

1. Review the following terms.

Volatile storage, Non-volatile storage  
Block (Page)

Fixed-length record  
Variable-length record

Heap file organization  
Sequential file organization  
Multitable clustering file organization

B+-tree  
Leaf node, Internal node, Root node  
Search key, pointer  
Insert, Delete

Primary index (clustering index)  
Secondary index (nonclustering index)  
Dense index  
Sparse index

Hashing

**Review the slides or the textbook (Chapters 12-14).**

2. Consider the following B+tree.

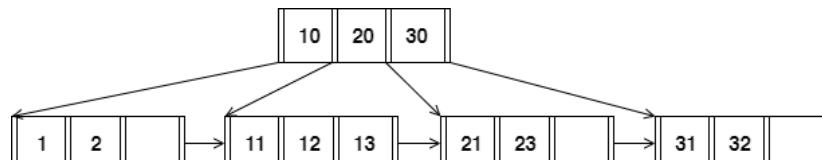


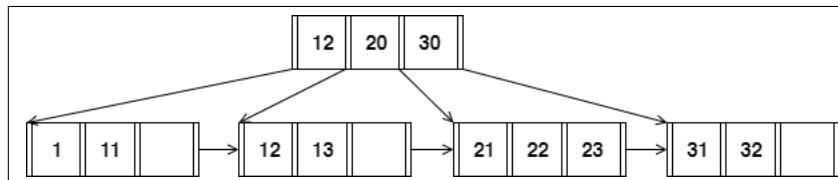
Figure: B+ Tree of degree  $n = 4$ .

When answering the following questions, be sure to follow the procedures described in class and in your textbook. You can make the following assumptions:

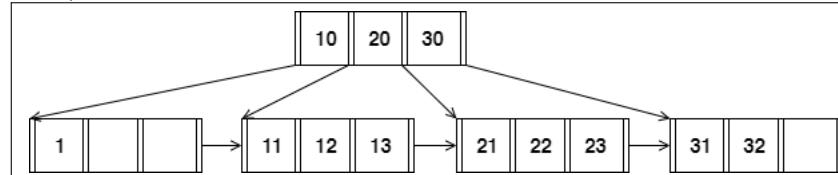
- A left pointer in a non-leaf node guides towards keys less than its corresponding key, while a right pointer guides towards keys greater than or equal to its corresponding key.
- A leaf node underflows when the number of keys goes below  $\lceil \frac{n-1}{2} \rceil$ .
- An internal node underflows when the number of pointers goes below  $\lceil \frac{n}{2} \rceil$ .

2.1 Insert 22\* into the B+tree, then delete 2\*. Select the resulting tree.

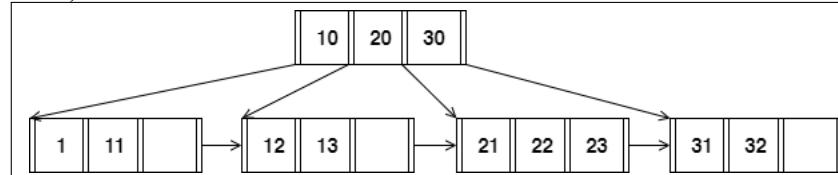
A)



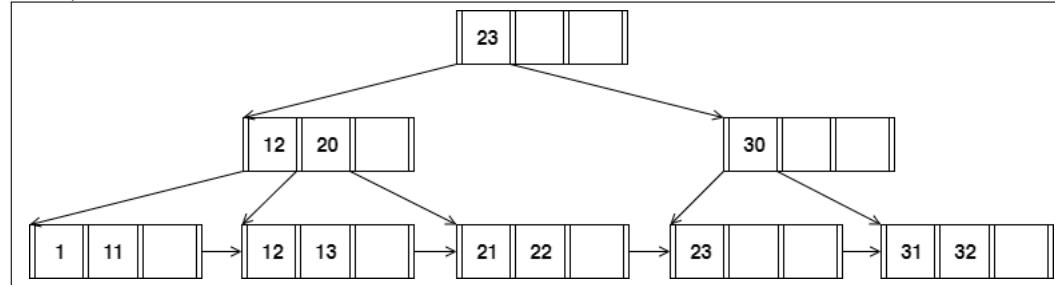
B)



C)



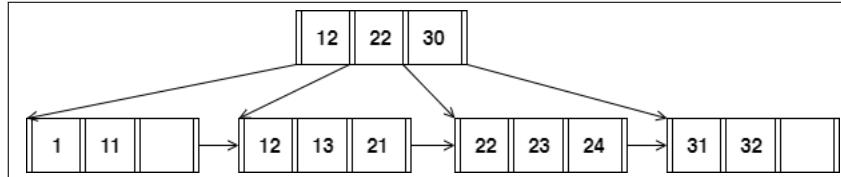
D)



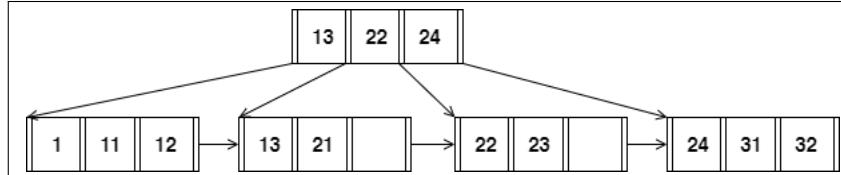
**Answer:** Insertion requires no splitting, deletion causes a redistribution.

2.2 Then Insert 24\* (based on the result in 2.1). Select the resulting tree.

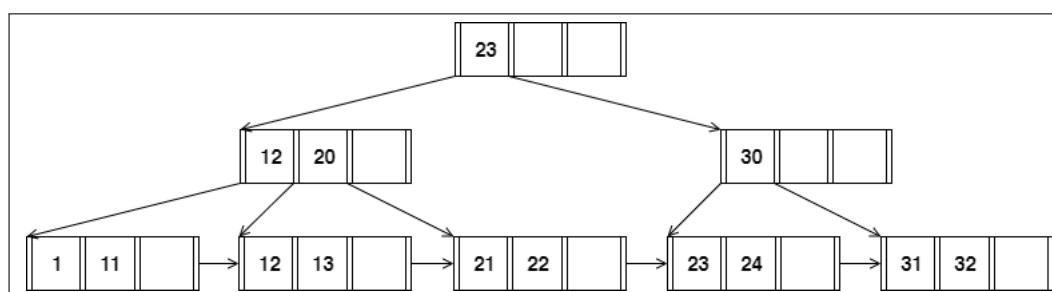
A)



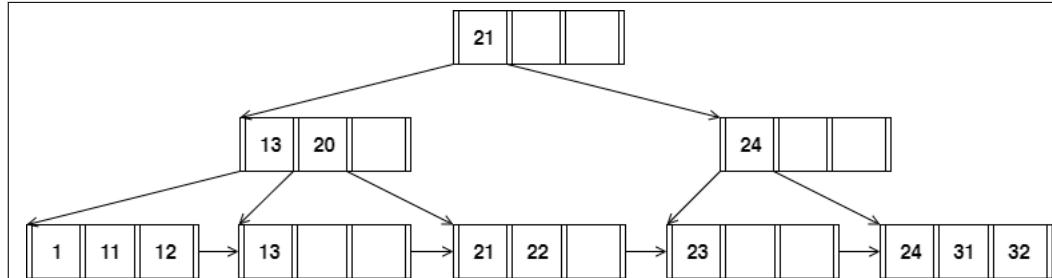
B)



C)



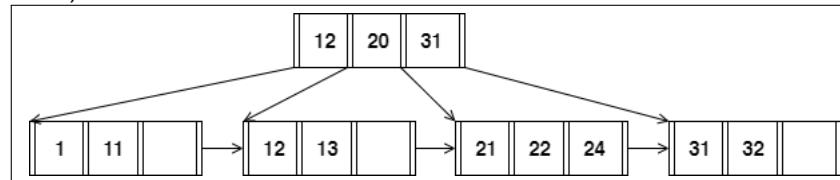
D)



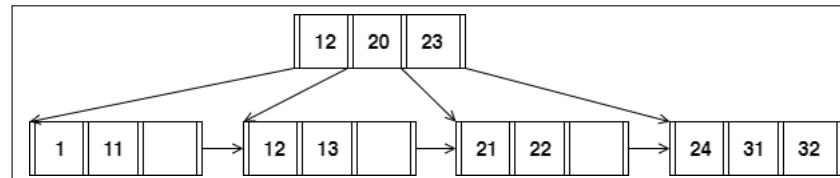
**Answer:** Insertion splits both the leaf node and the root/internal node.

2.3 Finally, delete 23\* (based on the result in 2.2). Select the resulting tree.

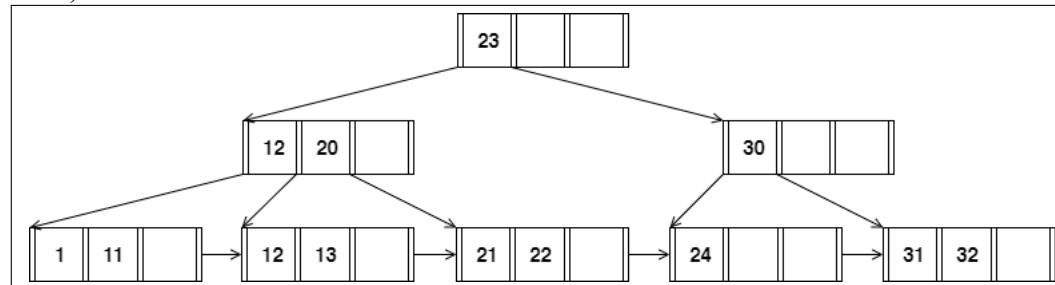
A)



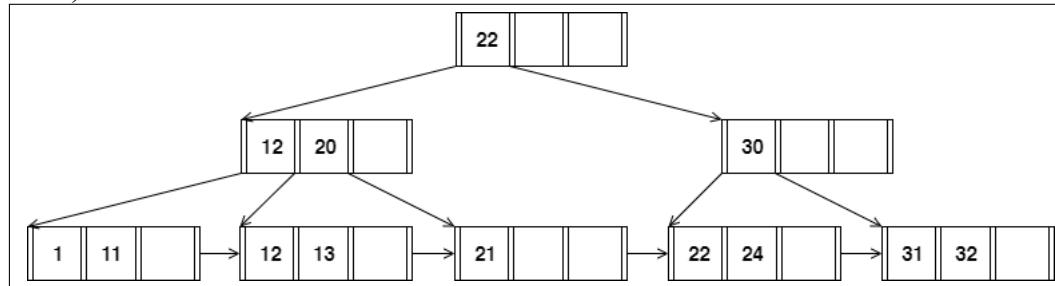
B)



C)



D)



**Answer:** Deletion merges the leaf nodes as well as the internal nodes. Root node is deleted and the merged internal node becomes the root.