Graph Theory

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2k16/MC/023

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Mathematics and Computing

Submitted to:

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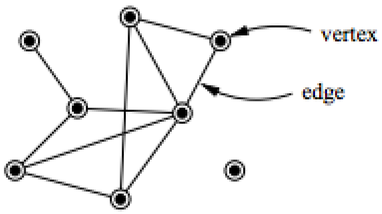
Content

SNo.	Practical Name / Description	Date	Remarks
1)	Write a program to find the number of vertices , even vertices , odd vertices and the number of edges in a graph		
2)	Write a program to find UNION, INTERSECTION and RING SUM of two graphs.		
3)	Write a program to find minimum spannin tree of a graph using Prim's Algorithm.		
4)	Write a program to find minimum spanning tree of a graph using Kruskal's Algorithm.		
5)	between 2 vertices in a graph using Disjkstra's Algorithm.		
6)	between every pair of vertices in a graph using Floyd Warshall's algorithm.		
7)	Write a program to find shortest path between every pair of vertices in a graph using Bellman Ford's algorithm.		
8)	Write a program to find maximum matching in a bipartite graph.		
9)	Write a program to find maximum matching for general graph.		
10)	Write a program to find max flow from source node to sink using Ford- Fulkerson algorithm.		

Practical 1:

Aim: Write a program to find the number of vertices, even vertices, odd vertices and the number of edges in a graph.



URL to Code: https://ide.geeksforgeeks.org/XlvtxaYHHN

Code:

```
#include<bits/stdc++.h>
#include<iostream>
#include<string>
#include<algorithm>
using namespace std;
class Graph
{
	int V;
	list < int >* adj;
public:
	Graph(int V)
	{
		this->V = V;
		adj = new list<int>[V];
	}
	void addEdge(int u, int v);
	int countEdges();
	void count_evenOdd();
};
void Graph::addEdge(int u, int v)
{
	adj[u].push_back(v);
	adj[v].push_back(u);
}
int Graph::countEdges()
{
	int sum = 0;
	for (int i = 0; i < V; i++)
		sum += adj[i].size();
	return sum / 2;
}
void Graph::count_evenOdd() {
	int even_degree = 0, odd_degree = 0;
	for (int i = 0; i < V; i++) {
		int degree = adj[i].size();
		if (degree % 2 == 0)
			even_degree++;
		else
```

```
                    odd_degree++;
        }
        cout << "No. of even vertices:" << even_degree << endl;
        cout << "No. of odd vertices:" << odd_degree << endl;
}
int main()
{
        int V, E, u, v, w;
        // cout<<"No. of Vertices:";
        cin >> V;
        // cout<<"No. of Edges:";
        cin >> E;
        Graph g(V);
        for (int i = 0; i < E; i++) {
                cin >> u;
                cin >> v;
                g.addEdge(u, v);
        }
        cout << "No.of vertices : " << V << endl;
        g.count_evenOdd();
        cout << "No.of edges : " << g.countEdges() << endl;
        return 0;
}
```

Output:

```
9
14
01
07
1 2
1 7
2 3
2 8
2 5
```

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https://ide.geeksforgeeks.org/XlvtxaYHHN

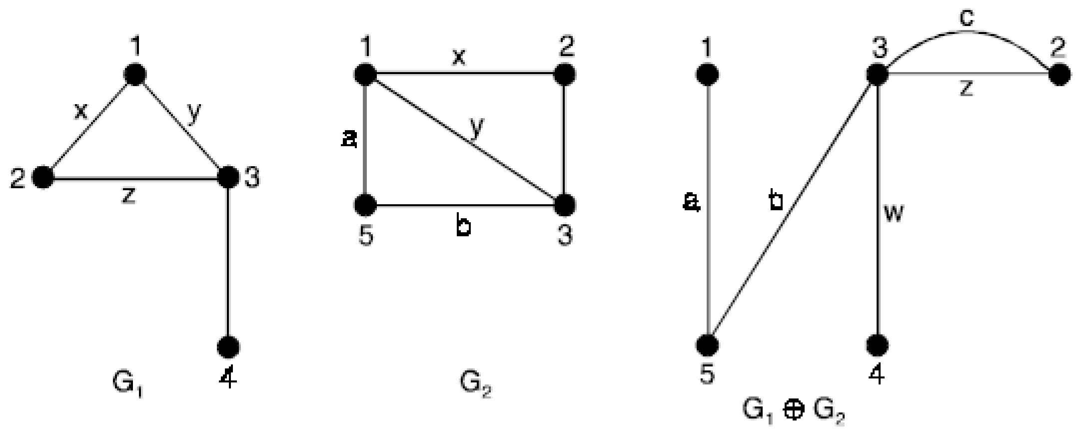
Output:

Copy

```
No.of vertices : 9
No. of even vertices:5
No. of odd vertices:4
No.of edges : 14
```

Practical 2:

Aim: Write a program to find UNION, INTERSECTION and RING SUM of two graphs.



URL to Code: https://ide.geeksforgeeks.org/L1GNIw3tuu

Code:

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

using namespace std;
int unionPrint(int arr1[], int arr2[], int m, int n)
{
	int i = 0, j = 0;
	while (i < m && j < n)
	{
		if (arr1[i] < arr2[j])
			printf(" %d ", arr1[i++]);
		else if (arr2[j] < arr1[i])
			printf(" %d ", arr2[j++]);
		else
		{
			printf(" %d ", arr2[j++]);
			i++;
		}
	}
	while (i < m)
		printf(" %d ", arr1[i++]);
	while (j < n)
		printf(" %d ", arr2[j++]);
}
int intersectionPrint(int arr1[], int arr2[], int m, int n)
{
	int i = 0, j = 0;
	while (i < m && j < n)
	{
		if (arr1[i] < arr2[j])
			i++;
		else if (arr2[j] < arr1[i])
			j++;
		else
```

```
                {
                        printf(" %d ", arr2[j++]);
                        i++;
                }
        }
}
int main()
{
        int m, n, i, j, k;
        cout << "Enter the number of vertices in G1 & G2 : ";
        cin >> m >> n;
        int V1[m], V2[n];
        for (i = 0; i < m; i++)
        {
                V1[i] = i;
        }
        for (i = 0; i < n; i++) {
                V2[i] = i;
        }
        int E1[m][m], E2[n][n], E3[m + n][m + n];
        printf("Enter the adjacency matrix(symmetric) for graph G1:\n");
        for (i = 0; i < m; i++)
        {
                for (j = 0; j < m; j++)
                {
                        printf("E1[%d][%d]=", i, j);
                        scanf("%d", &E1[i][j]);
                }
        }
        printf("Enter the adjacency matrix(symmetric) for graph G2:\n");
        for (i = 0; i < n; i++)
        {
                for (j = 0; j < n; j++)
                {
                        printf("E2[%d][%d]=", i, j);
                        scanf("%d", &E2[i][j]);
                }
        }
        printf("\nSet of vertices in union of the graphs G1 and G2 is:\n");
        unionPrint(V1, V2, m, n);
        printf("\n");
        for (i = 0; i < n; i++)
        {
                for (j = 0; j < n; j++)
                {
                        if (E1[i][j] > E2[i][j] && i < m && j < m)
                                E3[i][j] = E1[i][j];
                        else if (E1[i][j] < E2[i][j] && i < m && j < m)
                                E3[i][j] = E2[i][j];
                        else
                                E3[i][j] = E2[i][j];
                }
        }
        printf("Adjacency matrix of union of graphs G1 and G2 is:\n\t");
        for (i = 0; i < n; i++)
        {
                Cout<<"%d\t"<< i;
        }
        printf("\n\t");
        for (i = 0; i < n; i++)
        {
                printf("_______");
```

```c
}
for (i = 0; i < n; i++)
{
	printf("\n%d|\t", i);
	for (j = 0; j < n; j++)
	{
		printf("%d\t", E3[i][j]);
	}
}
printf("\nSet of vertices in intersection of the graphs G1 and G2 is:\n");
intersectionPrint(V1, V2, m, n);
printf("\n");
for (i = 0; i < m; i++)
{
	for (j = 0; j < m; j++)
	{
		if (E1[i][j] > E2[i][j])
			E3[i][j] = E1[i][j];
		else
			E3[i][j] = E2[i][j];
	}
}
printf("Adjacency matrix of intersection of graphs G1 and G2 is:\n\t");
for (i = 0; i < m; i++)
{
	printf("%d\t", i);
}
printf("\n\t");
for (i = 0; i < m; i++)
{
	printf("_______");
}
for (i = 0; i < m; i++)
{
	printf("\n%d|\t", i);
	for (j = 0; j < m; j++)
	{
		printf("%d\t", E3[i][j]);
	}
}
printf("\nSet of vertices in ring sum of the graphs G1 and G2 is:\n");
printUnion(V1, V2, m, n);
printf("\n");
for (i = 0; i < n; i++)
{
	for (j = 0; j < n; j++)
	{
		if (E1[i][j] == E2[i][j] && i < m && j < m)
			E3[i][j] = 0;
		else if (E1[i][j] < E2[i][j] && i < m && j < m)
			E3[i][j] = E2[i][j];
		if (E1[i][j] < E2[i][j] && i < m && j < m)
			E3[i][j] = E1[i][j];
		else
			E3[i][j] = E2[i][j];
	}
}
printf("Adjacency matrix of ring sum of graphs G1 and G2 is:\n\t");
for (i = 0; i < n; i++)
{
	printf("%d\t", i);
}
```

```
        printf("\n\t");
        for (i = 0; i < n; i++)
        {
                printf("_______");
        }
        for (i = 0; i < n; i++)
        {
                Cout<<"\n%d|\t"<<i
                for (j = 0; j < n; j++)
                {
                        Cout<<"%d\t"<< E3[i][j];
                }
        }
        return 0;
}
```

Output:

```
2 3
0
1
1
1
0
0
1
0
```

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https://ide.geeksforgeeks.org/L1GNIw3tuu

Output:

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```
Enter the number of vertices in G1 & G2 : Enter the adjacency matrix(symmetric) for graph G1:
E1[0][0]=E1[0][1]=E1[1][0]=E1[1][1]=Enter the adjacency matrix(symmetric) for graph G2:
E2[0][0]=E2[0][1]=E2[0][2]=E2[1][0]=E2[1][1]=E2[1][2]=E2[2][0]=E2[2][1]=E2[2][2]=
Set of vertices in union of the graphs G1 and G2 is:
 0  1  2
Adjacency matrix of union of graphs G1 and G2 is:
        0       1       2
        _____________________
0|      0       1       1
1|      1       1       1
```

Practical 3:

Aim: Write a program to find minimum spanning tree of a graph using Prim's Algorithm.

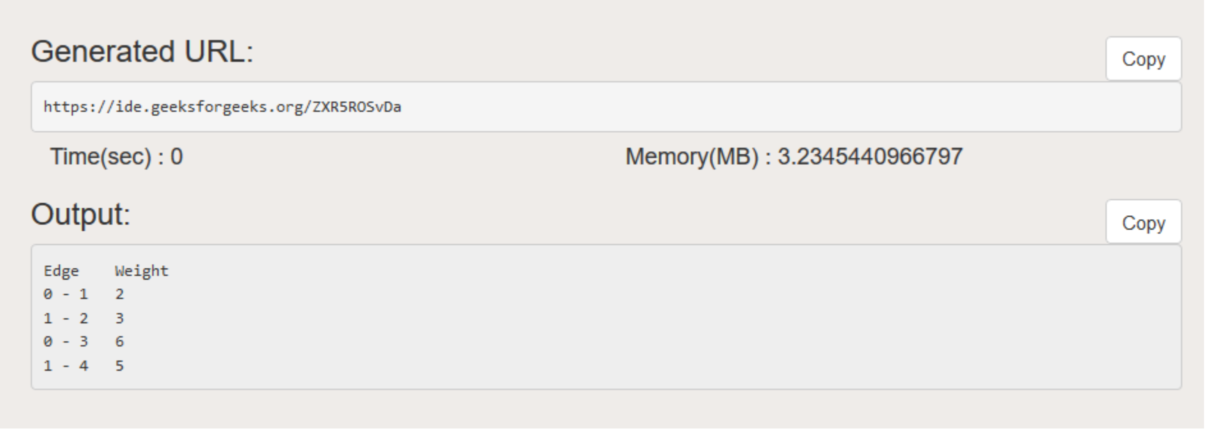
URL to Code: https://ide.geeksforgeeks.org/ZXR5ROSvDa

Code:

```
#include <bits/stdc++.h>
using namespace std;

// Number of vertices in the graph
#define V 5


int minKey(int key[], bool mstSet[])
{
	// Initialize min value
	int min = INT_MAX, min_index;

	for (int v = 0; v < V; v++)
		if (mstSet[v] == false && key[v] < min)
			min = key[v], min_index = v;

	return min_index;
}


void printMST(int parent[], int graph[V][V])
{
	cout << "Edge \tWeight\n";
	for (int i = 1; i < V; i++)
		cout << parent[i] << " - " << i << " \t" << graph[i][parent[i]] << " 
\n";
}


void primMST(int graph[V][V])
{
	// Array to store constructed MST
	int parent[V];

	// Key values used to pick minimum weight edge in cut
	int key[V];

	// To represent set of vertices not yet included in MST
	bool mstSet[V];

	// Initialize all keys as INFINITE
	for (int i = 0; i < V; i++)
		key[i] = INT_MAX, mstSet[i] = false;

	// Always include first 1st vertex in MST.
	// Make key 0 so that this vertex is picked as first vertex.
	key[0] = 0;
```

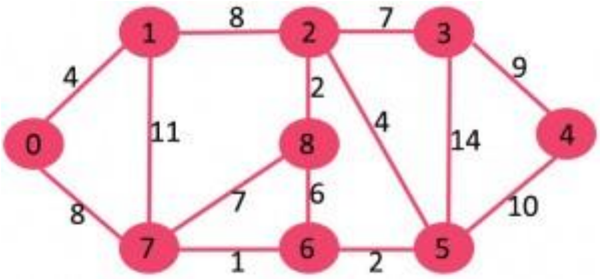
```
        parent[0] = -1; // First node is always root of MST

        // 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);

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

                // Update key value and parent index of
                // the adjacent vertices of the picked vertex.
                // Consider only those vertices which are not
                // yet included in MST
                for (int v = 0; v < V; v++)

                        // graph[u][v] is non zero only for adjacent vertices of m
                        // mstSet[v] is false for vertices not yet included in MST
                        // Update the key only if graph[u][v] is smaller than key[v]
                        if (graph[u][v] && mstSet[v] == false && graph[u][v] < key[v])
                                parent[v] = u, key[v] = graph[u][v];
        }

        // print the constructed MST
        printMST(parent, graph);
}

// Driver code
int main()
{

        int graph[V][V] = { { 0, 2, 0, 6, 0 },
                                                { 2, 0, 3, 8, 5 },
                                                { 0, 3, 0, 0, 7 },
                                                { 6, 8, 0, 0, 9 },
                                                { 0, 5, 7, 9, 0 } };

        // Print the solution
        primMST(graph);

        return 0;
}
```

Output:



Practical 4:

Aim: Write a program to find minimum spanning tree of a graph using Kruskal's Algorithm.



URL to Code: https://ide.geeksforgeeks.org/TvR0AjbQIR

Code:

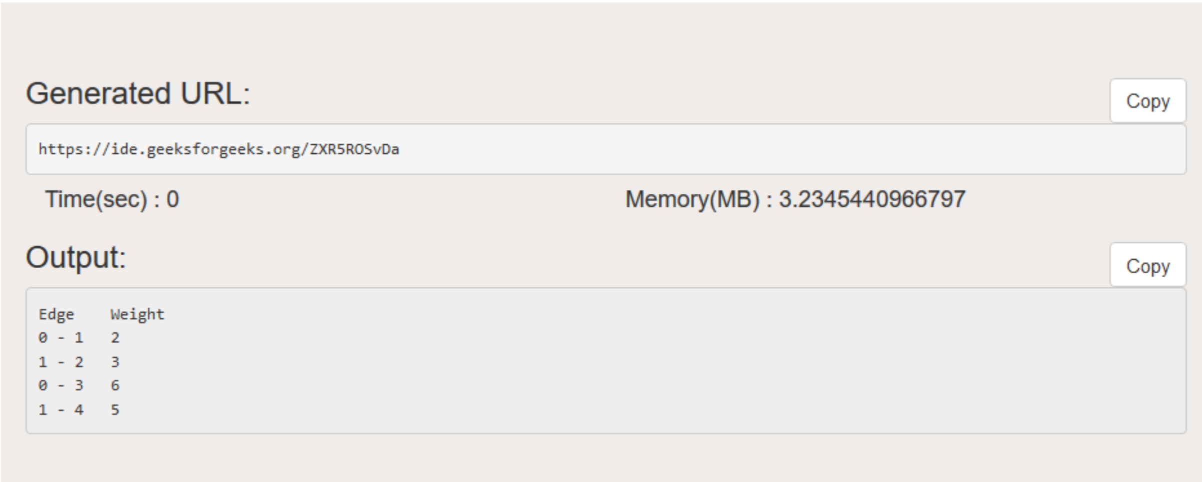
```
#include <bits/stdc++.h>
using namespace std;

// a structure to represent a weighted edge in graph
class Edge
{
public:
	int src, dest, weight;
};

// a structure to represent a connected, undirected
// and weighted graph
class Graph
{
public:
	// V-> Number of vertices, E-> Number of edges
	int V, E;


	Edge* edge;
};

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

	graph->edge = new Edge[E];

	return graph;
}

// A structure to represent a subset for union-find
class subset
{
public:
```

```
	int parent;
	int rank;
};

// A utility function to find set of an element i
// (uses path compression technique)
int find(subset subsets[], int i)
{
	// find root and make root as parent of i
	// (path compression)
	if (subsets[i].parent != i)
		subsets[i].parent = find(subsets, subsets[i].parent);

	return subsets[i].parent;
}

// A function that does union of two sets of x and y
// (uses union by rank)
void Union(subset subsets[], int x, int y)
{
	int xroot = find(subsets, x);
	int yroot = find(subsets, y);

	// Attach smaller rank tree under root of high
	// rank tree (Union by Rank)
	if (subsets[xroot].rank < subsets[yroot].rank)
		subsets[xroot].parent = yroot;
	else if (subsets[xroot].rank > subsets[yroot].rank)
		subsets[yroot].parent = xroot;

	// If ranks are same, then make one as root and
	// increment its rank by one
	else
	{
		subsets[yroot].parent = xroot;
		subsets[xroot].rank++;
	}
}

// Compare two edges according to their weights.
// Used in qsort() for sorting an array of edges
int myComp(const void* a, const void* b)
{
	Edge* a1 = (Edge*)a;
	Edge* b1 = (Edge*)b;
	return a1->weight > b1->weight;
}

// The main function to construct MST using Kruskal's algorithm
void KruskalMST(Graph* graph)
{
	int V = graph->V;
	Edge result[V]; // Tnis will store the resultant MST
	int e = 0; // An index variable, used for result[]
	int i = 0; // An index variable, used for sorted edges

	// Step 1: Sort all the edges in non-decreasing order

	qsort(graph->edge, graph->E, sizeof(graph->edge[0]), myComp);

	// Allocate memory for creating V ssubsets
	subset* subsets = new subset[(V * sizeof(subset))];
```

```
	// Create V subsets with single elements
	for (int v = 0; v < V; ++v)
	{
		subsets[v].parent = v;
		subsets[v].rank = 0;
	}

	// Number of edges to be taken is equal to V-1
	while (e < V - 1 && i < graph->E)
	{
		// Step 2: Pick the smallest edge. And increment
		// the index for next iteration
		Edge next_edge = graph->edge[i++];

		int x = find(subsets, next_edge.src);
		int y = find(subsets, next_edge.dest);

		// If including this edge does't cause cycle,
		// include it in result and increment the index
		// of result for next edge
		if (x != y)
		{
			result[e++] = next_edge;
			Union(subsets, x, y);
		}
		// Else discard the next_edge
	}

	// print the contents of result[] to display the
	// built MST
	cout << "Following are the edges in the constructed MST\n";
	for (i = 0; i < e; ++i)
		cout << result[i].src << " -- " << result[i].dest << " == " <<
result[i].weight << endl;
	return;
}

// Driver code
int main()
{

	int V = 4; // Number of vertices in graph
	int E = 5; // Number of edges in graph
	Graph* graph = createGraph(V, E);


	// add edge 0-1
	graph->edge[0].src = 0;
	graph->edge[0].dest = 1;
	graph->edge[0].weight = 10;

	// add edge 0-2
	graph->edge[1].src = 0;
	graph->edge[1].dest = 2;
	graph->edge[1].weight = 6;

	// add edge 0-3
	graph->edge[2].src = 0;
	graph->edge[2].dest = 3;
	graph->edge[2].weight = 5;
```

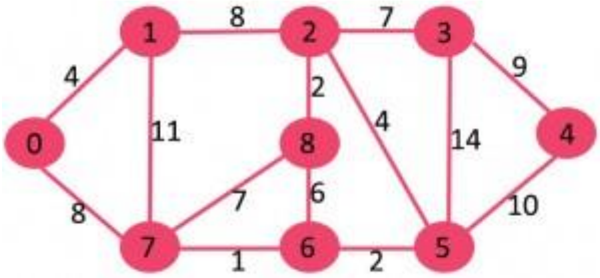
```
        // add edge 1-3
        graph->edge[3].src = 1;
        graph->edge[3].dest = 3;
        graph->edge[3].weight = 15;

        // add edge 2-3
        graph->edge[4].src = 2;
        graph->edge[4].dest = 3;
        graph->edge[4].weight = 4;

        KruskalMST(graph);

        return 0;
}
```

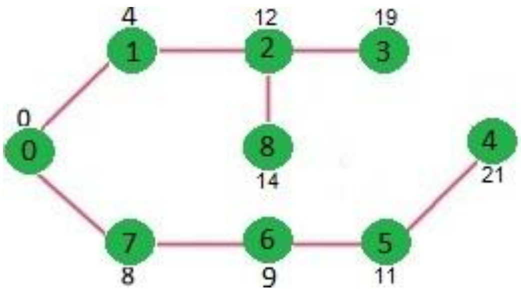
Output:



Practical 5:

Aim: Write a program to find shortest path between 2 vertices in a graph using Dijkstra's Algorithm.





URL to Code: https://ide.geeksforgeeks.org/TvR0AjbQIR

Code:

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


#define V 9


int minDistance(int dist[], bool sptSet[])
{
	// Initialize min value
	int min = INT_MAX, min_index;

	for (int v = 0; v < V; v++)
		if (sptSet[v] == false && dist[v] <= min)
			min = dist[v], min_index = v;

	return min_index;
}


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

```
}

void dijkstra(int graph[V][V], int src)
{
	int dist[V]; // The output array.  dist[i] will hold the shortest
	// distance from src to i

	bool sptSet[V]; // sptSet[i] will be true if vertex i is included in shortest
	// path tree or shortest distance from src to i is finalized

	// Initialize all distances as INFINITE and stpSet[] as false
	for (int i = 0; i < V; i++)
		dist[i] = INT_MAX, sptSet[i] = false;

	// Distance of source vertex from itself is always 0
	dist[src] = 0;

	// Find shortest path for all vertices
	for (int count = 0; count < V - 1; count++) {
		// Pick the minimum distance vertex from the set of vertices not
		// yet processed. u is always equal to src in the first iteration.
		int u = minDistance(dist, sptSet);

		// Mark the picked vertex as processed
		sptSet[u] = true;

		// Update dist value of the adjacent vertices of the picked vertex.
		for (int v = 0; v < V; v++)

			// Update dist[v] only if is not in sptSet, there is an edge from
			// u to v, and total weight of path from src to  v through u is
			// smaller than current value of dist[v]
			if (!sptSet[v] && graph[u][v] && dist[u] != INT_MAX
				&& dist[u] + graph[u][v] < dist[v])
				dist[v] = dist[u] + graph[u][v];
	}

	// print the constructed distance array
	printSolution(dist);
}

// driver program to test above function
int main()
{

	int graph[V][V] = { { 0, 4, 0, 0, 0, 0, 0, 8, 0 },
						{ 4, 0, 8, 0, 0, 0, 0, 11, 0 },
						{ 0, 8, 0, 7, 0, 4, 0, 0, 2 },
						{ 0, 0, 7, 0, 9, 14, 0, 0, 0 },
						{ 0, 0, 0, 9, 0, 10, 0, 0, 0 },
						{ 0, 0, 4, 14, 10, 0, 2, 0, 0 },
						{ 0, 0, 0, 0, 0, 2, 0, 1, 6 },
						{ 8, 11, 0, 0, 0, 0, 1, 0, 7 },
						{ 0, 0, 2, 0, 0, 0, 6, 7, 0 } };

	dijkstra(graph, 0);

	return 0;
}
```

Output:

Generated URL:

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```
https://ide.geeksforgeeks.org/dXD1gYHTyw
```

Time(sec) : 0

Memory(MB) : 1.4835064990234

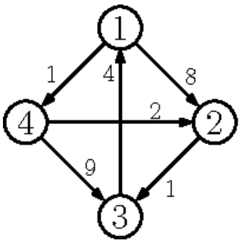
Output:

Copy

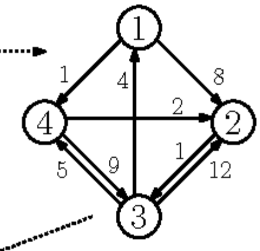
```
Vertex          Distance from Source
0               0
1               4
2               12
3               19
4               21
5               11
6               9
7               8
8               14
```

Practical 6:

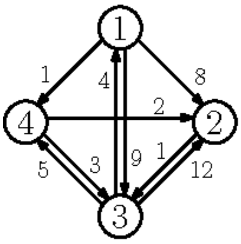
Aim: Write a program to find shortest path between every pair of vertices in a graph using Floyd Warshall's algorithm.



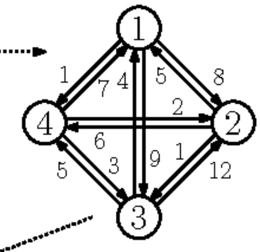
$$d^{(0)} = \begin{bmatrix} 0 & 8 & \infty & 1 \\ \infty & 0 & 1 & \infty \\ 4 & \infty & 0 & \infty \\ \infty & 2 & 9 & 0 \end{bmatrix}$$



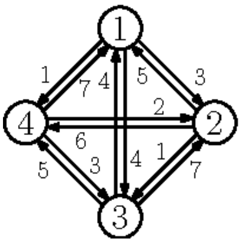
$$d^{(1)} = \begin{bmatrix} 0 & 8 & \infty & 1 \\ \infty & 0 & 1 & \infty \\ 4 & 12 & 0 & 5 \\ \infty & 2 & 9 & 0 \end{bmatrix}$$



$$d^{(2)} = \begin{bmatrix} 0 & 8 & 9 & 1 \\ \infty & 0 & 1 & \infty \\ 4 & 12 & 0 & 5 \\ \infty & 2 & 3 & 0 \end{bmatrix}$$



$$d^{(3)} = \begin{bmatrix} 0 & 8 & 9 & 1 \\ 5 & 0 & 1 & 6 \\ 4 & 12 & 0 & 5 \\ 7 & 2 & 3 & 0 \end{bmatrix}$$



$$d^{(4)} = \begin{bmatrix} 0 & 3 & 4 & 1 \\ 5 & 0 & 1 & 6 \\ 4 & 7 & 0 & 5 \\ 7 & 2 & 3 & 0 \end{bmatrix}$$

$$\text{final} = \begin{bmatrix} 0 & 3 & 4 & 1 \\ 5 & 0 & 1 & 6 \\ 4 & 7 & 0 & 5 \\ 7 & 2 & 3 & 0 \end{bmatrix}$$

URL to Code: https://ide.geeksforgeeks.org/LJBGuaqtQm

Code:

```
#include <bits/stdc++.h>
using namespace std;

// Number of vertices in the graph
#define V 4

#define INF 99999


void printSolution(int dist[][V]);


void floydWarshall(int graph[][V])
{

       int dist[V][V], i, j, k;
```

```
	for (i = 0; i < V; i++)
		for (j = 0; j < V; j++)
			dist[i][j] = graph[i][j];


	for (k = 0; k < V; k++)
	{
		// Pick all vertices as source one by one
		for (i = 0; i < V; i++)
		{
			// Pick all vertices as destination for the
			// above picked source
			for (j = 0; j < V; j++)
			{
				// If vertex k is on the shortest path from
				// i to j, then update the value of dist[i][j]
				if (dist[i][k] + dist[k][j] < dist[i][j])
					dist[i][j] = dist[i][k] + dist[k][j];
			}
		}
	}

	// Print the shortest distance matrix
	printSolution(dist);
}

/* A utility function to print solution */
void printSolution(int dist[][V])
{
	cout << "The following matrix shows the 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)
				cout << "INF" << "     ";
			else
				cout << dist[i][j] << "     ";
		}
		cout << endl;
	}
}

// Driver code
int main()
{

	int graph[V][V] = { {0, 5, INF, 10},
						{INF, 0, 3, INF},
						{INF, INF, 0, 1},
						{INF, INF, INF, 0}
	};

	// Print the solution
	floydWarshall(graph);
	return 0;
}
```

Output:

Generated URL:

Copy

```
https://ide.geeksforgeeks.org/LJBGuaqtQm
```

Time(sec) : 0   Memory(MB) : 3.1798970120239

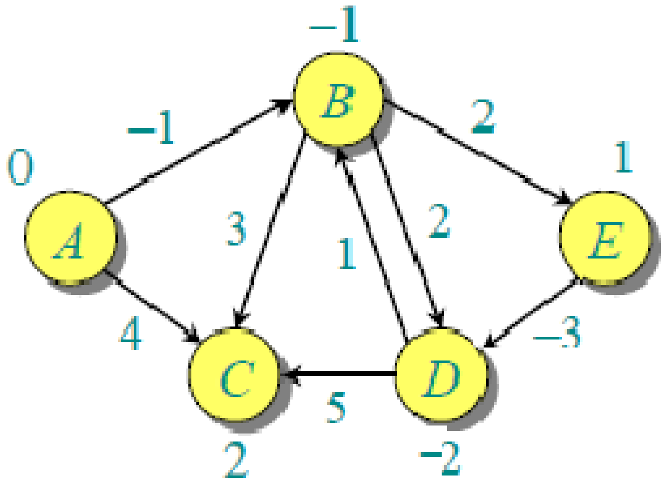
Output:

Copy

```
The following matrix shows the shortest distances between every pair of vertices
0      5      8      9
INF      0      3      4
INF      INF      0      1
INF      INF      INF      0
```

Practical 7:

Aim: Write a program to find shortest path between every pair of vertices in a graph using Bellman Ford's algorithm.



A	*B*	*C*	*D*	*E*
0	∞	∞	∞	∞
0	–1	∞	∞	∞
0	–1	4	∞	∞
0	–1	2	∞	∞
0	–1	2	∞	1
0	–1	2	1	1
0	–1	2	–2	1

URL to Code: https://ide.geeksforgeeks.org/qNjvnG5y5i

Code:

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

struct Edge {
	int src, dest, weight;
};

struct Graph {
	int V, E;

	struct Edge* edge;
};

struct Graph* createGraph(int V, int E)
{
	struct Graph* graph = new Graph;
	graph->V = V;
	graph->E = E;
	graph->edge = new Edge[E];
	return graph;
}

// A utility function used to print the solution
void printArr(int dist[], int n)
{
```

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

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

	for (int i = 0; i < V; i++)
		dist[i] = INT_MAX;
	dist[src] = 0;

	for (int i = 1; i <= V - 1; i++) {
		for (int j = 0; j < E; j++) {
			int u = graph->edge[j].src;
			int v = graph->edge[j].dest;
			int weight = graph->edge[j].weight;
			if (dist[u] != INT_MAX && dist[u] + weight < dist[v])
				dist[v] = dist[u] + weight;
		}
	}

	for (int i = 0; i < E; i++) {
		int u = graph->edge[i].src;
		int v = graph->edge[i].dest;
		int weight = graph->edge[i].weight;
		if (dist[u] != INT_MAX && dist[u] + weight < dist[v]) {
			printf("Graph contains negative weight cycle");
			return; // If negative cycle is detected, simply return
		}
	}

	printArr(dist, V);

	return;
}

// Driver program to test above functions
int main()
{
	int V = 5; // Number of vertices in graph
	int E = 8; // Number of edges in graph
	struct Graph* graph = createGraph(V, E);

	// add edge 0-1 (or A-B in above figure)
	graph->edge[0].src = 0;
	graph->edge[0].dest = 1;
	graph->edge[0].weight = -1;

	// add edge 0-2 (or A-C in above figure)
	graph->edge[1].src = 0;
	graph->edge[1].dest = 2;
	graph->edge[1].weight = 4;

	// add edge 1-2 (or B-C in above figure)
	graph->edge[2].src = 1;
	graph->edge[2].dest = 2;
	graph->edge[2].weight = 3;
```

```
    // add edge 1-3 (or B-D in above figure)
    graph->edge[3].src = 1;
    graph->edge[3].dest = 3;
    graph->edge[3].weight = 2;

    // add edge 1-4 (or A-E in above figure)
    graph->edge[4].src = 1;
    graph->edge[4].dest = 4;
    graph->edge[4].weight = 2;

    // add edge 3-2 (or D-C in above figure)
    graph->edge[5].src = 3;
    graph->edge[5].dest = 2;
    graph->edge[5].weight = 5;

    // add edge 3-1 (or D-B in above figure)
    graph->edge[6].src = 3;
    graph->edge[6].dest = 1;
    graph->edge[6].weight = 1;

    // add edge 4-3 (or E-D in above figure)
    graph->edge[7].src = 4;
    graph->edge[7].dest = 3;
    graph->edge[7].weight = -3;

    BellmanFord(graph, 0);

    return 0;
}
```

Output:

Generated URL: Copy

https://ide.geeksforgeeks.org/qNjvnG5y5i

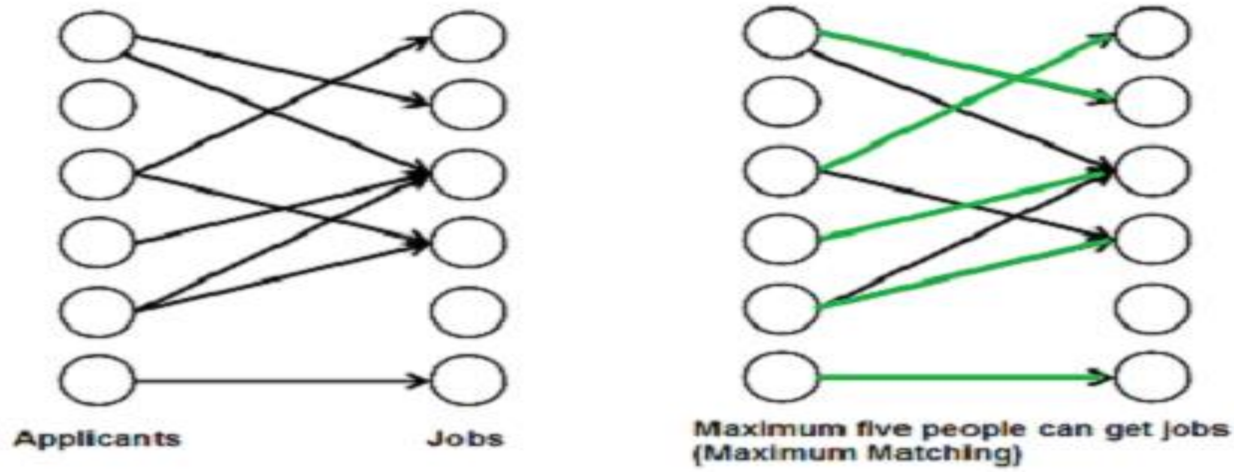
Time(sec) : 0 Memory(MB) : 3.4341827597046

Output: Copy

```
Vertex   Distance from Source
0            0
1            -1
2            2
3            -2
4            1
```

Practical 8:

Aim: Write a program to find maximum matching in a bipartite graph.



URL to Code: https://ide.geeksforgeeks.org/JHnbrDtIFH

Code:

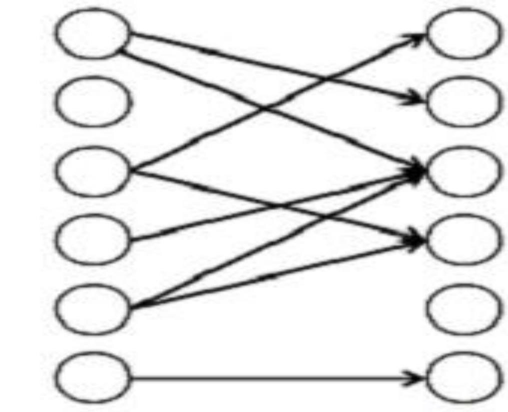
```
#include <iostream>
#include <string.h>
using namespace std;

#define M 6
#define N 6

bool bpm(bool bpGraph[M][N], int u,
        bool seen[], int matchR[])
{
        for (int v = 0; v < N; v++)
        {
                if (bpGraph[u][v] && !seen[v])
                {
                        // Mark v as visited
                        seen[v] = true;

                        if (matchR[v] < 0 || bpm(bpGraph, matchR[v],
                                seen, matchR))
                        {
                                matchR[v] = u;
                                return true;
                        }
                }
        }
        return false;
}

int maxBPM(bool bpGraph[M][N])
```

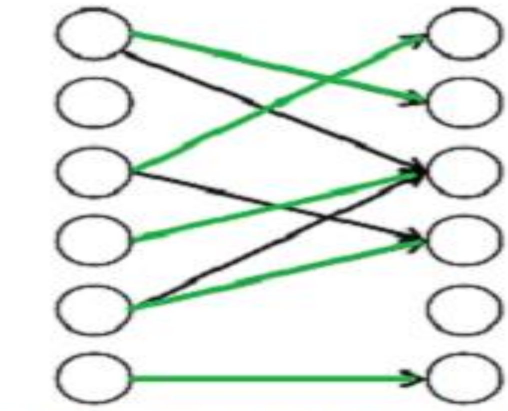
```
{
        int matchR[N];

        // Initially all jobs are available
        memset(matchR, -1, sizeof(matchR));

        // Count of jobs assigned to applicants
        int result = 0;
        for (int u = 0; u < M; u++)
        {
                bool seen[N];
                memset(seen, 0, sizeof(seen));

                // Find if the applicant 'u' can get a job
                if (bpm(bpGraph, u, seen, matchR))
                        result++;
        }
        return result;
}

int main()
{
        bool bpGraph[M][N] = { {0, 1, 1, 0, 0, 0},
                                                {1, 0, 0, 1, 0, 0},
                                                {0, 0, 1, 0, 0, 0},
                                                {0, 0, 1, 1, 0, 0},
                                                {0, 0, 0, 0, 0, 0},
                                                {0, 0, 0, 0, 0, 1} };

        cout << "Maximum number of applicants that can get job is "
                << maxBPM(bpGraph);

        return 0;
}
```

Output:

Practical 9:

Aim: Write a program to find maximum matching for a general graph.





URL to Code: https://ide.geeksforgeeks.org/ZoQagFGJIk

Code:

```
#include <bits/stdc++.h>
using namespace std;
const int M = 500;
struct struct_edge { int v; struct_edge* n; };
typedef struct_edge* edge;
struct_edge pool[M * M * 2];
edge top = pool, adj[M];
int V, E, match[M], qh, qt, q[M], father[M], base[M];
bool inq[M], inb[M], ed[M][M];
void add_edge(int u, int v)
{
	top->v = v, top->n = adj[u], adj[u] = top++;
	top->v = u, top->n = adj[v], adj[v] = top++;
}
int LCA(int root, int u, int v)
{
	static bool inp[M];
	memset(inp, 0, sizeof(inp));
	while (1)
	{
		inp[u = base[u]] = true;
		if (u == root) break;
		u = father[match[u]];
	}
	while (1)
	{
		if (inp[v = base[v]]) return v;
		else v = father[match[v]];
	}
}
```

```
void mark_blossom(int lca, int u)
{
	while (base[u] != lca)
	{
		int v = match[u];
		inb[base[u]] = inb[base[v]] = true;
		u = father[v];
		if (base[u] != lca) father[u] = v;
	}
}
void blossom_contraction(int s, int u, int v)
{
	int lca = LCA(s, u, v);
	memset(inb, 0, sizeof(inb));
	mark_blossom(lca, u);
	mark_blossom(lca, v);
	if (base[u] != lca)
		father[u] = v;
	if (base[v] != lca)
		father[v] = u;
	for (int u = 0; u < V; u++)
		if (inb[base[u]])
		{
			base[u] = lca;
			if (!inq[u])
				inq[q[++qt] = u] = true;
		}
}
int find_augmenting_path(int s)
{
	memset(inq, 0, sizeof(inq));
	memset(father, -1, sizeof(father));
	for (int i = 0; i < V; i++) base[i] = i;
	inq[q[qh = qt = 0] = s] = true;
	while (qh <= qt)
	{
		int u = q[qh++];
		for (edge e = adj[u]; e; e = e->n)
		{
			int v = e->v;
			if (base[u] != base[v] && match[u] != v)
				if ((v == s) || (match[v] != -1 && father[match[v]] != -
1))
					blossom_contraction(s, u, v);
				else if (father[v] == -1)
				{
					father[v] = u;
					if (match[v] == -1)
						return v;
					else if (!inq[match[v]])
						inq[q[++qt] = match[v]] = true;
				}
		}
	}
	return -1;
}
int augment_path(int s, int t)
{
	int u = t, v, w;
	while (u != -1)
	{
		v = father[u];
```

```
            w = match[v];
            match[v] = u;
            match[u] = v;
            u = w;
        }
        return t != -1;
}
int edmonds()
{
        int matchc = 0;
        memset(match, -1, sizeof(match));
        for (int u = 0; u < V; u++)
            if (match[u] == -1)
                matchc += augment_path(u, find_augmenting_path(u));
        return matchc;
}
int main()
{
        int u, v;
        cout << "Enter the number of vertices and edges : ";
        cin >> V >> E;
        cout << "Enter the edges : \n";
        while (E--)
        {
            cin >> u >> v;
            if (!ed[u - 1][v - 1])
            {
                add_edge(u - 1, v - 1);
                ed[u - 1][v - 1] = ed[v - 1][u - 1] = true;
            }
        }
        cout << "Number of matches : " << edmonds() << endl;
        cout << "The matches are : \n";
        for (int i = 0; i < V; i++)
            if (i < match[i])
                cout << i + 1 << " " << match[i] + 1 << endl;
}
```

Output:

- -
0 1
0 2
1 2
1 3
1 4
3 2
3 1
4 3
2

Copy

> Run

> Run+URL (Generates URL as well)

Generated URL:

Copy

https://ide.geeksforgeeks.org/ZoQagFGJIk

Time(sec) : 0

Memory(MB) : 11.211074171753

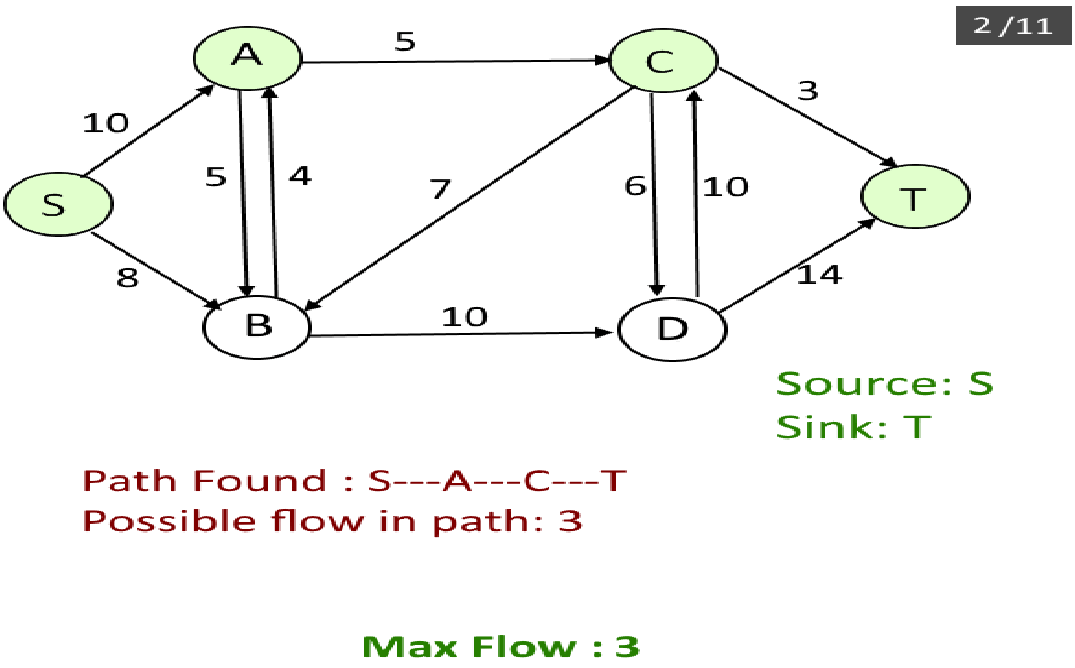
Output:

Copy

```
Enter the number of vertices and edges : Enter the edges :
Number of matches : 2
The matches are :
1 4
2 3
```

Practical 10:

Aim: Write a program to find maximum matching for a general graph.



URL to Code: https://ide.geeksforgeeks.org/ZoQagFGJIk

Code:

```
#include <iostream>
#include <limits.h>
#include <string.h>
#include <queue>
using namespace std;

#define V 6

bool bfs(int rGraph[V][V], int s, int t, int parent[])
{
	bool visited[V];
	memset(visited, 0, sizeof(visited));

	queue <int> q;
	q.push(s);
	visited[s] = true;
	parent[s] = -1;

	while (!q.empty())
	{
		int u = q.front();
		q.pop();

		for (int v = 0; v < V; v++)
```

```
            {
                    if (visited[v] == false && rGraph[u][v] > 0)
                    {
                            q.push(v);
                            parent[v] = u;
                            visited[v] = true;
                    }
            }
    }

    return (visited[t] == true);
}

int fordFulkerson(int graph[V][V], int s, int t)
{
    int u, v;

    int rGraph[V][V]; // Residual graph where rGraph[i][j] indicates
                                    // residual capacity of edge from i to j (if there
                                    // is an edge. If rGraph[i][j] is 0, then there is
not)
    for (u = 0; u < V; u++)
            for (v = 0; v < V; v++)
                    rGraph[u][v] = graph[u][v];

    int parent[V];  // This array is filled by BFS and to store path

    int max_flow = 0;  // There is no flow initially

    // Augment the flow while tere is path from source to sink
    while (bfs(rGraph, s, t, parent))
    {
            // Find minimum residual capacity of the edges along the
            // path filled by BFS. Or we can say find the maximum flow
            // through the path found.
            int path_flow = INT_MAX;
            for (v = t; v != s; v = parent[v])
            {
                    u = parent[v];
                    path_flow = min(path_flow, rGraph[u][v]);
            }

            // update residual capacities of the edges and reverse edges
            // along the path
            for (v = t; v != s; v = parent[v])
            {
                    u = parent[v];
                    rGraph[u][v] -= path_flow;
                    rGraph[v][u] += path_flow;
            }

            // Add path flow to overall flow
            max_flow += path_flow;
    }

    // Return the overall flow
    return max_flow;
}

// Driver program to test above functions
int main()
{
```

```
        // Let us create a graph shown in the above example
        int graph[V][V] = { {0, 16, 13, 0, 0, 0},
                                        {0, 0, 10, 12, 0, 0},
                                        {0, 4, 0, 0, 14, 0},
                                        {0, 0, 9, 0, 0, 20},
                                        {0, 0, 0, 7, 0, 4},
                                        {0, 0, 0, 0, 0, 0}
        };

        cout << "The maximum possible flow is " << fordFulkerson(graph, 0, 5);

        return 0;
}
```

Output: