

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.

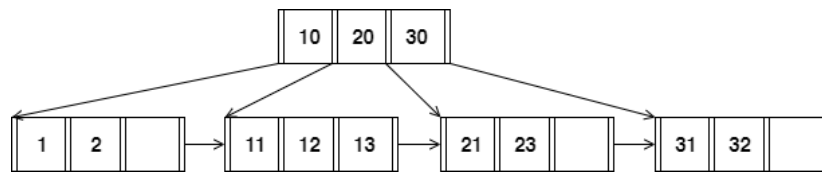


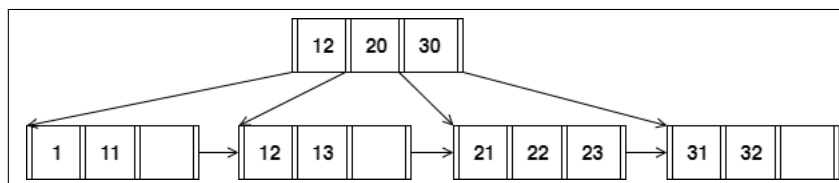
Figure: B+ Tree of degree $n = 4$.

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

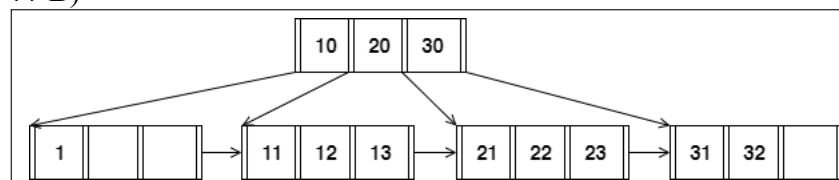
- A left pointer in a non-leaf node guides towards keys less than its corresponding key, while a right pointer guides towards keys greater than or equal to its corresponding key.
- A leaf node underflows when the number of keys goes below $\lceil \frac{n-1}{2} \rceil$.
- An internal node underflows when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

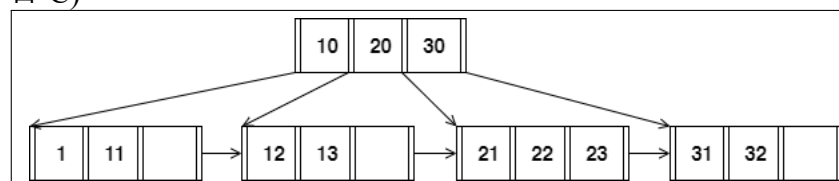
□ A)



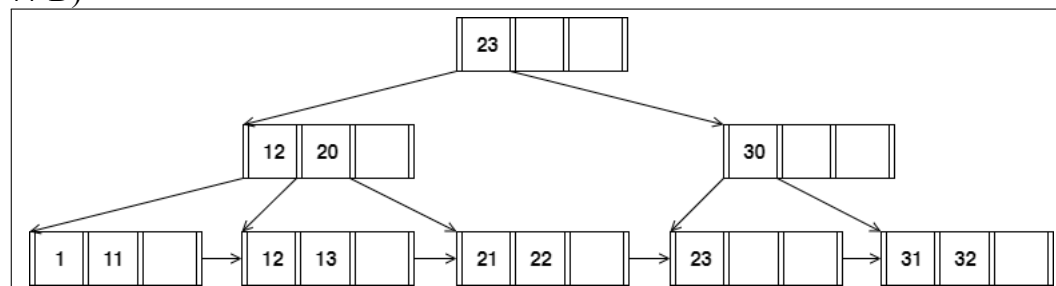
□ B)



□ C)



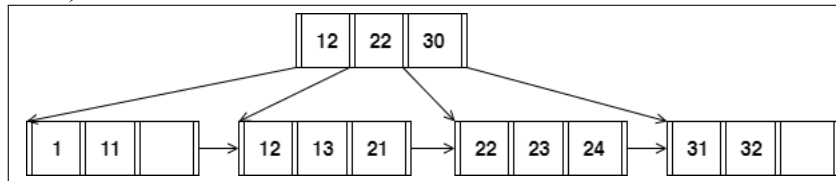
□ D)



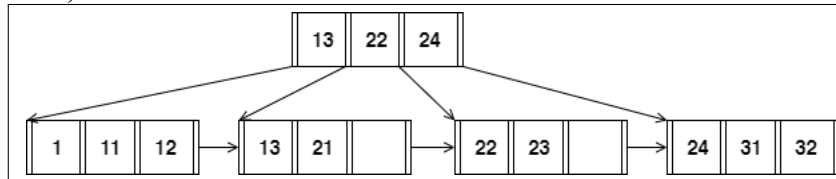
Answer: Insertion requires no splitting, deletion causes a redistribution.

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

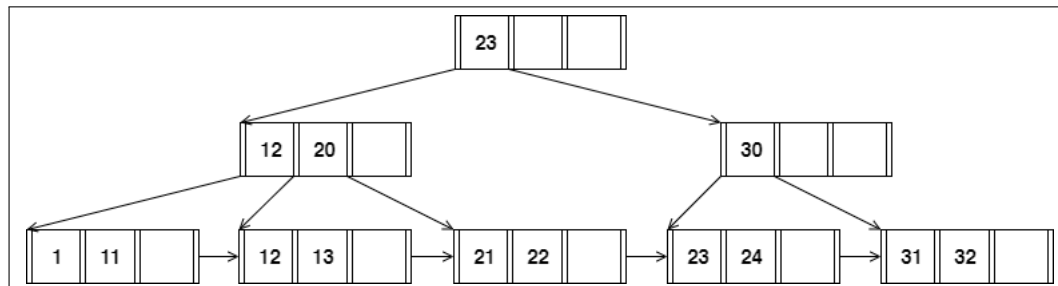
☐ A)



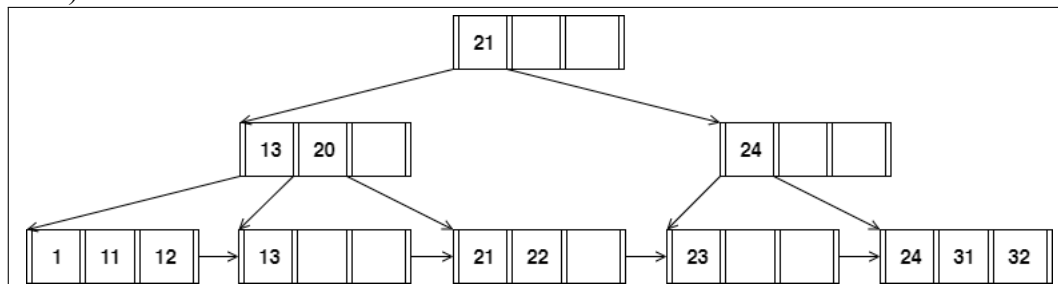
☐ B)



☒ C)



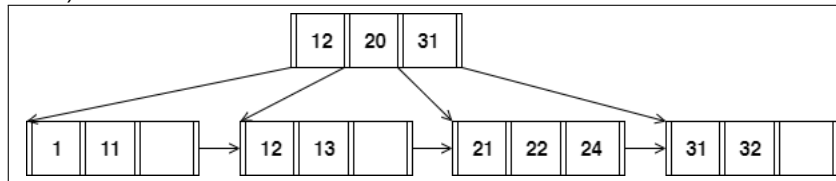
☐ D)



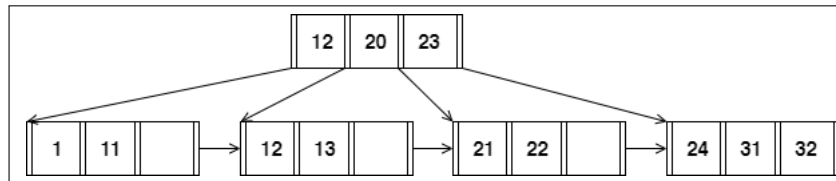
Answer: Insertion splits both the leaf node and the root/internal node.

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

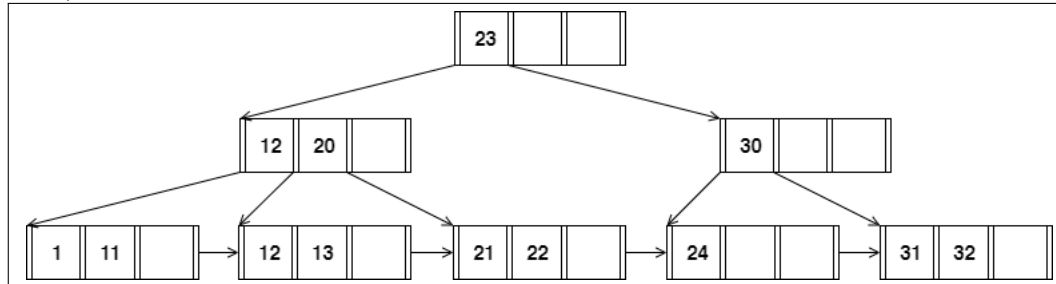
□ A)



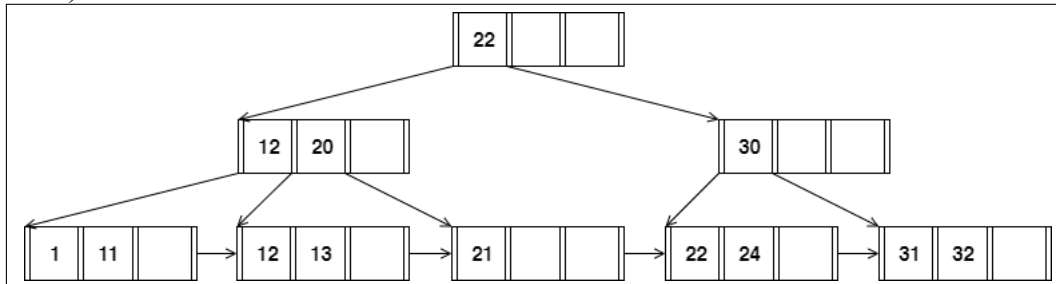
□ B)



□ 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.