck: Use your answers and the information provided above to show how you would find the lowest-cost path from A → D. Then write down the questions you have about how to continue searching for G.

using hashmaps b/c that's easier for people



Lowest Cost Found from A → G: 12

work from G to A

visited	node	cost	via
✓	A	0	N/A
✓	B	~~8~~ 6	~~A~~ D
✓	C	~~6~~ 5	A
✓	D	~~8~~ 6	C
✓	E	~~10~~ 8	C
	F	~~10~~ 8	B
	G	~~14~~ 12	E or F

1. C→A, B→A
2. D→C, E→C
3. B→D
4. F→B

Name: _____

(Additional space for Problem 6)

END OF QUESTIONS

Name: _____

EXTRA PAGE FOR SCRATCH WORK:

Name: _____

EXTRA PAGE FOR SCRATCH WORK: