Section 03: Binary Search Trees and AVL Trees

1. Binary Search Trees

Let a binary search tree be defined by the following class:

```
public class IntTree {
    private IntTreeNode overallRoot;

    // constructors and other methods omitted for clarity

    private class IntTreeNode {
        public int data;
        public IntTreeNode left;
        public IntTreeNode right;

        // constructors omitted for clarity
    }
}
```

(a) Given a binary search tree (as defined above), write a method (sufficient to present a pseudocode) to output the elements in sorted order.

(b) Let n be the number of nodes in a binary tree. What is the runtime of your method from Question 1(a) as a function of n?

(c) Draw the binary search tree after the execution of each operation in the sequence

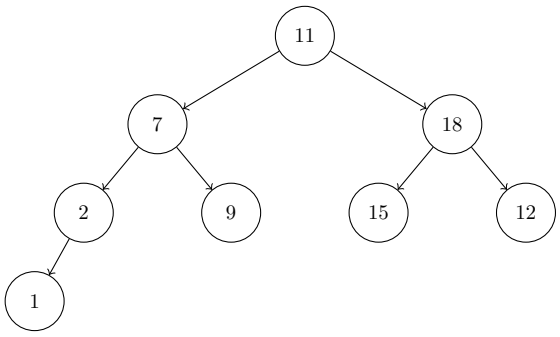
$$\mathsf{insert}(10), \mathsf{insert}(20), \mathsf{insert}(15), \mathsf{insert}(2), \mathsf{insert}(25), \mathsf{insert}(22), \mathsf{insert}(50),$$
$$\mathsf{remove}(2), \mathsf{remove}(20), \mathsf{remove}(10), \mathsf{insert}(33), \mathsf{remove}(50), \mathsf{insert}(20).$$

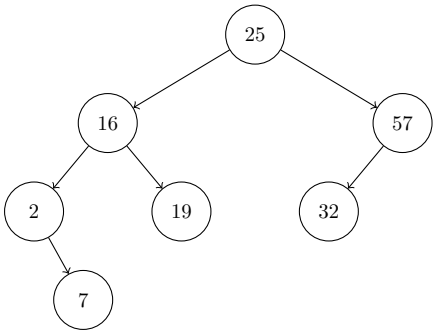
Assume that the tree is empty before the execution of the sequence.

2. AVL Trees

(a) Identify if the following trees are AVL trees. Explain your answer.

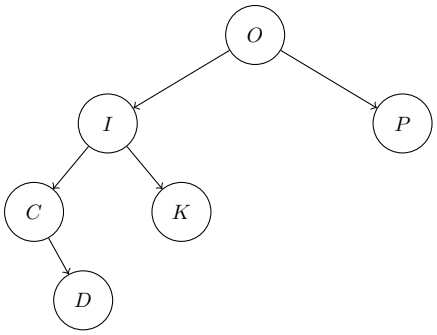
(i) Tree 1





(ii) Tree 2

(iii) Tree 3



(b) Draw an AVL Tree as each of the following keys are added in the order given. Show intermediate steps.

(i)

$$\{13, 17, 14, 19, 22, 18, 11, 10, 21\}$$

(ii)

$$\{1, 2, 3, 4, 5, 6\}$$