M.Sc. (Five Year Integrated) in Computer Science (Artificial Intelligence & Data Science)

Third Semester

Laboratory Record

21-805-0306: ALGORITHMS LAB

Submitted in partial fulfillment
of the requirements for the award of degree in
Master of Science (Five Year Integrated)
in Computer Science (Artificial Intelligence & Data Science) of
Cochin University of Science and Technology (CUSAT)
Kochi

Submitted by

MARIYA BENNY
(80521020)

DEPARTMENT OF COMPUTER SCIENCE
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY (CUSAT)
KOCHI-682022

JANUARY 2023

DEPARTMENT OF COMPUTER SCIENCE

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY (CUSAT)

KOCHI, KERALA-682022

This is to certify that the software laboratory record for ***21-805-0306: Algorithms Lab*** *is a record of work carried out by* ***MARIYA BENNY (80521020)****in partial fulfillment of the requirements for the award of degree in* ***Master of Science (Five Year Integrated)*** *in* ***Computer Science (Artificial Intelligence & Data Science)*** *of Cochin University of Science and Technology (CUSAT), Kochi. The lab record has been approved as it satisfies the academic requirements in respect of the third semester laboratory prescribed for the Master of Science (Five Year Integrated) in Computer Science degree.*

Faculty Member in-charge

Mrs. Raheena Salihin	Dr. Philip Samuel
Guest Faculty	Professor and Head
Department of Computer Science	Department of Computer Science
CUSAT	CUSAT

Table of Contents

QUICK SORT

AIM

To write a program to sort elements using quick sort.

PROGRAM

```
#include<iostream>
#include <ctime>
#include <iomanip>
#include<cstdlib>
#include<chrono>
using namespace std;
using namespace std::chrono;
int Partition(int *A,int LB,int UB)
{
    int pivot = A[LB];
    int START = LB;
    int END = UB;
    while(START < END)
    {
        while(A[START] <= pivot)
        {
            START++;
        }
        while(A[END] > pivot)
        {
            END--;
        }
        if(START < END)
        {
            int temp = A[START];
            A[START] = A[END];
            A[END] = temp;
        }
    }
    int t1 = A[LB];
    A[LB] = A[END];
    A[END] = t1;
    return END;
```

```
}
void QuickSort(int *A,int LB,int UB)
{
    if (LB < UB)
    {
        int LOC = Partition(A,LB,UB);
        QuickSort(A,LB,LOC-1);
        QuickSort(A,LOC+1,UB);
    }
}
void display(int *A, int n)
{
    cout<<"The sorted list is : "<<"  ";
    for(int i = 0; i<n; i++)
    {
        cout<<A[i]<<" ";
    }

}
int main()
{
    int n;
    char choice;
    do
    {
        cout<<"Enter the number of elements : "<<" ";
        cin>>n;
        int A[n];
        int endpt;
        cout<<"Enter the end point : "<<" ";
        cin>>endpt;
        for(int i = 0; i<n; i++)
        {
            A[i] = 1+rand()%endpt;
        }
        cout<<"The array is : "<<"  ";
        for(int i = 0; i<n; i++)
        {
            cout<<A[i]<<" ";
        }
        cout<<endl;
```

```
        int LB = 0;
        int UB = n;
        auto start = high_resolution_clock::now();
        QuickSort(A,LB,UB);
        auto stop = high_resolution_clock::now();
    auto doneTime = duration_cast<microseconds>(stop-start);
    //cout<< " You took " <<doneTime.count() << setprecision(8) << " nanoseconds\n";
        cout<< " You took " <<doneTime.count() << " nanoseconds\n";
        display(A,n);
        cout<<endl;
        cout<<"Do you want to continue(y/n)? : "<<" ";
        cin>>choice;
    } while (choice!=’n’);
}
\newpage
```

SAMPLE INPUT-OUTPUT

```
Enter the number of elements :  10
Enter the end point :  100
The array is :   84 87 78 16 94 36 87 93 50 22
 You took 0 nanoseconds
The sorted list is :   16 22 36 50 78 84 87 87 93 94
Do you want to continue(y/n)? :  n


...Program finished with exit code 0
Press ENTER to exit console.
```

BREADTH FIRST SEARCH

AIM

To write a program to implement Breadth First Search.

PROGRAM

```
#include<iostream>
#include<vector>
#include<queue>
using namespace std;
void add_edge(vector<int>adj[],int u,int v)
{
    adj[u].push_back(v);
}
void bfs(int source,vector<int>adj[],bool visited[])
{
    queue<int>q;
    q.push(source);
    visited[source] = true;
    while(!q.empty())
    {
        int u = q.front();
        cout<<u<<" ";
        q.pop();
        //Traversal
        for(int i = 0;i<adj[u].size();i++)
        {
            if(!visited[adj[u][i]])
            {
                q.push(adj[u][i]);
                visited[adj[u][i]] = true;
            }
        }
    }
}
int main()
{
    cout<<"--------------BREADTH FIRST SEARCH----------"<<endl;
    int n,e;
    cout<<"Enter the no: of vertices : "<<" ";
```

```
    cin>>n;
    vector<int>adj[n];
    bool visited[n];
    for(int i = 0; i<5; i++)
    {
        visited[i] = false;
    }
    cout<<"Enter the no: of edges    : "<<" ";
    cin>>e;
    int a,b,s;
    for(int i = 0 ; i<e;i++)
    {
        cout<<endl;
        cout<<"EDGE "<<i+1<<endl;
        cout<<"Enter the starting point : "<<" ";
        cin>>a;
        cout<<"Enter the final point    : "<<" ";
        cin>>b;
        add_edge(adj,a,b);
    }
    cout<<endl;
    cout<<"Choose any vertex as the source : "<<" ";
    cin>>s;
    cout<<endl;
    cout<<"BFS TRAVERSAL : "<<" ";
    bfs(s,adj,visited);
    cout<<endl;
}
\newpage
```

SAMPLE INPUT-OUTPUT

```
--------------BREADTH FIRST SEARCH----------
Enter the no: of vertices :  5
Enter the no: of edges    :  5

EDGE 1
Enter the starting point :  0
Enter the final point    :  1

EDGE 2
Enter the starting point :  1
Enter the final point    :  3

EDGE 3
Enter the starting point :  3
Enter the final point    :  4

EDGE 4
Enter the starting point :  4
Enter the final point    :  2

EDGE 5
Enter the starting point :  2
Enter the final point    :  0

Choose any vertex as the source :  0

BFS TRAVERSAL :  0 1 3 4 2
```

DJKSTRA'S ALGORITHM

AIM

To write a program to implement Djkstra's Algorithm.

PROGRAM

```
#include<iostream>
#include<stdio.h>
using namespace std;
#define INF 9999
#define V 5

void dijkstra(int G[V][V],int num,int start)
{
    int cost[V][V];
    int distance[V],pred[V];
    int visited[V],count,min_dist,next,i,j;
    for(i=0;i<num;i++)            //Assigning the values (initialisation)
    {
        for(j=0;j<num;j++)
        {
            if(G[i][j]==0)
            {
                cost[i][j]=INF;
            }
            else
            {
                cost[i][j]=G[i][j];
            }
        }
    }
    for(i=0;i<num;i++)
    {
        distance[i]=cost[start][i];
        pred[i]=start;
        visited[i] = 0;
    }
    distance[start] = 0;
    visited[start] = 1;
    count = 1;
```

```
    while(count < num-1)
    {
        min_dist=INF;
        for(i=0;i<num;i++)
        {
            if(distance[i]<min_dist && !visited[i])    //Initial checking for shortest pat
            {
                min_dist=distance[i];
                next = i;
            }
        }
        visited[next] = 1;
        for(i=0;i<num;i++)
        {
            if(!visited[i])
            {
                if(min_dist+cost[next][i]<distance[i])        //Relax function
                {
                    distance[i]=min_dist+cost[next][i];
                    pred[i]=next;
                }
            }
        }
        count++;
    }
    cout<<endl;
    cout<<"Vertex"<<"       "<<"Distance"<<endl<<endl;
    for(i=0;i<num;i++)
    {
        //if(i!=start)
        {
            cout<<i<<"              "<<distance[i]<<endl;
            cout<<endl;
        }
    }
}
int main()
{
    int G[V][V];
    int source;
    for(int i = 0; i <  V; i++)
```

```
    {
        cout<<"Enter the distance from vertex "<< i <<" to each vertex : "<<" ";
        for(int j = 0;j < V; j++)
        {
            cin>>G[i][j];
        }
    }
    cout<<endl<<endl;
    cout<<"Choose any vertex as source : "<<" ";
    cin>>source;
    dijkstra(G,V,source);
    return 0;
}
\newpage
```

SAMPLE INPUT-OUTPUT

```
Enter the distance from vertex 0 to each vertex :  0 1 2 4 2 3
Enter the distance from vertex 1 to each vertex :  0 4 5 7 1 3
Enter the distance from vertex 2 to each vertex :  1 3 2 4 5 0
Enter the distance from vertex 3 to each vertex :  0 2 4 0 1 5
Enter the distance from vertex 4 to each vertex :  2 1 3 4 5 0


Choose any vertex as source :
Vertex       Distance

0              3

1              0

2              4

3              5

4              5
```

LAB CYCLE 3

BELLMAN FORD

AIM

To write a program to implement Bellman Ford Algorithm.

PROGRAM

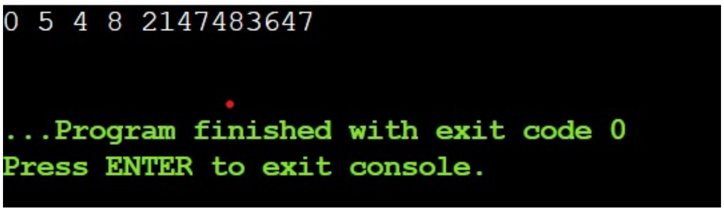
```
#include <bits/stdc++.h>

// Struct for the edges of the graph
struct Edge {
  int u;  //start vertex of the edge
  int v;  //end vertex of the edge
  int w;  //w of the edge (u,v)
};

// Graph - it consists of edges
struct Graph {
  int V;        // Total number of vertices in the graph
  int E;        // Total number of edges in the graph
  struct Edge* edge;  // Array of edges
};

// Creates a graph with V vertices and E edges
struct Graph* createGraph(int V, int E) {
  struct Graph* graph = new Graph;
  graph->V = V;  // Total Vertices
  graph->E = E;  // Total edges

  // Array of edges for graph
  graph->edge = new Edge[E];
  return graph;
}

// Printing the solution
void printArr(int arr[], int size) {
  int i;
  for (i = 0; i < size; i++) {
    printf("%d ", arr[i]);
```

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

void BellmanFord(struct Graph* graph, int u) {
  int V = graph->V;
  int E = graph->E;
  int dist[V];

  // Step 1: fill the distance array and predecessor array
  for (int i = 0; i < V; i++)
    dist[i] = INT_MAX;

  // Mark the source vertex
  dist[u] = 0;

  // Step 2: relax edges |V| - 1 times
  for (int i = 1; i <= V - 1; i++) {
    for (int j = 0; j < E; j++) {
      // Get the edge data
      int u = graph->edge[j].u;
      int v = graph->edge[j].v;
      int w = graph->edge[j].w;
      if (dist[u] != INT_MAX && dist[u] + w < dist[v])
        dist[v] = dist[u] + w;
    }
  }

  // Step 3: detect negative cycle
  // if value changes then we have a negative cycle in the graph
  // and we cannot find the shortest distances
  for (int i = 0; i < E; i++) {
    int u = graph->edge[i].u;
    int v = graph->edge[i].v;
    int w = graph->edge[i].w;
    if (dist[u] != INT_MAX && dist[u] + w < dist[v]) {
      printf("Graph contains negative w cycle");
      return;
    }
  }
```

```
  // No negative weight cycle found!
  // Print the distance and predecessor array
  printArr(dist, V);

  return;
}

int main() {
  // Create a graph
  int V = 5;  // Total vertices
  int E = 8;  // Total edges

  // Array of edges for graph
  struct Graph* graph = createGraph(V, E);

  //------- adding the edges of the graph
  /*
edge(u, v)
where  u = start vertex of the edge (u,v)
v = end vertex of the edge (u,v)

w is the weight of the edge (u,v)
*/

  //edge 0 --> 1
  graph->edge[0].u = 0;
  graph->edge[0].v = 1;
  graph->edge[0].w = 5;

  //edge 0 --> 2
  graph->edge[1].u = 0;
  graph->edge[1].v = 2;
  graph->edge[1].w = 4;

  //edge 1 --> 3
  graph->edge[2].u = 1;
  graph->edge[2].v = 3;
  graph->edge[2].w = 3;

  //edge 2 --> 1
  graph->edge[3].u = 2;
```

```
  graph->edge[3].v = 1;
  graph->edge[3].w = 6;

  //edge 3 --> 2
  graph->edge[4].u = 3;
  graph->edge[4].v = 2;
  graph->edge[4].w = 2;

  BellmanFord(graph, 0);  //0 is the source vertex

  return 0;
}
\newpage
```

SAMPLE INPUT-OUTPUT



FLOYD WARSHALL ALGORITHM

AIM

To write a program to implement Floyd Warshall Algorithm.

PROGRAM

```
#include <iostream>
#include <conio.h>
using namespace std;
void floyds(int b[][7])
{
    int i, j, k;
    for (k = 0; k < 7; k++)
    {
        for (i = 0; i < 7; i++)
        {
            for (j = 0; j < 7; j++)
            {
                if ((b[i][k] * b[k][j] != 0) && (i != j))
                {
                    if ((b[i][k] + b[k][j] < b[i][j]) || (b[i][j] == 0))
                    {
                        b[i][j] = b[i][k] + b[k][j];
                    }
                }
            }
        }
    }
    for (i = 0; i < 7; i++)
    {
        cout<<"\nMinimum Cost With Respect to Node:"<<i<<endl;
        for (j = 0; j < 7; j++)
        {
            cout<<b[i][j]<<"\t";
        }

    }
}
int main()
{
```

```
    int b[7][7];
    cout<<"ENTER VALUES OF ADJACENCY MATRIX\n\n";
    for (int i = 0; i < 7; i++)
    {
        cout<<"enter values for "<<(i+1)<<" row"<<endl;
        for (int j = 0; j < 7; j++)
        {
            cin>>b[i][j];
        }
    }
    floyds(b);
    getch();
}

\newpage
```

SAMPLE INPUT-OUTPUT

```
ENTER VALUES OF ADJACENCY MATRIX

enter values for 1 row
0 3 6 0 0 0 0
enter values for 2 row
3 0 2 4 0 0 0
enter values for 3 row
6 2 0 1 4 2 0
enter values for 4 row
0 4 1 0 2 0 4
enter values for 5 row
0 0 4 2 0 2 1
enter values for 6 row
0 0 2 0 2 0 1
enter values for 7 row
0 0 0 4 1 1 00□ □

Minimum Cost With Respect to Node:0
0     3     5     6     8     7     8
Minimum Cost With Respect to Node:1
3     0     2     3     5     4     5
Minimum Cost With Respect to Node:2
5     2     0     1     3     2     3
Minimum Cost With Respect to Node:3
6     3     1     0     2     3     3
Minimum Cost With Respect to Node:4
8     5     3     2     0     2     1
Minimum Cost With Respect to Node:5
7     4     2     3     2     0     1
Minimum Cost With Respect to Node:6
8     5     3     3     1     1     0
```

KRUSKAL'S ALGORITHM

AIM

To write a program to implement Kruskal's Algorithm.

PROGRAM

```
// Kruskal's algorithm in C++

#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

#define edge pair<int, int>

class Graph {
   private:
  vector<pair<int, edge> > G;  // graph
  vector<pair<int, edge> > T;  // mst
  int *parent;
  int V;  // number of vertices/nodes in graph
   public:
  Graph(int V);
  void AddWeightedEdge(int u, int v, int w);
  int find_set(int i);
  void union_set(int u, int v);
  void kruskal();
  void print();
};
Graph::Graph(int V) {
  parent = new int[V];

  //i 0 1 2 3 4 5
  //parent[i] 0 1 2 3 4 5
  for (int i = 0; i < V; i++)
    parent[i] = i;

  G.clear();
  T.clear();
}
```

```
void Graph::AddWeightedEdge(int u, int v, int w) {
  G.push_back(make_pair(w, edge(u, v)));
}
int Graph::find_set(int i) {
  // If i is the parent of itself
  if (i == parent[i])
    return i;
  else
    // Else if i is not the parent of itself
    // Then i is not the representative of his set,
    // so we recursively call Find on its parent
    return find_set(parent[i]);
}

void Graph::union_set(int u, int v) {
  parent[u] = parent[v];
}
void Graph::kruskal() {
  int i, uRep, vRep;
  sort(G.begin(), G.end());  // increasing weight
  for (i = 0; i < G.size(); i++) {
    uRep = find_set(G[i].second.first);
    vRep = find_set(G[i].second.second);
    if (uRep != vRep) {
      T.push_back(G[i]);  // add to tree
      union_set(uRep, vRep);
    }
  }
}
void Graph::print() {
  cout << "Edge :"
     << " Weight" << endl;
  for (int i = 0; i < T.size(); i++) {
    cout << T[i].second.first << " - " << T[i].second.second << " : "
       << T[i].first;
    cout << endl;
  }
}
int main() {
  Graph g(6);
  g.AddWeightedEdge(0, 1, 4);
```

```
  g.AddWeightedEdge(0, 2, 4);
  g.AddWeightedEdge(1, 2, 2);
  g.AddWeightedEdge(1, 0, 4);
  g.AddWeightedEdge(2, 0, 4);
  g.AddWeightedEdge(2, 1, 2);
  g.AddWeightedEdge(2, 3, 3);
  g.AddWeightedEdge(2, 5, 2);
  g.AddWeightedEdge(2, 4, 4);
  g.AddWeightedEdge(3, 2, 3);
  g.AddWeightedEdge(3, 4, 3);
  g.AddWeightedEdge(4, 2, 4);
  g.AddWeightedEdge(4, 3, 3);
  g.AddWeightedEdge(5, 2, 2);
  g.AddWeightedEdge(5, 4, 3);
  g.kruskal();
  g.print();
  return 0;
}
\newpage
```

SAMPLE INPUT-OUTPUT

```
Edge : Weight
1 - 2 : 2
2 - 5 : 2
2 - 3 : 3
3 - 4 : 3
0 - 1 : 4


...Program finished with exit code 0
Press ENTER to exit console.
```

PRIM'S ALGORITHM

AIM

To write a program to implement Prim's Algorithm.

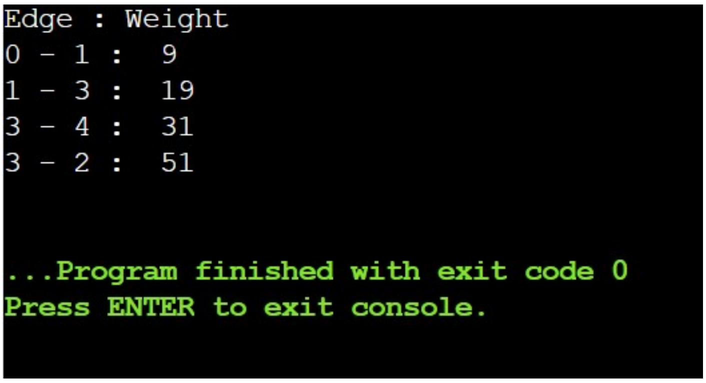
PROGRAM

```
// Prim's Algorithm in C++

#include <cstring>
#include <iostream>
using namespace std;

#define INF 9999999

// number of vertices in grapj
#define V 5

// create a 2d array of size 5x5
//for adjacency matrix to represent graph

int G[V][V] = {
  {0, 9, 75, 0, 0},
  {9, 0, 95, 19, 42},
  {75, 95, 0, 51, 66},
  {0, 19, 51, 0, 31},
  {0, 42, 66, 31, 0}};

int main() {
  int no_edge;  // number of edge

  // create a array to track selected vertex
  // selected will become true otherwise false
  int selected[V];

  // set selected false initially
  memset(selected, false, sizeof(selected));

  // set number of edge to 0
  no_edge = 0;
```

```
// the number of egde in minimum spanning tree will be
// always less than (V -1), where V is number of vertices in
//graph

// choose 0th vertex and make it true
selected[0] = true;

int x;  //  row number
int y;  //  col number

// print for edge and weight
cout << "Edge"
   << " : "
   << "Weight";
cout << endl;
while (no_edge < V - 1) {
  //For every vertex in the set S, find the all adjacent vertices
  // , calculate the distance from the vertex selected at step 1.
  // if the vertex is already in the set S, discard it otherwise
  //choose another vertex nearest to selected vertex  at step 1.

  int min = INF;
  x = 0;
  y = 0;

  for (int i = 0; i < V; i++) {
    if (selected[i]) {
      for (int j = 0; j < V; j++) {
        if (!selected[j] && G[i][j]) {  // not in selected and there is an edge
          if (min > G[i][j]) {
            min = G[i][j];
            x = i;
            y = j;
          }
        }
      }
    }
  }
  cout << x << " - " << y << " :  " << G[x][y];
  cout << endl;
  selected[y] = true;
```

```
    no_edge++;
  }

  return 0;
}
\newpage
```

SAMPLE INPUT-OUTPUT



TOPOLOGICAL SORTING

AIM

To write a program to implement Topological Sorting.

PROGRAM

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

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

cout<<"Enter the no of vertices:\n";
cin>>n;

cout<<"Enter the adjacency matrix:\n";
for(i=0;i<n;i++){
cout<<"Enter row "<<i+1<<"\n";
for(j=0;j<n;j++)
cin>>a[i][j];
}

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

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

    cout<<"\nThe topological order is:";

    while(count<n){
        for(k=0;k<n;k++){
            if((indeg[k]==0) && (flag[k]==0)){
                cout<<k+1<<" ";
                flag[k]=1;
            }
```

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

        count++;
    }

    return 0;
}
```

SAMPLE INPUT-OUTPUT

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

The topological order is:1 2 3 4 5

...Program finished with exit code 0
Press ENTER to exit console.
```

LAB CYCLE 3

MATRIX MULTIPLICATION CHAIN RULE

AIM

To write a program to implement Matrix Multiplication Chain Rule.

PROGRAM

```
#include<iostream>
#include<climits>
using namespace std;
int matOrder(int array[], int n){
   int minMul[n][n]; //holds the number of scalar multiplication needed
   for (int i=1; i<n; i++)
      minMul[i][i] = 0; //for multiplication with 1 matrix, cost is 0
      for (int length=2; length<n; length++){ //find the chain length starting from 2
         for (int i=1; i<n-length+1; i++){
            int j = i+length-1;
            minMul[i][j] = INT_MAX; //set to infinity
            for (int k=i; k<=j-1; k++){
               //store cost per multiplications
               int q = minMul[i][k] + minMul[k+1][j] + array[i-1]*array[k]*array[j];
               if (q < minMul[i][j])
                  minMul[i][j] = q;
            }
      }
   }
   return minMul[1][n-1];
}
int main(){
   int arr[] = {1, 2, 3, 4};
   int size = 4;
   cout << "Minimum number of matrix multiplications: "<<matOrder(arr, size);
}
```

SAMPLE INPUT-OUTPUT

```
Minimum number of matrix multiplications: 18

...Program finished with exit code 0
Press ENTER to exit console.
```

KNAPSACK PROBLEM

AIM

To write a program to implement Knapsack Problem.

PROGRAM

```
#include <iostream>
using namespace std;
int max(int x, int y) {
   return (x > y) ? x : y;
}
int knapSack(int W, int w[], int v[], int n) {
   int i, wt;
   int K[n + 1][W + 1];
   for (i = 0; i <= n; i++) {
      for (wt = 0; wt <= W; wt++) {
         if (i == 0 || wt == 0)
         K[i][wt] = 0;
         else if (w[i - 1] <= wt)
            K[i][wt] = max(v[i - 1] + K[i - 1][wt - w[i - 1]], K[i - 1][wt]);
         else
        K[i][wt] = K[i - 1][wt];
      }
   }
   return K[n][W];
}
int main() {
   cout << "Enter the number of items in a Knapsack:";
   int n, W;
   cin >> n;
   int v[n], w[n];
   for (int i = 0; i < n; i++) {
      cout << "Enter value and weight for item " << i << ":";
      cin >> v[i];
      cin >> w[i];
   }
   cout << "Enter the capacity of knapsack";
   cin >> W;
   cout << knapSack(W, w, v, n);
   return 0;
```

```
}
\newpage
```

SAMPLE INPUT-OUTPUT

```
Enter the number of items in a Knapsack:4
Enter value and weight for item 0:10
50
Enter value and weight for item 1:20
60
Enter value and weight for item 2:30
70
Enter value and weight for item 3:40
90
Enter the capacity of knapsack100
40

...Program finished with exit code 0
Press ENTER to exit console.
```

HUFFMAN CODE

AIM

To write a program to implement Huffman Code.

PROGRAM

```
// Huffman Coding in C++

#include <iostream>
using namespace std;

#define MAX_TREE_HT 50

struct MinHNode {
  unsigned freq;
  char item;
  struct MinHNode *left, *right;
};

struct MinH {
  unsigned size;
  unsigned capacity;
  struct MinHNode **array;
};

// Creating Huffman tree node
struct MinHNode *newNode(char item, unsigned freq) {
  struct MinHNode *temp = (struct MinHNode *)malloc(sizeof(struct MinHNode));

  temp->left = temp->right = NULL;
  temp->item = item;
  temp->freq = freq;

  return temp;
}

// Create min heap using given capacity
struct MinH *createMinH(unsigned capacity) {
  struct MinH *minHeap = (struct MinH *)malloc(sizeof(struct MinH));
  minHeap->size = 0;
```

```
  minHeap->capacity = capacity;
  minHeap->array = (struct MinHNode **)malloc(minHeap->capacity * sizeof(struct MinHNode *
  return minHeap;
}

// Print the array
void printArray(int arr[], int n) {
  int i;
  for (i = 0; i < n; ++i)
    cout << arr[i];

  cout << "\n";
}

// Swap function
void swapMinHNode(struct MinHNode **a, struct MinHNode **b) {
  struct MinHNode *t = *a;
  *a = *b;
  *b = t;
}

// Heapify
void minHeapify(struct MinH *minHeap, int idx) {
  int smallest = idx;
  int left = 2 * idx + 1;
  int right = 2 * idx + 2;

  if (left < minHeap->size && minHeap->array[left]->freq < minHeap->array[smallest]->freq)
    smallest = left;

  if (right < minHeap->size && minHeap->array[right]->freq < minHeap->array[smallest]->fre
    smallest = right;

  if (smallest != idx) {
    swapMinHNode(&minHeap->array[smallest],
           &minHeap->array[idx]);
    minHeapify(minHeap, smallest);
  }
}

// Check if size if 1
```

```
int checkSizeOne(struct MinH *minHeap) {
  return (minHeap->size == 1);
}

// Extract the min
struct MinHNode *extractMin(struct MinH *minHeap) {
  struct MinHNode *temp = minHeap->array[0];
  minHeap->array[0] = minHeap->array[minHeap->size - 1];

  --minHeap->size;
  minHeapify(minHeap, 0);

  return temp;
}

// Insertion
void insertMinHeap(struct MinH *minHeap, struct MinHNode *minHeapNode) {
  ++minHeap->size;
  int i = minHeap->size - 1;

  while (i && minHeapNode->freq < minHeap->array[(i - 1) / 2]->freq) {
    minHeap->array[i] = minHeap->array[(i - 1) / 2];
    i = (i - 1) / 2;
  }

  minHeap->array[i] = minHeapNode;
}

// BUild min heap
void buildMinHeap(struct MinH *minHeap) {
  int n = minHeap->size - 1;
  int i;

  for (i = (n - 1) / 2; i >= 0; --i)
    minHeapify(minHeap, i);
}

int isLeaf(struct MinHNode *root) {
  return !(root->left) && !(root->right);
}
```

```
struct MinH *createAndBuildMinHeap(char item[], int freq[], int size) {
  struct MinH *minHeap = createMinH(size);

  for (int i = 0; i < size; ++i)
    minHeap->array[i] = newNode(item[i], freq[i]);

  minHeap->size = size;
  buildMinHeap(minHeap);

  return minHeap;
}

struct MinHNode *buildHfTree(char item[], int freq[], int size) {
  struct MinHNode *left, *right, *top;
  struct MinH *minHeap = createAndBuildMinHeap(item, freq, size);

  while (!checkSizeOne(minHeap)) {
    left = extractMin(minHeap);
    right = extractMin(minHeap);

    top = newNode('$', left->freq + right->freq);

    top->left = left;
    top->right = right;

    insertMinHeap(minHeap, top);
  }
  return extractMin(minHeap);
}
void printHCodes(struct MinHNode *root, int arr[], int top) {
  if (root->left) {
    arr[top] = 0;
    printHCodes(root->left, arr, top + 1);
  }

  if (root->right) {
    arr[top] = 1;
    printHCodes(root->right, arr, top + 1);
  }
  if (isLeaf(root)) {
    cout << root->item << "  | ";
```

```
    printArray(arr, top);
  }
}

// Wrapper function
void HuffmanCodes(char item[], int freq[], int size) {
  struct MinHNode *root = buildHfTree(item, freq, size);

  int arr[MAX_TREE_HT], top = 0;

  printHCodes(root, arr, top);
}

int main() {
  char arr[] = {'A', 'B', 'C', 'D'};
  int freq[] = {5, 1, 6, 3};

  int size = sizeof(arr) / sizeof(arr[0]);

  cout << "Char | Huffman code ";
  cout << "\n----------------------\n";
  HuffmanCodes(arr, freq, size);
}
```

SAMPLE INPUT-OUTPUT

```
Char | Huffman code
----------------------
C   | 0
B   | 100
D   | 101
A   | 11


...Program finished with exit code 0
Press ENTER to exit console.
```

TRAVELING SALESMAN PROBLEM

AIM

To write a program to implement Traveling Salesman Problem.

PROGRAM

```
#include <bits/stdc++.h>
using namespace std;
#define vr 4
int TSP(int grph[][vr], int p) // implement traveling Salesman Problem. {
   vector<int> ver; //
   for (int i = 0; i < vr; i++)
      if (i != p)
         ver.push_back(i);
         int m_p = INT_MAX; // store minimum weight of a graph
   do {
      int cur_pth = 0;
      int k = p;
      for (int i = 0; i < ver.size(); i++) {
         cur_pth += grph[k][ver[i]];
         k = ver[i];
      }
      cur_pth += grph[k][p];
      m_p = min(m_p, cur_pth); // to update the value of minimum weight
   }
   while (next_permutation(ver.begin(), ver.end()));
   return m_p;
}
int main() {
   int grph[][vr] = { { 0, 5, 10, 15 }, //values of a graph in a form of matrix
      { 5, 0, 20, 30 },
      { 10, 20, 0, 35 },
      { 15, 30, 35, 0 }
   };
   int p = 0;
   cout<< "\n The result is: "<< TSP(grph, p) << endl;
   return 0;
}
```

SAMPLE INPUT-OUTPUT

```
The result is: 75
```