Coding Blocks

HEAP

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Priority Queue - Elements will be removed from the queue on the basis of the element's priority.

Heap / Priority Queue

	Sorted Array	Unsorted Array	Heap
Add	O(n)	O(1)	O(logn)
Delete	O(n)	O(n)	O(logn)
Get	O(1)	O(n)	O(1)

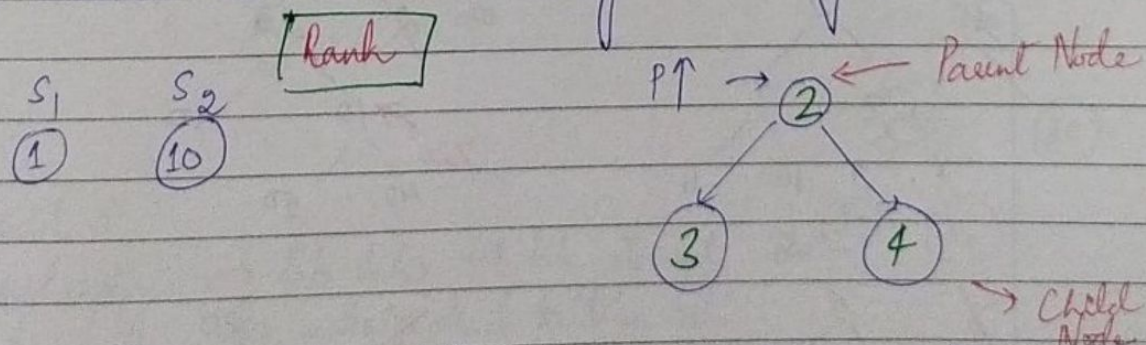
Heap

Heap is a binary tree which follows the following properties :-

1. Priority of parent is always more than children
2. It is a complete binary tree

1 PRIORITY

a) Smaller Value S.V. is having ↑ Priority P.



Rank → Parent Node will have a smaller value → P↑
Child Node will have a greater value → P↓

MIN HEAP

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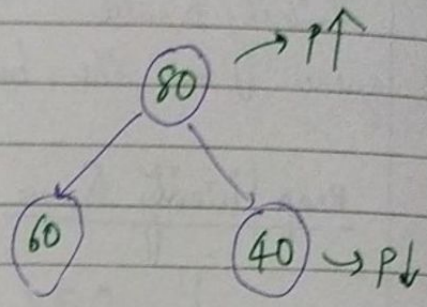
b) larger value is Priority P↑

Marks

S_1	S_2
80	60

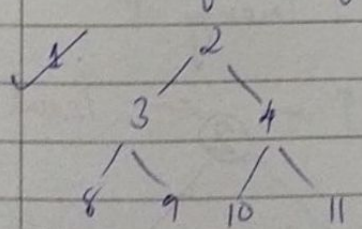


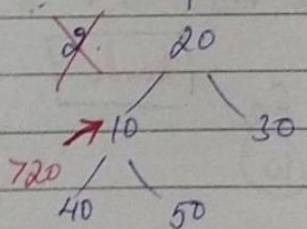
→ Greater marks → larger Priority → ∴ Parent Node will have greater value

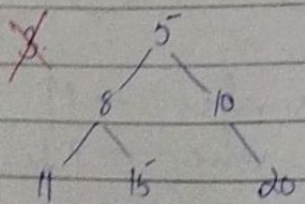
MAX HEAP → Parent value is more

2 COMPLETE BINARY TREE
In which every level except the last level, is completly filled ✓ and the last level is filled from left to right →

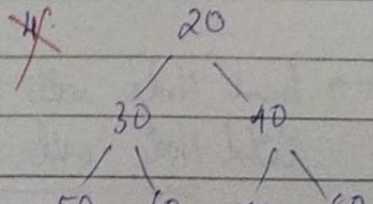
Q Which of the foll is a min heap?



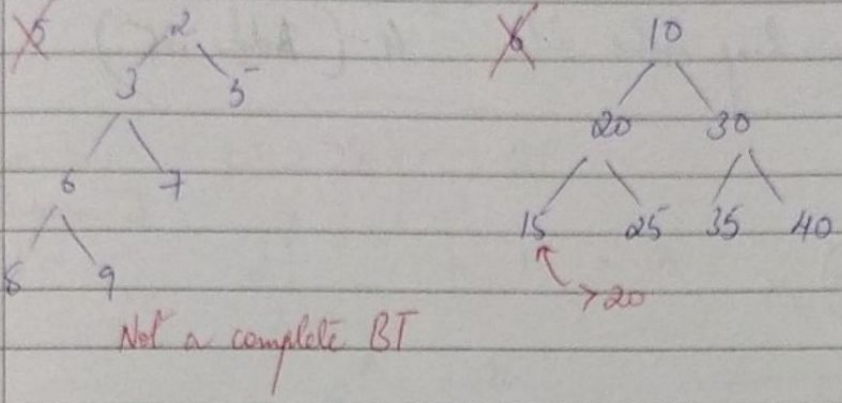




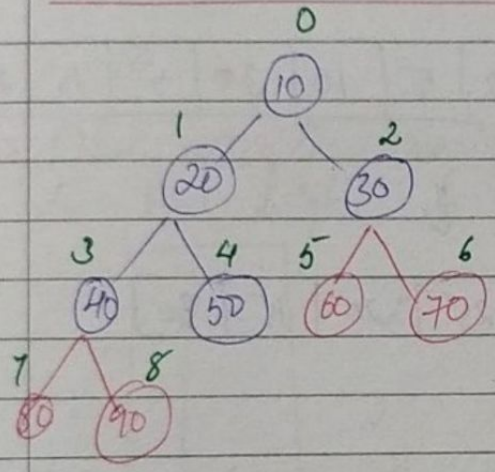
not a complete BT



not a complete BT



ADDITION & DELETION IN HEAP



$p_i = 1$

$l_i = 2p_i + 1 = 3$

$r_i = 2p_i + 2 = 4$

$p_i = 3$

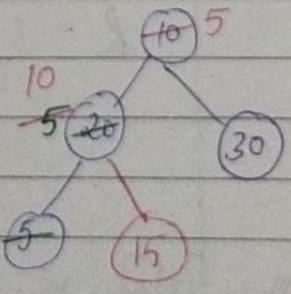
$l_i = 7$

$r_i = 8$

$$l_{ci} = 2p_i + 1 \qquad r_{ci} = 2p_i + 2$$

$$p_i = \frac{l_{ci} - 1}{2} \qquad p_i = \frac{r_{ci} - 2}{2}$$

data - | 0: ~~10~~ 5 | 1: ~~20~~ ~~5~~ 10 | 2: 30 | 3: ~~5~~ 20 | 4: 15 |



1. add 5
2. upheapify → tab tak jab tak element ko uska correct position nhi mil jaata
3. add 15

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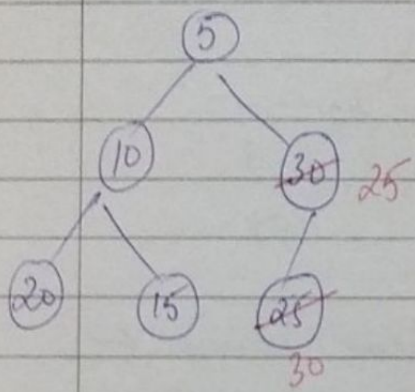
Now, the heap looks like – 4. (Add 25)



(25 < 30 : we need to swap)

dataList :- data → | 5 | 10 | 30 | 5 | 15 | 25 |
25 30

⇓

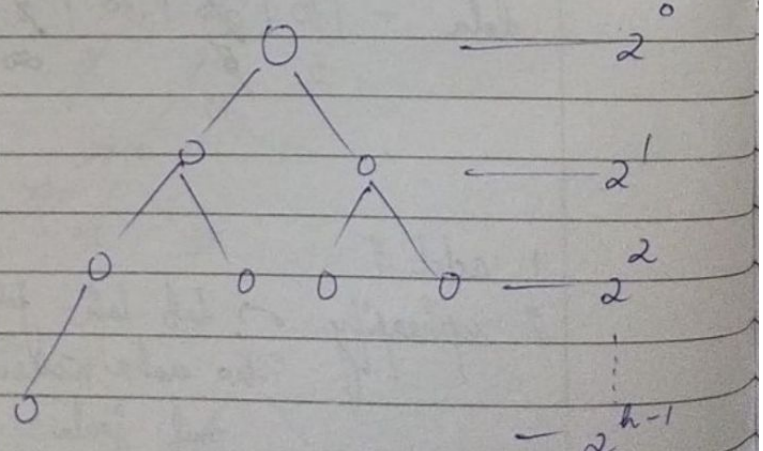
data :- | 5 | 10 | 25 | 20 | 15 | 30 |

(Code → MinHeap (add^n, deletion etc.) see Github)

COMPLEXITY ANALYSIS –

Q1. What are the minimum no. of nodes required in CBT to have height h ?

h = 3



n : Total no. of nodes in BT

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$$\underbrace{2^0 + 2^1 + 2^2 + \cdots + 2^{h-1}}_{GP} + 1 = n$$

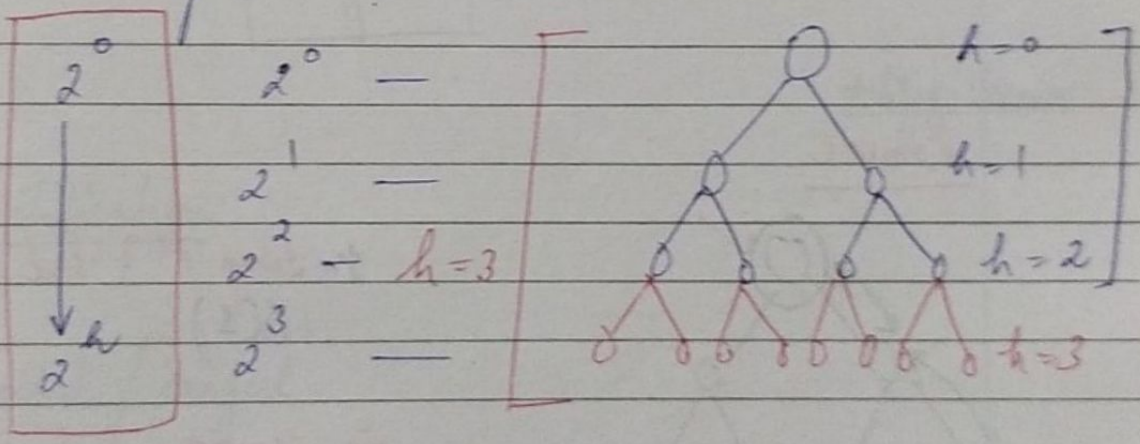
$$\frac{2^{h-1}}{2-1} + 1 = n$$

$$2^h = n$$

$$h = \log_2 n$$

$$\boxed{h = O(\log n)}$$

Q2. What are the maximum no. of nodes required in CBT to have height h?



$$\underbrace{2^0 + 2^1 + 2^2 + \cdots + 2^h}_{GP} = n$$

$$2^{h+1} - 1 = n$$

$$2^{h+1} = n+1$$

$$\log_2 2^{h+1} = \log_2 (n+1)$$

$$h+1 = \log_2 (n+1) \Rightarrow h = \log_2 (n+1) - 1$$

$$\Rightarrow \boxed{h = O(\log n)}$$

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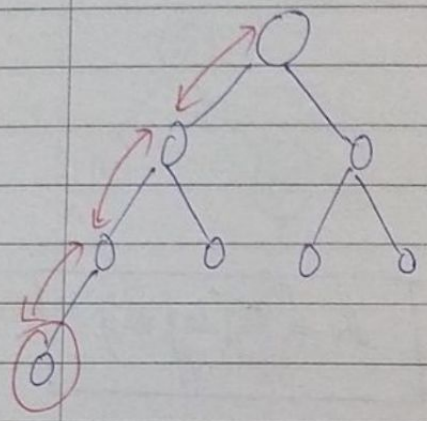
Add

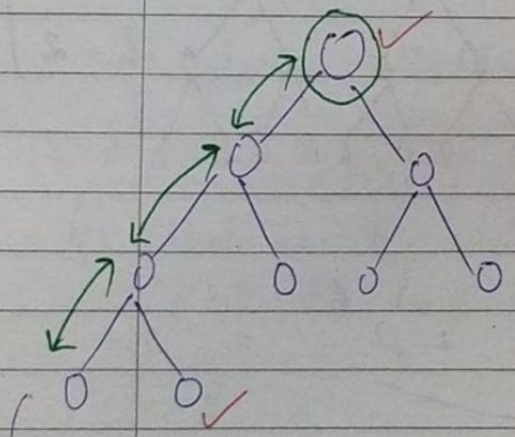


$O(1) + O(h)$

- $O(1)$ → to add the element at the end of the array
- $O(h)$ → upheapify (worst case me swap kete kete we reach the root element)

$O(h) = \boxed{O(\log n)}$

Remove



1. Swap 1st & last element
   $O(1)$

2. remove last me jo element hai (after swapping)

3. In worst case → downheapify kete kete we reach the last

$O(1) + O(h) = O(h)$

- $O(1)$ → swap
- $O(h)$ → downheapify

Yahan 3 swaps hue hai, 3 → dependent on h

CBT : $h = O(\log n)$

$\boxed{\text{Remove} : O(\log n)}$

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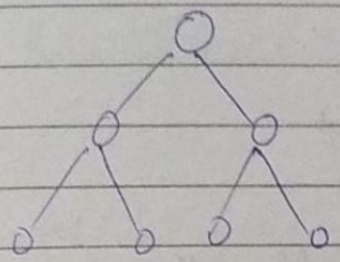
Get



data.get(0)

O(1)

Summarize :-

1. Add : O(log n)
2. Remove : O(log n)
3. Get : O(1)

Aditya Verma

Identification

1. K
2. Smallest / Largest

K + smallest ⇒ Max heap
K + largest ⇒ Min heap

Sorting — n log n (merge sort)

Heap K — n log k (Improved complexity)

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Q. K^{th} smallest element

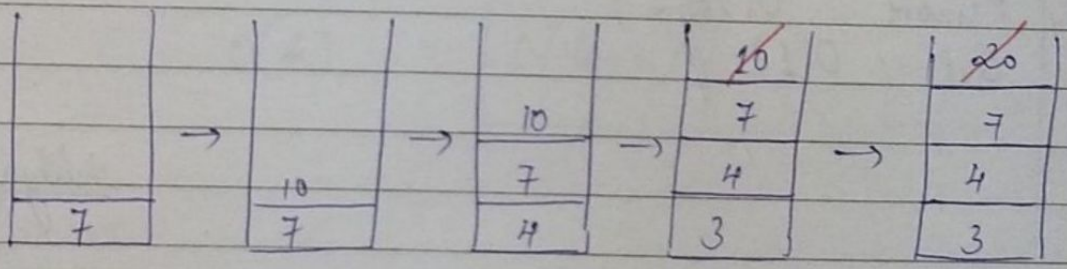
K smallest] → Qualify for heap

↓

Which heap? Max Heap

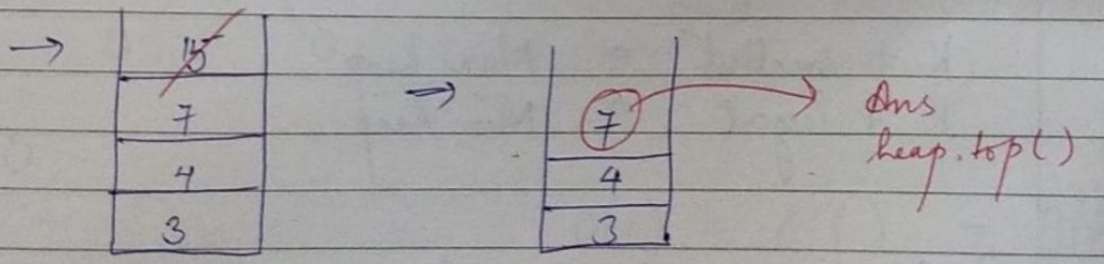
arr[] : 7 10 4 3 20 15

K = 3



size = 1 size = 2 size = 3 size > k size > k

= K : pop : pop



size > k

: pop

NOTE:- Max Heap makes sure the the largest element is always at the top (it does not guarantee that all elements are pushed in sorted order in the heap)

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Code : using max heap

```
PriorityQueue<Integer> pq = new PriorityQueue<>(Comparator.reverseOrder());

for(int i=0; i<size; i++){
    pq.add(arr[i]);
    if(pq.size() > k){
        pq.pop()/peek;
    }
}
return pq.top()/peek();
}
```

→ to build max heap

Q. Return K largest elements in Array

arr[] : 7 10 4 3 20 15

k = 3

| 20 | 15 | 10 | ⇒ o/p

① Approach 1 : Sorting

| 3 | 4 | 7 | 10 | 15 | 20 |

return

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But, sorting 3, 4 & 7 is extra work that we're doing

Hence, we need to optimize it

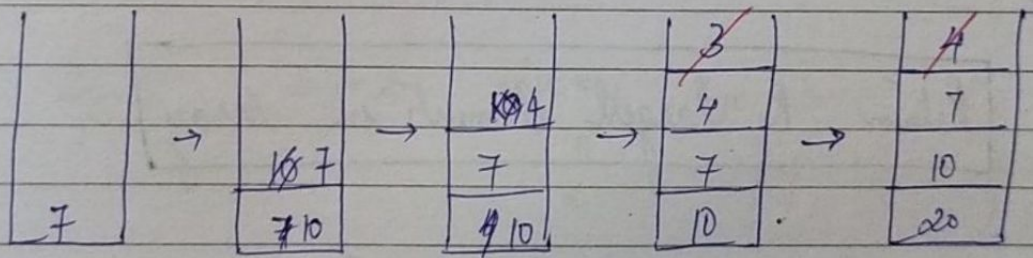
That we can do with help of heap

Identification

1. k
2. Largest

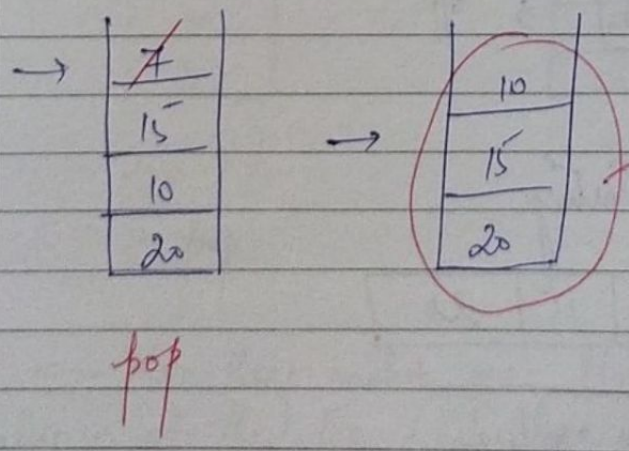
} ⇒ Min Heap

Approach 2 :



size > k ∴ pop

size > k ∴ pop



pop

→ Emptying the Heap

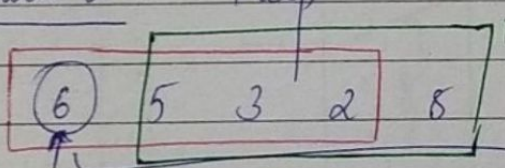
```
while (pq.size() > 0) {
    Sysout (pq.peek());
    pq.pop();
}
```

Q: Sort a K Sorted Array | Sort Nearly Sorted Array

Inp: arr: [6 | 5 | 3 | 2 | 8 | 10 | 9]
k = 3

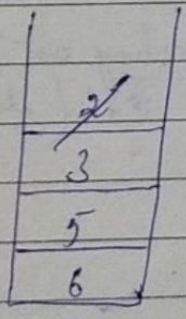
Approach 1: Sorting
Merge Sort O(n log n)
But we didn't use (K)

Approach 2: Heap



ye toh pata hai ki value tak index 0 would be till 6532 we don't need to see aage

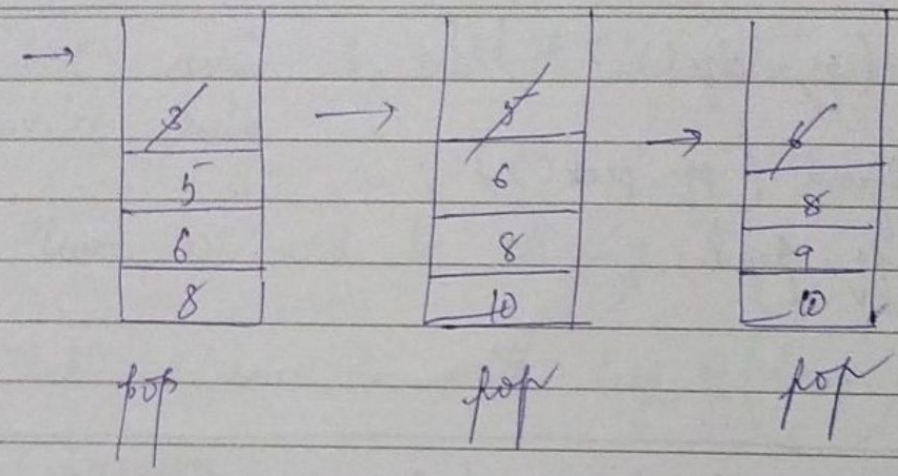
Min Heap

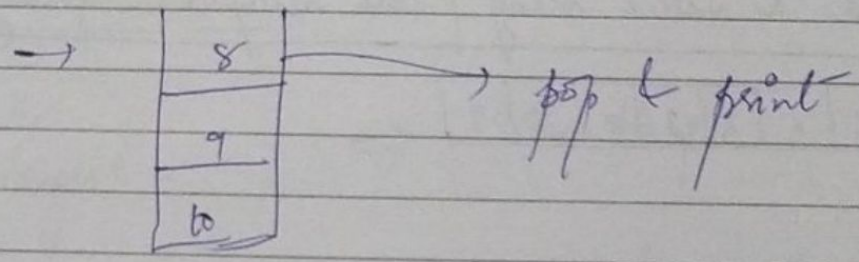


pop

nlogk → kyunki 'k' se upar no. of elements ke liye sort nhi kar rahe

Op: 2 3 5 6 8 9 10

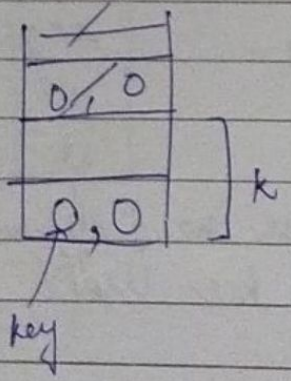




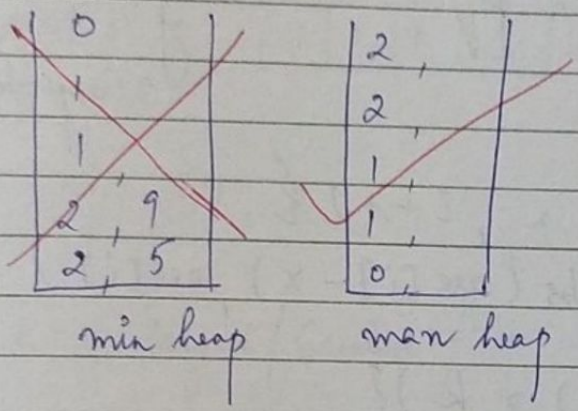
Q. **K Closest Numbers**

arr[] : 5 6 7 8 9
k = 3
x = 7

5 6 7 8 9
7 7 7 7 7
---
diff ⇒ 2 1 0 1 2 → sorting on the basis of that (diffarence)



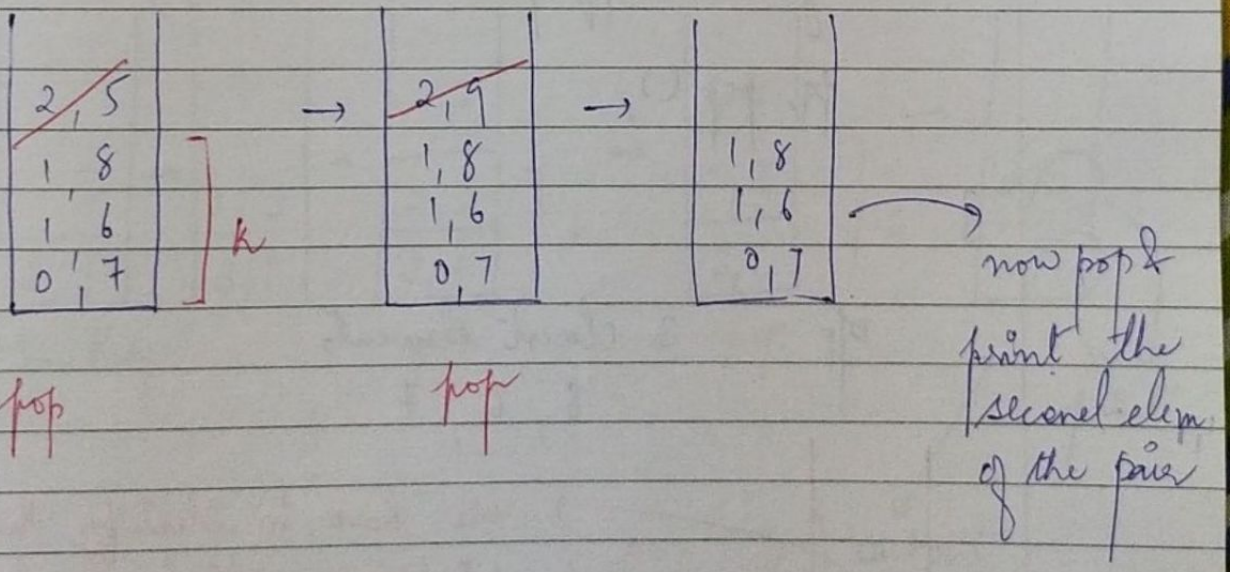
Which heap ??



(Suitable is max heap)

we always pop the useless once → Here useless is 2, 2,
∴ we cannot make max heap.

Pair class ⇒ `abs(arr[i] - x), arr[i]`



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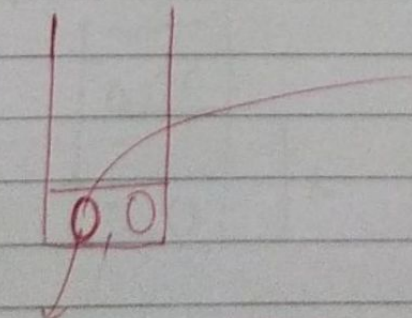
Code :

```
PriorityQueue<Pair<Integer>> pq = new PriorityQueue<>(Comparator.reverseOrder());

for (int i=0; i<n; i++) {
    pq.add(abs(arr[i]-x), arr[i])
    if (pq.size() > k){
        pq.pop();
    }
}
while(pq.size() > 0) {
    sysout(pq.peek().second);
    pq.pop();
}
```

o/p : 3 closest elements
8, 6, 7



→ we have to identify this key ki kispe sort karna hai

key → # itself
→ frequency
→ difference

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Q. **Top K frequent numbers**

arr[] = | 1 | 1 | 1 | 3 | 2 | 2 | 4 |

k = 2

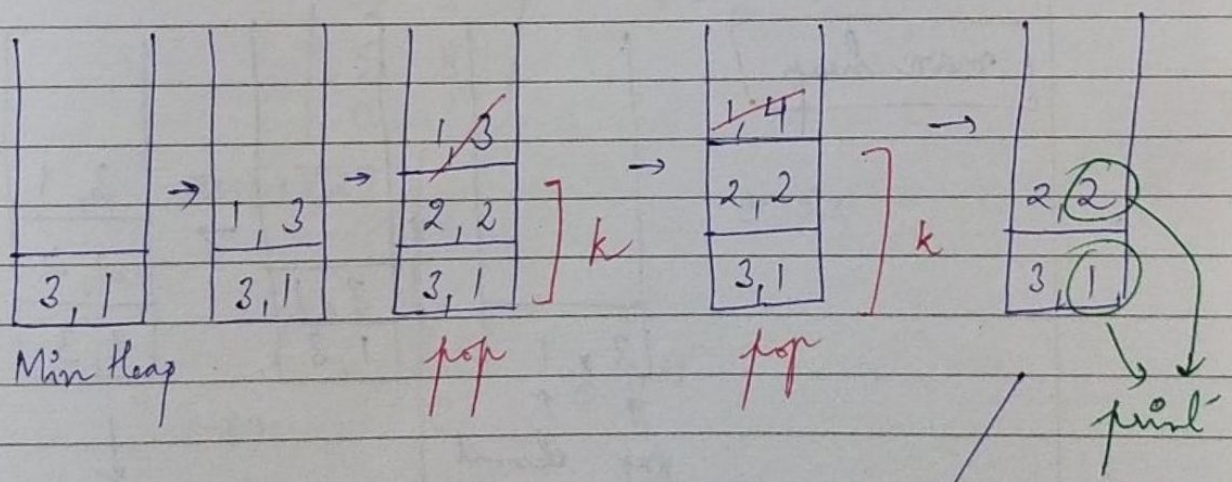
o/p : 1, 2

feel karo

k + Largest / Greatest / Top → **Min Heap**

HashMap

1	3
3	1
2	2
4	1
↑ arr[i]	↑ freq



(For the syntax of priority queue → check github repo) Output

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Q. Frequency Sort

arr[] : | 1 | 1 | 1 | 3 | 2 | 2 | 4 |

op : | 1 | 1 | 1 | 2 | 2 | 3 | 4 |

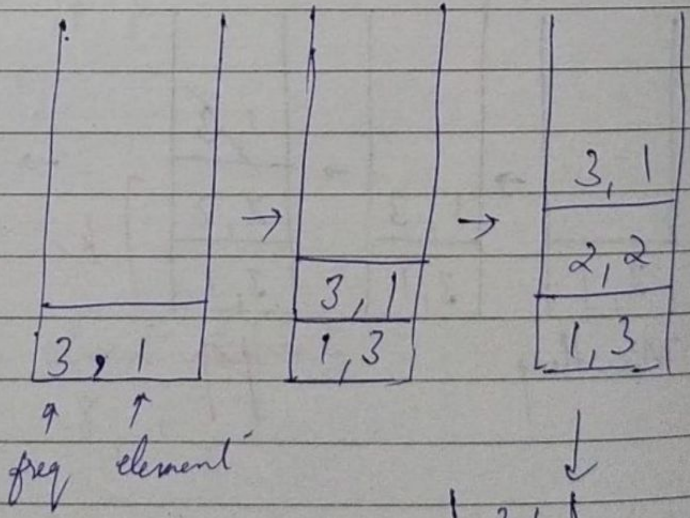
3 2 1 1

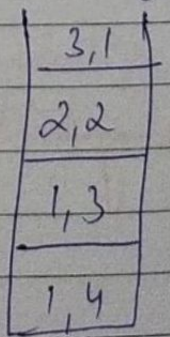
Sort based on frequency.

Map

key	value
1	3
3	1
2	2
4	1

max heap



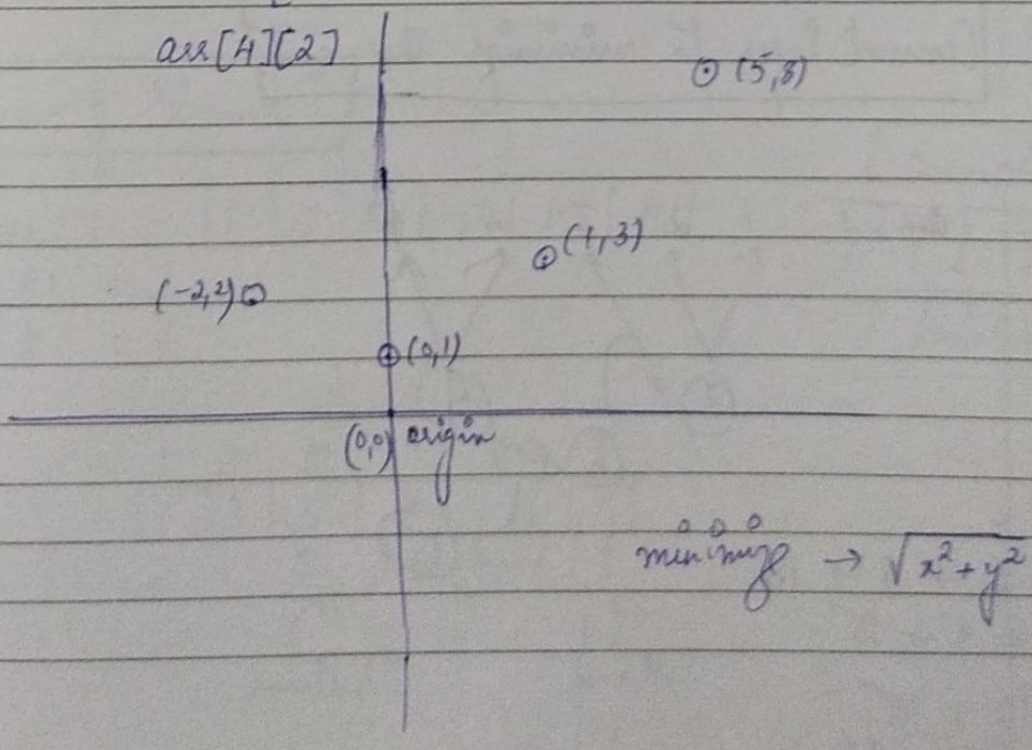


```
while (pq.size() > 0) {
    int freq = pq.top().first;
    int elem = pq.top().second;
    for (int i = 0; i <= freq; i++) {
        sysout (elem);
    }
    pq.pop();
}
```

Q. **K - Closest Points to Origin**

$$arr[] = \begin{bmatrix} 1 & 3 \\ -2 & 2 \\ 5 & 8 \\ 0 & 1 \end{bmatrix} \qquad K = 2$$

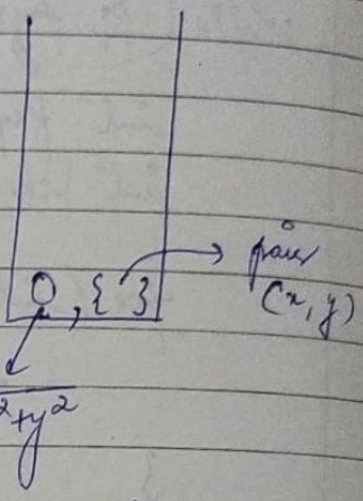
arr[4][2]



minimize → $\sqrt{x^2+y^2}$

k = 2

2 closest points from origin



pair < int < pair < int, int >> p ;

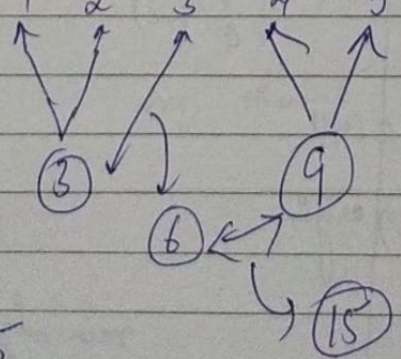
To ease out, we'll sort acc to $(\sqrt{x^2+y^2})^2 = x^2+y^2$

Max Heap Bana lenge

(jab samajh na aaye ki konsa heap banana hai toh make both & check konsa suitable hai & then implement that heap)

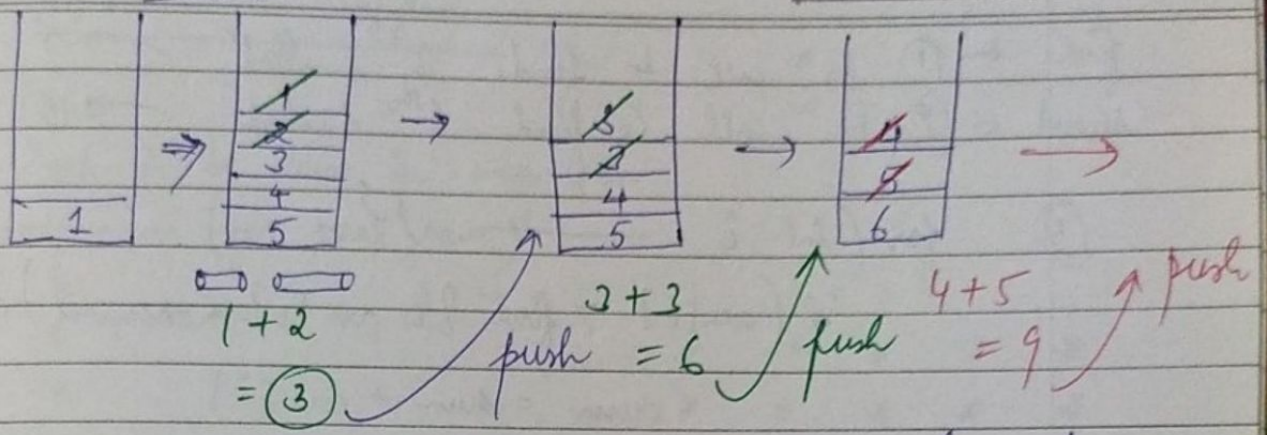
Q. Connect Ropes to minimize the cost

arr[] : 1 2 3 4 5

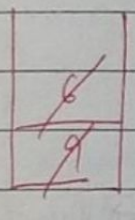


Cost =
3 + 6 + 9 + 15
9 + 9 + 15
18 + 15
= 33

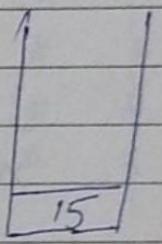
Min Heap



Sum Tcost
= 3+6
+9+15
= 33



pop ⇒ 6+9 =15 push



>=2 nhi hai

pop krke & add to Tcost

Return Tcost

Ans

Q. **Sum of Elements**

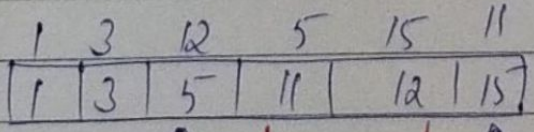
arr[] : | 1 | 3 | 12 | 5 | 15 | 11 |

k1 = 3

k2 = 6

concept

Variation



3rd smallest

6th smallest

11 + 12 = 23 Ans

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first ← ① Fxn call to find 3rd smallest → 5
second ← ② Fxn call to find 6th Smallest → 15

③ for(int i ———){
    if(arr[i] > first && arr[i] < second){
        sum = sum + arr[i];
    }
}
return sum;

Variations ⇒

k_1 → Largest	k_1 → Smallest
k_2 → Largest	k_2 → Largest

k_1 → Largest	k_1 → Smallest
k_2 → Smallest	k_2 → Smallest

Ase variations ban sakte hain ques ke

But CONCEPT wahi rahega !!!

ALL CODES : GITHUB.