

## **ASSIGNMENT NO.5.**

### **Aim :-**

You have a business with several offices; you want to lease phone lines to connect them up with each other; and the phone company charges different amounts of money to connect different pairs of cities. You want a set of lines that connects all your offices with a minimum total cost. Solve the problem by suggesting appropriate data structures .

**Objective:-** To study the use of kruskal's and prims algorithm in given problem.

### **Theory:-** *What is Minimum Spanning Tree?*

Given a connected and undirected graph, a *spanning tree* of that graph is a subgraph that is a tree and connects all the vertices together. A single graph can have many different spanning trees. A *minimum spanning tree (MST)* or minimum weight spanning tree for a weighted, connected and undirected graph is a spanning tree with weight less than or equal to the weight of every other spanning tree. The weight of a spanning tree is the sum of weights given to each edge of the spanning tree.

*How many edges does a minimum spanning tree has?*

A minimum spanning tree has  $(V - 1)$  edges where  $V$  is the number of vertices in the given graph.

*What are the applications of Minimum Spanning Tree?*

See [this](#) for applications of MST.

Below are the steps for finding MST using Kruskal's algorithm

1. Sort all the edges in non-decreasing order of their weight.
2. Pick the smallest edge. Check if it forms a cycle with the spanning tree formed so far. If cycle is not formed, include this edge. Else, discard it.
3. Repeat step#2 until there are  $(V-1)$  edges in the spanning tree.

The step#2 uses [Union-Find algorithm](#) to detect cycle.

The algorithm is a Greedy Algorithm. The Greedy Choice is to pick the smallest weight edge that does not cause a cycle in the MST constructed so far.

### **Algorithm:-**

- create a forest  $F$  (a set of trees), where each vertex in the graph is a separate tree
- create a set  $S$  containing all the edges in the graph
- while  $S$  is nonempty and  $F$  is not yet spanning
  - remove an edge with minimum weight from  $S$
  - if the removed edge connects two different trees then add it to the forest  $F$ , combining two trees into a single tree

At the termination of the algorithm, the forest forms a minimum spanning forest of the graph. If the graph is connected, the forest has a single component and forms a minimum spanning tree.

### **Program Code:-**

```
#include <iostream>

#include<iomanip>

using namespace std;

const int MAX=10;

class EdgeList; //forward declaration

class Edge      //USED IN KRUSKAL
{
    int u,v,w;
public:
    Edge(){} //Empty Constructor
    Edge(int a,int b,int weight)
    {
        u=a;
        v=b;
        w=weight;
    }
    friend class EdgeList;
    friend class PhoneGraph;
};

//---- EdgeList Class -----
```

```
class EdgeList
{
    Edge data[MAX];
    int n;
public:
    friend class PhoneGraph;
    EdgeList()
    { n=0;}
    void sort();
    void print();

};

//----Bubble Sort for sorting edges in increasing weights' order ---//
void EdgeList::sort()
{
    Edge temp;
    for(int i=1;i<n;i++)
        for(int j=0;j<n-1;j++)
            if(data[j].w>data[j+1].w)
            {
                temp=data[j];
                data[j]=data[j+1];
                data[j+1]=temp;
            }
}
```

```
void EdgeList::print()
{
    int cost=0;
    for(int i=0;i<n;i++)
    {
        cout<<"\n"<<i+1<<" "<<data[i].u<<"--"<<data[i].v<<" = "<<data[i].w;
        cost=cost+data[i].w;
    }
    cout<<"\nMinimum cost of Telephone Graph = "<<cost;
}

//----- Phone Graph Class-----

class PhoneGraph
{
    int data[MAX][MAX]={0, 28, 0, 0, 0,10,0},
        {28,0,16,0,0,0,14},
        {0,16,0,12,0,0,0},
        {0,0,12,0,22,0,18},
        {0,0,0,22,0,25,24},
        {10,0,0,0,25,0,0},
        {0,14,0,18,24,0,0},
    };
    int n;

public:
    PhoneGraph(int num)
```

```
{  
    n=num;  
}  
  
void readgraph();  
void printGraph();  
int mincost(int cost[],bool visited[];  
int prim();  
void kruskal(EdgeList &spanlist);  
int find(int belongs[], int vertexno);  
void unionComp(int belongs[], int c1,int c2);  
};  
void PhoneGraph::readgraph()  
{  
    cout<<"Enter Adjacency(Cost) Matrix: \n";  
    for(int i=0;i<n;i++)  
    {  
        for(int j=0;j<n; j++)  
            cin>>data[i][j];  
    }  
}  
void PhoneGraph::printGraph()  
{  
    cout<<"\nAdjacency (COST) Matrix: \n";  
    for(int i=0;i<n;i++)  
    {
```

```
        for(int j=0;j<n;j++)
        {
            cout<<setw(3)<<data[i][j];

        }
        cout<<endl;
    }
}

int PhoneGraph::mincost(int cost[],bool visited[]) //finding vertex with minimum cost
{
    int min=9999,min_index; //initialize min to MAX value(ANY) as temporary
    for(int i=0;i<n;i++)
    {
        if(visited[i]==0 && cost[i]<min)
        {
            min=cost[i];
            min_index=i;
        }
    }

    return min_index; //return index of vertex which is not visited and having
    minimum cost

}

int PhoneGraph::prim()
{
    bool visited[MAX];
```

```
int parents[MAX]; //storing vertices
int cost[MAX]; //saving minimum cost
for(int i=0;i<n;i++)
{
    cost[i]=9999; //set cost as infinity/MAX_VALUE
    visited[i]=0; //initialize visited array to false
}

cost[0]=0; //starting vertex cost
parents[0]=-1; //make first vertex as a root

for(int i=0;i<n-1;i++)
{
    int k=mincost(cost,visited); //minimum cost elements index
    visited[k]=1; //set visited

    for(int j=0;j<n;j++)//for adjacent vertices comparison
    {
        if(data[k][j] && visited[j]==0 && data[k][j] < cost[j])
        {
            parents[j]=k;
            cost[j]=data[k][j];
        }
    }
}
```

```

    cout<<"Minimum Cost Telephone Map:\n";
    for(int i=1;i<n;i++)
    {
        cout<<i<<" -- "<<parents[i]<<" = "<<cost[i]<<endl;
    }
    int mincost=0;
    for (int i = 1; i < n; i++)
        mincost+=cost[i];                //data[i][parents[i]];
    return mincost;
}
//----- Kruskal's Algorithm
void PhoneGraph::kruskal(EdgeList &spanlist)
{
    int belongs[MAX]; //Separate Components at start (No Edges, Only vertices)
    int cno1,cno2;    //Component 1 & 2
    EdgeList elist;
    for(int i=1;i<n;i++)
        for(int j=0;j<i;j++)
        {
            if(data[i][j]!=0)
            {
                elist.data[elist.n]=Edge(i,j,data[i][j]); //constructor for
initializing edge
                elist.n++;
            }
        }
}

```



```

        }

        elist.sort(); //sorting in increasing weight order
        for(int i=0;i<n;i++)
            belongs[i]=i;

        for(int i=0;i<elist.n;i++)
        {
            cno1=find(belongs,elist.data[i].u); //find set of u
            cno2=find(belongs,elist.data[i].v); //find set of v
            if(cno1!=cno2) //if u & v belongs to different sets
            {
                spanlist.data[spanlist.n]=elist.data[i]; //ADD Edge to spanlist
                spanlist.n=spanlist.n+1;
                unionComp(belongs,cno1,cno2); //ADD both components to same
set
            }
        }
    }

void PhoneGraph::unionComp(int belongs[],int c1,int c2)
{
    for(int i=0;i<n;i++)
    {
        if(belongs[i]==c2)
            belongs[i]=c1;
    }
}

```

```
}  
  
int PhoneGraph::find(int belongs[],int vertexno)  
{  
    return belongs[vertexno];  
}  
  
//----- MAIN PROGRAM-----  
  
int main() {  
    int vertices,choice;  
    EdgeList spantree;  
    cout<<"Enter Number of cities: ";  
    cin>>vertices;  
    PhoneGraph p1(vertices);  
    //p1.readgraph();  
    do  
    {  
        cout<<"\n1.Find Minimum Total Cost(By Prim's Algorithm)"  
        <<"\n2.Find Minimum Total Cost(by Kruskal's Algorithms)"  
        <<"\n3.Re-Read Graph(INPUT)"  
        <<"\n4.Print Graph"  
        <<"\n0. Exit"  
        <<"\nEnter your choice: ";  
        cin>>choice;  
        switch(choice)  
        {
```

```
        case 1:
            cout<<" Minimum cost of Phone Line to cities is: "<<p1.prim();
            break;
        case 2:
            p1.kruskal(spantree);
            spantree.print();
            break;
        case 3:
            p1.readgraph();
            break;
        case 4:
            p1.printGraph();
            break;
        default:
            cout<<"\nWrong Choice!!!";
    }
}while(choice!=0);

return 0;
}

/* Sample INPUT: vertices =7
*      {{0, 28, 0, 0, 0,10,0},
      {28,0,16,0,0,0,14},
      {0,16,0,12,0,0,0},
      {0,0,12,0,22,0,18},
```

{0,0,0,22,0,25,24},

{10,0,0,0,25,0,0},

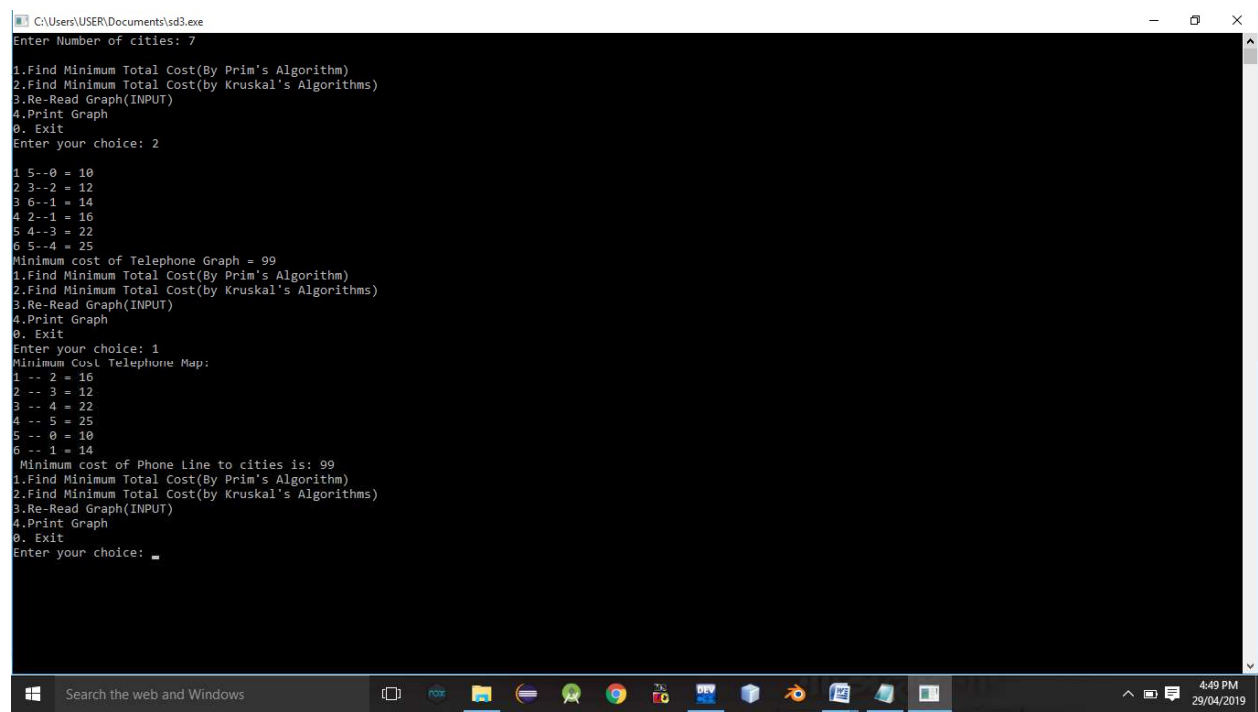
{0,14,0,18,24,0,0},

};

Minimum Cost: 99

\*/

## Output Screenshots:-



```
C:\Users\USER\Documents\sd3.exe
Enter Number of cities: 7
1.Find Minimum Total Cost(By Prim's Algorithm)
2.Find Minimum Total Cost(by Kruskal's Algorithms)
3.Re-Read Graph(INPUT)
4.Print Graph
0. Exit
Enter your choice: 2
1 5--0 = 10
2 3--2 = 12
3 6--1 = 14
4 2--1 = 16
5 4--3 = 22
6 5--4 = 25
Minimum cost of Telephone Graph = 99
1.Find Minimum Total Cost(By Prim's Algorithm)
2.Find Minimum Total Cost(by Kruskal's Algorithms)
3.Re-Read Graph(INPUT)
4.Print Graph
0. Exit
Enter your choice: 1
Minimum Cost Telephone Map:
1 -- 2 = 16
2 -- 3 = 12
3 -- 4 = 22
4 -- 5 = 25
5 -- 0 = 10
6 -- 1 = 14
Minimum cost of Phone Line to cities is: 99
1.Find Minimum Total Cost(By Prim's Algorithm)
2.Find Minimum Total Cost(by Kruskal's Algorithms)
3.Re-Read Graph(INPUT)
4.Print Graph
0. Exit
Enter your choice: _
```

**Conclusion:-** Thus,we have studied implementation of kruskal's algorithm.