Tutorial 8: Indexing Techniques

CS3402 Database Systems

Question 1

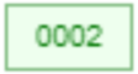
- Construct a B^+-tree for the following set of key values:

  (2, 3, 5, 7, 11, 17, 19, 23, 29, 31)

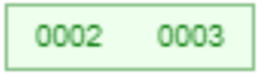
  Assuming that the tree is initially empty, values are added in ascending order, and the number of key values in internal nodes and leaf nodes are both 3 (i.e., the maximum number of tree pointers in an internal node is 4 = max. degree).

Question 1 (Answer) (1/8)

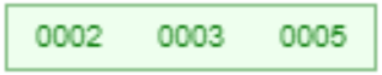
- Insert 2
  - The node has an empty space (Case 1)



- Insert 3
  - The node has an empty space (Case 1)



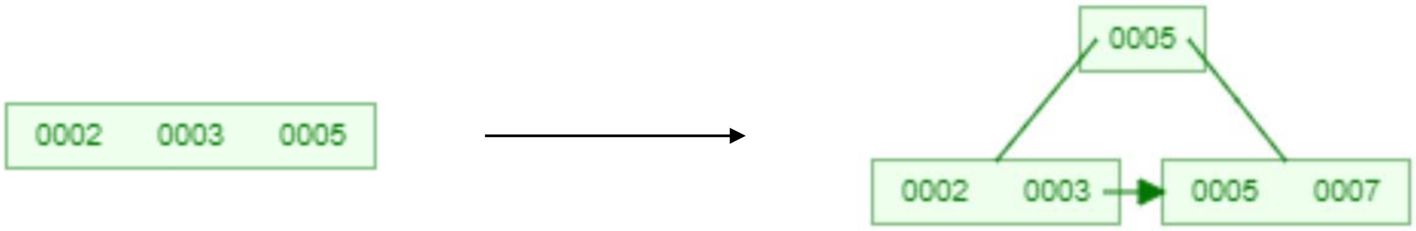
- Insert 5
  - The node has an empty space (Case 1)



B$^+$-tree visualization tool: https://www.cs.usfca.edu/~galles/visualization/BPlusTree.html

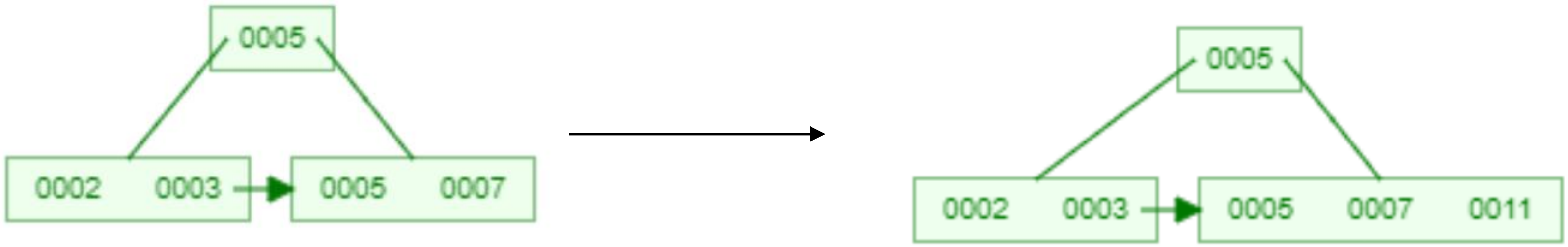
Question 1 (Answer) (2/8)

- Insert 7
  - Since the node is already full (Case 2), split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 5) and repeat the insertion algorithm to insert it into the parent node.



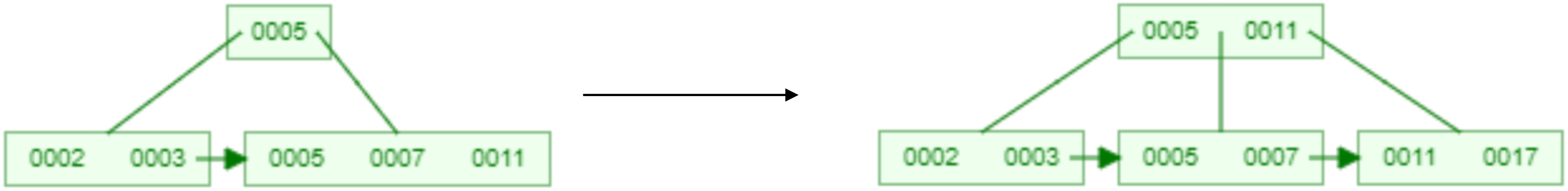
Question 1 (Answer) (3/8)

- Insert 11
  - The node has an empty space (Case 1)



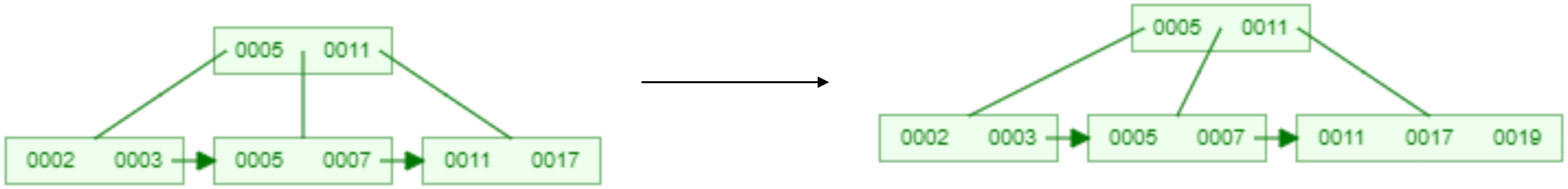
Question 1 (Answer) (4/8)

- Insert 17
  - Since the node is already full (Case 2), split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 11) and repeat the insertion algorithm to insert it into the parent node.



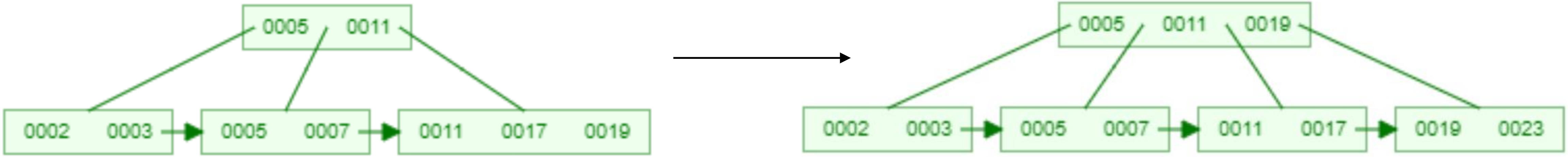
Question 1 (Answer) (5/8)

- Insert 19
  - The node has an empty space (Case 1)



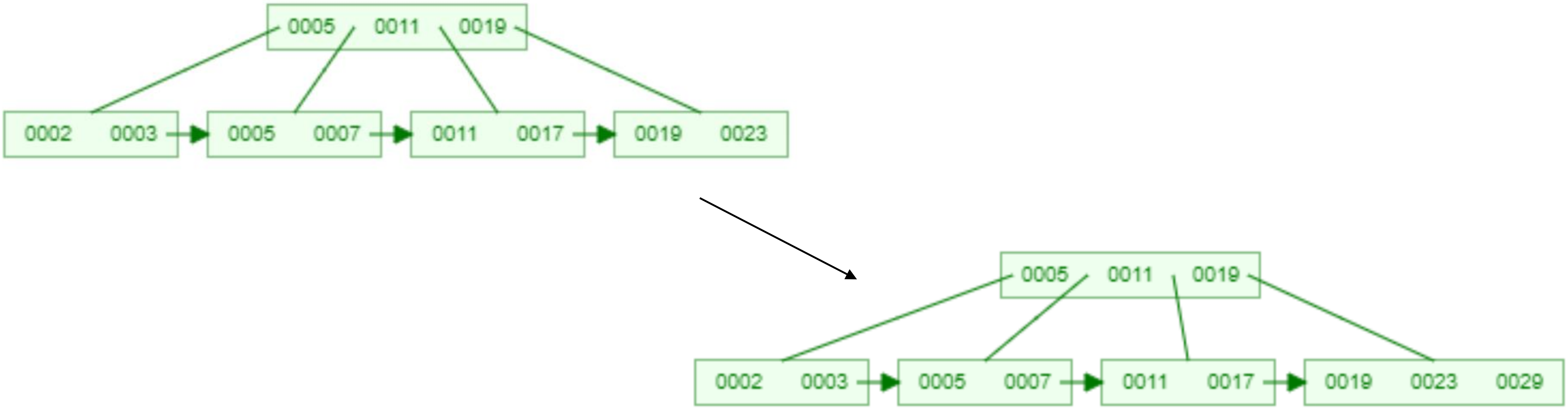
Question 1 (Answer) (6/8)

- Insert 23
  - Since the node is already full (Case 2), split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 19) and repeat the insertion algorithm to insert it into the parent node.



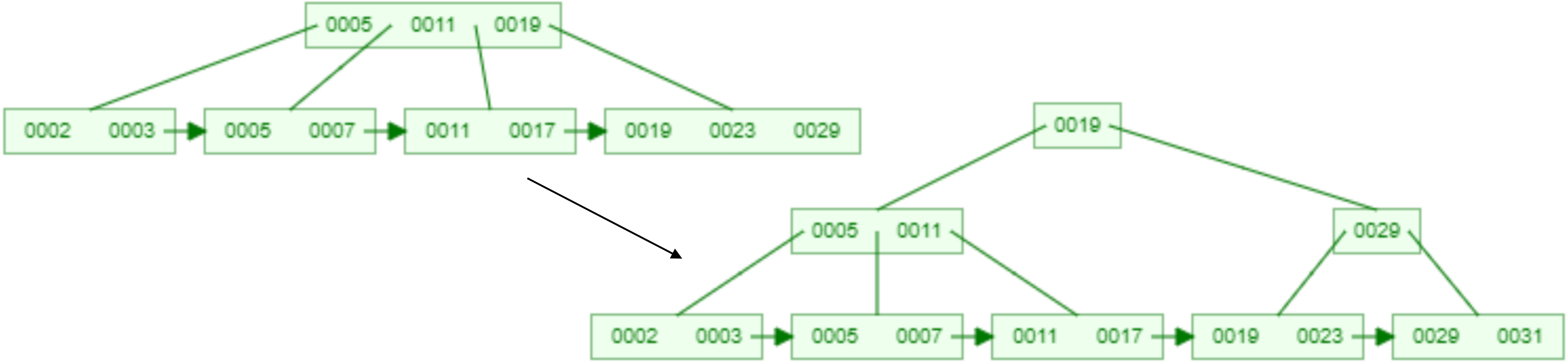
Question 1 (Answer) (7/8)

- Insert 29
  - The node has an empty space (Case 1)



Question 1 (Answer) (8/8)

- Insert 31
  - Since the node is already full, split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 29) and repeat the insertion algorithm to insert it into the parent node.
  - Since the parent node is a non-leaf, exclude the middle value (i.e., 19) during the split and repeat this insertion algorithm to insert this excluded value into the parent node (i.e., the root).

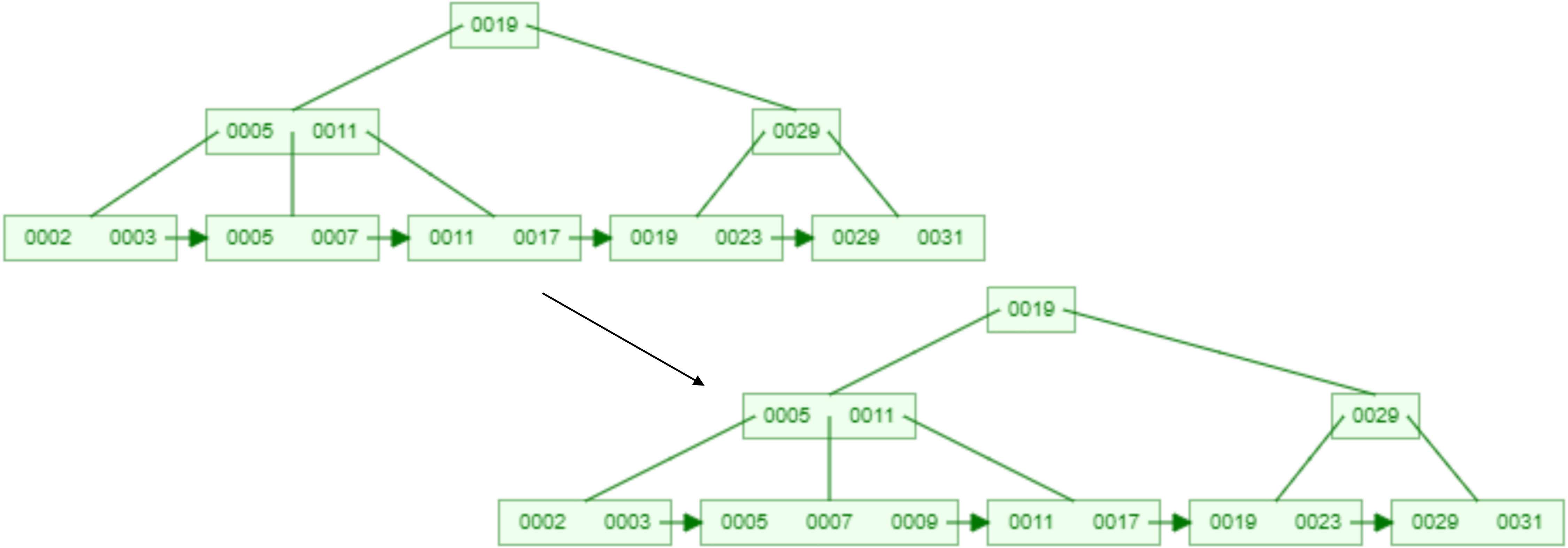


Question 2

- For the B$^+$-tree constructed for Question 1, show the form of the tree after each of the following series of operations:
  - Insert 9
  - Insert 10
  - Insert 8
  - Delete 7
  - Delete 8
  - Delete 5
  - Delete 3
  - Delete 11

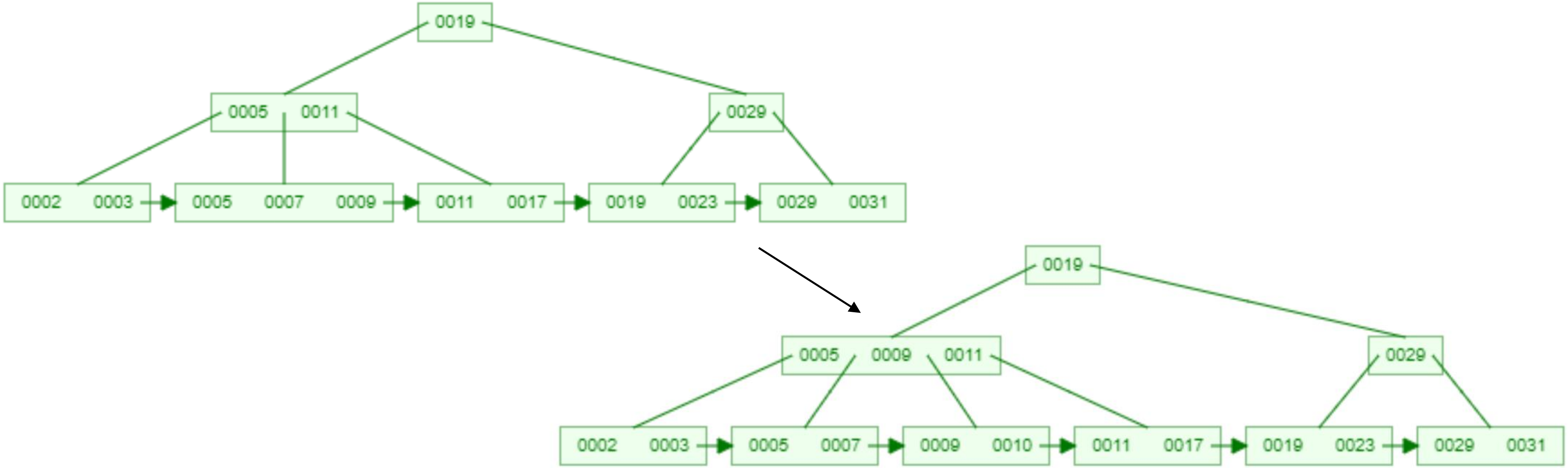
Question 2 (Answer) (1/8)

- Insert 9
  - The node has an empty space (Case 1)



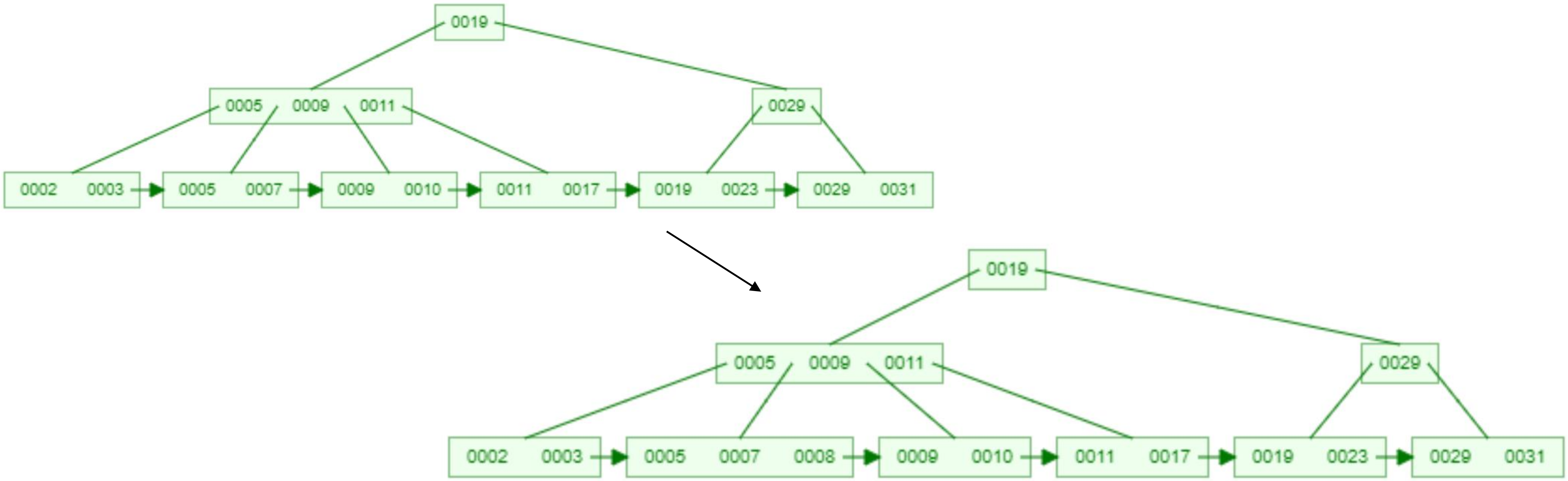
Question 2 (Answer) (2/8)

- Insert 10
  - Since the node is already full, split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 9) and repeat the insertion algorithm to insert it into the parent node.



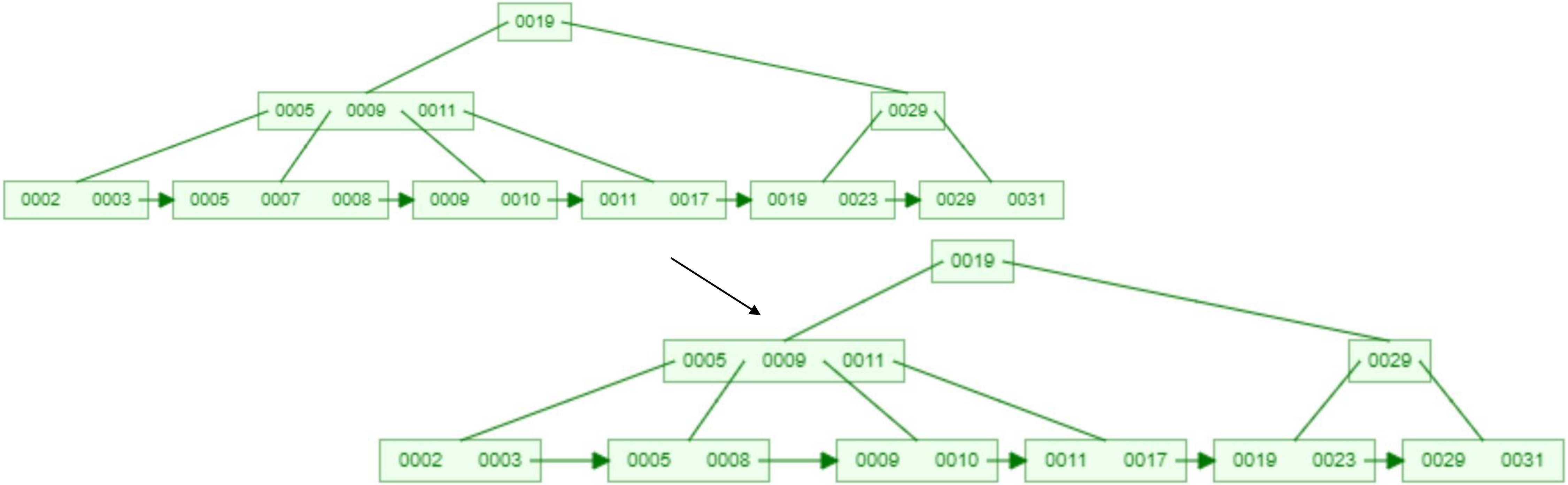
Question 2 (Answer) (3/8)

- Insert 8
    - The node has an empty space (Case 1)



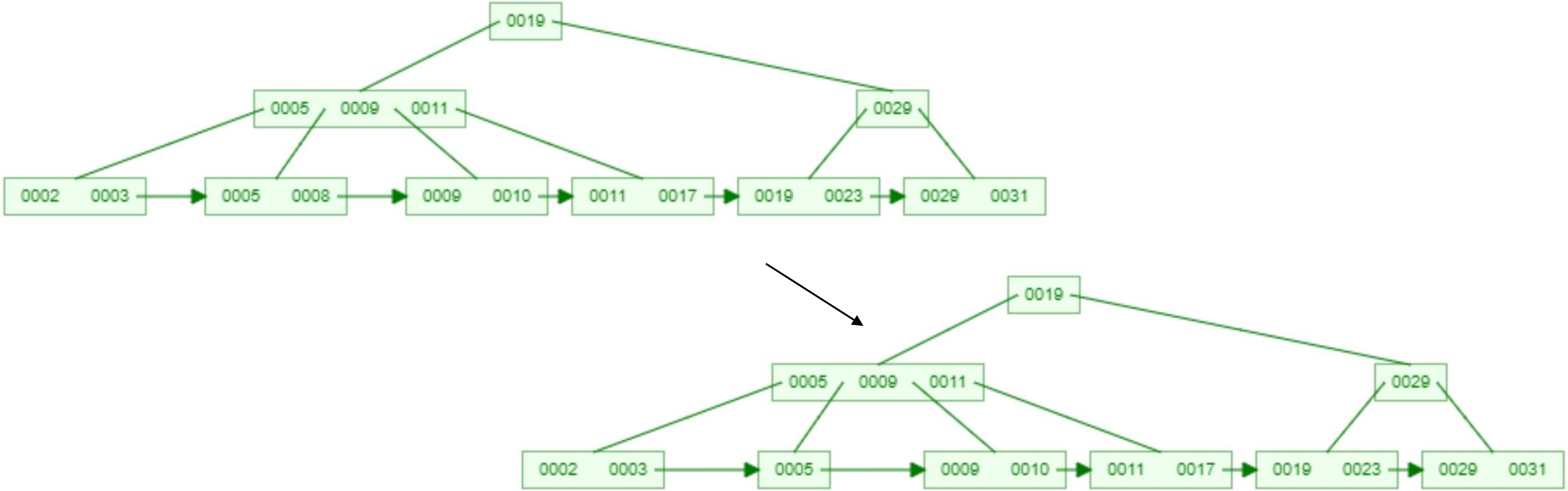
Question 2 (Answer) (4/8)

- Delete 7
  - The node still has half-full keys (Case 1)



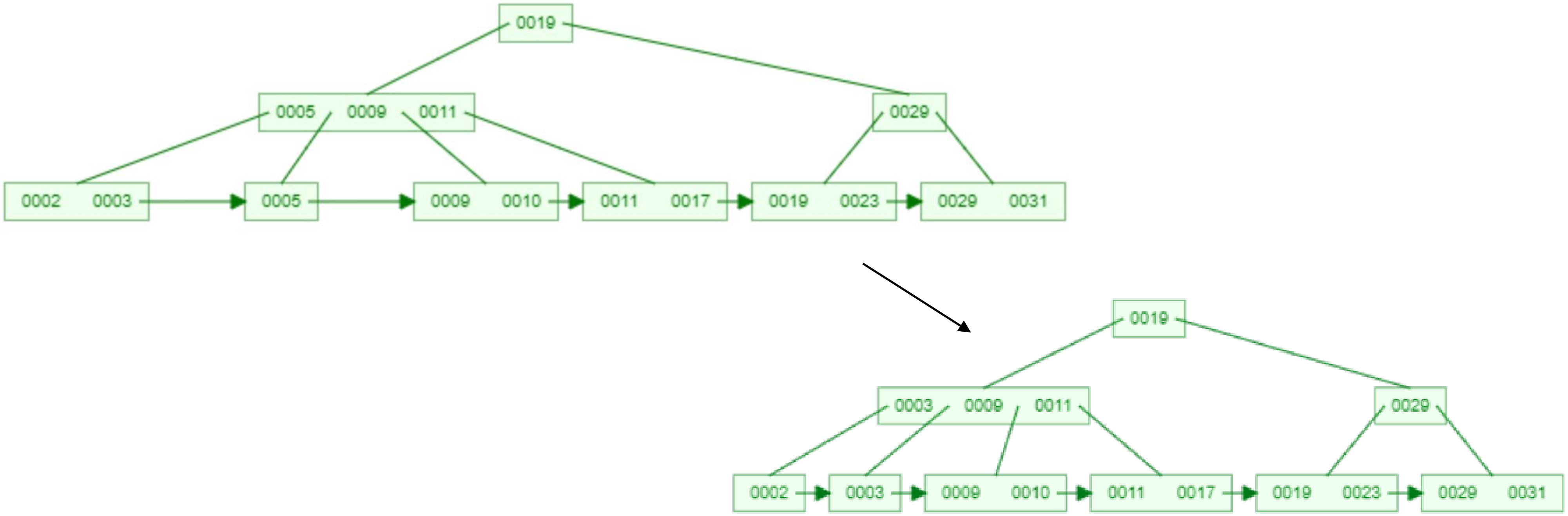
Question 2 (Answer) (5/8)

- Delete 8
  - The node still has half-full keys (Case 1)



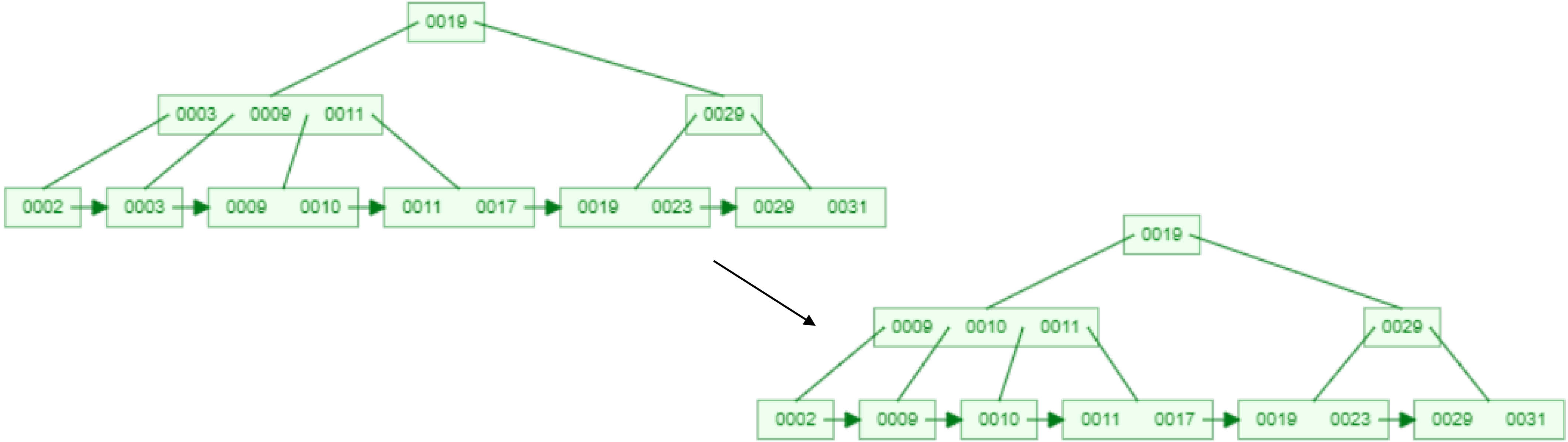
Question 2 (Answer) (6/8)

- Delete 5
  - Distribute the keys between the node and the neighbour (Case 2). Repair the keys in the levels above.



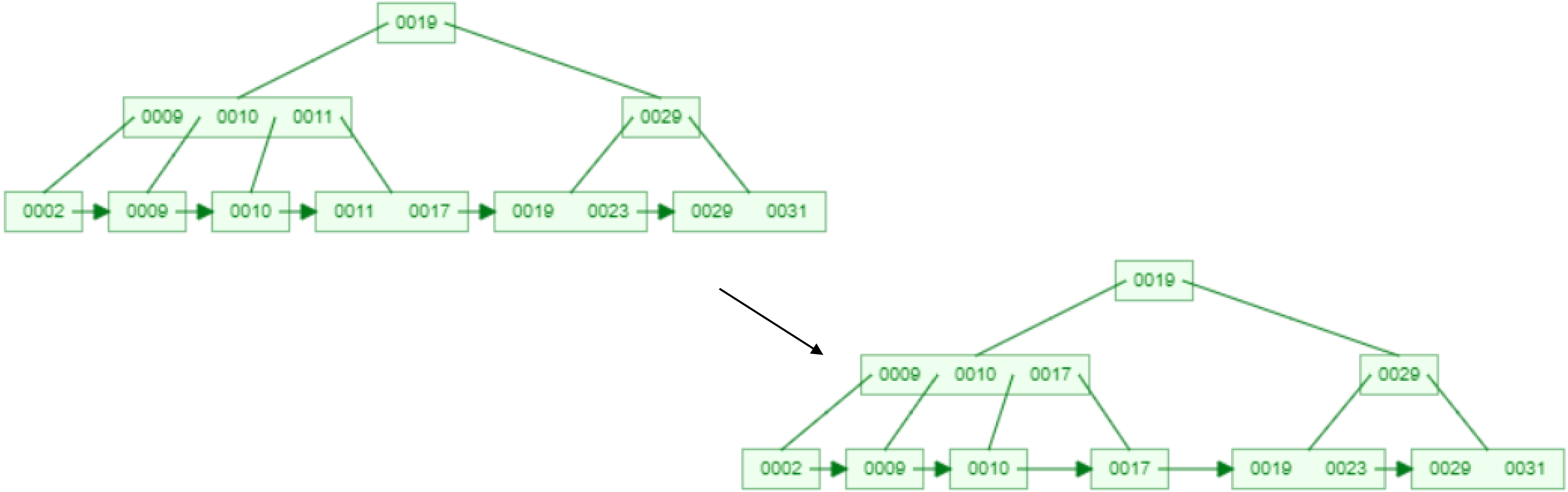
Question 2 (Answer) (7/8)

- Delete 3
  - Distribute the keys between the node and the neighbour (Case 2). Repair the keys in the levels above.



Question 2 (Answer) (8/8)

- Delete 11
  - Distribute the keys between the node and the neighbour (Case 2). Repair the keys in the levels above.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