

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** → (key, value)
- **No duplicate keys** are allowed
- Values **can be duplicated**
- Allows **null key** (only one) and **multiple null values**
- Fast operations → **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 → **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 → tree (Red-Black Tree)
- When chain size < 6 → back to linked list

Most Used Operations in HashMap

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

Operation	Meaning
isEmpty()	Check empty
size()	Return number of entries
keySet()	Returns all keys
values()	Returns all values
entrySet()	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
Inorder	Used to get sorted output in BST
Preorder	Used to create copy of tree
Postorder	Used to delete tree bottom-up
Level Order (BFS)	Used in shortest path, BFS
Search	Find any element
Height	Balanced/unbalanced tree check
Count Nodes	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
0 Child	Delete node directly
1 Child	Replace node with its single child
2 Children	Replace with inorder successor (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
LL (Left-Left)	Insert in left subtree of left child	Right Rotation
RR (Right-Right)	Insert in right subtree of right child	Left Rotation
LR (Left-Right)	Insert in right subtree of left child	Left Rotation on Left Child + Right Rotation
RL (Right-Left)	Insert in left subtree of right child	Right Rotation on Right Child + Left Rotation

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 → Right Rotate
 - RR → Left Rotate
 - LR → Left Rotate + Right Rotate
 - RL → 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
- $\text{arr}[\text{parent}] \geq \text{arr}[\text{left/right child}]$

(2) Min Heap

- Root has **minimum** value
- Every parent \leq children
- $\text{arr}[\text{parent}] \leq \text{arr}[\text{left/right child}]$

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

```