VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT

On

ANALYSIS AND DESIGN OF ALGORITHMS

(23CS4PCADA)

Submitted by

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING

(Autonomous Institution under VTU)

BENGALURU-560019

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Department of Computer Science and Engineering

This is to certify that the Lab work entitled **"ANALYSIS AND DESIGN OF ALGORITHMS"** carried out by **DISHA D S (1BM23CS094)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2024-25. The Lab report has been approved as it satisfies the academic requirements in respect of Analysis and Design of Algorithms Lab - **(23CS4PCADA)** work prescribed for the said degree.

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INDEX SHEET

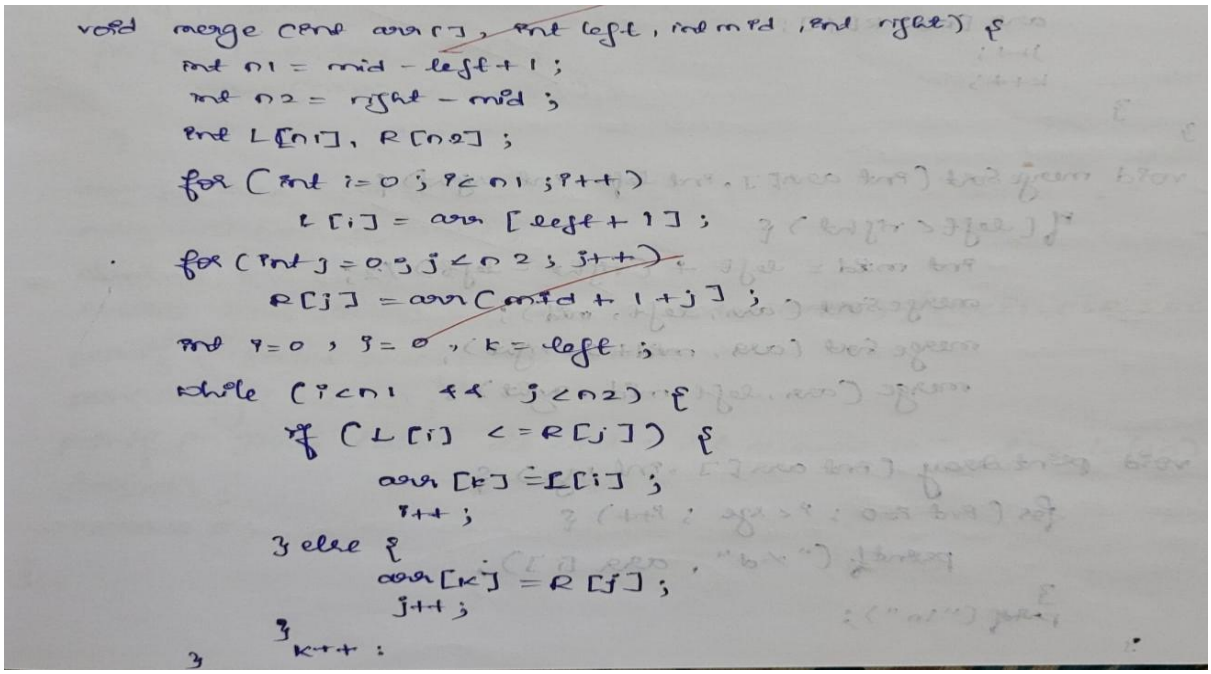
COURSE OUTCOMES

CO1	Analyze time complexity of Recursive and Non-recursive algorithms using asymptotic notations.
CO2	Apply various design techniques for the given problem.
CO3	Apply the knowledge of complexity classes P, NP, and NP-Complete and prove certain problems are NP-Complete
CO4	Design efficient algorithms and conduct practical experiments to solve problems.

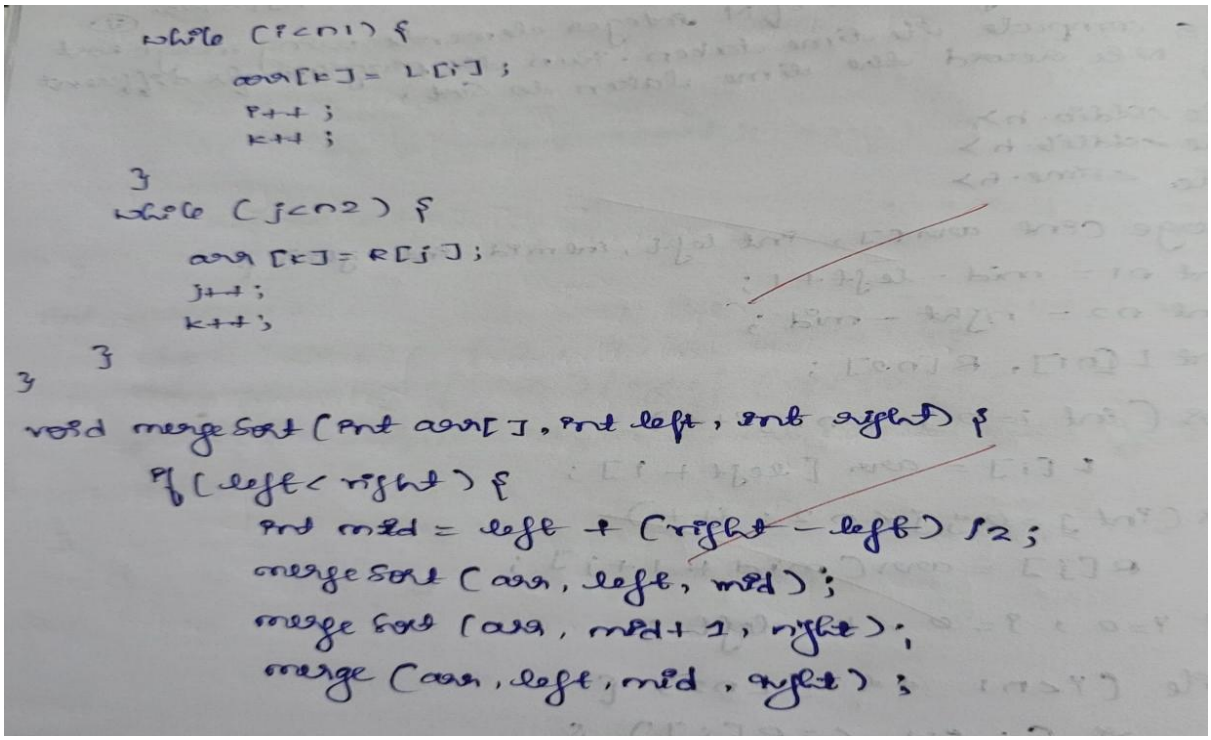
PROGRAM 1

Sort a given set of N integer elements using Merge Sort technique and compute its time taken. Run the program for different values of N and record the time taken to sort.

ALGORITHM:



```
void merge (int arr[], int left, int mid, int right) {
    int n1 = mid - left + 1;
    int n2 = right - mid;
    int L[n1], R[n2];
    for (int i=0; i<n1; i++)
        L[i] = arr[left + i];
    for (int j=0; j<n2; j++)
        R[j] = arr[mid + 1 + j];
    int i=0, j=0, k=left;
    while (i<n1 && j<n2) {
        if (L[i] <= R[j]) {
            arr[k] = L[i];
            i++;
        } else {
            arr[k] = R[j];
            j++;
        }
        k++;
    }
```



```
    while (i<n1) {
        arr[k] = L[i];
        i++;
        k++;
    }
    while (j<n2) {
        arr[k] = R[j];
        j++;
        k++;
    }
}
void mergeSort (int arr[], int left, int right) {
    if (left < right) {
        int mid = left + (right - left) / 2;
        mergeSort (arr, left, mid);
        mergeSort (arr, mid+1, right);
        merge (arr, left, mid, right);
```

CODE:

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

// Function to merge two halves
void merge(int arr[], int left, int mid, int right) {
    int i, j, k;
    int n1 = mid - left + 1;
    int n2 = right - mid;

    // Temporary arrays
    int L[n1], R[n2];

    // Copy data
    for (i = 0; i < n1; i++)
        L[i] = arr[left + i];
    for (j = 0; j < n2; j++)
        R[j] = arr[mid + 1 + j];

    // Merge the temp arrays
    i = 0;
    j = 0;
    k = left;
    while (i < n1 && j < n2) {
        if (L[i] <= R[j]) {
            arr[k++] = L[i++];
        } else {
            arr[k++] = R[j++];
        }
    }
```

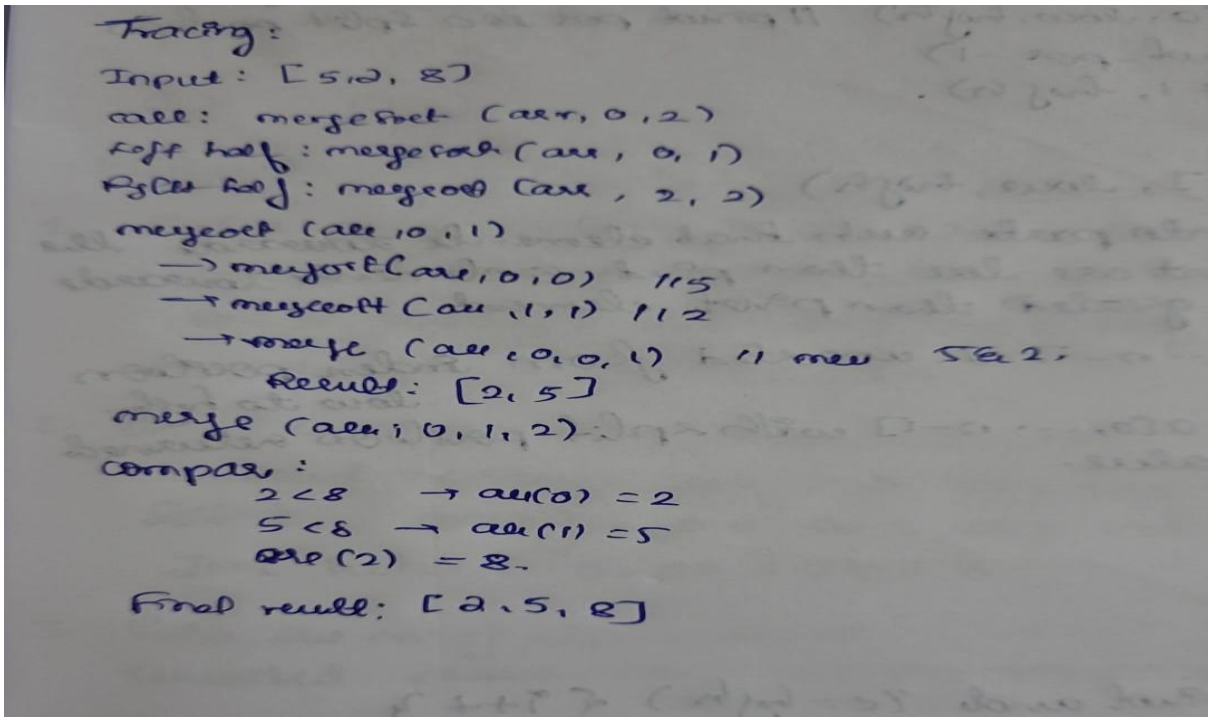
```
    // Copy remaining elements
    while (i < n1) {
        arr[k++] = L[i++];
    }
    while (j < n2) {
        arr[k++] = R[j++];
    }
}

// Merge Sort function
void mergeSort(int arr[], int left, int right) {
    if (left < right) {
        int mid = (left + right) / 2;

        mergeSort(arr, left, mid);        // Left half
        mergeSort(arr, mid + 1, right);   // Right half

        merge(arr, left, mid, right);     // Merge halves
    }
}

int main() {
    int N, i;
    printf("Enter the number of elements (N): ");
    scanf("%d", &N);

    int arr[N];
    printf("Enter %d integer elements:\n", N);
    for (i = 0; i < N; i++) {
```

```
        scanf("%d", &arr[i]);
    }

    clock_t start, end;
    double time_taken;

    start = clock();
    mergeSort(arr, 0, N - 1);
    end = clock();

    time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;

    printf("Sorted array:\n");
    for (i = 0; i < N; i++) {
        printf("%d ", arr[i]);
    }

    printf("\nTime taken to sort %d elements: %f seconds\n", N, time_taken);

    return 0;
}
```

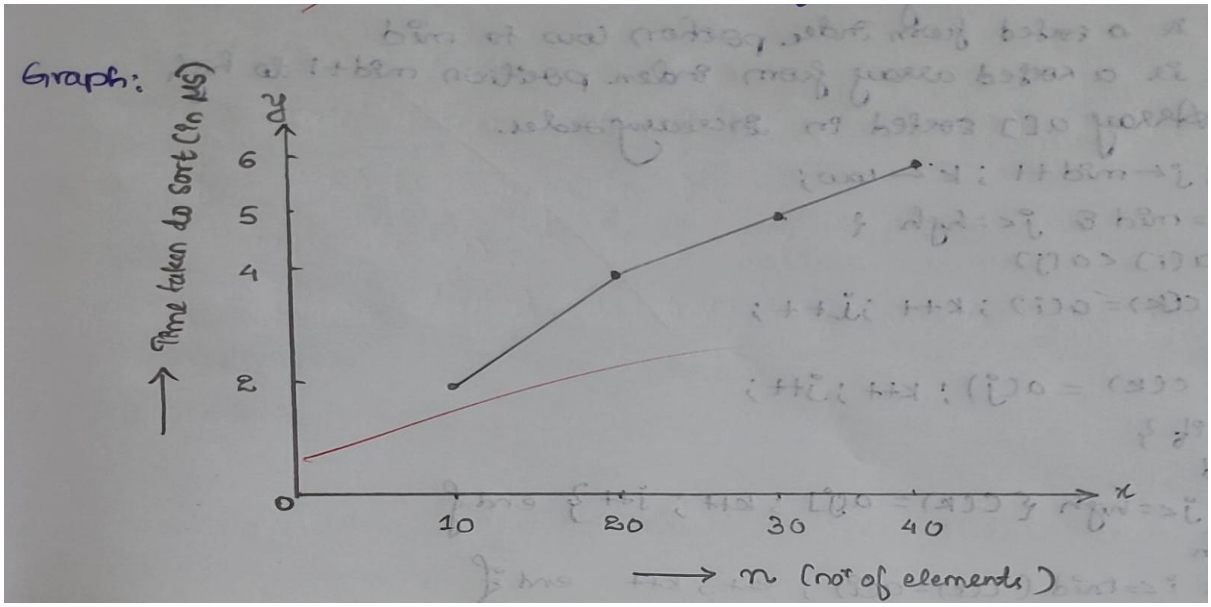
OUTPUT:

```
Enter the number of elements (N): 5
Enter 5 integer elements:
1 2 3 4 5
Sorted array:
1 2 3 4 5
Time taken to sort 5 elements: 0.000002 seconds
```

TRACING:



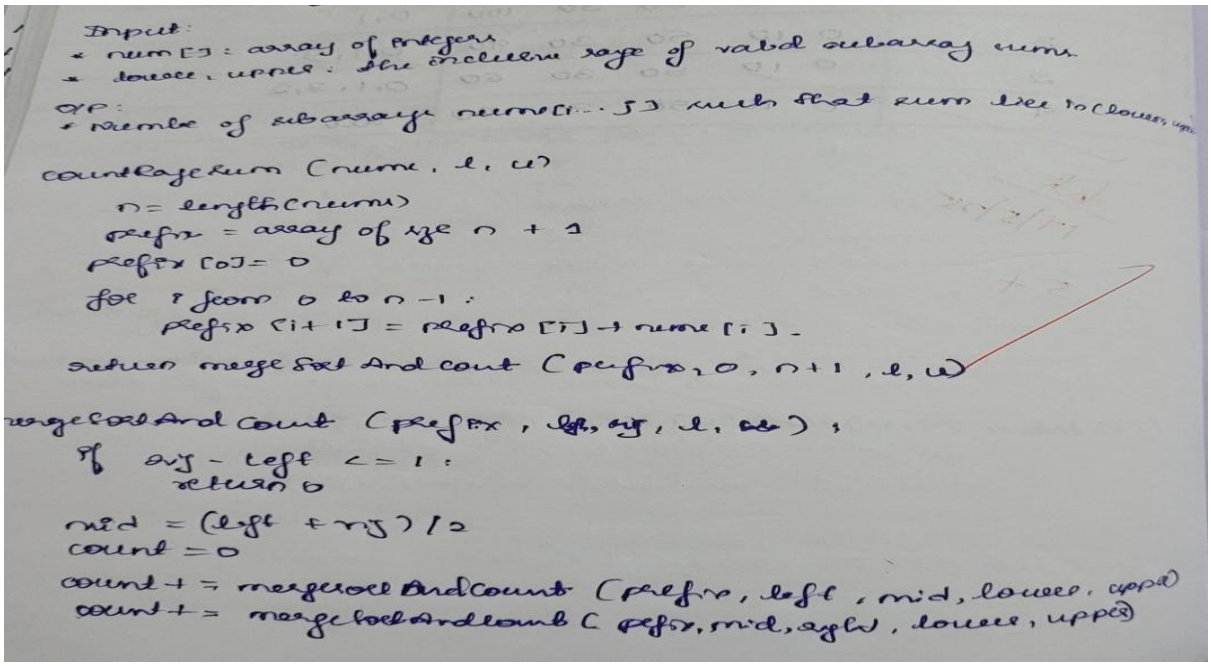
GRAPH:

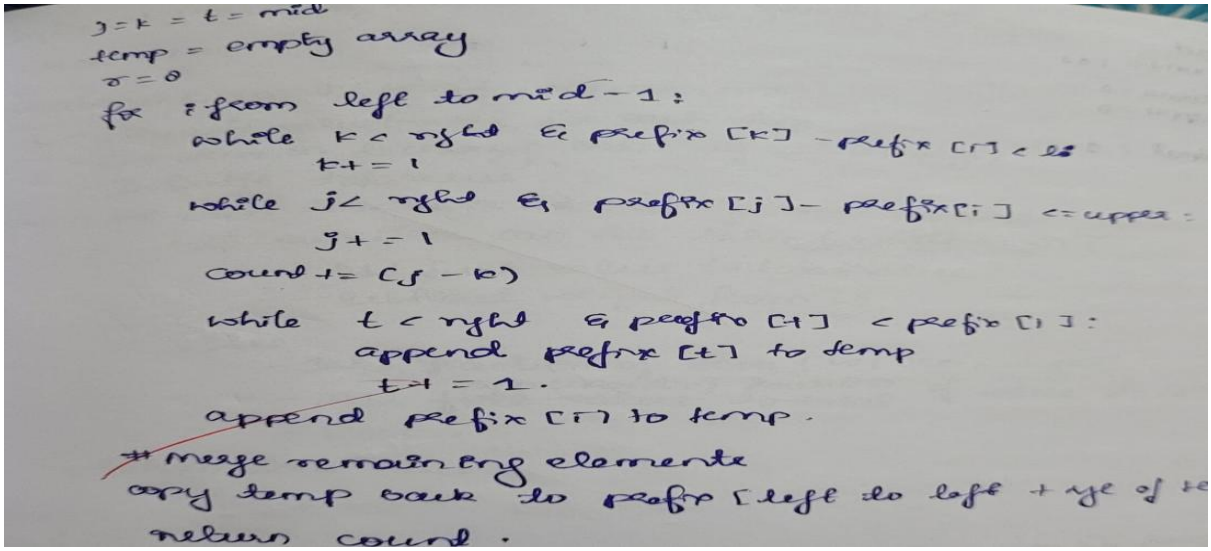


LEETCODE 1

COUNT RANGE SUM

ALGORITHM





CODE:

```
#include <stdio.h>
#include <stdlib.h>

int countWhileMergeSort(long* sum, int left, int right, int lower, int upper) {
    if (right - left <= 1) return 0;

    int mid = (left + right) / 2;
    int count = countWhileMergeSort(sum, left, mid, lower, upper) +
                countWhileMergeSort(sum, mid, right, lower, upper);

    int j = mid, k = mid, t = mid, r = 0;
    long* cache = (long*)malloc((right - left) * sizeof(long));

    for (int i = left; i < mid; ++i) {
        while (k < right && sum[k] - sum[i] < lower) k++;
        while (j < right && sum[j] - sum[i] <= upper) j++;
        count += j - k;

        while (t < right && sum[t] < sum[i])
            cache[r++] = sum[t++];
        cache[r++] = sum[i];
    }

    for (int i = 0; i < t - left; ++i)
        sum[left + i] = cache[i];

    free(cache);
    return count;
}
```

```
int countRangeSum(int* nums, int numsSize, int lower, int upper) {
    long* prefix = (long*)malloc((numsSize + 1) * sizeof(long));
    prefix[0] = 0;
    for (int i = 0; i < numsSize; i++) {
        prefix[i + 1] = prefix[i] + nums[i];
    }

    int result = countWhileMergeSort(prefix, 0, numsSize + 1, lower, upper);
    free(prefix);
    return result;
}

int main() {
    int nums[] = {-2, 5, -1};
    int size = sizeof(nums) / sizeof(nums[0]);
    int lower = -2, upper = 2;

    int result = countRangeSum(nums, size, lower, upper);
    printf("Count of Range Sum in [%d, %d] is: %d\n", lower, upper, result);

    return 0;
}
```

OUTPUT:

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

nums =
[0]

lower =
0

upper =
0

Output

1

Expected

1

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

nums =
[-2,5,-1]

lower =
-2

upper =
2

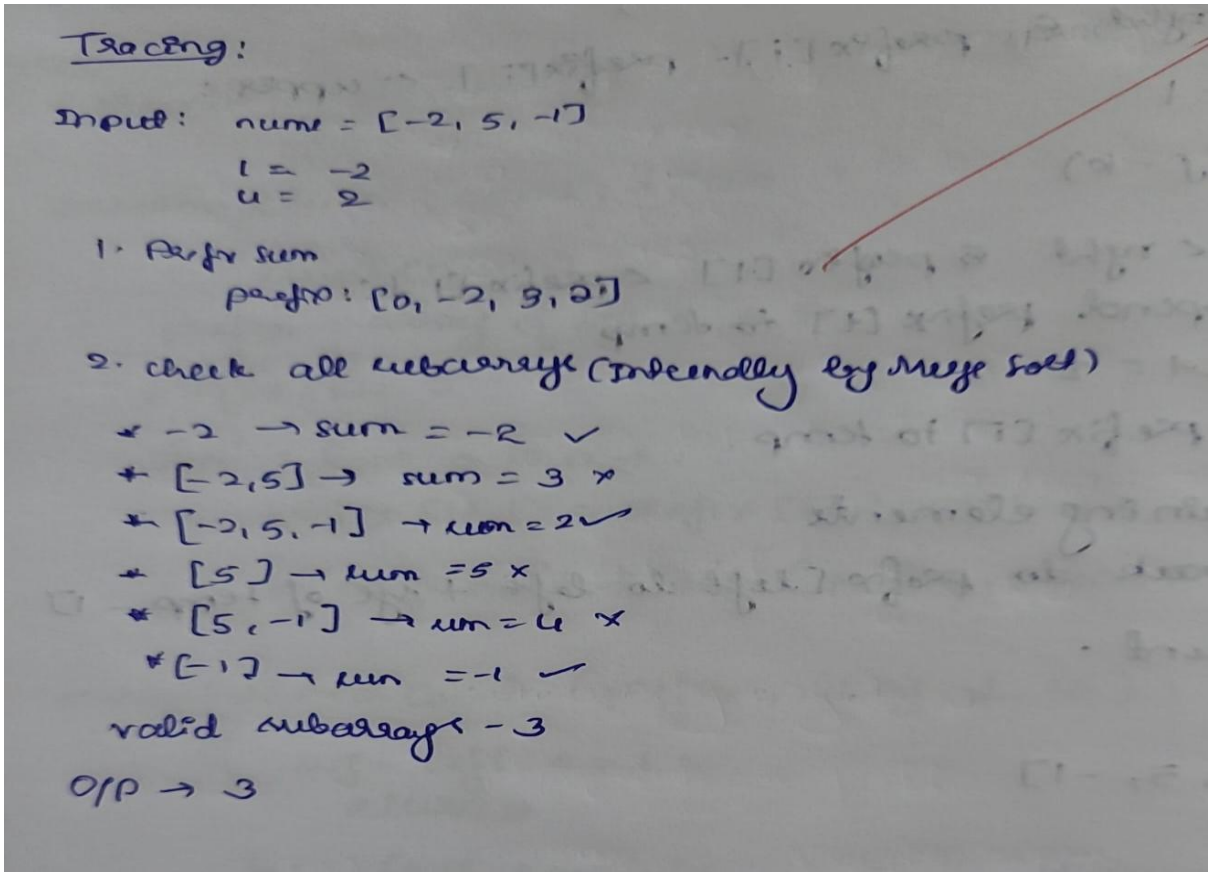
Output

3

Expected

3

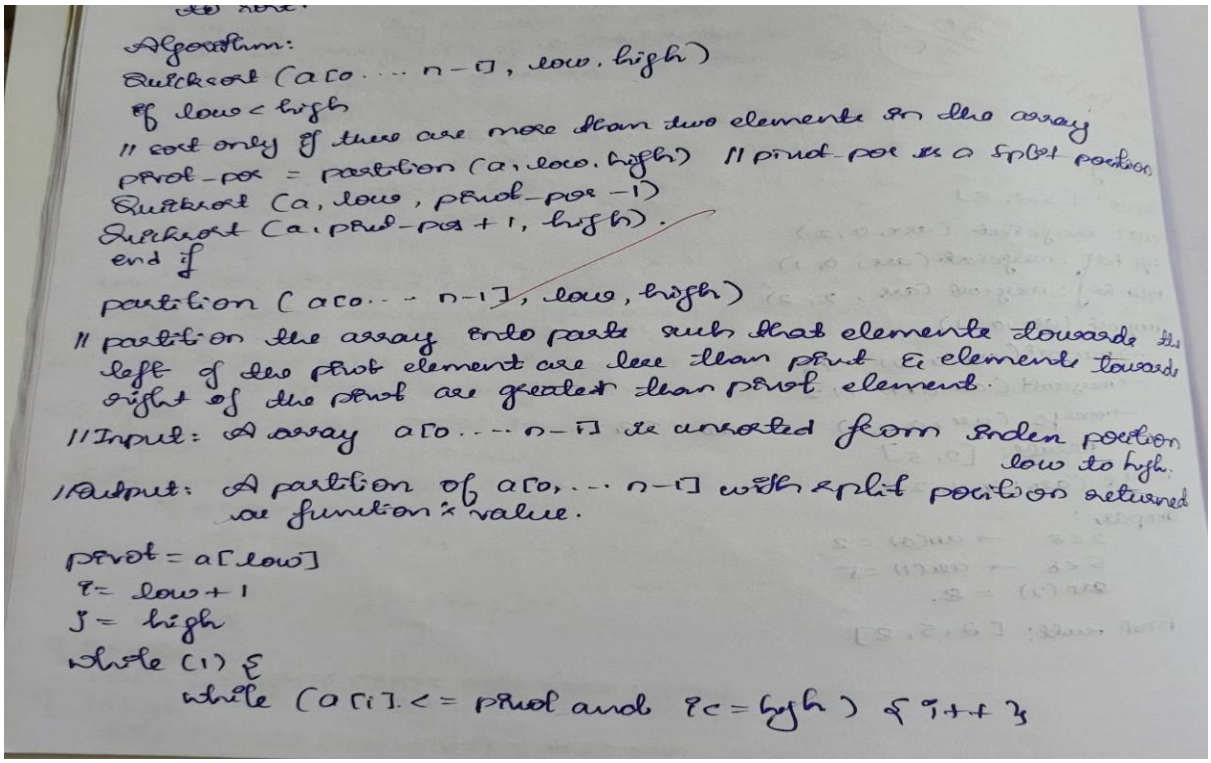
TRACING:



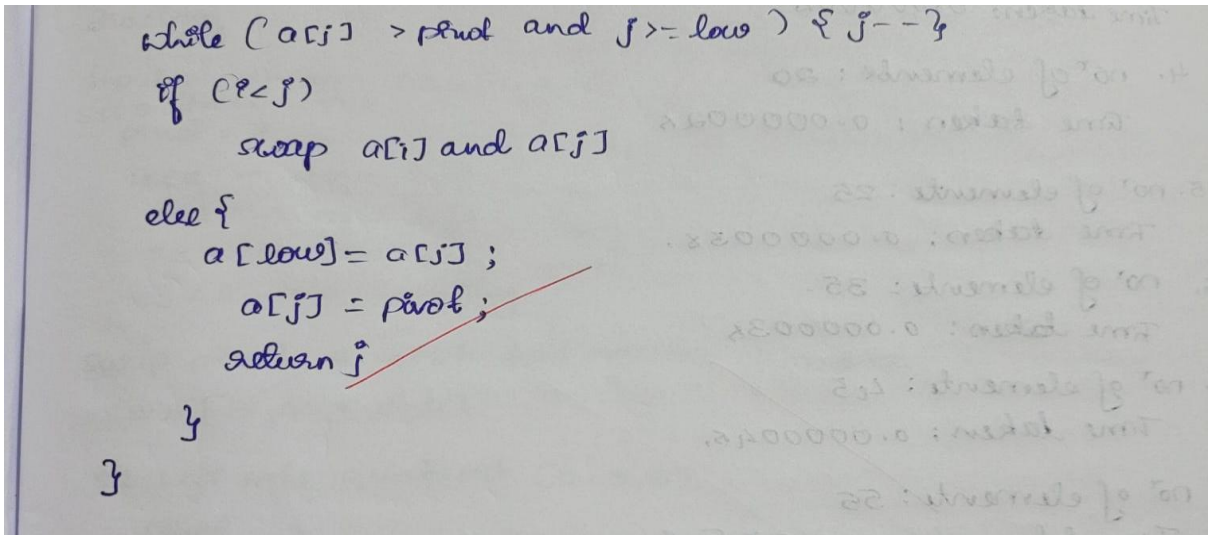
PROGRAM 2

Sort a given set of N integer elements using Quick Sort technique and compute its time taken.

ALGORITHM:



```
Algorithm:
Quicksort (a[0 .... n-1], low, high)
if low < high
// sort only if there are more than two elements in the array
pivot_pos = partition (a, low, high) // pivot_pos is a split position
Quicksort (a, low, pivot_pos -1)
Quicksort (a, pivot_pos + 1, high).
end if
partition ( a[0 .... n-1], low, high)
// partition the array into parts such that elements towards the
left of the pivot element are less than pivot & elements towards
right of the pivot are greater than pivot element.
//Input: An array a[0 .... n-1] is unsorted from index position
                                                    low to high.
//Output: A partition of a[0, ... n-1] with split position returned
        as function's value.
pivot = a[low]
i = low + 1
j = high
while (1) {
      while (a[i] <= pivot and i <= high ) { i++ }
```



```
while (a[j] > pivot and j >= low ) { j-- }
if (i < j)
    swap a[i] and a[j]
else {
   a[low] = a[j] ;
    a[j] = pivot ;
    return j
   }
}
```

CODE

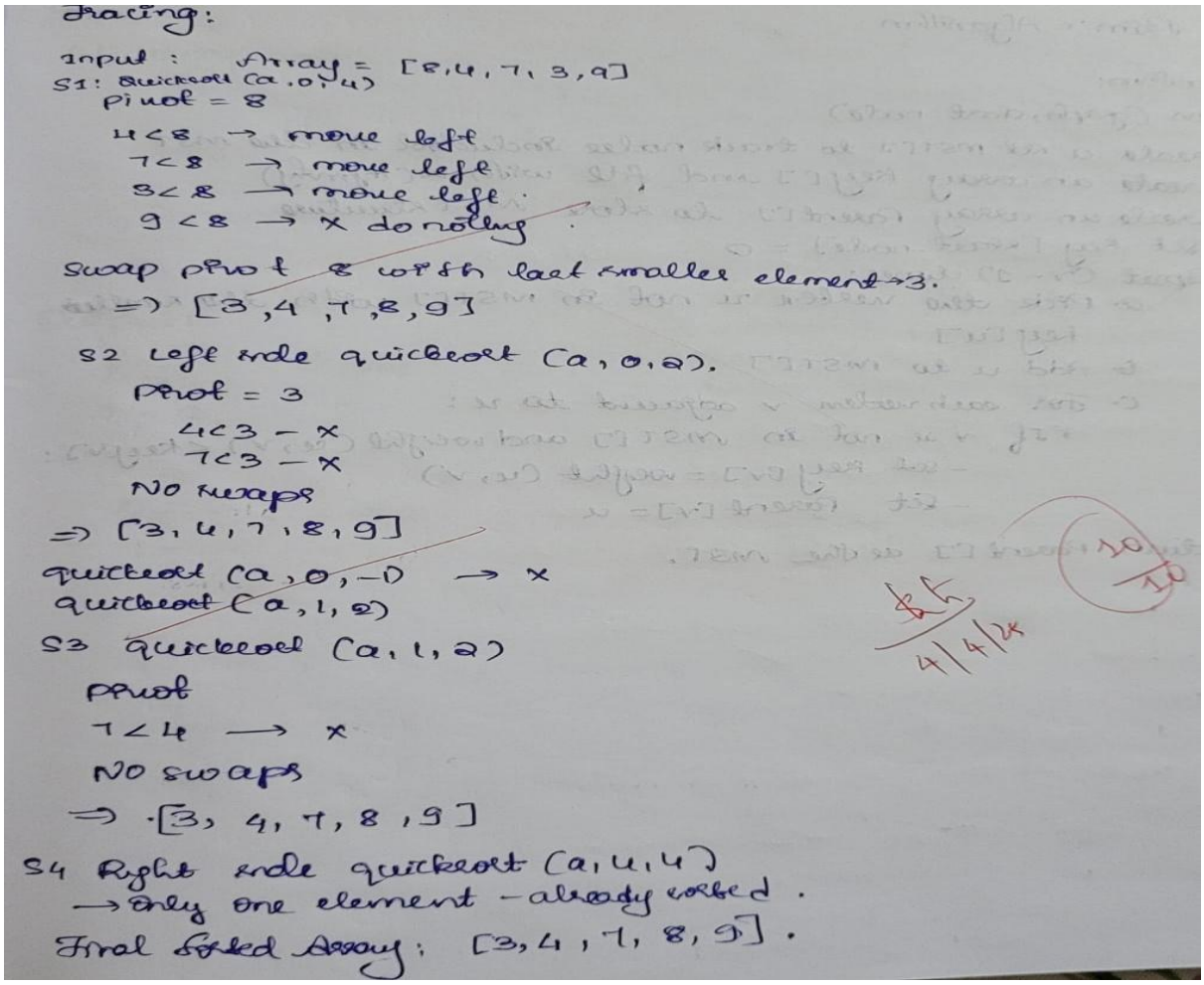
```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

// Function to swap two elements
void swap(int* a, int* b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}

// Partition function
int partition(int arr[], int low, int high) {
    int pivot = arr[high];  // last element as pivot
    int i = low - 1;
    for (int j = low; j < high; j++) {
        if (arr[j] <= pivot) {
            i++;
            swap(&arr[i], &arr[j]);
        }
    }
    swap(&arr[i + 1], &arr[high]);
    return i + 1;
}

// QuickSort function
void quickSort(int arr[], int low, int high) {
    if (low < high) {
        int pi = partition(arr, low, high);
```

```
        quickSort(arr, low, pi - 1);
        quickSort(arr, pi + 1, high);
    }
}

int main() {
    int n;
    printf("Enter number of elements: ");
    scanf("%d", &n);

    int arr[n];
    printf("Enter %d integers:\n", n);
    for (int i = 0; i < n; i++)
        scanf("%d", &arr[i]);

    clock_t start = clock();

    quickSort(arr, 0, n - 1);

    clock_t end = clock();
    double time_taken = (double)(end - start) / CLOCKS_PER_SEC;

    printf("\nSorted array:\n");
    for (int i = 0; i < n; i++)
        printf("%d ", arr[i]);

    printf("\n\nTime taken: %f seconds\n", time_taken);
    return 0;
}
```

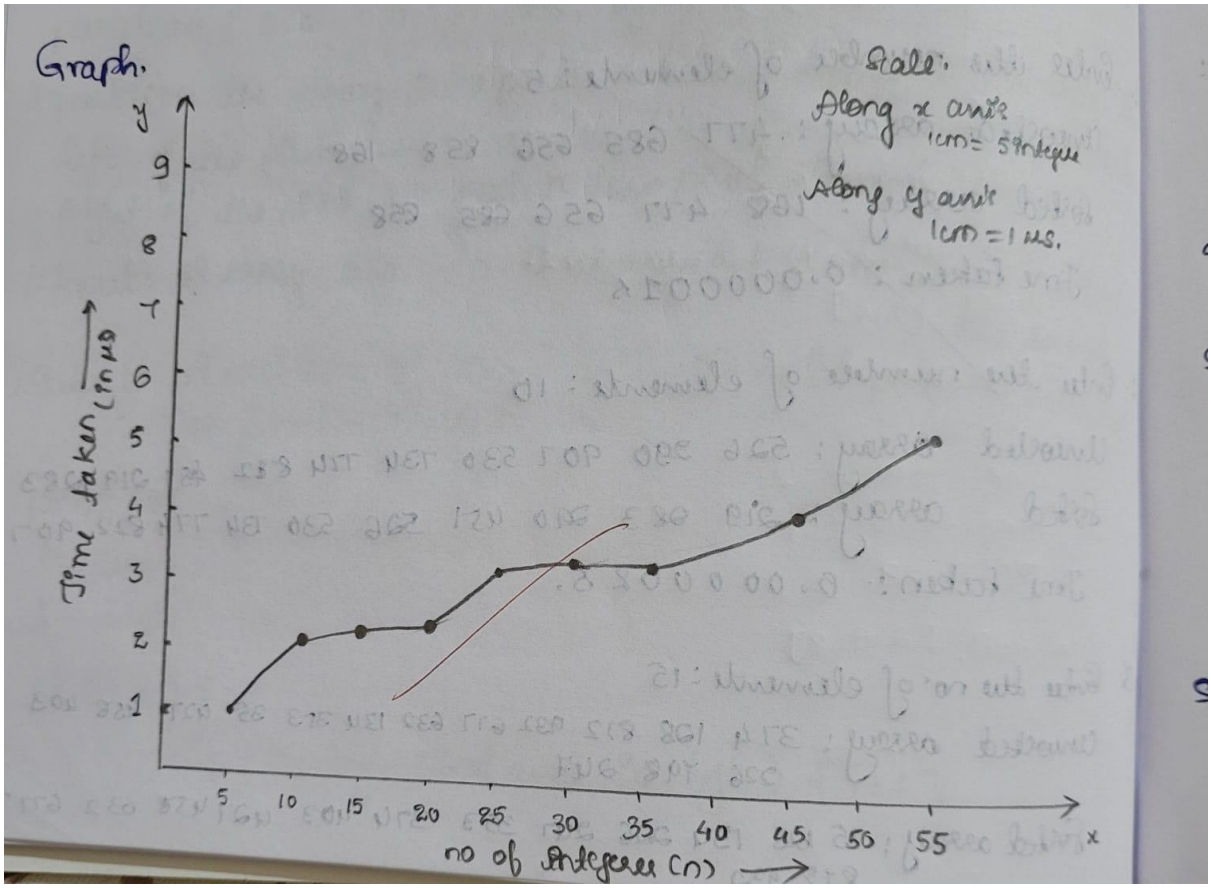
OUTPUT:

```
Enter number of elements: 5
Enter 5 integers:
56 89 45 2 45

Sorted array:
2 45 45 56 89

Time taken: 0.000002 seconds
```

TRACING:

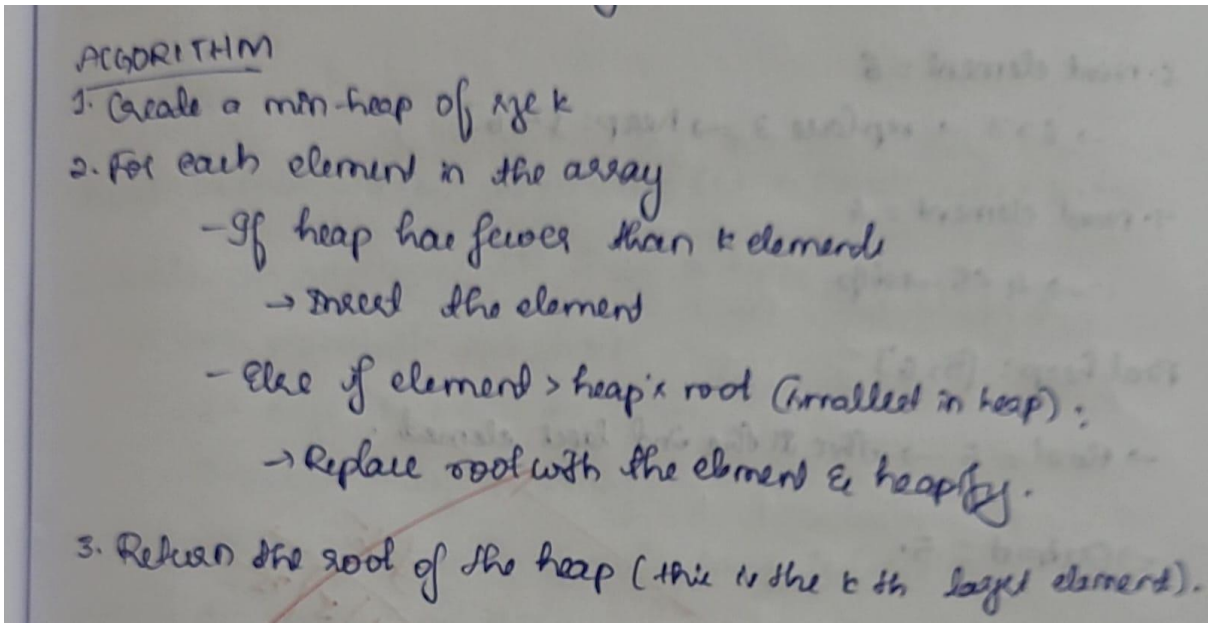


GRAPH:


Graph.
Scale:
Along x axis
1cm = 5 Integers
Along y axis
1cm = 1 μs.
Time taken (in μs)
y
9
8
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
45
50
55
x
no of Integers (n)

LEETCODE 2:
K th LARGEST ELEMENT IN AN ARRAY

ALGORITHM:



CODE

```
#include <stdlib.h>


// Swap function
void swap(int* a, int* b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}


// Partition for QuickSort
int partition(int* nums, int low, int high) {
    int pivot = nums[high];
    int i = low - 1;
    for (int j = low; j < high; j++) {
        if (nums[j] <= pivot) {
```

```
            i++;
            swap(&nums[i], &nums[j]);
        }
    }
    swap(&nums[i + 1], &nums[high]);
    return i + 1;
}

// QuickSort
void quickSort(int* nums, int low, int high) {
    if (low < high) {
        int pi = partition(nums, low, high);
        quickSort(nums, low, pi - 1);
        quickSort(nums, pi + 1, high);
    }
}

int findKthLargest(int* nums, int numsSize, int k) {
    quickSort(nums, 0, numsSize - 1);
    return nums[numsSize - k]; // kth largest is (n-k)th smallest in sorted array
}
```

OUTPUT:

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

nums =
[3,2,1,5,6,4]

k =
2

Output

5

Expected

5

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

nums =
[3,2,3,1,2,4,5,5,6]

k =
4

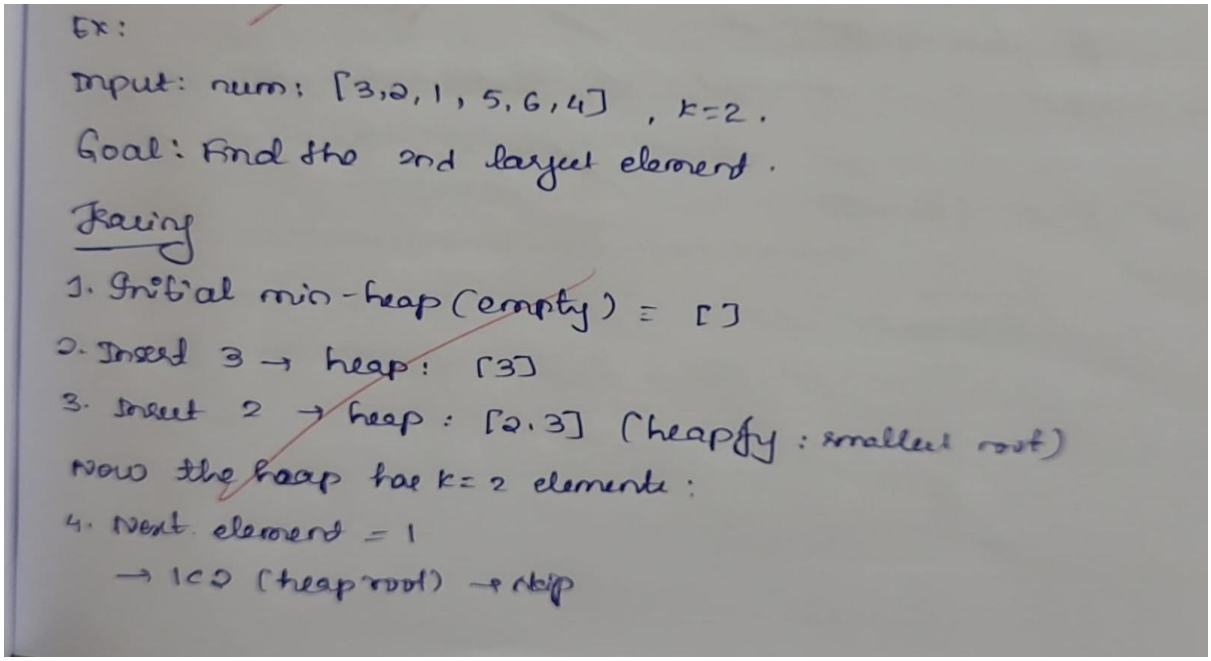
Output

4

Expected

4

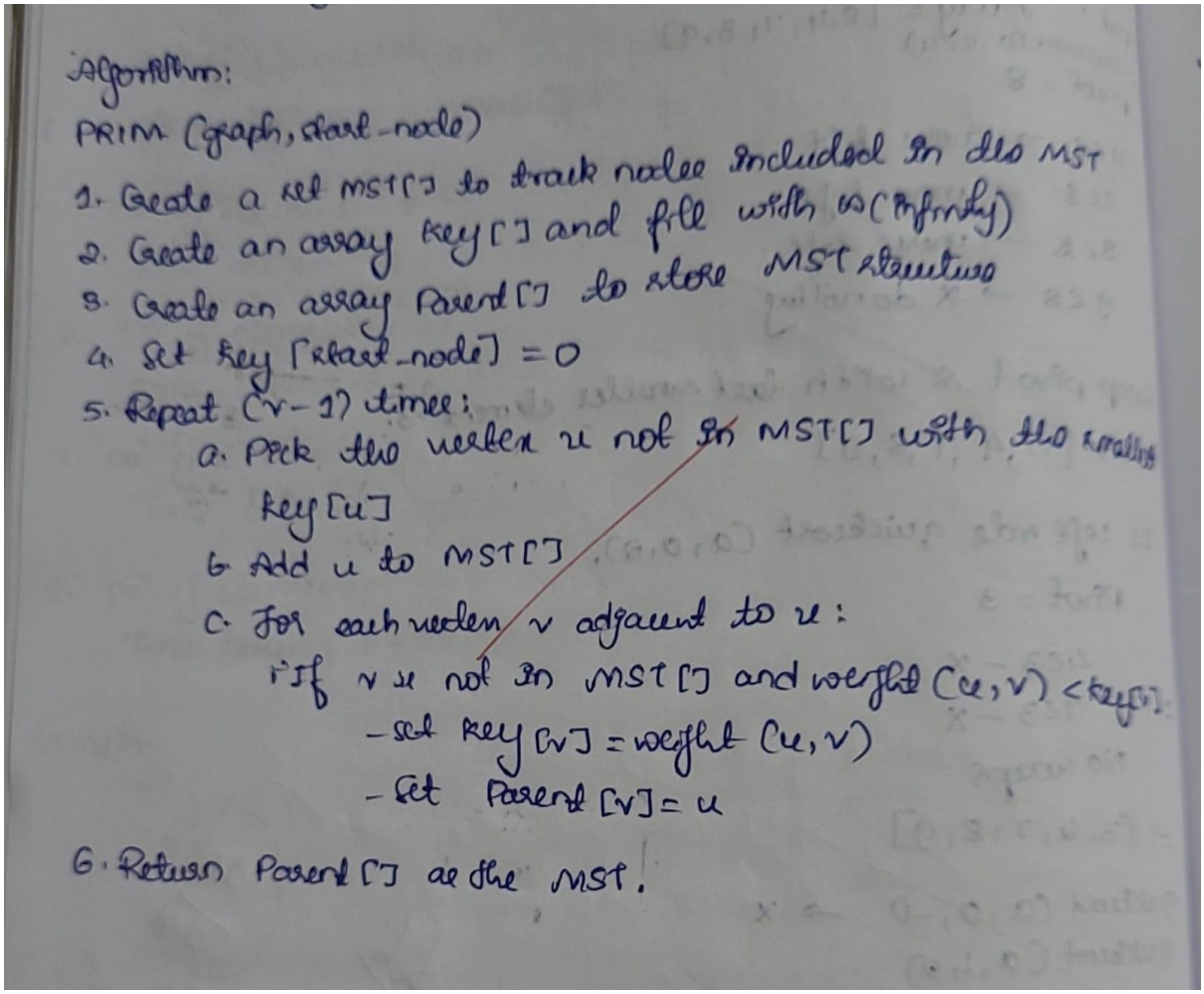
TRACING:



PROGRAM 3

3.1 Find Minimum Cost Spanning Tree of a given undirected graph using Prim's algorithm.

ALGORITHM



CODE

```
#include <stdio.h>
#include <limits.h>

#define MAX 100

int findMinKey(int key[], int mstSet[], int n) {
    int min = INT_MAX, minIndex;
```

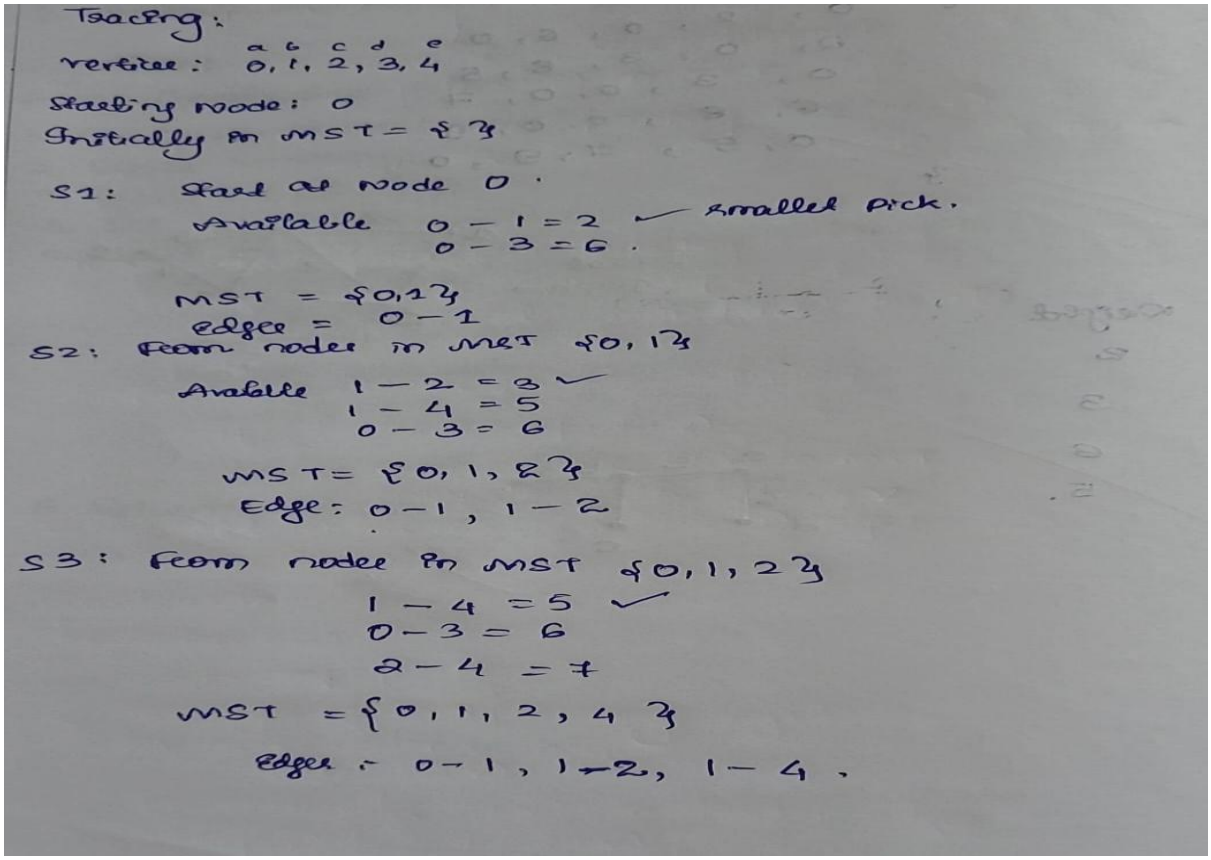
```
    for (int v = 0; v < n; v++)
        if (mstSet[v] == 0 && key[v] < min) {
            min = key[v];
            minIndex = v;
        }

    return minIndex;
}

void primMST(int graph[MAX][MAX], int n) {
    int parent[MAX]; // stores MST
    int key[MAX];    // used to pick minimum weight edge
    int mstSet[MAX]; // included in MST

    for (int i = 0; i < n; i++) {
        key[i] = INT_MAX;
        mstSet[i] = 0;
    }

    key[0] = 0;      // Start from first vertex
    parent[0] = -1;  // First node is root

    for (int count = 0; count < n - 1; count++) {
        int u = findMinKey(key, mstSet, n);
        mstSet[u] = 1;

        for (int v = 0; v < n; v++) {
            if (graph[u][v] && mstSet[v] == 0 && graph[u][v] < key[v]) {
                parent[v] = u;
                key[v] = graph[u][v];
```

```
            }
        }
    }

    int totalCost = 0;
    printf("\nEdge \tWeight\n");
    for (int i = 1; i < n; i++) {
        printf("%d - %d \t%d\n", parent[i], i, graph[i][parent[i]]);
        totalCost += graph[i][parent[i]];
    }
    printf("\nTotal Cost of MST = %d\n", totalCost);
}

int main() {
    int n;
    int graph[MAX][MAX];

    printf("Enter number of vertices: ");
    scanf("%d", &n);

    printf("Enter the adjacency matrix (use 0 for no edge):\n");
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            scanf("%d", &graph[i][j]);

    primMST(graph, n);

    return 0;
}
```

OUTPUT

```
Enter number of vertices: 5
Enter the adjacency matrix (use 0 for no edge):
0 2 0 6 0
2 0 3 8 5
0 3 0 0 7
6 8 0 0 9
0 5 7 9 0

Edge    Weight
0 - 1   2
1 - 2   3
0 - 3   6
1 - 4   5

Total Cost of MST = 16
```

TRACING



S4:

From MST nodes {0, 1, 2, 4}

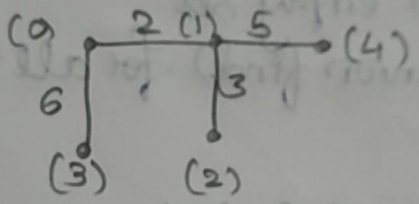
0 - 3 = 6 ✓

3 - 4 = 9

Pick 0-3

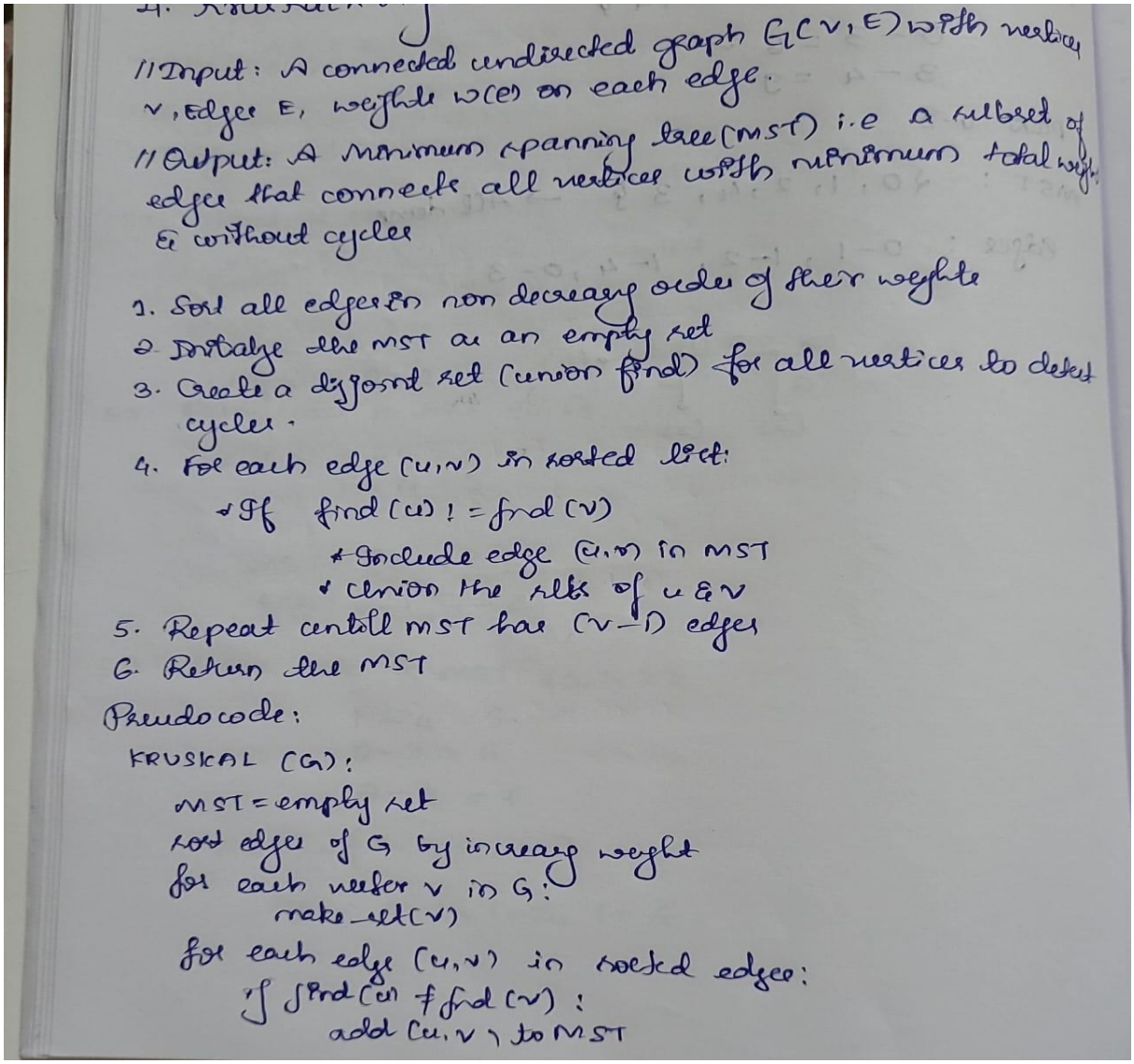
MST : {0, 1, 2, 4, 3} → All done

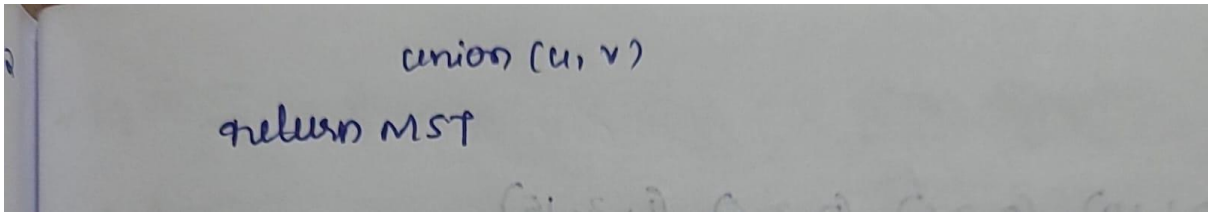
Edges : 0-1, 1-2, 1-4, 0-3



3.2 Find Minimum Cost Spanning Tree of a given undirected graph using Kruskal's algorithm.

ALGORITHM





CODE

```
#include <stdio.h>
#include <stdlib.h>

#define MAX 100

// Structure to represent an edge
struct Edge {
    int src, dest, weight;
};

// Structure to represent a graph
struct Graph {
    int V, E;
    struct Edge edge[MAX];
};

// Find parent of a node (with path compression)
int find(int parent[], int i) {
    if (parent[i] != i)
        parent[i] = find(parent, parent[i]);
    return parent[i];
}

// Union of two sets
void Union(int parent[], int x, int y) {
    parent[x] = y;
}

// Comparator for sorting edges by weight
```

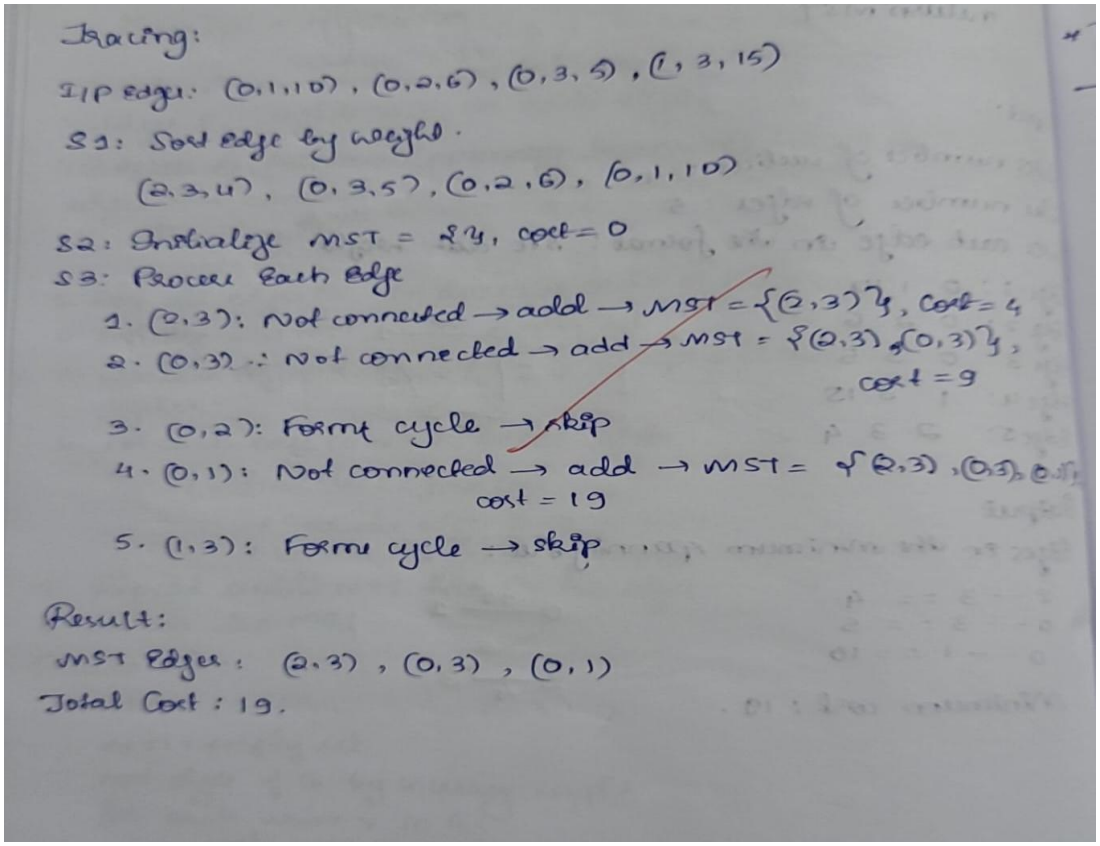
```
int compare(const void* a, const void* b) {
    struct Edge* e1 = (struct Edge*)a;
    struct Edge* e2 = (struct Edge*)b;
    return e1->weight - e2->weight;
}

// Kruskal's algorithm
void KruskalMST(struct Graph* graph) {
    int V = graph->V;
    struct Edge result[MAX];
    int parent[MAX];
    int e = 0; // count of edges in MST
    int i = 0;

    // Initially each node is its own parent
    for (int v = 0; v < V; v++)
        parent[v] = v;

    // Sort edges by weight
    qsort(graph->edge, graph->E, sizeof(graph->edge[0]), compare);

    while (e < V - 1 && i < graph->E) {
        struct Edge next = graph->edge[i++];
        int x = find(parent, next.src);
        int y = find(parent, next.dest);

        if (x != y) {
            result[e++] = next;
            Union(parent, x, y);
        }
```

```
    }

    int totalCost = 0;
    printf("\nEdge \tWeight\n");
    for (i = 0; i < e; ++i) {
        printf("%d - %d \t%d\n", result[i].src, result[i].dest, result[i].weight);
        totalCost += result[i].weight;
    }
    printf("\nTotal Cost of MST = %d\n", totalCost);
}

int main() {
    struct Graph graph;
    printf("Enter number of vertices and edges: ");
    scanf("%d %d", &graph.V, &graph.E);

    printf("Enter each edge as: src dest weight\n");
    for (int i = 0; i < graph.E; i++) {
        scanf("%d %d %d", &graph.edge[i].src, &graph.edge[i].dest, &graph.edge[i].weight);
    }

    KruskalMST(&graph);

    return 0;
}
```

OUTPUT

```
Enter number of vertices and edges: 4 5
Enter each edge as: src dest weight
0 1 10
0 2 6
0 3 5
1 3 15
2 3 4

Edge    Weight
2 - 3   4
0 - 3   5
0 - 1   10

Total Cost of MST = 19
```

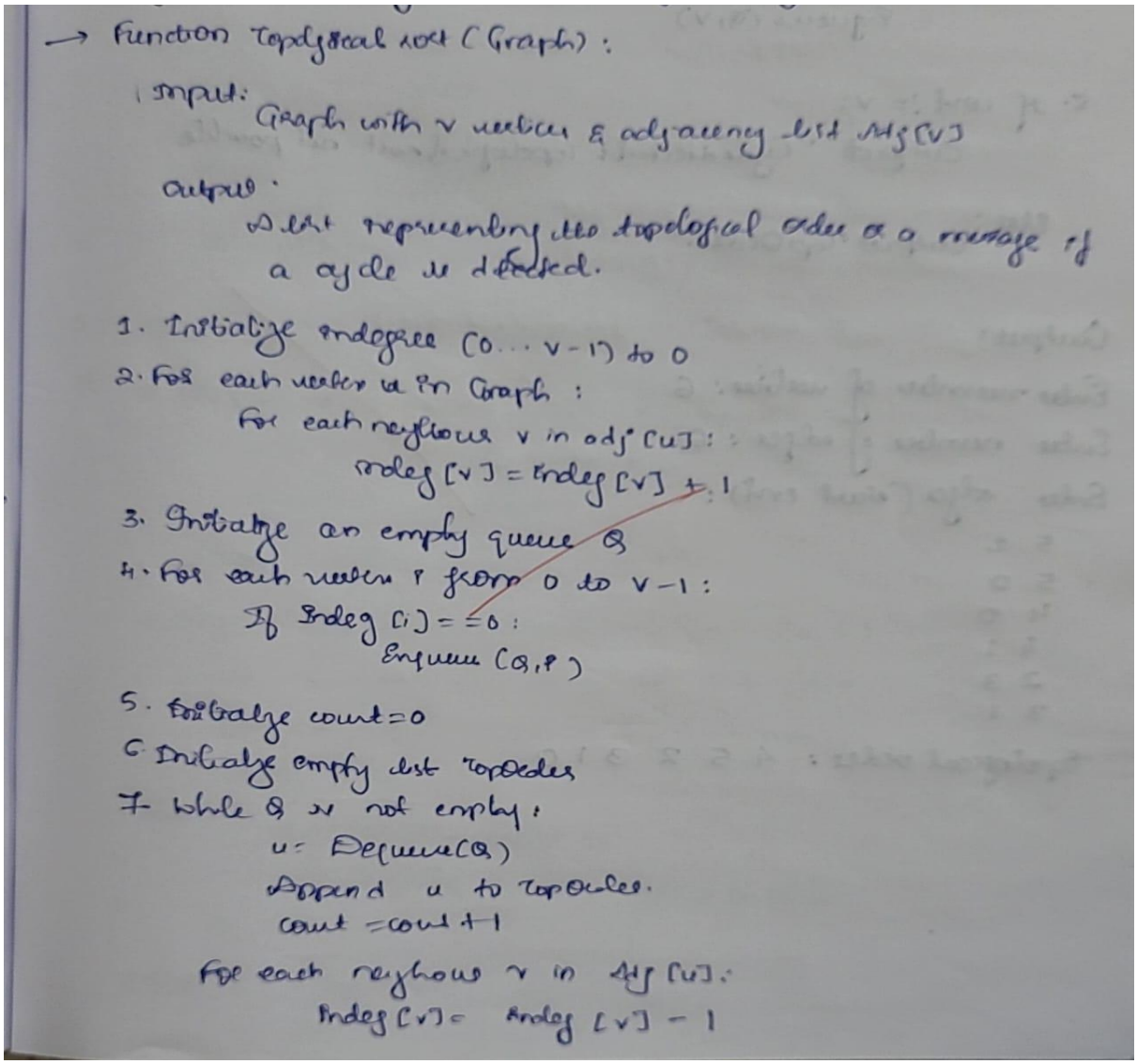
TRACING

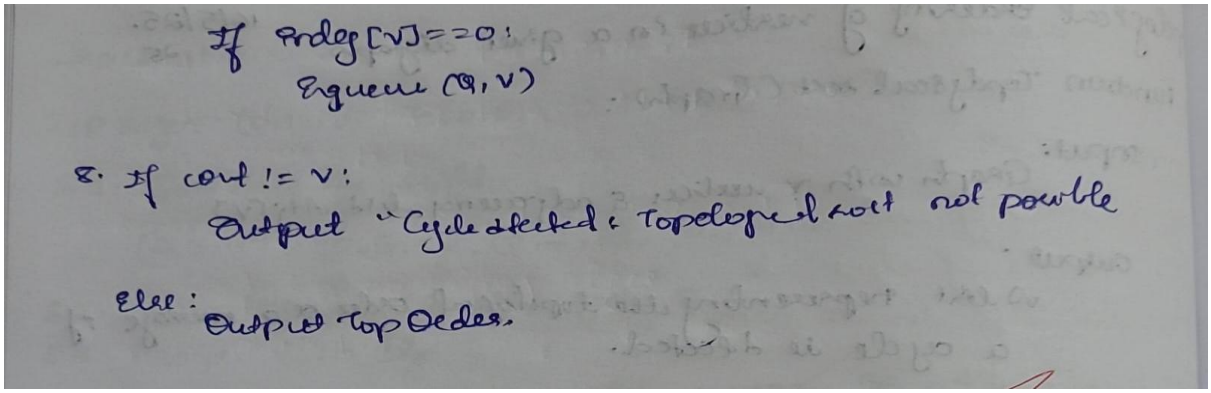


PROGRAM 4

Write program to obtain the Topological ordering of vertices in a given digraph.

ALGORITHM





CODE

```
#include <stdio.h>
#include <stdlib.h>

#define MAX 100

int adj[MAX][MAX];     // adjacency matrix
int indegree[MAX];     // array to store indegree of vertices
int queue[MAX];        // queue for BFS
int front = -1, rear = -1;

// Add edge from u -> v
void addEdge(int u, int v) {
    adj[u][v] = 1;
    indegree[v]++;
}

// Enqueue
void enqueue(int value) {
    if (rear == MAX - 1)
        return;
    if (front == -1)
        front = 0;
    queue[++rear] = value;
}

// Dequeue
int dequeue() {
    if (front == -1 || front > rear)
        return -1;
```

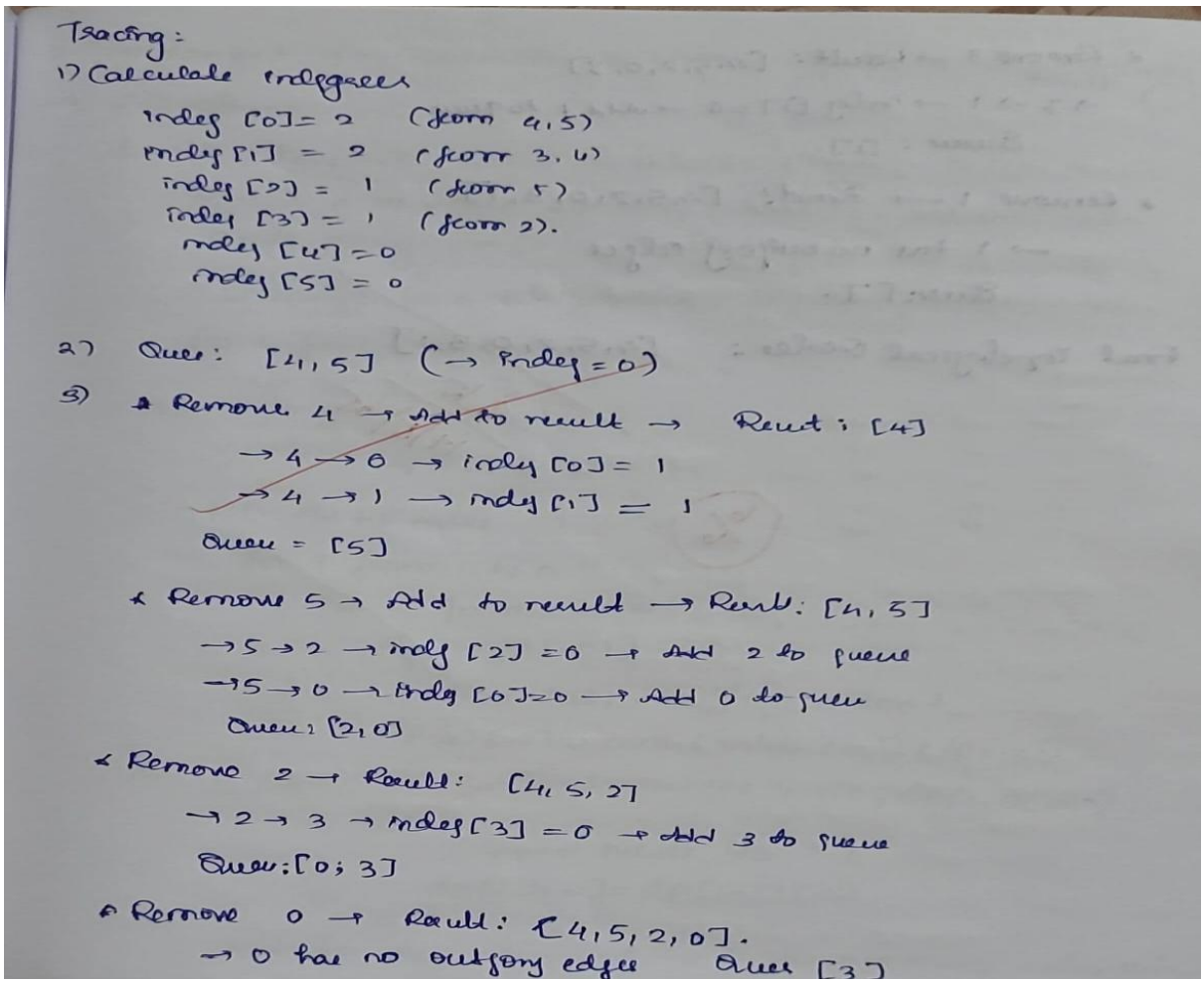
```
    return queue[front++];
}

// Topological Sort using Kahn's Algorithm
void topologicalSort(int n) {
    // Enqueue vertices with 0 indegree
    for (int i = 0; i < n; i++)
        if (indegree[i] == 0)
            enqueue(i);

    int count = 0;
    int topoOrder[MAX];

    while (front <= rear) {
        int u = dequeue();
        topoOrder[count++] = u;

        for (int v = 0; v < n; v++) {
            if (adj[u][v]) {
                indegree[v]--;
                if (indegree[v] == 0)
                    enqueue(v);
            }
        }
    }

    if (count != n) {
        printf("Cycle detected! Topological sort not possible.\n");
    } else {
        printf("Topological Order: ");
```

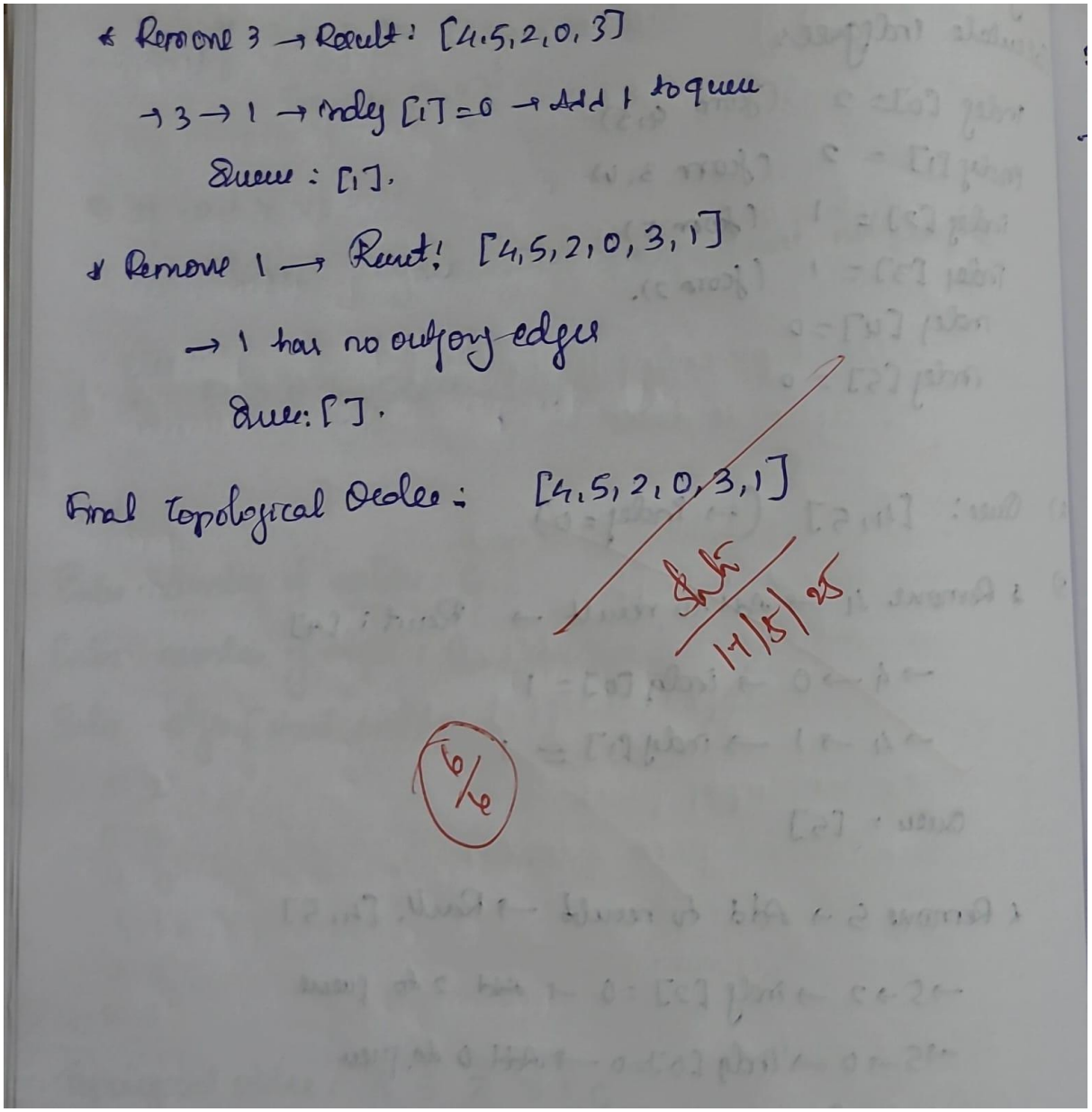
```
        for (int i = 0; i < count; i++)
            printf("%d ", topoOrder[i]);
        printf("\n");
    }
}

int main() {
    int n, e, u, v;

    printf("Enter number of vertices: ");
    scanf("%d", &n);
    printf("Enter number of edges: ");
    scanf("%d", &e);

    printf("Enter edges (from to):\n");
    for (int i = 0; i < e; i++) {
        scanf("%d %d", &u, &v);
        addEdge(u, v);
    }

    topologicalSort(n);

    return 0;
}
```

OUTPUT

```
Enter number of vertices: 6
Enter number of edges: 6
Enter edges (from to):
5 2
5 0
4 0
4 1
2 3
3 1
Topological Order: 4 5 0 2 3 1
```

TRACING

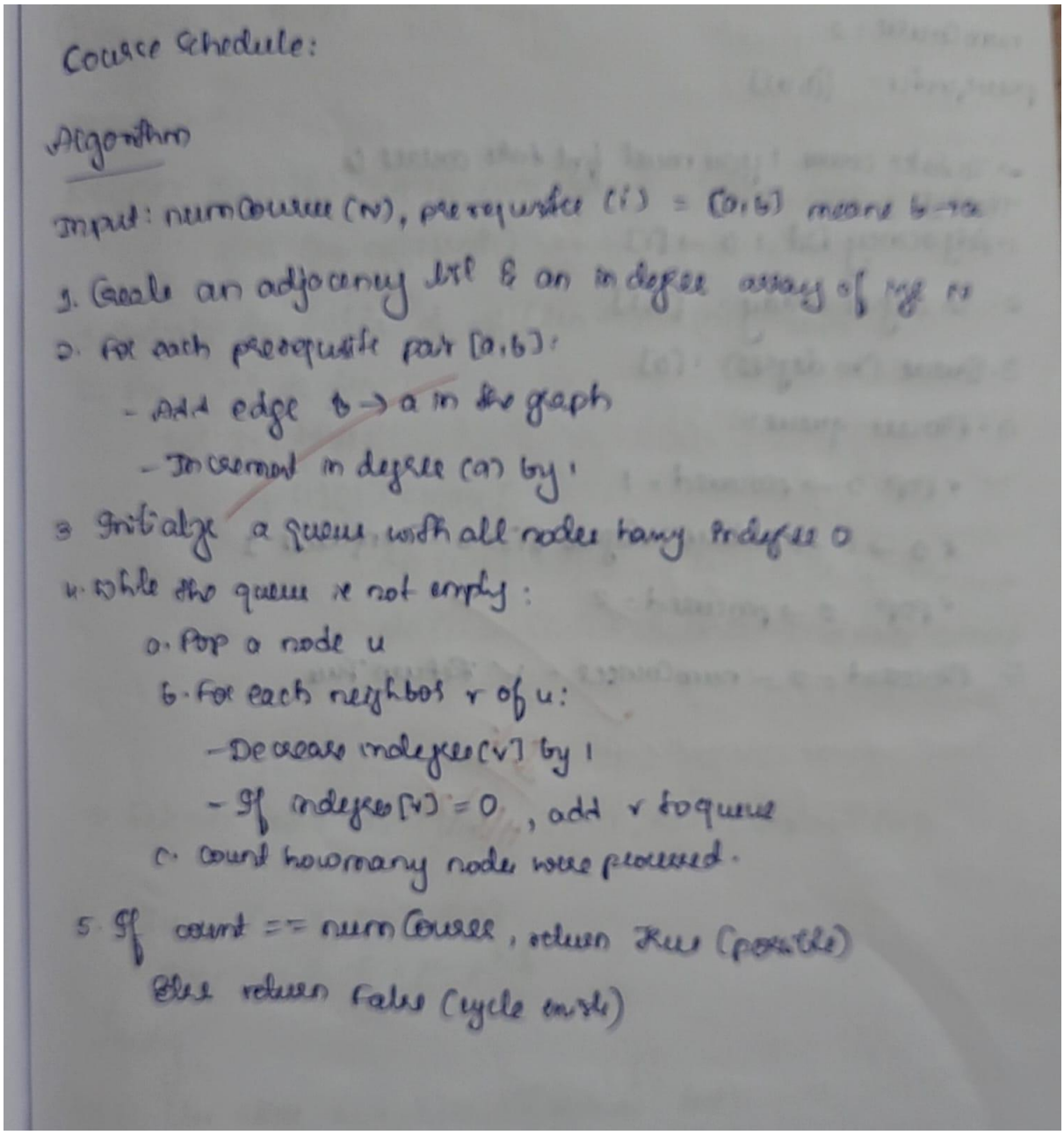



* Remove 3 → Result: [4,5,2,0,3]
→ 3 → 1 → indeg[1] = 0 → Add 1 to queue
Queue: [1].
* Remove 1 → Result: [4,5,2,0,3,1]
→ 1 has no outgoing edges
Queue: [].
Final topological Order: [4,5,2,0,3,1]
17/5/25
6/6

LEETCODE 3

COURSE SCHEDULE

ALGORITHM



CODE

```
bool canFinish(int numCourses, int** prerequisites, int prerequisitesSize, int*
prerequisitesColSize){
    // Build graph using adjacency list
    int* adj[numCourses];
```

```
int adjSize[numCourses];
int indegree[numCourses];

for (int i = 0; i < numCourses; i++) {
    adj[i] = (int*)malloc(sizeof(int) * numCourses); // worst case
    adjSize[i] = 0;
    indegree[i] = 0;
}

// Fill graph and indegree
for (int i = 0; i < prerequisitesSize; i++) {
    int to = prerequisites[i][0];
    int from = prerequisites[i][1];
    adj[from][adjSize[from]++] = to;
    indegree[to]++;
}

// Queue for BFS
int* queue = (int*)malloc(sizeof(int) * numCourses);
int front = 0, rear = 0;

// Push all courses with 0 indegree
for (int i = 0; i < numCourses; i++) {
    if (indegree[i] == 0)
        queue[rear++] = i;
}

int visited = 0;

while (front < rear) {
```

```
        int curr = queue[front++];
        visited++;

        for (int i = 0; i < adjSize[curr]; i++) {
            int neighbor = adj[curr][i];
            indegree[neighbor]--;
            if (indegree[neighbor] == 0)
                queue[rear++] = neighbor;
        }
    }

    free(queue);
    for (int i = 0; i < numCourses; i++) {
        free(adj[i]);
    }

    return visited == numCourses;
}
```

OUTPUT:

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

numCourses =

2

prerequisites =

[[1,0]]

Output

true

Expected

true

• Case 1 • Case 2

Input

numCourses =

2

prerequisites =

[[1,0],[0,1]]

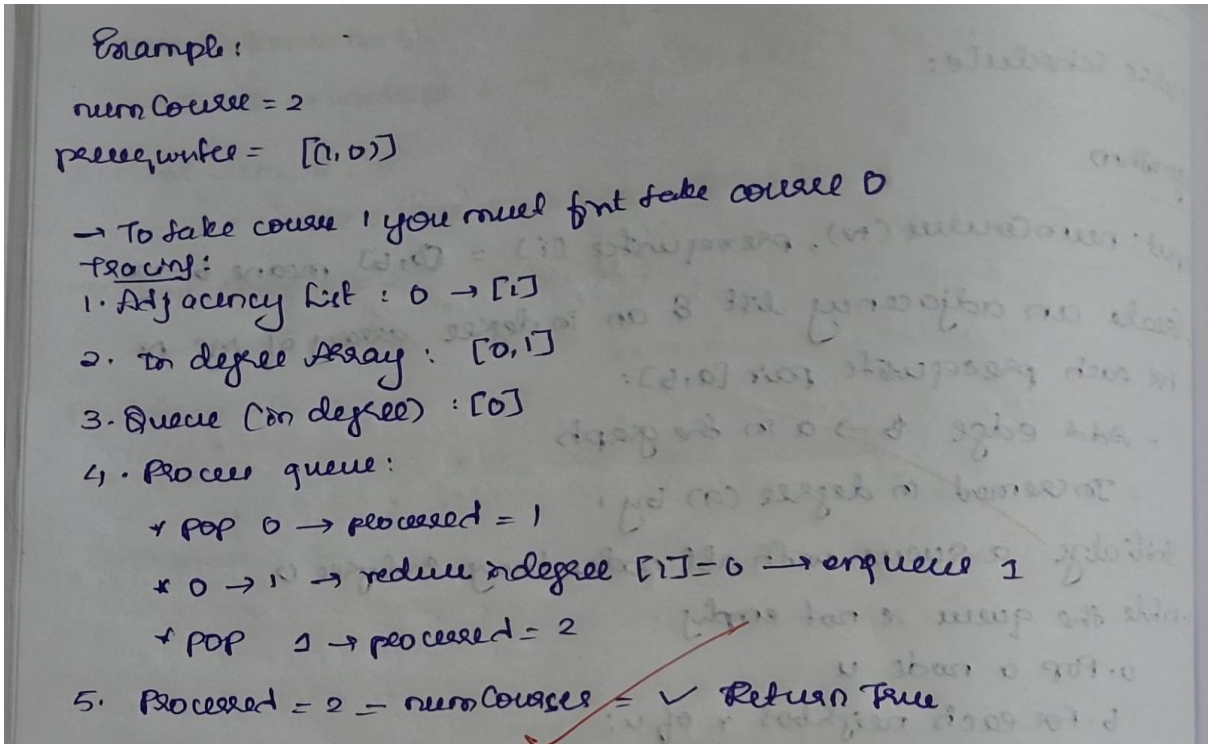
Output

false

Expected

false

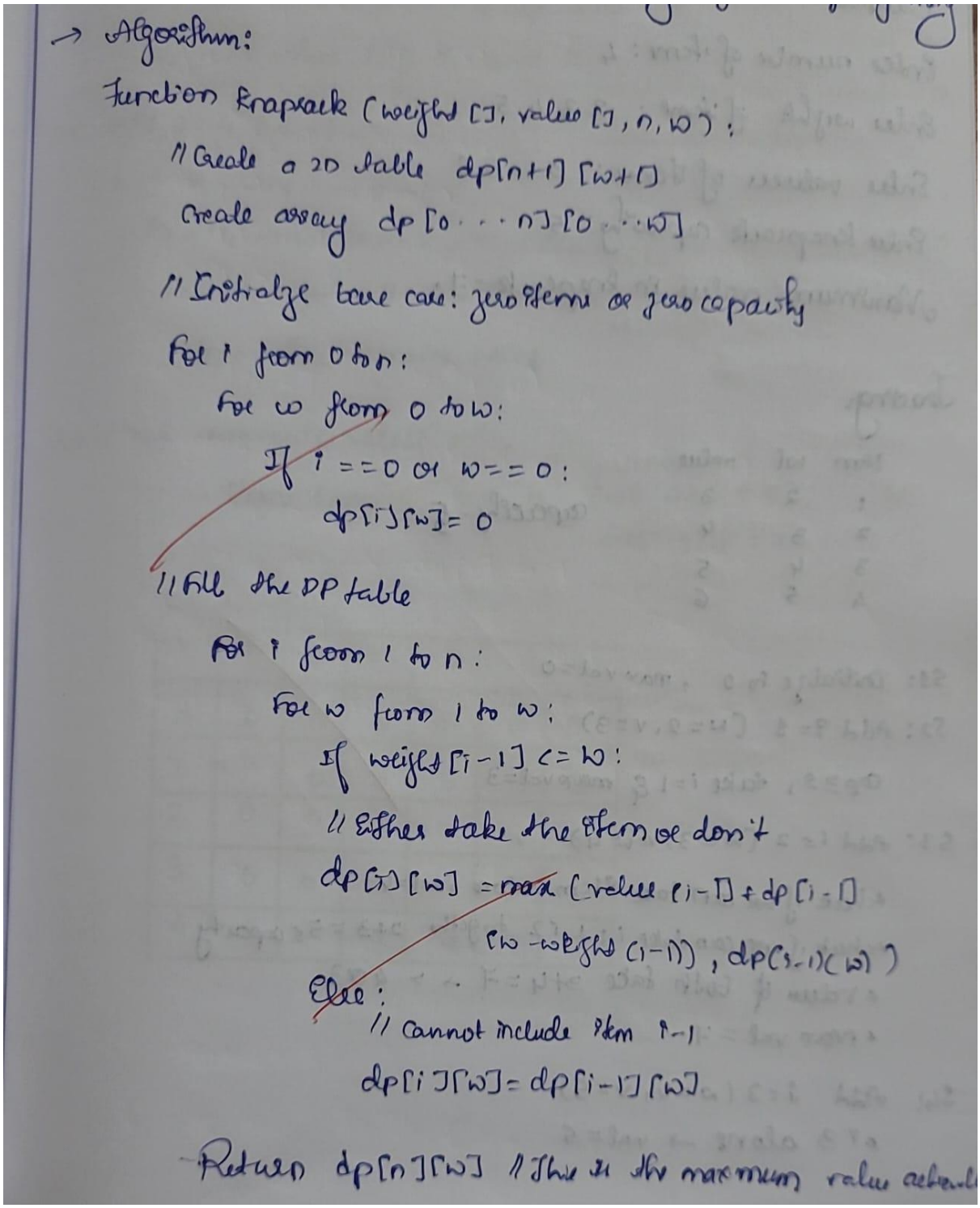
TRACING



PROGRAM 5

Implement 0/1 Knapsack problem using dynamic programming.

ALGORITHM



→ Algorithm:

function knapsack (weight [], value [], n, W):

// Create a 2D table dp[n+1] [W+1]

Create array dp [0 . . . n] [0 . . . W]

// Initialize base case: zero items or zero capacity

for i from 0 to n:

for w from 0 to W:

If i == 0 or w == 0:

dp[i][w] = 0

// Fill the DP table

for i from 1 to n:

for w from 1 to W:

If weight[i-1] <= W:

// Either take the item or don't

dp[i][w] = max (value[i-1] + dp[i-1]

[w - weight(i-1)], dp(i-1)(w))

Else:

// Cannot include item i-1

dp[i][w] = dp[i-1][w]

Return dp[n][w] // This is the maximum value achieved

CODE

```
#include <stdio.h>

int max(int a, int b) {
    return (a > b) ? a : b;
}

// Function to solve knapsack problem using DP
int knapsack(int W, int wt[], int val[], int n) {
    int dp[n + 1][W + 1];

    // Build table dp[][] in bottom-up manner
    for (int i = 0; i <= n; i++) {
        for (int w = 0; w <= W; w++) {
            if (i == 0 || w == 0)
                dp[i][w] = 0;
            else if (wt[i - 1] <= w)
                dp[i][w] = max(val[i - 1] + dp[i - 1][w - wt[i - 1]], dp[i - 1][w]);
            else
                dp[i][w] = dp[i - 1][w];
        }
    }

    return dp[n][W];
}

int main() {
    int n, W;

    printf("Enter number of items: ");
```

```
    scanf("%d", &n);

    int wt[n], val[n];

    printf("Enter weights of items:\n");
    for (int i = 0; i < n; i++)
        scanf("%d", &wt[i]);

    printf("Enter values of items:\n");
    for (int i = 0; i < n; i++)
        scanf("%d", &val[i]);

    printf("Enter capacity of knapsack: ");
    scanf("%d", &W);

    int maxValue = knapsack(W, wt, val, n);

    printf("Maximum value that can be obtained = %d\n", maxValue);

    return 0;
}
```

OUTPUT

```
Enter number of items: 4
Enter weights of items:
2 3 4 5
Enter values of items:
3 4 5 6
Enter capacity of knapsack: 5
Maximum value that can be obtained = 7
```

TRACING

Tracing:

Item	wt	value
1	2	3
2	3	4
3	4	5
4	5	6

capacity - 5

S1: Initialize to 0 , max val = 0

S2: Add i = 1 (w = 2, v = 3)

cap ≥ 2, take i = 1 & max val = 3

S3: Add i = 2 (w = 3, val = 4)

• check if we can take Item 2 alone → val = 4

• check if we can take i1 + i2 together 2+3 = 5 ≤ capacity

• value if both take 3+4 = 7 → > 4 & 3.

• max val = 7.

S4: Add j = 3 (w = 4, v = 5)

• i3 alone → val = 5

• i1 + i3 → wt = 2+4 = 6 ≤ capacity - yes

• i2 + i3 → wt = 3+4 = 7 ≤ cap → no

So max value stays the same 7.

S5: Add j = 4 (w = 5, v = 6)

• i = 4 alone → v = 6.

i3 + i4 → wt = 2+5 = 7 < capacity — no

i2 + i4 → wt = 3+5 = 8 < capacity — no

max value remains same

So Final maximum value = 7

Items Chosen 1 & 2 (wt 2+3 = 5).

Val 3+4 = 7

i \ w	0	1	2	3	4	5
0	0	0	0	0	0	0
1	0	0	3	3	3	3
2	0	0	3	4	4	7
3	0	0	3	4	5	7
4	0	0	3	4	5	7

Back tracking

- i=4, w=5
- dp[4][5] = dp[3][5] = 7

  4 not included.

  w=5 i=3
- dp[3][5]=7 } equal
  dp[2][5]=7

  3 not included

  w=5 i=2
- dp[2][5]=7 } no equal
  dp[1][5]=3

  2 included

  w = 5 - wt[2-1] = 5-3 = 2.

  i=1
- dp[1][2]= 3 ≠ dp[0][2] = 0

  Item 1 was included.

  w = 2 - w[1-1] = 2-2 = 0

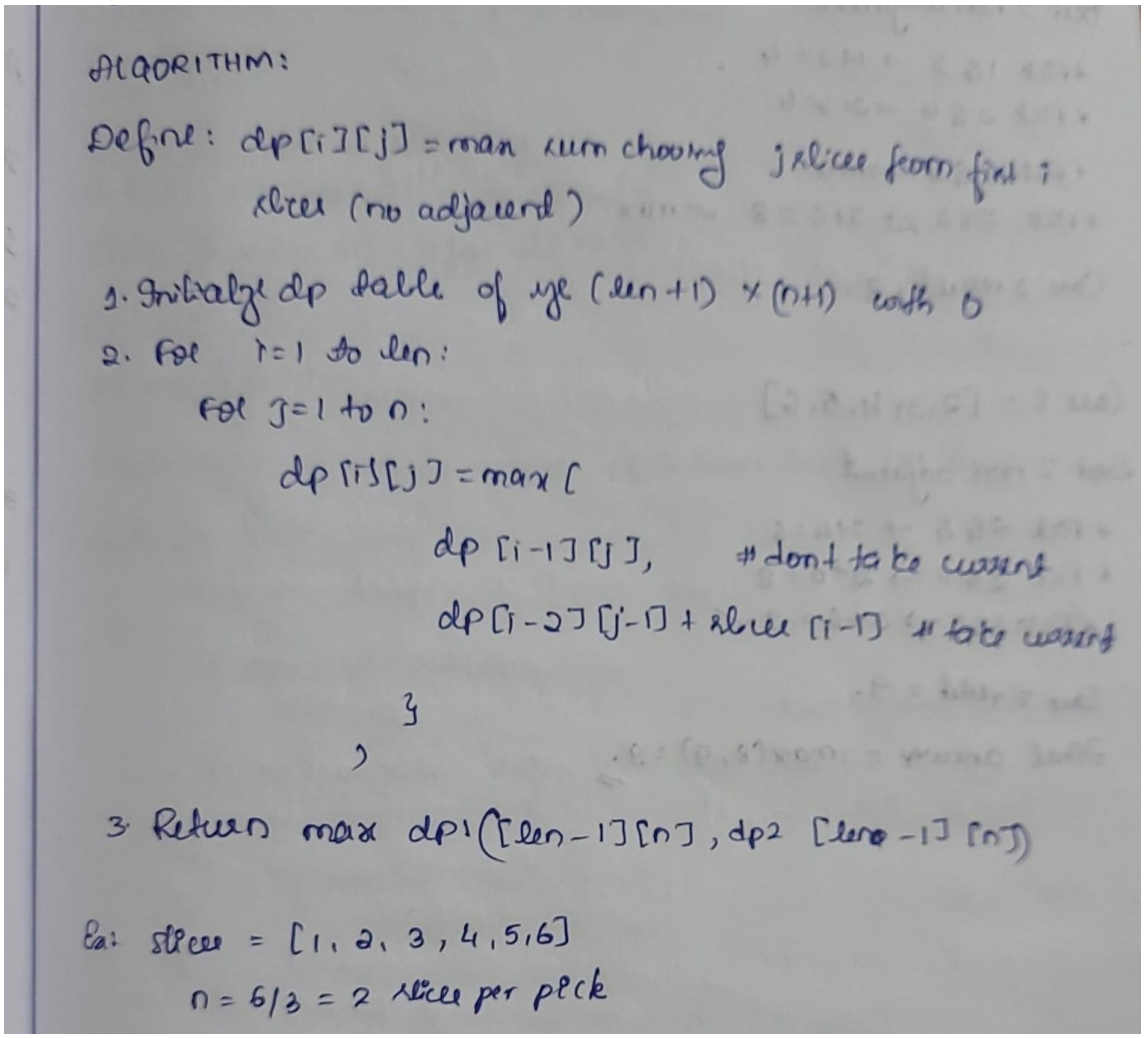
⇒ Total weight
= 2+3 = 5

Total value
= 3+4 = 7.

LEETCODE 4

PIZZA WITH 3n SLICES

ALGORITHM



CODE

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int max(int a, int b) {
   return (a > b) ? a : b;
}
```

```
// Function to compute the max sum using DP (like 0/1 Knapsack)
int calculate(int* slices, int start, int end, int n) {
    int len = end - start + 1;
    int dp[len + 2][n + 1];
    memset(dp, 0, sizeof(dp));

    for (int i = len - 1; i >= 0; i--) {
        for (int j = 1; j <= n; j++) {
            int take = slices[start + i] + dp[i + 2][j - 1];  // pick slice
            int skip = dp[i + 1][j];                          // skip slice
            dp[i][j] = max(take, skip);
        }
    }
    return dp[0][n];
}

int maxSizeSlices(int* slices, int slicesSize) {
    int n = slicesSize / 3;
    int max1 = calculate(slices, 0, slicesSize - 2, n);     // exclude last
    int max2 = calculate(slices, 1, slicesSize - 1, n);     // exclude first
    return max(max1, max2);
}
```

OUTPUT

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

slices =

[1,2,3,4,5,6]

Output

10

Expected

10

Contribute a testcase

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

slices =

[8,9,8,6,1,1]

Output

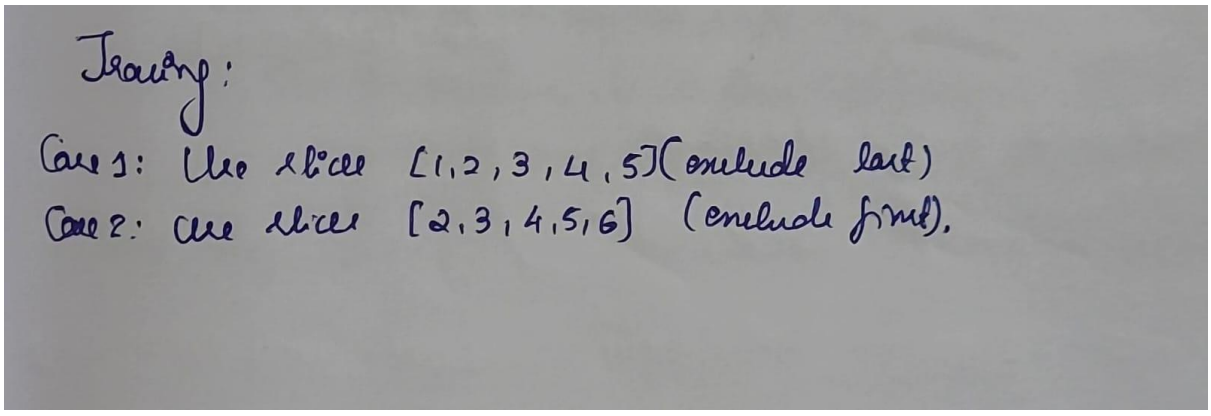
16

Expected

16

Contribute a testcase

TRACING



Case 1: [1, 2, 3, 4, 5]

Best 2 non adjacent

* Pick 1 & 3 → 1+3 = 4
* Pick 2 & 4 → 2+4 = 6
* Pick 1 & 4 → 1+4 = 5
* Pick 3 & 5 → 3+5 = 8 ✓ max.

Case 1 result = 8.

Case 2 : [2, 3, 4, 5, 6]

Best 2 non adjacent

* Pick 2 & 4 → 2+4 = 6
* Pick 2 & 5 → 2+6 = 8
* Pick 3 & 5 → 3+6 = 9 ✓

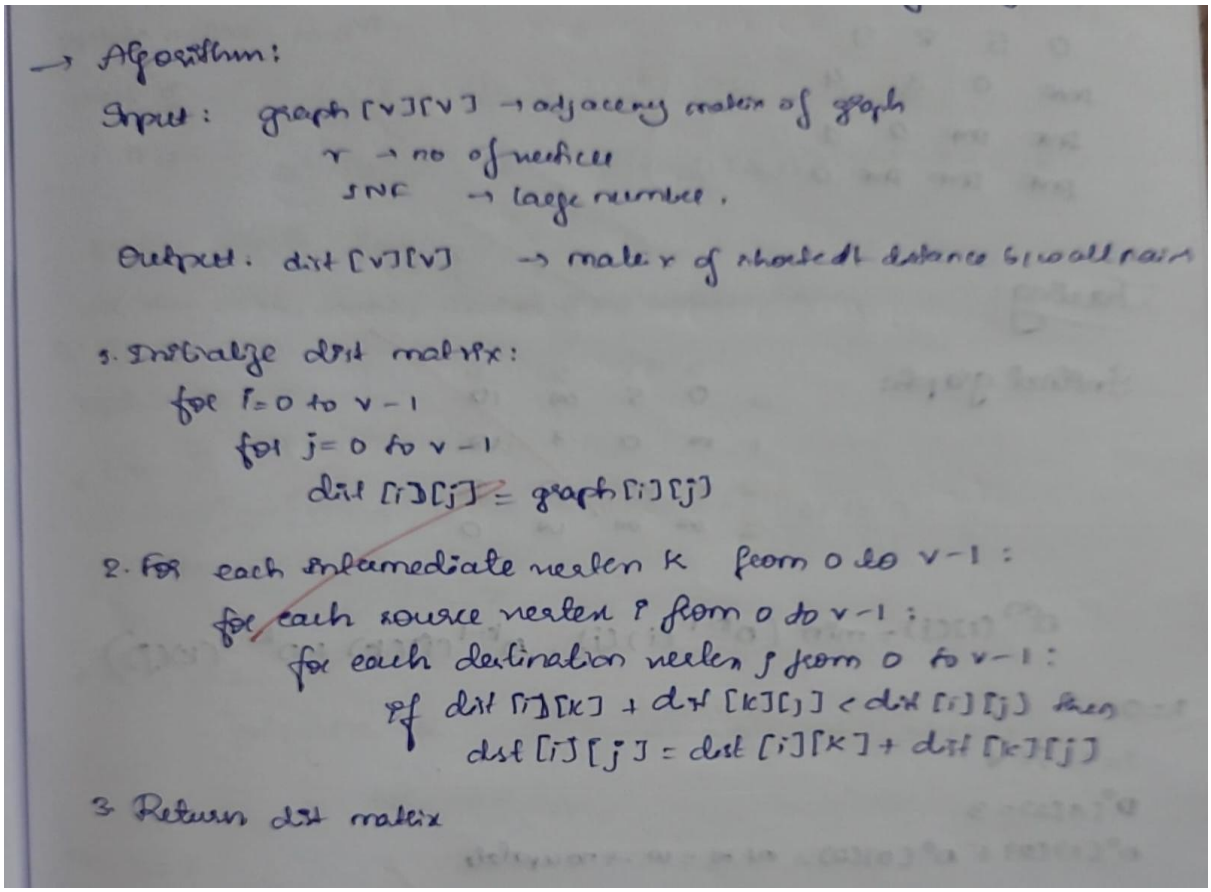
Case 2 result = 9.

Final answer = max(8, 9) = 9.

PROBLEM 6

Implement All Pair Shortest paths problem using Floyd's algorithm.

ALGORITHM



CODE

```
#include <stdio.h>


#define INF 99999
#define V 4  // Number of vertices


// Function to print the shortest distance matrix
void printSolution(int dist[V][V]) {
    printf("Shortest distances between every pair of vertices:\n");
    for (int i = 0; i < V; i++) {
        for (int j = 0; j < V; j++) {
            if (dist[i][j] == INF)
```

```
            printf("%7s", "INF");
        else
            printf("%7d", dist[i][j]);
    }
    printf("\n");
  }
}

// Floyd-Warshall algorithm
void floydWarshall(int graph[V][V]) {
  int dist[V][V];

  // Initialize the solution matrix with input graph
  for (int i = 0; i < V; i++)
    for (int j = 0; j < V; j++)
      dist[i][j] = graph[i][j];

  // Update dist[i][j] to the shortest path
  for (int k = 0; k < V; k++) {
    for (int i = 0; i < V; i++) {
      for (int j = 0; j < V; j++) {
        if (dist[i][k] + dist[k][j] < dist[i][j])
          dist[i][j] = dist[i][k] + dist[k][j];
      }
    }
  }

  printSolution(dist);
}
```

```
// Driver code
int main() {
    // Example graph with 4 vertices
    int graph[V][V] = {
        {0,   5,  INF, 10},
        {INF, 0,   3,  INF},
        {INF, INF, 0,   1},
        {INF, INF, INF, 0}
    };

    floydWarshall(graph);

    return 0;
}
```

OUTPUT:

```
Shortest distances between every pair of vertices:
      0      5      8      9
    INF      0      3      4
    INF    INF      0      1
    INF    INF    INF      0
```

TRACING

Tracing:

Initial graph:

	0	1	2	3
0	0	5	∞	10
1	∞	0	3	∞
2	∞	∞	0	1
3	∞	∞	∞	0

$D^{(k)}[i][j] = \min\left(D^{k-1}[i][j],\ D^{k-1}[i][k] + D^{k-1}[k][j]\right)$

k=0

i=1, j=2

$D^0[1][2] = 3$

$D^0[1][0] + D^0[0][2] = \infty + \infty = \infty$ → no update

i=0, j=2.

$D^0[0][2] = \infty$

$D^0[0][0] + D^0[0][2] = 0 + \infty = \infty$ → no update

No update since going through 0 doesn't improve any distance

S2: k=1

update matrix to $D^{(1)}$:

check if $D^1[i][j] > D^1[j][1] + D^1[1][j]$ - yes

i=0 j=2 $D^{(1)}[0][2] = \infty$, $D^1[0][1] + D^1[1][2] = 5+3 = 8$.

$8 < \infty$, update $D^{(2)}[0][2] = 8$.

All other pairs, similarly checked & no updates done.

S3: k=2

update to $D^{(3)}$:

i=0 j=3

$D^2[0][3] = 10$, $D^2[0][2] + D^2[2][3] = 8+1 = 9$.

$9 < 10$

$\Rightarrow D^3[0][3] = 9$.

i=1, j=3:

$D^2[1][3] = \infty$, $D^2[1][2] + D^2[2][3] = 3+1 = 4$

$D^3[1][3] = 4$

S4: k=3.

Update to $D^{(4)}$:

When checked $D^3[i][j] > D^3[1][3] + D^3[3][j]$

for i=0 j=0 $D[0][0] = 0$ $D[0][3] + D[3][0] = 9 + \infty = \infty$ → no update.

i=0, j=3 $D[0][3] = 9$ $D[0][3] + D[3][3] = 9 + 0 = 9$ → same no update.

Similarly when checked for remaining vertices, the condition not satisfies. Hence no

Final matrix $D^{(4)}$:

$$\begin{bmatrix} 0 & 5 & 8 & 9 \\ \infty & 0 & 3 & 4 \\ \infty & \infty & 0 & 1 \\ \infty & \infty & \infty & 0 \end{bmatrix}.$$

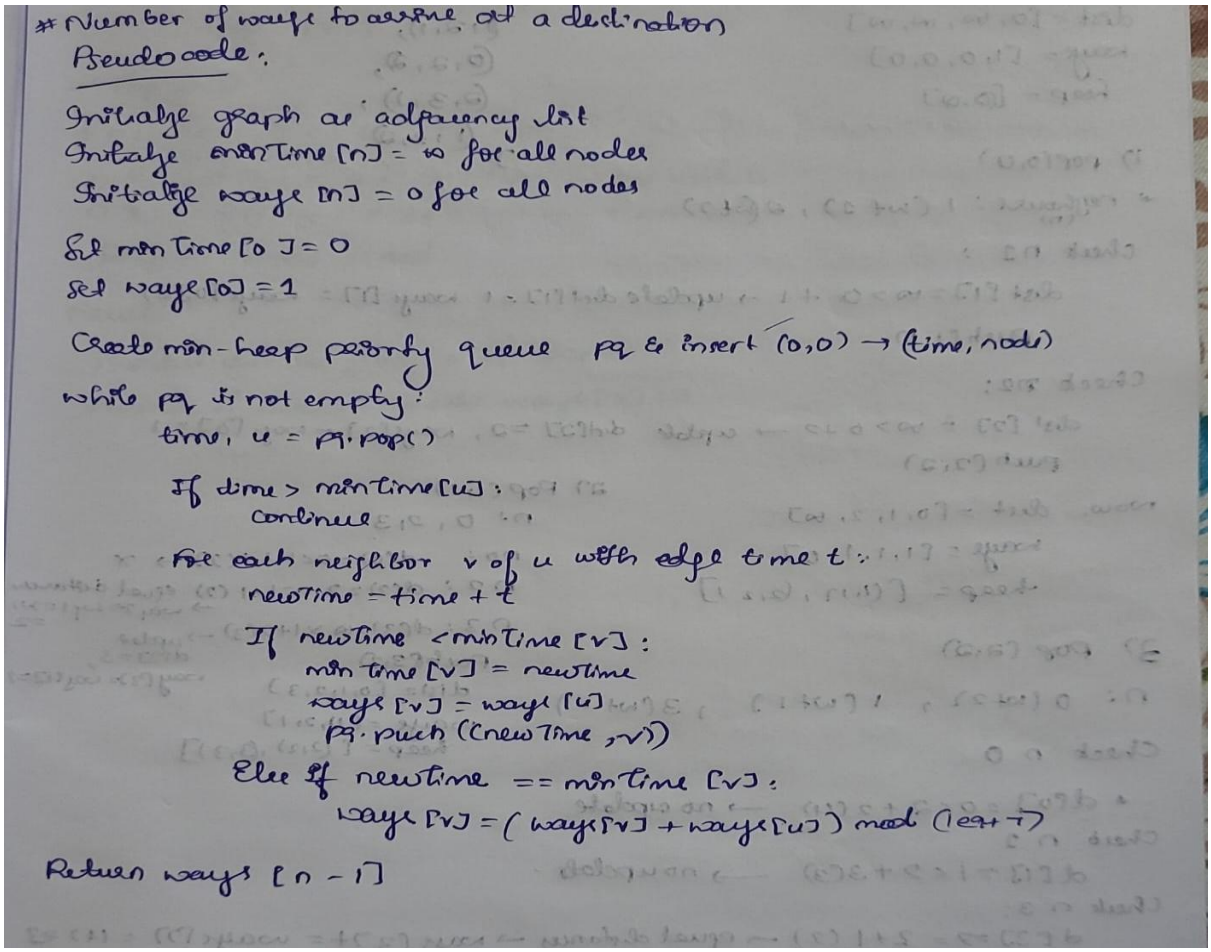
6/6

17/5/25

LEETCODE 5

NUMBER OF WAYS TO ARRIVE AT DESTINATION

ALGORITHM



CODE

```
#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

#define MOD 1000000007

typedef struct {
    int to, weight;
} Edge;
```

```
typedef struct {
    Edge* edges;
    int size, capacity;
} AdjList;

typedef struct {
    long long time;
    int node;
} HeapNode;

typedef struct {
    HeapNode* arr;
    int size;
} MinHeap;

void swap(HeapNode* a, HeapNode* b) {
    HeapNode tmp = *a;
    *a = *b;
    *b = tmp;
}

void heapify_up(MinHeap* h, int i) {
    while (i > 0 && h->arr[i].time < h->arr[(i - 1) / 2].time) {
        swap(&h->arr[i], &h->arr[(i - 1) / 2]);
        i = (i - 1) / 2;
    }
}

void heapify_down(MinHeap* h, int i) {
    int left, right, smallest;
```

```
    while (2 * i + 1 < h->size) {
        left = 2 * i + 1;
        right = 2 * i + 2;
        smallest = i;

        if (left < h->size && h->arr[left].time < h->arr[smallest].time)
            smallest = left;
        if (right < h->size && h->arr[right].time < h->arr[smallest].time)
            smallest = right;

        if (smallest == i) break;
        swap(&h->arr[i], &h->arr[smallest]);
        i = smallest;
    }
}

void push(MinHeap* h, long long time, int node) {
    h->arr[h->size++] = (HeapNode){time, node};
    heapify_up(h, h->size - 1);
}

HeapNode pop(MinHeap* h) {
    HeapNode top = h->arr[0];
    h->arr[0] = h->arr[--h->size];
    heapify_down(h, 0);
    return top;
}

int countPaths(int n, int** roads, int roadsSize, int* roadsColSize) {
    // Step 1: Build graph
```

```
AdjList* graph = malloc(n * sizeof(AdjList));
for (int i = 0; i < n; ++i) {
    graph[i].edges = malloc(100 * sizeof(Edge));
    graph[i].size = 0;
    graph[i].capacity = 100;
}

for (int i = 0; i < roadsSize; ++i) {
    int u = roads[i][0], v = roads[i][1], w = roads[i][2];
    graph[u].edges[graph[u].size++] = (Edge){v, w};
    graph[v].edges[graph[v].size++] = (Edge){u, w};
}

// Step 2: Initialize minTime and ways
long long* minTime = malloc(n * sizeof(long long));
int* ways = malloc(n * sizeof(int));
for (int i = 0; i < n; ++i) {
    minTime[i] = LLONG_MAX;
    ways[i] = 0;
}
minTime[0] = 0;
ways[0] = 1;

// Step 3: Min-heap priority queue
MinHeap heap;
heap.arr = malloc(100000 * sizeof(HeapNode));
heap.size = 0;
push(&heap, 0, 0); // (time, node)

while (heap.size > 0) {
```

```
    HeapNode curr = pop(&heap);
    long long time = curr.time;
    int u = curr.node;

    if (time > minTime[u]) continue;

    for (int i = 0; i < graph[u].size; ++i) {
        int v = graph[u].edges[i].to;
        int t = graph[u].edges[i].weight;
        long long newTime = time + t;

        if (newTime < minTime[v]) {
            minTime[v] = newTime;
            ways[v] = ways[u];
            push(&heap, newTime, v);
        } else if (newTime == minTime[v]) {
            ways[v] = (ways[v] + ways[u]) % MOD;
        }
    }
}

int result = ways[n - 1];

// Clean up
for (int i = 0; i < n; ++i) free(graph[i].edges);
free(graph);
free(minTime);
free(ways);
free(heap.arr);
```

```
    return result;
}
```

OUTPUT

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

n =
7

roads =
[[0,6,7],[0,1,2],[1,2,3],[1,3,3],[6,3
,1],[6,5,1],[2,5,1],[0,4,5],[4,6,2]]

Output

4

Expected

4

Accepted Runtime: 0 ms

• Case 1 • Case 2

Input

n =
2

roads =
[[1,0,10]]

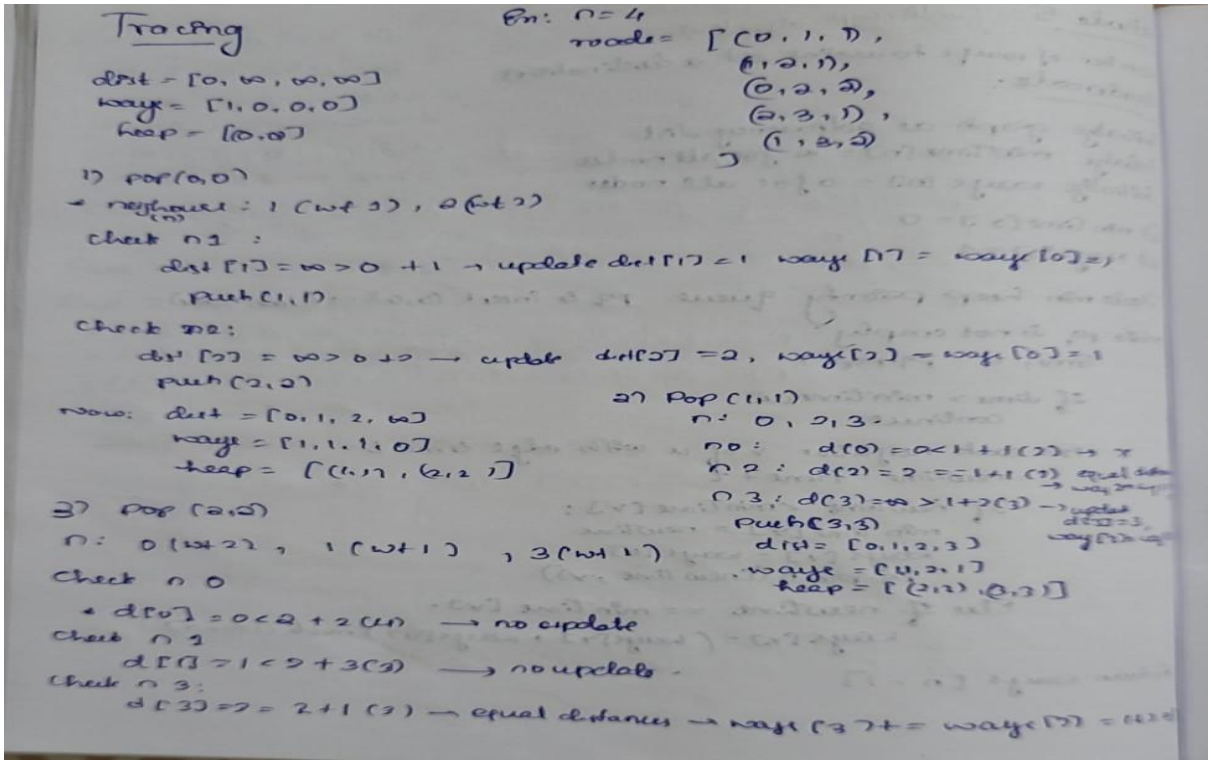
Output

1

Expected

1

TRACING



Now: dist = [0, 1, 2, 3]
ways = [1, 1, 2, 3]
heap = (3, 3)

4) Pop (3, 3)

* n: 2 (wt 1), 1 (wt 5)
n 2: d[2] = 2 < 3+1 (4) → no update
n 1: d[1] = 1 < 3+2 (5) → no update
Heap → empty → end.

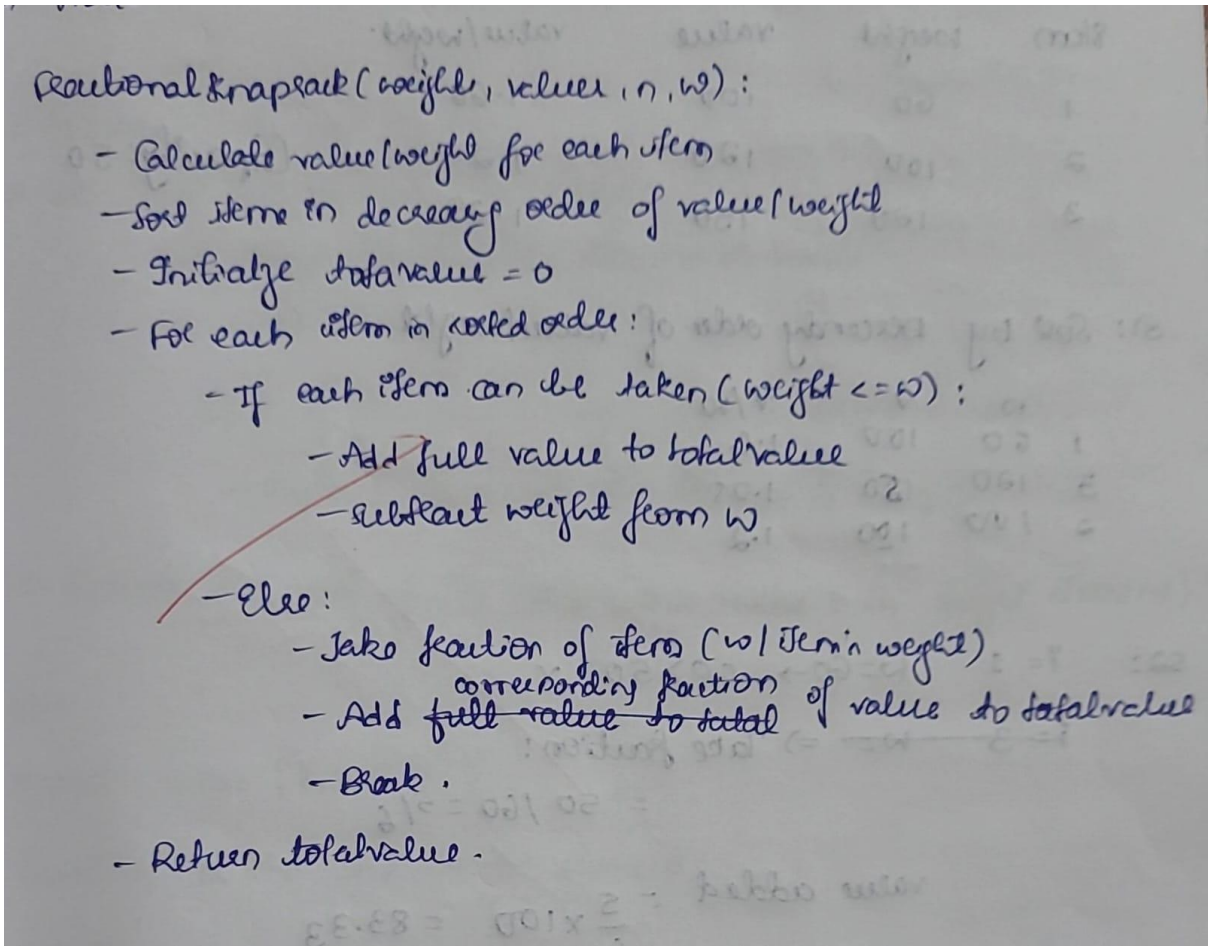
Result:

Shortest distance from 0 to 3 is 3
Number of shortest paths ways[3] = 3

PROGRAM 7

Implement Fractional Knapsack using Greedy technique.

ALGORITHM



CODE

```
#include <stdio.h>
#include <stdlib.h>

// Structure for an item
struct Item {
    int value, weight;
};

// Function to compare items by value/weight ratio
int compare(const void *a, const void *b) {
```

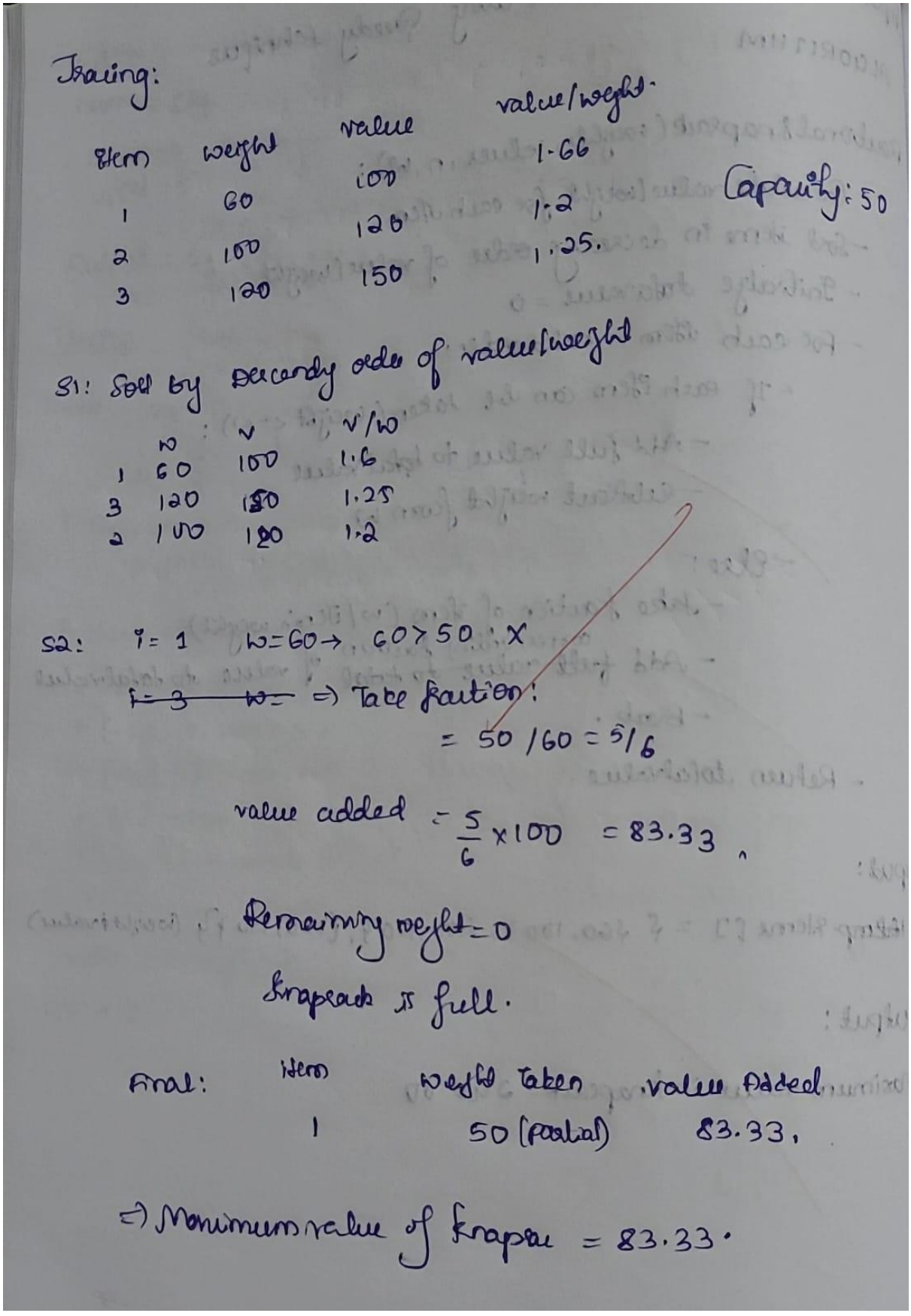
```
    double r1 = (double)((struct Item *)a)->value / ((struct Item *)a)->weight;
    double r2 = (double)((struct Item *)b)->value / ((struct Item *)b)->weight;
    return (r1 < r2) ? 1 : -1; // Descending order
}

// Function to return maximum value that can be put in knapsack
double fractionalKnapsack(int W, struct Item arr[], int n) {
    // Sort items by value/weight ratio
    qsort(arr, n, sizeof(arr[0]), compare);

    double totalValue = 0.0;

    for (int i = 0; i < n; i++) {
        if (W == 0) break;

        if (arr[i].weight <= W) {
            // Take full item
            W -= arr[i].weight;
            totalValue += arr[i].value;
        } else {
            // Take fractional part
            totalValue += arr[i].value * ((double)W / arr[i].weight);
            break;
        }
    }

    return totalValue;
}

// Main function
```

```
int main() {
    int n, W;

    printf("Enter number of items: ");
    scanf("%d", &n);

    struct Item arr[n];
    printf("Enter value and weight of each item:\n");
    for (int i = 0; i < n; i++) {
        scanf("%d %d", &arr[i].value, &arr[i].weight);
    }

    printf("Enter capacity of knapsack: ");
    scanf("%d", &W);

    double maxValue = fractionalKnapsack(W, arr, n);

    printf("Maximum value in knapsack = %.2f\n", maxValue);

    return 0;
}
```

OUTPUT:

```
Enter number of items: 3
Enter value and weight of each item:
100 60
120 100
150 120
Enter capacity of knapsack: 50
Maximum value in knapsack = 83.33
```

TRACING



Tracing:

Item	weight	value	value/weight
1	60	100	1.66
2	100	120	1.2
3	120	150	1.25

Capacity: 50

S1: Sort by decreasing order of value/weight

	w	v	v/w
1	60	100	1.6
3	120	150	1.25
2	100	120	1.2

S2: i = 1 w = 60 → 60 > 50 : X

~~i = 3 w =~~ ⇒ Take fraction:

= 50 / 60 = 5/6

value added = $\frac{5}{6} \times 100 = 83.33$

Remaining weight = 0

Knapsack is full.

Final:

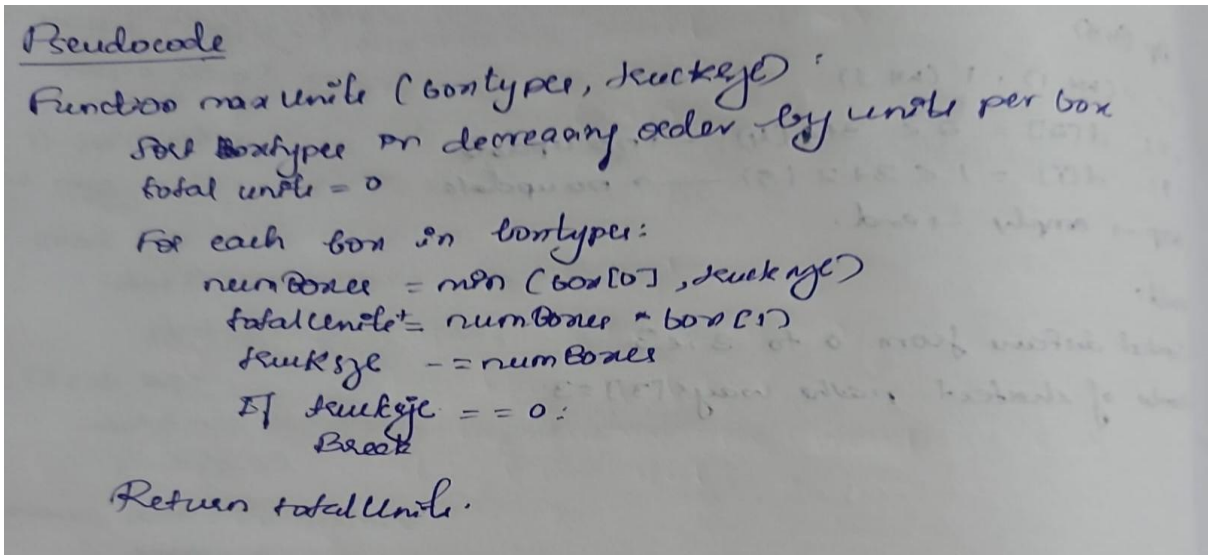
item	weight taken	value added
1	50 (Partial)	83.33

⇒ Maximum value of knapsack = 83.33.

LEETCODE 6

MAXIMUM UNITS ON A TRUCK

ALGORITHM

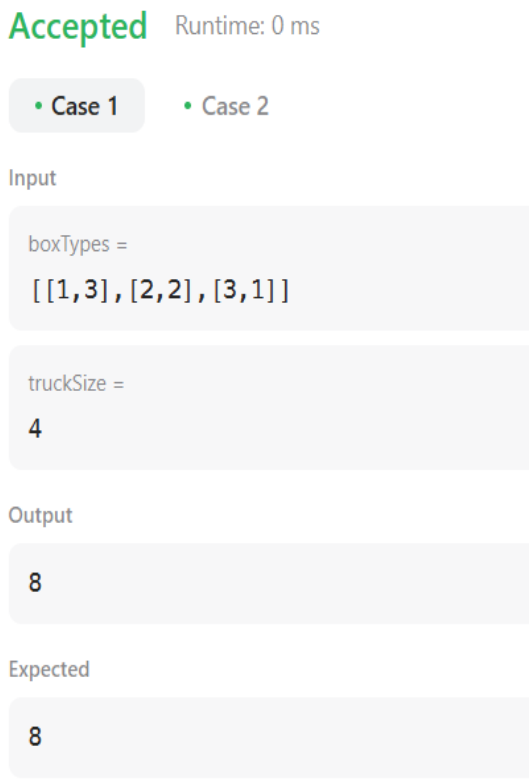


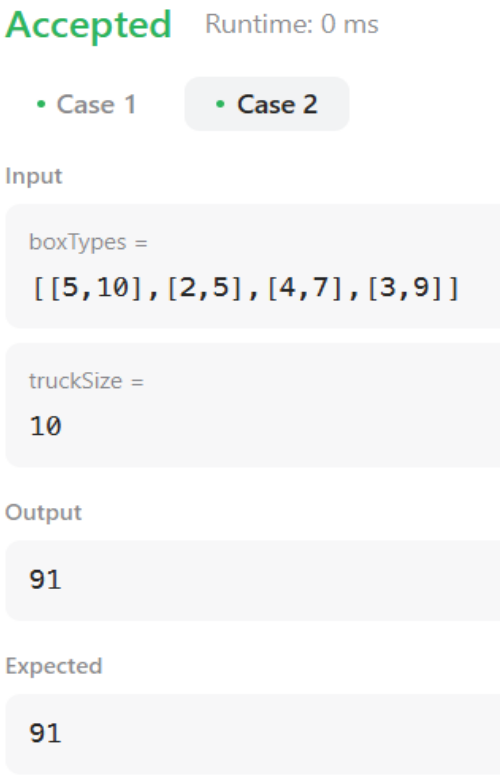
CODE

```
int cmp(const void* a, const void* b) {
    // Sort by units per box in descending order
    int* boxA = *(int**)a;
    int* boxB = *(int**)b;
    return boxB[1] - boxA[1];
}

int maximumUnits(int** boxTypes, int boxTypesSize, int* boxTypesColSize, int truckSize) {
    qsort(boxTypes, boxTypesSize, sizeof(int*), cmp);

    int totalUnits = 0;

    for (int i = 0; i < boxTypesSize; i++) {
        int boxCount = boxTypes[i][0];
        int unitsPerBox = boxTypes[i][1];
```

```
        int numBoxes = boxCount < truckSize ? boxCount : truckSize;
        totalUnits += numBoxes * unitsPerBox;
        truckSize -= numBoxes;

        if (truckSize == 0)
            break;
    }

    return totalUnits;
}
```

OUTPUT





TRACING

Example tracing

Input: boxTypes = [[5,10], [2,5], [4,7], [3,9]]
truckSize = 10.

S1: Sort by units per box (descending):
sorted boxTypes: [[5,10], [3,9], [4,7], [2,5]]

S2: Initialize totalUnits = 0, truckSize = 10

S3: Loop through sorted boxTypes

Step	Picked Boxes	Units/Box	Used	Remaining truckSize	TotalUnits
1	[5,10]	10	5	10-5=5	0+50=50
2	[3,9]	9	3	5-3=2	50+27=77
3	[4,7]	7	2	2-2=0	77+14=91

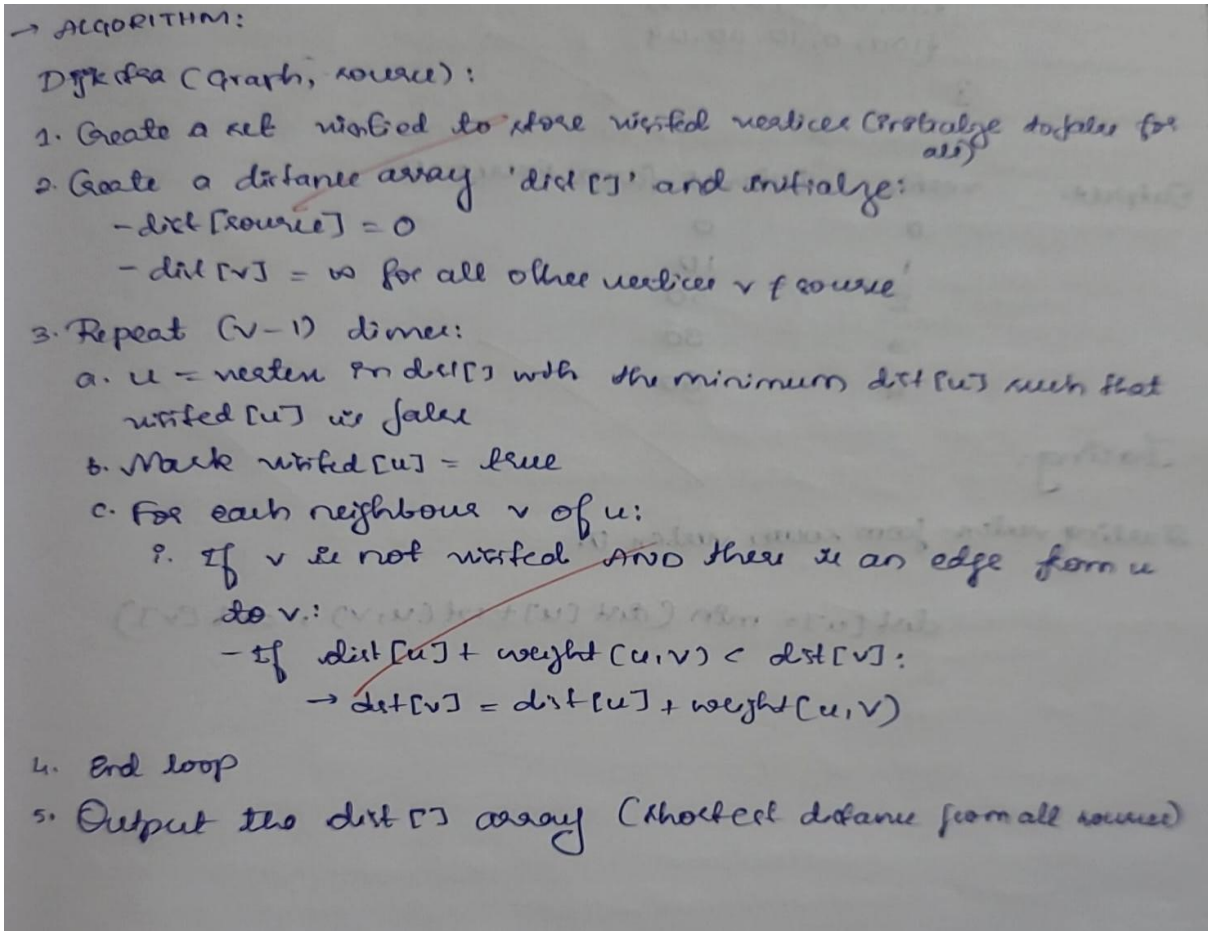
→ truckSize = 0 : stop.

Output:
91.

PROGRAM 8

From a given vertex in a weighted connected graph, find shortest paths to other vertices using Dijkstra's algorithm.

ALGORITHM



CODE

```
#include <stdio.h>
#include <limits.h>
#define V 100 // max number of vertices

// Find vertex with minimum distance not yet processed
int minDistance(int dist[], int visited[], int n) {
    int min = INT_MAX, min_index = -1;
    for (int v = 0; v < n; v++) {
        if (!visited[v] && dist[v] <= min) {
```

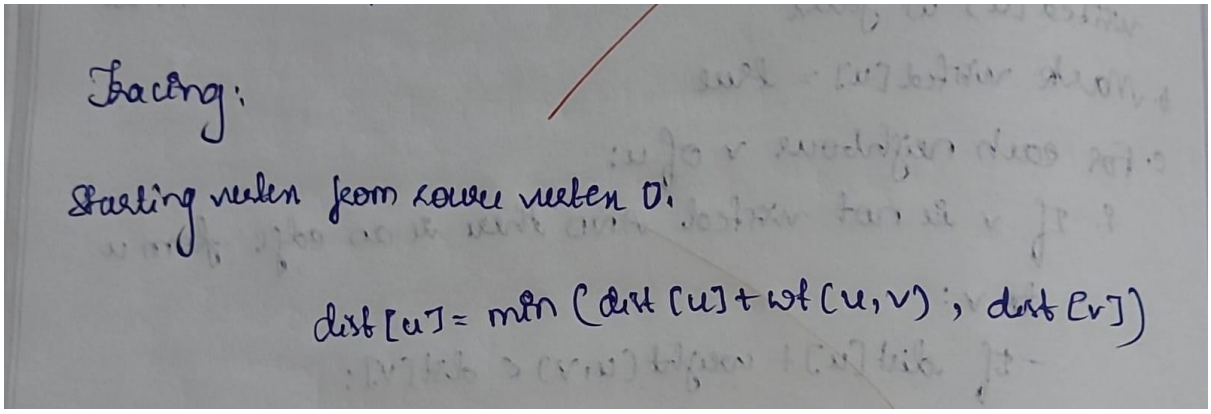
```
            min = dist[v], min_index = v;
        }
    }
    return min_index;
}

void dijkstra(int graph[V][V], int src, int n) {
    int dist[V];      // Shortest distances
    int visited[V];   // True if vertex is included in shortest path tree

    // Initialize distances and visited
    for (int i = 0; i < n; i++) {
        dist[i] = INT_MAX;
        visited[i] = 0;
    }

    dist[src] = 0; // Distance to itself is 0

    // Find shortest path for all vertices
    for (int count = 0; count < n - 1; count++) {
        int u = minDistance(dist, visited, n);
        visited[u] = 1;

        // Update distances of adjacent vertices
        for (int v = 0; v < n; v++) {
            if (!visited[v] && graph[u][v] && dist[u] != INT_MAX &&
                dist[u] + graph[u][v] < dist[v]) {
                dist[v] = dist[u] + graph[u][v];
            }
        }
```

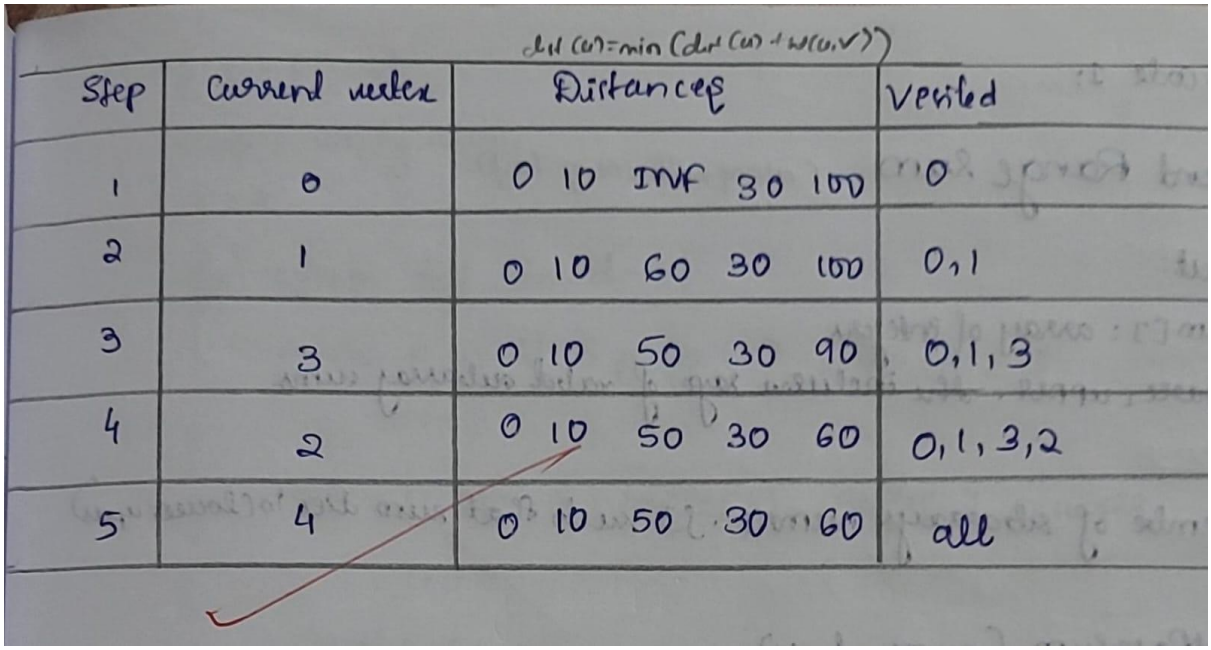
```
    }

    // Print results
    printf("Vertex \t Distance from Source\n");
    for (int i = 0; i < n; i++)
        printf("%d \t\t %d\n", i, dist[i]);
}

// Driver code
int main() {
    int n;
    printf("Enter number of vertices: ");
    scanf("%d", &n);

    int graph[V][V];

    printf("Enter the adjacency matrix (use 0 if no edge):\n");
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            scanf("%d", &graph[i][j]);

    int src;
    printf("Enter source vertex: ");
    scanf("%d", &src);

    dijkstra(graph, src, n);

    return 0;
}
```

OUTPUT

```
Enter number of vertices: 5
Enter the adjacency matrix (use 0 if no edge
    ):
0 10 0 30 100
10 0 50 0 0
0 50 0 20 10
30 0 20 0 60
100 0 10 60 0
Enter source vertex: 0
Vertex    Distance from Source
0         0
1         10
2         50
3         30
4         60
```

TRACING

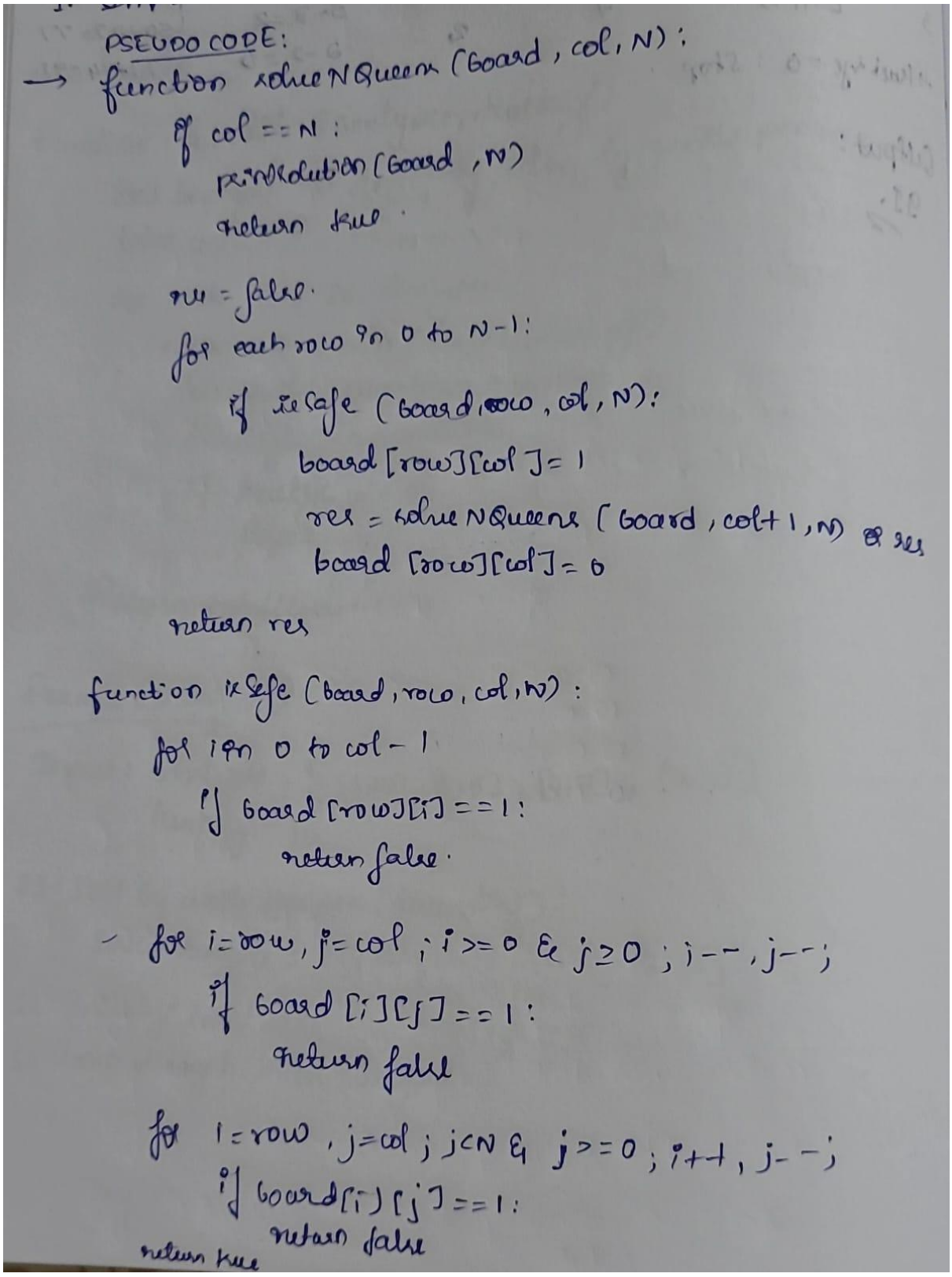




PROGRAM 9

Implement "N-Queens Problem" using Backtracking.

ALGORITHM



```
PSEUDO CODE:
→ function solveNQueens(board, col, N):
    if col == N:
        printSolution(board, N)
        return true

    res = false
    for each row in 0 to N-1:
        if isSafe(board, row, col, N):
            board[row][col] = 1
            res = solveNQueens(board, col+1, N) || res
            board[row][col] = 0

    return res

function isSafe(board, row, col, N):
    for i in 0 to col-1
        if board[row][i] == 1:
            return false

    for i=row, j=col; i>=0 && j>=0; i--, j--;
        if board[i][j] == 1:
            return false

    for i=row, j=col; j<N && j>=0; i++, j--;
        if board[i][j] == 1:
            return false
return true
```

CODE

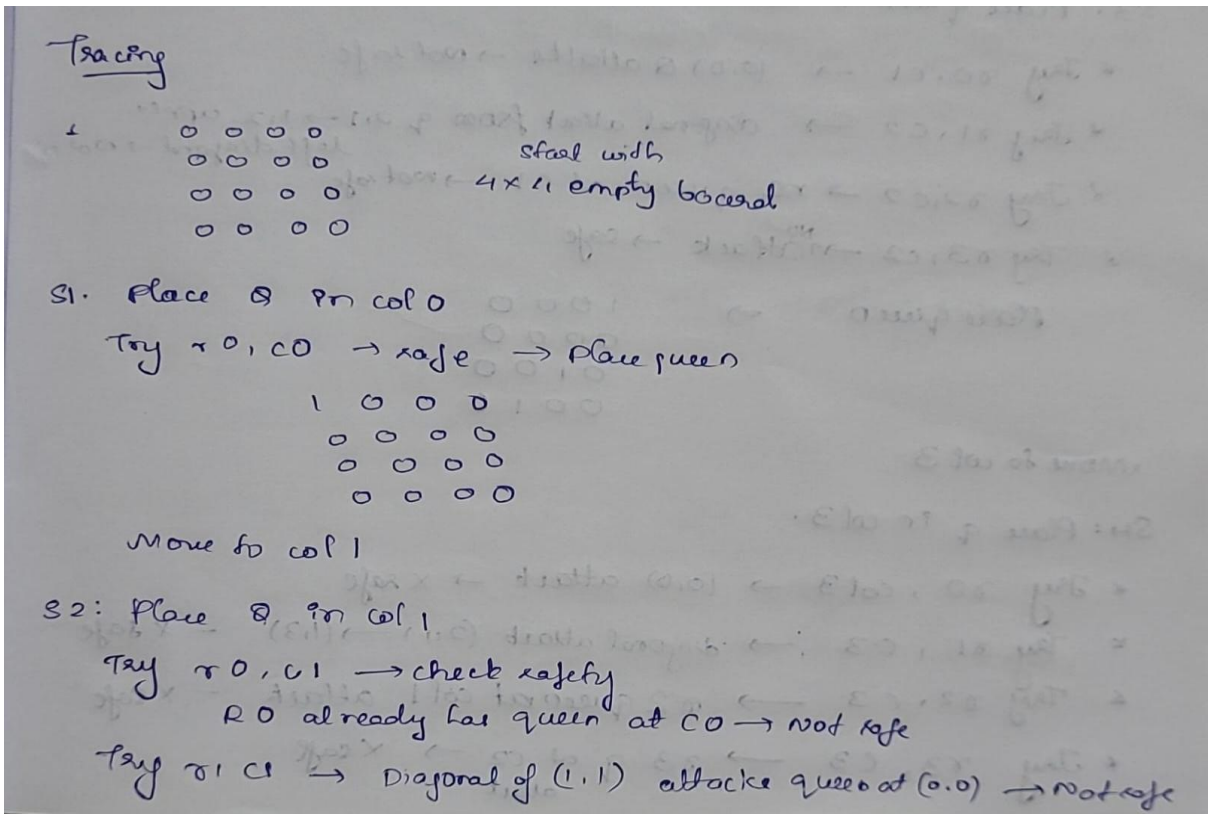
```
#include <stdio.h>
#include <stdlib.h>

#define MAX 20

int board[MAX];
int N;

int isSafe(int row, int col) {
    for (int i = 0; i < row; i++) {
        if (board[i] == col || abs(board[i] - col) == abs(i - row))
            return 0;
    }
    return 1;
}

void printSolution() {
    printf("\nSolution:\n");
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < N; j++) {
            if (board[i] == j)
                printf("Q ");
            else
                printf(". ");
        }
        printf("\n");
    }
}
```

```
int solveNQueens(int row) {
    if (row == N) {
        printSolution();
        return 1;
    }

    int found = 0;
    for (int col = 0; col < N; col++) {
        if (isSafe(row, col)) {
            board[row] = col;
            found |= solveNQueens(row + 1);  // Try next row
        }
    }

    return found;
}

int main() {
    printf("Enter number of queens (N): ");
    scanf("%d", &N);

    if (N < 1 || N > MAX) {
        printf("N should be between 1 and %d\n", MAX);
        return 1;
    }

    if (!solveNQueens(0))
        printf("No solution exists for N = %d\n", N);

    return 0;}
```

OUTPUT

```
Enter number of queens (N): 4

Solution:
. Q . .
. . . Q
Q . . .
. . Q .

Solution:
. . Q .
Q . . .
. . . Q
. Q . .
```

TRACING



* Try r2, c1
* No q in same row, no diagonal attack → safe
Place queen

1 0 0 0
0 0 0 0
0 1 0 0
0 0 0 0

move to col 2.

S3: Place queen in col 2.

* Try r0, c1 → (0,0) Q attacks → Not safe.
* Try r1, c2 → diagonal attack from q 2,1 → 1,2 upper left diagonal → not safe
* Try r2, c2 → r2 queen at c1 → not safe
* Try r3, c2 → No attack → safe

Place queen ⇒

1 0 0 0
0 0 0 0
0 1 0 0
0 0 1 0

Move to col 3

S4: Place q in col 3.

* Try r0, col 3 → (0,0) attack → x safe
* Try r1, c3 → diagonal attack (2,1) → (1,3) — x safe
* Try r2, c3 → r2 queen at col 1 attack — x safe
* Try r3, c3 → r3 q at c2 → x safe (attack)

No valid pos in col 3 → Backtrack

Backtrack S1: Remove q from (3,2)

1 0 0 0
0 0 0 0
0 1 0 0
0 0 0 0

S3 continued: Try next rows in col 2

* No more rows in col 2 — Backtrack again.

Backtrack S2: Remove q from (2,1)

⇒

1 0 0 0
0 0 0 0
0 0 0 0
0 0 0 0

S2 → continued: Try next rows in col 1

* Try r3, c1 → No attack safe → Place queen

1 0 0 0
0 0 0 0
0 0 0 0
0 1 0 0

S3 → continued: Place queen in col 2.

* Try r0, c2 → q(0,0) attacks — x safe
* Try r1, c2 → Diagonal attack from (3,1) → x safe.
* Try r2, c2 → No attack — safe. → Place queen

1 0 0 0
0 0 0 0
0 0 1 0
0 1 0 0

S4: Place Q in col 3.

- Try (0,3) → (0,0) attack – ✗ Unsafe
- Try (1,3) → No attack – ✓ Safe

Place queen.

1 0 0 0
0 0 0 1
0 0 1 0
0 1 0 0

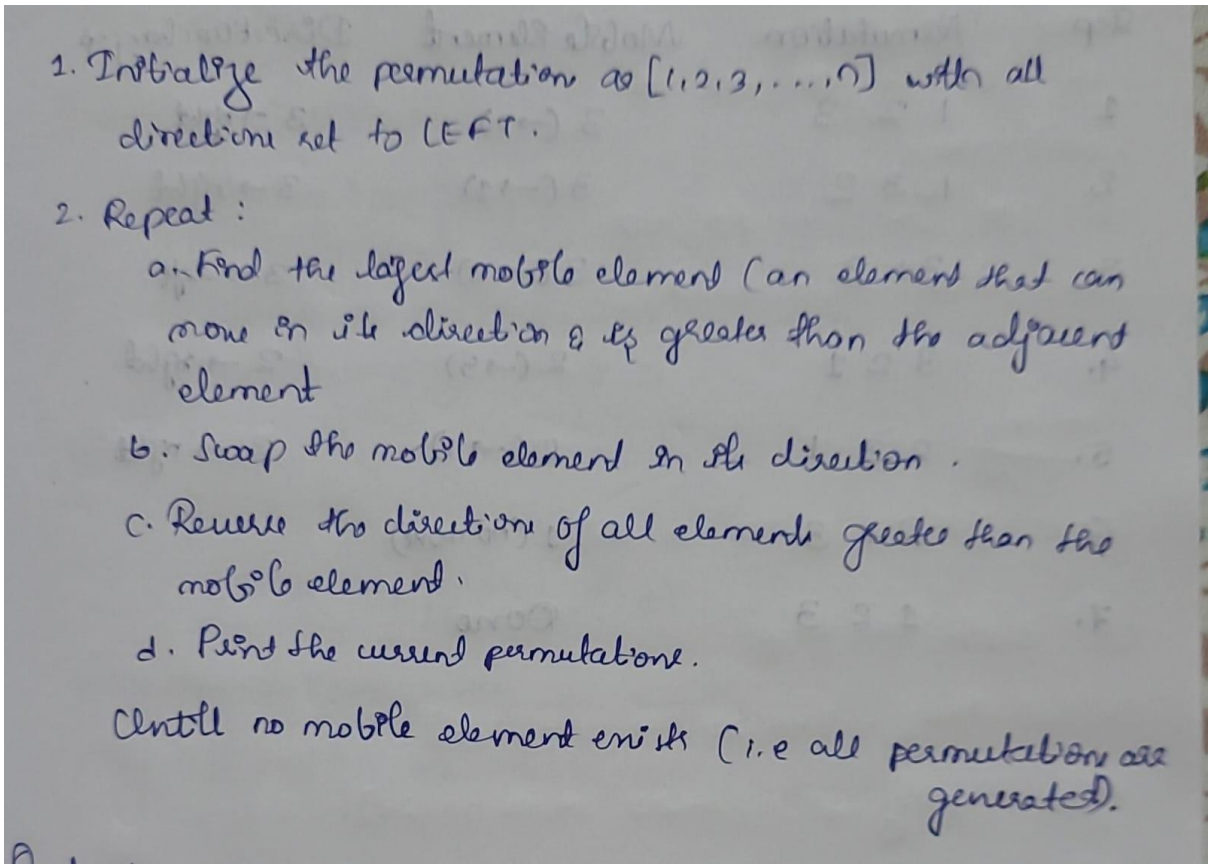
Final step: All queens placed

1 0 0 0
0 0 0 1
0 0 1 0
0 1 0 0

PROGRAM 10

Implement Johnson Trotter algorithm to generate permutations.

ALGORITHM



CODE

```
#include <stdio.h>

#define MAX 20
#define LEFT -1
#define RIGHT 1

int n;
int perm[MAX];     // Current permutation
int dir[MAX];      // Directions: -1 for LEFT, 1 for RIGHT
```

```
// Function to print the current permutation
void printPerm() {
    for (int i = 0; i < n; i++)
        printf("%d ", perm[i]);
    printf("\n");
}

// Function to find the largest mobile integer
int getMobile() {
    int mobile = 0, mobileIndex = -1;

    for (int i = 0; i < n; i++) {
        int next = i + dir[i];
        if (next >= 0 && next < n && perm[i] > perm[next]) {
            if (perm[i] > mobile) {
                mobile = perm[i];
                mobileIndex = i;
            }
        }
    }

    return mobileIndex;
}

// Function to swap two elements and their directions
void swap(int i, int j) {
    int temp = perm[i];
    perm[i] = perm[j];
    perm[j] = temp;
```

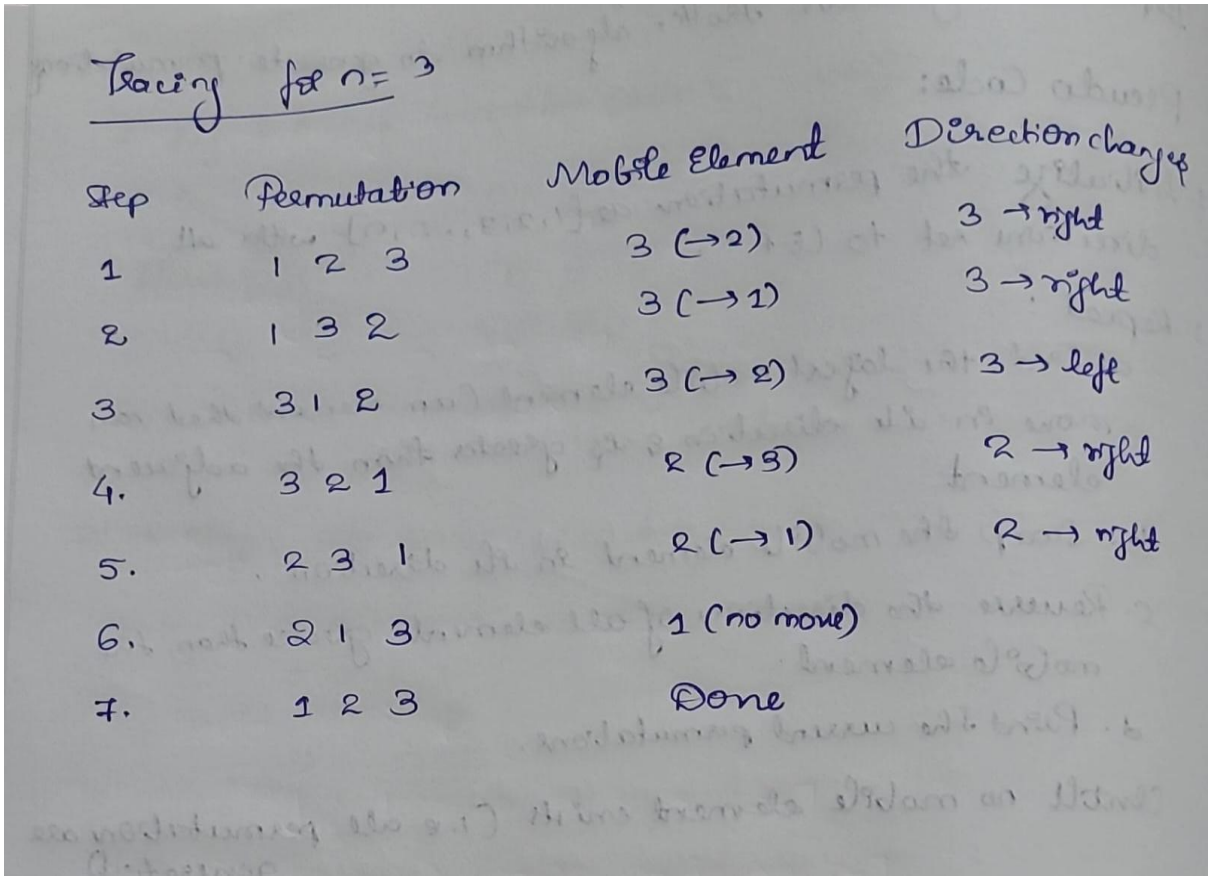
```
    int dtemp = dir[i];
    dir[i] = dir[j];
    dir[j] = dtemp;
}

void generatePermutations() {
    printPerm();  // First permutation

    while (1) {
        int mobileIndex = getMobile();
        if (mobileIndex == -1)
            break;

        int next = mobileIndex + dir[mobileIndex];
        swap(mobileIndex, next);

        // After moving, change direction of all elements > moved element
        for (int i = 0; i < n; i++) {
            if (perm[i] > perm[next])
                dir[i] *= -1;
        }

        printPerm();
    }
}

int main() {
    printf("Enter number of elements (n): ");
    scanf("%d", &n);
```

```
    // Initialize permutation and directions
    for (int i = 0; i < n; i++) {
        perm[i] = i + 1;
        dir[i] = LEFT;
    }

    printf("All permutations using Johnson-Trotter:\n");
    generatePermutations();

    return 0;
}
```

OUTPUT

```
Enter number of elements (n): 3
All permutations using Johnson-Trotter:
1 2 3
1 3 2
3 1 2
3 2 1
2 3 1
2 1 3
```

TRACING



Tracing for n = 3

Step	Permutation	Mobile Element	Direction change
1	1 2 3	3 (→ 2)	3 → right
2	1 3 2	3 (→ 1)	3 → right
3	3 1 2	3 (→ 2)	3 → left
4.	3 2 1	2 (→ 3)	2 → right
5.	2 3 1	2 (→ 1)	2 → right
6.	2 1 3	1 (no move)	
7.	1 2 3	Done	

PROGRAM 11

Sort a given set of N integer elements using Heap Sort technique and compute its time taken.

ALGORITHM

```
Heap_sort (arr[], n):
    Build_max_heap (arr, n)
    for i = n-1 to 1:
        swap arr[0] with arr[i]
        max_heapify (arr, 0, i)

Build_max_heap (arr, n)
    for i = n/2 - 1 down to 0:
        max_heapify (arr, i, n)

max_heapify (arr, i, n):
    left = 2*i + 1
    right = 2*i + 2
    largest = i
    if left < n & arr[left] > arr[largest]:
        largest = left
    if right < n & arr[right] > arr[largest]:
        largest = right
    if largest != i:
        swap arr[i] with arr[largest]
        max_heapify (arr, largest, n)
```

CODE

```
#include <stdio.h>
#include <time.h>

// Function to heapify a subtree rooted at index i
void max_heapify(int arr[], int i, int n) {
    int left = 2 * i + 1;
    int right = 2 * i + 2;
    int largest = i;

    if (left < n && arr[left] > arr[largest])
        largest = left;

    if (right < n && arr[right] > arr[largest])
        largest = right;

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

        max_heapify(arr, largest, n);
    }
}

// Function to build a max heap
void build_max_heap(int arr[], int n) {
    for (int i = n / 2 - 1; i >= 0; i--)
        max_heapify(arr, i, n);
}
```

```
// Heap Sort function
void heap_sort(int arr[], int n) {
    build_max_heap(arr, n);

    for (int i = n - 1; i >= 1; i--) {
        // Swap arr[0] with arr[i]
        int temp = arr[0];
        arr[0] = arr[i];
        arr[i] = temp;

        // Call max_heapify on the reduced heap
        max_heapify(arr, 0, i);
    }
}

// Function to print the array
void print_array(int arr[], int n) {
    for (int i = 0; i < n; i++)
        printf("%d ", arr[i]);
    printf("\n");
}

int main() {
    int arr[100], n;
    clock_t start, end;
    double time_taken;

    printf("Enter number of elements: ");
    scanf("%d", &n);
```

```
    printf("Enter %d elements:\n", n);
    for (int i = 0; i < n; i++)
        scanf("%d", &arr[i]);

    start = clock();  // Start timing

    heap_sort(arr, n);

    end = clock();    // End timing
    time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;

    printf("Sorted array:\n");
    print_array(arr, n);

    printf("Time taken: %f seconds\n", time_taken);

    return 0;
}
```

OUTPUT

```
Enter number of elements: 6
Enter 6 elements:
45 20 35 10 50 25
Sorted array:
10 20 25 35 45 50
Time taken: 0.000003 seconds
```

TRACING

Tracing

Input: [45, 20, 35, 10, 50, 25]

S1: Build max Heap

Initial Array: [45, 20, 35, 10, 50, 25]

After heapify (2): [45, 20, 35, 10, 50, 25]

After heapify (1): [45, 50, 35, 10, 20, 25]

After heapify (0): [50, 45, 35, 10, 20, 25]

S2: sorting Phase

Swap 50 <-> 25 : [25, 45, 35, 10, 20, 50]

Heapify : [45, 25, 35, 10, 20, 50]

Swap 45 <-> 20 : [20, 25, 35, 10, 45, 50]

Heapify : [35, 25, 20, 10, 45, 50]

Swap 35 <-> 10 : [10, 25, 20, 35, 45, 50]

Heapify : [25, 10, 20, 35, 45, 50]

Swap 25 <-> 20 : [20, 10, 25, 35, 45, 50]

Heapify : [20, 10, 25, 35, 45, 50]

Swap 20 <-> 10 : [10, 20, 25, 35, 45, 50]

Final Sorted Array

[10, 20, 25, 35, 45, 50].

GIT HUB LINK

https://github.com/DishaDS094/DISHA_DS_1BM23CS094_ADA_LAB

LAB OBSERVATION INDEX PAGE: