Instructor: Dr. Sartaj Sahni
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Advanced Data Structures
(COP 5536 /AD 711R)
Exam 2

CLOSED BOOK
75 Minutes

Name: ______________________________

NOTE:
1. **For all problems, use only the algorithms discussed in class/text.**
2. All answers will be graded on correctness, efficiency, clarity, elegance and other normal criteria that determine quality.
3. The points assigned to each question are provided in parentheses.

1. (14)

   (a) (6)For the following min Fibonacci heap, assume that the *ChildCut* field of each node is TRUE except node 7. And the ChildCut of a root node is undefined.

```
      min
       |
       V
       1
    / |    \
   4  5     7 (F)
      |    / \
      6  8    10(T)
               |
              12 (T)
             /  \
            13  14(T)
                 |
                15 (T)
```

   Perform a *DecreaseKey* operation by changing 14 to 9. On the resulting Fibobacci heap, clearly label *ChildCut* values (Draw the resulting *Fibonacci* heap.)

   (b) (8) Show that if we start with an empty Fibonacci heap and do not perform cascading cuts, then it is possible for a sequence of Fibonacci heap operations to result in degree-k min trees that have only k+1 nodes, k >=1.

2. (8) Start with an empty *two-pass min* pairing heap,

   (a) (4) Insert the following sequence of keys: 5, 8, 4, 12, 3, 14, 20, 15, and 9 in this order. Show the pairing heap after each insert.

   (b) (4) Perform a $RemoveMin$ operation on the resulting min heap of (a), showing each step.

3. (10) Recall that *inserting* a node into an *AVL* tree may require LL, LR, RL, or RR rotations. Draw AVL trees in which inserting a node requires an *RL* rotation. Remember that there are *three* cases for *RL* rotations. For each case, indicate a node to be inserted, perform an insert operation, and draw the AVL tree following the insertion.

4. (8) Draw a 2-3 tree with 11 elements (keys from 1 to 11) and height 3, where all nodes at levels 2 and 3 are 2-nodes (the root is at level 1). *Delete* the element in the rightmost node at level 2 and draw the resulting 2-3 tree. From the resulting tree, *delete* the *min* element. Draw the new 2-3 tree.

5. (10) For red-black trees,

   (a) (7)Construct a red-black tree by inserting the keys in the following sequence into an initially empty red-black tree : 4, 9, 1, 13, 11, 7, and 5.
   Use the $bottom - up$ algorithm. Show each step.

   (b) (3)For the resulting red-black tree of (a), perform the $Delete$ operation for key value 13, showing each step.