

# **Tutorial 8: Indexing Techniques**

## **CS3402 Database Systems**

# Question 1

- Construct a B<sup>+</sup>-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)

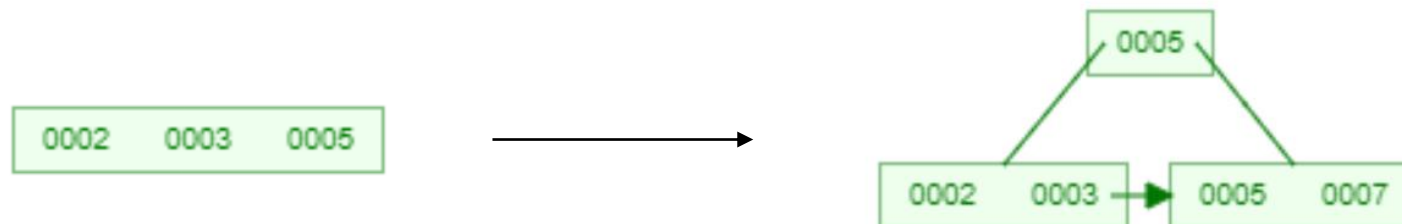
0002

0002 0003

0002 0003 0005

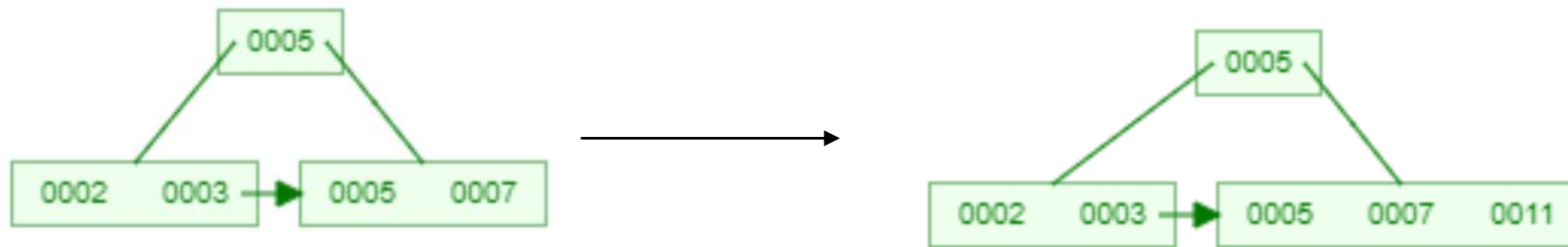
# Question 1 (Answer) (2/8)

- 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.



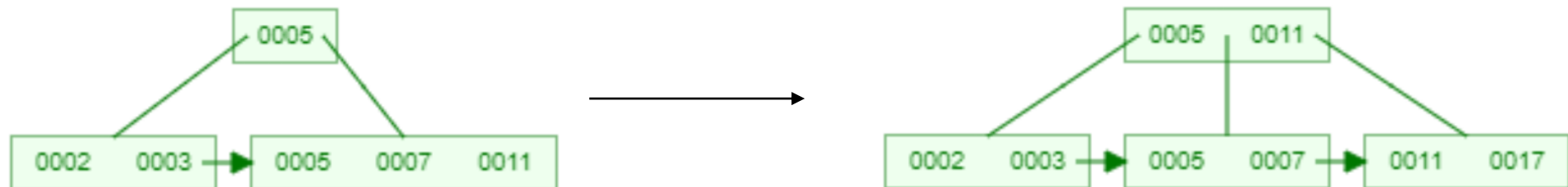
# Question 1 (Answer) (3/8)

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



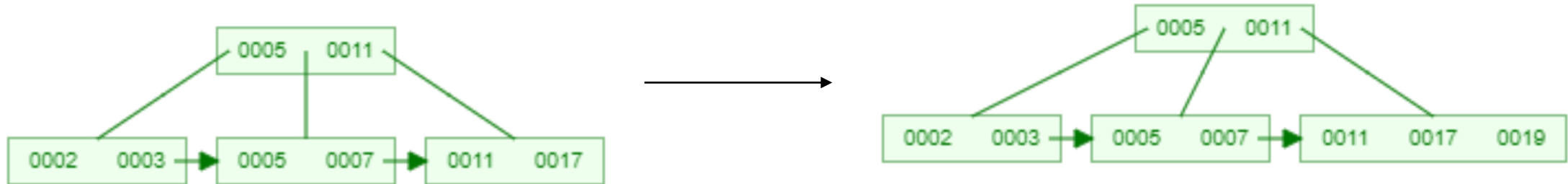
# Question 1 (Answer) (4/8)

- 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.



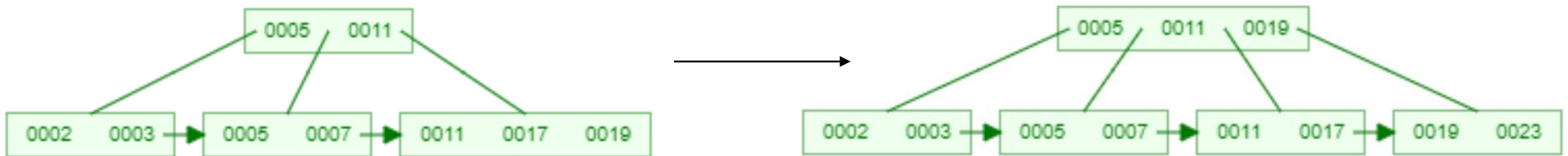
# Question 1 (Answer) (5/8)

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



# Question 1 (Answer) (6/8)

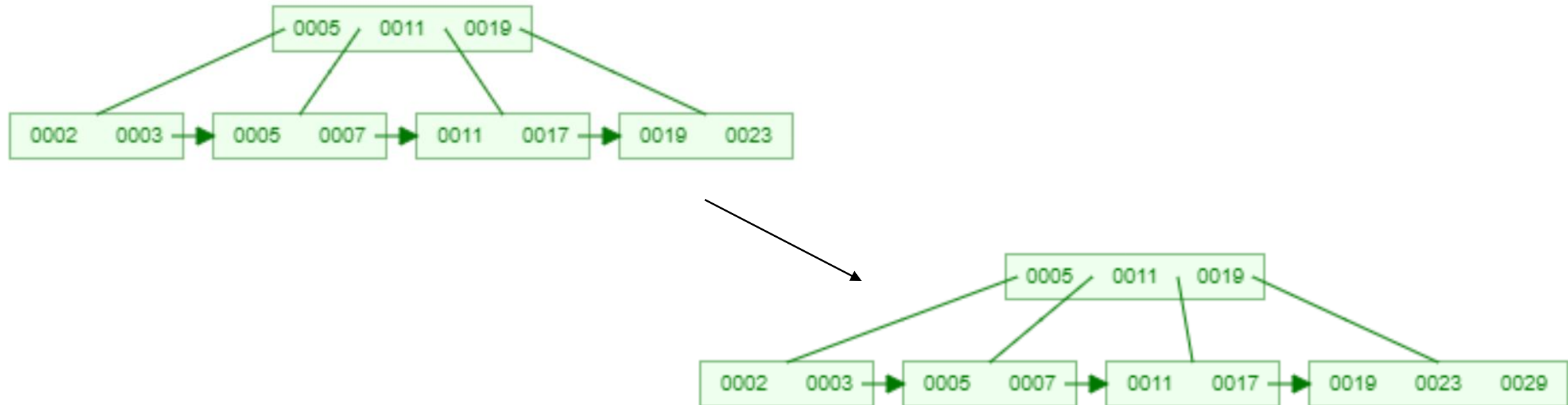
- Insert 23
  - Since the node is already full (Case 2), split it into two nodes, distributing the keys evenly between the two nodes.
  - Since the node is a leaf, take a copy of the minimum value in the second of these two nodes (i.e., 19) and repeat the insertion algorithm to insert it into the parent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





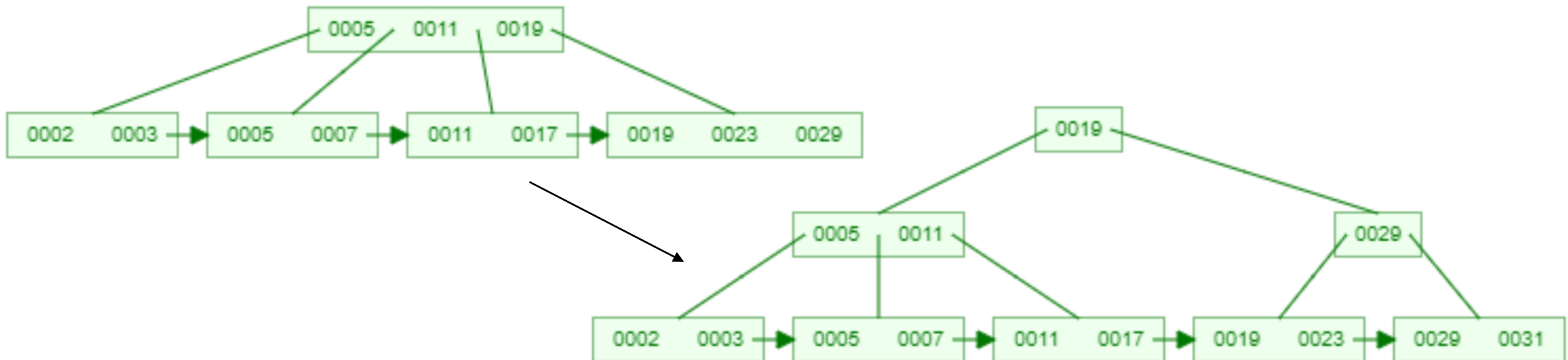
# Question 1 (Answer) (7/8)

- 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).

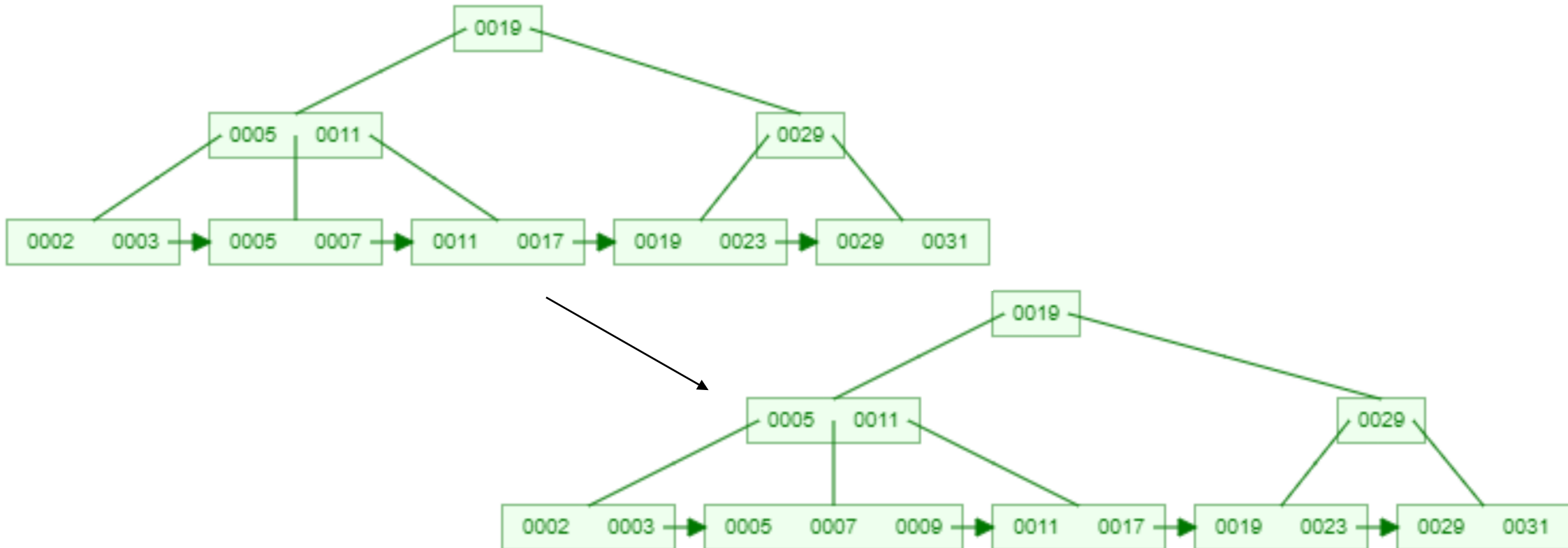


# Question 2

- For the B<sup>+</sup>-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

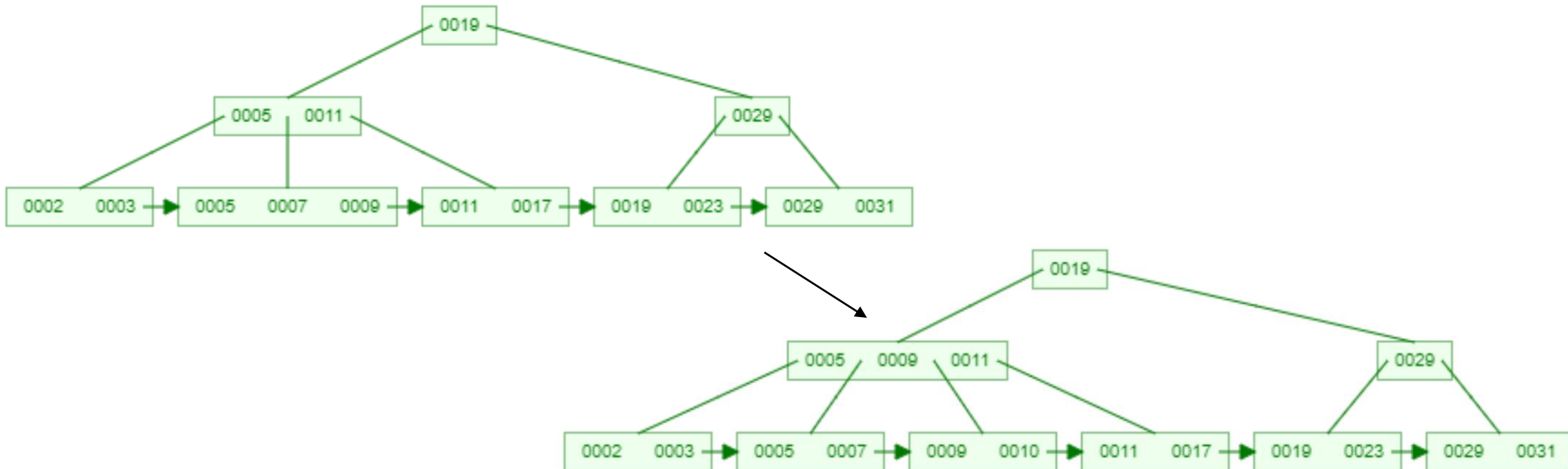
# Question 2 (Answer) (1/8)

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



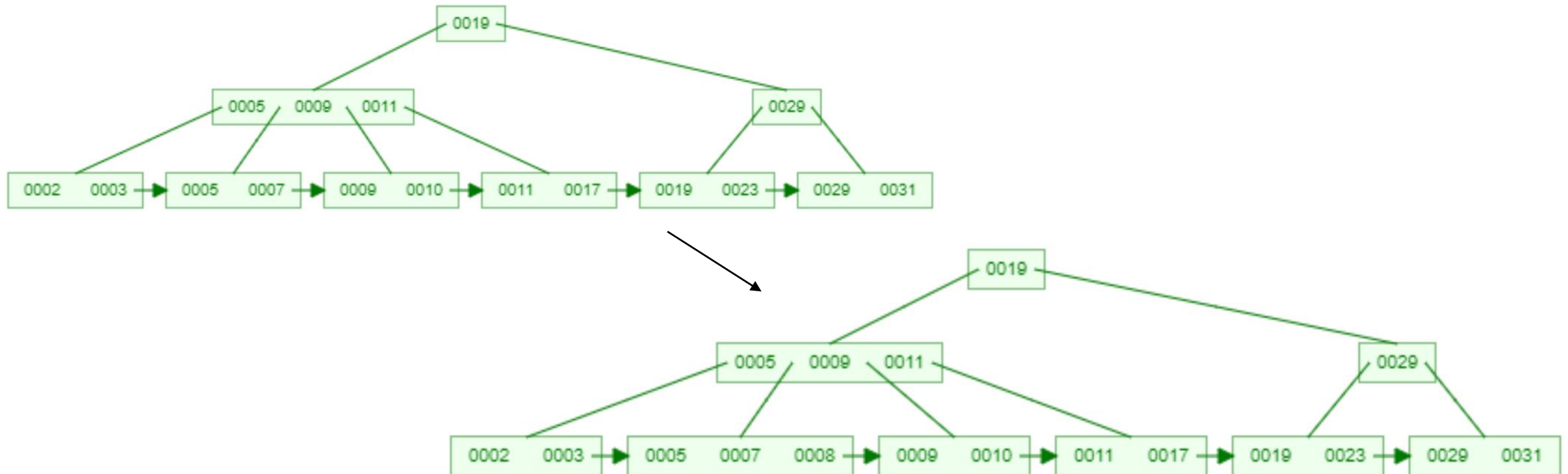
# Question 2 (Answer) (2/8)

- 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.



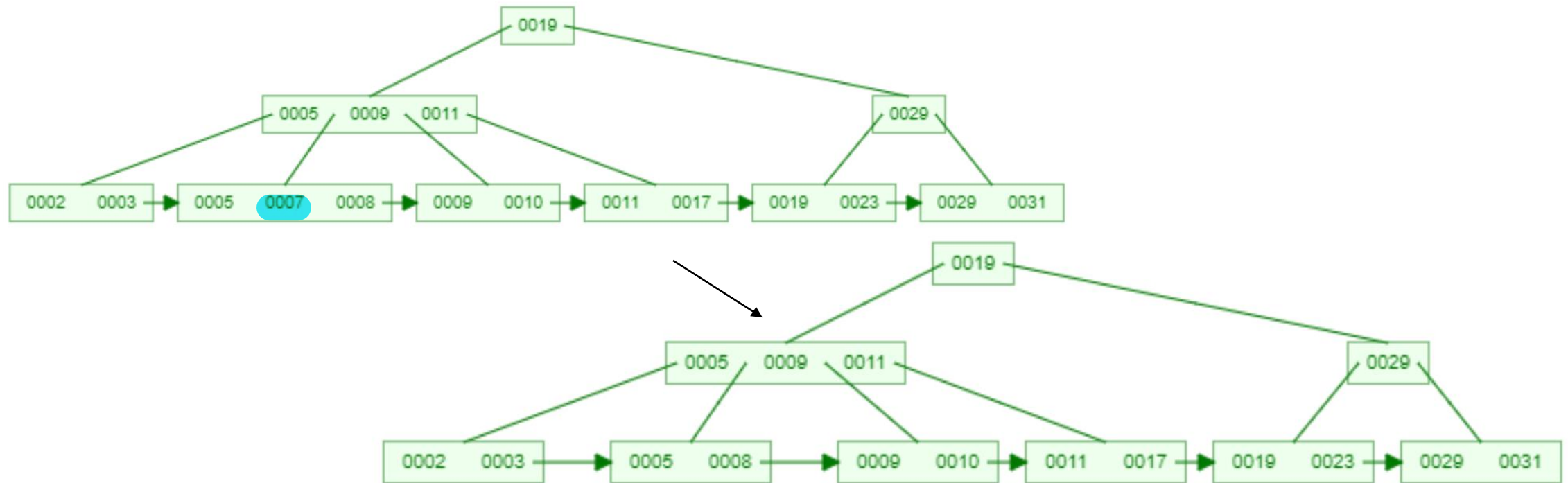
# Question 2 (Answer) (3/8)

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



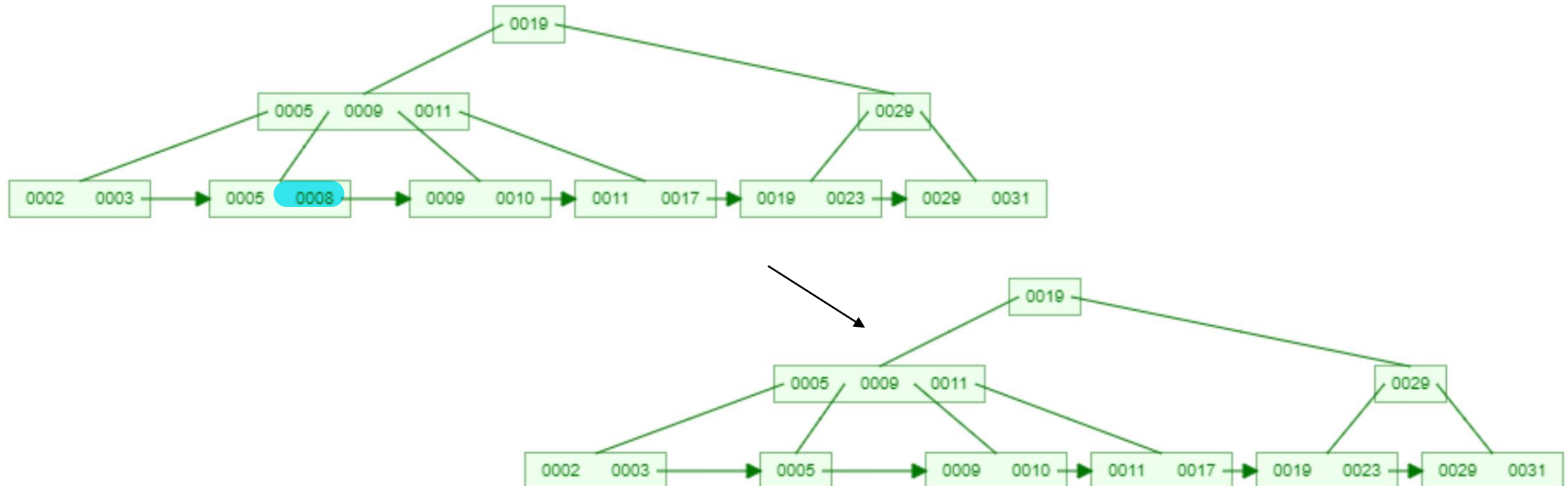
# Question 2 (Answer) (4/8)

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



# Question 2 (Answer) (5/8)

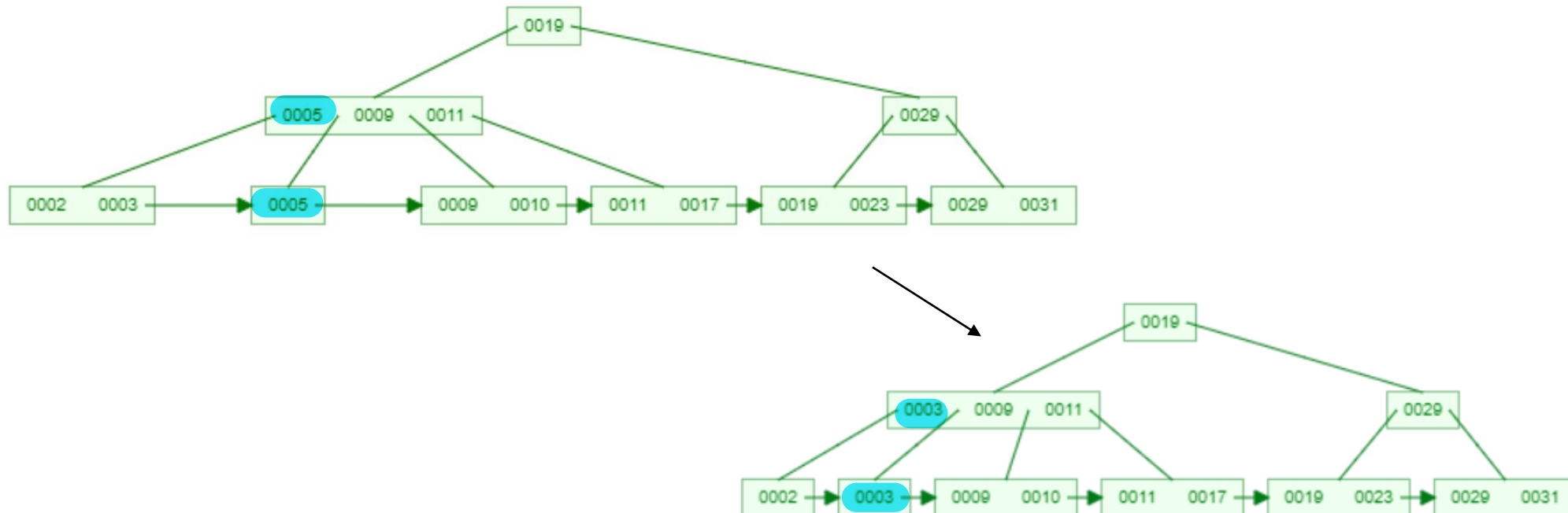
- Delete 8
  - The node still has half-full keys (Case 1)





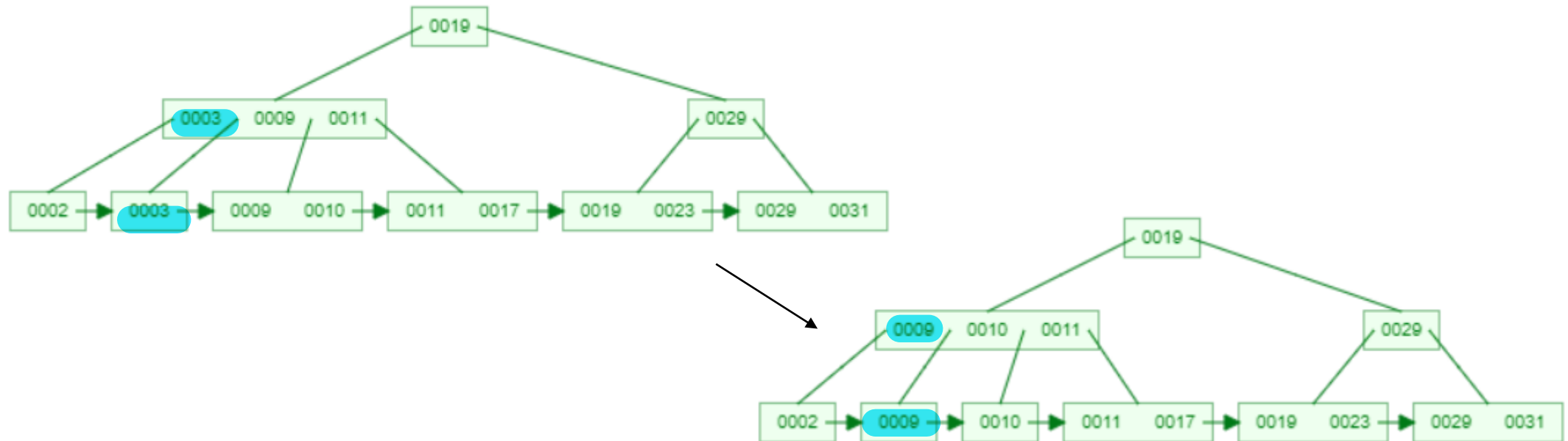
# Question 2 (Answer) (6/8)

- 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.

