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"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

Analysis and Design of Algorithms

Submitted by

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In partial fulfilment 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
May-2023 to July-2023

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Bull Temple Road, Bangalore 560019

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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "**Analysis and Design of Algorithms**" carried out by **Anoshor B. Paul (1BM21CS024),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfilment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the academic semester May-2023 to July-2023. The Lab report has been approved as it satisfies the academic requirements in respect of an **Analysis and Design of Algorithms (22CS4PCADA)** work prescribed for the said degree.

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Index Sheet

Course Outcome

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.

1. Experiments

1.1 Experiment - 1

1.1.1 Question:

Write program to do the following:

(a) Print all the nodes reachable from a given starting node in a digraph using BFS method.

(b) Check whether a given graph is connected or not using DFS method.

1.1.2 Code:

(a) BFS method:

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

int a[20][20],q[20],visited[20],n,i,j,f=0,r=-1;
void bfs(int v)
{
	for(i=1;i<=n;i++)
	if(a[v][i] && !visited[i])
	q[++r]=i;
	if(f<=r)
	{
		visited[q[f]]=1;
		bfs(q[f++]);
	}
}

void main()
{
	int v;

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

	for(i=1;i<=n;i++)
	{
		q[i]=0;
		visited[i]=0;
	}

	printf("\n Enter graph data in matrix form:\n");
	for(i=1;i<=n;i++)
		for(j=1;j<=n;j++)
			scanf("%d",&a[i][j]);
```

```
	printf("\n Enter the starting vertex:");
	scanf("%d",&v);
	bfs(v);

	printf("\n The node which are reachable are:\n");
	for(i=1;i<=n;i++)
		if(visited[i])
		printf("%d\t",i);

	getch();
}
```

(b) <u>DFS method</u>:

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

int a[20][20],reach[20],n;

void dfs(int v)
{
	int i;
	reach[v]=1;
	for(i=1;i<=n;i++)
	if(a[v][i]&&!reach[i])
	{
		printf("\n%d->%d",v,i);
		dfs(i);
	}
}

int main()
{
	int i,j,count=0;
	printf("\nEnter no of vertices : ");
	scanf("%d",&n);

	for(i=1;i<=n;i++)
		for(j=1;j<=n;j++)
		{
			reach[i]=0;
			a[i][j]=0;
		}
	printf("\nEnter adjacency matrix : \n");

	for(i=1;i<=n;i++)
		for(j=1;j<=n;j++)
```

```
                scanf("%d",&a[i][j]);
                dfs(1);

        for(i=1;i<=n;i++)
        if(reach[i])
        count++;

        if(count==n)
                printf("\nGraph is connected.");
        else
                printf("\nGraph is disconnected.");

        getch();
        return(0);
}
```

1.1.3 Output:

(a) BFS method:

```
 Enter the number of vertices:4

 Enter graph data in matrix form:
0 1 1 1
0 0 0 1
0 0 0 0
0 0 1 0

 Enter the starting vertex:1

 The node which are reachable are:
2       3       4
```

DFS method

```
Enter no of vertices : 4

Enter adjacency matrix :
0 1 1 1
0 0 0 1
0 0 0 0
0 0 1 0

1->2
2->4
4->3
Graph is connected.
```

```
Enter no of vertices : 4

Enter adjacency matrix :
0 1 0 0
0 0 1 0
0 0 0 0
1 1 1 0

1->2
2->3
Graph is disconnected.
```

1.2 Experiment - 2

1.2.1 Question:

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

1.2.2 Code:

```
#include <stdio.h>

int main()
{
   int i,j,k,n,a[10][10],indeg[10],visited[10],count=0;

   printf("Enter the no of vertices:\n");
   scanf("%d",&n);

   printf("Enter the adjacency matrix:\n");
   for(i=0;i<n;i++)
   {
      for(j=0;j<n;j++)
      scanf("%d",&a[i][j]);
   }

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

   for(i=0;i<n;i++)
      for(j=0;j<n;j++)
         indeg[i]=indeg[i]+a[j][i];

   printf("\nThe topological order is:");

   while(count<n)
      {
      for(k=0;k<n;k++)
      {
         if((indeg[k]==0) && (visited[k]==0))
         {
            printf("%d ",(k+1));
            visited [k]=1;
```

```
        }

        for(i=0;i<n;i++)
        {
           if(a[i][k]==1)
              indeg[k]--;
        }
      }
      count++;
   }
   return 0;
}
```

1.2.3 Output:

```
Enter the no of vertices:
7
Enter the adjacency matrix:
Enter row 1
0 0 0 0 1 0 0
Enter row 2
1 0 1 0 0 0 0
Enter row 3
0 0 0 1 0 0 0
Enter row 4
0 0 0 0 1 1 0
Enter row 5
0 0 0 0 0 1 0
Enter row 6
0 0 0 0 0 0 1
Enter row 7
0 0 0 0 0 0 0

The topological order is:2 1 3 4 5 6 7
```

1.3 Experiment - 3

1.3.1 Question:

Implement Johnson Trotter algorithm to generate permutations.

1.3.2 Code:

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

#define MAX_N 10

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

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

void generatePermutations(int n)
{
   int permutation[MAX_N];
   int direction[MAX_N];
   bool mobile[MAX_N];

   for (int i = 0; i < n; i++)
   {
      permutation[i] = i + 1;
      direction[i] = -1;
      mobile[i] = true;
   }

   printPermutation(permutation, direction, n);
```

```
int mobileElement, mobileIndex, temp;

while (true)
{
   mobileElement = -1;
   mobileIndex = -1;

   for (int i = 0; i < n; i++)
   {
      if (direction[i] == -1 && i > 0 && permutation[i] > permutation[i - 1] && mobile[i])
      {
         if (mobileElement == -1 || permutation[i] > mobileElement)
         {
            mobileElement = permutation[i];
            mobileIndex = i;
         }
      }

      if (direction[i] == 1 && i < n - 1 && permutation[i] > permutation[i + 1] && mobile[i])
      {
         if (mobileElement == -1 || permutation[i] > mobileElement)
         {
            mobileElement = permutation[i];
            mobileIndex = i;
         }
      }
   }

   if (mobileIndex == -1)
   {
      break;
   }

   if (direction[mobileIndex] == -1)
   {
      swap(&permutation[mobileIndex], &permutation[mobileIndex - 1]);
      swap(&direction[mobileIndex], &direction[mobileIndex - 1]);
   }
   else
   {
      swap(&permutation[mobileIndex], &permutation[mobileIndex + 1]);
```

```
            swap(&direction[mobileIndex], &direction[mobileIndex + 1]);
        }

        for (int i = 0; i < n; i++)
        {
            if (permutation[i] > mobileElement)
            {
                direction[i] *= -1;
            }
        }
        printPermutation(permutation, direction, n);
    }
}

int main()
{
    int n;

    printf("Enter the value of n: ");
    scanf("%d", &n);

    if (n < 1 || n > MAX_N)
    {
        printf("Invalid input!\n");
        return 0;
    }

    generatePermutations(n);
    return 0;
}
```

1.3.3 Output:

```
Enter the value of n: 2
12
21
```

```
Enter the value of n: 3
123
132
312
321
231
213
```

```
Enter the value of n: 4
1234
1243
1423
4123
4132
1432
1342
1324
3124
3142
3412
4312
4321
3421
3241
3214
2314
2341
2431
4231
4213
2413
2143
2134
```

1.4 Experiment - 4

1.4.1 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.

1.4.2 Code:

```
#include <iostream>
#include <vector>

using namespace std;

void merge(int low, int mid, int high, vector<int>& arr) {
    int i=low,j=mid+1;
    vector<int> a;
    while(i<=mid && j<=high) {
        if(arr[i]<arr[j]) {
            a.push_back(arr[i]);
            i++;
        }
        else {
            a.push_back(arr[j]);
            j++;
        }
    }

    while(i<=mid) {
        a.push_back(arr[i]);
        i++;
    }

    while(j<=high) {
        a.push_back(arr[j]);
        j++;
    }
    int k=0;
    for(int i=0;i<(high-low+1);i++) {
        arr[low+i]=a[i];
    }
}
void mergesort(int low, int high, vector<int>& arr) {
    int n = arr.size();

    // if(n==1) return;

    if(low<high) {
```

```
        int mid=low+(high-low)/2;

        mergesort(low,mid,arr);
        mergesort(mid+1,high,arr);
        merge(low, mid, high, arr);
    }
}

int main() {
    vector<int> arr = {2,3,1,5};
    mergesort(0,arr.size()-1,arr);

    for(int i=0;i<arr.size();i++) {
        cout<<arr[i]<<" ";
    }

    return 0;
}
```

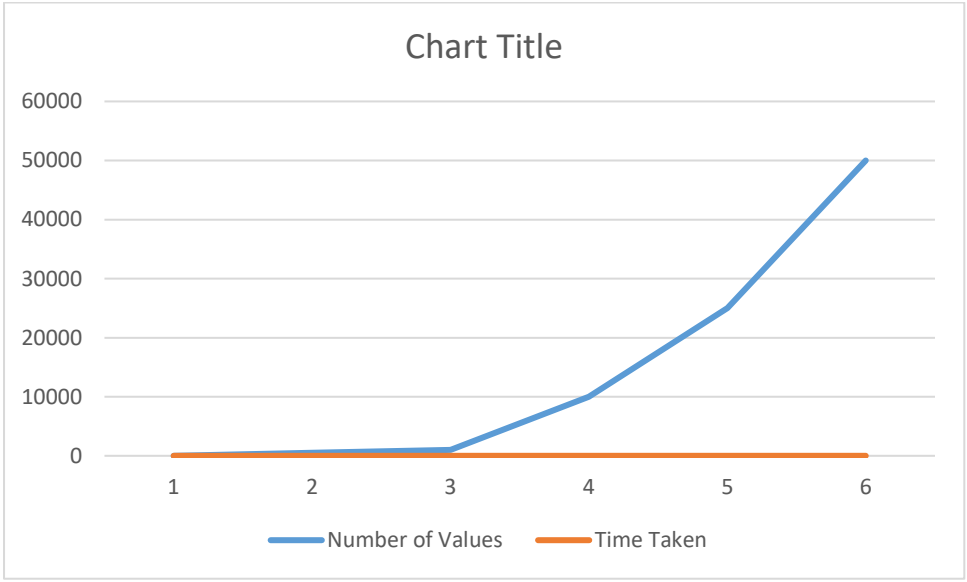
1.4.3 Output:

```
Enter the number of elements: 50

Enter array elements: (By Random)
Starting of the program, start_t = 1166
End of the program, end_t = 1387
Total time taken by CPU: 0.000221

Sorted array is:
273 304 768 1028 1368 1650 1652 2035 2230 4247 4313 4402 4470 460
3 4990 5026 5106 5133 5542 5862 5919 5953 6070 6185 6470 6688 669
6 6715 7300 7355 7515 7681 7836 7857 7887 7935 7971 8462 8750 907
9 9166 9214 9353 9384 9415 9777 9799 9820 9920 9949
```

1.4.4 Example Graph (Not Done in class)



1.5 Experiment - 5

1.5.1 Question:

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

1.5.2 Code:

```
#include <iostream>
#include <vector>

using namespace std;

int partition(int low, int high, vector<int>& arr) {
   int i=low,j=high;
   int pivot=arr[low];
   while(i<j) {
      while((arr[i]<=pivot) && (i<=(high+1))) {
         i++;
      }
      while((arr[j]>pivot)  &&  (j>=(low-1))) {
         j--;
      }
      if(i<j) {
         swap(arr[i],arr[j]);
      }
   }

   swap(arr[low], arr[j]);
   return j;
}

void quicksort(int low, int high, vector<int>& arr) {
   if(low<high) {
```

```
        int p = partition(low, high, arr);
        quicksort(low,p-1,arr);
        quicksort(p+1,high,arr);
    }
}


int main() {

    vector<int> arr = {2,1,5,3};

    quicksort(0,arr.size()-1,arr);

    for(auto x: arr) {
        cout<<x<<" ";
    }
    // cout<<"e";
    return 0;
}
```

1.5.3 Output:

```
enter number of elements 5
enter the elements: 3 5 4 1 7
1 3 4 5 7
```

1.6 Experiment - 6

1.6.1 Question:

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

1.6.2 Code:

```
#include <bits/stdc++.h>
#include <vector>
#include <algorithm>
#include <iostream>

using namespace std;


void heapify(vector<int>& arr, int N, int i)
{

    // Initialize largest as root
    int largest = i;

    // left = 2*i + 1
    int l = 2 * i + 1;

    // right = 2*i + 2
    int r = 2 * i + 2;

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

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

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

        // Recursively heapify the affected
        // sub-tree
        heapify(arr, N, largest);
    }
}
vector<int> heapSort(vector<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--) {


        swap(arr[0], arr[i]);


        heapify(arr, i, 0);
    }

    return arr;

}

int main() {

  vector<int> arr = {3,1,4,2,8};

  heapSort(arr, arr.size());

  for(auto x : arr) { cout<<x<<" "; }

  return 0;
}
```

1.6.3 Output:

```
Enter the number of elements: 5
Enter 5 elements:
3 6 1 2 8
Sorted array: 1 2 3 6 8
```

1.7 Experiment - 7

1.7.1 Question:

Implement 0/1 Knapsack problem using dynamic programming.

1.7.2 Code:

```
#include <iostream>
#include <algorithm>
#include <vector>

using namespace std;


int knapsack(int w, vector<int> p, vector<int> weights) {
    int n = p.size();
    vector<vector<int>> v(n+1,vector<int>(w+1));

    // for(int i=1;i<v.size();i++) {
    //     for(int j=1;j<v[0].size();j++) {
    //         if(weights[i-1]>j) {
    //             v[i][j] = v[i-1][j];
    //         }
    //         else {
    //             v[i][j] = max(v[i-1][j], v[i-1][j-weights[i-1]]+p[i-1]);
    //         }
    //     }
    // }

    for(int i=0;i<v.size();i++) {
        for(int j=0;j<v[0].size();j++) {
            if(i == 0 || j == 0) {
                v[i][j] = 0;
            }
            else if(weights[i-1]>j) {
                v[i][j] = v[i-1][j];
            }
            else {
                v[i][j] = max(v[i-1][j], v[i-1][j-weights[i-1]]+p[i-1]);
            }
        }
    }

    return v[n][w];
}
int main() {
    // vector<int> weights = {2,1,3,2};
```

```
    // vector<int> profit = {12,15,25,10};

    vector<int> weights = {2,3,1,2,4};
    vector<int> profit = {10,12,25,13,11};

    cout<<knapsack(5,profit,weights);

    return 0;
}
```

1.7.3 Output:

```
Enter the number of items: 4
Enter the values of the items: 3 4 5 6
Enter the weights of the items: 2 3 4 5
Enter the capacity of the knapsack: 5
The maximum profit is 7
The objects selected for the optimal solution are: 1 2
```

1.8 Experiment - 8

1.8.1 Question:

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

1.8.2 Code:

```
#include <stdio.h>

#define INFINITY 999

int nV;
void printMatrix(int matrix[][nV]);

void floyd(int graph[][nV])
{
   int matrix[nV][nV], i, j, k;

   for (i = 0; i < nV; i++)
      for (j = 0; j < nV; j++)
         matrix[i][j] = graph[i][j];

   for (k = 0; k < nV; k++)
   {
      for (i = 0; i < nV; i++)
      {
         for (j = 0; j < nV; j++)
         {
            if (matrix[i][k] + matrix[k][j] < matrix[i][j])
            matrix[i][j] = matrix[i][k] + matrix[k][j];
         }
      }
   }
   printMatrix(matrix);
}

void printMatrix(int matrix[][nV])
{
   printf("\nAll Pairs Shortest Path is :\n");
   for (int i = 0; i < nV; i++)
   {
      for (int j = 0; j < nV; j++)
      {
         if (matrix[i][j] == INFINITY)
            printf("%4s", "INF");
         else
            printf("%4d", matrix[i][j]);
```

```
        }
        printf("\n");
    }
}

int main()
{
    printf("Enter the number of vertices in the graph: ");
    scanf("%d", &nV);

    int graph[nV][nV];
    printf("Enter the weight of edges in the graph:\n");
    for (int i = 0; i < nV; i++)
    {
        for (int j = 0; j < nV; j++)
        {
            scanf("%d", &graph[i][j]);
        }
    }
    floyd(graph);
}
```

1.8.3 Output:

```
Enter the number of vertices in the graph: 4
Enter the weight of edges in the graph:
0 4 9 999
999 0 7 999
999 999 0 6
2 3 999 0

All Pairs Shortest Path is :
   0   4   9  15
  15   0   7  13
   8   9   0   6
   2   3  10   0
```

1.9 Experiment - 9

1.9.1 Question:

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

1.9.2 Code:

(a) Prim's Algorithm:

```
#include<stdio.h>

int a,b,u,v,n,i,j,ne=1;

int visited[10]={0},min,mincost=0,cost[10][10];

void main()
{
   printf("Prim's algorithm:\n");

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

        printf("\nEnter the adjacency matrix:\n");
        for(i=1;i<=n;i++)
      for(j=1;j<=n;j++)
      {
         scanf("%d",&cost[i][j]);
         if(cost[i][j]==0)
            cost[i][j]=999;
      }
        visited[1]=1;
        printf("\n");

   printf("\nThe edges of Minimum Cost Spanning Tree are:");
        while(ne < n)
        {
                for(i=1,min=999;i<=n;i++)
          for(j=1;j<=n;j++)
             if(cost[i][j]< min)
             if(visited[i]!=0)
             {
                min=cost[i][j];
                a=u=i;
                b=v=j;
             }

                 if(visited[u]==0 || visited[v]==0)
```

```
            {
                printf("\nEdge %d:(%d,%d) Weight:%d",ne++,a,b,min);
                mincost+=min;
                visited[b]=1;
            }
            cost[a][b]=cost[b][a]=999;
        }
        printf("\n\nMinimun Cost=%d",mincost);
}
```

(b) Kruskal's Algorithm:

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

int i, j, k, a, b, u, v, n, ne = 1;
int min, mincost = 0, cost[10][10], parent[9];

int find(int);
int uni(int, int);

void main()
{
 printf("Kruskal's algorithm:\n");

 printf("Enter the no. of vertices:\n");
 scanf("%d", &n);

 printf("\nEnter the cost adjacency matrix:\n");
 for (i = 1; i <= n; i++)
 {
  for (j = 1; j <= n; j++)
  {
   scanf("%d", &cost[i][j]);
   if (cost[i][j] == 0)
    cost[i][j] = 999;
  }
 }

 printf("\nThe edges of Minimum Cost Spanning Tree are\n");
 while (ne < n)
 {
  for (i = 1, min = 999; i <= n; i++)
  {
   for (j = 1; j <= n; j++)
   {
    if (cost[i][j] < min)
```

```
        {
          min = cost[i][j];
          a = u = i;
          b = v = j;
        }
      }
    }

    u = find(u);
    v = find(v);

    if (uni(u, v))
    {
      printf("Edge %d:(%d,%d) Weight:%d\n", ne++, a, b, min);
      mincost += min;
    }

    cost[a][b] = cost[b][a] = 999;
  }

  printf("\nMinimum cost = %d\n", mincost);
}

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

int uni(int i, int j)
{
  if (i != j)
  {
    parent[j] = i;
    return 1;
  }

  return 0;
}
```

1.9.3 Output:

(a) Prim's Algorithm:

```
Prim's algorithm:
Enter the number of nodes:5

Enter the adjacency matrix:
0 1 7 10 5
1 0 3 999 999
7 3 0 4 999
10 999 4 0 2
5 999 999 2 0


The edges of Minimum Cost Spanning Tree are:
Edge 1:(1,2) Weight:1
Edge 2:(2,3) Weight:3
Edge 3:(3,4) Weight:4
Edge 4:(4,5) Weight:2

Minimun Cost=10
```

(b) Kruskal's Algorithm:

```
Kruskal's algorithm:
Enter the no. of vertices:
5

Enter the cost adjacency matrix:
0 1 7 10 5
1 0 3 999 999
7 3 0 4 999
10 999 4 0 2
5 999 999 2 0

The edges of Minimum Cost Spanning Tree are
Edge 1:(1,2) Weight:1
Edge 2:(4,5) Weight:2
Edge 3:(2,3) Weight:3
Edge 4:(3,4) Weight:4

Minimum cost = 10
```

1.10 Experiment - 10

1.10.1 Question:

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

1.10.2 Code:

```
#include <iostream>
#include <vector>
#include <queue>
#include <limits.h>

const int MAX_NODES = 100;
using namespace std;


vector <int> dijkstra(int V, vector<vector<int>> adj[], int S)
   {
      // Code here

      priority_queue<pair<int,int>, vector<pair<int,int>>, greater<pair<int,int>>> pq;

      vector<int> dist(V, INT_MAX);

      dist[S] = 0;

      pq.push({0,S});

      while(!pq.empty()) {
         int dis = pq.top().first;
         int node = pq.top().second;

         pq.pop();

         for(auto it: adj[node]) {
            int edgeWeight = it[1];

            int adjNode = it[0];

            if(dis+edgeWeight < dist[adjNode]) {
               dist[adjNode] = dis + edgeWeight;

               pq.push({dist[adjNode], adjNode});
            }
         }
      }
```

```
    return dist;
}


int main() {

    vector<vector<int>> adj[MAX_NODES];
    int V;
    cout << "Enter the number of vertices: ";
    cin >> V;

    while(true) {
        int u,v,w;
        cout <<endl<< "Enter edge (u v w): ";
        cin >> u >> v >> w;

        if(u==-1) {
            break;
        }
        adj[u].push_back({v,w});
        adj[v].push_back({u,w});
    }

    vector<int> res;

    res = dijkstra(V, adj, 0);

    for(auto x: res) {
        cout<<x<<" ";
    }

    return 0;
}
```

1.10.3 Output:

```
Enter the number of vertices: 4

Enter the cost adjacency matrix:
0 3 999 7
3 0 2 999
999 2 0 1
7 999 1 0

Enter the source vertex: 1
Shortest Path:
1->1=0
1->2=3
1->3=5
1->4=6
```

1.11 Experiment - 11

1.11.1 Question:

Implement “N-Queens Problem” using Backtracking.

1.11.2 Code:

```
#include <iostream>
#include <cmath>

using namespace std;

bool canPlace(int x[], int k, int i) {
    for (int j = 1; j <= k - 1; j++) {
        if (x[j] == i || abs(x[j] - i) == abs(j - k)) {
            return false;
        }
    }
    return true;
}

void nQueens(int n) {
    int x[n + 1];
    int k = 1;
    x[k] = 0;

    while (k > 0) {
        x[k]++;

        while (x[k] <= n && !canPlace(x, k, x[k])) {
            x[k]++;
        }
```

```
        if (x[k] <= n) {
            if (k == n) {
                cout << "Solution: ";
                for (int i = 1; i <= n; i++) {
                    cout << "(" << i << ", " << x[i] << ") ";
                }
                cout << endl;
            } else {
                k++;
                x[k] = 0;
            }
        } else {
            k--;
        }
    }
}

int main() {
    int n;
    cout << "Enter the number of queens: ";
    cin >> n;

    nQueens(n);

    return 0;
}
```

1.11.3 Output:

```
N Queens Problem Using Backtracking:

Enter number of Queens:4


Solution 1:

        1       2       3       4

1       -       Q       -       -

2       -       -       -       Q

3       Q       -       -       -

4       -       -       Q       -

Solution 2:

        1       2       3       4

1       -       -       Q       -

2       Q       -       -       -

3       -       -       -       Q

4       -       Q       -       -
```