

# Introduction to HashMap in Java

A **HashMap** in Java is a part of the **java.util** package.  
It is a **key-value data structure** (like a dictionary/map).

## Key Points:

- Stores data in **pairs**  $\rightarrow$  (key, value)
- **No duplicate keys** are allowed
- Values **can be duplicated**
- Allows **null key** (only one) and **multiple null values**
- Fast operations  $\rightarrow$  **O(1)** average time for insertion, search, delete
- Elements are **not stored in order**

## Why is HashMap Fast?

HashMap uses a technique called **Hashing**.

- Each key is passed through a **hash function**
- Hash function returns a **hash code (index)**
- Value is stored in a **bucket** at that index
- If two keys generate same index  $\rightarrow$  **Collision**
  - Collision is handled using **LinkedList or Tree (Java 8+)**

## Internal Structure (Java 8+)

HashMap stores elements in an array of **Node<K, V>[]** table.

Each `Node` contains:

```
key
value
hash
next (linked list OR tree node)
```

If a bucket has many nodes:

- When chain size  $> 8 \rightarrow$  tree (Red-Black Tree)
- When chain size  $< 6 \rightarrow$  back to linked list

## Most Used Operations in HashMap

Operation	Meaning
<code>put(key, value)</code>	Insert or update
<code>get(key)</code>	Fetch value
<code>remove(key)</code>	Delete a key
<code>containsKey(key)</code>	Check if key exists
<code>containsValue(value)</code>	Check if value exists

Operation	Meaning
<code>isEmpty()</code>	Check empty
<code>size()</code>	Return number of entries
<code>keySet()</code>	Returns all keys
<code>values()</code>	Returns all values
<code>entrySet()</code>	Returns key-value pairs

## HashMap Example in Java (Basic Operations)

```
import java.util.*;

public class HashMapDemo {
    public static void main(String[] args) {

        HashMap<String, Integer> map = new HashMap<>();

        // Insert elements
        map.put("Amit", 101);
        map.put("Rahul", 102);
        map.put("Neha", 103);

        // Update value
        map.put("Rahul", 202);

        // Access elements
        System.out.println("Rahul's ID: " + map.get("Rahul"));

        // Check key
        System.out.println(map.containsKey("Amit"));    // true

        // Remove key
        map.remove("Neha");

        // Iterate through Map
        for (Map.Entry<String, Integer> e : map.entrySet()) {
            System.out.println(e.getKey() + " → " + e.getValue());
        }

        // Size
        System.out.println("Total Entries: " + map.size());
    }
}
```

## Count Frequency of Each Element

### Problem:

Given an array, count how many times each element appears.

### Solution Idea:

Use a **HashMap** where:

- **key** → **element**

- value → frequency

### Java Code:

```
import java.util.*;

public class FrequencyCount {
    public static void main(String[] args) {
        int[] arr = {1, 2, 2, 3, 1, 4, 2};
        HashMap<Integer, Integer> map = new HashMap<>();

        for(int x : arr) {
            map.put(x, map.getOrDefault(x, 0) + 1);
        }

        System.out.println("Frequency of each element:");
        for(Map.Entry<Integer, Integer> e : map.entrySet()) {
            System.out.println(e.getKey() + " -> " + e.getValue());
        }
    }
}
```

## Find the First Non-Repeating Character in a String

### Problem:

Given a string "swiss", find the **first character** that does **not repeat**.

### Solution Idea:

1. Use HashMap to count frequency
2. Iterate again and return first with count = 1

### Java Code:

```
import java.util.*;

public class FirstUniqueChar {
    public static void main(String[] args) {
        String s = "swiss";

        HashMap<Character, Integer> map = new HashMap<>();
        for(char c : s.toCharArray()) {
            map.put(c, map.getOrDefault(c, 0) + 1);
        }

        for(char c : s.toCharArray()) {
            if(map.get(c) == 1) {
                System.out.println("First non-repeating: " + c);
                return;
            }
        }
        System.out.println("No unique character found");
    }
}
```

## Check if Two Strings Are Anagrams

### Problem:

"listen" and "silent" → Anagram? (Both have same characters)

### Solution Idea:

Count frequency of each character using HashMap.

### Java Code:

```
import java.util.*;

public class AnagramCheck {
    public static boolean isAnagram(String s1, String s2) {
        if(s1.length() != s2.length()) return false;

        HashMap<Character, Integer> map = new HashMap<>();
        for(char c : s1.toCharArray()) {
            map.put(c, map.getOrDefault(c, 0) + 1);
        }

        for(char c : s2.toCharArray()) {
            if(!map.containsKey(c)) return false;
            map.put(c, map.get(c) - 1);
            if(map.get(c) < 0) return false;
        }
        return true;
    }

    public static void main(String[] args) {
        System.out.println(isAnagram("listen", "silent"));
    }
}
```

## Find Duplicate Elements in Array

### Problem:

Print elements that appear more than once.

### Solution Idea:

Use HashMap → count frequency → print elements with value > 1.

### Java Code:

```
import java.util.*;

public class FindDuplicates {
    public static void main(String[] args) {
        int[] arr = {10, 20, 20, 30, 10, 40, 20};

        HashMap<Integer, Integer> map = new HashMap<>();
```

```

        for(int x : arr) {
            map.put(x, map.getOrDefault(x, 0) + 1);
        }

        System.out.println("Duplicate elements:");
        for(int key : map.keySet()) {
            if(map.get(key) > 1) {
                System.out.println(key + " appears " + map.get(key) + "
times");
            }
        }
    }
}

```

## Find the Most Frequent Element

### Problem:

Which element occurs the maximum number of times?

### Solution Idea:

Maintain max frequency while iterating map.

### Java Code:

```

import java.util.*;

public class MostFrequent {
    public static void main(String[] args) {
        int[] arr = {1, 3, 2, 3, 4, 3, 2};

        HashMap<Integer, Integer> map = new HashMap<>();

        for(int x : arr) {
            map.put(x, map.getOrDefault(x, 0) + 1);
        }

        int maxFreq = 0;
        int ans = -1;

        for(int key : map.keySet()) {
            if(map.get(key) > maxFreq) {
                maxFreq = map.get(key);
                ans = key;
            }
        }

        System.out.println("Most Frequent Element: " + ans);
    }
}

```

## Custom Implementation of HashMap (Simplified)

This is a **DSA-style implementation** using **array of linked lists** (bucket array).

## Node Class

```
class Node {
    String key;
    int value;
    Node next;

    Node(String key, int value) {
        this.key = key;
        this.value = value;
    }
}
```

## HashMap Implementation

```
class MyHashMap {

    private Node[] buckets;
    private int capacity = 10;

    MyHashMap() {
        buckets = new Node[capacity];
    }

    private int getHash(String key) {
        return Math.abs(key.hashCode()) % capacity;
    }

    // Insert or Update
    public void put(String key, int value) {
        int index = getHash(key);
        Node head = buckets[index];

        // If key already exists → update
        while (head != null) {
            if (head.key.equals(key)) {
                head.value = value;
                return;
            }
            head = head.next;
        }

        // Insert at beginning
        Node newNode = new Node(key, value);
        newNode.next = buckets[index];
        buckets[index] = newNode;
    }

    // Get value by key
    public Integer get(String key) {
        int index = getHash(key);
        Node head = buckets[index];

        while (head != null) {
            if (head.key.equals(key)) return head.value;
            head = head.next;
        }
        return null; // not found
    }
}
```

```

// Remove key
public void remove(String key) {
    int index = getHash(key);
    Node head = buckets[index];
    Node prev = null;

    while (head != null) {
        if (head.key.equals(key)) {
            if (prev == null) buckets[index] = head.next;
            else prev.next = head.next;
            return;
        }
        prev = head;
        head = head.next;
    }
}
}

```

## Test the Custom HashMap

```

public class TestMap {
    public static void main(String[] args) {
        MyHashMap map = new MyHashMap();

        map.put("India", 91);
        map.put("USA", 1);
        map.put("Japan", 81);
        map.put("India", 911); // update

        System.out.println(map.get("India")); // 911
        System.out.println(map.get("USA")); // 1

        map.remove("Japan");
        System.out.println(map.get("Japan")); // null
    }
}

```

## Summary (Perfect for Notes)

HashMap stores **key-value pairs**

Very fast: **O(1)** average

Uses **hashing and buckets**

Uses **linked list + tree** for collision handling

Important methods: put, get, remove, containsKey, size, entrySet

Custom implementation uses **array of linked lists**

## Binary Tree Code

We will include:

Node structure  
Insert (manual insertion)  
Traversals (Inorder, Preorder, Postorder, Level Order)  
Height of tree  
Count nodes  
Search in tree

## 1. Node Class

```
class Node {
    int data;
    Node left, right;

    Node(int value) {
        data = value;
        left = right = null;
    }
}
```

## 2. Binary Tree Class with Operations

```
import java.util.LinkedList;
import java.util.Queue;

class BinaryTree {
    Node root;

    // Constructor
    BinaryTree() {
        root = null;
    }

    // 1. Insert nodes manually (simple tree)
    public void createSampleTree() {
        root = new Node(1);
        root.left = new Node(2);
        root.right = new Node(3);

        root.left.left = new Node(4);
        root.left.right = new Node(5);
    }

    // 2. Inorder Traversal (Left, Root, Right)
    public void inorder(Node node) {
        if (node == null) return;

        inorder(node.left);
        System.out.print(node.data + " ");
        inorder(node.right);
    }

    // 3. Preorder Traversal (Root, Left, Right)
    public void preorder(Node node) {
        if (node == null) return;

        System.out.print(node.data + " ");
        preorder(node.left);
        preorder(node.right);
    }
}
```



```

    }

    // 4. Postorder Traversal (Left, Right, Root)
    public void postorder(Node node) {
        if (node == null) return;

        postorder(node.left);
        postorder(node.right);
        System.out.print(node.data + " ");
    }

    // 5. Level Order Traversal (BFS)
    public void levelOrder(Node node) {
        if (node == null) return;

        Queue<Node> q = new LinkedList<>();
        q.add(node);

        while (!q.isEmpty()) {
            Node curr = q.poll();
            System.out.print(curr.data + " ");

            if (curr.left != null) q.add(curr.left);
            if (curr.right != null) q.add(curr.right);
        }
    }

    // 6. Search a value in tree
    public boolean search(Node node, int key) {
        if (node == null) return false;

        if (node.data == key) return true;

        // search in left or right subtree
        return search(node.left, key) || search(node.right, key);
    }

    // 7. Find height of tree
    public int height(Node node) {
        if (node == null) return 0;

        int l = height(node.left);
        int r = height(node.right);

        return Math.max(l, r) + 1;
    }

    // 8. Count total nodes
    public int countNodes(Node node) {
        if (node == null) return 0;

        return 1 + countNodes(node.left) + countNodes(node.right);
    }

    // Main method
    public static void main(String[] args) {
        BinaryTree tree = new BinaryTree();

        tree.createSampleTree();

        System.out.println("Inorder Traversal:");
    }

```

```

        tree.inorder(tree.root);

        System.out.println("\nPreorder Traversal:");
        tree.preorder(tree.root);

        System.out.println("\nPostorder Traversal:");
        tree.postorder(tree.root);

        System.out.println("\nLevel Order Traversal:");
        tree.levelOrder(tree.root);

        System.out.println("\n\nSearch 5: " + tree.search(tree.root, 5));
        System.out.println("Height of tree: " + tree.height(tree.root));
        System.out.println("Total Nodes: " + tree.countNodes(tree.root));
    }
}

```

## Output Example

```

Inorder: 4 2 5 1 3
Preorder: 1 2 4 5 3
Postorder: 4 5 2 3 1
Level Order: 1 2 3 4 5
Search 5: true
Height: 3
Total Nodes: 5

```

## Most Used Operations Summary

Operation	Description
<b>Inorder</b>	Used to get sorted output in BST
<b>Preorder</b>	Used to create copy of tree
<b>Postorder</b>	Used to delete tree bottom-up
<b>Level Order (BFS)</b>	Used in shortest path, BFS
<b>Search</b>	Find any element
<b>Height</b>	Balanced/unbalanced tree check
<b>Count Nodes</b>	Total nodes in tree

## Binary Search Tree (BST)

A **Binary Search Tree (BST)** is a special type of binary tree where the data is arranged in a sorted manner.

### BST Property

For every node:

- **Left subtree contains values smaller** than the node.
- **Right subtree contains values greater** than the node.
- No duplicate values (generally).

## Why BST is Important?

Operation	Time Complexity (Average)
Search	$O(\log n)$
Insert	$O(\log n)$
Delete	$O(\log n)$

If BST becomes skewed (linked-list-like), the time becomes  $O(n)$  → reason AVL/Red-Black Trees are used.

## Basic Operations in BST

1. **Insert a node**
2. **Search a value**
3. **Delete a node**
4. **Inorder Traversal (gives sorted order)**
5. **Preorder & Postorder (optional)**

## BST Traversals

### Inorder:

Left → Root → Right

✓ gives sorted output

### Preorder:

Root → Left → Right

✓ used to create copy of tree

### Postorder:

Left → Right → Root

✓ used to delete tree safely

## BST Code in Java (Most Important Operations)

### Node Structure

```
class Node {
    int data;
    Node left, right;

    Node(int value) {
        data = value;
        left = right = null;
    }
}
```

## Binary Search Tree Class

```
class BST {
    Node root;

    BST() {
        root = null;
    }

    // 1. Insert a value in BST
    Node insert(Node node, int value) {
        if (node == null) {
            return new Node(value);
        }

        if (value < node.data) {
            node.left = insert(node.left, value);
        } else if (value > node.data) {
            node.right = insert(node.right, value);
        }

        return node; // unchanged root
    }

    // 2. Search a value in BST
    boolean search(Node node, int key) {
        if (node == null) return false;

        if (key == node.data) return true;

        if (key < node.data)
            return search(node.left, key);
        else
            return search(node.right, key);
    }

    // 3. Find minimum node (used in deletion)
    Node findMin(Node node) {
        while (node.left != null)
            node = node.left;
        return node;
    }

    // 4. Delete a node from BST
    Node delete(Node node, int key) {
        if (node == null) return null;

        if (key < node.data) {
            node.left = delete(node.left, key);
        } else if (key > node.data) {
            node.right = delete(node.right, key);
        } else {
            // Case 1: Node has no child
            if (node.left == null && node.right == null)
                return null;

            // Case 2: One child
            else if (node.left == null)
                return node.right;
        }
    }
}
```

```

        else if (node.right == null)
            return node.left;

        // Case 3: Two children
        Node minRight = findMin(node.right);
        node.data = minRight.data; // replace value
        node.right = delete(node.right, minRight.data);
    }
    return node;
}

// 5. Inorder Traversal (sorted order)
void inorder(Node node) {
    if (node == null) return;

    inorder(node.left);
    System.out.print(node.data + " ");
    inorder(node.right);
}

// 6. Preorder Traversal
void preorder(Node node) {
    if (node == null) return;

    System.out.print(node.data + " ");
    preorder(node.left);
    preorder(node.right);
}

// 7. Postorder Traversal
void postorder(Node node) {
    if (node == null) return;

    postorder(node.left);
    postorder(node.right);
    System.out.print(node.data + " ");
}

// Main method
public static void main(String[] args) {
    BST tree = new BST();

    int[] values = {50, 30, 20, 40, 70, 60, 80};

    for (int v : values) {
        tree.root = tree.insert(tree.root, v);
    }

    System.out.println("Inorder (Sorted):");
    tree.inorder(tree.root);

    System.out.println("\nSearch 40: " + tree.search(tree.root, 40));

    tree.root = tree.delete(tree.root, 30);
    System.out.println("Inorder after deleting 30:");
    tree.inorder(tree.root);
}
}

```

## Example Output

```
Inorder (Sorted):  
20 30 40 50 60 70 80  
Search 40: true  
Inorder after deleting 30:  
20 40 50 60 70 80
```

## BST Deletion Summary (Easy)

Case	Explanation
<b>0 Child</b>	Delete node directly
<b>1 Child</b>	Replace node with its single child
<b>2 Children</b>	Replace with <b>inorder successor</b> (minimum in right subtree)

## AVL Tree – Notes

An AVL Tree is a **self-balancing Binary Search Tree**.

It was invented by **Adelson-Velsky and Landis** (hence the name AVL).

### Why AVL Tree?

In a normal BST, if the tree becomes skewed, operations (search, insert, delete) become **O(n)**.

AVL tree **keeps the height balanced**, ensuring operations always take:

**Time Complexity: O(log n)**

(for Search, Insert, Delete)

### Balance Factor (VERY Important)

Each node stores:

```
Balance Factor = height(left subtree) - height(right subtree)
```

**Allowed values: -1, 0, +1**

If balance factor becomes:

- $< -1$
  - $+1$
- **Tree is unbalanced** → perform rotations.

### Rotations in AVL Tree

To fix unbalanced cases, AVL performs **rotations**.

### Four imbalance cases:

Case	Condition	Rotation
<b>LL (Left-Left)</b>	Insert in left subtree of left child	<b>Right Rotation</b>
<b>RR (Right-Right)</b>	Insert in right subtree of right child	<b>Left Rotation</b>
<b>LR (Left-Right)</b>	Insert in right subtree of left child	<b>Left Rotation on Left Child + Right Rotation</b>
<b>RL (Right-Left)</b>	Insert in left subtree of right child	<b>Right Rotation on Right Child + Left Rotation</b>

### Rotation Summary (Easy to Remember)

LL → Right Rotate

RR → Left Rotate

LR → Left Rotate → Right Rotate

RL → Right Rotate → Left Rotate

### AVL Tree Properties

- Self-balancing BST
- Height always  **$O(\log n)$**
- No skewed structure
- Uses rotations to maintain balance

### AVL Tree Code in Java (Insert + Rotations)

This is clean, standard, easy-to-understand code.

### Node Structure

```
class Node {
    int key, height;
    Node left, right;

    Node(int d) {
        key = d;
        height = 1;
    }
}
```

### AVL Tree Class with Insert Operation

```
class AVLTree {
    Node root;
```

```

// Get height of node
int height(Node N) {
    if (N == null)
        return 0;
    return N.height;
}

// Get balance factor
int getBalance(Node N) {
    if (N == null)
        return 0;
    return height(N.left) - height(N.right);
}

// Right Rotation (LL Case)
Node rightRotate(Node y) {
    Node x = y.left;
    Node T2 = x.right;

    // Rotation
    x.right = y;
    y.left = T2;

    // Update heights
    y.height = Math.max(height(y.left), height(y.right)) + 1;
    x.height = Math.max(height(x.left), height(x.right)) + 1;

    return x; // new root
}

// Left Rotation (RR Case)
Node leftRotate(Node x) {
    Node y = x.right;
    Node T2 = y.left;

    // Rotation
    y.left = x;
    x.right = T2;

    // Update heights
    x.height = Math.max(height(x.left), height(x.right)) + 1;
    y.height = Math.max(height(y.left), height(y.right)) + 1;

    return y; // new root
}

// Insert node
Node insert(Node node, int key) {

    // 1. Normal BST insert
    if (node == null)
        return new Node(key);

    if (key < node.key)
        node.left = insert(node.left, key);
    else if (key > node.key)
        node.right = insert(node.right, key);
    else
        return node; // duplicates not allowed
}

```



```

// 2. Update height
node.height = 1 + Math.max(height(node.left), height(node.right));

// 3. Get balance factor
int balance = getBalance(node);

// 4. Check imbalance cases

// LL Case
if (balance > 1 && key < node.left.key)
    return rightRotate(node);

// RR Case
if (balance < -1 && key > node.right.key)
    return leftRotate(node);

// LR Case
if (balance > 1 && key > node.left.key) {
    node.left = leftRotate(node.left);
    return rightRotate(node);
}

// RL Case
if (balance < -1 && key < node.right.key) {
    node.right = rightRotate(node.right);
    return leftRotate(node);
}

return node; // unchanged root
}

// Inorder Traversal (sorted)
void inorder(Node node) {
    if (node != null) {
        inorder(node.left);
        System.out.print(node.key + " ");
        inorder(node.right);
    }
}

public static void main(String[] args) {

    AVLTree tree = new AVLTree();

    int[] values = { 10, 20, 30, 40, 50, 25 };

    for (int v : values)
        tree.root = tree.insert(tree.root, v);

    System.out.println("Inorder Traversal:");
    tree.inorder(tree.root);
}

```

## Output

```

Inorder Traversal:
10 20 25 30 40 50

```

## AVL Tree Summary (One-Page Notes)

- AVL = Self-balancing BST
- Balance Factor must be **-1, 0, +1**
- Height is always  **$\log n$**
- Uses **rotations** to maintain balance
- Four cases:
  - LL  $\rightarrow$  Right Rotate
  - RR  $\rightarrow$  Left Rotate
  - LR  $\rightarrow$  Left Rotate + Right Rotate
  - RL  $\rightarrow$  Right Rotate + Left Rotate

## HEAP TREE

A **Heap** is a **complete binary tree** used mainly for **priority queues**.

### 1. What is a Heap?

A **Heap** is a special complete binary tree that satisfies the **heap property**.

#### Complete Binary Tree

All levels must be filled completely  
(except last level – filled left to right)

### 2. Types of Heaps

#### (1) Max Heap

- Root has **maximum** value
- Every parent  $\geq$  children
- `arr[parent] >= arr[left/right child]`

#### (2) Min Heap

- Root has **minimum** value
- Every parent  $\leq$  children
- `arr[parent] <= arr[left/right child]`

### 3. Why Heap?

Used in:

- **Priority Queue**
- **Heap Sort**
- **Dijkstra's Algorithm**
- **Scheduling**
- **Memory management**

### 4. Heap Representation

Heaps are usually stored in **arrays**, not linked nodes.

For any index  $i$ :

Left child        =  $2*i + 1$   
Right child      =  $2*i + 2$   
Parent            =  $(i-1) / 2$

## 5. Basic Heap Operations

Operation	Time Complexity
Insert	$O(\log n)$
Delete root	$O(\log n)$
Get min/max	$O(1)$
Build heap	$O(n)$

## 6. Heapify Function (Most Important)

Heapify = Bring subtree into heap order.

Two types:

- **Max-Heapify**
- **Min-Heapify**

### Java Code: Max Heap (Insert + Delete + Build)

```
class MaxHeap {
    int[] heap;
    int size;

    MaxHeap(int capacity) {
        heap = new int[capacity];
        size = 0;
    }

    // Get parent index
    int parent(int i) { return (i - 1) / 2; }

    // Get left child
    int left(int i) { return 2 * i + 1; }

    // Get right child
    int right(int i) { return 2 * i + 2; }

    // Insert value
    void insert(int val) {
        heap[size] = val;
        int i = size;
        size++;

        // Fix max heap property by moving up
        while (i != 0 && heap[parent(i)] < heap[i]) {
```

```

        int temp = heap[i];
        heap[i] = heap[parent(i)];
        heap[parent(i)] = temp;

        i = parent(i);
    }
}

// Max-Heapify (fix downward)
void maxHeapify(int i) {
    int largest = i;
    int l = left(i);
    int r = right(i);

    if (l < size && heap[l] > heap[largest])
        largest = l;

    if (r < size && heap[r] > heap[largest])
        largest = r;

    if (largest != i) {
        int temp = heap[i];
        heap[i] = heap[largest];
        heap[largest] = temp;

        maxHeapify(largest);
    }
}

// Remove max element (root)
int extractMax() {
    if (size <= 0) return -1;
    if (size == 1) return heap[--size];

    int root = heap[0];
    heap[0] = heap[size - 1];
    size--;

    maxHeapify(0);

    return root;
}

// Print heap
void printHeap() {
    for (int i = 0; i < size; i++)
        System.out.print(heap[i] + " ");
    System.out.println();
}

public static void main(String[] args) {
    MaxHeap mh = new MaxHeap(10);
    mh.insert(20);
    mh.insert(15);
    mh.insert(30);
    mh.insert(40);

    System.out.println("Max Heap:");
    mh.printHeap();

    System.out.println("Extract Max = " + mh.extractMax());
}

```

```

        mh.printHeap();
    }
}

```

## Output Example

```

Max Heap:
40 30 20 15
Extract Max = 40
30 15 20

```

## Min Heap Code (Simple Version)

```

class MinHeap {
    int[] heap;
    int size;

    MinHeap(int capacity) {
        heap = new int[capacity];
        size = 0;
    }

    int parent(int i) { return (i - 1) / 2; }
    int left(int i) { return 2 * i + 1; }
    int right(int i) { return 2 * i + 2; }

    void insert(int val) {
        heap[size] = val;
        int i = size++;

        // Move upward to restore min-heap
        while (i != 0 && heap[parent(i)] > heap[i]) {
            int temp = heap[i];
            heap[i] = heap[parent(i)];
            heap[parent(i)] = temp;
            i = parent(i);
        }
    }

    // Fix downward
    void minHeapify(int i) {
        int smallest = i;
        int l = left(i);
        int r = right(i);

        if (l < size && heap[l] < heap[smallest])
            smallest = l;

        if (r < size && heap[r] < heap[smallest])
            smallest = r;

        if (smallest != i) {
            int temp = heap[i];
            heap[i] = heap[smallest];
            heap[smallest] = temp;

            minHeapify(smallest);
        }
    }
}

```

```

int extractMin() {
    if (size <= 0) return -1;
    if (size == 1) return heap[--size];

    int root = heap[0];
    heap[0] = heap[size - 1];
    size--;

    minHeapify(0);

    return root;
}

void printHeap() {
    for (int i = 0; i < size; i++)
        System.out.print(heap[i] + " ");
    System.out.println();
}

public static void main(String[] args) {
    MinHeap mh = new MinHeap(10);

    mh.insert(40);
    mh.insert(20);
    mh.insert(30);
    mh.insert(10);

    System.out.println("Min Heap:");
    mh.printHeap();

    System.out.println("Extract Min = " + mh.extractMin());
    mh.printHeap();
}
}

```

## Output

```

Min Heap:
10 20 30 40
Extract Min = 10
20 40 30

```