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LAB REPORT
on

ANALYSIS AND DESIGN OF ALGORITHMS

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
Feb 2025 to Jun 2025

B. M. S. College of Engineering,

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CERTIFICATE

This is to certify that the Lab work entitled "ANALYSIS AND DESIGN OF ALGORITHMS – 23CS4PCADA" carried out by **GOPIKA PUSHPARAJAN (1BM23CS101),** who is a 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 2025. The Lab report has been approved as it satisfies the academic requirements in respect of a **ANALYSIS AND DESIGN OF ALGORITHMS - (23CS4PCADA)** work prescribed for the said degree.

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Index Sheet

INDEX

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Sr.No.	Title	~~Page No.~~ Date	Sign./Remarks
1.	Stacks - using Arrays & Linked Lists	28/2/25	
2	Queues - using Arrays & Linked Lists	7/3/25	
3	Mergesort	21/3/25	10
4.	Quicksort	4/4/25	10
5	Prims algorithm	4/4/25	6
6.	Topological sort	16/5/25	6
7	0/1 Knapsack	16/5/25	6
8	Floyd's Algorithm	16/5/25	10
9.	Dijkstra's Algorithm	16/5/25	10
10.	N Queen's, using Backtrack	16/5/25	10
11.	Johnson Trotter's Algorithm	23/5/25	10
12.	Heap sort	23/5/25	10

Program -1

Question: Topological Sorting

Code:

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

// Maximum number of vertices in the graph
#define MAX_VERTICES 100

// Structure for adjacency list
struct Graph {
    int V;            // Number of vertices
    int **adj;        // Adjacency matrix
    int *inDegree;    // Array to store in-degrees of vertices
};

// Function to create a graph
struct Graph* createGraph(int V) {
    struct Graph *graph = (struct Graph*)malloc(sizeof(struct Graph));
    graph->V = V;
    graph->adj = (int**)malloc(V * sizeof(int*));
    graph->inDegree = (int*)malloc(V * sizeof(int));

    for (int i = 0; i < V; i++) {
        graph->adj[i] = (int*)malloc(V * sizeof(int));
        graph->inDegree[i] = 0;  // Initialize in-degrees to 0
        for (int j = 0; j < V; j++) {
            graph->adj[i][j] = 0;  // Initialize adjacency matrix to 0
        }
    }

    return graph;
}
```

```c
// Function to add an edge to the graph
void addEdge(struct Graph *graph, int u, int v) {
    graph->adj[u][v] = 1;
    graph->inDegree[v]++;
}

// Function for Topological Sort using Kahn's Algorithm (BFS)
void topologicalSort(struct Graph *graph) {
    int V = graph->V;
    int *queue = (int*)malloc(V * sizeof(int));  // Queue for Kahn's algorithm
    int front = 0, rear = 0;

    // Add all vertices with in-degree 0 to the queue
    for (int i = 0; i < V; i++) {
        if (graph->inDegree[i] == 0) {
            queue[rear++] = i;
        }
    }

    int count = 0;  // Counter for visited vertices

    // Process the graph
    while (front != rear) {
        int u = queue[front++];  // Dequeue a vertex
        printf("%d ", u);         // Print the current vertex
        count++;

        // Reduce the in-degree of neighboring vertices
        for (int v = 0; v < V; v++) {
            if (graph->adj[u][v] == 1) {
                graph->inDegree[v]--;
                if (graph->inDegree[v] == 0) {
                    queue[rear++] = v;  // Enqueue if in-degree becomes 0
                }
            }
        }
    }

    // If the number of visited vertices is less than the number of vertices in
the graph,
    // it indicates a cycle, so topological sorting is not possible.
    if (count != V) {
        printf("\nCycle detected, topological sort not possible.\n");
    }
}

int main() {
    int V, E;
```

```
    // Taking user input for number of vertices and edges
    printf("Enter the number of vertices: ");
    scanf("%d", &V);

    // Create a graph with V vertices
    struct Graph *graph = createGraph(V);

    // Taking user input for number of edges
    printf("Enter the number of edges: ");
    scanf("%d", &E);

    // Taking user input for each edge (u, v)
    for (int i = 0; i < E; i++) {
        int u, v;
        printf("Enter edge (u v): ");
        scanf("%d %d", &u, &v);
        if (u >= V || v >= V || u < 0 || v < 0) {
            printf("Invalid edge. Please enter valid vertices.\n");
            i--;  // Decrement to re-enter the edge
            continue;
        }
        addEdge(graph, u, v);
    }

    // Perform topological sort
    printf("Topological Sort: ");
    topologicalSort(graph);

    // Free memory
    for (int i = 0; i < V; i++) {
        free(graph->adj[i]);
    }
    free(graph->adj);
    free(graph->inDegree);
    free(graph);

    return 0;
}
```

Result:

```
PS C:\Users\student\Desktop\os_207> cd "c:\Users\student\Desktop\os_207\" ; if ($?) { gcc ada.c -o ada } ; if ($?) { .\ada }
Enter the number of vertices: 6
Enter the number of edges: 6
Enter edge (u v): 5 2
Enter edge (u v): 5 0
Enter edge (u v): 4 0
Enter edge (u v): 4 1
Enter edge (u v): 2 3
Enter edge (u v): 3 1
Topological Sort: 4 5 0 2 3 1
PS C:\Users\student\Desktop\os_207>
```

Program -2

Question: Merge Sort

Code:

```c
#include <stdio.h>

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

    // Create temp arrays
    int L[n1], R[n2];

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

    // Merge temp arrays back into arr[l..r]
    i = 0; j = 0; k = l;

    while (i < n1 && j < n2) {
        if (L[i] <= R[j])
            arr[k++] = L[i++];
        else
            arr[k++] = R[j++];
    }
```

```c
    // 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 l, int r) {
    if (l < r) {
        int m = l + (r - l) / 2;

        // Sort first and second halves
        mergeSort(arr, l, m);
        mergeSort(arr, m + 1, r);

        merge(arr, l, m, r);
    }
}

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

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

    mergeSort(arr, 0, n - 1);

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

    return 0;
}
```

Result:

```
PS C:\Users\student\Desktop\os_207> cd "c:\Users\student\Desktop\os_207\" ; if ($?) { gcc ada.c -o ada } ; if ($?) { .\ada }
Enter number of elements: 5
Enter 5 elements:
2 3 1 5 4
Sorted array (Merge Sort): 1 2 3 4 5
PS C:\Users\student\Desktop\os_207>
```

Program -3

Question: Quick Sort

Code:

```c
#include <stdio.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;        // Index of smaller element

    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;
}

// Quick sort function
void quickSort(int arr[], int low, int high) {
    if (low < high) {
        int pi = partition(arr, low, high); // Partition index

        // Recursively sort subarrays
        quickSort(arr, low, pi - 1);
        quickSort(arr, pi + 1, high);
    }
}
```

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

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

    quickSort(arr, 0, n - 1);

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

    return 0;
}
```

Result:

Program -4

Question: Prims Algorithm

Code:

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

// Function to find the vertex with the minimum key value
```

```
int minKey(int key[], bool mstSet[], int V) {
    int min = INT_MAX, min_index;

    for (int v = 0; v < V; v++) {
        if (!mstSet[v] && key[v] < min) {
            min = key[v];
            min_index = v;
        }
    }

    return min_index;
}

// Function to implement Prim's algorithm
void primMST(int graph[][5], int V) {
    int parent[V];  // Array to store the constructed MST
    int key[V];     // Key values used to pick the minimum weight edge
    bool mstSet[V]; // To represent the set of vertices included in MST

    // Initialize all keys to infinity, mstSet to false
    for (int i = 0; i < V; i++) {
        key[i] = INT_MAX;
        mstSet[i] = false;
    }

    // Always include the first vertex in MST
    key[0] = 0;  // Make key[0] 0 so that it is picked first
    parent[0] = -1; // First node has no parent

    // The MST will have V vertices
    for (int count = 0; count < V - 1; count++) {
        // Pick the minimum key vertex from the set of vertices
        // not yet included in MST
        int u = minKey(key, mstSet, V);

        // Add the picked vertex to the MST set
        mstSet[u] = true;

        // Update key and parent values of the adjacent vertices of the picked
vertex
        for (int v = 0; v < V; v++) {
            // graph[u][v] is non-zero only for adjacent vertices of u
            // mstSet[v] is false for vertices not yet included in MST
            // Update the key only if graph[u][v] is smaller than the current
key[v]
            if (graph[u][v] && !mstSet[v] && graph[u][v] < key[v]) {
                key[v] = graph[u][v];
                parent[v] = u;
            }
```

```
        }
    }

    // Print the constructed MST
    printf("Edge   Weight\n");
    for (int i = 1; i < V; i++) {
        printf("%d - %d   %d\n", parent[i], i, graph[i][parent[i]]);
    }
}

// Main function
int main() {
    int V, E;
    printf("Enter the number of vertices: ");
    scanf("%d", &V);
    printf("Enter the number of edges: ");
    scanf("%d", &E);

    int graph[V][V];
    // Initialize the graph to 0
    for (int i = 0; i < V; i++) {
        for (int j = 0; j < V; j++) {
            graph[i][j] = 0;
        }
    }

    // Take input for the edges
    printf("Enter the edges (u, v, weight):\n");
    for (int i = 0; i < E; i++) {
        int u, v, weight;
        printf("Enter edge %d (u v weight): ", i + 1);
        scanf("%d %d %d", &u, &v, &weight);
        graph[u][v] = weight;
        graph[v][u] = weight;  // Undirected graph
    }

    primMST(graph, V);

    return 0;
}
```

Result:

```
Enter the number of vertices: 5
Enter the number of edges: 7
Enter the edges (u, v, weight):
Enter edge 1 (u v weight): 0 1 2
Enter edge 2 (u v weight): 0 3 6
Enter edge 3 (u v weight): 1 2 3
Enter edge 4 (u v weight): 1 3 8
Enter edge 5 (u v weight): 1 4 5
Enter edge 6 (u v weight): 2 4 7
Enter edge 7 (u v weight): 3 4 9
Edge   Weight
0 - 1   2
1 - 2   3
0 - 3   6
1 - 4   5
PS C:\Users\student\Desktop\os_207>
```

Program -5

Question: Krushkals Algorithm

Code:

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

// Structure to represent a weighted edge
typedef struct {
    int u, v, weight;
} Edge;

// Structure to represent a subset for union-find
typedef struct {
    int parent, rank;
} Subset;

// Function to compare two edges based on their weights
int compareEdges(const void *a, const void *b) {
    return ((Edge *)a)->weight - ((Edge *)b)->weight;
}

// Find function for Union-Find with path compression
int find(Subset subsets[], int i) {
    if (subsets[i].parent != i) {
        subsets[i].parent = find(subsets, subsets[i].parent); // Path compression
    }
    return subsets[i].parent;
}
```

```c
// Union function for Union-Find with union by rank
void unionSets(Subset subsets[], int x, int y) {
    int rootX = find(subsets, x);
    int rootY = find(subsets, y);

    if (rootX != rootY) {
        if (subsets[rootX].rank < subsets[rootY].rank) {
            subsets[rootX].parent = rootY;
        } else if (subsets[rootX].rank > subsets[rootY].rank) {
            subsets[rootY].parent = rootX;
        } else {
            subsets[rootY].parent = rootX;
            subsets[rootX].rank++;
        }
    }
}

// Kruskal's algorithm to find the MST
void kruskalMST(Edge edges[], int V, int E) {
    Edge result[V];  // Array to store the final MST
    int e = 0;       // Count of edges in MST
    int i = 0;       // Index for sorted edges
    Subset *subsets = (Subset *)malloc(V * sizeof(Subset));

    // Initialize subsets: each vertex is its own parent and rank is 0
    for (int v = 0; v < V; v++) {
        subsets[v].parent = v;
        subsets[v].rank = 0;
    }

    // Sort edges in non-decreasing order of weight
    qsort(edges, E, sizeof(edges[0]), compareEdges);

    // Process each edge
    while (e < V - 1 && i < E) {
        // Get the next edge
        Edge nextEdge = edges[i++];

        // Find roots of the vertices u and v
        int x = find(subsets, nextEdge.u);
        int y = find(subsets, nextEdge.v);

        // If including this edge does not cause a cycle, include it in the
result
        if (x != y) {
            result[e++] = nextEdge;
            unionSets(subsets, x, y);
        }
```

```
    }

    // Print the resulting MST
    printf("Edges in the MST:\n");
    for (int i = 0; i < e; i++) {
        printf("%d -- %d == %d\n", result[i].u, result[i].v, result[i].weight);
    }

    free(subsets);
}

// Driver program to test the above functions
int main() {
    int V, E;

    // Take user input for number of vertices and edges
    printf("Enter the number of vertices: ");
    scanf("%d", &V);
    printf("Enter the number of edges: ");
    scanf("%d", &E);

    // Dynamically allocate space for edges
    Edge *edges = (Edge *)malloc(E * sizeof(Edge));

    // Take user input for each edge (u, v, weight)
    printf("Enter the edges in the format (u v weight):\n");
    for (int i = 0; i < E; i++) {
        printf("Edge %d: ", i + 1);
        scanf("%d %d %d", &edges[i].u, &edges[i].v, &edges[i].weight);
    }

    // Call Kruskal's algorithm
    kruskalMST(edges, V, E);

    // Free allocated memory
    free(edges);

    return 0;
}
```

Result:

```
Enter the number of vertices: 4
Enter the number of edges: 5
Enter the edges in the format (u v weight):
Edge 1: 0 1 10
Edge 2: 0 2 6
Edge 3: 0 3 5
Edge 4: 1 3 15
Edge 5: 2 3 4
Edges in the MST:
2 -- 3 == 4
0 -- 3 == 5
0 -- 1 == 10
PS C:\Users\student\Desktop\os_207>
```

Program -6

Question: Dijkstras Algorithm

Code:

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

#define MAX 100  // Maximum number of vertices

// Function to find the vertex with the minimum distance
int minDistance(int dist[], bool visited[], int V) {
    int min = INT_MAX, min_index;

    for (int v = 0; v < V; v++) {
        if (!visited[v] && dist[v] < min) {
            min = dist[v];
            min_index = v;
        }
    }
```

```
    return min_index;
}

// Function to print the shortest distances
void printSolution(int dist[], int V, int src) {
    printf("Vertex\tDistance from Source %d\n", src);
    for (int i = 0; i < V; i++) {
        printf("%d\t%d\n", i, dist[i]);
    }
}

// Dijkstra's algorithm function
void dijkstra(int graph[MAX][MAX], int V, int src) {
    int dist[V];         // Output array. dist[i] will hold the shortest distance
from src to i
    bool visited[V];     // visited[i] will be true if vertex i is processed

    // Initialize all distances as infinite and visited[] as false
    for (int i = 0; i < V; i++) {
        dist[i] = INT_MAX;
        visited[i] = false;
    }

    dist[src] = 0;  // Distance to self is always 0

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

        for (int v = 0; v < V; 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];
            }
        }
    }

    printSolution(dist, V, src);
}

// Main function
int main() {
    int V, E;
    int graph[MAX][MAX] = {0};

    printf("Enter the number of vertices: ");
    scanf("%d", &V);
```

```
    printf("Enter the number of edges: ");
    scanf("%d", &E);

    printf("Enter the edges (u v weight):\n");
    for (int i = 0; i < E; i++) {
        int u, v, w;
        printf("Edge %d: ", i + 1);
        scanf("%d %d %d", &u, &v, &w);
        graph[u][v] = w;
        // If the graph is undirected, uncomment the next line
        // graph[v][u] = w;
    }

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

    dijkstra(graph, V, src);

    return 0;
}
```

Result:

```
Enter the number of vertices: 5
Enter the number of edges: 7
Enter the edges (u v weight):
Edge 1: 0 1 10
Edge 2: 0 4 5
Edge 3: 1 2 1
Edge 4: 2 3 4
Edge 5: 4 1 3
Edge 6: 4 2 9
Edge 7: 4 3 2
Enter the source vertex: 0
Vertex  Distance from Source 0
0       0
1       8
2       9
3       7
4       5
PS C:\Users\student\Desktop\os_207>
```

Program -7

Question: Johnson Trotter Algorithm

Code:

```cpp
#include <iostream>
#include <vector>
using namespace std;

#define LEFT -1
#define RIGHT 1

// Function to print a permutation
void printPermutation(const vector<int>& perm) {
    for (int num : perm)
        cout << num << " ";
    cout << endl;
}

// Function to find the largest mobile integer
int getMobile(const vector<int>& perm, const vector<int>& dir) {
    int mobile = 0;
    for (int i = 0; i < perm.size(); i++) {
        int next = i + dir[perm[i] - 1];
        if (next >= 0 && next < perm.size() && perm[i] > perm[next]) {
            if (perm[i] > mobile) {
                mobile = perm[i];
            }
        }
    }
    return mobile;
}

// Function to find the index of a given element in the permutation
int findPosition(const vector<int>& perm, int mobile) {
    for (int i = 0; i < perm.size(); i++) {
        if (perm[i] == mobile)
            return i;
    }
    return -1;
}

// Johnson-Trotter algorithm
void generatePermutations(int n) {
    vector<int> perm(n), dir(n, LEFT);

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

    printPermutation(perm);
```

```
    while (true) {
        int mobile = getMobile(perm, dir);
        if (mobile == 0)
            break;

        int pos = findPosition(perm, mobile);
        int swapPos = pos + dir[mobile - 1];

        // Swap the mobile number with its adjacent element
        swap(perm[pos], perm[swapPos]);
        swap(dir[perm[swapPos] - 1], dir[perm[pos] - 1]);

        // Reverse direction of all elements greater than the mobile number
        for (int i = 0; i < n; i++) {
            if (perm[i] > mobile)
                dir[perm[i] - 1] = -dir[perm[i] - 1];
        }

        printPermutation(perm);
    }
}

// Main function
int main() {
    int n;
    cout << "Enter the number of elements: ";
    cin >> n;

    cout << "Permutations using Johnson-Trotter algorithm:" << endl;
    generatePermutations(n);

    return 0;
}
```

Result:

Input:

```typescript
Enter the number of elements: 3
```

Output:

```cpp
Permutations using Johnson-Trotter algorithm:
1 2 3
1 3 2
3 1 2
3 2 1
2 3 1
2 1 3
```

Program -8

Question: Fractional Knapsack Algorithm

Code:

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

// Structure to represent an item
typedef struct {
    int weight;
    int value;
    double ratio;
} Item;

// Comparison function to sort items by value-to-weight ratio in descending order
int compare(const void *a, const void *b) {
    Item *item1 = (Item *)a;
    Item *item2 = (Item *)b;

    if (item1->ratio < item2->ratio)
        return 1;
    else if (item1->ratio > item2->ratio)
        return -1;
    return 0;
}
```

```c
// Function to solve the fractional knapsack problem
double fractionalKnapsack(int capacity, Item items[], int n) {
    // Sort items by their value-to-weight ratio
    for (int i = 0; i < n; i++) {
        items[i].ratio = (double)items[i].value / items[i].weight;
    }

    // Sort items by their ratio in decreasing order
    qsort(items, n, sizeof(Item), compare);

    double totalValue = 0.0;  // Variable to store the total value of the
knapsack
    int currentWeight = 0;    // Current weight of the knapsack

    // Loop through the items
    for (int i = 0; i < n; i++) {
        if (currentWeight + items[i].weight <= capacity) {
            // If the whole item can be taken, take it
            currentWeight += items[i].weight;
            totalValue += items[i].value;
        } else {
            // If the item cannot be taken whole, take the fraction that fits
            int remainingCapacity = capacity - currentWeight;
            totalValue += items[i].value * ((double)remainingCapacity /
items[i].weight);
            break;  // The knapsack is full
        }
    }

    return totalValue;
}

// Driver code
int main() {
    int n, capacity;

    // Take the number of items and knapsack capacity as input
    printf("Enter the number of items: ");
    scanf("%d", &n);

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

    Item items[n];

    // Take item values and weights as input
    for (int i = 0; i < n; i++) {
        printf("Enter weight and value for item %d: ", i + 1);
        scanf("%d %d", &items[i].weight, &items[i].value);
```

```
    }

    // Get the maximum value that can be obtained in the knapsack
    double maxValue = fractionalKnapsack(capacity, items, n);

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

    return 0;
}
```

Result:

```
Enter the number of items: 3
Enter the capacity of the knapsack: 50
Enter weight and value for item 1: 10 60
Enter weight and value for item 2: 20 100
Enter weight and value for item 3: 30 120
Maximum value in the knapsack = 240.00
PS C:\Users\student\Desktop\os_207>
```

Program -9

Question: Leetcode – 1903

1903. Largest Odd Number in String

Easy | Topics | Companies | Hint

You are given a string `num`, representing a large integer. Return *the **largest-valued odd** integer (as a string) that is a **non-empty substring** of `num`, or an empty string `""` if no odd integer exists.*

A **substring** is a contiguous sequence of characters within a string.

Example 1:

Code:

```cpp
class Solution {
public:
    string largestOddNumber(string num) {
        if (num.back() % 2 == 1) return num;
        int i = num.length() - 1;
        while (i >= 0) {
            int n = num[i];
            if (n % 2 == 1) return num.substr(0, i + 1);
            i--;
        }
        return "";
    }
};
```

Result:

Program -10

Question: Heap Sort

Code:

```c
#include <stdio.h>

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

// Function to heapify a subtree rooted at node i
void heapify(int arr[], int n, int i) {
    int largest = i;   // Initialize largest as root
    int left = 2 * i + 1;  // Left child index
    int right = 2 * i + 2; // Right child index

    // If left child is larger than root
    if (left < n && arr[left] > arr[largest]) {
        largest = left;
    }

    // If right child is larger than largest so far
    if (right < n && arr[right] > arr[largest]) {
        largest = right;
    }

    // If largest is not root
    if (largest != i) {
        swap(&arr[i], &arr[largest]);

        // Recursively heapify the affected subtree
        heapify(arr, n, largest);
    }
}

// Function to implement heap sort
void heapSort(int arr[], int n) {
    // Build a max heap
    for (int i = n / 2 - 1; i >= 0; i--) {
        heapify(arr, n, i);
    }

    // One by one extract elements from heap
```

```
    for (int i = n - 1; i >= 0; i--) {
        // Move current root to end
        swap(&arr[0], &arr[i]);

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

// Main function
int main() {
    int n;

    // Take user input for the array size
    printf("Enter the number of elements: ");
    scanf("%d", &n);

    int arr[n];

    // Take user input for the array elements
    printf("Enter the elements:\n");
    for (int i = 0; i < n; i++) {
        scanf("%d", &arr[i]);
    }

    // Call heapSort to sort the array
    heapSort(arr, n);

    // Print the sorted array
    printf("Sorted array (Heap Sort): ");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    return 0;
}
```

Result:

```
Enter the number of elements: 10
Enter the elements:
1 3 2 5 9 8 7 10 6 4
Sorted array (Heap Sort): 1 2 3 4 5 6 7 8 9 10
PS C:\Users\student\Desktop\os_207>
```

Program -11

Question: Floyd Warshall Algorithm

Code:

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

#define MAX 100
#define INF INT_MAX  // Infinite distance value

// Function to implement Floyd-Warshall algorithm
void floydWarshall(int graph[MAX][MAX], int V) {
    // dist[][] will be the output matrix that contains the shortest distances
    int dist[V][V];

    // Initialize the solution matrix with the input graph
    for (int i = 0; i < V; i++) {
        for (int j = 0; j < V; j++) {
            if (graph[i][j] == 0 && i != j) {
                dist[i][j] = INF;  // No path exists
            } else {
                dist[i][j] = graph[i][j];
            }
        }
    }

    // Floyd-Warshall algorithm to compute 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] != INF && dist[k][j] != INF && dist[i][k] +
dist[k][j] < dist[i][j]) {
                    dist[i][j] = dist[i][k] + dist[k][j];
```

```
                }
            }
        }
    }

    // Printing the result
    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("INF ");
            } else {
                printf("%d ", dist[i][j]);
            }
        }
        printf("\n");
    }
}

// Main function
int main() {
    int V, E;

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

    printf("Enter the number of edges: ");
    scanf("%d", &E);

    int graph[MAX][MAX] = {0};  // Initialize graph with 0 (no path)

    // Take input for the edges
    printf("Enter the edges (u v weight):\n");
    for (int i = 0; i < E; i++) {
        int u, v, weight;
        printf("Edge %d: ", i + 1);
        scanf("%d %d %d", &u, &v, &weight);
        graph[u][v] = weight;
        // If the graph is undirected, uncomment the following line:
        // graph[v][u] = weight;
    }

    // Run Floyd-Warshall algorithm
    floydWarshall(graph, V);

    return 0;
}
```

Result:

```
PS C:\Users\student\Desktop\os_207> cd "c:\Users\student\Desktop\os_207\" ; if ($?) { g++ ada.cpp -o ada } ; if ($?) { .\ada }
Enter the number of vertices: 4
Enter the number of edges: 6
Enter the edges (u v weight):
Edge 1: 0 1 5
Edge 2: 0 2 10
Edge 3: 1 2 2
Edge 4: 1 3 3
Edge 5: 2 3 1
Edge 6: 3 0 7
Shortest distances between every pair of vertices:
0 5 7 8
10 0 2 3
8 13 0 1
7 12 14 0
PS C:\Users\student\Desktop\os_207>
```

Program -12

Question: Leetcode 847

847. Shortest Path Visiting All Nodes

Solved

Hard | Topics | Companies

You have an undirected, connected graph of `n` nodes labeled from `0` to `n - 1`. You are given an array `graph` where `graph[i]` is a list of all the nodes connected with node `i` by an edge.

Return *the length of the shortest path that visits every node*. You may start and stop at any node, you may revisit nodes multiple times, and you may reuse edges.

Code:

Code

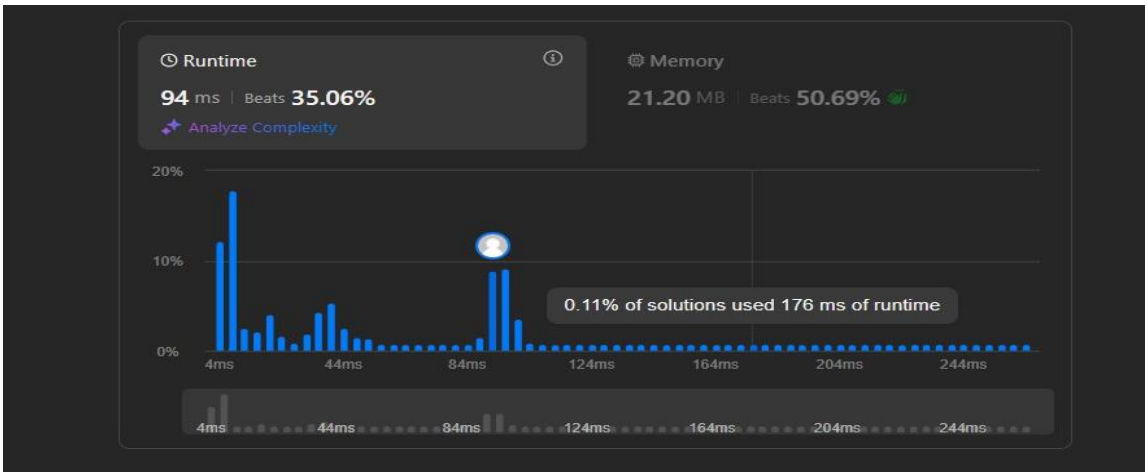
C++ | Auto

```cpp
class Solution {
public:
    // Class to carry three values at a time
    class tuple
    {
        public:
        int node; // on which current node we are standing
        int mask; // mask of that node
        int cost; // cost of path explore by this node
        tuple(int node, int mask, int cost)
        {
            this -> node = node;
            this -> mask = mask;
            this -> cost = cost;
        }
    };

    int shortestPathLength(vector<vector<int>>& graph) {
        // total number of nodes present
        int n = graph.size(); // extracting size of graph


        queue<tuple> q; // queue of class tuple type

         // set to take care which path we have already visited
        set<pair<int, int>> vis;

        int all = (1 << n) - 1; // if all nodes visited then

        // we don't know which node will give us shortest path so intially for all nodes we will store in our queue
        for(int i = 0; i < n; i++)
        {
            int maskValue = (1 << i); // 2 ^ i

            tuple thisNode(i, maskValue, 1); // make a tuple for every nod

            q.push(thisNode); // push tuple into our queue

            vis.insert({i, maskValue}); // also update into our set
        }

        // Implementing BFS
        while(q.empty() == false) // until queue is not empty
        {
```

Saved

```cpp
        }

        // Implementing BFS
        while(q.empty() == false) // until queue is not empty
        {
            tuple curr = q.front(); // extracting front tuple
            q.pop(); // pop from queuu

            // if mask value becomes all, that means we have visited all of our nodes, so from here return cost - 1
            if(curr.mask == all)
            {
                return curr.cost - 1;
            }

            // if not, start exploring in its adjcant
            for(auto &adj: graph[curr.node])
            {
                int bothVisitedMask = curr.mask; // current mask

                // we are moving from one node o anthor node
                bothVisitedMask = bothVisitedMask | (1 << adj);

                // make tuple of this path
                tuple ThisNode(adj, bothVisitedMask, curr.cost + 1);

                // if this path is not explored i.e
                // if it is not present in our set then,
                if(vis.find({adj, bothVisitedMask}) == vis.end())
                {
                    vis.insert({adj, bothVisitedMask}); // insert into set

                    q.push(ThisNode); // also insert into queue
                }
            }

        }

        // return -1, but this condition will never come
        return -1;
    }
};
```

Result:



Program -13

Question: N-Queens Algorithm

Code:

```c
#include <stdio.h>
#include <stdbool.h>

#define MAX 100

// Function to print the chessboard
void printSolution(int board[MAX][MAX], int N) {
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < N; j++) {
            printf("%d ", board[i][j]);
        }
        printf("\n");
    }
}

// Function to check if a queen can be placed on board[row][col]
// It checks the row, upper diagonal, and lower diagonal
bool isSafe(int board[MAX][MAX], int row, int col, int N) {
    // Check this column on the upper side
    for (int i = 0; i < row; i++) {
        if (board[i][col] == 1) {
            return false;
        }
    }

    // Check upper diagonal on the left side
    for (int i = row - 1, j = col - 1; i >= 0 && j >= 0; i--, j--) {
        if (board[i][j] == 1) {
            return false;
        }
    }

    // Check upper diagonal on the right side
    for (int i = row - 1, j = col + 1; i >= 0 && j < N; i--, j++) {
        if (board[i][j] == 1) {
            return false;
```

```
        }
    }

    return true;
}

// Function to solve the N-Queens problem using backtracking
bool solveNQueens(int board[MAX][MAX], int row, int N) {
    // If all queens are placed, return true
    if (row >= N) {
        return true;
    }

    // Consider this row and try all columns
    for (int col = 0; col < N; col++) {
        // Check if it's safe to place the queen
        if (isSafe(board, row, col, N)) {
            // Place the queen
            board[row][col] = 1;

            // Recur to place the rest of the queens
            if (solveNQueens(board, row + 1, N)) {
                return true;
            }

            // If placing queen in board[row][col] doesn't lead to a solution,
remove it (backtrack)
            board[row][col] = 0;
        }
    }

    // If the queen cannot be placed in any column in this row, return false
    return false;
}

// Main function
int main() {
    int N;

    // Take user input for the number of queens
    printf("Enter the number of queens: ");
    scanf("%d", &N);

    // Initialize the board with 0s
    int board[MAX][MAX] = {0};

    // Solve the N-Queens problem
    if (solveNQueens(board, 0, N)) {
        // Print the solution if a solution is found
```

```
        printf("Solution:\n");
        printSolution(board, N);
    } else {
        printf("No solution exists for %d queens.\n", N);
    }

    return 0;
}
```

Result:

```
PS C:\Users\student\Desktop\os_207> cd "c:\Users\student\Desktop\os_207\" ; if ($?) { g++ ada.cpp -o ada } ; if ($?) { .\ada }
Enter the number of queens: 4
Solution:
0 1 0 0
0 0 0 1
1 0 0 0
0 0 1 0
PS C:\Users\student\Desktop\os_207>
```