CS 692 Capstone Exam Algorithms Spring 2020: Choose any 2 of the 3 problems.

1) Given a binary tree, write a function that returns the number of nodes in the tree that have exactly one child.
Notes:
The function should have just one argument, a pointer to the root.
No global variables may be used.
No additional functions may be defined.

2) Consider the following insertion sort algorithm.

```
void insertion_sort(element a[], int n)
// Put a[0]..a[n-1] into ascending order by insertion sort.
{
  for (int k = 1; k < n; k++) {
    // At this point, a[0]..a[k-1] are already in order.

    // Insert a[k] where it belongs among a[0]..a[k].
        You need to write code for this insertion as the body
        of the for-k loop.

  }//endfor k
}
```

a) Write the code for the body of the for-k loop to complete the insertion sort routine.
b) Count the precise best case and worst case number of "element comparisons" in your insertion sort routine. Your answers should be functions of n in closed form. Note that "closed form" means that you must resolve all sigmas and …'s. Asymptotic answers (such as ones that use big-oh, big-theta, etc.) are not acceptable.

3) Which of the following five statements correctly describes the relationship between the functions f and g defined in a)-d) below? Note that more than one of the five statements may be correct for each part. You do not need to explain your choices.

$f \in o(g)$ $f \in O(g)$ $f \in \theta(g)$ $g \in o(f)$ $g \in O(f)$

a) $f(n) = 3n^2, \quad g(n) = 2n^2$

b) $f(n) = 2^n, \quad g(n) = 3^n$

c) $f(n) = 2^{n-1}, \quad g(n) = 2^n$

d) $f(n) = \sqrt{n}, \quad g(n) = log_2(n)$

SYSTEMS EXAM

Spring 2020

90 minutes

Check which problems you are submitting:

- ❑ #1
- ❑ #2
- ❑ #3

How many pages total?_____

Please do not write on the back of any pages.

_____

(print name)

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(signature)

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CS 692 Capstone Exam – Systems Spring 2020

Directions: Choose only two out of the three problems listed below. If you attempt all three, only questions one and two will be graded. A score of 24/40 is needed to pass the test. Please show all work.

1) **CPU Scheduling**
   a. (6pts) What are the possible **states** of a **process**? Draw a **diagram** and **label** transitions.

   b. (3pts) Indicate which of the following are **shared** by **threads**? **Code, stack, data, register set, file pointers.**

   a. (8pts) Below is a set of processes with CPU burst times listed in milliseconds. Draw a **Gantt chart** for the ***preemptive Shortest Remaining Time First*** scheduling algorithm. Label the **ending** times of each process.

Process	Arrival Time	CPU burst
P1	0	10
P2	3	5
P3	5	6
P4	7	2
P5	10	4

   b. (3pts) What is the definition of ***average turnaround time***? What is the **value** of average turnaround time in this problem?

2) Dining Philosophers

   a. (2pts) The term for when a process is **denied** necessary **resources** indefinitely is: (Circle your answer).

      a) latency b) starvation c) inversion d) aging

   b. (4pts) List the **four** standard, necessary conditions of ***deadlock***.

c. (4pts) Describe an option for **recovering** from deadlock.

d. (2pts) Consider the solution below to the dining philosopher's problem. There are 7 philosophers. (Philosopher i where (i = 0, 1, 2,…6)). Semaphores are initialized to 1. **Can deadlock occur?**

(4pts) **Explain** or give a **sequence** of events that prove your answer to **part d** above.

```
while (true){
       think;
       wait(mutex);
              wait fork[i];
              wait fork[(i+1) %7]
       signal(mutex);
       eat;
       signal(fork[i]);
       signal(fork[(i + 1) %7];
}
```

e. (4pts) The function **wait** is implemented with a ***Last In First Out queue (LIFO).*** Can **starvation** occur? Explain or give a sequence of events that prove your answer.

3) Memory

a. (4pts) Explain how ***first fit*** and ***best fit*** memory allocation work. Give **one advantage** and **one disadvantage** of each of these allocation methods.

b. (4pts) What is meant by the term ***thrashing***? Describe one mechanism for solving this problem which uses memory **efficiently**.

c. **Page replacement – using the 2nd chance algorithm**. Assume **3 page frames** have been allocated to a process.

(8pts) Show the **contents** of the page frames and the **reference bits *after every page access*** for the following list of page requests: **1, 2, 3, 4, 2, 5, 6, 4, 3, 3, 2, 6**. In addition, indicate when a **page fault** has occurred.

1	2	3	4	2	5	6	4	3	3	2	6

(4pts) Repeat using the **optimal** algorithm.

1	2	3	4	2	5	6	4	3	3	2	6

Theory Exam

Answer **ANY TWO** of the following three questions:

1. Give the state diagram for a pushdown automaton (PDA) that recognizes the following language over $\Sigma = \{0, 1, \#\}$:

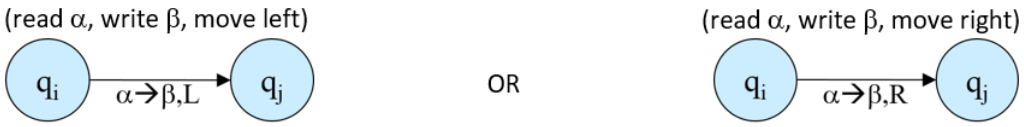
   $$\{w_1\#w_2 : w_1, w_2 \in \{0, 1\}^* \text{ and } |w_1| > |w_2|\}$$

   In English: two substrings separated by # where the first substring is longer than the second.

2. Give the state diagram for a deterministic Turing machine that decides the following language over $\Sigma = \{0, 1\}$:

   $$L = \{w : w \text{ contains both the substrings 011 and 110}\}$$

   Use ONLY the following notation to label each of your machine's transitions:

3. A clique in an undirected graph is a collection of vertices that are fully interconnected by edges. Consider the following language:

   $$\text{CLIQUE} = \{G, k : G = (V, E) \text{ is an undirected graph containing a clique of at least size } k\}$$

   Prove that CLIQUE $\in$ **NP**.

   NOTE THE FOLLOWING:

   You are being asked to prove that CLIQUE is in NP, and not that CLIQUE is NP-Complete!
   No definitions or discussions required, and will earn no points.