Hash Map {Order is not maintained}

O(1) ① put → hm.put(key, value); ⇒ if key is already present then, value is overided.

O(1) ② containsKey → hm.containsKey(key); ⇒ true (present) / false (not present)

O(1) ③ get → hm.get(key); → if key is present, returns the value, else returns null.

O(1) ④ getOrDefault → hm.getOrDefault(key, specVal); if key is present, returns the val, else returns the specified val.

O(N) ⑤ keySet() → hm.keySet() ⇒ returns a set of keys.

Highest frequency Character

Highest Frequency Character

Easy

Prev Next

1. You are given a string str.
2. You are required to find the character with maximum frequency.

"aabbaccabcdabbbaddda"

a - X 2 3 4 5 6 7

b - 1 2 3 4 5 6

c - X 2 3

d - 1 X 3 4

Code for Max freq Character

```java
public static void main(String[] args) throws Exception {
    // write your code here
    Scanner scn = new Scanner(System.in);
    String str = scn.nextLine();
    HashMap<Character,Integer> fmap = new HashMap<>();

    for(int i=0;i<str.length();i++) {
        fmap.put(str.charAt(i),fmap.getOrDefault(str.charAt(i),0) + 1);
    }

    char ans = '0';
    int maxFreq = 0;
    for(Character ch : fmap.keySet()) {
        if(fmap.get(ch) > maxFreq) {
            ans = ch;
            maxFreq = fmap.get(ch);
        }
    }

    System.out.println(ans);
}
```

Get Common Elements - 1

$a_1 \rightarrow$ 1 1 2 2 2 3 5

$a_2 \rightarrow$ 1 1 1 2 2 4 5

Ans : 1 2 5

Here we do not need a hashmap as only hashset will be enough to check the occ of ele in the array once.

hm1 (for a1)

1 - 2

2 - 3

3 - 1

5 - 1

hm2 (for a2)

~~1 - 3~~

~~2 - 2~~

~~4 - 1~~

5 - 1

Code for Get Common Elements -1

```java
public static void main(String[] args) throws Exception {
    // write your code here
    Scanner scn = new Scanner(System.in);
    int n1 = scn.nextInt();
    int[] a1 = new int[n1];
    HashSet<Integer> hs1 = new HashSet<>();
    for(int i=0;i<n1;i++) {
        a1[i] = scn.nextInt();
        hs1.add(a1[i]);
    }

    int n2 = scn.nextInt();
    int[] a2 = new int[n2];
    HashSet<Integer> hs2 = new HashSet<>();
    for(int i=0;i<n2;i++) {
        a2[i] = scn.nextInt();
        hs2.add(a2[i]);
    }

    for(int i=0;i<a2.length;i++) {
        if(hs2.contains(a2[i]) && hs1.contains(a2[i])) {
            System.out.println(a2[i]);
            hs2.remove(a2[i]);
        }
    }

 }

}
```

Get Common Elements - II (find Intersection)

```java
Scanner scn = new Scanner(System.in);
int n1 = scn.nextInt();
int[] a1 = new int[n1];

HashMap<Integer,Integer> hm1 = new HashMap<>();
for(int i=0;i<n1;i++) {
    a1[i] = scn.nextInt();
    int oFreq = hm1.getOrDefault(a1[i],0);
    hm1.put(a1[i],oFreq + 1);
}

int n2 = scn.nextInt();
int[] a2 = new int[n2];
HashMap<Integer,Integer> hm2 = new HashMap<>();
for(int i=0;i<n2;i++) {
    a2[i] = scn.nextInt();
    int oFreq = hm2.getOrDefault(a2[i],0);
    hm2.put(a2[i],oFreq + 1);
}

for(int ele : a2) {
    if(hm2.get(ele) > 0) {
        if(hm1.containsKey(ele) && hm1.get(ele) > 0) {
            System.out.println(ele);
            hm1.put(ele, hm1.get(ele) - 1);
            hm2.put(ele, hm2.get(ele) - 1);
        }
    }
}
```

Here we need hashmap because in intersection, frequency is also necessary.

Longest Consecutive Sequence of Elements {Longest Consecutive Seq : Leetcode - 128}

{ 100, 4, 200, 1, 3, 2 }

① Put true against all eles in Hash Map.
② Now, if ele - 1 is found in hashmap, make ele false as it is not the start of seq.
③ If the value is true, try to find out the max len.

100 - t
4 - t f
200 - t
1 - t
3 - t f
2 - t f

Code

```java
public int longestConsecutive(int[] nums) {
    HashMap<Integer,Boolean> hm = new HashMap<>();

    for(int i=0;i<nums.length;i++) {
        hm.put(nums[i],true);
    }

    for(int key: hm.keySet()) {
        if(hm.containsKey(key-1) == true) {
            hm.put(key,false);
        }
    }

    int maxLen = 0;
    for(int key: hm.keySet()) {
        if(hm.get(key) == true) {
            int x = key;
            int len = 1;
            while(hm.containsKey(x + 1) == true) {
                len++;
                 x = x + 1;
            }
            maxLen = Math.max(maxLen,len);
        }
    }
```

Heaps { Priority Queue } { Removes higher Priority element first }

Based on Priority {
- add } O(log N)
- remove } O(log N)
- peek → O(1)
}

```
public static void main(String[] args) throws Exception {
    PriorityQueue<Integer> pq = new PriorityQueue<>(Collections.reverseOrder());
    int[] ranks = {22, 99, 3, 11, 88, 4, 1};
```

Now, it will give high priority to higher value!

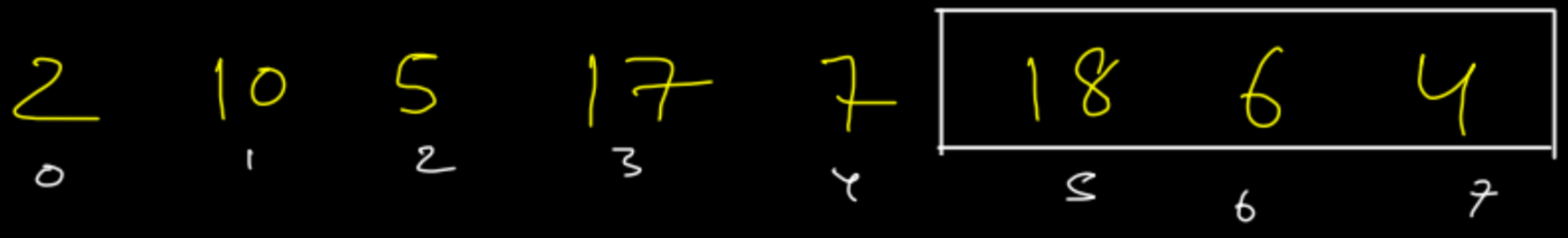
In PQ, we can specify whether lower value has a higher Priority or vice versa. { By default, lower value has higher priority }

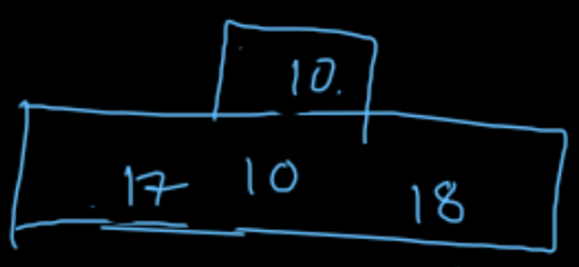
K Largest Elements

3 largest elements.

2 10 5 17 7 18 6 4

⇒ Make a PQ of size = 3.





6∝

4∝

↳ 10 17 18 (3 largest elts in sorted order)

Code for K Largest Elements

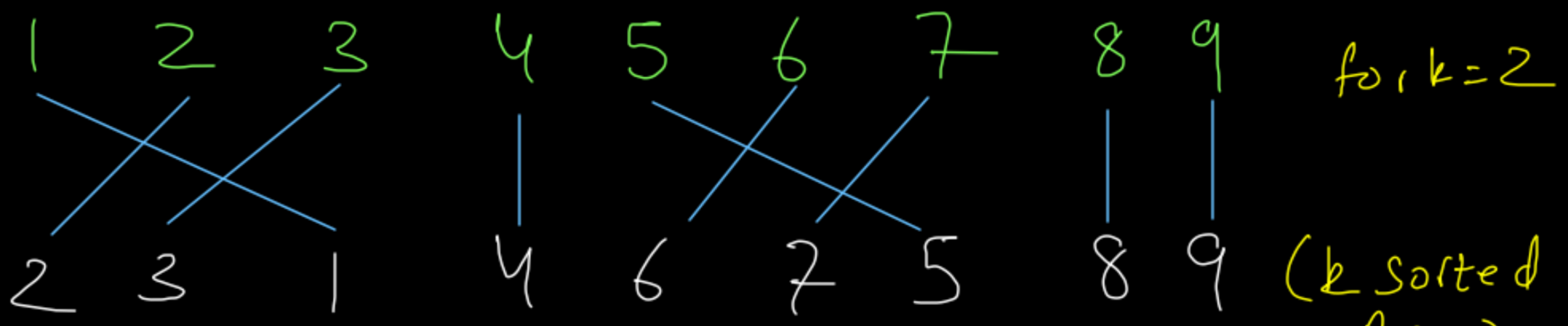
```
    int k = Integer.parseInt(br.readLine());
    // write your code here
    PriorityQueue<Integer> pq = new PriorityQueue<>();

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

    for(int i=1;i<=n-k;i++) {
        int incomingEle = arr[i + k -1];
        if(incomingEle > pq.peek()) {
            pq.remove();
            pq.add(incomingEle);
        }
    }

    while(pq.size() > 0) {
        System.out.println(pq.remove());
    }

}
```

K^th Largest Element {Leetcode : 215}

Same as prev ques. Just, return the peek at the end.

```
class Solution {
    public int findKthLargest(int[] arr, int k) {
        PriorityQueue<Integer> pq = new PriorityQueue<>();
        int n = arr.length;
        for(int i=0;i<k;i++) {
            pq.add(arr[i]);
        }

        for(int i=1;i<=n-k;i++) {
            int incomingEle = arr[i + k -1];
            if(incomingEle > pq.peek()) {
                pq.remove();
                pq.add(incomingEle);
            }
        }

        return pq.peek();
    }
```

Sort k Sorted Array



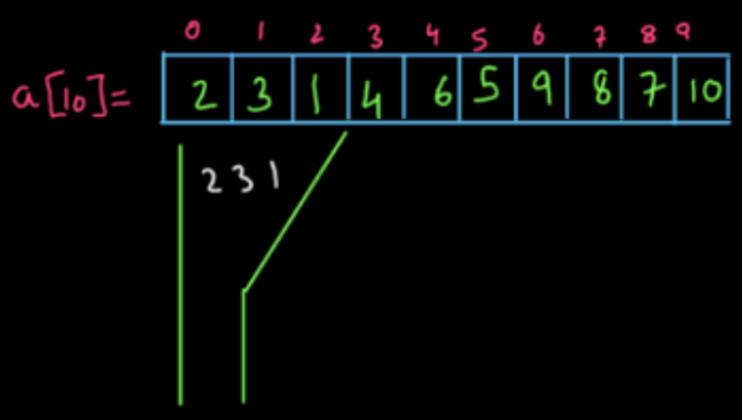
k Sorted Array: Every element in the array moves to atmost k right / left positions from its sorted position.

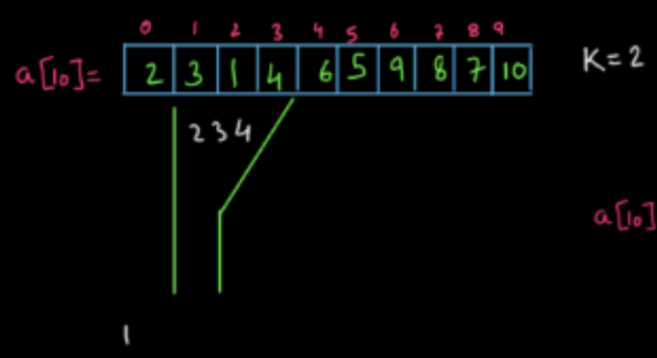
Q 2 3 1 4 6 7 5 8 9

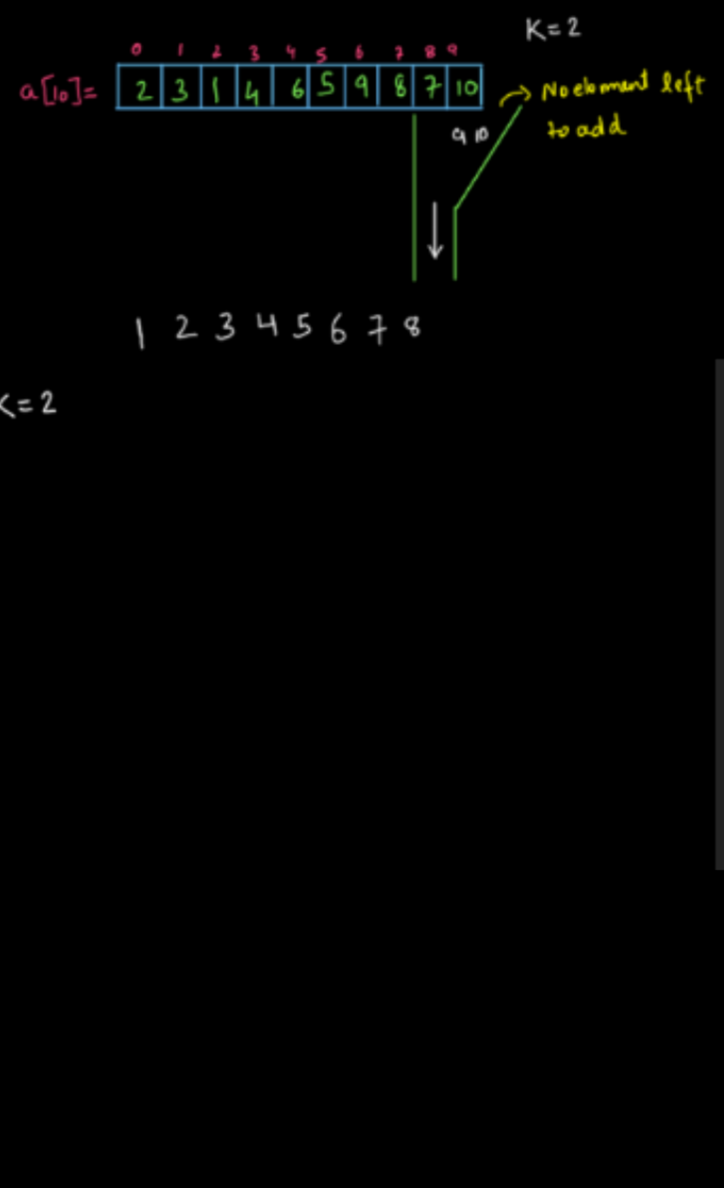
Allowed

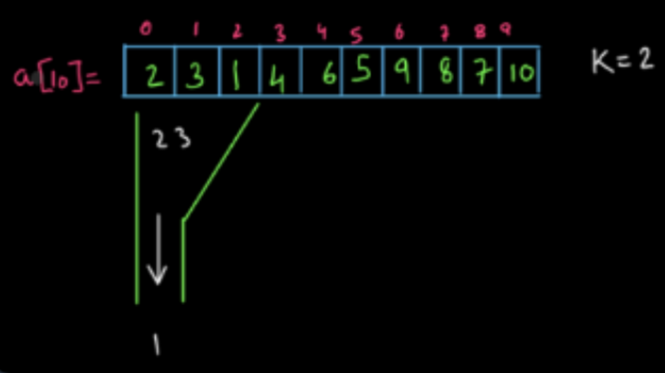
TC = $O(n \log_2 K)$

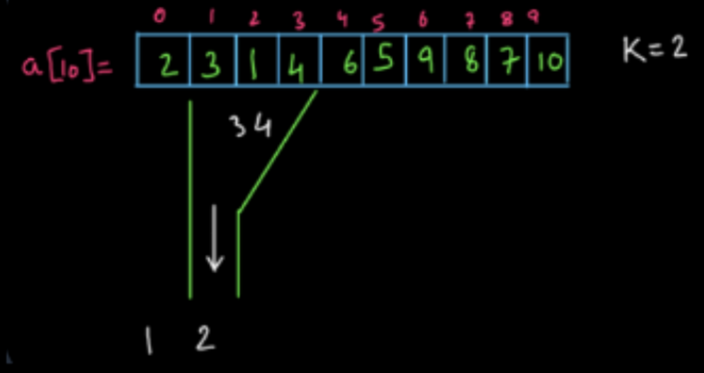
SC = $O(K)$











Code

```java
public static void main(String[] args) throws Exception {
    BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
    int n = Integer.parseInt(br.readLine());
    int[] arr = new int[n];

    for (int i = 0; i < n; i++) {
        arr[i] = Integer.parseInt(br.readLine());
    }

    int k = Integer.parseInt(br.readLine());
    // write your code here

    PriorityQueue<Integer> pq = new PriorityQueue<>();
    int[] ans = new int[n];

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

    for(int i=k+1 ; i< n; i++) {
        System.out.println(pq.remove());
        pq.add(arr[i]);
    }

    while(pq.size() > 0) {
        System.out.println(pq.remove());
    }
```

Median Priority Queue (VVVImp) & find Median from Data Stream } Hard

add → adds an element to the Median PQ

remove → removes the median ele from the PQ

peek → returns the median element.

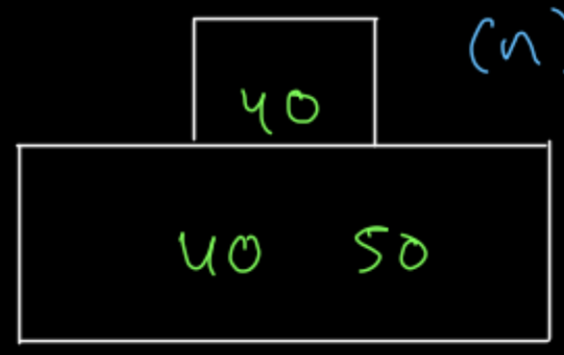
size → returns the size of the PQ.

10, 20, 30, 40 ⇒ In case of even eles
↓↓
median

10, 20, 30, 40, 50 ⇒ odd eles
↓
median

We will use 2 priority queues to obtain the MPQ.

(2n+1) eles



left = smaller half of the data (max Heap)

right = larger half of the data (min Heap)

Ex: 10, 20, 30, 40, 50

** The gap b/w size of PQs should always be either 0 or 1 not more-

By default, try to add in left. If incoming ele is greater than peek of the right, then insert the ele in the right.

Median will be the peek of that PQ whose size is bigger.

If size is equal, median will be picked from the left PQ.

Remove the ele from largest sized PQ. In case of same size, remove from left.

Concept

add (10)

add (20) * size diff

add (30) → right peek

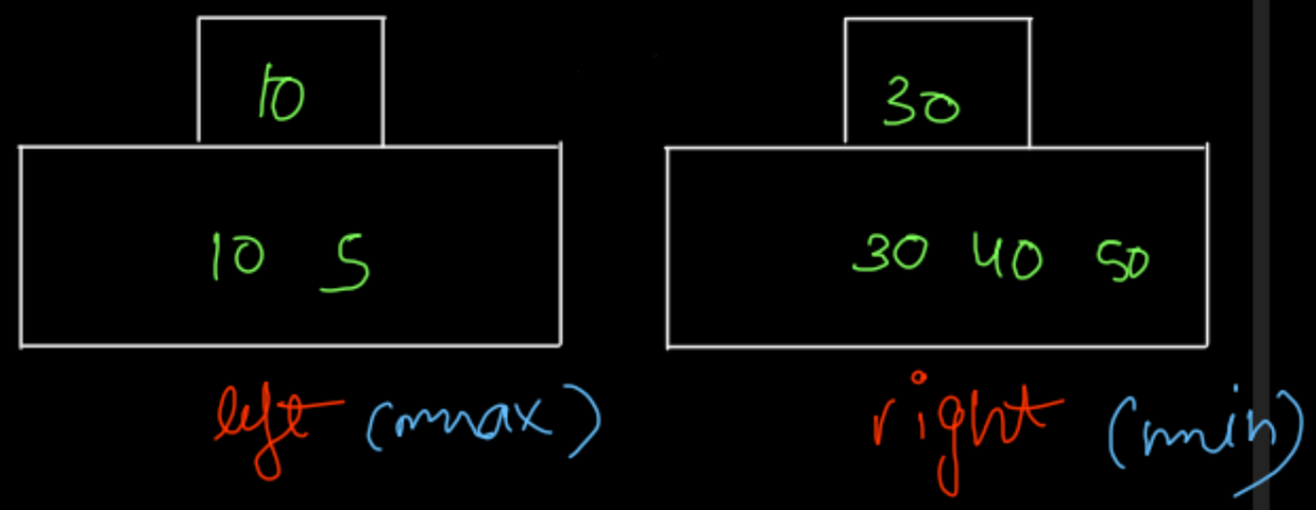
add (40) * size diff

add (50)

add (5)

remove

Implementation



Code & COPY PASTE THE SAME CODE IN LINTCODE :)

```
public static class MedianPriorityQueue {
  PriorityQueue<Integer> left;
  PriorityQueue<Integer> right;

  public MedianPriorityQueue() {
    left = new PriorityQueue<>(Collections.reverseOrder());
    right = new PriorityQueue<>();
  }
```

```
public void add(int val) {
  // write your code here
  if(right.size() > 0 && val > right.peek()) right.add(val);
  else left.add(val);

  if(left.size() - right.size() >= 2) right.add(left.remove());
  else if(right.size() - left.size() >= 2) left.add(right.remove());
}
```

```
public int size() {
  // write your code here
  return left.size() + right.size();
}
```

```
public int peek() {
  // write your code here
  if(size() == 0) {
      System.out.println("Underflow");
      return -1;
  }

  if(left.size() < right.size()) return right.peek();

  return left.peek();
}
```

```
public int remove() {
  // write your code here
  if(size() == 0) {
      System.out.println("Underflow");
      return -1;
  }

  if(left.size() < right.size()) return right.remove();

  return left.remove();
}
```

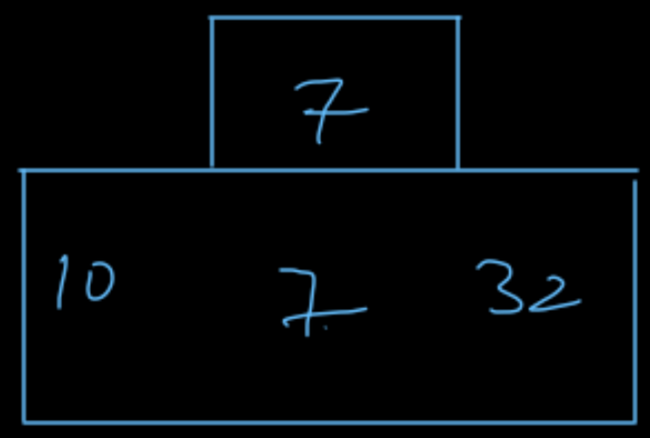
Merge K Sorted Lists

10 20 30 40 50

5 7 9 11 19 55 57

1 2 3

32 39



1 2 3 5

Code

```java
public static class Pair implements Comparable<Pair>{
    int li;
    int di;
    int val;

    Pair() {

    }

    Pair(int li, int di, int val) {
        this.li = li;
        this.di = di;
        this.val = val;
    }

    public int compareTo(Pair other) {
        return this.val - other.val;
    }
}
```

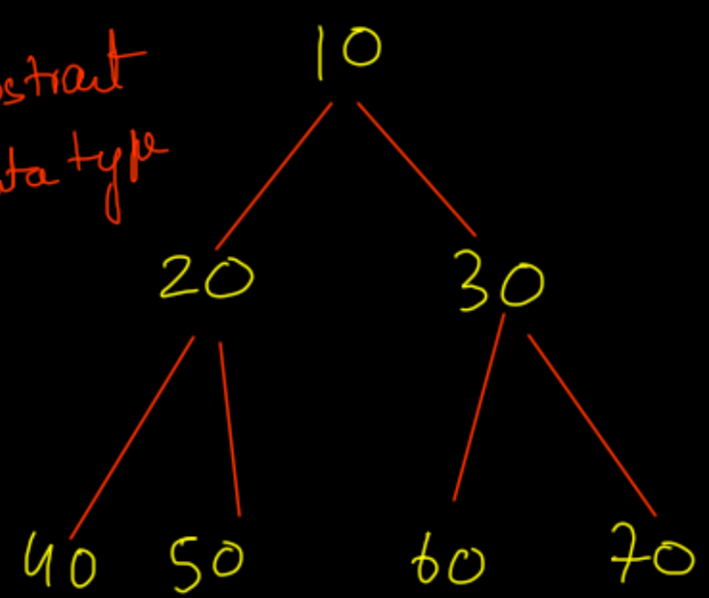
```java
public static ArrayList<Integer> mergeKSortedLists(ArrayList<ArrayList<Integer>> lists){
    ArrayList<Integer> rv = new ArrayList<>();

    PriorityQueue<Pair> pq = new PriorityQueue<>();
    for(int i=0;i<lists.size();i++) {
        Pair p = new Pair(i,0,lists.get(i).get(0));
        pq.add(p);
    }

    while(pq.size() > 0) {
        Pair p = pq.remove();
        rv.add(p.val);
        p.di++;
        if(p.di < lists.get(p.li).size()) {
            p.val = lists.get(p.li).get(p.di);
            pq.add(p);
        }
    }

    return rv;
}
```

Write Priority Queue using Heap → Binary Heap (DS)

Heap: A BT data structure that follows 2 properties.

1. Heap Order Property
2. Complete Binary Tree Property

Abstract Data type



What

Heap Order Property: Every parent has higher priority than their children. There is no specification on whether left child's priority will be higher than right or vice versa.

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Why Heap Order Property?

=> Because of the Heap Order Property, every parent will have greater priority than its children. Since root is the ancestor of all the nodes in a tree, root will have the highest priority. So, we will be able to achieve peek() in O(1) time.

Aim

add
remove
} $O(\log_2 n)$

✓ peek $\Rightarrow$ O(1) (Achieved due to Heap)

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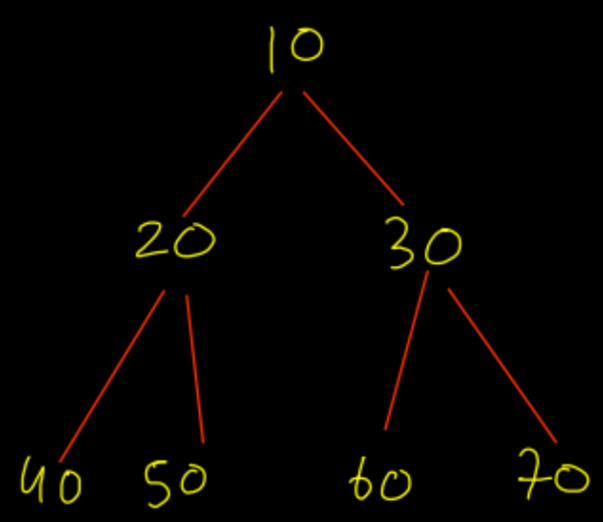
What is complete binary tree property?

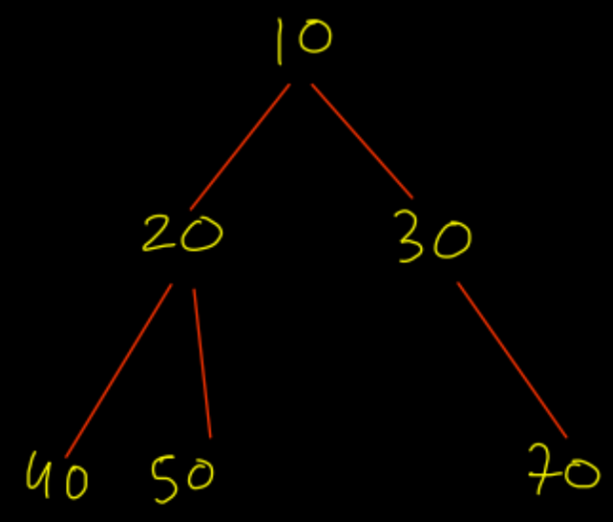
⇒ Either all the levels of a tree should be completely filled or H-1 levels should be completely filled & the last level (H^th level) should be filled from left to right.

Why??

To achieve add & remove in $O(\log_2 N)$



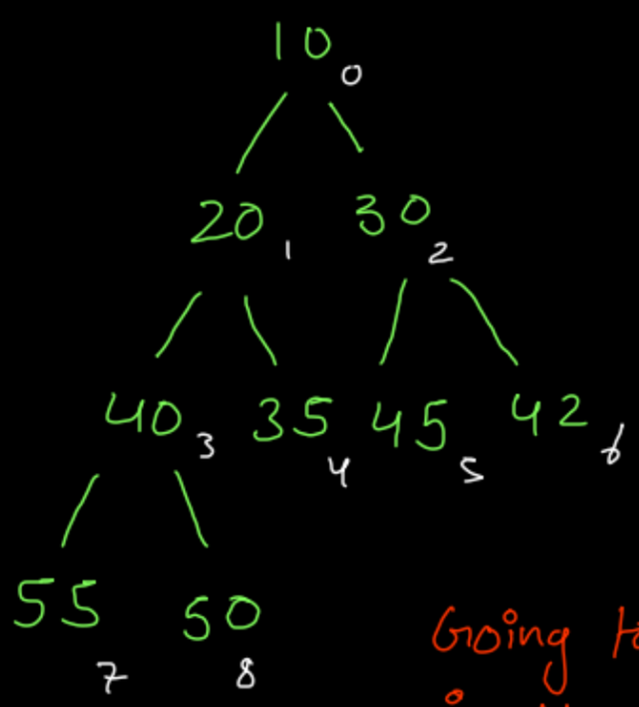
Complete BT ✓



Not a complete BT ✗

for storage, heap uses an arraylist only internally.

10 20 30 40 35 45 42 55 50



leftchild index = 2 * parent index + 1

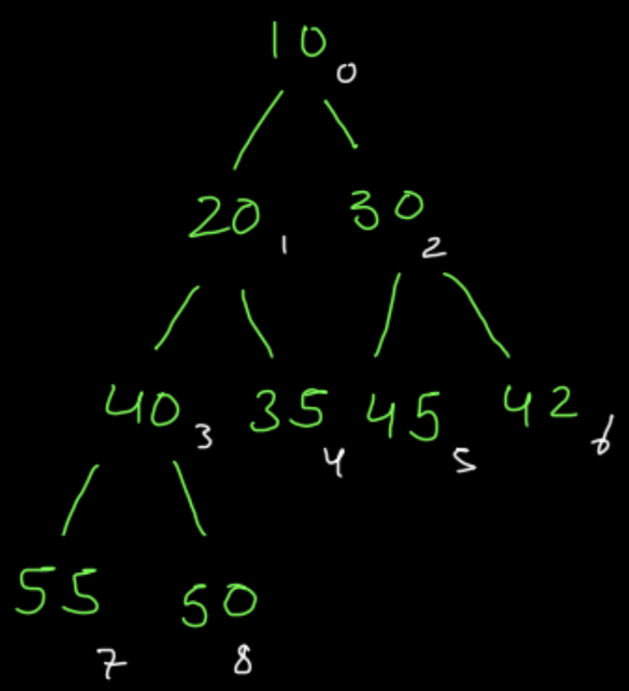
rightchild index = 2 * parent index + 2

$$\text{parent index} = \frac{\text{child index} - 1}{2}$$

Going towards the parent from the child is the extra capability that we get on seing arraylist as a tree.

Add

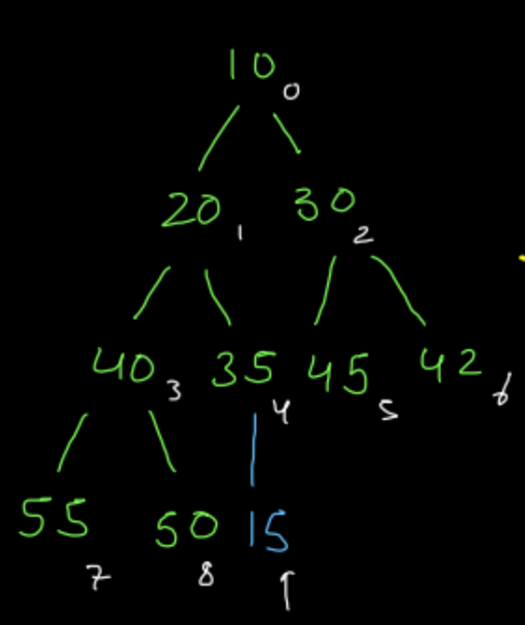
10 20 30 40 35 45 42 55 50

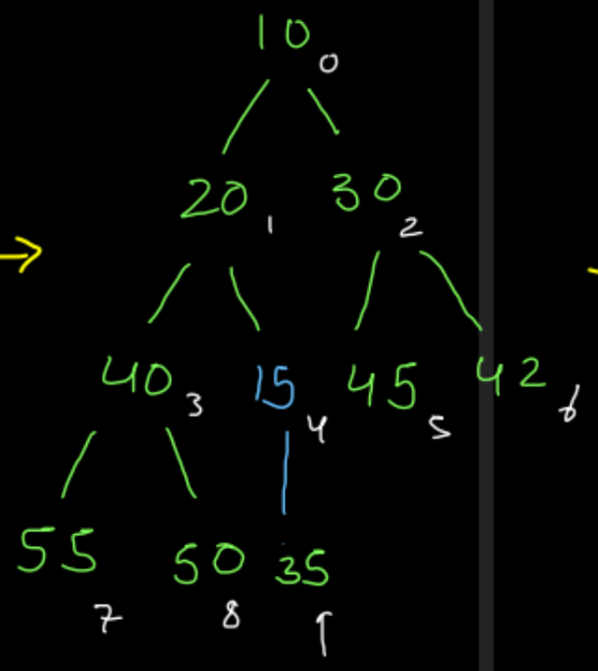


Add 15

10 20 30 40 35 45 42 55 50 15

0 1 2 3 4 5 6 7 8 9





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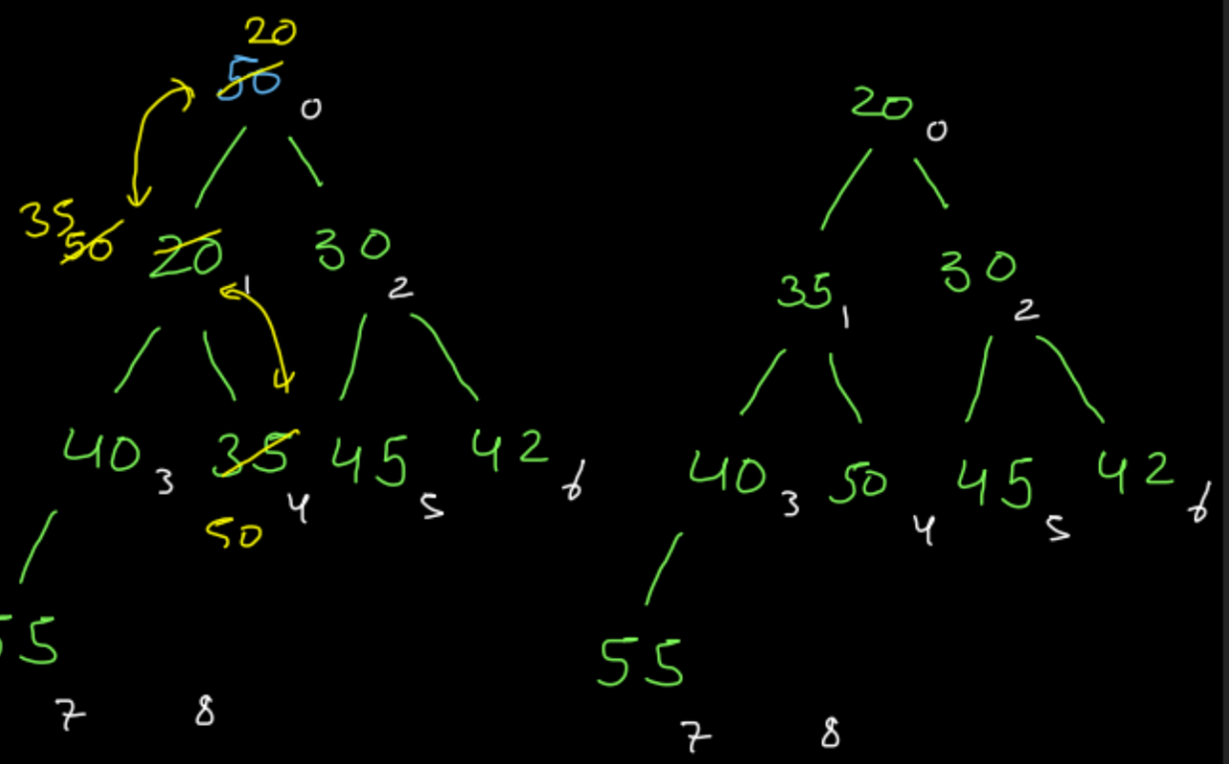
Complete Binary Tree → AL → 9dx → parent → upheapify → Add O(logn)

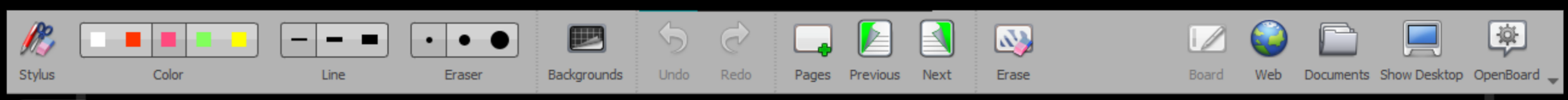
Remove

① Swap idx=0 & last idx.

② Delete last element.

③ Down heapify.






```java
public static class PriorityQueue {
  ArrayList<Integer> data;

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

```java
  public void add(int val) {
    // write your code here
    data.add(val);
    upheapify(data.size() - 1);
  }

  private void upheapify(int i) {

      if(i == 0) {
          return;
      }

      int pi = (i-1)/2;
      if(data.get(i) < data.get(pi)) {
          swap(i,pi);
          upheapify(pi);
      }
  }
```

```java
  public int remove() {
    // write your code here
    if(this.size() == 0) {
        System.out.println("Underflow");
        return -1;
    }

    swap(0,data.size() - 1);
    int val = data.remove(data.size() - 1);
    downheapify(0);
    return val;
  }

  private void downheapify(int pi) {

      int mini = pi;

      int li = 2*pi + 1;
      if(li < data.size() && data.get(li) < data.get(mini)) {
          mini = li;
      }

      int ri = 2*pi + 2;
      if(ri < data.size() && data.get(ri) < data.get(mini)) {
          mini = ri;
      }

      if(mini != pi) {
          swap(pi,mini);
          downheapify(mini);
      }
  }
```

```java
  private void swap(int i, int j) {
      int ith = data.get(i);
      int jth  = data.get(j);
      data.set(i,jth);
      data.set(j,ith);
  }
```

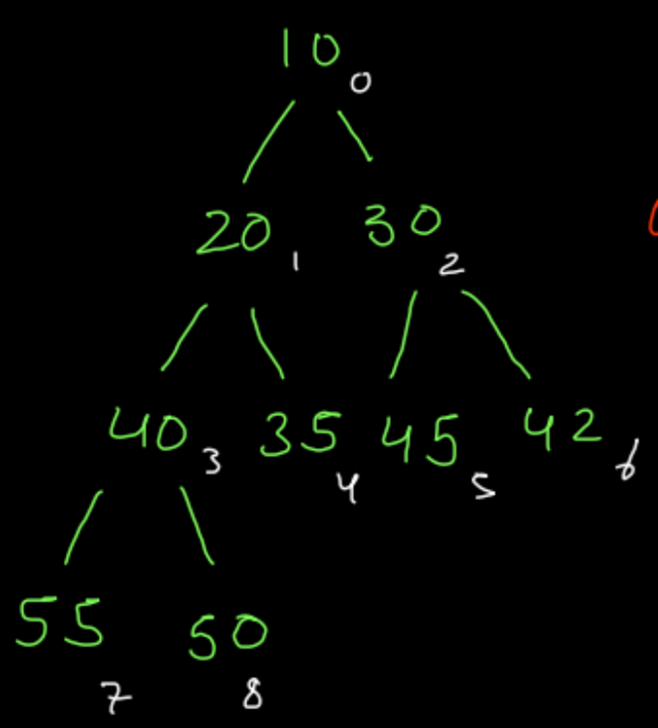
```java
  public int peek() {
    // write your code here
    if(this.size() == 0) {
        System.out.println("Underflow");
        return -1;
    }

    return data.get(0);
  }

  public int size() {
    // write your code here
    return data.size();
  }
```

Heap Sort

{ By dfault not stable, stable banava padega }



Removed elements will be in Sorted order

10
20
30
35
:
:

TC = O(N * logN)

SC = O(N)

QuickSort → ~~Stable~~
Heap Sort → Stable
Merge Sort → Stable

We can keep the element attached to the heap instead of removing it & the space complexity will be O(1) in that case.

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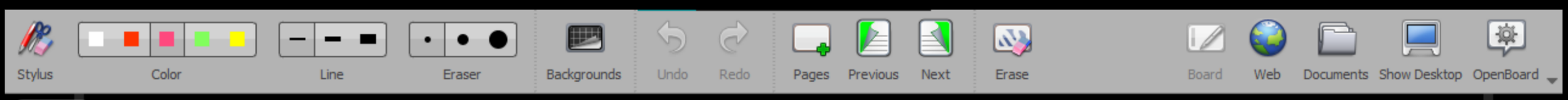
Heap Sort Code

```
public ArrayList<Integer> heapSort(){
    ArrayList<Integer> sorted = new ArrayList<>();

    while(this.size() > 0) {
        int val = this.remove();
        sorted.add(val);
    }

    return sorted;
  }
}
```

O(n log N) Time

O(n) Space




```java
public static class PriorityQueue {
  ArrayList<Integer> data;
  private int size;

  public PriorityQueue() {
    data = new ArrayList<>();
    size = 0;
  }
```

```java
  public void add(int val) {
    // write your code here
    data.add(val);
    size++;
    upheapify(data.size() - 1);
  }

  private void upheapify(int i) {

      if(i == 0) {
          return;
      }

      int pi = (i-1)/2;
      if(data.get(i) < data.get(pi)) {
          swap(i,pi);
          upheapify(pi);
      }
  }
```

```java
  private void swap(int i, int j) {
      int ith = data.get(i);
      int jth  = data.get(j);
      data.set(i,jth);
      data.set(j,ith);
  }

  public int remove() {
    // write your code here
    if(this.size() == 0) {
        System.out.println("Underflow");
        return -1;
    }

    swap(0,data.size() - 1);
    int val = this.peek();
    size--;
    downheapify(0);
    return val;
  }
```

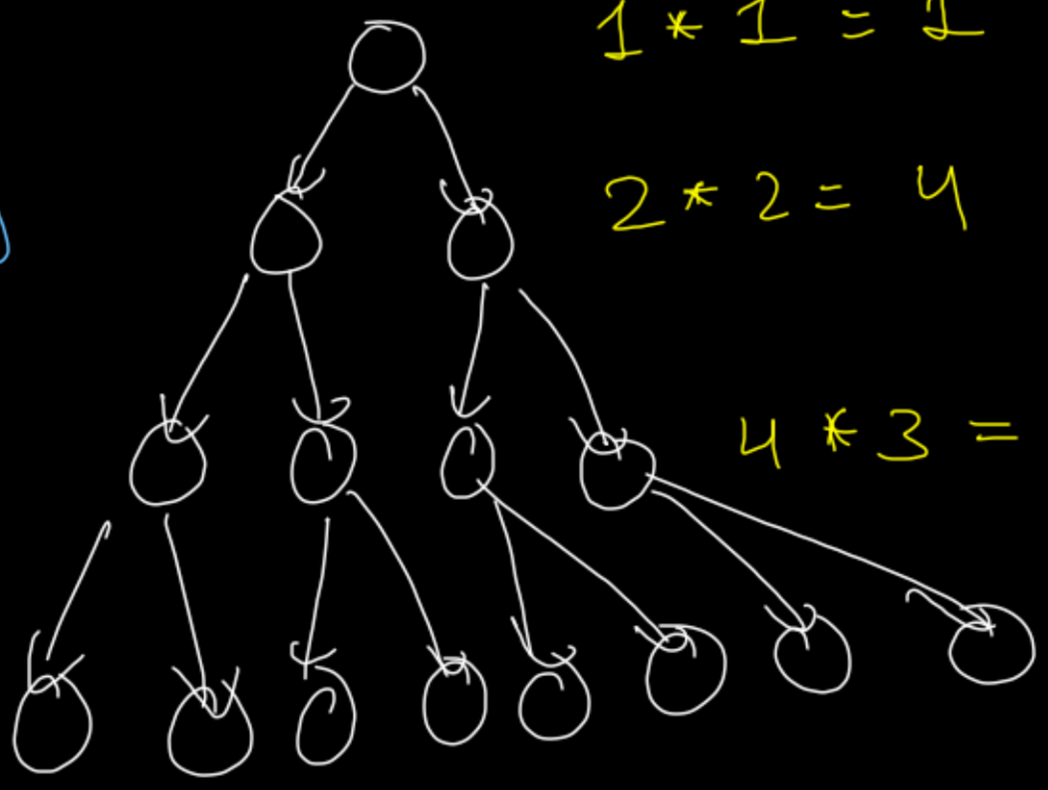
```java
  public ArrayList<Integer> inPlaceHeapSort() {
      while(size() > 0) {
          remove();
      }
      return data;
  }
}
```

O(1) space

```java
  private void downheapify(int pi) {

      int mini = pi;

      int li = 2*pi + 1;
      if(li < size && data.get(li) < data.get(mini)) {
          mini = li;
      }

      int ri = 2*pi + 2;
      if(ri < size && data.get(ri) < data.get(mini)) {
          mini = ri;
      }

      if(mini != pi) {
          swap(pi,mini);
          downheapify(mini);
      }
  }
```

```java
  public int peek() {
    // write your code here
    if(this.size() == 0) {
        System.out.println("Underflow");
        return -1;
    }

    return data.get(0);
  }

  public int size() {
    // write your code here
    return size;
  }
```

Insertion using Down Heapify



$1 * 1 = 1$

$2 * 2 = 4$

$4 * 3 = 12$

$8 * 4 = 32$

UpHeapify

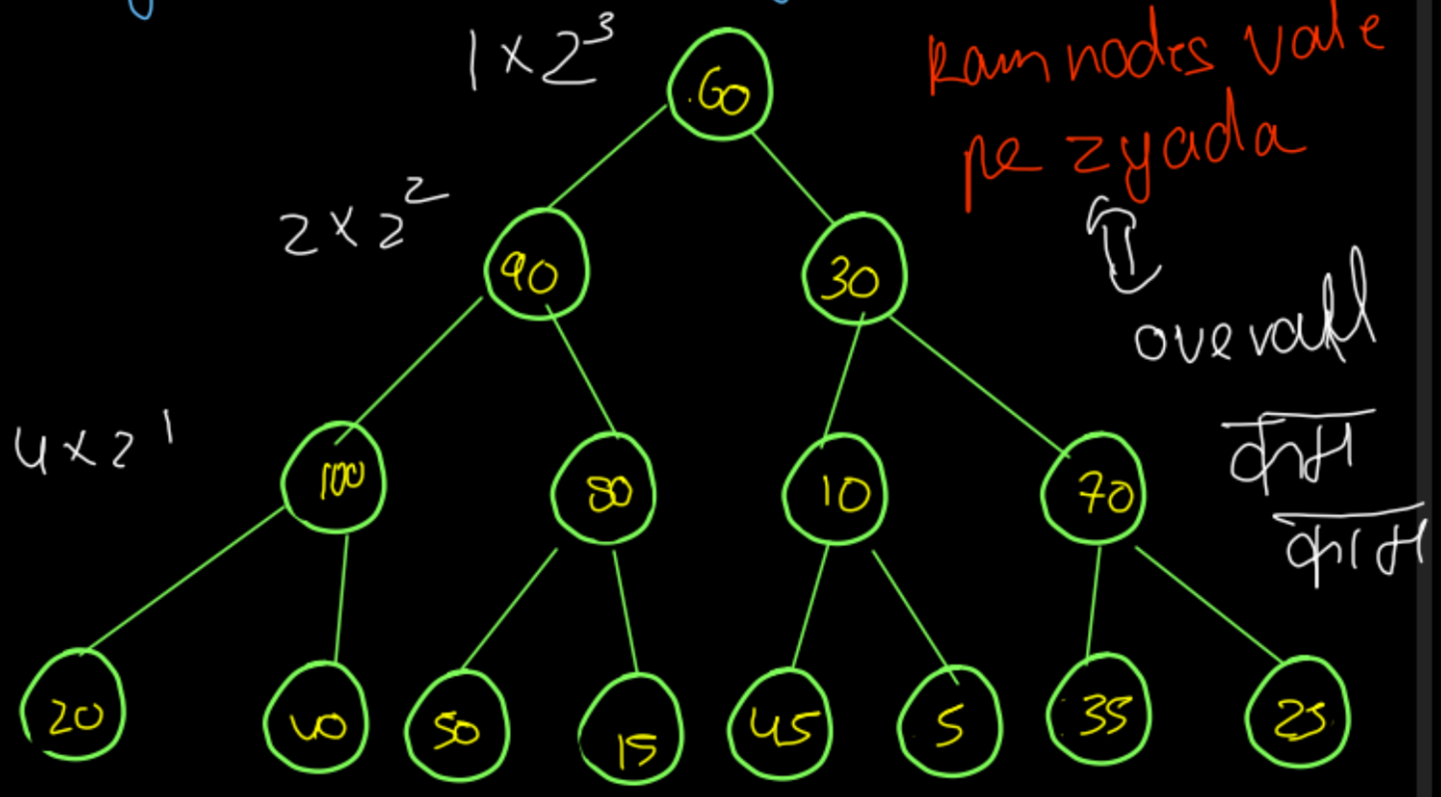
TC

$2^0 \times 1 + 2^1 \times 2 + 2^2 \times 3 + 2^3 \times 4$ upto N terms $\Rightarrow$ NlogN

Insertion using Down Heapify

⇒ Pass the entire array as input in one go.

Down Heapify TC



Zyada nodes vale level pe kam kaam & kam nodes vale pe zyada

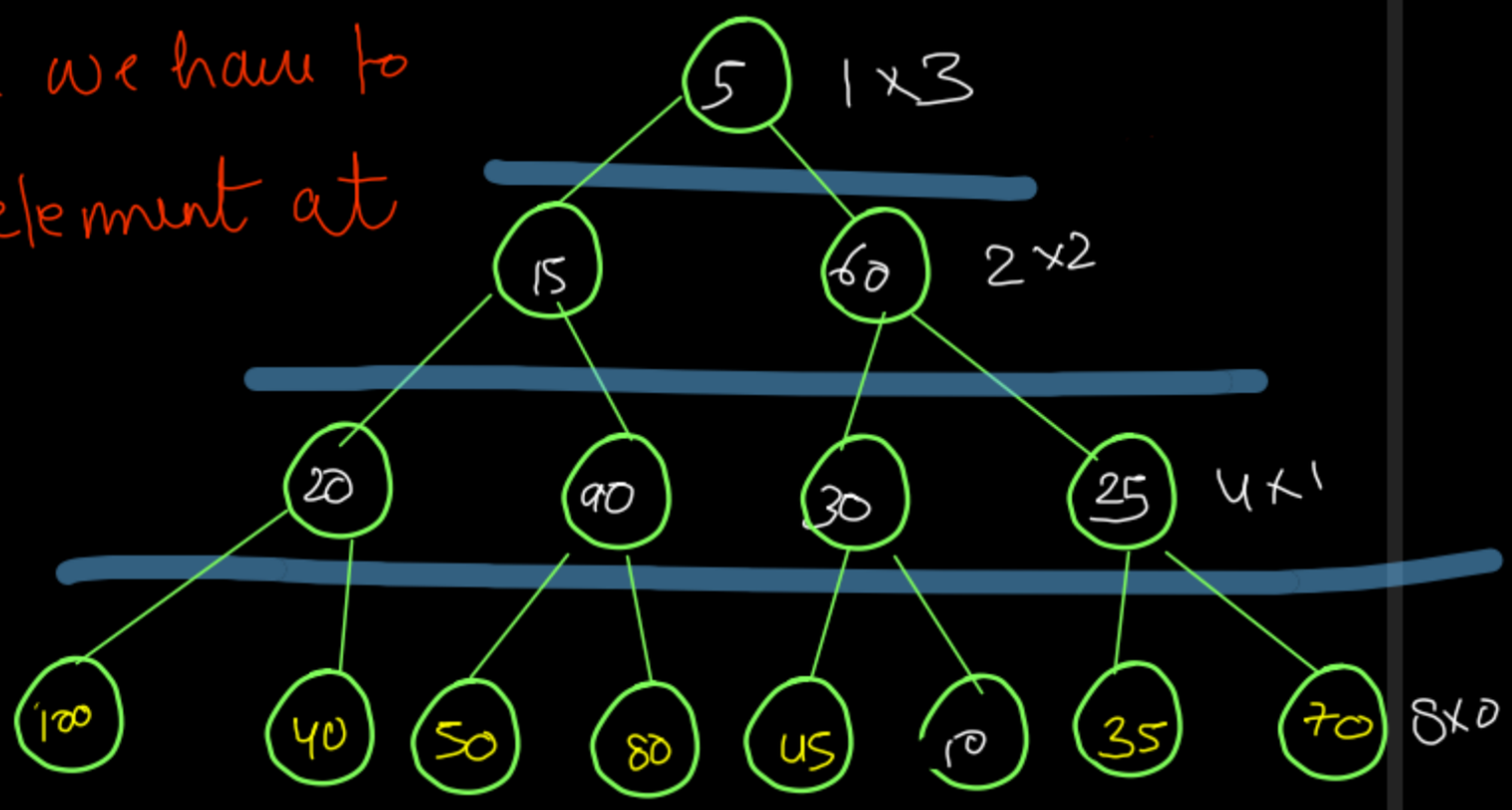
overall

कम

काम

down heapify will start from the bottom level because we have to bring the smallest element at the top-

No work at the last level.



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Code for Insertion using downHeapify

```java
// O(n) time for inserting N Elements
public PriorityQueue(int[] arr) {
    data = new ArrayList<>();

    for(int val : arr) {
        data.add(val);
        size++;
    }

    for(int i=(size()-1)/2;i>=0;i--) {
        downheapify(i);
    }
}
```

Efficient Heap Constructor

Time Complexity of Insertion using down-heapify -

① $T(n) = 2^0 \cdot h + 2^1 \cdot (h-1) + 2^2 \cdot (h-2) + 2^3 \cdot (h-3) + \cdots 2^{h-1} \cdot 1$

AGP

② $2T(n) = 2^1 \cdot h + 2^2 (h-1) + 2^3 (h-2) + \cdots 2^h \cdot 1$

② − ①

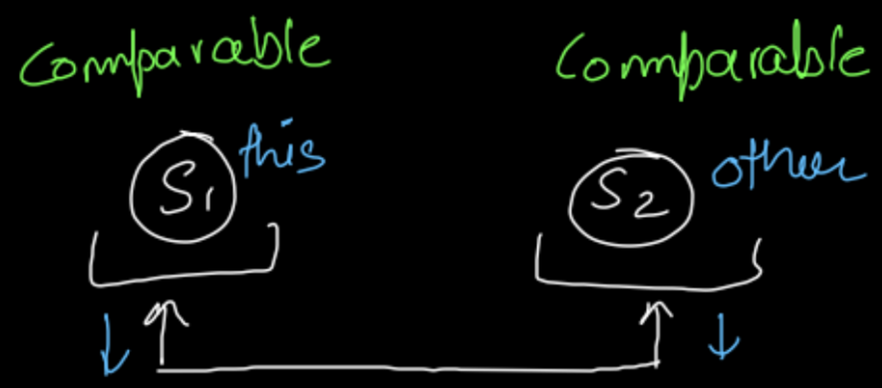
$$(2-1)T(n) = -2^0 \cdot h + \{2^1 \cdot 1 + 2^2 \cdot 1 + 2^3 \cdot 1 + \cdots 2^h \cdot 1\}$$

$2-1 = 1$

$$T(n) = (2^h - 1) - 2^0 \cdot h = 2^{\log_2 n} - 1 - \log_2 n$$

$$\Rightarrow TC = n - 1 - \log_2 n = \boxed{O(n)}$$

Comparable & Comparator



to give higher priority to higher rollNo

other.RollNo - this.RollNo

S1↓ S2↑

{this.rollNo - other.rollNo}

↓↓

-ve ⇒ we are giving priority to smaller element

Comparable Interface Example

```java
public static class Student implements Comparable<Student>{
    int rollNo;
    int marks;
    int height;
    int weight;

    Student() {

    }

    Student(int rollNo, int marks, int height, int weight) {
        this.rollNo = rollNo;
        this.height = height;
        this.marks = marks;
        this.weight = weight;
    }

    public int compareTo(Student other) {
       //Smaller roll No -> Greater Priority
       return this.rollNo - other.rollNo;
    }

    @Override
    public String toString() {
        return ("rollNo = " + this.rollNo + " marks = " + this.marks + " height = " + this.height);
    }
}
```

```java
public static void main(String[] args) throws Exception {

    PriorityQueue<Student> q = new PriorityQueue<>();
    q.add(new Student(30,91,100,70));
    q.add(new Student(40,90,101,71));
    q.add(new Student(50,100,102,72));
    q.add(new Student(60,89,103,73));

    while(q.size() > 0) {
        Student top = q.remove();
        System.out.println(top);
    }

}
```

Comparator Example

```java
public static class StudentComparator implements Comparator<Student> {
    public int compare(Student s, Student other) {
        //Greater the marks-> Greater the priority
        return other.marks - s.marks;
    }
}
```

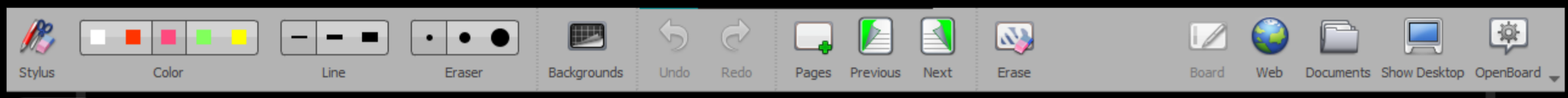
```java
public static void main(String[] args) throws Exception {

    PriorityQueue<Student> q = new PriorityQueue<>(new StudentComparator());
    q.add(new Student(30,91,100,70));
    q.add(new Student(40,90,101,71));
    q.add(new Student(50,100,102,72));
    q.add(new Student(60,89,103,73));

    while(q.size() > 0) {
        Student top = q.remove();
        System.out.println(top);
    }


}
```

Generic PQ

```java
public static class Student implements Comparable<Student> {
  int marks;
  int rollNo;
  int weight;
  int height;

  Student() {

  }

    @Override
    public String toString() {
        return ("rollNo = " + this.rollNo + " marks = " + this.marks + " height = " + this.height);
    }

  Student(int marks,int weight, int rollNo, int height) {
      this.marks = marks;
      this.weight = weight;
      this.height = height;
      this.rollNo = rollNo;
  }

  public int compareTo(Student other) {
      return other.marks - this.marks;
  }
}
```

```java
public static class StudentRollNoComparator implements Comparator<Student> {

    public int compare(Student me, Student other) {
        return me.rollNo - other.rollNo;
    }
}
```

```java
public static class PriorityQueue<K> {
    ArrayList<K> data;
    private int size;
    private Comparator<K> comp;

    public PriorityQueue() {
      data = new ArrayList<>();
      size = 0;
      comp = null;
    }

    public PriorityQueue(Comparator<K> comp) {
        this.comp = comp;
        data = new ArrayList<>();
        size = 0;
    }

    // O(n) time for inserting N Elements
    public PriorityQueue(K[] arr) {
        data = new ArrayList<>();

        for(K val : arr) {
            data.add(val);
            size++;
        }

        for(int i=(size()-1)/2;i>=0;i--) {
            downheapify(i);
        }
    }
```




```java
public void add(K val) {
  // write your code here
  data.add(val);
  size++;
  upheapify(size() - 1);
}
```

```java
private void downheapify(int pi) {

    int mini = pi;

    int li = 2*pi + 1;
    if(li < size && isSmaller(li,mini) == true) {
        mini = li;
    }

    int ri = 2*pi + 2;
    if(ri < size && isSmaller(ri,mini) == true) {
        mini = ri;
    }

    if(mini != pi) {
        swap(pi,mini);
        downheapify(mini);
    }
}
```

```java
public K peek() {
  // write your code here
  if(this.size() == 0) {
      System.out.println("Underflow");
      return null;
  }

  return data.get(0);
}

public int size() {
  // write your code here
  return size;
}
```

```java
private boolean isSmaller(int i1,int i2) {
    K obj1 = data.get(i1);
    K obj2 = data.get(i2);

    if(comp == null) {
        Comparable obj1C = (Comparable)obj1;
        Comparable obj2C = (Comparable)obj2;

        if(obj1C.compareTo(obj2C) < 0) {
            return true;
        }

        return false;
    } else {
        if(comp.compare(obj1,obj2) < 0) return true;
        else return false;
    }
}
```

```java
public ArrayList<K> heapSort() {
    ArrayList<K> sorted = new ArrayList<>();

    while(this.size() > 0) {
        sorted.add(this.remove());
    }

    return sorted;
}

public ArrayList<K> inPlaceHeapSort() {
    while(size() > 0) {
        remove();
    }

    return data;
}
```

```java
private void upheapify(int i) {

    if(i == 0) {
        return;
    }

    int pi = (i-1)/2;
    if(isSmaller(i,pi)) {
        swap(i,pi);
        upheapify(pi);
    }
}

private void swap(int i, int j) {
    K ith = data.get(i);
    K jth  = data.get(j);
    data.set(i,jth);
    data.set(j,ith);
}

public K remove() {
  // write your code here
  if(this.size() == 0) {
      System.out.println("Underflow");
      return null;
  }

  swap(0,size() - 1);
  K val = data.get(size - 1);
  size--;
  downheapify(0);
  return val;
}
```

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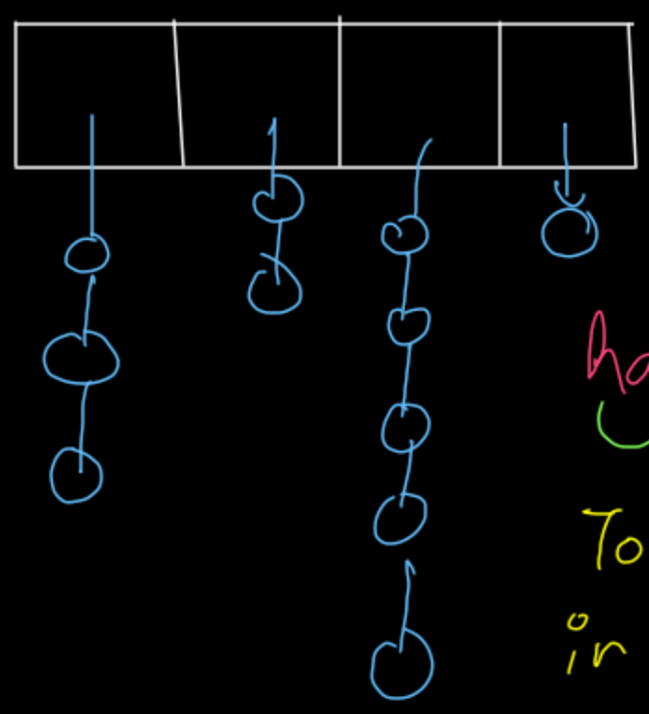
```java
public static void main(String[] args) throws Exception {
  PriorityQueue<Student> pq = new PriorityQueue<>(new StudentRollNoComparator());

  pq.add(new Student(80,75,2,103));
  pq.add(new Student(70,70,1,150));
  pq.add(new Student(20,60,8,120));
  pq.add(new Student(90,90,4,115));

  while(pq.size() > 0) {
      Student top = pq.remove();
      System.out.println(top);
  }
}
```

HashMap Construction

Array < LinkedList >

⇓

HashMap Node



Hashcode is there for every predefined class in Java -

User defined → make yourself

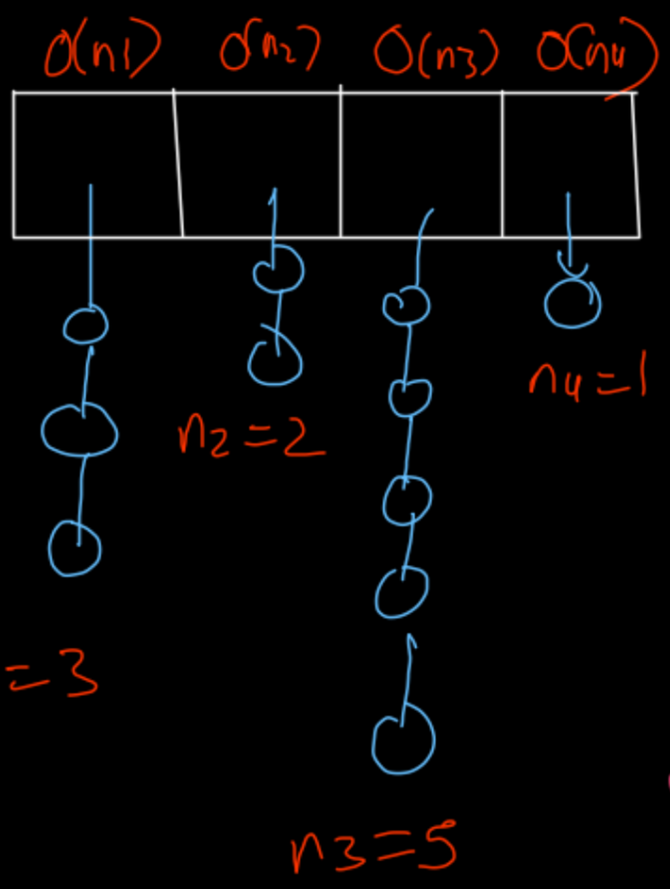
hash fun % 4

To get the data in one of the 4 buckets.

hash function

2 different keys can have the same hash function

but one key cannot have 2 diff hash funcs & a key will have a unique hash func$



Put TC = $O(\lambda)$ $\approx O(2) \approx$ constant

⇓

loading factor

λ = Total nodes / No of buckets = 11/4 = 2

↳ Avg nodes per bucket.

Loading factor = $\frac{\text{No of nodes}}{\text{No of Buckets}}$ ↑ (↑ inc will inc TC of put)

Worst case TC is O(N) if all nodes belong to LL.

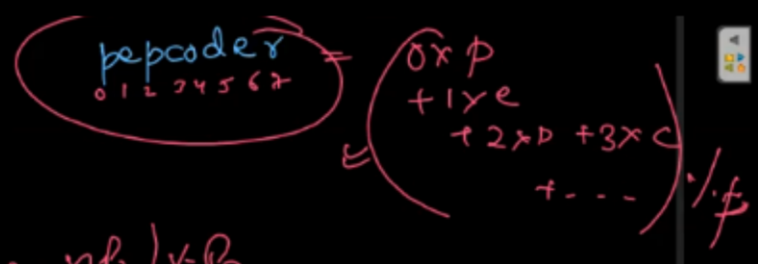
Hence, with inc no of nodes, no of buckets should also be increased.

Collisions should be minimized ⇒ create such a hash fun (good hash fun)

else

(bad hash function)

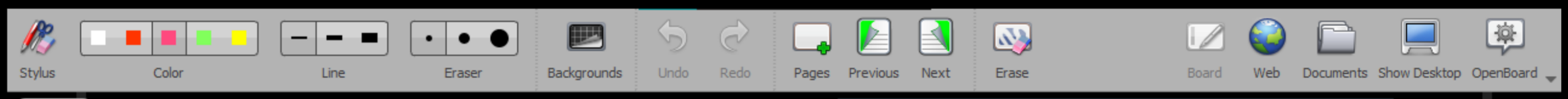
↳ String ⇒



↳ int → P_1, P_2 → (key × P_1) × P_2

```java
public static class HashMap<K, V> {

  private class HMNode {}

  private LinkedList<HMNode>[] buckets;
  private int noOfNodes;
  private int noOfBuckets;
  private double loadingFactor;

  public HashMap() {
      noOfBuckets = 4;
      noOfNodes = 0;
      loadingFactor = 0.0;
      init();
  }

  public void init() {
      buckets = new LinkedList[noOfBuckets];

      for(int i=0;i<noOfBuckets;i++) {
          buckets[i] = new LinkedList<>();
      }
  }
```

```java
public int getBucketID(K key) {
    //O(1)
    int hashCode = key.hashCode();
    int bucketID = (Math.abs(hashCode)) % noOfBuckets;
    return bucketID;
}

public HMNode getData(int bucketID, K key) {
    for(HMNode node : buckets[bucketID]) {
        if(node.key.equals(key) == true) {
            return node; //data already exist
            //return its index in the LL
        }

    }

    return null; //data does not exist
}
```




```java
public void put(K key, V value) throws Exception {
    // write your code here

    //O(1)
    int bucketIdx = getBucketID(key);
    HMNode data = getData(bucketIdx,key);

    if(data == null) {
        //Insertion (does not exist)
        double newLoadingFactor = (noOfNodes + 1.0) / noOfBuckets;

        if(newLoadingFactor > 2.0) {
            //rehashing
            LinkedList<HMNode>[] oldBuckets = buckets;
            noOfBuckets = 2 * noOfBuckets;
            init();

            for(int i=0;i<oldBuckets.length;i++) {
                for(HMNode node: oldBuckets[i]) {
                    int bucketID = getBucketID(node.key);
                    buckets[bucketID].addLast(node);
                }
            }
            int newBucketID = getBucketID(key);
            HMNode node = new HMNode(key,value);
            buckets[newBucketID].addLast(node);
            noOfNodes++;
            loadingFactor = (noOfNodes * 1.0) / noOfBuckets;

        } else {
            //Updation (key already exist)
            data.value = value;
        }
    }
```

```java
public V get(K key) throws Exception {
    // write your code here
    int bucketID = getBucketID(key);
    HMNode data = getData(bucketID,key);

    if(data != null) {
        return data.value;
    } else {
        return null;
    }
}

public boolean containsKey(K key) {
    // write your code here
    int bucketID = getBucketID(key);
    HMNode data = getData(bucketID,key);

    if(data != null) return true;
    else return false;
}

public V remove(K key) throws Exception {
    // write your code here
    int bucketID  = getBucketID(key);
    HMNode data = getData(bucketID,key);

    if(data == null) return null;

    V value = data.value;
    buckets[bucketID].remove(data);
    noOfNodes--;
    loadingFactor = (noOfNodes * 1.0) / noOfBuckets;
    return value;
}
```

```
    public ArrayList<K> keyset() throws Exception {
      // write your code here
      ArrayList<K> keys = new ArrayList<>();

      for(int i=0;i<noOfBuckets;i++) {
          for(HMNode node : buckets[i]) {
              keys.add(node.key);
          }
      }

      return keys;
    }

    public int size() {
      // write your code here
      return noOfNodes;
    }

  public void display() {
      System.out.println("Display Begins");
      for (int bi = 0; bi < buckets.length; bi++) {
        System.out.print("Bucket" + bi + " ");
        for (HMNode node : buckets[bi]) {
          System.out.print( node.key + "@" + node.value + " ");
        }
        System.out.println(".");
      }
      System.out.println("Display Ends");
  }
}
```