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
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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 Ghanshyam Sharma **(1BM23CS100)**, 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 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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Name Ghanshyam Sharma Class IV B

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Course outcomes:

CO1	Analyze time complexity of recursive and non-recursive algorithms using asymptotic notations
CO2	Apply various algorithm 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.

Lab Program 1

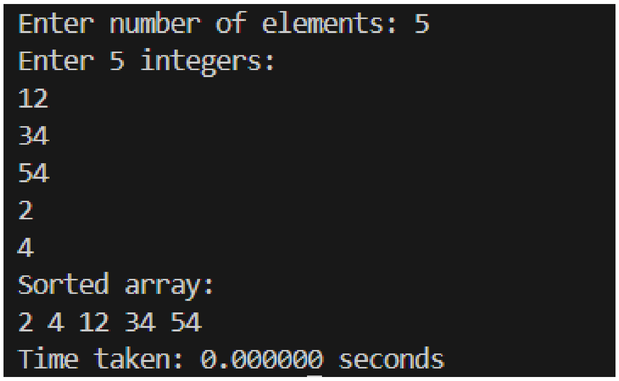
1.1.1 Question

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.

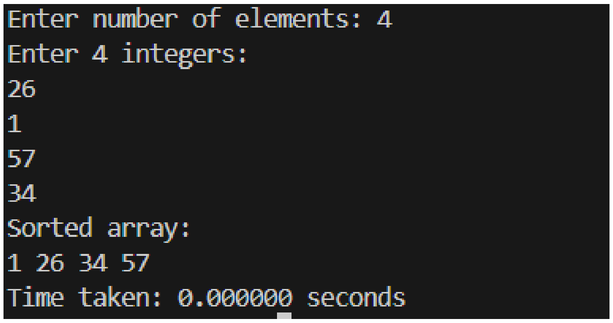
1.1.2 Code

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

void merge(int arr[], int left, int mid, int right) {
    int i, j, k;
    int n1 = mid - left + 1;
    int n2 = right - mid;
    int *L = (int *)malloc(n1 * sizeof(int));
    int *R = (int *)malloc(n2 * sizeof(int));
    for (i = 0; i < n1; i++)
        L[i] = arr[left + i];
    for (j = 0; j < n2; j++)
        R[j] = arr[mid + 1 + j];
    i = 0; j = 0; k = left;
    while (i < n1 && j < n2) {
        arr[k++] = (L[i] <= R[j]) ? L[i++] : R[j++];
    }
    while (i < n1) arr[k++] = L[i++];
    while (j < n2) arr[k++] = R[j++];
    free(L);
    free(R);
}

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);
    }
}

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

    int *arr = (int *)malloc(N * sizeof(int));
    if (arr == NULL) {
        printf("Memory allocation failed\n");
        return 1;
    }

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

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

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

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

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

    free(arr);
    return 0;
}
```

1.1.3 Output

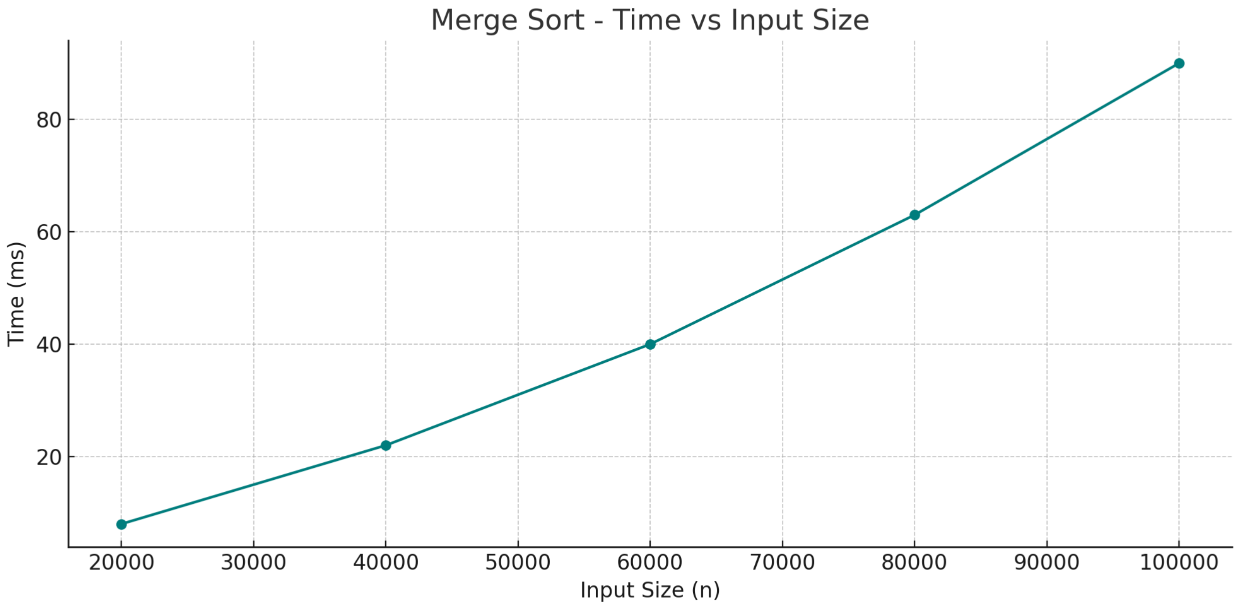


```
Enter number of elements: 5
Enter 5 integers:
12
34
54
2
4
Sorted array:
2 4 12 34 54
Time taken: 0.000000 seconds
```



```
Enter number of elements: 4
Enter 4 integers:
26
1
57
34
Sorted array:
1 26 34 57
Time taken: 0.000000 seconds
```

1.1.4 Graph

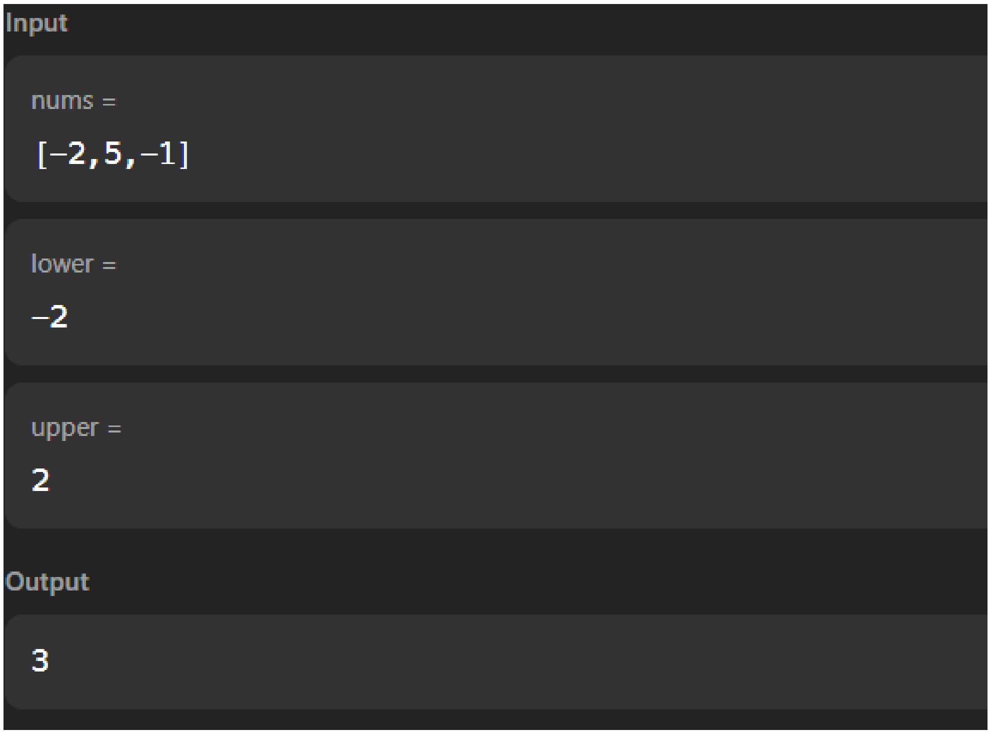


1.2.1 Leetcode Question
Count of Range Sum

1.2.2 Code

```
int countRangeSum(int* nums, int numsSize, int lower, int upper) {
    int count = 0;
    for (int i = 0; i < numsSize; i++) {
        long long sum = 0;
        for (int j = i; j < numsSize; j++) {
            sum += nums[j];
            if (sum >= lower && sum <= upper)
                count++;
        }
    }
    return count;
}
```

1.2.3 Output



```
Input
nums =
[-2,5,-1]
lower =
-2
upper =
2
Output
3
```

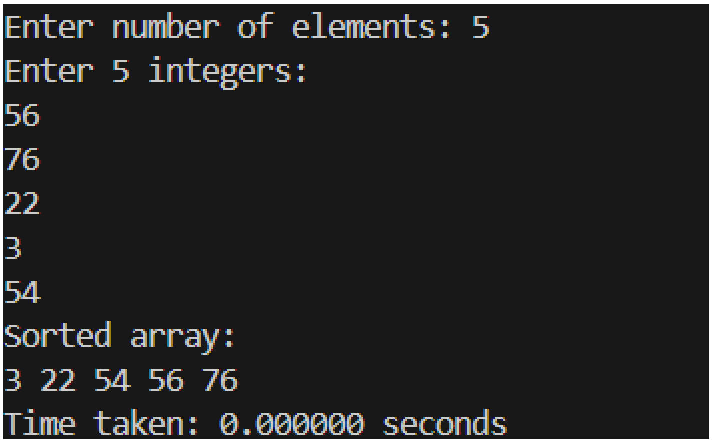
Lab Program 2

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

2.1.2 Code

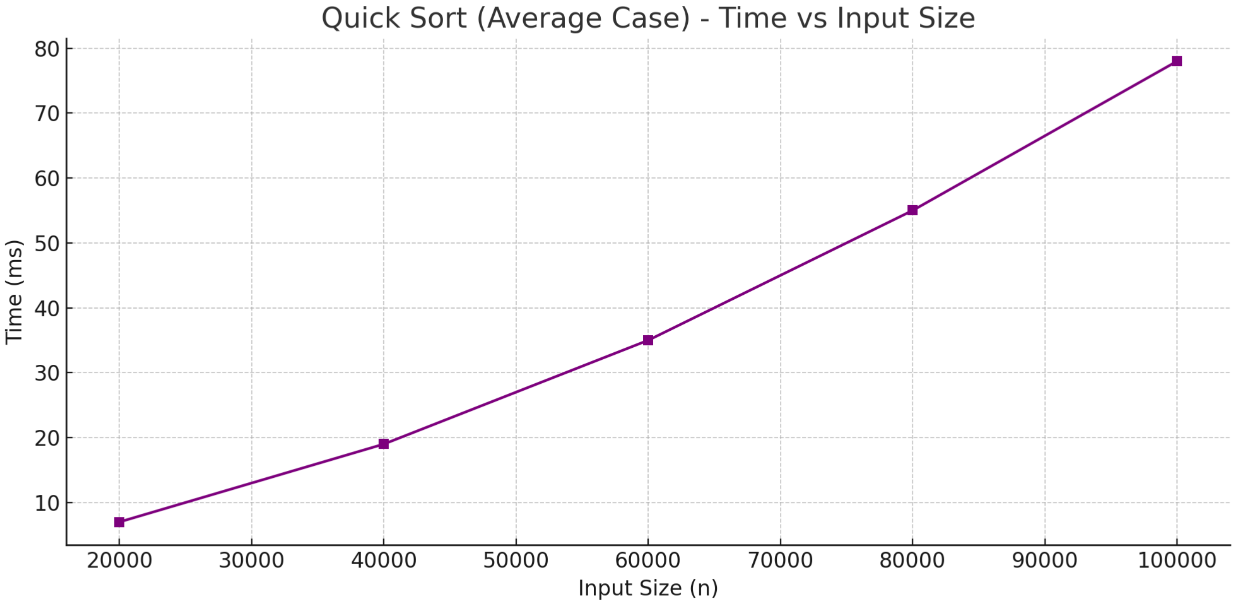
```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

int partition(int arr[], int low, int high) {
    int pivot = arr[high];
    int i = low - 1, temp;
    for (int j = low; j < high; j++) {
        if (arr[j] <= pivot) {
            i++;
            temp = arr[i]; arr[i] = arr[j]; arr[j] = temp;
        }
    }
    temp = arr[i + 1]; arr[i + 1] = arr[high]; arr[high] = temp;
    return i + 1;
}

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 = (int *)malloc(N * sizeof(int));
    if (arr == NULL) {
        printf("Memory allocation failed\n");
        return 1;
    }

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

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

    free(arr);
    return 0;
}
```

2.1.3 Output



```
Enter number of elements: 5
Enter 5 integers:
56
76
22
3
54
Sorted array:
3 22 54 56 76
Time taken: 0.000000 seconds
```

2.1.4 Graph

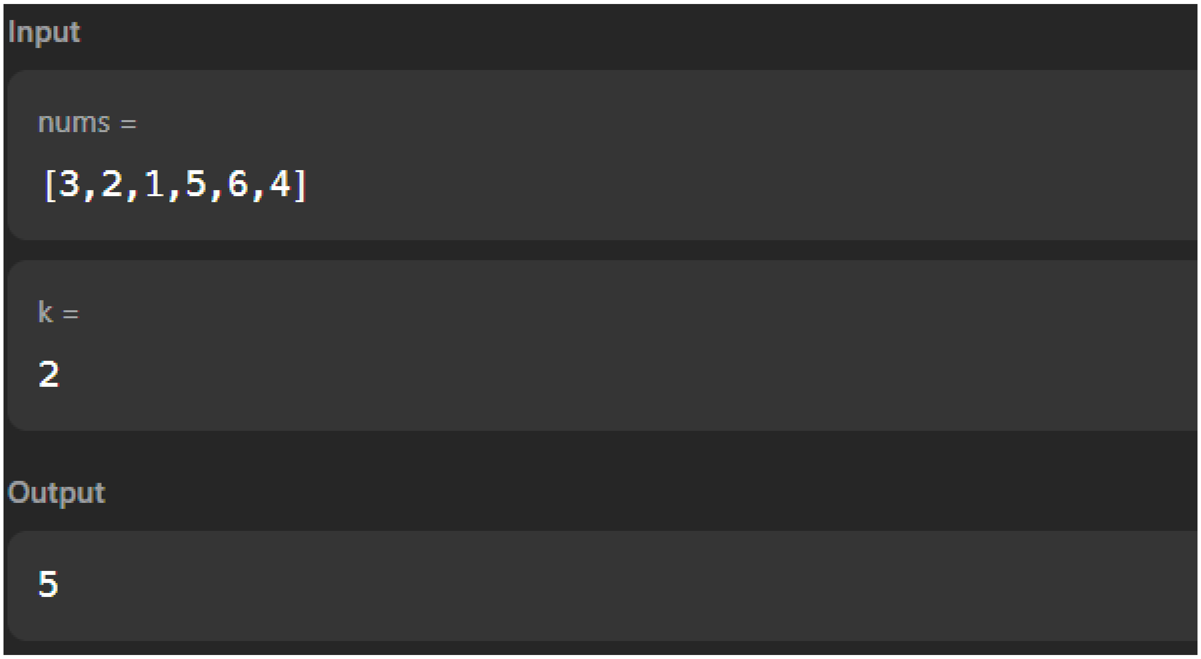


2.2.1 Leetcode Question
Kth Largest element in an array

2.2.2 Code

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

int partition(int arr[], int left, int right) {
    int pivot = arr[right];
    int i = left;
    for (int j = left; j < right; j++) {
        if (arr[j] <= pivot) {
            swap(&arr[i], &arr[j]);
            i++;
        }
    }
    swap(&arr[i], &arr[right]);
    return i;
}

int quickSelect(int arr[], int left, int right, int k) {
    if (left == right)
        return arr[left];

    int pivotIndex = partition(arr, left, right);

    if (k == pivotIndex)
        return arr[k];
    else if (k < pivotIndex)
        return quickSelect(arr, left, pivotIndex - 1, k);
    else
        return quickSelect(arr, pivotIndex + 1, right, k);
}

int findKthLargest(int arr[], int n, int k) {
    return quickSelect(arr, 0, n - 1, n - k);
}
```

2.2.3 Output



Input

nums =

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

k =

2

Output

5

Lab Program 3

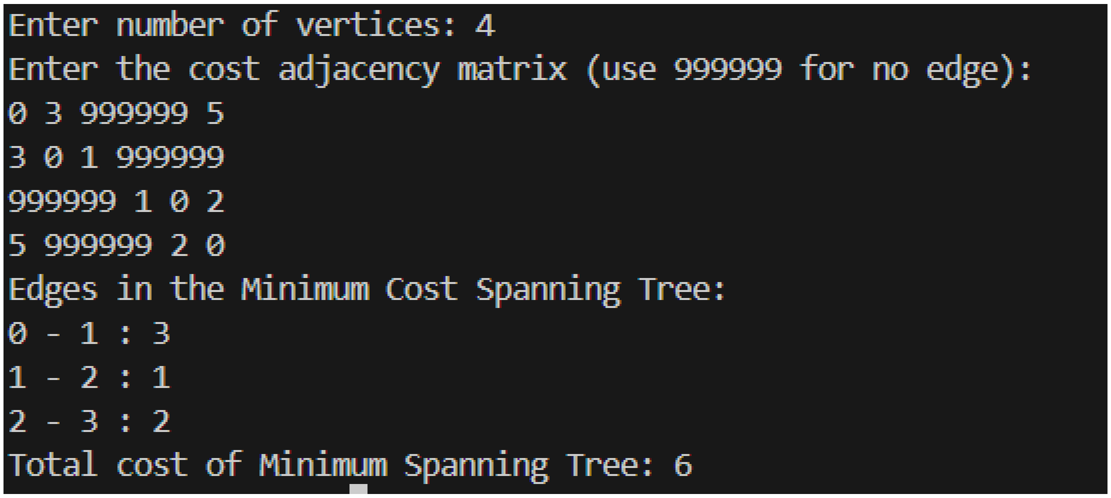
3.1.1 Question
Find Minimum Cost Spanning Tree of a given undirected graph using Prim's algorithm.

3.1.2 Code

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

#define MAX 100
#define INF 999999

int main() {
  int cost[MAX][MAX], visited[MAX];
  int n, i, j, min, u, v, total_cost = 0;

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

  printf("Enter the cost adjacency matrix (use %d for no edge):\n", INF);
```

```
    for (i = 0; i < n; i++) {
        for (j = 0; j < n; j++) {
            scanf("%d", &cost[i][j]);
            if (cost[i][j] == 0)
                cost[i][j] = INF;
        }
    }

    for (i = 0; i < n; i++)
        visited[i] = 0;

    visited[0] = 1;

    printf("Edges in the Minimum Cost Spanning Tree:\n");

    for (i = 0; i < n - 1; i++) {
        min = INF;
        for (j = 0; j < n; j++) {
            if (visited[j]) {
                for (int k = 0; k < n; k++) {
                    if (!visited[k] && cost[j][k] < min) {
                        min = cost[j][k];
                        u = j;
                        v = k;
                    }
                }
            }
        }
        visited[v] = 1;
        printf("%d - %d : %d\n", u, v, min);
        total_cost += min;
    }

    printf("Total cost of Minimum Spanning Tree: %d\n", total_cost);

    return 0;
}
```

3.1.3 Output



```
Enter number of vertices: 4
Enter the cost adjacency matrix (use 999999 for no edge):
0 3 999999 5
3 0 1 999999
999999 1 0 2
5 999999 2 0
Edges in the Minimum Cost Spanning Tree:
0 - 1 : 3
1 - 2 : 1
2 - 3 : 2
Total cost of Minimum Spanning Tree: 6
```

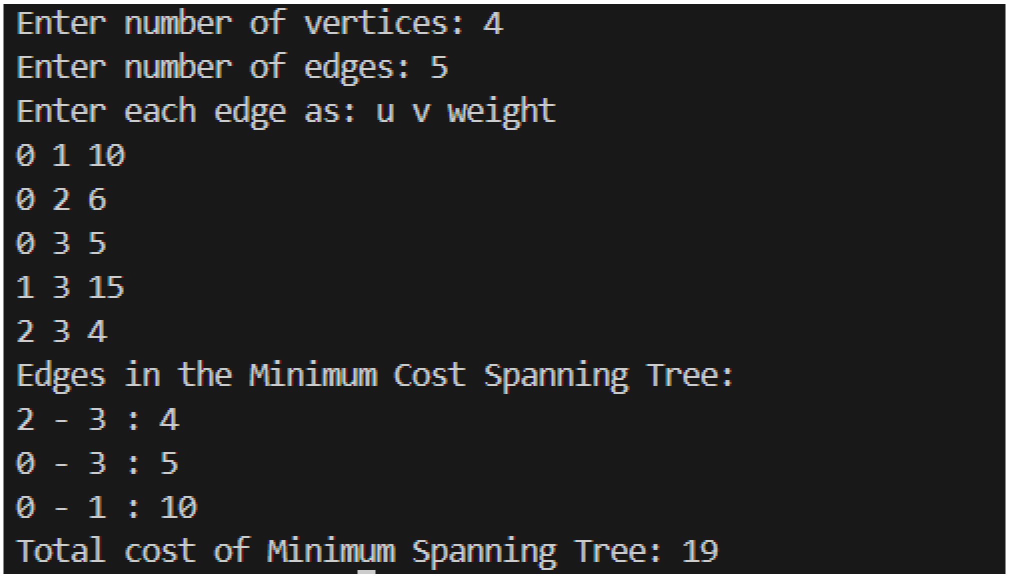
3.2.1 Question

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

3.2.2 Code

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

#define MAX 100
#define INF 999999

typedef struct {
   int u, v, w;
} Edge;

int parent[MAX];
int find(int i) {
    while (parent[i] != i)
        i = parent[i];
    return i;
}

void union_sets(int i, int j) {
    int a = find(i);
    int b = find(j);
    parent[a] = b;
}

void kruskal(Edge edges[], int n, int e) {
    int i, j;
    Edge temp;
    for (i = 0; i < e - 1; i++) {
        for (j = 0; j < e - i - 1; j++) {
            if (edges[j].w > edges[j + 1].w) {
                temp = edges[j];
                edges[j] = edges[j + 1];
                edges[j + 1] = temp;
            }
        }
    }

    for (i = 0; i < n; i++)
        parent[i] = i;

    int total_cost = 0;
    printf("Edges in the Minimum Cost Spanning Tree:\n");

    int count = 0;
    for (i = 0; i < e && count < n - 1; i++) {
        int u = edges[i].u;
        int v = edges[i].v;
        int w = edges[i].w;

        if (find(u) != find(v)) {
            union_sets(u, v);
            printf("%d - %d : %d\n", u, v, w);
            total_cost += w;
            count++;
        }
    }
    printf("Total cost of Minimum Spanning Tree: %d\n", total_cost);
}

int main() {
    int n, e;
    Edge edges[MAX];

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

    printf("Enter each edge as: u v weight\n");
    for (int i = 0; i < e; i++) {
        scanf("%d %d %d", &edges[i].u, &edges[i].v, &edges[i].w);
    }

    kruskal(edges, n, e);

    return 0;
}
```

3.2.3 Output



```
Enter number of vertices: 4
Enter number of edges: 5
Enter each edge as: u v weight
0 1 10
0 2 6
0 3 5
1 3 15
2 3 4
Edges in the Minimum Cost Spanning Tree:
2 - 3 : 4
0 - 3 : 5
0 - 1 : 10
Total cost of Minimum Spanning Tree: 19
```

Lab Program 4

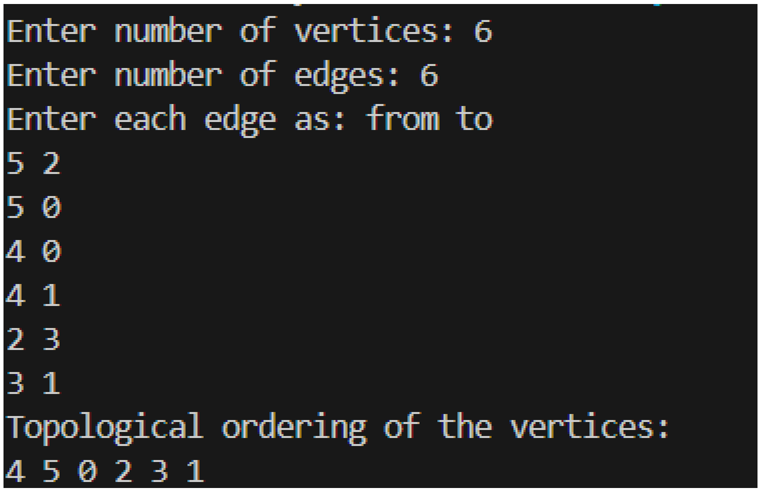
4.1.1 Question

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

4.1.2 Code

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

#define MAX 100

int queue[MAX], front = -1, rear = -1;

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

int dequeue() {
    if (front == -1 || front > rear) return -1;
    return queue[front++];
}

int isEmpty() {
    return (front == -1 || front > rear);
}

int main() {
    int n, e, i, j;
    int graph[MAX][MAX] = {0};
    int indegree[MAX] = {0};

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

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

    printf("Enter each edge as: from to\n");
    for (i = 0; i < e; i++) {
        int u, v;
        scanf("%d %d", &u, &v);
        graph[u][v] = 1;
        indegree[v]++;
    }
    for (i = 0; i < n; i++) {
        if (indegree[i] == 0)
            enqueue(i);
    }

    int count = 0;
    int topo_order[MAX];

    while (!isEmpty()) {
        int u = dequeue();
        topo_order[count++] = u;

        for (j = 0; j < n; j++) {
            if (graph[u][j]) {
                indegree[j]--;
                if (indegree[j] == 0)
                    enqueue(j);
            }
        }
    }

    if (count != n) {
        printf("Cycle detected. Topological ordering not possible.\n");
    } else {
        printf("Topological ordering of the vertices:\n");
        for (i = 0; i < count; i++) {
            printf("%d ", topo_order[i]);
        }
        printf("\n");
    }

    return 0;
}
```

4.1.3 Output



```
Enter number of vertices: 6
Enter number of edges: 6
Enter each edge as: from to
5 2
5 0
4 0
4 1
2 3
3 1
Topological ordering of the vertices:
4 5 0 2 3 1
```

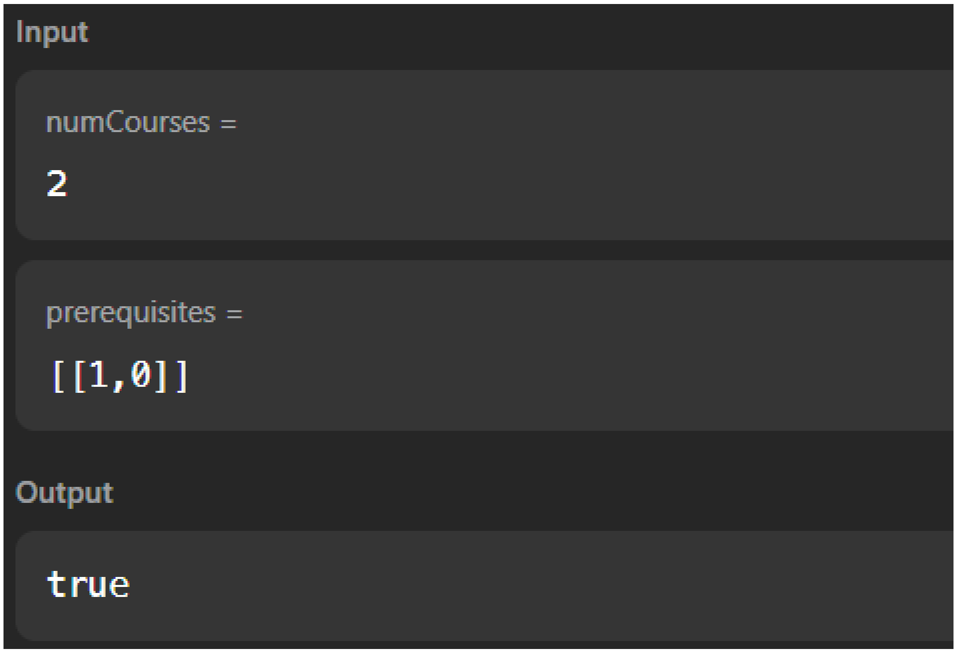
4.2.1 Leetcode Question
Course Schedule

4.2.2 Code

```
bool dfs(int node, int** graph, int* graphColSize, int* visited, int* inStack) {
   visited[node] = 1;
   inStack[node] = 1;

   for (int i = 0; i < graphColSize[node]; i++) {
      int neighbor = graph[node][i];
      if (!visited[neighbor]) {
         if (dfs(neighbor, graph, graphColSize, visited, inStack)) {
            return true;
         }
      } else if (inStack[neighbor]) {
         return true;
      }
   }

   inStack[node] = 0;
   return false;
}

bool canFinish(int numCourses, int** prerequisites, int prerequisitesSize, int*
prerequisitesColSize) {

   int** graph = (int**)malloc(numCourses * sizeof(int*));
   int* graphColSize = (int*)calloc(numCourses, sizeof(int));
   int* tempSizes = (int*)calloc(numCourses, sizeof(int));

   for (int i = 0; i < prerequisitesSize; i++) {
      int course = prerequisites[i][0];
      tempSizes[course]++;
   }

   for (int i = 0; i < numCourses; i++) {
      graph[i] = (int*)malloc(tempSizes[i] * sizeof(int));
   }

   for (int i = 0; i < prerequisitesSize; i++) {
      int course = prerequisites[i][0];
      int pre = prerequisites[i][1];
      graph[course][graphColSize[course]++] = pre;
   }
   int* visited = (int*)calloc(numCourses, sizeof(int));
   int* inStack = (int*)calloc(numCourses, sizeof(int));
```

```
    for (int i = 0; i < numCourses; i++) {
        if (!visited[i]) {
            if (dfs(i, graph, graphColSize, visited, inStack)) {

                for (int j = 0; j < numCourses; j++) free(graph[j]);
                free(graph); free(graphColSize); free(visited); free(inStack); free(tempSizes);
                return false;
            }
        }
    }

    for (int i = 0; i < numCourses; i++) free(graph[i]);
    free(graph); free(graphColSize); free(visited); free(inStack); free(tempSizes);
    return true;
}
```

4.2.3 Output



```
Input

numCourses =
2

prerequisites =
[[1,0]]

Output

true
```

Lab Program 5

5.1.1 Question

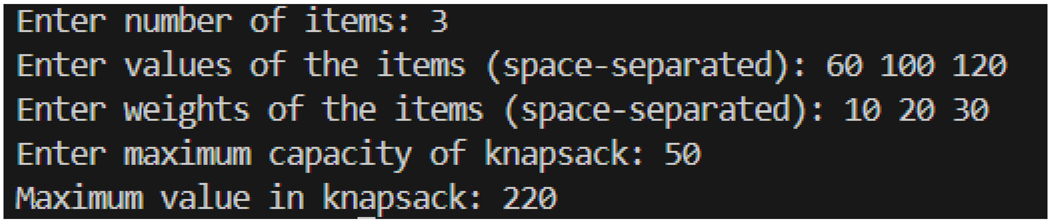
Implement 0/1 Knapsack problem using dynamic programming.

5.1.2 Code

```
#include <stdio.h>

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

int knapsack(int W, int weights[], int values[], int n) {
   int dp[n + 1][W + 1];
   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 (weights[i - 1] <= w)
            dp[i][w] = max(values[i - 1] + dp[i - 1][w - weights[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 values[n], weights[n];

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

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

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

   int result = knapsack(W, weights, values, n);
   printf("Maximum value in knapsack: %d\n", result);
```

```
    return 0;
}
```

5.1.3 Output



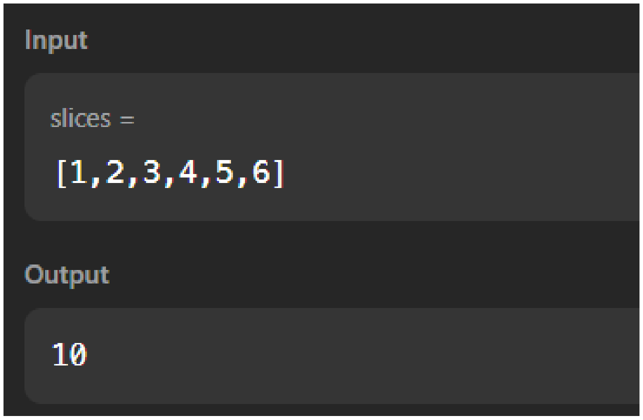
```
Enter number of items: 3
Enter values of the items (space-separated): 60 100 120
Enter weights of the items (space-separated): 10 20 30
Enter maximum capacity of knapsack: 50
Maximum value in knapsack: 220
```

5.2.1 Leetcode Question
Pizza With 3n slices

5.2.2 Code

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

int maxSizeSlicesLinear(int* slices, int start, int end, int n) {
    int len = end - start + 1;
    int dp[len + 1][n + 1];

    for (int i = 0; i <= len; i++)
        for (int j = 0; j <= n; j++)
            dp[i][j] = 0;

    for (int i = 1; i <= len; i++) {
        for (int j = 1; j <= n; j++) {
            if (i == 1)
                dp[i][j] = slices[start + i - 1];
            else
                dp[i][j] = max(dp[i - 1][j], dp[i - 2][j - 1] + slices[start + i - 1]);
        }
    }
    return dp[len][n];
}

int maxSizeSlices(int* slices, int slicesSize) {
    int n = slicesSize / 3;
    int case1 = maxSizeSlicesLinear(slices, 0, slicesSize - 2, n);
    int case2 = maxSizeSlicesLinear(slices, 1, slicesSize - 1, n);
    return max(case1, case2);
}
```

5.2.3 Output



Input

```
slices =
[1,2,3,4,5,6]
```

Output

```
10
```

Lab program 6

6.1.1 Question

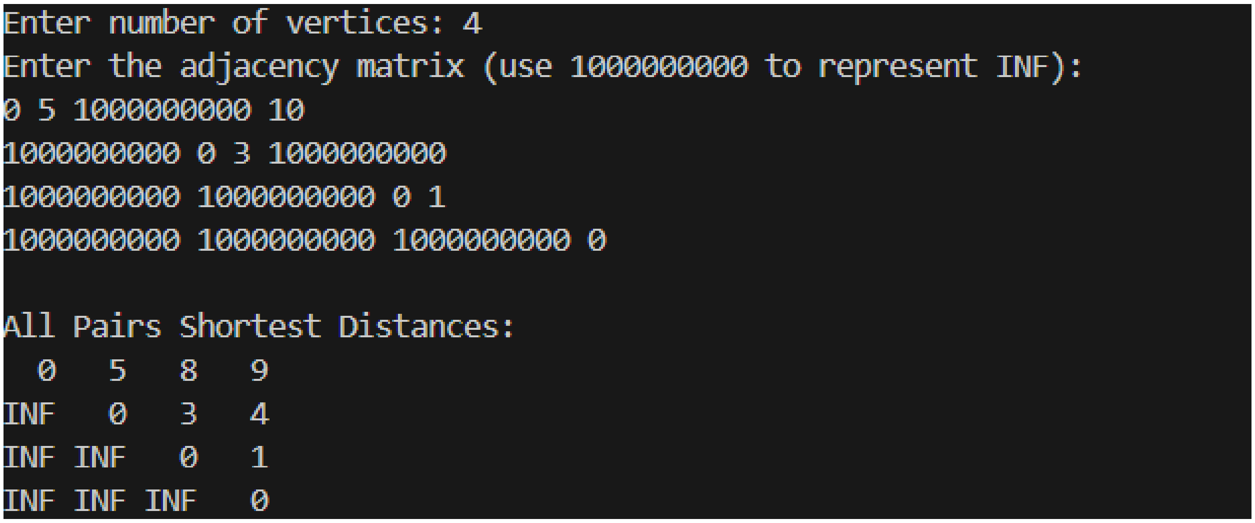
Implement All Pair Shortest paths problem using Floyd's algorithm.

6.1.2 Code

```
#include <stdio.h>

#define INF 1000000000

void floydWarshall(int n, int graph[100][100]) {
   int dist[100][100];

   for (int i = 0; i < n; i++)
      for (int j = 0; j < n; j++)
         dist[i][j] = graph[i][j];

   for (int k = 0; k < n; k++)
      for (int i = 0; i < n; i++)
         for (int j = 0; j < n; j++)
            if (dist[i][k] + dist[k][j] < dist[i][j])
               dist[i][j] = dist[i][k] + dist[k][j];

   printf("\nAll Pairs Shortest Distances:\n");
   for (int i = 0; i < n; i++) {
      for (int j = 0; j < n; j++) {
         if (dist[i][j] == INF)
            printf("INF ");
         else
            printf("%3d ", dist[i][j]);
      }
      printf("\n");
   }
}

int main() {
   int n;
   int graph[100][100];

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

   printf("Enter the adjacency matrix (use %d to represent INF):\n", INF);
   for (int i = 0; i < n; i++)
      for (int j = 0; j < n; j++)
         scanf("%d", &graph[i][j]);
```

```
    floydWarshall(n, graph);

    return 0;
}
```

6.1.3 Output



```
Enter number of vertices: 4
Enter the adjacency matrix (use 1000000000 to represent INF):
0 5 1000000000 10
1000000000 0 3 1000000000
1000000000 1000000000 0 1
1000000000 1000000000 1000000000 0

All Pairs Shortest Distances:
  0   5   8   9
INF   0   3   4
INF INF   0   1
INF INF INF   0
```

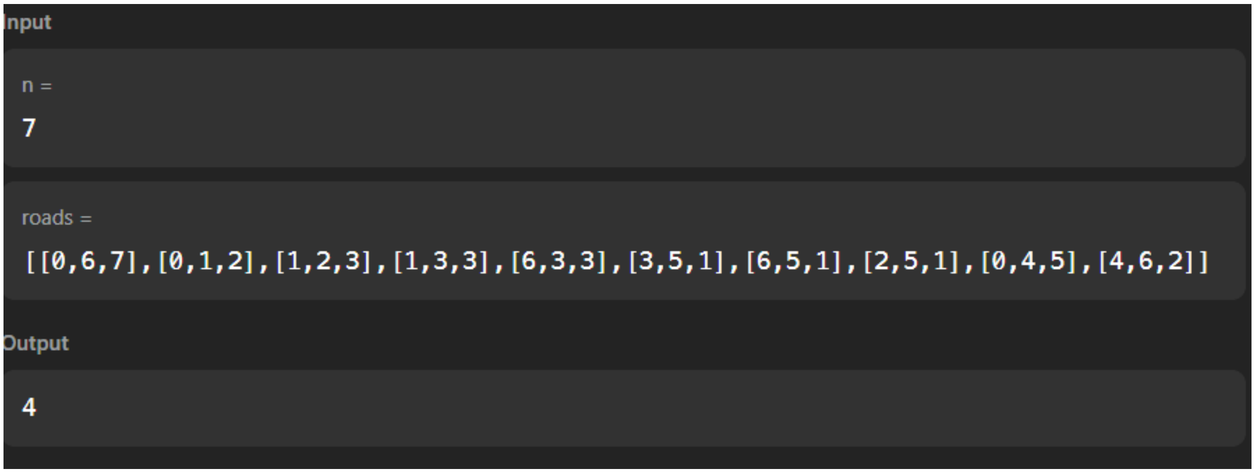
6.2.1 Leetcode question

Number of ways to arrive at a destination.

6.2.2 Code

```
#define MOD 1000000007
#define MAXN 100001
#define MAXEDGES 300000

int head[MAXN], to[MAXEDGES], cost[MAXEDGES], next[MAXEDGES], edgeCount;

int heap[MAXN], heapSize;
long long dist[MAXN];

int ways[MAXN];
int pos[MAXN];

void addEdge(int u, int v, int c) {
    to[edgeCount] = v;
    cost[edgeCount] = c;
    next[edgeCount] = head[u];
    head[u] = edgeCount++;
}

void swap(int i, int j) {
    int tmp = heap[i];
    heap[i] = heap[j];
    heap[j] = tmp;
    pos[heap[i]] = i;
    pos[heap[j]] = j;
}

void push(int node) {
    int i = heapSize++;
    heap[i] = node;
    pos[node] = i;
    while (i > 0 && dist[heap[i]] < dist[heap[(i - 1) / 2]]) {
        swap(i, (i - 1) / 2);
        i = (i - 1) / 2;
    }
}

int pop() {
    int top = heap[0];
    heap[0] = heap[--heapSize];
    pos[heap[0]] = 0;
    int i = 0;
    while (1) {
        int smallest = i, l = 2 * i + 1, r = 2 * i + 2;
        if (l < heapSize && dist[heap[l]] < dist[heap[smallest]]) smallest = l;
        if (r < heapSize && dist[heap[r]] < dist[heap[smallest]]) smallest = r;
        if (smallest == i) break;
        swap(i, smallest);
        i = smallest;
    }
    return top;
}

int countPaths(int n, int** roads, int roadsSize, int* roadsColSize) {
    for (int i = 0; i < n; i++) head[i] = -1;

    edgeCount = 0;
    for (int i = 0; i < roadsSize; i++) {
        int u = roads[i][0], v = roads[i][1], c = roads[i][2];
        addEdge(u, v, c);
        addEdge(v, u, c);
    }

    for (int i = 0; i < n; i++) {
        dist[i] = LLONG_MAX;
        ways[i] = 0;
        pos[i] = -1;
    }

    dist[0] = 0;
    ways[0] = 1;
    heapSize = 0;
    push(0);

    while (heapSize > 0) {
        int u = pop();
        for (int e = head[u]; e != -1; e = next[e]) {
            int v = to[e];
            long long d = dist[u] + cost[e];
            if (d < dist[v]) {
                dist[v] = d;
                ways[v] = ways[u];
                if (pos[v] == -1)
                    push(v);
                else {
                    int i = pos[v];
                    while (i > 0 && dist[heap[i]] < dist[heap[(i - 1) / 2]]) {
                        swap(i, (i - 1) / 2);
                        i = (i - 1) / 2;
                    }
                }
            } else if (d == dist[v]) {
                ways[v] = (ways[v] + ways[u]) % MOD;
            }
        }
    }

    return ways[n - 1];
}
```

6.2.3 Output



```
Input
n =
7
roads =
[[0,6,7],[0,1,2],[1,2,3],[1,3,3],[6,3,3],[3,5,1],[6,5,1],[2,5,1],[0,4,5],[4,6,2]]
Output
4
```

Lab program 7

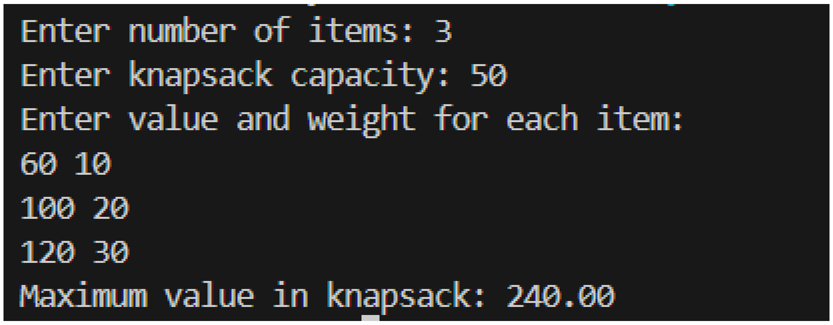
7.1.1 Question

Implement Fractional Knapsack using Greedy technique.

7.1.2 Code

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

typedef struct {
    int value;
    int weight;
    double ratio;
} Item;

int compare(const void *a, const void *b) {
    double r1 = ((Item *)b)->ratio;
    double r2 = ((Item *)a)->ratio;
    return (r1 > r2) - (r1 < r2);
}

int main() {
    int n;
    double capacity;

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

    printf("Enter knapsack capacity: ");
    scanf("%lf", &capacity);

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

    qsort(items, n, sizeof(Item), compare);

    double totalValue = 0.0;

    for (int i = 0; i < n && capacity > 0; i++) {
        if (items[i].weight <= capacity) {
            totalValue += items[i].value;
            capacity -= items[i].weight;
        } else {
            totalValue += items[i].ratio * capacity;
            capacity = 0;
        }
    }

    printf("Maximum value in knapsack: %.2lf\n", totalValue);

    return 0;
}
```

7.1.3 Output



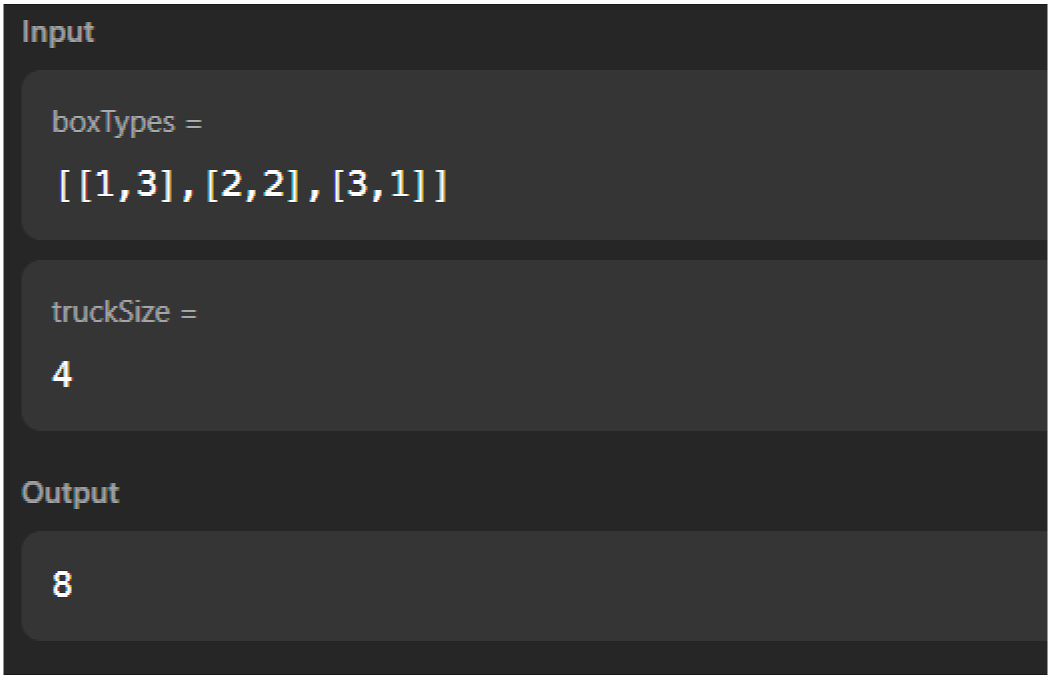
```
Enter number of items: 3
Enter knapsack capacity: 50
Enter value and weight for each item:
60 10
100 20
120 30
Maximum value in knapsack: 240.00
```

7.2.1 Leetcode Questions
Maximum units on a truck

7.2.2 Code

```
int compare(const void *a, const void *b) {
   int u1 = ((int **)b)[0][1];
   int u2 = ((int **)a)[0][1];
   return u1 - u2;
}

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

   int totalUnits = 0;
   for (int i = 0; i < boxTypesSize && truckSize > 0; i++) {
      int boxesToTake = boxTypes[i][0] < truckSize ? boxTypes[i][0] : truckSize;
      totalUnits += boxesToTake * boxTypes[i][1];
      truckSize -= boxesToTake;
   }
   return totalUnits;
}
```

7.2.3 Output



```
Input

boxTypes =
[[1,3],[2,2],[3,1]]

truckSize =
4

Output

8
```

Lab Program 8

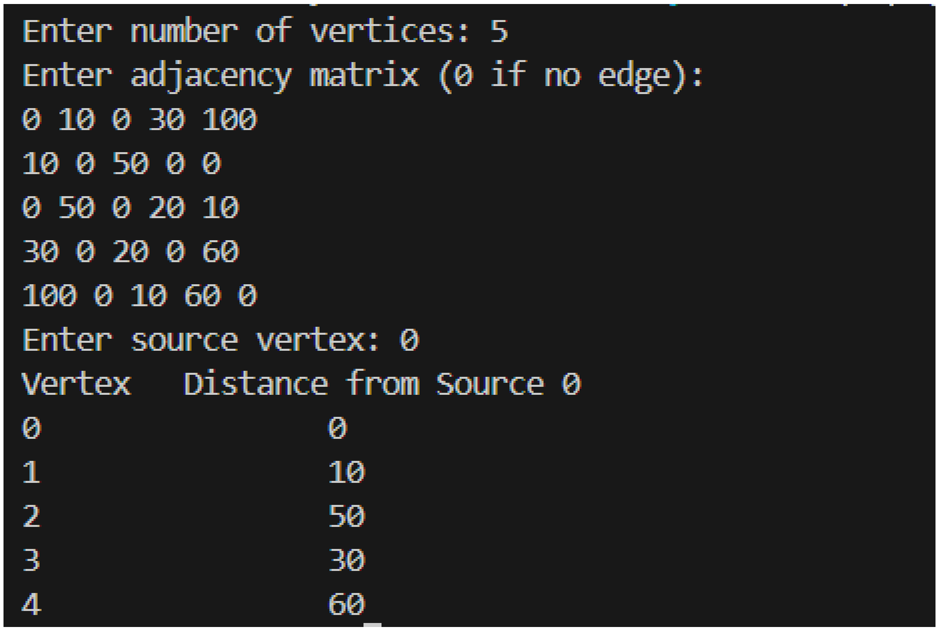
8.1.1 Question
Dijkstra's Algorithm

8.1.2 Code

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

#define V 100  // Max number of vertices

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 n, int src) {
   int dist[V];     // Shortest distance from src to i
   int visited[V];  // Visited vertices

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

   dist[src] = 0;

   for (int count = 0; count < n - 1; count++) {
      int u = minDistance(dist, visited, n);
      if (u == -1) break;  // All reachable nodes are processed

      visited[u] = 1;

      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];
         }
      }
   }
```

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

int main() {
    int n, src;
    int graph[V][V];

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

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

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

    dijkstra(graph, n, src);

    return 0;
}
```

8.1.3 Output



```
Enter number of vertices: 5
Enter adjacency matrix (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                0
1                10
2                50
3                30
4                60
```

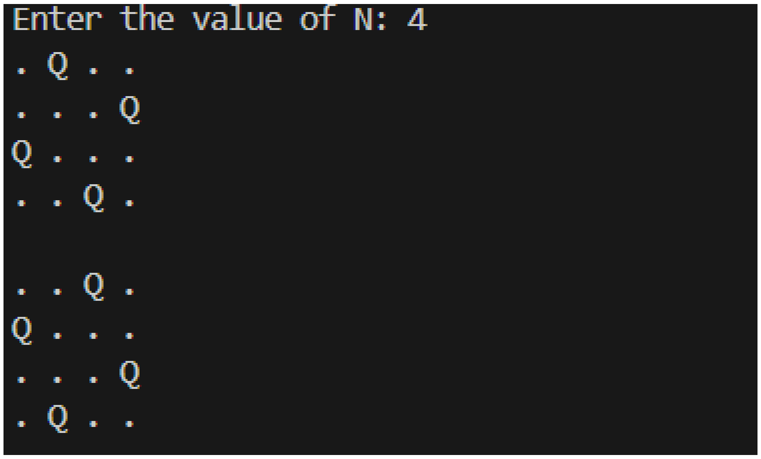
Lab Program 9

9.1.1 Question
N Queens

9.1.2 Code

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

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

void solveNQueens(int row) {
    if (row == N) {
        printSolution();
        return;
    }
    for (int col = 0; col < N; col++) {
        if (isSafe(row, col)) {
            board[row] = col;
            solveNQueens(row + 1);

        }
    }
}

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

    board = (int *)malloc(N * sizeof(int));

    solveNQueens(0);

    free(board);
    return 0;
}
```

9.1.3 Output



```
Enter the value of N: 4
. Q . .
. . . Q
Q . . .
. . Q .

. . Q .
Q . . .
. . . Q
. Q . .
```

Lab Program 10

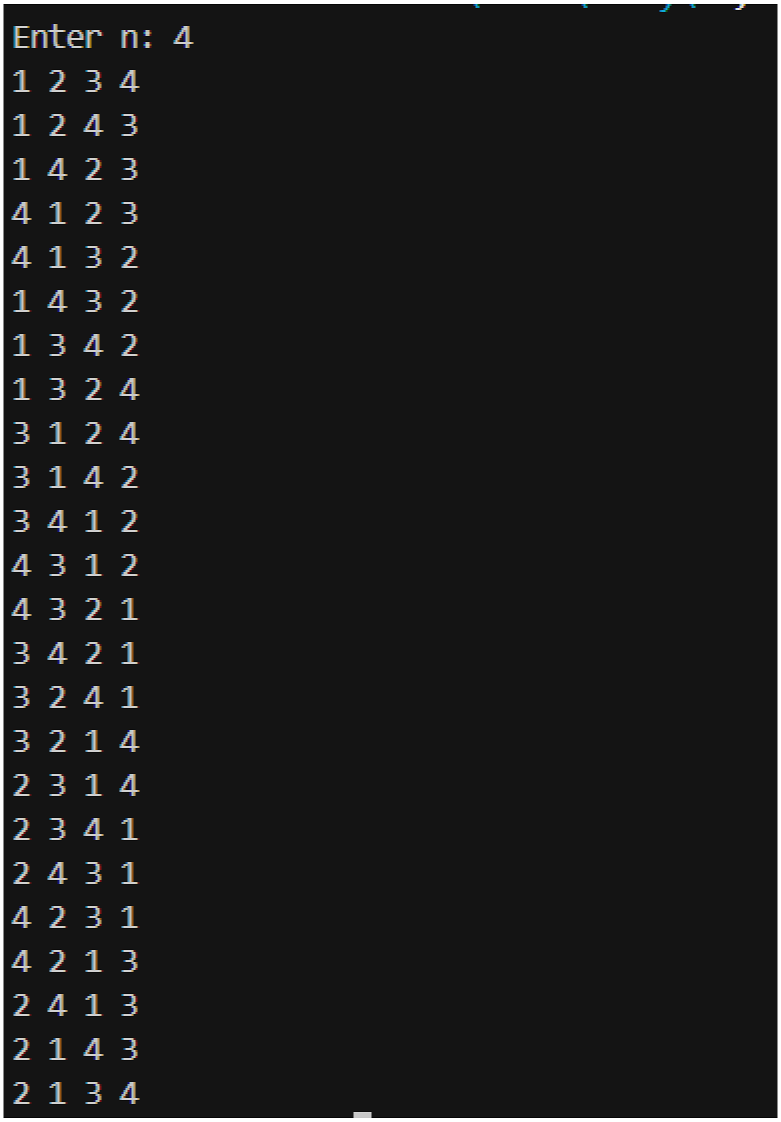
10.1.1 Question
Implement Johnson Trotter algorithm to generate permutations.

10.1.2 Code

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

#define LEFT 0
#define RIGHT 1

int n;

void printPermutation(int *arr) {
    for (int i = 0; i < n; i++)
        printf("%d ", arr[i]);
    printf("\n");
}

int getLargestMobile(int *arr, int *dir) {
    int largestMobileIndex = -1;
    int largestMobile = 0;

    for (int i = 0; i < n; i++) {
        int nextIndex = (dir[i] == LEFT) ? i - 1 : i + 1;

        if (nextIndex >= 0 && nextIndex < n) {
            if (arr[i] > arr[nextIndex] && arr[i] > largestMobile) {
                largestMobile = arr[i];
                largestMobileIndex = i;
            }
        }
    }
    return largestMobileIndex;
}

void johnsonTrotter() {
    int *arr = malloc(n * sizeof(int));
    int *dir = malloc(n * sizeof(int));

    for (int i = 0; i < n; i++) {
        arr[i] = i + 1;
        dir[i] = LEFT;
    }

    printPermutation(arr);
```

```
  while (1) {
    int largestMobileIndex = getLargestMobile(arr, dir);
    if (largestMobileIndex == -1)
      break; // No more mobile integer, done

    int swapIndex = (dir[largestMobileIndex] == LEFT) ? largestMobileIndex - 1 :
largestMobileIndex + 1;

    int temp = arr[largestMobileIndex];
    arr[largestMobileIndex] = arr[swapIndex];
    arr[swapIndex] = temp;

    temp = dir[largestMobileIndex];
    dir[largestMobileIndex] = dir[swapIndex];
    dir[swapIndex] = temp;

    largestMobileIndex = swapIndex;

    for (int i = 0; i < n; i++) {
      if (arr[i] > arr[largestMobileIndex]) {
        dir[i] = (dir[i] == LEFT) ? RIGHT : LEFT;
      }
    }

    printPermutation(arr);
  }

  free(arr);
  free(dir);
}

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

  johnsonTrotter();

  return 0;
}
```

10.1.3 Output



```
Enter n: 4
1 2 3 4
1 2 4 3
1 4 2 3
4 1 2 3
4 1 3 2
1 4 3 2
1 3 4 2
1 3 2 4
3 1 2 4
3 1 4 2
3 4 1 2
4 3 1 2
4 3 2 1
3 4 2 1
3 2 4 1
3 2 1 4
2 3 1 4
2 3 4 1
2 4 3 1
4 2 3 1
4 2 1 3
2 4 1 3
2 1 4 3
2 1 3 4
```

Lab Program 11

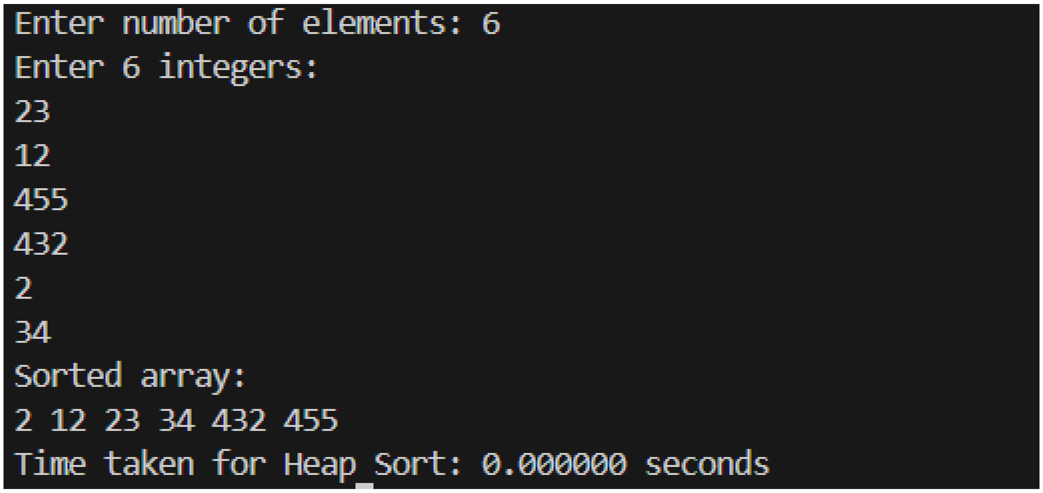
11.1.1 Question

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

11.1.2 Code

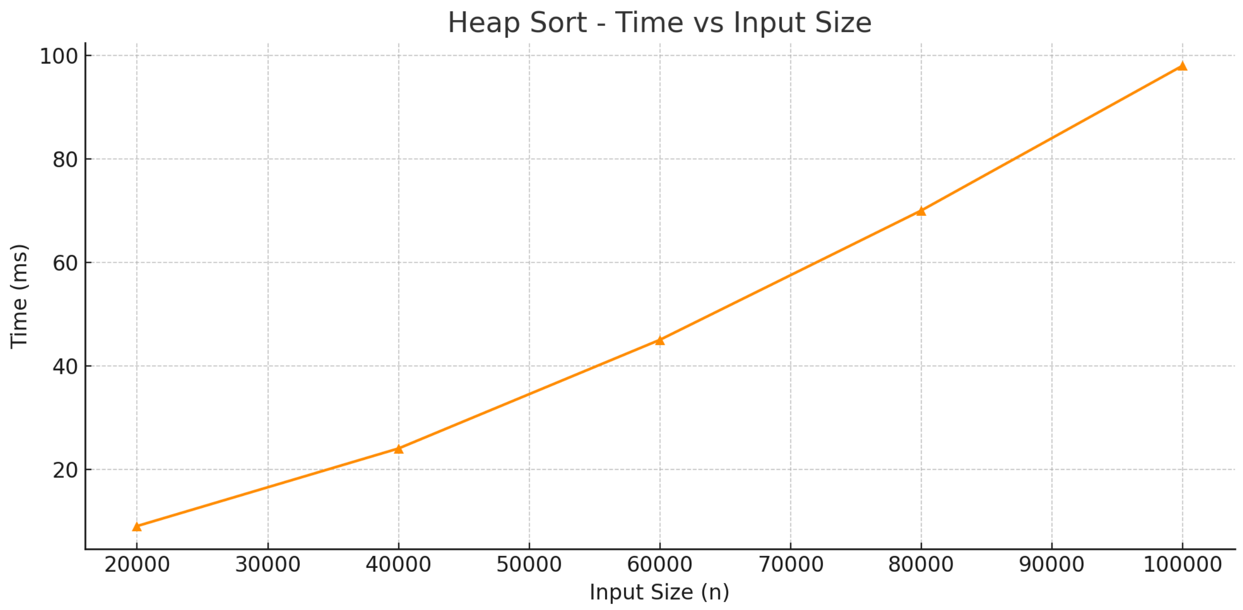
```
#include <stdio.h>
#include <time.h>

void heapify(int arr[], int n, int i) {
    int largest = i;
    int left = 2*i + 1;
    int right = 2*i + 2;

    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;

        heapify(arr, n, largest);
    }
}

void heapSort(int arr[], int n) {
    for (int i = n/2 -1; i >= 0; i--)
        heapify(arr, n, i);

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

        heapify(arr, i, 0);
    }
}

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();
    heapSort(arr, n);
    clock_t end = clock();

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

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

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

    return 0;
}
```

11.1.3 Output



```
Enter number of elements: 6
Enter 6 integers:
23
12
455
432
2
34
Sorted array:
2 12 23 34 432 455
Time taken for Heap Sort: 0.000000 seconds
```

11.1.4 Graph


Heap Sort - Time vs Input Size
Time (ms)
100
80
60
40
20
20000
30000
40000
50000
60000
70000
80000
90000
100000
Input Size (n)