Heap [min pq]

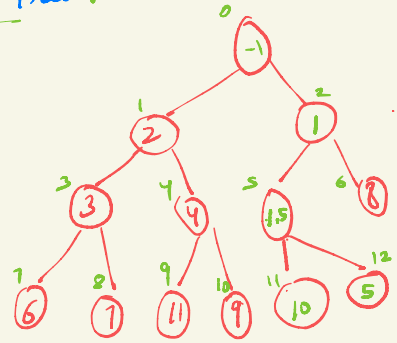
Complete Binary Tree (CBT)

Heap order property

why?
what?
how?

-1

upHeapify → every parent will be smaller than child



{-1, 2, 1, 3, 4, 1.5, 8, 6, 7, 11, 9, 10, 5}

pi = 4

lci = 2*pi+1;

rci = 2*pi+2;

lci = 9

rci = 10

pi = 12-1/2 ⇒ 5

pi = 5-1/2 ⇒ 2

pi = 2-1/2 ⇒ 0

swap(ci, pi)

ci

{pi = ci-1/2}

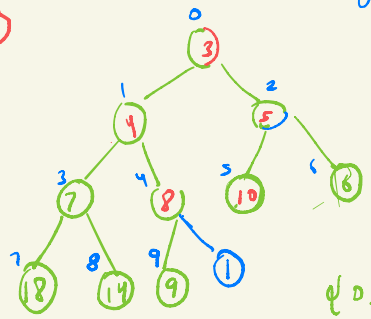
12

```
static class Heap {
    ArrayList<Integer> data;

    public Heap(){
        data = new ArrayList<>();
    }

    public void swap(int i, int j){
        int valAtI = data.get(i);
        int valAtJ = data.get(j);

        data.set(i,valAtJ);
        data.set(j,valAtI);
    }

    public void upHeapify(int ci){
        int pi = (ci-1)/2;

        if(data.get(pi) > data.get(ci)){
            swap(ci,pi);
            upHeapify(pi);
        }
    }
    // add
    public void add(int val){
        data.add(val);

        upHeapify(data.size()-1);
    }
```

data ⇒ {3, 4, 5, 7, 8, 10, 6, 18, 14, 9}

O(n)

-1



down Heapify

{0, 1} pi, minCi

pi = 0

lci = 2*pi+1 = 1

rci = 2*pi+2 = 2

pi = 1

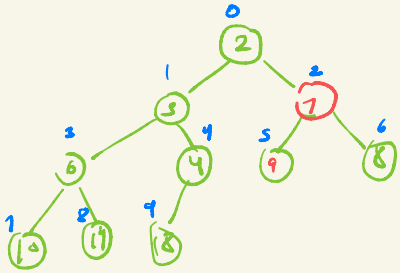
lci = 3

rci = 4

{1, 4}

```java
private void downHeapify(int pi){
    int lci = 2*pi + 1;
    int rci = 2*pi + 2;

    int mini = pi;

    if(lci < data.size() &&  data.get(lci) < data.get(mini)){
        mini = lci;
    }

    if(rci < data.size() && data.get(rci) < data.get(mini)){
        mini = rci;
    }

    if(mini != pi){
        swap(pi,mini);
        downHeapify(mini);
    }
}
// remove
public int remove(){
    if(data.size()==0){
        System.out.println(x: "There is no element in heap");
        return -1;
    }

    swap(i: 0,data.size()-1);
    int rv = data.remove(data.size()-1);

    downHeapify(pi: 0);

    return rv;
}
```

{2, 3, 7, 6, 4, 9, 8, 10, 19, 18}



break till 10:30

mini = 0 1 3 8

pi = 0 1 3

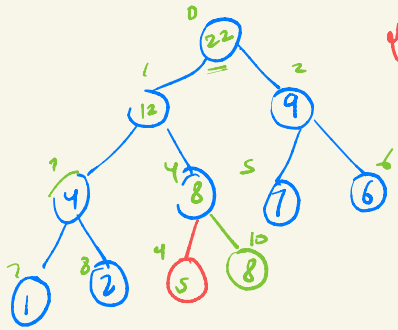
lci = 1 3 7

rci = 2 4 8

{22, 12, 9, 4, 8, 7, 6, 1, 2, 5, 8, 3}

ci = 10 1 0

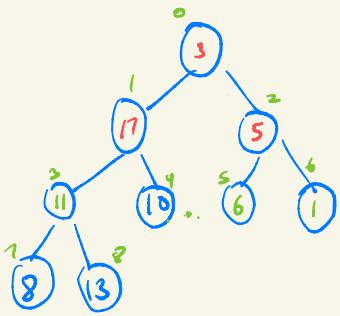
pi = 1 0 -1



```java
private void swap(int i, int j){
    int valAtI = data.get(i);
    int valAtJ = data.get(j);

    data.set(i,valAtJ);
    data.set(j,valAtI);
}

private void upHeapify(int ci){
    int pi = (ci-1)/2;

    if(pi>=0 && data.get(pi) < data.get(ci)){
        swap(ci,pi);
        upHeapify(pi);
    }
}
// add
public void add(int val){
    data.add(val);

    upHeapify(data.size()-1);
}
```

6, 4, 1, 3, 10, 9, 17, 8, 13

HOP



arr => {3, 17, 5, 11, 10, 6, 1, 8, 13}
0 1 2 3 4 5 6 7 8

```
void swap(int[] data, int i, int j){
    int temp = data[i];

    data[i] = data[j];
    data[j] = temp;
}

void upHeapify(int[] data, int ci){
    int pi = (ci-1)/2;

    if(pi>=0 && data[pi] > data[ci]){
        swap(data,pi,ci);
        upHeapify(data,pi);
    }
}

void buildHeap(int arr[]) {
    for(int i=0; i<arr.length; i++){
        upHeapify(arr,i);
    }
}
```

PQ

Priority Queue

PriorityQueue<Integer> pq = new PriorityQueue<>();
↳ min pq {min Heap}

pq.add(3)
pq.add(4)

pq.add(2);

pq.peek();

pq.remove()
pq.remove

class Student {
int roll_no;
String name;
}

Comparable
↓
Interface
comparator

51, 52

```
public int compareTo(Student o){
    return this.roll_no - o.roll_no;
}
```

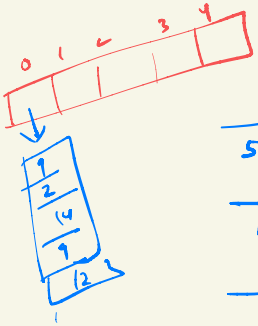
s1 = {1}
s2 = {2}

1 - 2 ⇒ -1

this.roll_no > 0. roll_no
⇓
(+) ve

this.roll_no < 0.
⇓
(-) ve

smaller on the top ⇒ this - other
greater on the top ⇒ other - this



matrix

5 10 averages

matrix

→ 5	9	2	14	9	12	8
→ 1	1	5	10	11	7	13
→ 4	5	7	15	6	17	18
→ 2	3	1	19	16	5	4
→ 3	4	8	9	1	2	3

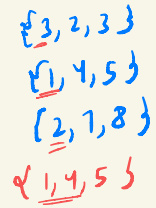
PQ < int[] > pq
= new PQ <>();

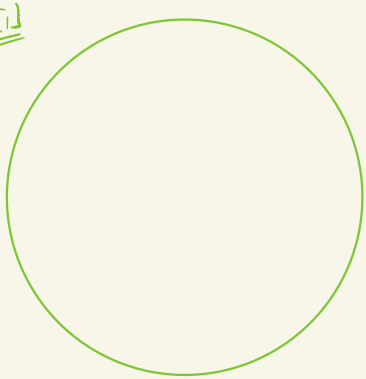
pq

{3, 2, 3}
{1, 4, 5}
{2, 7, 8}

```java
int[][] matrix={{3,2,3},{1,4,5},{2,7,8}};

PriorityQueue<int[]> pq = new PriorityQueue<>((int[] t, int[] o) ->{
    // return t[0] - o[0]; // min pq
    return o[1] - t[1];
});

for(int i=0; i<matrix.length; i++){
    pq.add(matrix[i]);
}

int[] top=pq.remove();
for(int i=0; i<top.length; i++){
    System.out.print(top[i]+" ");
}
```

{3,2,3}





```java
public int compareTo(Student other){
    return this.roll_no - other.roll_no; // min pq
    // return other.roll_no - this.roll_no //=> max pq
}
```

```
6
7 10 4 3 20 15
4
```

3 smallest elements

③

5, 1, 10, 4, 9, 3, 11, 4, 12

```java
public static int findKthLargest(int[] arr, int n, int k){
    PriorityQueue<Integer> pq = new PriorityQueue<>();

    for(int i=0; i<n; i++){
        pq.add(arr[i]);

        if(pq.size() > k){
            pq.remove();
        }
    }

    return pq.peek();
}
```

```java
public static int findKthSmallest(int[] arr, int n, int k){
    PriorityQueue<Integer> pq = new PriorityQueue<>(Collections.reverseOrder());

    for(int i=0; i<n; i++){
        pq.add(arr[i]);

        if(pq.size() > k){
            pq.remove();
        }
    }

    return pq.peek();
}
```

10:30

break

aaabbcdefegefee

sb a= "Samreet"

```java
public String frequencySort(String s) {
    HashMap<Character,Integer> map = new HashMap<>();

    for(int i=0; i<s.length(); i++){
        char ch = s.charAt(i);
        map.put(ch,map.getOrDefault(ch, defaultValue: 0)+1);
        // if(map.containsKey(ch)){
        //     map.put(ch,map.get(ch)+1);
        // } else {
        //     map.put(ch,1);
        // }
    }

    ArrayList<Character> keys = new ArrayList<>(map.keySet());

    PriorityQueue<Character> pq = new PriorityQueue<>((Character t, Character o) -> {
        return map.get(o) - map.get(t);
    });

    for(char ch : keys){
        pq.add(ch);
    }

    StringBuilder sb = new StringBuilder();
    while(pq.size()>0){
        char ch = pq.remove();
        int fre = map.get(ch);

        while(fre -- >0){
            sb.append(ch);
        }
    }

    return sb.toString();
}
```

a=3
b=2
c=1
d=1
e=5
f=2
g=1

map.get(other)
map.get(this)

a>b

ch=b
fre=2

b f d c g

sb.append

sb=eeeeeaaabbfdcg

⇒ eeeeeaaaafbbgdc

6 7
1 2 3 9 10 12

k=10

pq

13 29 12

t1=9
t2=10

1×9+2×10

steps = 0+1+2 = 3

```java
static int solve(int a[],int n,int k){
    PriorityQueue<Integer> pq = new PriorityQueue<>();

    for(int e:a){
        pq.add(e);
    }

    int steps = 0;
    while(pq.size()>1){
        if(pq.peek()>=k) return steps;

        int t1 = pq.remove();
        int t2 = pq.remove();

        int newSweetness = 1*t1 + 2*t2;
        pq.add(newSweetness);

        steps++;
    }

    if(pq.peek()<k) return -1;
    return steps;
}
```

10 < 20

ans = { 10, 14, 16, 18, 20 }

x = 15

k = 4

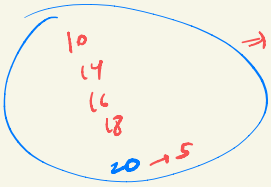
n = 10^8

k = 10, 20

n log k

14 15 18

element with smaller dis with x



⇒ n log n

n log k

ans = { 14, 16, 18, 10 }

{ 10, 14, 16, 18 }

```java
public List<Integer> findClosestElements(int[] arr, int k, int x) {
    PriorityQueue<Integer> pq = new PriorityQueue<>((Integer t, Integer o) -> {
        if(Math.abs(t-x) == Math.abs(o-x)){
            return t - o;
        }

        return Math.abs(t-x) - Math.abs(o-x);
    });

    for(int e:arr){
        pq.add(e);
    }

    List<Integer> ans = new ArrayList<>();
    while(ans.size()<k){
        ans.add(pq.remove());
    }

    Collections.sort(ans);
    return ans;
}
```

this - other // 8

abs(this - x) - abs(other - x)

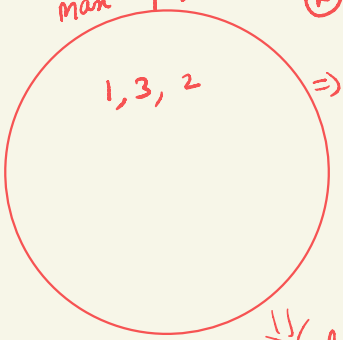
k = 3

{ 5, 1, 3, 7, 2, 4, 11 }

{ 1, 2, 3 }

k smallest elements → n log n (min pq)

n log k (max pq)



⇒ log k

n log k

n log n