BOSSCODER ACADEMY

Heap

From Root To Leaf

Swipe

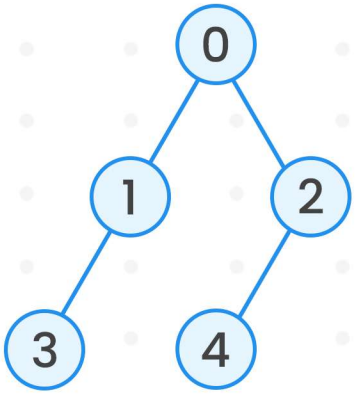
X

Ashish Gupta

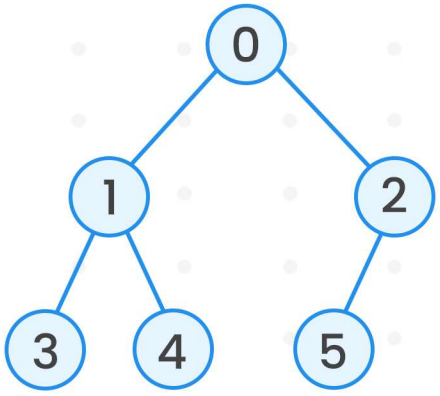
BOSSCODER ACADEMY

Complete Binary Tree – Must know before Heap

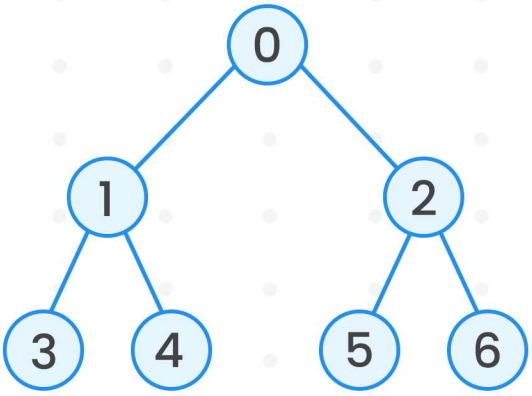
Before learning about heaps, you should know about complete binary trees.



Full Binary Tree



Complete Binary Tree



Perfect Binary Tree

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A **full binary tree** is a binary tree in which every node in the tree has exactly zero or two children except the leaves of the tree.

A **complete binary tree** is a binary tree in which every level of the binary tree is completely filled except the last level.

In the last unfilled level, the nodes are attached to the tree starting from the left.

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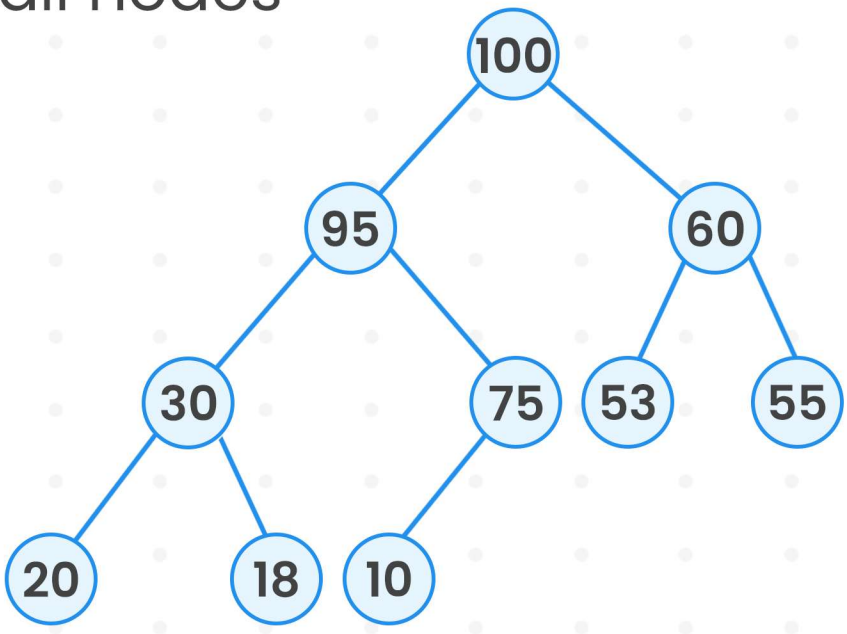
What is a heap?

A heap data structure is a complete binary tree and can be of two types:

Max Heap: Each node's value in the heap is lesser than or equal to its parent's value. This is applicable across each subsequent subtree.

The root node has the maximum value of all nodes



Maximum
Binary Tree

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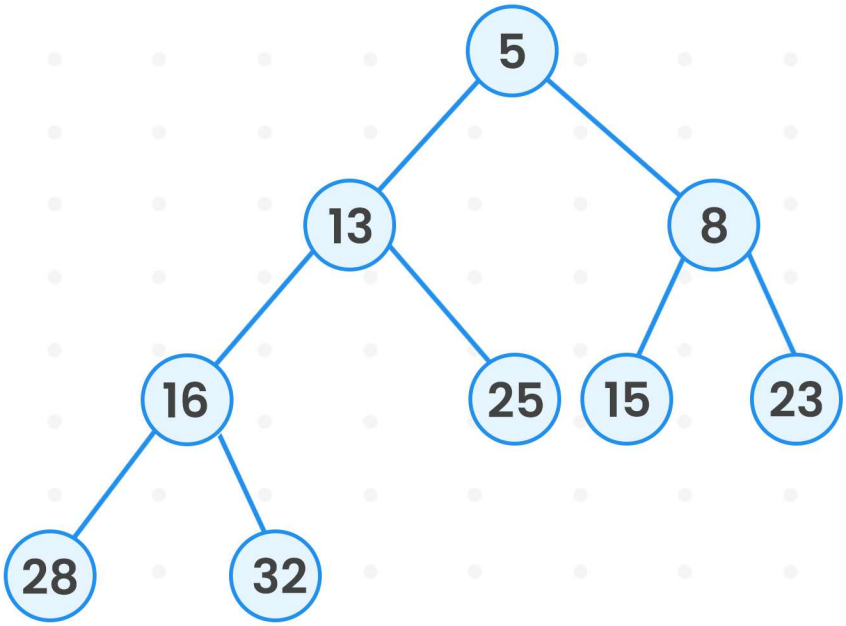
Min Heap: Each node's value in the heap is greater than or equal to its parent's value.

This is applicable across each subsequent subtree.

The root node has the minimum value of all nodes.



Minimum
Binary Tree

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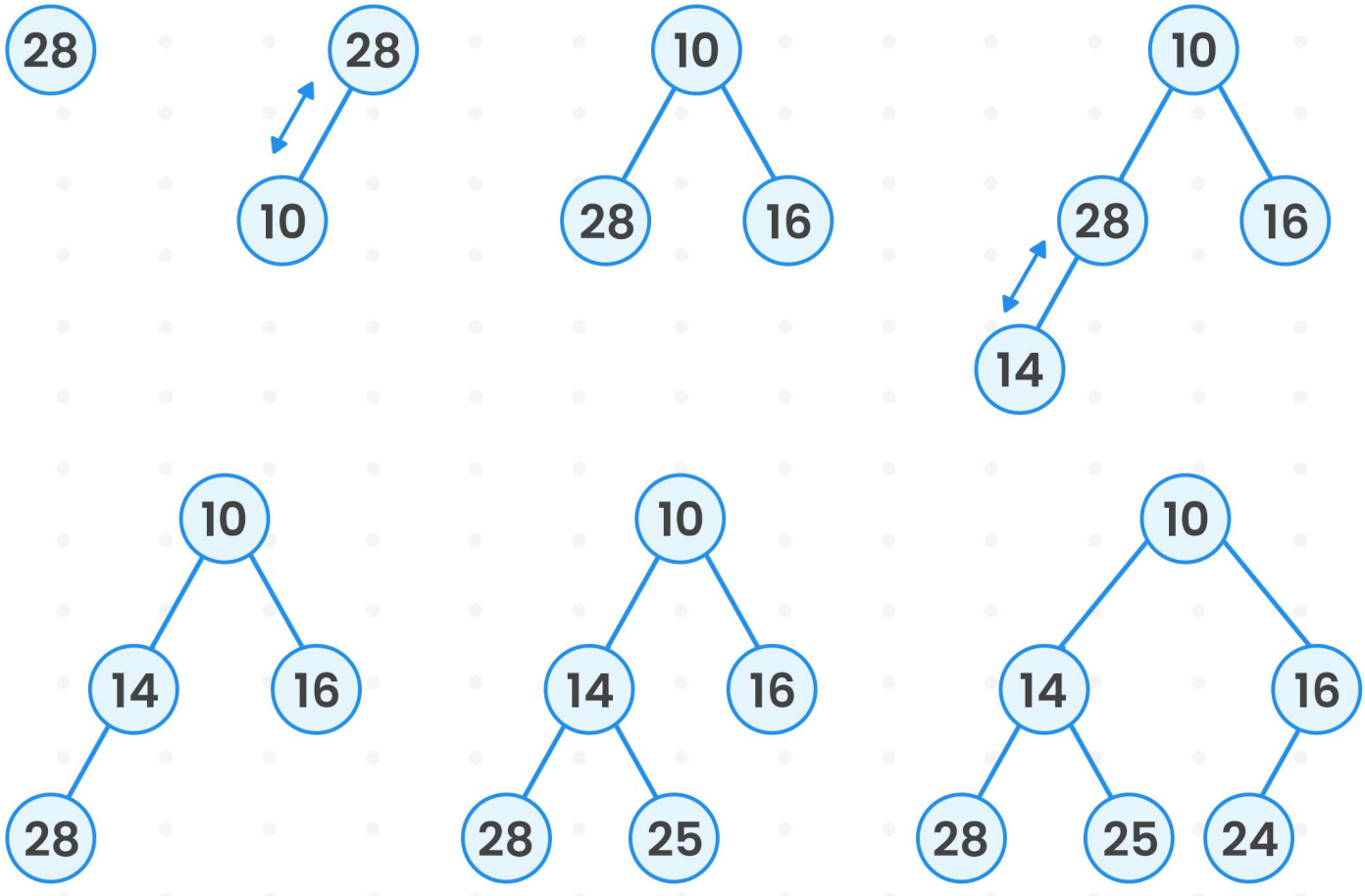
How to construct a heap?

Min Heap Construction:

Example: 28, 10, 16, 14, 25, 24, 18, 12, 22



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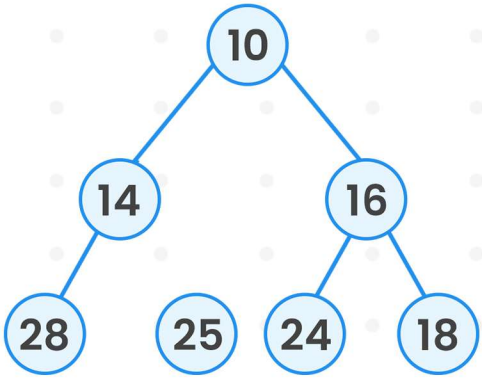

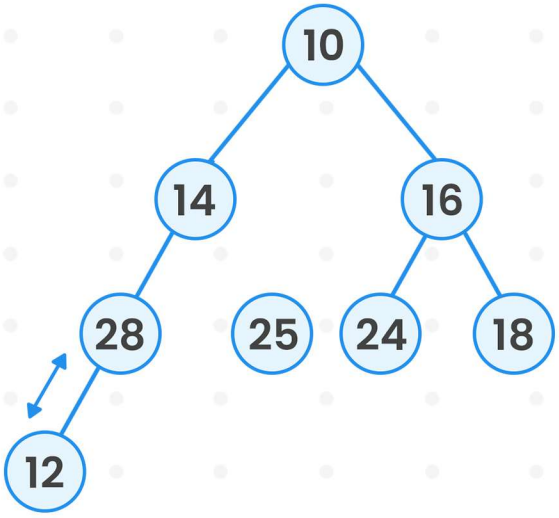

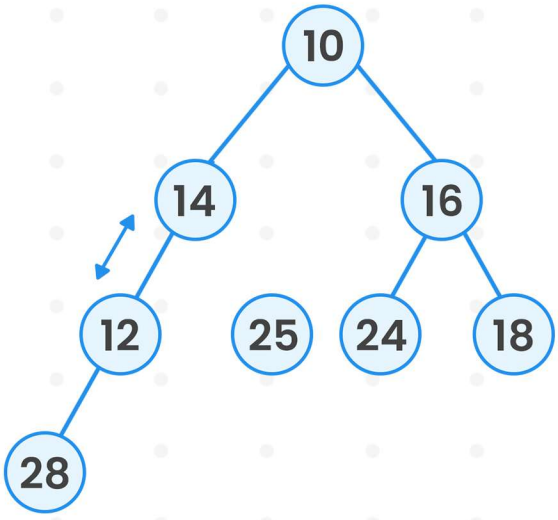

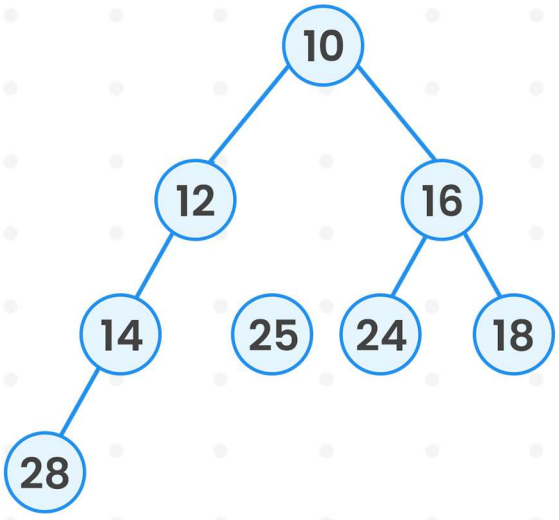

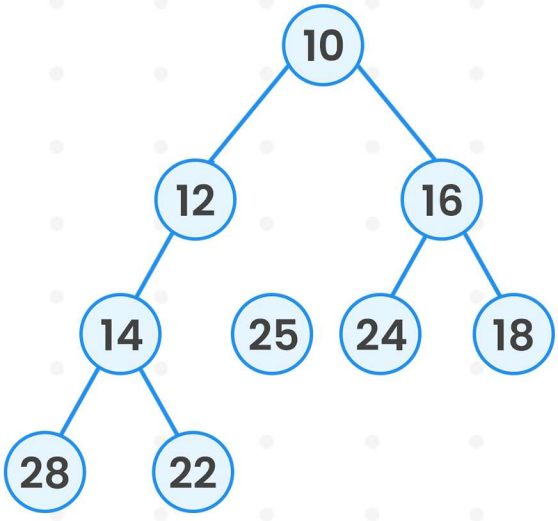

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Algorithm to construct a Min Heap

- [ ] Create a new node at the end of the heap.
- [ ] Assign value to the node.
- [ ] Compare the value of this child node with its parent.
- [ ] If the value of the parent is greater than that of the child, then swap them.

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Algorithm to construct a Max Heap

- [ ] Create a new node at the end of the heap.
- [ ] Assign value to the node.
- [ ] Compare the value of this child node with its parent.
- [ ] If the value of the parent is greater than that of the child, then swap them.
- [ ] Repeat 3 & 4 until the Heap property holds.

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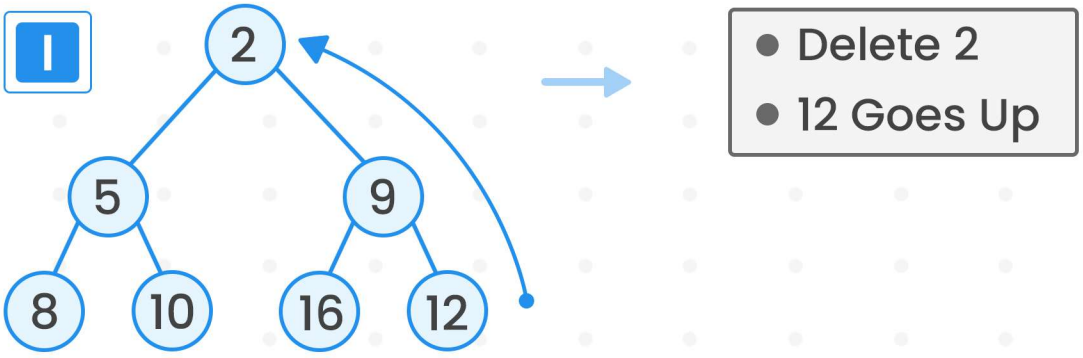
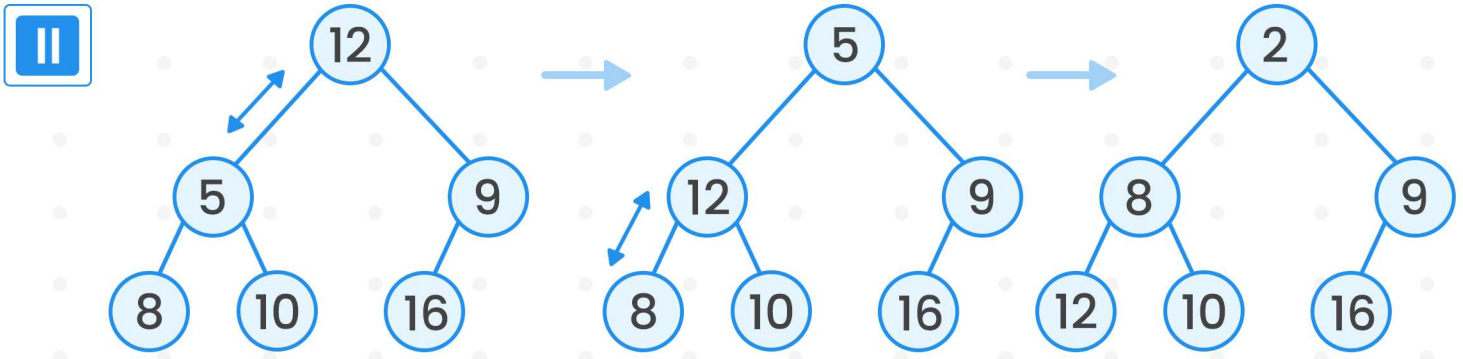
How to use a Heap?

Heaps are used to get the maximum or minimum element by deleting the root node of Max Heap or Min Heap accordingly.

Example:





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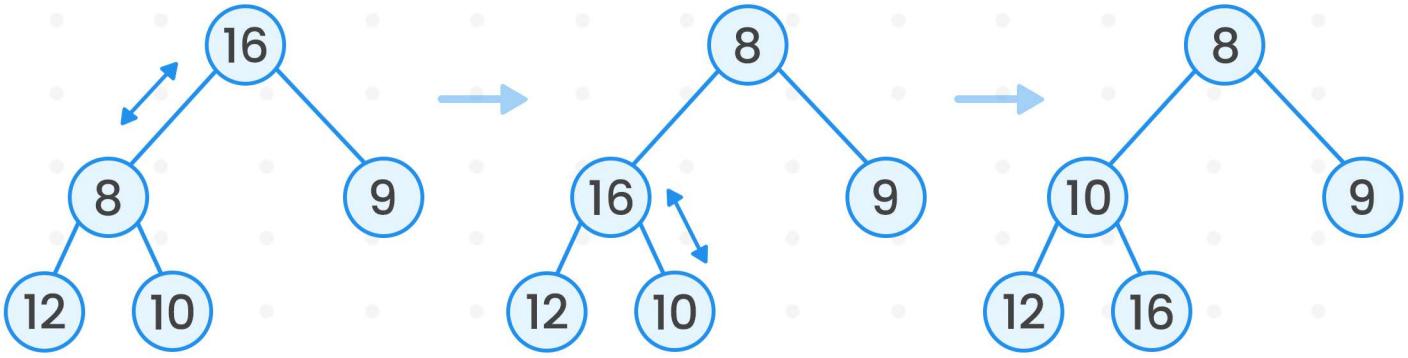
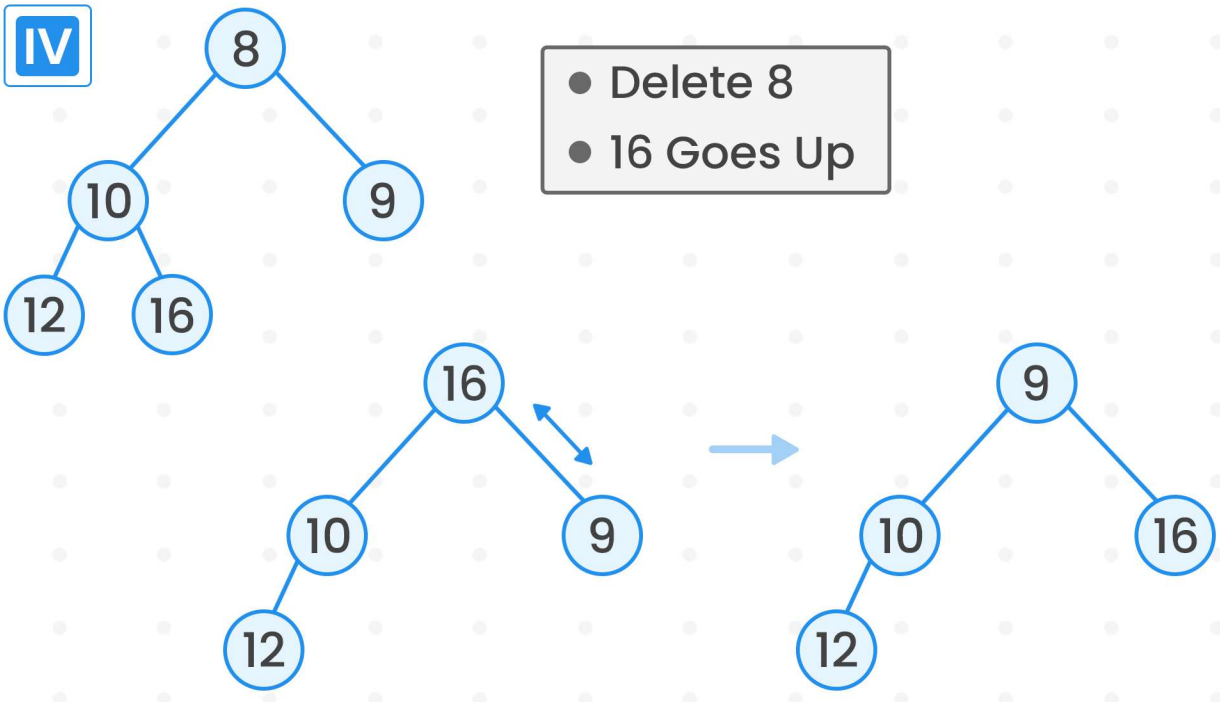
III



IV



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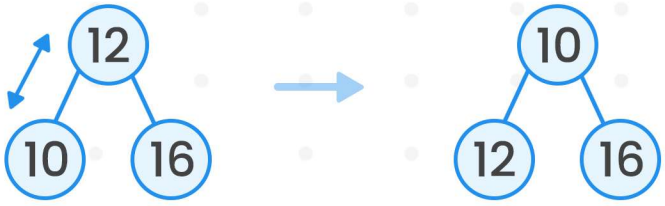
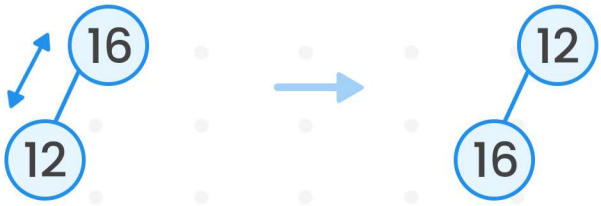
V
- Delete 9
- 12 Goes Up



VI
- Delete 10
- 16 Goes Up



VII
- Delete 12
- 16 Goes Up

VIII
- Delete 16

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Algo to Delete the Node from Min Heap

- [ ] Remove the root node.
- [ ] Move the last element of the last level to root.
- [ ] Compare the value of this child node with its parent.
- [ ] If the value of the parent is lesser than the child, then swap them.
- [ ] Repeat 3 & 4 until the Heap property holds.

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Algo to Delete the Node from Max Heap

- [ ] Remove the root node.
- [ ] Move the last element of the last level to root.
- [ ] Compare the value of this child node with its parent.
- [ ] If the value of the parent is greater than the child, then swap them.
- [ ] Repeat 3 & 4 until the Heap property holds.

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Heap Operations:

Heapify():

Consider the following min heap. Suppose we remove the root element. According to the algorithm, the last element at the last level now occupies the root position.

Heapify is used to rearrange the elements to satisfy the min heap property.

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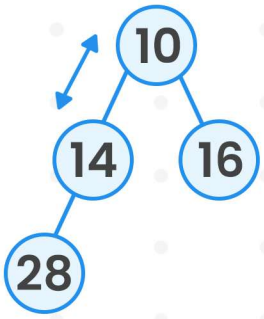
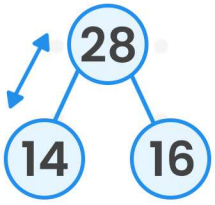
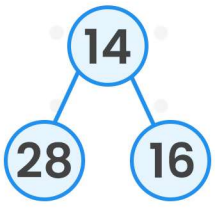
Heapify():



Removing 10
and sending 28 to root



Compare present and child
Parent > Child = Swap



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Find Max Element or Find Min Element:

This operation is used to return the maximum or minimum element in the heap. The value of the root node is returned.

In a max heap, the root node has the maximum value and in a min heap, the root node has the minimum value.

Example: In the above min heap, root node 10 is returned as the minimum element.

Remember, this operation doesn't remove the root node from the heap, rather it just returns the value of it.

Time Complexity: O(1)

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Extract Max/Extract Min():

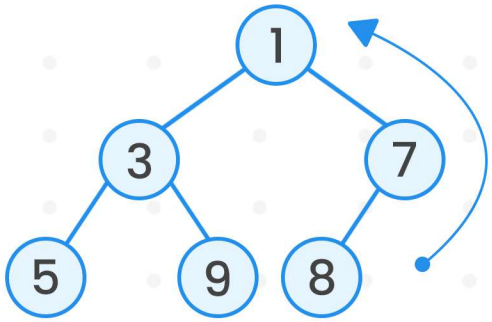
This operation deletes the respective max or min element from the heap.

Unlike FindMaxElement or FindMinElement, this operation has to rearrange the heap after deletion of the root node.

Hence it has a **time complexity of O(logn)** where n is the number of nodes in the heap.

Example:

Extracting Min Elements



Removing min elements

Copying/sending all the elements to root

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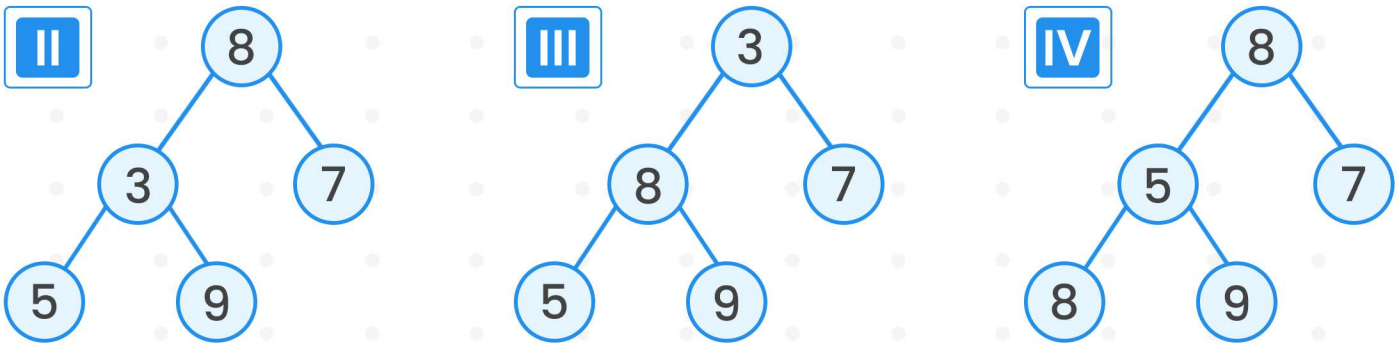

insert():

This operation is used to insert an element into the heap. We add the elements from the left, in the lowermost level of the tree.

In case of a min heap, we check if the element is lesser than its parent, and swap them accordingly.

In case of a max heap, we check if the element is greater than the parent.

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delete():

This operation is used to delete an element into heap with the **time complexity of O(logn).**

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Applications of Heap:

Heap Sort:

This is a comparison based sorting technique. It is an in place algorithm where sorting of the array through continuous deleting of root nodes and using heapify() function to rearrange the array.

First we build the heap according to the initial array elements.

Then we remove the root node and append to the last level of heap (virtually). This signifies that the first element of the sorted array is obtained. We then rearrange the elements using Heapify function. The process is continued until the heap is empty.

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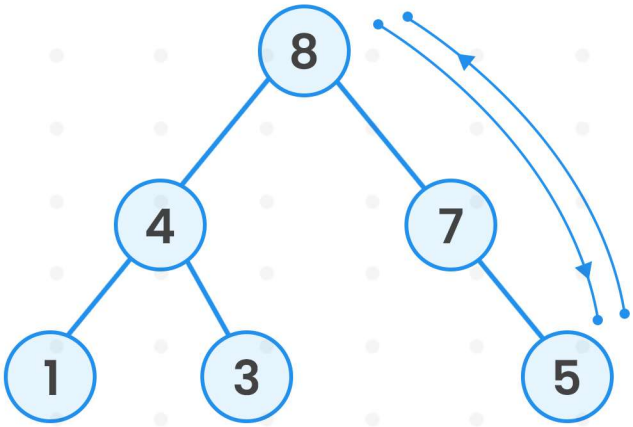
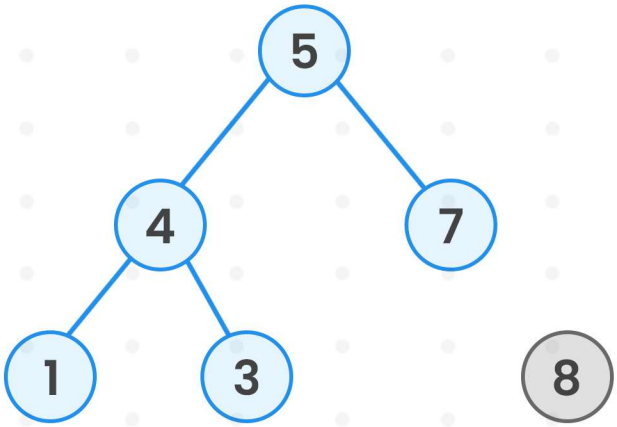
Step 1

Initial elements

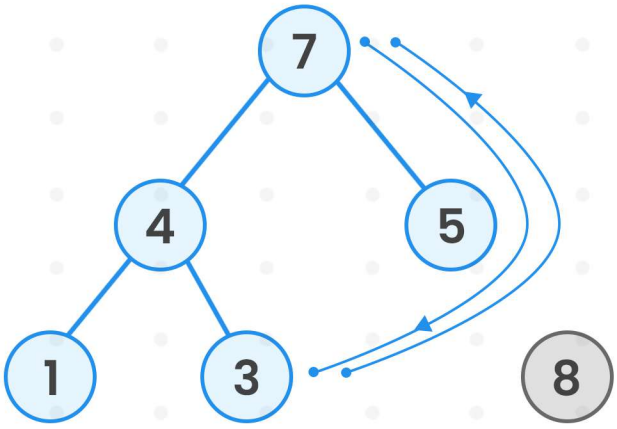


Step 2

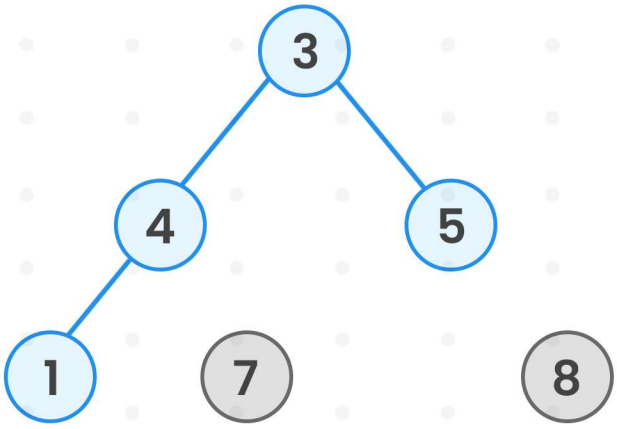


Step 3

Max Heap



Step 4



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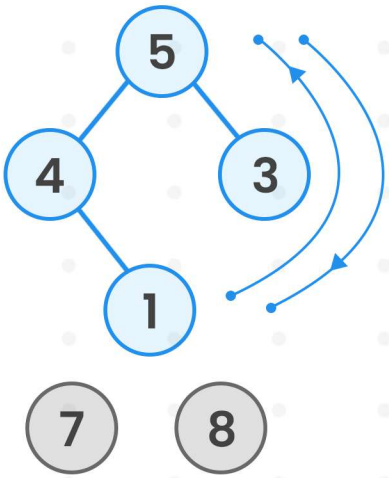
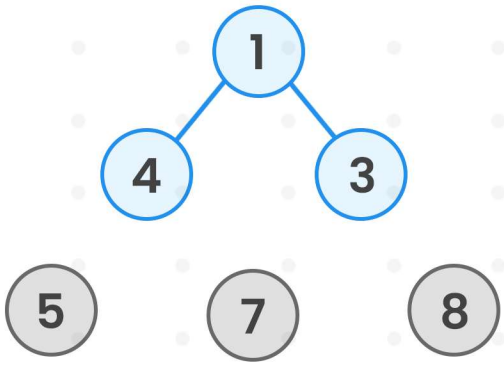
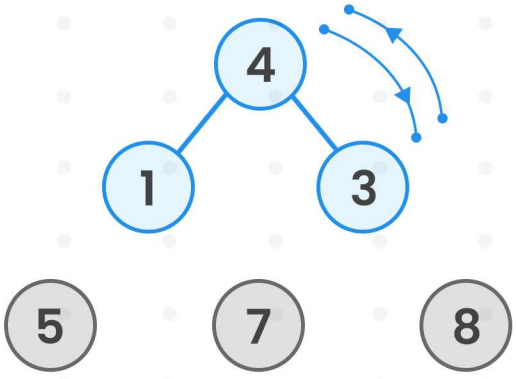
Step 5 Max Heap



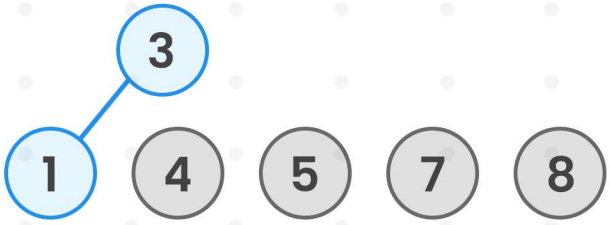
Step 6



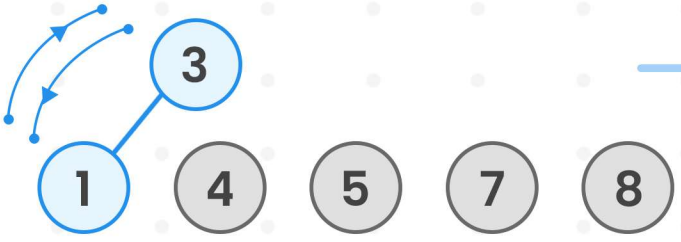
Step 7 Max Heap



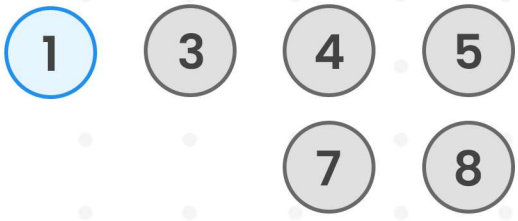
Step 8



Step 9 Max Heap



Step 10



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