

Computer Science Foundation Exam

January 15, 2022

Section A

BASIC DATA STRUCTURES

**NO books, notes, or calculators may be used,
and you must work entirely on your own.**

Name: _____

UCFID: _____

NID: _____

Question #	Max Pts	Category	Score
1	10	DSN	
2	5	ALG	
3	10	DSN	
TOTAL	25	----	

You must do all 3 problems in this section of the exam.

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1) (10 pts) DSN (Dynamic Memory Management in C)

Consider the following structures and the main function shown below:

```

typedef struct StringType {
    char *string;
    int length;
} StringType;

typedef struct Employee {
    StringType *ename;
    double salary;
} Employee;

#include <string.h>
#include <stdio.h>
int main() {
    //array of employees' names
    char nameList[][50] = {"Adam", "Josh", "Kyle", "Ali", "Mohammed"};
    //array of salaries, where 15.80 is the salary of Adam, 13.50 is
    // the salary of Josh, etc.
    double salaries[5] = {15.80, 13.5, 20.9, 12.99, 10.5};
    Employee *employees = createEmployees(nameList, salaries, 5);
    // Other code here...
    return 0;
}

```

Write a function createEmployees() that takes the list of employees' names, list of their salaries, and length of the list (empCount) as the parameters, **and returns a pointer to a dynamically allocated array of Employee storing the relevant information for empCount employees.** The function dynamically allocates memory for empCount number of employees and assigns the name and salaries for each of them from the input parameters. During this process, the names are stored in the dynamically allocated memory of StringType, and also make sure you assign the length of the name appropriately. Your code should use exact amount of memory needed to store the corresponding names. You may assume no name is longer than 49 characters.

```

Employee* createEmployees(char names[][50], double *salaries, int empCount)
{

}

```

2) (5 pts) ALG (Linked Lists)

Suppose we have a linked list implemented with the structure below. We also have a function that takes in the head of the list and returns a node pointer.

```
typedef struct node {
    int num;
    struct node* next;
} node;

node* something(node* head) {
    node* t = head;
    if(t==NULL || t->next == NULL ) return t;

    while(t->next->next != NULL)
        t = t->next;

    t->next->next = head;
    head = t->next;
    t->next = NULL;

    return head;
}
```

A linked list, **mylist**, has the following nodes: 1 -> 9 -> 6 -> 7 -> 4 -> 8, where 1 is at the head node of the list.

a) What will be the status of the linked list (draw the full list) after following function call.

```
mylist = something(mylist);
```

Draw the updated linked list after the function call:

```
mylist ->
```

b) What general task does the function something perform? Please answer in a single sentence.

3) (10 pts) DSN (Stacks)

Consider a string mathematical expression can have two kind of parenthesis '(' and '{'. The parenthesis in an expression can be imbalanced, if they are not closed in the correct order, or if there are extra starting parenthesis or extra closing parenthesis. The following table shows some examples:

Expression	Status	Expression	Status
{ }	Imbalanced due to incorrect order of).	{ { } }	Imbalanced due to extra)
{ (}	Imbalanced due to extra ({ { } }	Balanced
{ () }	Balanced		

Write a function that will take an expression in the parameter and returns 1, if the expression is balanced, otherwise returns 0. You have to use stack operations during this process. Assume the following stack definition and the functions already available to you. You may assume that the stack has enough storage to carry out the desired operations without checking.

```
void initialize(stack* s); // initializes an empty stack.
int push(stack* s, char value); //pushes the char value to the stack
int isEmpty(stack* s); // Returns 1 if the stack is empty, 0 otherwise.
char pop(stack* s); // pops and returns character at the top of the stack.
char peek(stack* s); // returns character at the top of the stack.
```

Note: pop and peek return 'I' if the stack s is empty.

// Pre-condition: e only contains the characters '(', ')', '{' and '}'.

```
int isBalanced(char *e) {
    struct stack s;
    initialize(&s);
    for(int i=0; e[i]!='\0'; i++) {
```

```
    }
```

```
    ;
```

```
}
```

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Section B

ADVANCED DATA STRUCTURES

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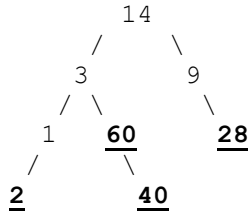
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1	10	DSN	
2	5	ALG	
3	10	DSN	
TOTAL	25		

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1) (10 pts) DSN (Binary Trees)

The goal of a function named *legacyCount()* is to take the root of a binary tree (*root*) and return the number of nodes that contain a value greater than at least one of their ancestors. For example, this function would return **4** for the following tree, since **60** is greater than both of its ancestors (3 and 14), **40** is greater than two of its ancestors (3 and 14) (even though 40 isn't greater than its parent!), **28** is greater than both of its ancestors (9 and 14), and **2** is greater than one of its ancestors (1).



Our node struct is as follows:

```

typedef struct node {
    int data;
    struct node *left;
    struct node *right;
} node;
  
```

To make the code work, *legacyCount()* is a wrapper function for a recursive function called *legacyHelper()*. Included below is the code for *legacyCount()* as well as the function signature for *legacyHelper()*. Write all of the code for the *legacyHelper()* function. Note: If *root* is NULL, you should return 0.

```

int legacyCount(node *root) {
    if (root == NULL) return 0;
    return legacyHelper(root->left, root->data) +
           legacyHelper(root->right, root->data);
}
  
```

```

int legacyHelper(node* root, int minAncestor) {
  
```

```

}
  
```

2) (5 pts) ALG (Hash Tables)

Suppose have some hash function that produces the following hash values for the following strings.

String	hash value
Wicked	35429
Cheesy	171745742
Lasagna	72457241
For	559079
Dinner	96879

Using the hash values above, insert the strings (one by one, in the order given above, from “wicked” down through “dinner”) into the following hash table. Use **quadratic probing** to resolve any collisions. Note that there is a standard technique for dealing with hash values that exceed the length of a table (e.g., values that exceed 9 in the case of this particular table), and it’s up to you to use that technique here.

Note: The length of the hash table is **10**.

0	1	2	3	4	5	6	7	8	9

3) (10 pts) DSN (Tries)

Write an **iterative, non-recursive** function that takes the root of a trie (*root*) and a string (*str*) and returns the number of new nodes we would have to add to our trie in order to insert that string. You may assume that *str* is non-NULL, non-empty, and contains lowercase alphabetic characters only (i.e., it won't contain uppercase letters or non-alphabetic characters). However, you must handle the case where *root* is NULL.

Special Restrictions:

- Please do not use pointer arithmetic (e.g., `str + 1`).
- Do not modify or corrupt the trie or the string. (Do not add nodes to the trie!)
- Do not call `strlen()` repeatedly, as it is an $O(k)$ function (where k is the length of the string). If you need to call `strlen()`, find a way to do it only once for the given string.

The trie node struct and function signature are as follows. Do NOT write any helper functions.

```
#include <string.h>
typedef struct TrieNode {
    struct TrieNode *children[26];
    int flag; // 1 if the string is in our trie, 0 otherwise
} TrieNode;

int newNodeCount(TrieNode* root, char* str) {
```

```
}
```


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Section C

ALGORITHMS ANALYSIS

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Question #	Max Pts	Category	Score
1	5	ANL	
2	10	ANL	
3	10	ANL	
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1) (5 pts) ANL (Algorithm Analysis)

What is the best and worst case runtime for the following algorithm, in terms of the input parameter n ? You may assume that the array pointed to by `arr` is of length n . Give a brief explanation for your answers.

```
int foo(int * arr, int n, int value){  
  
    int cur = 0, jump = n/2;  
    while (jump > 0) {  
        if (value > arr[cur])  
            cur += jump;  
        else if (value == arr[cur])  
            return cur;  
  
        jump = jump/2;  
    }  
  
    return cur;  
}
```

2) (10 pts) ANL (Algorithm Analysis)

An algorithm processes an array of size r by c in $O(rc^2)$ time. For an array of size $r = 200$ and $c = 500$, the algorithm takes 5.0 seconds. How long, in seconds, will the algorithm take to process an input array of size $r = 800$ and $c = 300$? Please express your answer with exactly one digit after the decimal point.

3) (10 pts) ANL (Summations)

With proof, find the ordered pair of values (a, b) which satisfy the equation below?

$$\sum_{k=1}^{2n} (ak + b) = 7n^2 + 3n$$

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Section D

ALGORITHMS

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1	5	DSN	
2	10	ANL	
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1) (5 pts) DSN (Recursive Coding)

Consider the problem of a frog jumping out of a well. Initially, the frog is n feet below the top of the well. When the frog jumps up, it elevates u feet. If a jump gets the frog to the top of the well or past it, the frog escapes the well. If not, unfortunately, the frog slips down by d feet before clinging to the side of the well. (Note that $d < u$.) Write a recursive function that takes in positive integers, n , u , and d , and returns the number of times the frog must jump to get out of the well.

For example, if $n = 10$, $u = 5$ and $d = 3$, the function should return 4. On the first jump, the frog goes from 10 feet below the top to 8 feet below (5-3 is the progress). On the second jump, the frog goes from 8 feet below the top to 6 feet below the top. On the third jump, the frog goes from 6 feet below the top to 4 feet below the top. On the last jump, since 5 feet is enough to clear the top of the well, the frog does not slip down and gets out. In this case, had $n = 11$, the frog would have also gotten out in 4 jumps.

(Note: Although one can do some math to arrive at an $O(1)$ solution without recursion, please use recursion to simulate the jumping process described as this is what is being tested - the ability to take a process and express it in code, recursively. Also, though this is a toy problem, it's surprisingly similar to the real life process of paying off a loan, though in the latter process, the amount you "slip down" slowly decreases, month after month.)

```
int numJumps(int n, int u, int d) {
```

```
}
```

2) (10 pts) ANL (Sorting)

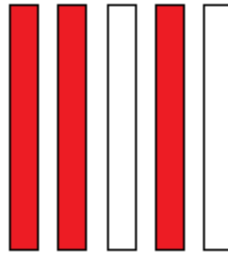
Jesse has mistakenly written his Merge Sort so that instead of making recursive calls on each half of the array (code below), he calls a function that runs an Insertion Sort on each half of the array. You may assume the function `insertionSort` runs properly and executes the steps of an Insertion Sort. He tests his function on an array of size 100,000 in reverse sorted order, and discovers that instead of running in under one second, his code takes 9 seconds. How long (in seconds) would sorting the same array (100,000 elements in reverse order), *on the same computer*, using a single Insertion Sort, be expected to take?

To earn full credit, you must justify your answer by looking at the number of simple operations in both algorithms and comparing the differences in multiplicative constants between the two algorithms.

```
void mergeSort(int array[], int low, int high) {
    if (low >= high) return;
    int mid = (low+high)/2;
    insertionSort(array, low, mid);
    insertionSort(array, mid+1, high);
    merge(array, low, mid, high);
}
```

3) (10 pts) DSN (Bitwise Operators)

Imagine the task of painting a picket fence with 20 pickets. Let each picket be numbered from 0 to 19, from left to right and initially each is painted white. A pattern is 5 pickets long and can be placed with the pattern's left end aligned with any picket in between number 0 and number 15, inclusive. (If you line the pattern up with any of the pickets 16 through 19, the right end of the pattern goes past the right end of the fence and this isn't allowed.) Below is a picture of an example pattern, with the 3 of the 5 possible pickets painted:



If this pattern was lined up with picket number 4, then pickets 4, 5 and 7 would get painted. Think of the process as a placing a stamp on a portion of the whole fence. We can represent this pattern with the integer 11 ($2^0 + 2^1 + 2^3$), the integer where bits 0, 1 and 3 are set to 1. The bit positions represent, relative to the left end of the pattern, which positions have paint on them.

One way to paint a fence with a pattern is to line up the pattern with a few different picket numbers and apply the pattern. For example, if we lined up this pattern with the pickets at positions 1 and 4, then the pickets that would be painted would be at positions 1, 2, 4, 5 and 7. (Notice that painting an individual picket more than once leaves it still painted.)

Complete the function below so that it takes in an integer, *pattern*, in between 0 and 31, inclusive, representing the pattern, an integer array, *paintLoc*, which stores the locations to line up the pattern with for painting, and *paintLen*, representing the length of the array *paintLoc* and returns a single integer storing the state of the painted fence (for each picket number, *k*, that is painted, bit *k* in the returned integer should be set to 1). Each of the values in *paintLoc* will be distinct integers in between 0 and 15, inclusive.

```
int paintFence(int pattern, int paintLoc[], int paintLen) {

}
}
```