

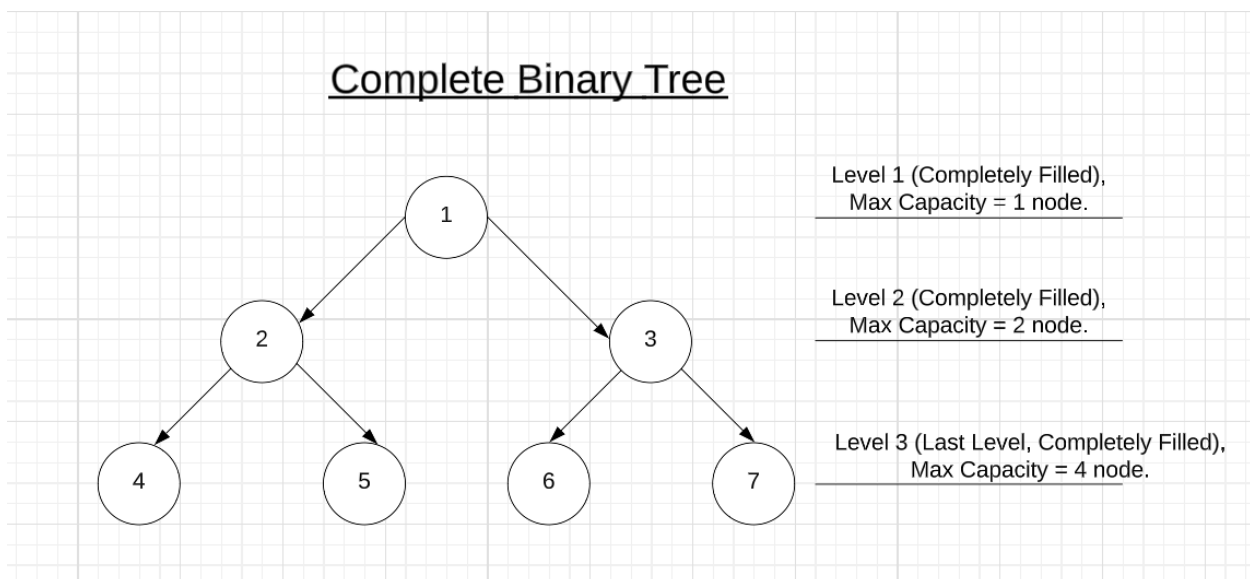
Heap Data Structure

What is Heap ?

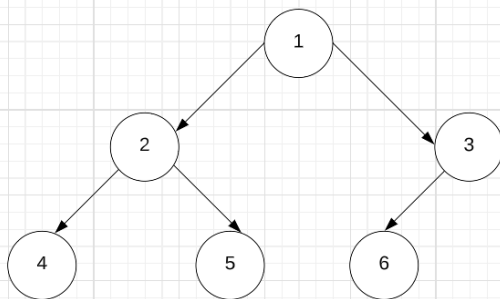
1. A Heap is a special **Tree-based** data structure in which the **tree is a complete binary tree**.
2. Heap comes with a special property called as **Heap Order property**.
3. In simple words, we can say that, A heap is a special tree-based data structure that satisfies the heap property and in which the tree is a Complete Binary Tree.

What is Complete Binary Tree (AKA CBT) ?

1. A binary tree is called complete binary tree **when all the level of binary tree is completely filled except the last level (last level can be completely filled or cannot be completely filled)**.
2. A Complete Binary Tree is always filled from left to right. This means that if a node has two children, the left child will always be filled before the right child.
3. And if a node has only one child, then that child must be left child because of the order that we have just discussed in point 2.



Complete Binary Tree

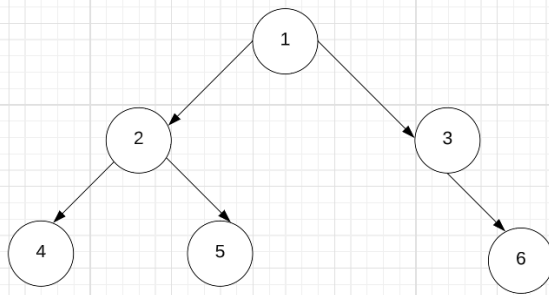


Level 1 (Completely Filled),
Max Capacity = 1 node.

Level 2 (Completely Filled),
Max Capacity = 2 nodes.

Level 3 (Last Level, Not Completely Filled),
Max Capacity = 4 nodes, but only 3 nodes are there, but it is the last level so we can ignore it.

Not a Complete Binary Tree



Level 1 (Completely Filled),
Max Capacity = 1 node.

Level 2 (Completely Filled),
Max Capacity = 2 nodes.

Level 3 (Last Level, Not Completely Filled),
Max Capacity = 4 nodes, but only 3 nodes are there.

Note: If the last Level is not completely filled, we can ignore it but, Complete Binary Tree is always filled from left to right, this means that if a node has two children, the left child will always be filled before the right child and in this case left child of 3 is missing and if a node has only one child then it must be a left child.

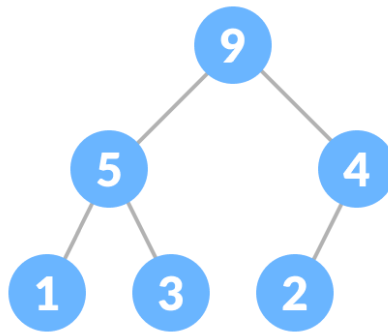
That's why it is not a complete binary tree.

What is Heap Order Property ?

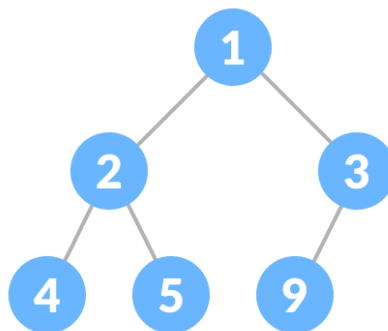
The heap order property says that, for every node, the value of the root node or parent node must be (\geq or \leq) than the value of its child nodes.

In Simple Words, Heap Order property is,

1. For every node,
 - a. The value of root node or parent node \geq the value of its child nodes or,



- b. The value of root node or parent node \leq the value of its child nodes .

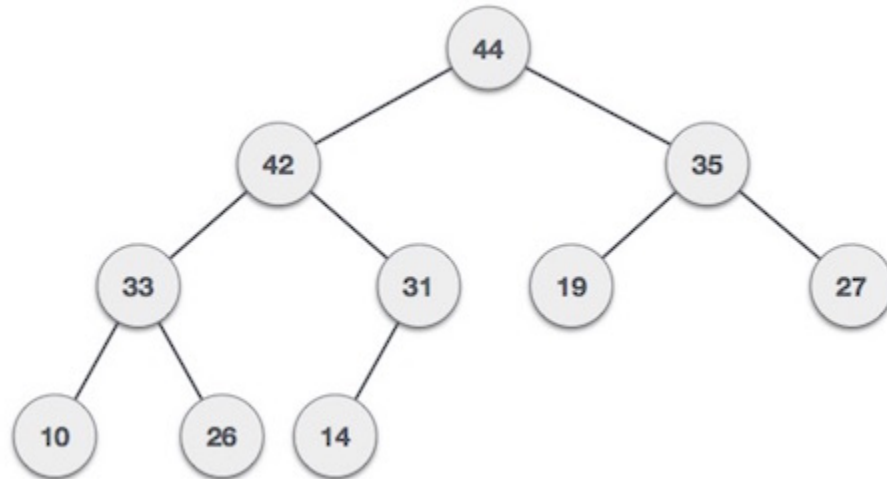


Types of Heap ?

Based on the property of heap (Heap Order property), we can classify heaps into two types,

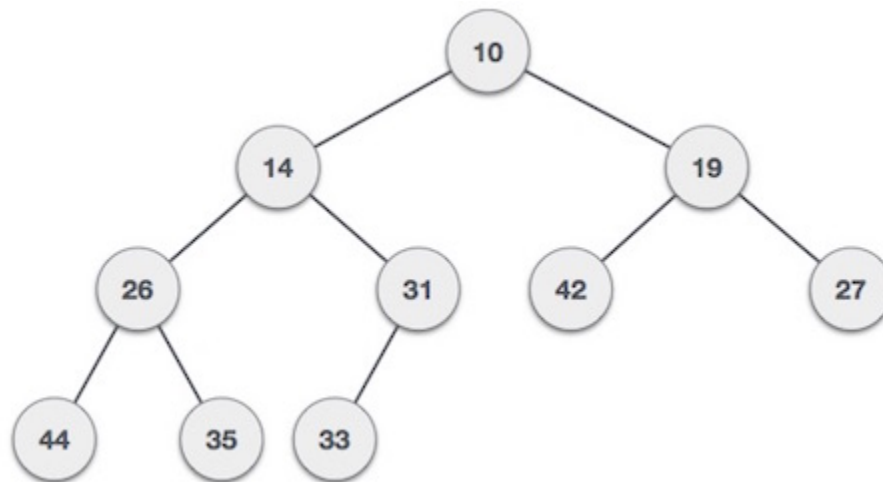
1. Max Heap

- a. The value of root node or parent node \geq the value of its child nodes.



2. Min Heap

- a. The value of root node or parent node \leq the value of its child nodes .



How to implement Heap ?

Arrays are commonly used to implement heaps because heap are complete binary tree so there will be not wastage of memory.

In an array-based representation of a heap, the elements of the heap are stored in an array, where the root of the tree is located at index 0 and each child of a node at index i is located at indices $2i+1$ and $2i+2$.

In Short,

1. In 0-based Indexing

- a. Left Child = $2*i+1$
- b. Right Child = $2*i+2$
- c. Parent Node = $((i-1) / 2)$.
- d. Leaf Nodes = $[n/2, n-1]$, n is the size of array in integers.

2. In 1-based Indexing

- a. Left Child = $2*i$
- b. Right Child = $2*i+1$
- c. Parent Node = $(i / 2)$.
- d. Leaf Nodes = $[((n/2) + 1), n-1]$, n is the size of array in integers or $[((n/2) + 1), n]$, if you are taking n as the number of nodes in the tree.