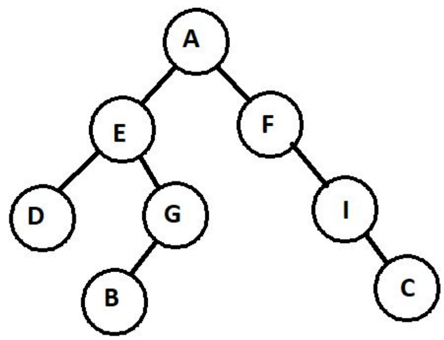
1. [3] Given the following preorder and in-order traversals, reconstruct the appropriate binary search tree. NOTE: You must draw a single tree that works for both traversals.

Pre-order: A, E, D, G, B, F, I, C

In-order: D, E, B, G, A, F, I, C

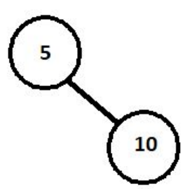


2. [3] Starting with an empty BST, draw each step in the following operation sequence. Assume that all removals come from the left subtree when the node to remove has two children.

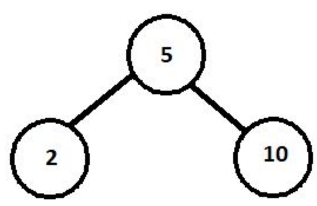
Insert(5), Insert(10), Insert(2), Insert(9), Insert(1), Insert(3), Remove(5).

Insert(5)

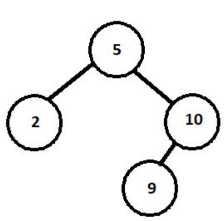
Insert (10)



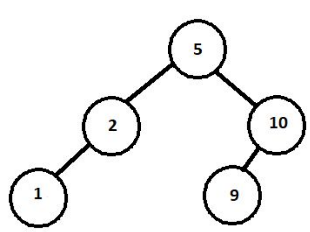
Insert (2)



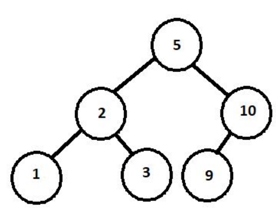
Insert(9)



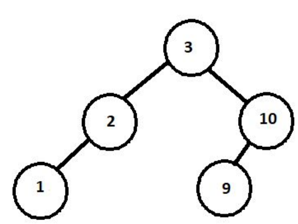
Insert (1)



Insert (3)

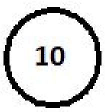


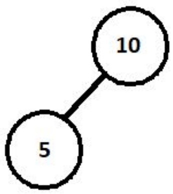
Remove(5)

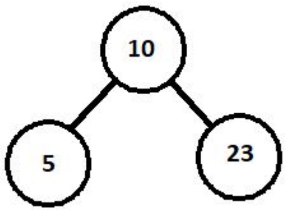


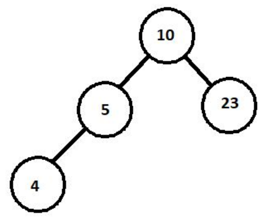
3. [3] Starting with an empty BST, draw each step in the following operation sequence. Assume that all removals come from the right subtree when the node to remove has two children.
Insert(10), Insert(5), Insert(23), Insert(4), Insert(19), Insert(7), Insert(9), Insert(6), Remove(5).

Insert(10) Insert(5) Insert(23) Insert(4)

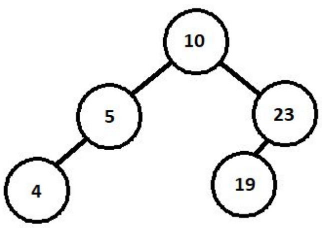


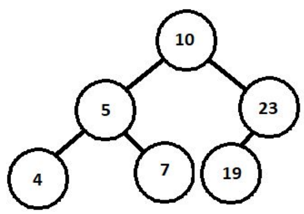


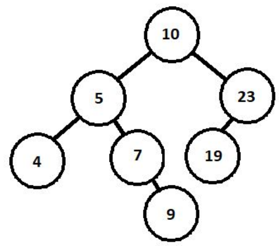




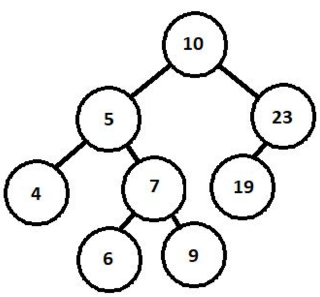
Insert(19) Insert(7) Insert(9)

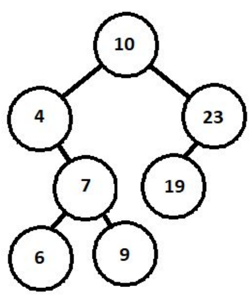




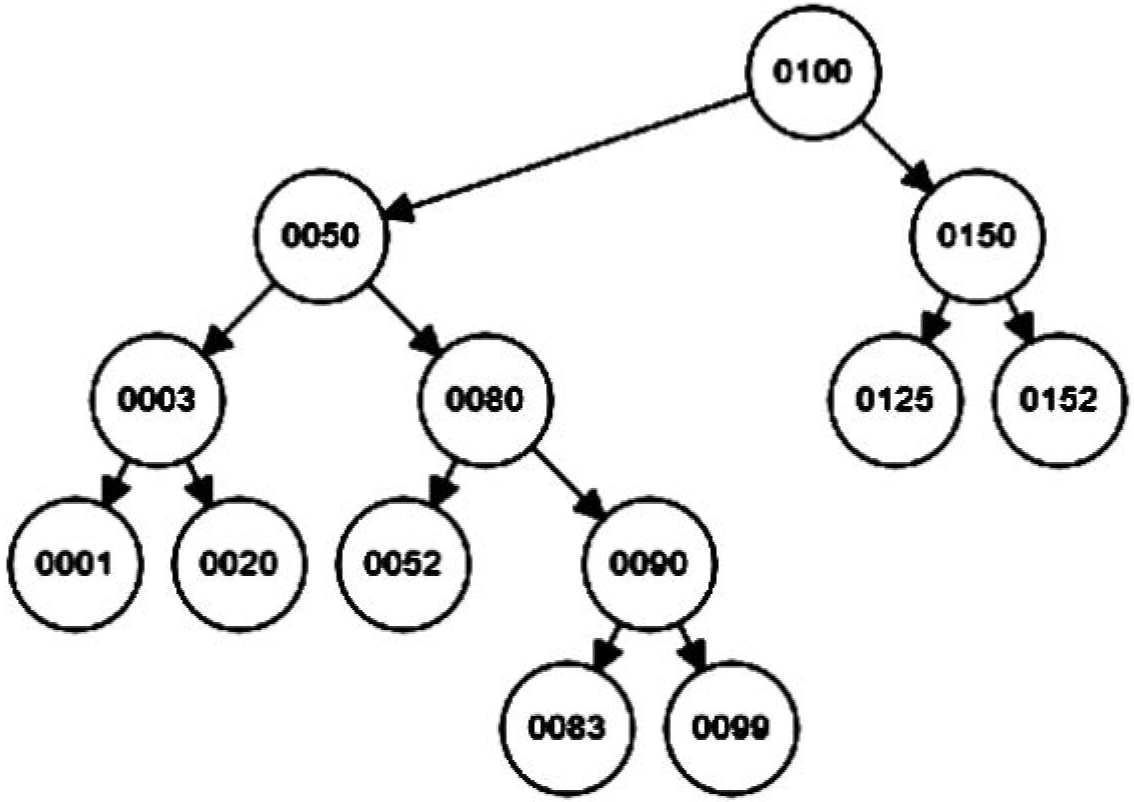


Insert(6) Remove(5)





4. Given the following binary tree (where nullptr height == -1):



A.[1] What is the height of the tree?

The height is 4 at node 99 or 83

B.[1] What is the depth of node 90?

The depth of node 90 is 3

C.[1] What is the height of node 90?

The Height of node 90 is 1

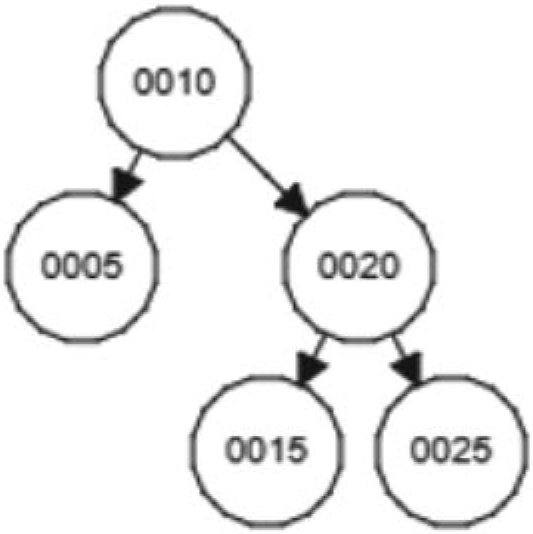
D.[3] Give the pre-order, in-order, and post-order traversal of this tree.

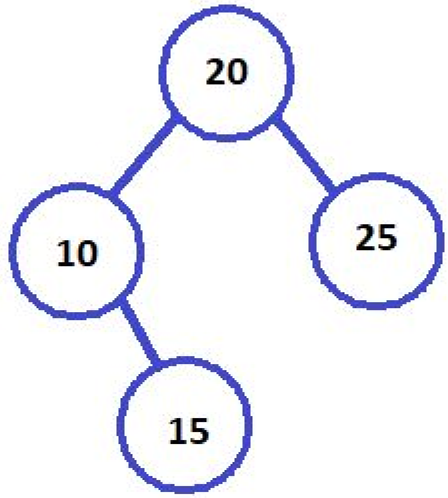
Pre: 100,50,3,1,20,80,52,90,83,99,150,125,152

In:1,3,20,50,52,80,83,90,99,100,125,150,152

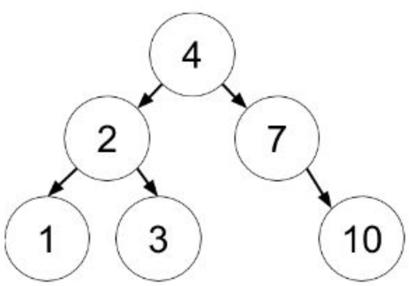
Post:1,20,3,52,83,99,90,80,50,125,152,150,100

5. [3] Remove 5 from the following AVLtree; draw the results:



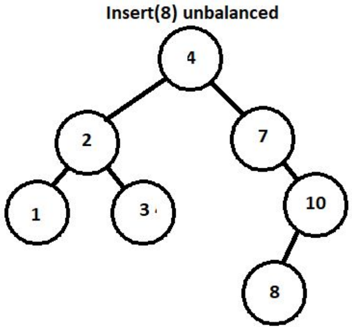


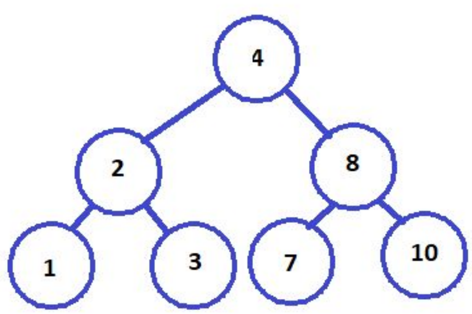
6. [3] Insert the value "8" into the following AVL tree; draw the result:



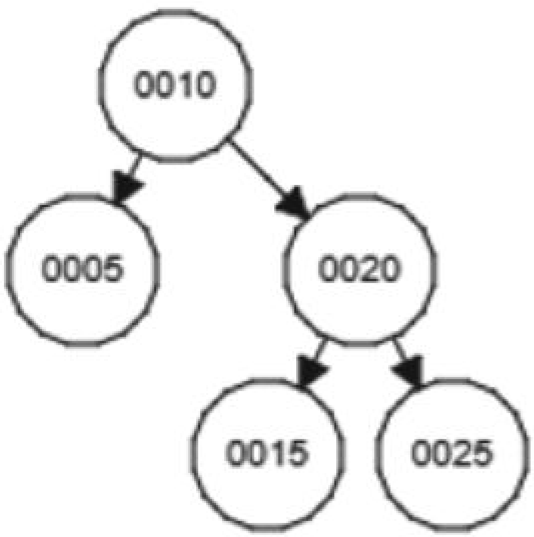
Final answer in Blue

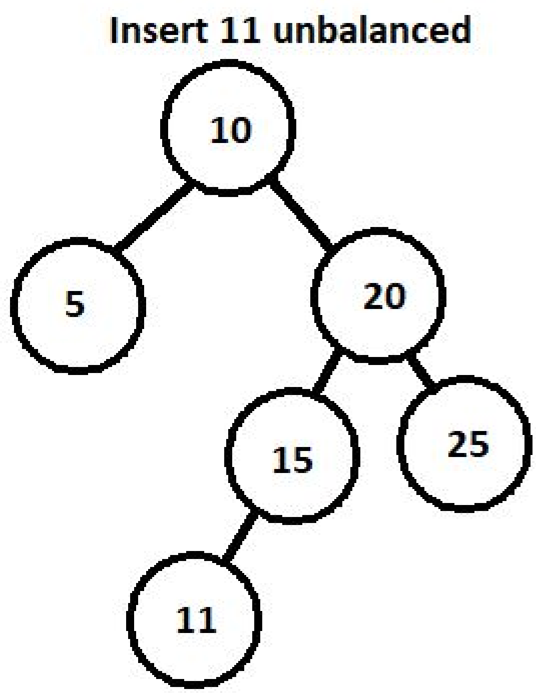
Insert(8) unbalanced



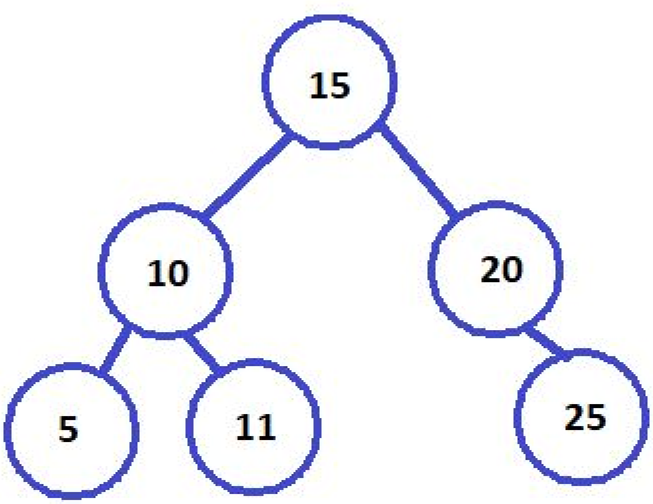


7. [3] Insert the value “11” into the following AVL tree; draw the result:

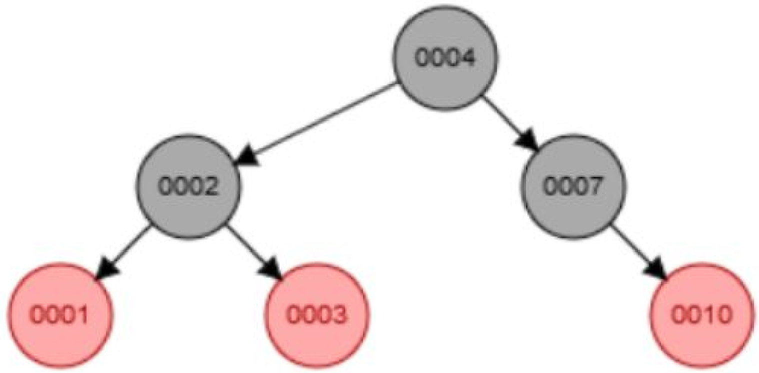




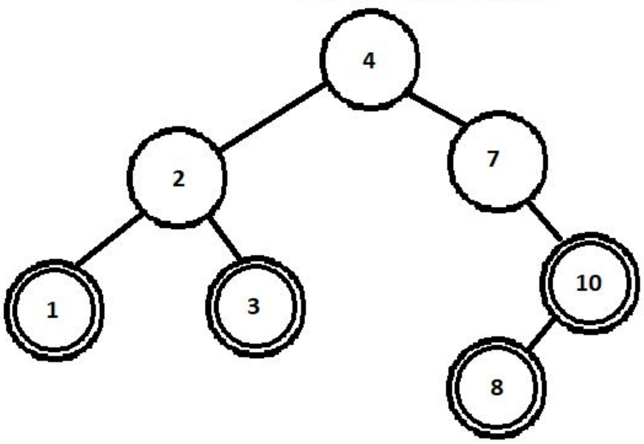
Answer In Blue.



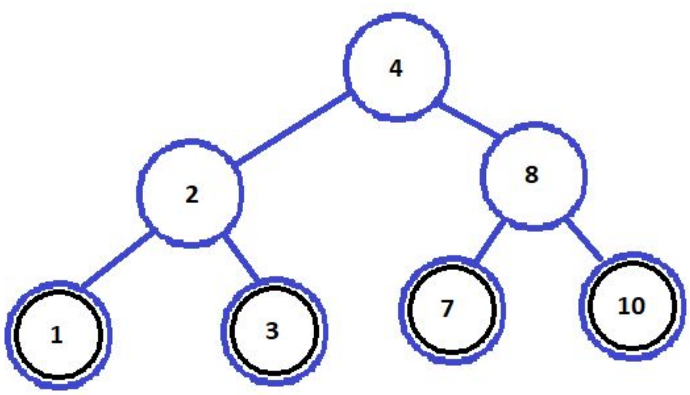
8. [3] Insert the value "8" into the following Red-Black tree; draw the result. Use Double-circle to denote red nodes and single circle to denote black nodes.



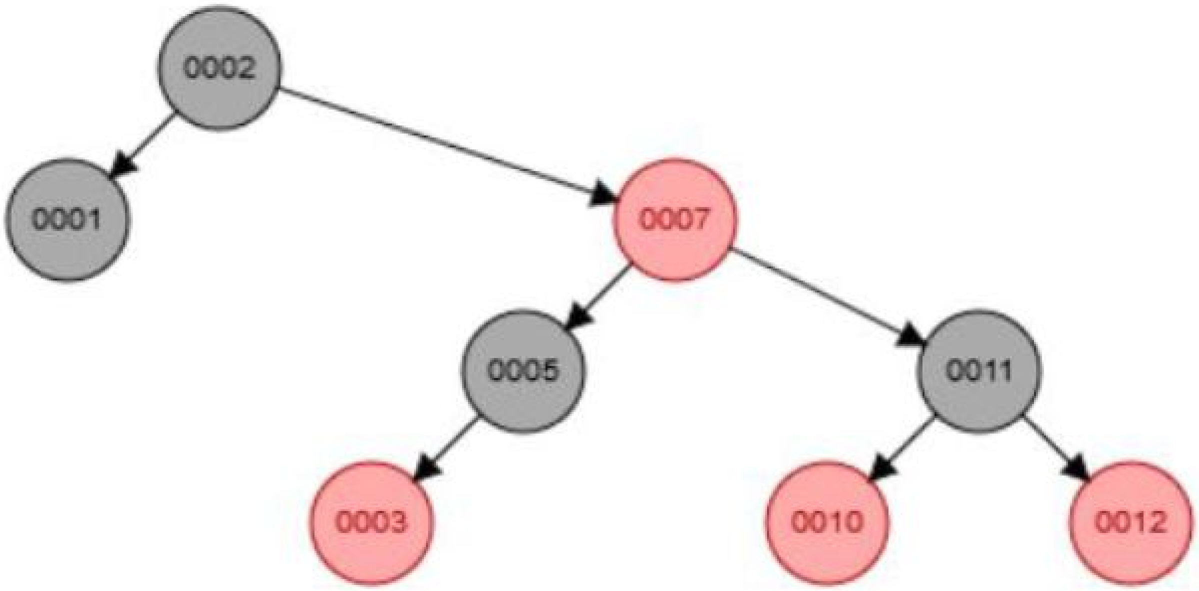
insert 8 before rotation

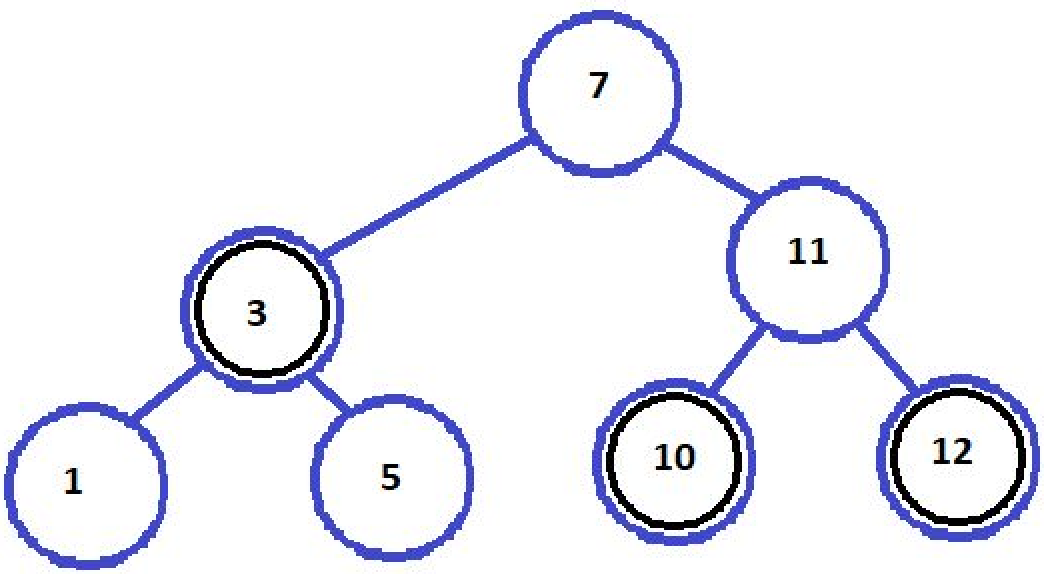


Answer in Blue

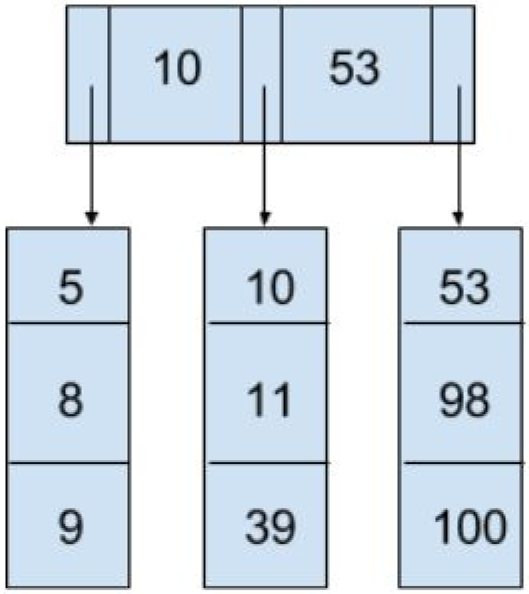


9. [3] Delete the value "2" from the following Red-Black tree; draw the result. Use Double-circle to denote red nodes and a single circle to denote black nodes.

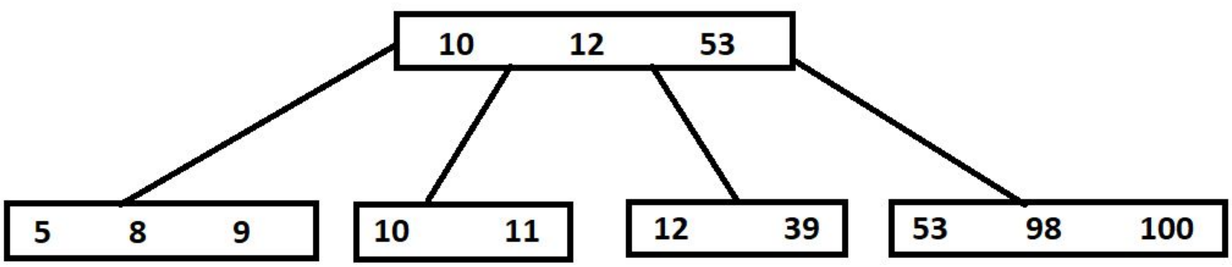




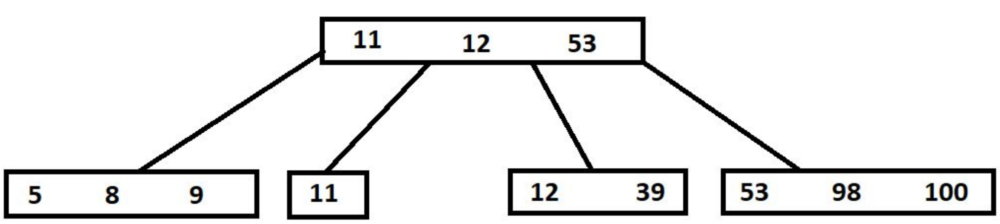
10. [4] Given the following B+ tree (M = 3, L = 3):



A) Insert 60 into the tree and draw the resulting B+ Tree:



B) Based on the tree resulting from part (A), now remove 10 and draw the new tree:



11. [6] We are going to design our B+ Tree to be as optimal as possible for our old hard drives (since the management won't buy new ones, those cheapskates!). We want to keep the tree as short as we can andpack each disk block in the filesystem as tightly as possible. We also want to access our data in sorted order for printing out reports, so each leaf node will have a pointer to the next one. See figure #1 on next page for a visualization of our tree.

CPU architecture: Intel Xeon with 64 bit cores
Filesystem: Ext4 with 4KB (4096 byte) blocks
The customer records are keyed by a random UUID of 128 bits
Customer's Data record definition from the java file:

```
#include <uuid>
struct CustomerData {
       UUID uuid;   // Customer 128 bit key1
       char[32] name;// Customer name (char is 2 bytes each)2
       int ytd_sales;// Customer year to date sales
       };
```

Calculate the size of the internal nodes (M) for our B-tree:

The nodes storing the M-1 keys, with the internal nodes nodes being 4.

The size of the internal nodes in 3.

Calculate the size of the B-tree leaf nodes (L) for this tree make sure to include the pointer (note CPU architecture!) to keep the list of leaf nodes:

The size of leaf nodes is the number of keys. Which is 6 for the children.

The size of the internal nodes in 6.

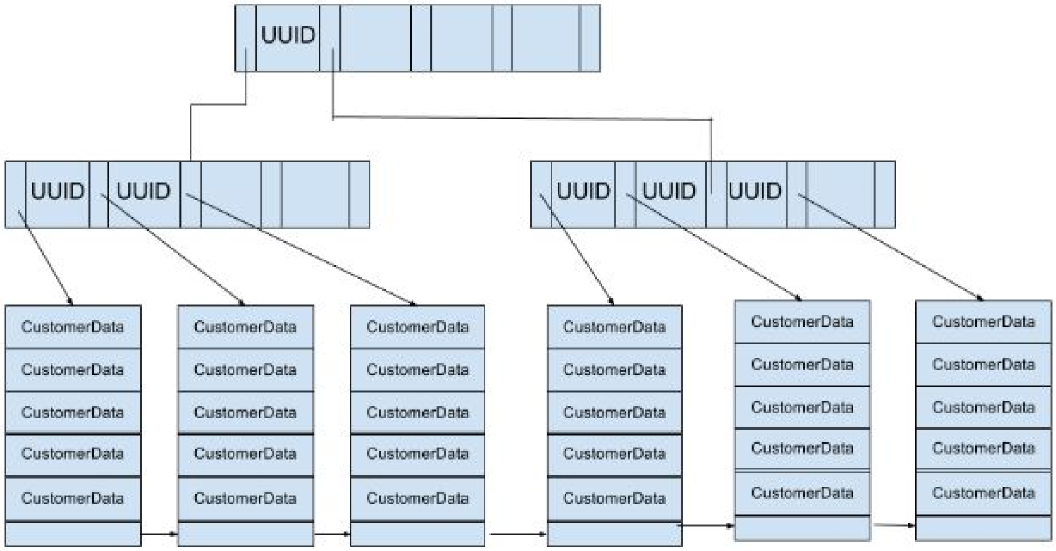


Figure #1: Visualization of our B+ Tree of height 2, customer data records, and pointers between the leaf nodes.

How tall (on average) will our tree be (in terms of M) with N customer records?

Since the tree can hold 5 pointers

25 Records:: height = 1

26-125 Records:: height = 2

126-625 Records:: height = 3

626-3125 Records:: height = 4

5^m < n <= 5^(m+1) height = m

If we insert 30,000 CustomerData records, how tall will be tree be?

n= 30000

=5^6 < 30000 <= 5^7

= 15627< 30000<=78125

Since the value is between 5^6 and 5^7 the height of the tree will be 6.

If we insert 2,500,000 customers how tall will the tree be?

n= 2,500,000

=5^9 < 2,500,000 <= 5^10

=1953125 < 2,500,000 <= 9765625

Since the value is between 5^6 and 5^7 the height of the tree will be 9.