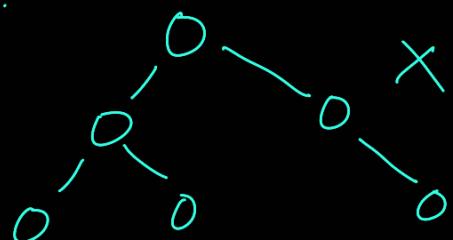
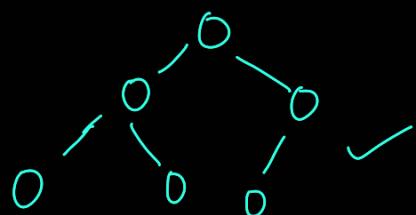


Heaps / Priority Queue :

What is a Heap?

⇒ a Complete Binary Tree that comes with a heap order property.
 ↳ all levels completely filled except last level filled from left.

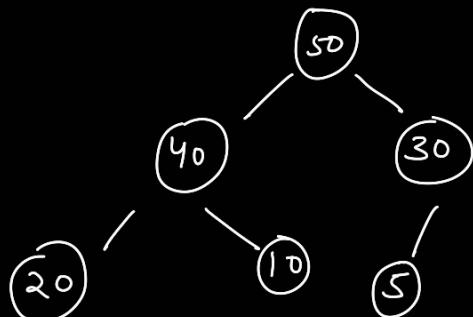
e.g



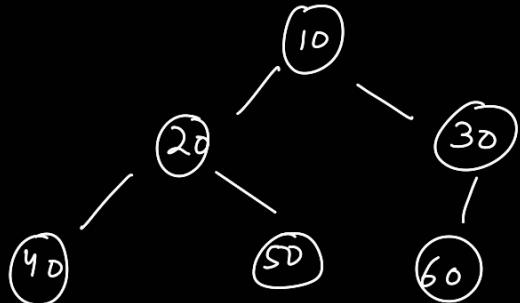
Max heap / Min heap

node ↑ node ↓
 child ↓ child ↑

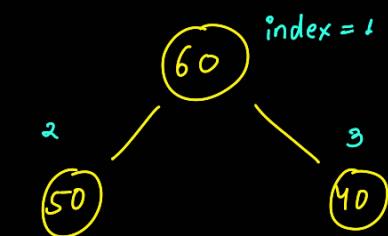
max heap →



Min-Heap →



Insertion in a heap :



X	60	50	40	30	20
0	1	2	3	4	5



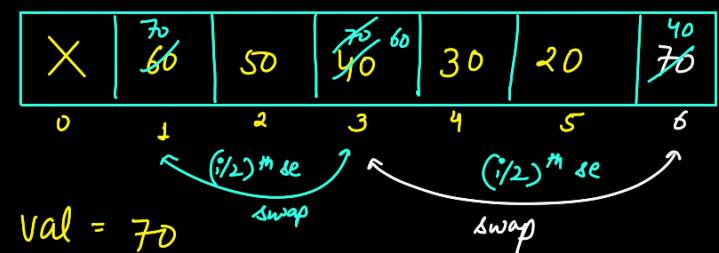
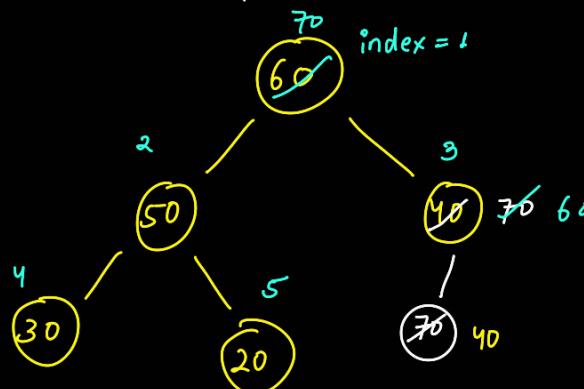
Steps in insertion :

- ① insert at end
- ② take it to its correct pos by comparing it with successive parents and swapping along the way.

If node is at i^{th} index, its:
 (L based indexing)

parent : $(i/2)^{\text{th}}$ index
left child : (2^*i)
right child : $(2^*i) + 1$

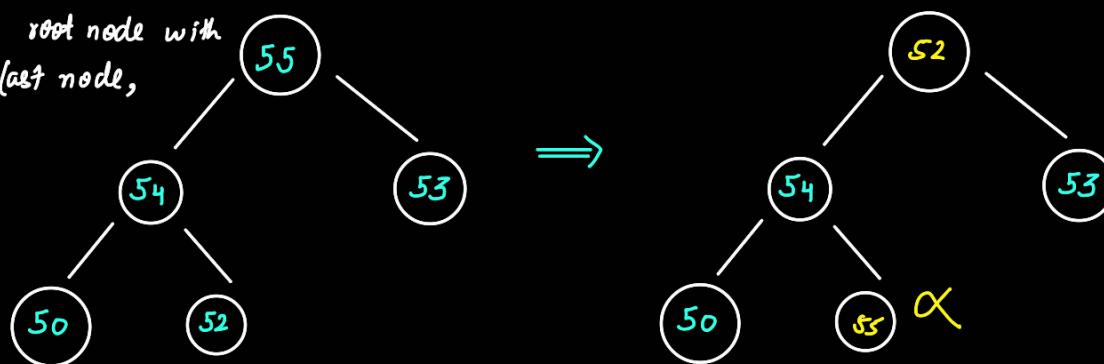
maxheap



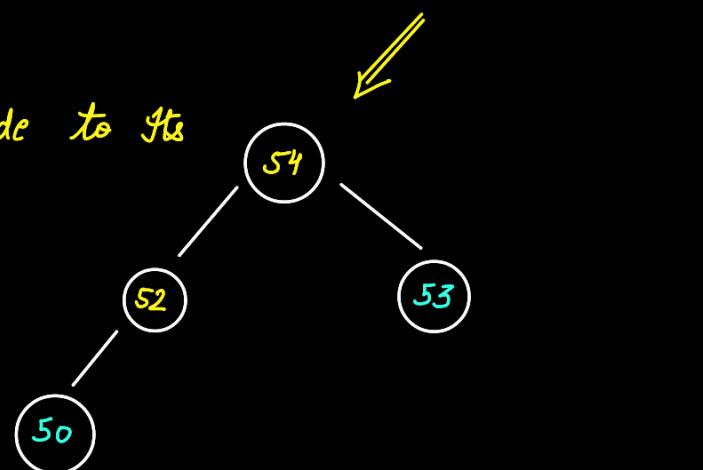
Deletion in a heap : (means deleting the root node)

(i) remove last node

- ① swap root node with last node,



- (ii) propagate root node to its correct pos.



[Heapify Algorithm] : convert an array to heap.

Key point : leaf nodes are always heaps, so we don't alter them.

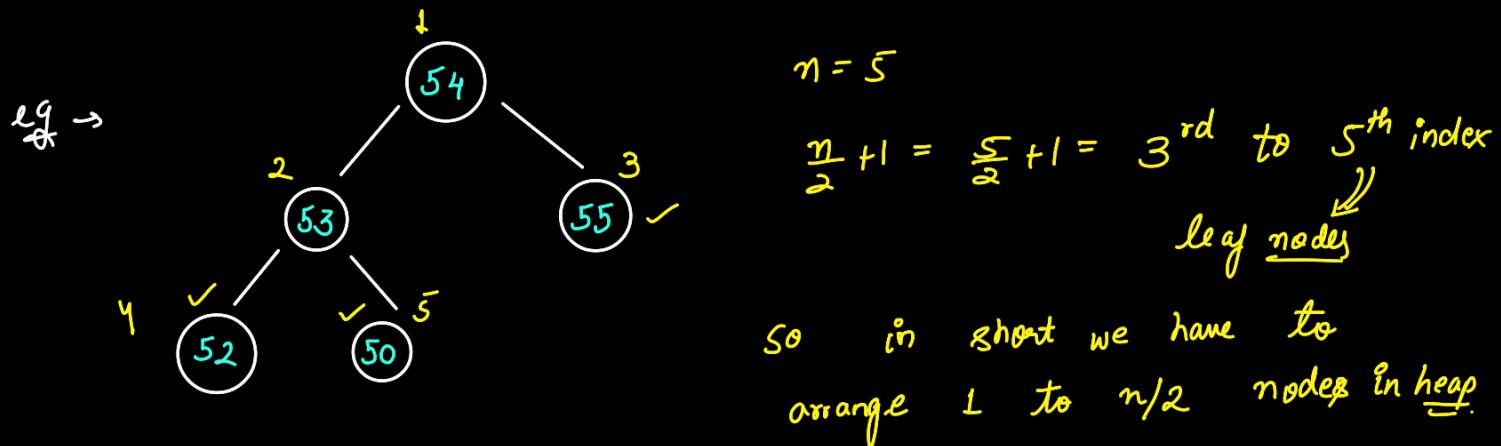
leaf nodes while heapifying.

if:

X	54	53	55	52	50
0	1	2	3	4	5

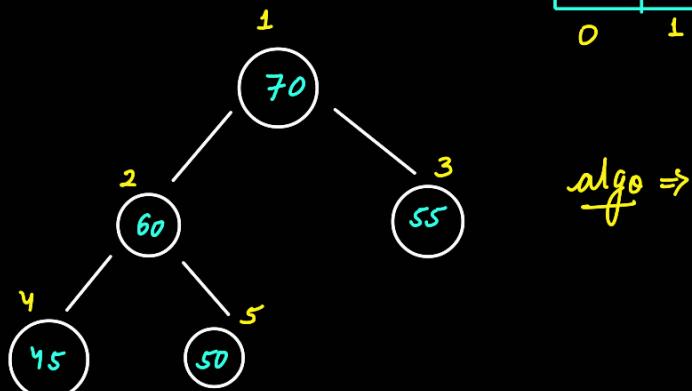
⇒ convert to heap.

imp point → all the leaf nodes lie b/w $(\frac{n}{2} + 1)^{th}$ → n^{th} index
in CBT



Heap-Sort :

X	70	60	55	45	50
0	1	2	3	4	5



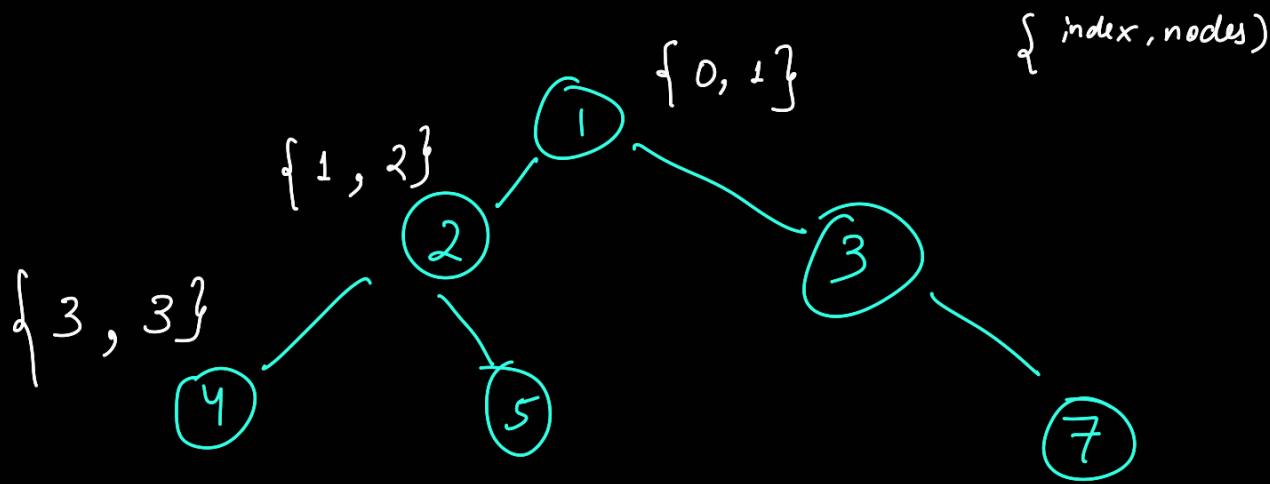
while (heapSize > 1) {

① swap $a[1]$ with $a[n]$
root last node

② root node ⇒ correct pos ⇒ heapify
(size--)

- i) numbering zero. (index, nodecnt)
- ii) if a node exists but its index > size,

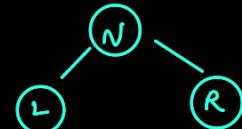
return false;



Convert BST to Min heap (also a BST)

★ hint: since BST is given to be a complete Binary Tree (CBT),
its structure will remain intact.

★ Inorder → ascending order
of BST



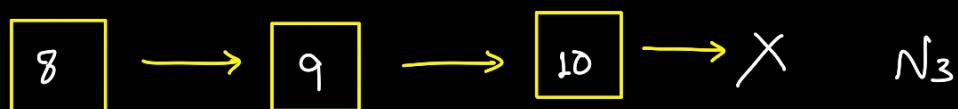
$N < L$ and $N < R$

★ $L < R$

$N < L < R \Rightarrow NLR$ (preorder)

* so, simply Populate the BST again in preorder fashion .

Merge K-sorted Arrays / Lists :



```

f( list <node> lists) {
    head = lists[0];
    for ( i=1 ; i<lists.size ; i++ ) {
        head = merge2lists ( head, lists [i] )
    }
    return head;
}

```

$$\text{time comp} = N_1 + N_2 + ((N_1 + N_2) + N_3) \dots$$

$$\text{let } N_1 = N_2 = N_3$$

$$= N + 2N + 3N$$

$$= N (1+2+3+\dots+k)$$

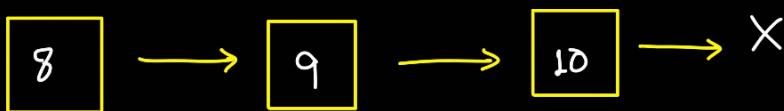
$$= N \left(\frac{k(k+1)}{2} \right)$$

$$\text{if } N = k \approx$$

$$\Rightarrow N \left(\frac{N(N+1)}{2} \right) \approx \underline{N^3}$$

Space = O(1) (except recursive stack space)

[Using Min-Heap] \Rightarrow



$B, 8$
$2, 2$
$1, 1$

Merge k-sorted arrays → same as above, just create a min-heap custom comparator & class node to keep track of each cell.

class node $\begin{cases} \text{int data} \\ \text{int row} \\ \text{int column} \end{cases}$

Heaps Hard Questions :

eg → $\left\{ \begin{matrix} 1, 10, 11 \end{matrix} \right\} \times$ ① sare lists ke 1st element ek array me daal do.
 $\left\{ \begin{matrix} 2, 3, 20 \end{matrix} \right\}$ ② us array me max-min nikalo.
 $\left\{ \begin{matrix} 5, 6, 12 \end{matrix} \right\}$ ③ range banao
 $\Rightarrow \left\{ \begin{matrix} 1, 2, 5 \end{matrix} \right\}$
range = $\left\{ \begin{matrix} 1, 5 \end{matrix} \right\}$ can't decrease this bcz fer range min. nahi rhegi.
increase this
next itr ⇒ $\left\{ \begin{matrix} 10, 2, 5 \end{matrix} \right\}$
range = $\left\{ \begin{matrix} 2, 10 \end{matrix} \right\}$ ans update \times

next it = $\left\{ \begin{matrix} 3, 10, 5 \end{matrix} \right\} \Rightarrow \left\{ \begin{matrix} 3, 10 \end{matrix} \right\} \times$

next = $\left\{ \begin{matrix} 20, 10, 5 \end{matrix} \right\} = \left\{ \begin{matrix} 5, 20 \end{matrix} \right\} \times$

next = $\left\{ \begin{matrix} 20, 10, 6 \end{matrix} \right\} = \left\{ \begin{matrix} 6, 20 \end{matrix} \right\} \times$

next = $\left\{ \begin{matrix} 20, 10, 12 \end{matrix} \right\} = \left\{ \begin{matrix} 10, 20 \end{matrix} \right\} \times$

next = $\left\{ \begin{matrix} 20, 11, 12 \end{matrix} \right\} = \left\{ \begin{matrix} 11, 20 \end{matrix} \right\} \times$

next = 10 → next = null, stop.

$O(k) \hookrightarrow O(\log k)$

ans = {1, 5} \rightarrow smallest range

4, 10, 15, 24, 26

0, 9, 12, 20

5, 18, 22, 30

4, 0, 5 $(0, 5)$

4, 9, 5 $(4, 9)$

10, 9, 5 $(5, 10)$

10, 9, 18 $(9, 18)$

10, 12, 18 $(10, 18)$

15, 12, 18 $(12, 18)$

15, 20, 18 $(15, 20)$

24, 20, 18 $(20, 24)$

α

Ques \Rightarrow (4, 10, 15, 24, 26)

(0, 9, 12, 20)

(5, 18, 22, 30)

[4, 0, 5]

sol



3 $\textcircled{9} < \underline{\textcircled{9}}$

0 $\xrightarrow{\text{maxi}}$
0, 1, 2
1, 2, 3

1 1, 2, 3

2 1, 2, 3

heap

[1, 1, 1]

$\min^o = 1$
 $\max^o = 1$

range = 0

newnode = 2, 0, 1

min - range ka check
~,

maxi = 2

$$\begin{matrix} 0 & 1 & 2 & 3 \\ [1, \underbrace{2, 3}, 4] \end{matrix} \quad n = 4$$

$$\frac{n}{2} = 2$$