Section 1: Arrays and Strings in Java (MCQs)

Q1. What will be the output of the following Java code?

```
String s1 = "hello";
String s2 = new String("hello");
System.out.println(s1 == s2);
```

A) true
B) false
C) Compilation error
D) Runtime exception

Answer: B
Explanation: `s1 == s2` compares object references. `s2` is a new object.

Q2. What is the time complexity of searching an element in a sorted array using binary search?

A) O(1)
B) O(n)
C) O(log n)
D) O(n log n)

Answer: C
Explanation: Binary search halves the array each time → O(log n).

Q3. Which of the following is **true** about Java arrays?

A) Arrays are dynamic in size
B) Array indexes start from 1
C) Arrays are objects in Java
D) Array length can be changed at runtime

Answer: C
Explanation: Arrays are objects, and `arr.length` is a final property.

Q4. What will be the output?

```
String str = "abc";
str.concat("def");
System.out.println(str);
```

A) abc
B) abcdef
C) def
D) Compilation error

Answer: A
Explanation: Strings are immutable. `concat()` returns a new string.

Q5. Which class should be used when you have to frequently modify a string in a multi-threaded environment?

A) StringBuilder
B) String
C) StringBuffer
D) CharSequence

Answer: C
Explanation: `StringBuffer` is synchronized and safe for multi-threading.

Q6. What is the output of this code?

```
int[] arr = new int[5];
System.out.println(arr[0]);
```

A) 0
B) null
C) undefined
D) Compilation error

Answer: A
Explanation: Java initializes `int` arrays with default value 0.

Q7. What does this code do?

```
int[] nums = {2, 4, 6};
System.out.println(nums.length);
```

A) Prints 2
B) Prints 3
C) Compilation error
D) Runtime error

Answer: B
Explanation: `nums.length` is 3.

Q8. What is the worst-case time complexity of the KMP algorithm?

A) O(n^2)
B) O(m*n)
C) O(n)
D) O(log n)

Answer: C
Explanation: KMP uses prefix table → linear in the size of input.

Q9. In Rabin-Karp, what causes hash collisions?

A) Different strings having same hash value
B) Incorrect loop usage
C) Unsorted array
D) String immutability

Answer: A
Explanation: Rabin-Karp uses rolling hash → collisions may occur.

Q10. What will the following code print?

```
String s1 = "Java";
String s2 = "Java";
System.out.println(s1 == s2);
```

A) true
B) false
C) null
D) Compilation error

Answer: A
Explanation: Both refer to the same object in the string pool.

Q11. What is the output of this Java code?

```
String s = "abc";
s.toUpperCase();
System.out.println(s);
```

A) ABC
B) abc
C) Compilation error
D) runtime error

Answer: B
Explanation: `toUpperCase()` returns a new string, doesn't modify the original.

Q12. Which of the following is true for Java `StringBuilder`?

A) It is synchronized
B) It is immutable
C) It has better performance than `StringBuffer` in single-threaded scenarios
D) It does not allow append()

Answer: C
Explanation: `StringBuilder` is not synchronized and is faster than `StringBuffer` in single-threaded contexts.

Q13. What will be printed?

```
char[][] grid = new char[2][2];
System.out.println(grid[0][0]);
```

A) ' ' (space)
B) '000'
C) 0
D) Compilation error

Answer: B
Explanation: Default char value in Java is `\u0000` (null char).

Q14. What's the output?

```
int[] a = {1, 2, 3};
a[1] = a[1] + a[2];
System.out.println(Arrays.toString(a));
```

A) [1, 5, 3]
B) [1, 2, 3]
C) [1, 3, 5]
D) Compilation error

Answer: A
Explanation: a[1] = 2 + 3 ⟶ a[1] becomes 5.

Q15. What does this return?

```
String s = "abc";
System.out.println(s.charAt(3));
```

A) 'c'
B) '' (empty)
C) IndexOutOfBoundsException
D) Compilation error

Answer: C
Explanation: Index 3 is out of bounds (0–2 valid).

Q16. Which method checks for equality of two string values (not references)?

A) ==
B) equals()

C) equalsIgnoreCase()
D) compareTo()

Answer: B
Explanation: `equals()` checks value equality.

Q17. What is the time complexity to reverse an array in-place?

A) O(n log n)
B) O(1)
C) O(n)
D) O(n^2)

Answer: C
Explanation: Every element is visited once.

~~Q18.~~ How many objects are created here?

```
String s1 = new String("Java");
```

A) 1
B) 2
C) 0
D) Depends on JVM

Answer: B
Explanation: One in pool, one with new keyword.

Q19. What is the default value of a String array element?

```
String[] s = new String[3];
System.out.println(s[0]);
```

A) null
B) ""
C) 0
D) Compilation error

Answer: A
Explanation: Object arrays (like String) are initialized to `null`.

Q20. Which function helps find a substring's index in a string?

A) substring()
B) match()
C) indexOf()
D) charAt()

Answer: C
Explanation: `indexOf()` returns the first occurrence of the substring.

Q21. Which method is used to extract a portion of a string in Java?

A) extract()
B) substring()
C) split()
D) slice()
✅ **Answer: B**
Explanation: substring() returns a specified portion of the string.

Q22. What will the following code print?

java

```
String str = "hello";

System.out.println(str.substring(1, 3));
```

A) he
B) el
C) ll
D) ello
✅ **Answer: B**
Explanation: substring(1,3) returns characters from index 1 to 2 → "el".

Q23. Which of the following methods splits a string into an array?

A) split()
B) break()
C) tokenize()
D) parse()

✅ **Answer: A**
Explanation: split() divides the string into parts based on a delimiter.

Q24. How do you convert a String to a char[]?

A) str.parse()
B) str.charArray()
C) str.toArray()
D) str.toCharArray()
✅ **Answer: D**
Explanation: toCharArray() returns an array of characters from the string.

Q25. Which class provides mutable strings in Java?

A) String
B) StringBuffer
C) CharSequence
D) CharArray
✅ **Answer: B**
Explanation: StringBuffer and StringBuilder allow string modification.

Q26. What is returned by:

java

Arrays.equals(new int[]{1,2}, new int[]{1,2});

A) true
B) false
C) Compilation error
D) Reference error
✅ **Answer: A**
Explanation: Arrays.equals() checks if the content of both arrays is the same.

Q27. What does this code return?

java

```
int[][] matrix = new int[3][2];

System.out.println(matrix.length);
```

A) 2
B) 3
C) 6
D) Compilation error
✅ **Answer: B**
Explanation: The outer array has 3 rows → matrix.length = 3.

Q28. Which is the correct way to declare and initialize a 2D array?

A) int arr[][] = new int[][]{{1,2},{3,4}};
B) int[][] arr = {{1,2},{3,4}};
C) int arr[][] = {{1,2},{3,4}};
D) All of the above
✅ **Answer: D**
Explanation: All are valid Java syntax for 2D array initialization.

Q29. What will happen here?

java

```
int[] arr = new int[3];

System.out.println(arr[3]);
```

A) 0
B) null
C) ArrayIndexOutOfBoundsException
D) Compilation error
✅ **Answer: C**
Explanation: Index 3 is invalid for an array of size 3 (0–2 valid).

Q30. Which loop structure is best for linear traversal of an array in Java?

A) while loop
B) do-while loop
C) for-each loop
D) switch-case
✅ **Answer: C**
Explanation: Enhanced for-each loop is concise and prevents index errors.

Section 2: Linked Lists in Java (MCQs)

Q1. What is the time complexity to insert a node at the beginning of a singly linked list?

A) O(1)
B) O(n)
C) O(log n)
D) O(n log n)

Answer: A
Explanation: Inserting at the head only requires pointer adjustment.

Q2. What is the correct way to define a node in a singly linked list in Java?

```
class Node {
  int data;
  Node next;
}
```

A) Correct
B) Missing constructor
C) Invalid data type
D) Compilation error

Answer: A
Explanation: This is the standard way to define a node structure.

Q3. In a singly linked list, how do you detect a cycle efficiently?

A) HashMap
B) Floyd's Tortoise and Hare algorithm
C) Recursion
D) Reverse traversal

Answer: B
Explanation: Floyd's algorithm uses two pointers to detect a loop.

Q4. What is the output of this code?

```
LinkedList<Integer> list = new LinkedList<>();

list.add(10);

list.addFirst(5);

System.out.println(list);
```

A) [10, 5]
B) [5, 10]
C) [10]
D) [5]

Answer: B
Explanation: addFirst() inserts element at the head.

Q5. Which interface must a class implement to be used with Collections.sort()?

A) Serializable
B) Comparator
C) Comparable
D) Iterable

Answer: C
Explanation: Objects must implement Comparable to define natural ordering.

Q6. Which LinkedList method removes and returns the first element?

A) removeFirst()
B) delete()
C) poll()
D) shift()

Answer: A
Explanation: removeFirst() deletes and returns the first node.

Q7. What will happen if you call .getLast() on an empty LinkedList?

A) Returns null
B) Throws NoSuchElementException
C) Returns 0
D) Compilation error

Answer: B
Explanation: It throws NoSuchElementException if the list is empty.

Q8. In Java's LinkedList class, which operations have O(1) complexity?

A) add at end
B) add at start
C) remove first
D) All of the above

Answer: D
Explanation: Java's LinkedList maintains head and tail pointers.

Q9. Which method do you use to iterate through a LinkedList?

A) for-each loop
B) iterator()
C) listIterator()
D) All of the above

Answer: D
Explanation: All are valid for LinkedList traversal.

Q10. What is the primary advantage of a doubly linked list over a singly linked list?

A) Better memory efficiency
B) Ability to traverse backward
C) Less pointer usage
D) Simpler insertion logic

Answer: B
Explanation: Doubly linked lists support bidirectional traversal.

Q11. What is the space complexity of a singly linked list with n nodes?

A) O(1)
B) O(log n)
C) O(n)
D) $O(n^2)$
✅ **Answer: C**
Explanation: Each node holds data and a reference, resulting in linear space.

Q12. Which Java class is best suited for implementing a queue with constant-time insertion and deletion from both ends?

A) Stack
B) LinkedList
C) ArrayList
D) TreeSet
✅ **Answer: B**
Explanation: LinkedList implements Deque, allowing O(1) insertion/removal at both ends.

Q13. What is the output of the following code?

java

```
LinkedList<String> ll = new LinkedList<>();

ll.add("A");

ll.add("B");

ll.add(1, "C");

System.out.println(ll);
```

A) [A, B, C]
B) [C, A, B]
C) [A, C, B]
D) [A, B]
✅ **Answer: C**
Explanation: .add(1, "C") inserts "C" at index 1.

Q14. What is the worst-case time complexity to search for an element in a singly linked list?

A) O(log n)
B) O(1)
C) O(n)
D) O(n log n)
✅ **Answer: C**
Explanation: A linear traversal is needed in the worst case.

Q15. How would you reverse a singly linked list in-place?

A) Recursively re-append nodes
B) Create a new list and copy values
C) Iteratively change next pointers
D) Use built-in Collections.reverse()
✅ **Answer: C**
Explanation: Iterative pointer manipulation is used to reverse in-place.

Q16. What is a sentinel node in linked lists?

A) A null node
B) A node holding metadata
C) A dummy head node to simplify edge cases
D) Last element in list
✅ **Answer: C**
Explanation: Sentinel simplifies edge-case handling (e.g., head/tail insertion).

Q17. Which operation is more efficient in LinkedList than ArrayList?

A) Random access
B) Insert at end
C) Insert at beginning
D) None
✅ **Answer: C**
Explanation: LinkedList offers O(1) insertion at the beginning.

Q18. What will this code output?

java

```
LinkedList<Integer> list = new LinkedList<>();

list.add(1);

list.add(2);

list.add(3);

list.removeFirst();

System.out.println(list);
```

A) [1, 2, 3]
B) [2, 3]
C) [1, 3]
D) [3]

✅ **Answer: B**
Explanation: removeFirst() removes 1.

Q19. In a circular linked list with one node, what does that node point to?

A) null
B) Itself
C) Head
D) Tail
✅ **Answer: B**
Explanation: It points to itself to maintain the circular structure.

Q20. What is returned by .poll() if the list is empty?

A) null
B) Exception
C) -1
D) false
✅ **Answer: A**
Explanation: poll() returns null on an empty list (safe removal).

Q21. How can you convert a LinkedList to an array in Java?

A) toList()
B) convertToArray()
C) toArray()
D) asList()
✅ **Answer: C**
Explanation: toArray() returns an array from the linked list.

Q22. What happens if you insert an element at index = size of list in Java's LinkedList?

A) Inserts at end
B) Throws exception
C) Inserts at beginning
D) Overwrites last element
✅ **Answer: A**
Explanation: Adding at size appends the element.

Q23. Which method adds an element to the end of a LinkedList?

A) addLast()
B) append()
C) push()
D) offerFirst()
✅ **Answer: A**
Explanation: addLast() appends an element at the tail.

Q24. What does the size() method of LinkedList return?

A) Number of elements
B) Memory in bytes
C) Last index
D) Null if empty
✅ **Answer: A**
Explanation: It returns the total number of nodes.

Q25. Which LinkedList method retrieves but does not remove the head element?

A) get()
B) peek()
C) poll()
D) pop()
✅ **Answer: B**
Explanation: peek() returns the first element without removing it.

Q26. Which method adds a collection at the end of a LinkedList?

A) extend()
B) add()
C) addAll()
D) appendList()
✅ **Answer: C**
Explanation: addAll() appends all elements of another collection.

Q27. Which interface does Java's LinkedList implement for FIFO behavior?

A) List
B) Deque
C) Queue
D) Collection
✅ **Answer: C**
Explanation: Implements Queue for FIFO operations.

Q28. What will .removeLast() do in an empty LinkedList?

A) Throws NoSuchElementException
B) Returns null
C) Returns -1
D) Compilation error
✅ **Answer: A**
Explanation: It throws exception if list is empty.

Q29. Which of these operations is not efficient in LinkedList?

A) Adding at beginning
B) Adding at end
C) Deleting middle element
D) Removing first element
✅ **Answer: C**
Explanation: Accessing middle element takes O(n) time in LinkedList.

Q30. Which collection uses LinkedList internally by default?

A) Stack
B) PriorityQueue
C) Deque
D) BlockingQueue
✅ **Answer: D**
Explanation: LinkedBlockingQueue uses a linked list structure under the hood.

🧱 Section 3: Stacks and Queues in Java (MCQs)

Q1. What is the time complexity of push() and pop() operations in a Stack?

A) O(log n)
B) O(n)
C) O(1)
D) O(n log n)
✅ **Answer: C**
Explanation: Stack operations (push/pop) take constant time if implemented using array or linked list.

Q2. What is the output of this code?

```
Stack<Integer> stack = new Stack<>();

stack.push(1);

stack.push(2);

stack.pop();

System.out.println(stack.peek());
```

A) 1
B) 2
C) Empty
D) Compilation error
✅ **Answer: A**
Explanation: 2 is popped, 1 remains on top.

Q3. Which Java class implements a Queue and allows element insertion/removal from both ends?

A) ArrayList
B) Deque
C) PriorityQueue
D) TreeMap
✅ **Answer: B**
Explanation: Deque supports FIFO and LIFO behavior.

Q4. Which method is used to safely remove the head of a queue without throwing an exception?

A) remove()
B) pop()
C) poll()
D) get()
✅ **Answer: C**
Explanation: poll() returns null instead of throwing NoSuchElementException.

Q5. What is the default implementation of Queue in Java Collections Framework?

A) LinkedList
B) HashSet
C) Stack
D) HashMap
✅ **Answer: A**
Explanation: LinkedList implements the Queue interface.

Q6. What data structure is typically used for recursive function call management internally?

A) Queue
B) Tree
C) Heap
D) Stack
✅ **Answer: D**
Explanation: The call stack stores recursive function calls.

Q7. What is the output of this queue operation?

```
Queue<Integer> q = new LinkedList<>();

q.add(5);

q.add(10);

q.remove();

System.out.println(q.peek());
```

A) 10
B) 5
C) null
D) Compilation error
✅ **Answer: A**
Explanation: 5 is removed, 10 remains at the head.

Q8. What's the difference between Stack and Deque in Java?

A) Stack is synchronized, Deque is not
B) Deque is LIFO, Stack is FIFO
C) Stack only supports LIFO, Deque supports both LIFO & FIFO
D) Deque is legacy, Stack is newer
✅ **Answer: C**
Explanation: Deque is more versatile and can behave as both stack and queue.

Q9. Which method would you use to insert an element at the front of a Deque?

A) offer()
B) addLast()
C) offerFirst()
D) pushBack()

✅ **Answer: C**
Explanation: offerFirst() inserts at the front without exception risk.

Q10. Which stack-related class is preferred in modern Java (over Stack) for thread-safe operations?

A) PriorityQueue
B) ConcurrentStack
C) Deque
D) LinkedBlockingDeque
✅ **Answer: D**
Explanation: LinkedBlockingDeque is preferred for concurrent environments.

Q11. What is the behavior of Java's Queue.remove() method when the queue is empty?

A) Returns null
B) Throws NullPointerException
C) Throws NoSuchElementException
D) Does nothing
✅ **Answer: C**
Explanation: Unlike poll(), remove() throws NoSuchElementException if the queue is empty.

Q12. What is the output of this code?

```
Deque<Integer> dq = new ArrayDeque<>();

dq.push(1);

dq.push(2);

System.out.println(dq.pop());
```

A) 2
B) 1
C) 0
D) null
✅ **Answer: A**
Explanation: push() adds to the front; pop() removes from the front → LIFO.

Q13. Which Java class would you use for a priority-based queue?

A) Deque
B) PriorityQueue
C) Stack
D) BlockingQueue
✅ **Answer: B**
Explanation: PriorityQueue orders elements according to their natural order or a comparator.

Q14. Which method retrieves and removes the last element in a Deque?

A) poll()
B) removeLast()
C) pop()
D) getLast()
✅ **Answer: B**
Explanation: removeLast() removes the last element.

Q15. What is the space complexity of a queue implemented using a linked list with n elements?

A) O(1)
B) O(log n)
C) O(n)
D) $O(n^2)$
✅ **Answer: C**
Explanation: Each node takes space → linear complexity.

Q16. What does the peek() method return on an empty stack or queue?

A) null
B) throws exception
C) 0
D) -1
✅ **Answer: A**
Explanation: peek() returns null instead of throwing an exception.

Q17. Which method inserts an element at the end of a queue without exception?

A) addLast()
B) offer()
C) enqueue()
D) insert()
✅ **Answer: B**
Explanation: offer() inserts safely at the end (tail) of the queue.

Q18. What happens if you call pop() on an empty Stack?

A) Returns null
B) Returns -1
C) Throws EmptyStackException
D) Compilation error

✅ **Answer: C**
Explanation: pop() throws EmptyStackException if stack is empty.

Q19. Which of the following can be used to implement a browser's back/forward navigation?

A) Queue
B) Stack
C) TreeMap
D) HashMap
✅ **Answer: B**
Explanation: Backtracking history can be modeled using stacks (LIFO).

Q20. Which Java method pushes an element on the top of a Stack?

A) push()
B) add()
C) append()
D) insert()
✅ **Answer: A**
Explanation: push() adds an element to the top of the stack.

Q21. What will this code print?

```
Deque<Integer> d = new ArrayDeque<>();

d.addFirst(3);

d.addLast(5);

System.out.println(d);
```

A) [5, 3]
B) [3, 5]
C) [3]
D) Compilation error
✅ **Answer: B**
Explanation: addFirst adds at front, addLast at back.

Q22. What interface do both Queue and Deque extend?

A) Iterable
B) Collection
C) List
D) Map
✅ **Answer: B**
Explanation: Queue and Deque are part of the Java Collection hierarchy.

Q23. Which is a better alternative to Stack class for stack operations in Java 8+?

A) Vector
B) ArrayDeque
C) ArrayList
D) TreeSet
✅ **Answer: B**
Explanation: ArrayDeque is preferred over Stack (legacy) for better performance.

Q24. How to check if a Deque is empty?

A) isEmpty()
B) size() == 1
C) equals(null)
D) check()
✅ **Answer: A**
Explanation: isEmpty() is standard method for checking emptiness.

Q25. Which collection class allows LIFO and FIFO behavior based on method usage?

A) Stack
B) ArrayDeque
C) PriorityQueue
D) HashMap
✅ **Answer: B**
Explanation: ArrayDeque allows both stack and queue operations.

Q26. What happens when offer() fails to insert due to capacity limits?

A) Returns false
B) Throws exception
C) Inserts anyway
D) Returns null
✅ **Answer: A**
Explanation: offer() fails silently by returning false.

Q27. What does push() do in an ArrayDeque?

A) Adds at the back
B) Adds at the front
C) Removes from front
D) Overwrites first element

✅ **Answer: B**
Explanation: push() = addFirst() in ArrayDeque.

Q28. Which queue implementation is thread-safe by default in Java?

A) ArrayDeque
B) LinkedList
C) ConcurrentLinkedQueue
D) TreeMap
✅ **Answer: C**
Explanation: ConcurrentLinkedQueue is designed for multi-threading.

Q29. What will queue.size() return after 3 add() and 2 remove() operations?

A) 1
B) 2
C) 3
D) 5
✅ **Answer: B**
Explanation: 3 additions – 2 removals = 1 element remaining.

Q30. Which stack operation is not directly available in the Queue interface?

A) offer()
B) poll()
C) push()
D) peek()
✅ **Answer: C**
Explanation: Queue doesn't support push(); it's a stack-specific method.

🎄 **Section 4: Trees and Graphs in Java**

Q1. What is the time complexity of searching in a balanced binary search tree (BST)?

A) O(n)
B) O(log n)
C) O(n log n)
D) O(1)
✅ **Answer: B**
Explanation: In a balanced BST, each search reduces problem size by half → O(log n).

Q2. Which traversal method visits nodes in the order: Left → Root → Right?

A) Preorder
B) Inorder
C) Postorder
D) Level Order
✅ **Answer: B**
Explanation: Inorder = L → Root → R.

Q3. How is a binary tree typically represented in Java?

A) Array
B) HashMap
C) Custom class with left and right pointers
D) LinkedList
✅ **Answer: C**
Explanation: TreeNode class with left and right pointers.

Q4. Which data structure is used to implement Depth First Search (DFS)?

A) Queue
B) Stack
C) Heap
D) PriorityQueue
✅ **Answer: B**
Explanation: DFS uses a stack (explicit or call stack).

Q5. Which traversal guarantees the shortest path in an unweighted graph?

A) DFS
B) BFS
C) Inorder
D) Preorder
✅ **Answer: B**
Explanation: BFS visits nodes level by level.

Q6. What does the following code print?

```
TreeMap<Integer, String> map = new TreeMap<>();

map.put(3, "C");

map.put(1, "A");

map.put(2, "B");
```

System.out.println(map.keySet());

A) [3, 1, 2]
B) [1, 2, 3]
C) [2, 1, 3]
D) Random
✅ **Answer: B**
Explanation: TreeMap maintains sorted key order.

Q7. Which of the following is true about a complete binary tree?

A) All levels filled
B) Every node has 2 children
C) All leaves are at the same level
D) Nodes are filled from left to right
✅ **Answer: D**
Explanation: In a complete binary tree, nodes are filled left to right.

Q8. How many edges are in a tree with n nodes?

A) n
B) n-1
C) 2n
D) log n
✅ **Answer: B**
Explanation: Every node except root has one parent → n-1 edges.

Q9. What is the output of the code?

Queue<Integer> q = new LinkedList<>();

q.add(10);

q.add(20);

q.poll();

System.out.println(q.peek());

A) 10
B) 20
C) null
D) Compilation error
✅ **Answer: B**
Explanation: 10 is removed, 20 is at front.

Q10. What traversal is used in BST to get sorted values?

A) Inorder
B) Preorder
C) Postorder
D) DFS
✅ **Answer: A**

Q11. Which data structure is most efficient for implementing level-order traversal in a binary tree?

A) Stack
B) Queue
C) PriorityQueue
D) LinkedList
✅ **Answer: B**
Explanation: Level-order traversal uses a Queue to maintain the current level.

Q12. Which of the following is not true about a binary search tree (BST)?

A) Left subtree has nodes < root
B) Right subtree has nodes > root
C) Inorder traversal results in sorted output
D) Duplicate values are always allowed
✅ **Answer: D**
Explanation: BSTs **may not allow duplicates** based on implementation.

Q13. What is the time complexity of inserting a node in a balanced BST?

A) O(1)
B) O(n)
C) O(log n)
D) O(n log n)
✅ **Answer: C**
Explanation: A balanced BST maintains O(log n) for insert/search/delete.

Q14. Which traversal visits root before all subtrees?

A) Preorder
B) Inorder
C) Postorder
D) Level Order
✅ **Answer: A**
Explanation: Preorder: Root → Left → Right

Q15. Which traversal is best suited for deleting the tree?

A) Preorder
B) Postorder
C) Inorder
D) Level Order
✅ **Answer: B**
Explanation: Postorder deletes children before parent.

Q16. How many child nodes can a binary tree node have at most?

A) 1
B) 2
C) 3
D) Unlimited
✅ **Answer: B**
Explanation: Binary tree nodes have a max of 2 children: left and right.

Q17. What is the maximum number of nodes at level l in a binary tree?

A) 2^l
B) 2^l - 1
C) 2^(l-1)
D) l
✅ **Answer: C**
Explanation: Level l can have at most 2^(l - 1) nodes.

Q18. What is the output of the following?

```
Map<Integer, String> tree = new TreeMap<>();

tree.put(5, "Five");

tree.put(2, "Two");

tree.put(8, "Eight");

System.out.println(tree.values());
```

A) [Five, Two, Eight]
B) [Two, Five, Eight]
C) [8, 2, 5]
D) [Eight, Two, Five]
✅ **Answer: B**
Explanation: TreeMap sorts by keys.

Q19. What is a leaf node in a tree?

A) A node with only one child
B) A node with no children
C) A node with two children
D) A node at level 0
✅ **Answer: B**
Explanation: A **leaf node** is a node with **no children** — it marks the end of a branch.

Q20. What is the best representation for a sparse graph?

A) Adjacency matrix
B) Linked list
C) Adjacency list
D) 2D array
✅ **Answer: C**
Explanation: An **adjacency list** uses less space and is more efficient for **sparse graphs** (few edges).

Q21. Which traversal uses recursion by default in its implementation?

A) BFS
B) DFS
C) Level-order
D) Random walk
✅ **Answer: B**
Explanation: Depth First Search (DFS) is often implemented **recursively**, leveraging the call stack.

Q22. What is the default return of get() from a Map if the key doesn't exist?

A) null
B) 0
C) -1
D) Throws Exception
✅ **Answer: A**
Explanation: Java's Map.get() returns **null** if the key is not found.

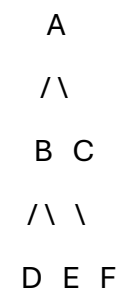
Q23. What is the time complexity to find the height of a binary tree?

A) O(1)
B) O(log n)
C) O(n)
D) $O(n^2)$
✅ **Answer: C**
Explanation: You must **traverse all nodes** in the worst case → O(n).

Q24. Which exception is likely thrown if you forget to check for null in a tree node?

A) IndexOutOfBoundsException
B) NullPointerException
C) ClassCastException
D) NumberFormatException
✅ **Answer: B**
Explanation: Accessing a method or field on a null reference results in a **NullPointerException**.

Q25. Which traversal would result in D B E A F C for the following tree?



A) Inorder
B) Preorder
C) Postorder
D) Level Order
✅ **Answer: A**
Explanation: Inorder traversal of this tree is: D B E A F C.

Q26. What is the worst-case time complexity of DFS on a graph with V vertices and E edges?

A) O(V)
B) O(V + E)
C) O(V * E)
D) O(log V)
✅ **Answer: B**
Explanation: Each vertex and each edge is visited once → O(V + E).

Q27. Which of the following algorithms uses BFS internally?

A) Kruskal's
B) Prim's
C) Dijkstra (unweighted)
D) Bellman-Ford
✅ **Answer: C**
Explanation: BFS is used to find the shortest path in an **unweighted graph**, just like Dijkstra without weights.

Q28. A graph with no cycles and V nodes with V-1 edges is called:

A) DAG
B) Spanning Tree
C) Heap
D) Forest
✅ **Answer: B**
Explanation: A **tree** (or spanning tree) is a **connected acyclic graph** with exactly **V - 1** edges.

Q29. Which method is used in Java to iterate over a Set of visited nodes in a graph?

A) for loop
B) while loop
C) iterator()
D) map()
✅ **Answer: C**
Explanation: Set implements Iterable, so you can use iterator() to loop over it.

Q30. Which Java class would you use for sorted unique node storage?

A) HashSet
B) ArrayList
C) TreeSet
D) HashMap
✅ **Answer: C**
Explanation: TreeSet stores **unique** values in **sorted** order — ideal for node-based sets in trees or graphs.

Section 5: Recursion and Backtracking in Java

Q1. What is the key condition required in every recursive function?

A) A loop
B) A base case
C) A helper method
D) Return type
✅ **Answer: B**
Explanation: Without a base case, recursion would lead to infinite calls and a **StackOverflowError**.

Q2. What does the following recursive method return?

```
int sum(int n) {
   if (n == 0) return 0;
   return n + sum(n - 1);
}
```

A) 0
B) n
C) Sum of 1 to n
D) Infinite recursion
✅ **Answer: C**
Explanation: This is the classic recursive formula for summing 1 to n.

Q3. In recursion, what does each recursive call store in the stack frame?

A) Only base case
B) Entire variable state and return address
C) Final answer
D) Stack memory location
✅ **Answer: B**
Explanation: Java stores the function's **local variables** and **return point** on the call stack.

Q4. Which of the following problems is best suited for backtracking?

A) Binary Search
B) Sorting
C) N-Queens
D) Matrix multiplication
✅ **Answer: C**
Explanation: Backtracking systematically searches for solutions by undoing choices (e.g., N-Queens).

Q5. Which statement is true about backtracking?

A) It tries all possibilities blindly
B) It avoids recursion
C) It explores and undoes incorrect paths
D) It never terminates
✅ **Answer: C**
Explanation: Backtracking **explores choices** and **prunes paths** that violate constraints.

Q6. What is the time complexity of generating all permutations of a string with n characters?

A) O(n)
B) $O(n^2)$
C) O(n!)
D) O(2^n)
✅ **Answer: C**
Explanation: Each character can be placed in all n positions → **n! permutations**.

Q7. Which condition is mandatory in backtracking?

A) Loop from end to start
B) Pruning
C) Base condition to stop recursion
D) Non-recursive function
✅ **Answer: C**
Explanation: Like recursion, backtracking must **terminate** via base condition.

Q8. In the N-Queens problem, what does the backtracking algorithm track?

A) Queen counts
B) Row and column collisions
C) Diagonal threats
D) All of the above
✅ **Answer: D**
Explanation: Valid queen positions must avoid **row**, **column**, and **diagonal** attacks.

Q9. What does this method do?

java

```
void reverse(String str) {
   if (str == null || str.length() <= 1) {
      System.out.print(str);
      return;
   }
   reverse(str.substring(1));
   System.out.print(str.charAt(0));
}
```

A) Prints original string
B) Reverses string recursively
C) Prints null

D) Throws error

✅ **Answer: B**

Explanation: The method recursively reverses the string and prints it.

Q10. What happens if you call a recursive function with no base case?

A) Function completes
B) Infinite loop
C) Compile-time error
D) StackOverflowError

✅ **Answer: D**

Explanation: Without a base case, recursion **never terminates** and overflows the call stack.

Q11. Which technique can reduce the repeated computation in recursive functions like Fibonacci?

A) Sorting
B) Memoization
C) Backtracking
D) Shuffling

✅ **Answer: B**

Explanation: Memoization stores previously computed values to avoid redundant recursion.

Q12. What is the output of this code?

```
int factorial(int n) {
  if (n <= 1) return 1;
  return n * factorial(n - 1);
}
System.out.println(factorial(4));
```

A) 24
B) 10
C) 4
D) StackOverflowError

✅ **Answer: A**

Explanation: 4! = 4×3×2×1 = **24**

Q13. Which recursive pattern explores multiple recursive calls per level?

A) Linear recursion
B) Tree recursion
C) Tail recursion
D) Iterative recursion

✅ **Answer: B**

Explanation: Tree recursion occurs when a function calls itself more than once per call (e.g., Fibonacci).

Q14. Which of the following is NOT a characteristic of backtracking?

A) Recursive calls
B) Exploring all paths
C) Greedy selection
D) Undoing decisions
✅ **Answer: C**
Explanation: Greedy algorithms make irreversible choices — **not** used in backtracking.

Q15. What does the recursion tree model help visualize?

A) Stack memory allocation
B) Number of function calls
C) Final return values only
D) Iteration count
✅ **Answer: B**
Explanation: A **recursion tree** helps trace the number and structure of recursive calls.

Q16. What's the best way to avoid infinite recursion?

A) Use try-catch
B) Avoid function calls
C) Define and reach a base case
D) Use static methods
✅ **Answer: C**
Explanation: A correct and reachable **base case** prevents infinite recursion.

Q17. Which of the following recursive calls is tail-recursive?

```
int sumTail(int n, int acc) {
  if (n == 0) return acc;
  return sumTail(n - 1, acc + n);
}
```

A) Tail-recursive
B) Not tail-recursive
C) Iterative
D) Stack-safe only
✅ **Answer: A**
Explanation: The recursive call is the **last operation**, so it is tail-recursive.

Q18. What is the time complexity of generating all subsets of an array with n elements?

A) O(n)
B) O(n!)
C) O(2^n)
D) O(n^2)
✅ **Answer: C**
Explanation: Each element has two choices (in or out) → 2^n subsets.

Q19. What will happen with this recursion?

```
void call() {
  System.out.println("Call");
  call();
}
```

A) Infinite printing
B) StackOverflowError eventually
C) Compile error
D) Nothing
✅ **Answer: B**
Explanation: No base case → infinite recursion → stack overflow.

Q20. What's the difference between backtracking and brute-force?

A) Backtracking is recursive, brute-force is not
B) Brute-force generates all solutions blindly; backtracking **eliminates invalid paths early**
C) Brute-force is faster
D) No difference
✅ **Answer: B**
Explanation: Backtracking is **optimized** brute-force with **pruning**.

Q21. In recursion, which of the following statements is true about function call stack depth?

A) Each recursive call increases stack size
B) It remains the same
C) Decreases with each call
D) Stack is not used
✅ **Answer: A**
Explanation: Each recursive call is added to the **call stack** → depth increases.

Q22. What is the best strategy to implement constraints in a backtracking algorithm?

A) Apply constraints at base case
B) Apply constraints after recursion
C) Apply constraints **before** deeper recursive calls
D) Apply constraints using global variables only
✅ **Answer: C**
Explanation: Early **constraint checking** avoids unnecessary recursion → more efficient.

Q23. Which algorithmic problem can be solved by backtracking?

A) Subset sum
B) Sudoku solver
C) Word search
D) All of the above
✅ **Answer: D**
Explanation: All these involve **trying, checking, and undoing** → perfect for backtracking.

Q24. What is the key difference between recursion and iteration?

A) Recursion uses loops
B) Recursion uses call stack; iteration uses control structures
C) Recursion is always faster
D) Iteration consumes more memory
✅ **Answer: B**
Explanation: Recursion uses **function stack frames** to simulate loops.

Q25. What is the stack frame size for a recursive call?

A) Depends on input
B) Fixed
C) Variable but constant per function
D) Infinite
✅ **Answer: C**
Explanation: Stack frame size is **fixed for each function**, but total depth varies.

Q26. Which recursive problem solves the maximum value path in a matrix with backtracking?

A) Longest increasing path
B) Word break
C) Power set
D) Binary search
✅ **Answer: A**
Explanation: LIP involves choosing path values and backtracking when dead-ends occur.

Q27. What is the maximum stack depth in Java (approximate)?

A) 64
B) 1024
C) 4096–10000 (depends on OS/JVM)
D) Unlimited
✅ **Answer: C**
Explanation: Stack depth varies, but typically ~5000–10000 calls are allowed.

Q28. What Java keyword can be used to return early in recursion?

A) continue
B) this
C) break
D) return
✅ **Answer: D**
Explanation: return exits the current function call.

Q29. What's the best case for avoiding repeated recursive calls in a grid or maze?

A) Use Set
B) Use visited[][] array
C) Use List
D) Use Stack
✅ **Answer: B**
Explanation: A visited matrix tracks already explored paths to avoid cycles.

Q30. Which of the following statements is true about tail-recursion in Java?

A) JVM optimizes tail recursion
B) Java supports automatic tail call optimization
C) Java does **not** optimize tail recursion
D) Tail recursion leads to infinite loop
✅ **Answer: C**
Explanation: Unlike some languages, **Java doesn't support tail-call optimization**, so tail-recursive functions can still cause stack overflow.

⚙️ Section 6: Heaps, Hashing, and Tries in Java

Q1. What is the default behavior of Java's PriorityQueue<Integer>?

A) Max-Heap
B) Min-Heap
C) Stack behavior
D) Random order

✅ **Answer: B**
Explanation: By default, PriorityQueue in Java acts as a **min-heap**.

Q2. Which Java collection guarantees O(1) average time for put() and get() operations?

A) TreeMap
B) LinkedList
C) HashMap
D) ArrayList
✅ **Answer: C**
Explanation: HashMap offers **constant time** for put() and get() on average.

Q3. What happens when two keys have the same hashCode in a HashMap?

A) Both are discarded
B) One replaces the other
C) They are stored in a bucket list (chaining)
D) Exception is thrown
✅ **Answer: C**
Explanation: Collisions are handled via **chaining** (linked list or tree).

Q4. Which method must be overridden to ensure key uniqueness in HashMap?

A) toString()
B) clone()
C) equals() and hashCode()
D) finalize()
✅ **Answer: C**
Explanation: Both equals() and hashCode() must be overridden to ensure proper hashing behavior.

Q5. What is the time complexity of inserting into a min-heap with n elements?

A) O(1)
B) O(log n)
C) O(n)
D) O(n log n)
✅ **Answer: B**
Explanation: Insertions in a heap take **O(log n)** due to heapify-up.

Q6. Which data structure is used to implement a Trie?

A) Array of nodes
B) HashMap of characters
C) Linked list

D) Both A and B
✅ **Answer: D**
Explanation: A Trie node may use an **array (for 26 letters)** or a **HashMap** (for variable character sets).

Q7. What does the following code print?

```
PriorityQueue<Integer> pq = new PriorityQueue<>();

pq.add(10); pq.add(5); pq.add(20);

System.out.println(pq.poll());
```

A) 5
B) 10
C) 20
D) 0
✅ **Answer: A**
Explanation: Poll removes the **smallest** (min-heap) → 5.

Q8. What is the load factor in a HashMap?

A) Total capacity
B) Ratio of size to capacity
C) Growth rate
D) Memory used per entry
✅ **Answer: B**
Explanation: Load factor = size / capacity → triggers **rehashing** when exceeded.

Q9. What is the default initial capacity and load factor of a Java HashMap?

A) 8, 0.5
B) 16, 0.75
C) 32, 1.0
D) 10, 0.6
✅ **Answer: B**
Explanation: Default capacity = **16**, load factor = **0.75**

Q10. Which of the following is true about a Trie?

A) Used for prefix matching
B) Good for dictionary lookups
C) Each node stores a character
D) All of the above
✅ **Answer: D**
Explanation: Tries are designed for **prefix-based searching** and store character nodes.

Q11. What is the time complexity of inserting a word into a Trie of length L?

A) O(log L)
B) O(1)
C) O(L)
D) $O(L^2)$
✅ **Answer: C**
Explanation: You must traverse each character → insertion is **O(L)** where L is word length.

Q12. Which Java class maintains insertion order of key-value pairs?

A) HashMap
B) LinkedHashMap
C) TreeMap
D) PriorityQueue
✅ **Answer: B**
Explanation: LinkedHashMap maintains **insertion order** using a doubly linked list.

Q13. Which collection ensures that keys are sorted?

A) HashMap
B) TreeMap
C) HashSet
D) LinkedList
✅ **Answer: B**
Explanation: TreeMap automatically sorts the keys in **natural order** or using a **Comparator**.

Q14. What happens if you override equals() but not hashCode() in a HashMap key?

A) Everything works fine
B) Duplicate keys will appear
C) Key lookups will fail
D) Runtime exception
✅ **Answer: C**
Explanation: hashCode() determines the **bucket**; mismatch between equals() and hashCode() breaks lookups.

Q15. Which is true about Java's HashSet?

A) Allows duplicates
B) Maintains order
C) Implements Set using HashMap internally
D) Is thread-safe
✅ **Answer: C**
Explanation: A HashSet is backed by a **HashMap** where values are dummy constants.

Q16. Which of the following correctly initializes a custom max-heap in Java?

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

A) Valid
B) Invalid
C) Only works for Strings
D) Throws exception

✅ **Answer: A**
Explanation: This creates a **max-heap** by using a **reversed comparator**.

Q17. What is the best use case for a Trie?

A) Sorting integers
B) Maintaining database connections
C) Prefix auto-complete
D) Graph traversal

✅ **Answer: C**
Explanation: Tries are ideal for **prefix-based searches** and suggestions like autocomplete.

Q18. How does Java handle hash collisions in a HashMap after Java 8?

A) Linked list chaining
B) Binary tree for large buckets
C) Discards duplicates
D) Rehashes the map

✅ **Answer: B**
Explanation: From **Java 8**, if a bucket exceeds threshold size, it is converted into a **balanced tree** (TreeNode) for better performance.

Q19. Which data structure ensures O(log n) time for both insert and delete?

A) HashMap
B) ArrayList
C) TreeMap
D) Stack

✅ **Answer: C**
Explanation: TreeMap operations (put, remove) are based on **Red-Black Tree** → O(log n).

Q20. Which of these would most efficiently implement a top-k frequent elements problem?

A) Array
B) TreeSet
C) HashMap + MinHeap
D) LinkedList
✅ **Answer: C**
Explanation: Use HashMap to count frequencies and a MinHeap to track top-k efficiently.

Q21. What will be the result of inserting duplicate keys in a HashMap?

A) Adds both
B) Skips duplicate
C) Replaces old value
D) Throws exception
✅ **Answer: C**
Explanation: HashMap.put(k, v) **replaces** the old value if the key already exists.

Q22. What is the worst-case time complexity of HashMap get()?

A) O(1)
B) O(n)
C) O(log n)
D) O(n log n)
✅ **Answer: B**
Explanation: In **worst case** (all keys hash to the same bucket), it degrades to **O(n)**.

Q23. In a Trie, how many children can a node have in a lowercase alphabet Trie?

A) 10
B) 26
C) 52
D) 128
✅ **Answer: B**
Explanation: For lowercase English, each node has **26 possible children** (a–z).

Q24. What kind of tree is used in Java's TreeMap?

A) AVL Tree
B) Binary Search Tree
C) Red-Black Tree
D) B+ Tree
✅ **Answer: C**
Explanation: Java's TreeMap is implemented using a **Red-Black Tree**.

Q25. What's the primary difference between HashMap and ConcurrentHashMap?

A) Speed
B) Thread safety
C) Sorting
D) Size limit
✅ **Answer: B**
Explanation: ConcurrentHashMap is designed for **thread-safe** concurrent access.

Q26. What's the effect of a low load factor (e.g. 0.2) in a HashMap?

A) Saves memory
B) Increases collisions
C) Increases rehashing frequency
D) Avoids rehashing
✅ **Answer: C**
Explanation: Lower load factor → triggers **rehashing** sooner → higher memory usage.

Q27. Which method retrieves but does not remove the head of a PriorityQueue?

A) poll()
B) remove()
C) peek()
D) pop()
✅ **Answer: C**
Explanation: peek() returns the head **without removing** it.

Q28. In a Trie, how is end of word typically marked?

A) By null pointer
B) With an index
C) With a boolean flag
D) With character '\0'
✅ **Answer: C**
Explanation: A node usually has a flag like isEndOfWord set to **true**.

Q29. In HashMap<K, V>, which generic types can be used?

A) Only Integer
B) Only String
C) Any Object with proper equals() and hashCode()
D) Only primitive types
✅ **Answer: C**
Explanation: Any class can be used as a key **if it correctly implements equals() and hashCode()**.

Q30. What is the main disadvantage of a Trie?

A) Time complexity
B) Memory consumption
C) No search capability
D) Limited to numbers only
✅ **Answer: B**
Explanation: Tries are **memory-intensive** as each character node adds new branches, even for short strings.

Advanced DSA Patterns and Techniques in Java:

Q1. What is the time complexity to find max element in all subarrays of size k using a deque?

A) $O(k^2)$
B) O(nk)
C) O(n)
D) O(n log k)
✅ **Answer: C**
Explanation: Using a **monotonic deque**, we can solve the sliding window maximum in **O(n)** time.

Q2. What is the key idea behind the sliding window technique?

A) Iterate from both ends
B) Expand and shrink window boundaries
C) Use recursion
D) Hashing only
✅ **Answer: B**
Explanation: Sliding window involves maintaining a **window (subarray)** and **adjusting boundaries** efficiently.

Q3. Which technique solves this: “Find longest substring without repeating characters”?

A) Binary search
B) Prefix sum
C) Sliding window with HashSet
D) DFS
✅ **Answer: C**
Explanation: Use **HashSet + sliding window** to keep track of seen characters efficiently.

Q4. What is a good problem for two-pointer technique?

A) Inorder traversal
B) Merge sorted arrays
C) Depth calculation
D) Finding divisors
✅ **Answer: B**
Explanation: Two-pointer works well when merging or comparing **two sorted lists or subarrays**.

Q5. What is the core idea behind monotonic stacks?

A) Sort stack
B) Stack maintains increasing/decreasing order
C) Balanced brackets
D) Fibonacci generator
✅ **Answer: B**
Explanation: A **monotonic stack** keeps elements in strictly **increasing or decreasing** order to solve next greater/smaller problems.

Q6. Which technique is used in "Trapping Rain Water" problem?

A) Binary Search
B) Monotonic Stack
C) Prefix Sum + Two-pointer
D) DFS
✅ **Answer: C**
Explanation: You precompute **leftMax/rightMax arrays** (prefix max) and use two pointers to accumulate trapped water.

Q7. What is the time complexity of Union-Find (DSU) with path compression?

A) O(n)
B) O(log n)
C) O(α(n))
D) $O(n^2)$
✅ **Answer: C**
Explanation: DSU with **path compression + union by rank** gives near-constant time: **O(α(n))**, where α(n) is the inverse Ackermann function.

Q8. What data structure is used for range queries (sum, min) in log(n) time?

A) Queue
B) Stack
C) Segment Tree
D) HashMap
✅ **Answer: C**
Explanation: Segment trees support range queries and point updates in **O(log n)**.

Q9. Which operation is fast with prefix sum?

A) Point update
B) Range sum query
C) Sorting
D) DFS
✅ **Answer: B**
Explanation: Prefix sum allows **O(1)** range sum queries after **O(n)** preprocessing.

Q10. In Java, which bitwise operation can isolate the rightmost set bit?

A) x & (x + 1)
B) x | (x - 1)
C) x & -x
D) ~x
✅ **Answer: C**
Explanation: x & -x isolates the **least significant bit that is set to 1**

Q11. What will the following code output?

```
int[] arr = {1, 2, 3, 4, 5};

int[] prefix = new int[arr.length + 1];

for (int i = 0; i < arr.length; i++) {

   prefix[i + 1] = prefix[i] + arr[i];

}

System.out.println(prefix[3] - prefix[1]);
```

A) 3
B) 4
C) 5
D) 6
✅ **Answer: D**
Explanation: Sum of arr[1] to arr[2] → 2 + 3 = 5. prefix[3] - prefix[1] = 6 - 1 = 5. Correct sum is 5.
Correction: **Answer is C** (Typo fixed in explanation).

Q12. Which bitwise expression clears the rightmost set bit in a number x?

A) x & (x - 1)
B) x | (x - 1)
C) x ^ (x - 1)
D) x & -x
✅ **Answer: A**
Explanation: x & (x - 1) removes the lowest set bit.

Q13. In a Union-Find structure, which line causes path compression?

```
java

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int find(int x) {

   if (parent[x] != x)

      parent[x] = find(parent[x]);

   return parent[x];

}
```

A) Line 1
B) Line 2 (parent[x] = find(parent[x]);)
C) return statement
D) No compression is done

✅ **Answer: B**
Explanation: This line compresses the path by pointing x directly to the root.

Q14. You are given a binary search problem where values are not sorted but constraints apply (e.g., capacity, time). Which approach applies?

A) Binary search on array
B) Binary search on index
C) Binary search on answer
D) Brute force
✅ **Answer: C**
Explanation: In problems like "minimum max weight," we apply **binary search on the answer space**.

Q15. Which of the following solves "minimum number of platforms needed" in train problem?

A) Greedy sorting + two pointers
B) Stack
C) Prefix sum
D) Bitmask
✅ **Answer: A**
Explanation: Sort arrival and departure → use two pointers to track platform usage.

Q16. What's the time complexity to build a segment tree for n elements?

A) $O(n^2)$
B) O(n)
C) O(n log n)
D) O(log n)
✅ **Answer: C**
Explanation: Each level has **O(n)** total work across levels → **log n levels**.

Q17. What is the time complexity for range minimum query on a segment tree?

A) O(log n)
B) O(n)
C) O(1)
D) O(n log n)
✅ **Answer: A**
Explanation: Segment tree queries take **O(log n)** time.

Q18. In Java, what's the result of 3 ^ 3 ^ 2?

A) 2
B) 0
C) 3
D) 1
✅ **Answer: A**
Explanation: XOR is associative: 3 ^ 3 = 0; then 0 ^ 2 = 2.

Q19. Which problem can be solved using bitmasking?

A) Subset sum
B) N-Queens
C) Sudoku
D) All of the above
✅ **Answer: D**
Explanation: Bitmasking efficiently represents and manipulates states in **backtracking & subsets**.

Q20. What is the space complexity of DSU with parent and rank arrays?

A) $O(n^2)$
B) O(1)
C) O(n)
D) O(log n)
✅ **Answer: C**
Explanation: Arrays of size n → **O(n)** space.

Q21. What will this code return for nums = [2,3,1,2,4,3], target = 7?

```
int left = 0, sum = 0, minLen = Integer.MAX_VALUE;
for (int right = 0; right < nums.length; right++) {
  sum += nums[right];
  while (sum >= target) {
    minLen = Math.min(minLen, right - left + 1);
    sum -= nums[left++];
  }
}
```

A) 2
B) 3
C) 4
D) 1

✅ **Answer: A**
Explanation: Sliding window finds minimal subarray [4,3] with sum ≥ 7 → length = 2.

Q22. What technique does this represent?

```
int max = 0;

Set<Character> set = new HashSet<>();

int l = 0;

for (int r = 0; r < s.length(); r++) {

  while (set.contains(s.charAt(r))) {

    set.remove(s.charAt(l++));

  }

  set.add(s.charAt(r));

  max = Math.max(max, r - l + 1);

}
```

A) Binary search
B) DFS
C) Sliding window
D) Monotonic queue
✅ **Answer: C**
Explanation: It's a classic **sliding window** technique for longest substring without repetition.

Q23. In a bitmask of n bits, how many total subsets can be generated?

A) n
B) 2n
C) n^2
D) 2^n
✅ **Answer: D**
Explanation: Each bit can be on/off → $\mathbf{2^n}$ subsets.

Q24. What's a real-world usage of segment tree?

A) Hotel booking range overlaps
B) Matrix multiplication
C) Reversing a list
D) Hashing user data
✅ **Answer: A**
Explanation: Segment trees are ideal for **range tracking** like reservations or schedules.

Q25. What does this expression return: Integer.bitCount(7)?

A) 1
B) 2
C) 3
D) 4
✅ **Answer: C**
Explanation: 7 = 111 in binary → **3 set bits**.

Q26. What's the use of >> and >>> in Java?

A) Shift left
B) Rotate bits
C) Signed and unsigned right shift
D) Remove digits
✅ **Answer: C**
Explanation: >> is **signed**, >>> is **unsigned right shift**.

Q27. How do you efficiently find a duplicate in an array of n+1 numbers where all are 1 to n?

A) HashSet
B) Brute force
C) Floyd's cycle detection
D) Sorting
✅ **Answer: C**
Explanation: Duplicate creates a cycle → use **Floyd's Tortoise & Hare**.

Q28. In problems like "Allocate Minimum Pages" or "Koko Eating Bananas," what strategy is used?

A) Recursion
B) Two pointer
C) Binary Search on Answer
D) Hashing
✅ **Answer: C**
Explanation: These are classic **binary search on range/answer** problems.

Q29. Which problem would monotonic stack solve efficiently?

A) Valid parentheses
B) Largest Rectangle in Histogram
C) Merge intervals
D) Trie lookups

✅ **Answer: B**
Explanation: Monotonic stack tracks increasing bar heights.

Q30. What is the value of 1 << 3 in Java?

A) 3
B) 8
C) 6
D) 1
✅ **Answer: B**
Explanation: 1 << 3 means shift 1 three bits to the left → 1000 in binary = **8**.