COL 106 MINOR EXAM II
SEMESTER I 2019-2020
1 hour

Please do not allow any bag, phone or other electronic device near you. Keep your ID card next to you on the desk. Maximum marks available for questions are listed in **[]**. *Write answers in the provided space. Justify all answers.*

1. (11)

a) [8] Given the Hash function *h* below, list the table slots touched/probed and show the status of the Hash table after each listed operation (in order from left to right, starting with an empty hash table). The table has 5 slots. Assume open addressing with h_i as given: (Deletion is by marking as deleted.)

$$h = h_0 = (\sum \text{digits}) \% 5$$
$$h_i = (h_0 + 3*i) \% 5$$

Insert:873   Insert:9734   Insert:280   Delete:9734   Search 143   Insert:14   Rough space

Slots probed:

| | | | | | |

b) [3] What is the termination condition for a search in such a Hash table?

2. [5] Write code (approximate syntax is OK) to restructure to balance the following configuration. Assume references left, right, parent and value are stored for each node. Assume *p.parent.left == p* and *n.parent.right == n*. (No references should be assumed to be null.) `Restructure(Node n):`

```
Node p = n.parent, g = p.parent;
```
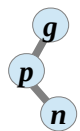
3. (10) Consider a binary search tree that allows keys to be repeated in multiple nodes such that *keys equal to any node's key are always in that node's left subtree*. Write the pseudo-code for search and delete for this tree that each take time O(*h*) for a tree with height *h*. The search function must return all instances and the delete function must delete all instances of the given key.

[6] Delete(root, key):

[4] Search(root, key):

4. [5] You need to implement a *Red-Black tree* that supports multiple threads inserting, searching or deleting in parallel. (You may assume that each thread uses the standard algorithms to perform these operations.) What synchronization is required to ensure that the threads do not interfere with each other's operation?

5. [5] Consider a *skip-list* that supports multiple threads inserting, searching or deleting in parallel. (Assume each thread uses the standard algorithms to perform these operations.) What synchronization is required to ensure that the threads do not interfere with each other's operation?

6. [4+3+3] Show that the height of a 2-4 tree with n keys is (a) no less than floor($0.5 \log_2 n$) and (b) no more than $\log_2 n$. (c) Also show that the number of comparisons required to find a key is no more than $2 \log_2 n$. (5 extra marks to show the bound to be $1.3 \log_2 n$)

7. [6] You are given two heaps with 2^h keys each, where h is an integer. Provide an O(h) algorithm to merge these two heap. (Assume all keys in the two heaps are comparable to each other.)

8. [6] In an AVL tree with with 20 nodes having numbers 1 to 20, respectively, as keys, which numbers may not appear in the root?

9. [6] Given the keys of a Red-black tree in the pre-order traversal order, provide an algorithm to re-construct the Red-black tree. (You do not have to determine the nodes' colors.)

10. [6] Provide *non-recursive* pseudo-code to compute the depth of a binary tree.