VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

ANALYSIS AND DESIGN OF ALGORITHMS (23CS4PCADA)

Submitted by

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in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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This is to certify that the Lab work entitled **"ANALYSIS AND DESIGN OF ALGORITHMS"** carried out by Shashank U **(1BM23CS314)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2024-25. The Lab report has been approved as it satisfies the academic requirements in respect of Analysis and Design of Algorithms Lab - **(23CS4PCADA)** work prescribed for the said degree.

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Index Sheet

Course outcomes:

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.

Lab program 1:

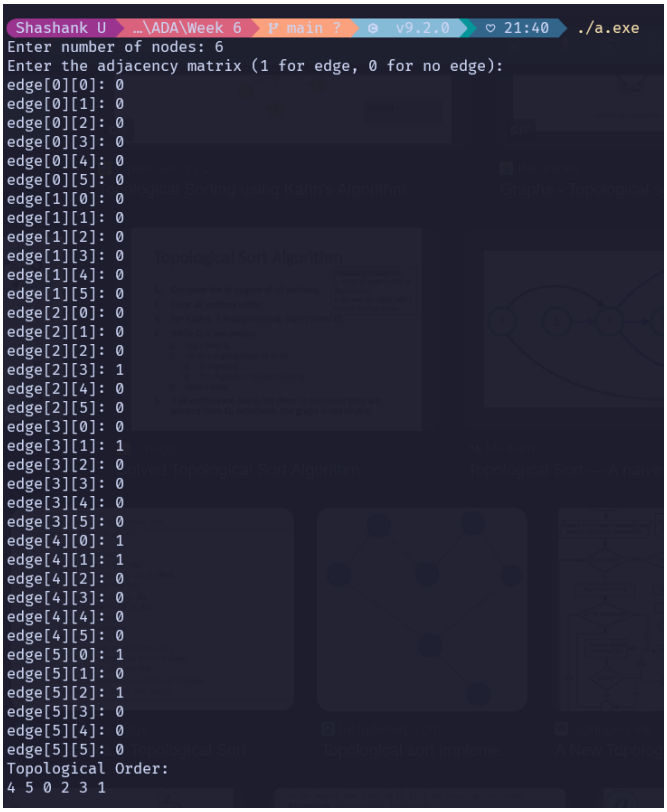
Write program to obtain the Topological ordering of vertices in a given digraph.

```
#include <stdio.h>
#include <stdlib.h>
// Create adjacency matrix
int** create_graph(int n){
	int** graph = (int**)calloc(n, sizeof(int*));
	for(int i = 0; i < n; i++){
		graph[i] = (int*)calloc(n, sizeof(int));
	}

	printf("Enter the adjacency matrix (1 for edge, 0 for no edge):\n");
	for(int i = 0; i < n; i++){
		for(int j = 0; j < n; j++){
			printf("edge[%d][%d]: ", i, j);
			scanf("%d", &graph[i][j]);
		}
	}
	return graph;
}

// Calculate in-degrees of all nodes
void compute_indegree(int** graph, int* indegree, int n){
	for(int i = 0; i < n; i++){
		indegree[i] = 0;
		for(int j = 0; j < n; j++){
			if(graph[j][i] == 1){
				indegree[i]++;
			}
		}
	}
}
```

```
// Perform topological sort using source removal
void topo_sort(int** graph, int n){
	int* indegree = (int*)calloc(n, sizeof(int));
	int* visited = (int*)calloc(n, sizeof(int));
	int count = 0;

	compute_indegree(graph, indegree, n);

	printf("Topological Order:\n");
	while(count < n){
		int found = 0;
		for(int i = 0; i < n; i++){
			if(indegree[i] == 0 && visited[i] == 0){
				// Node with no incoming edges → print and remove
				printf("%d ", i);
				visited[i] = 1;
				count++;
				found = 1;
				// Reduce indegree of its neighbors
				for(int j = 0; j < n; j++){
					if(graph[i][j] == 1){
						indegree[j]--;
					}
				}
				break;
			}
		}
		if(!found){
			printf("\nCycle detected. Topological sort not possible.\n");
			break;
		}
```

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

        free(indegree);
        free(visited);
}
void free_graph(int** graph, int n){
        for(int i = 0; i < n; i++){
                free(graph[i]);
        }
        free(graph);
}
int main(){
        int n;
        printf("Enter number of nodes: ");
        scanf("%d", &n);

        int** graph = create_graph(n);
        topo_sort(graph, n);
        free_graph(graph, n);
        return 0;
}
```

OUTPUT:



Lab program 2:

Implement Johnson Trotter algorithm to generate permutations.

```
#include<stdio.h>
#include<stdlib.h>
#include<stdbool.h>
#define LEFT -1
#define RIGHT 1

typedef struct{
	int direction,value;
}element;

void init(element items[],int n){
	for(int i=0;i<n;i++){
		items[i].value = i+1;
		items[i].direction = LEFT;
	}
}

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


int largest_mobile_integer(element items[],int n,int* adj_index){
	int largest_mi = -1; //index
	int adj;
	for(int i=0;i<n;i++){
		int curr_dir = items[i].direction;
```

```
                adj = i + curr_dir; //adjacent index wrt mobile integer
                if(adj>=0 && adj<n){
                   if(items[i].value > items[adj].value){
                     if(largest_mi==-1 || items[i].value > items[largest_mi].value){
                          largest_mi = i;
                        }
                }
             }
            }
            if(largest_mi!=-1){
              *adj_index = largest_mi + items[largest_mi].direction;
            }
            return largest_mi;
}

void print_permutation(element items[],int n){
            for(int i=0;i<n;i++){
                printf("%d ",items[i].value);
            }
            printf("\n");
}

void reverse_direction(element items[],int n,int index){
            int mi = items[index].value; //mobile integer
            for(int i=0;i<n;i++){
                if(items[i].value>mi){
                        items[i].direction*=-1;
                }
            }
}
```

```
void johnsonn_trotter(element items[],int n){
        init(items,n);
        print_permutation(items,n);
        int adj,index;
        while(true){
          //Step 1: find out largest mobile integer
          index = largest_mobile_integer(items,n,&adj);
          if(index==-1){ break; }
         //Step 2: Swap it with it's adjacent
          swap(&items[index],&items[adj]);
         //Step 3: Reverse directions of integer > mobile integer
         //Since index was swapped so adj took the value of index
          reverse_direction(items,n,adj);
         //Step 4: Print the permutation obtained
          print_permutation(items,n);
        }
}
int main(){
        int n;
        printf("Enter upper bound:");
        scanf("%d",&n);
        element items[n];
        johnsonn_trotter(items,n);
        return 0;
}
```

OUTPUT:

```
Shashank U …\ADA\Week 5 ᚠ main ? ⚙ v9.2.0 ♡ 21:49 gcc johnson_trotter.c && .\a.exe
Enter upper bound:3
1 2 3
1 3 2
3 1 2
3 2 1
2 3 1
2 1 3
```

Lab Program 3

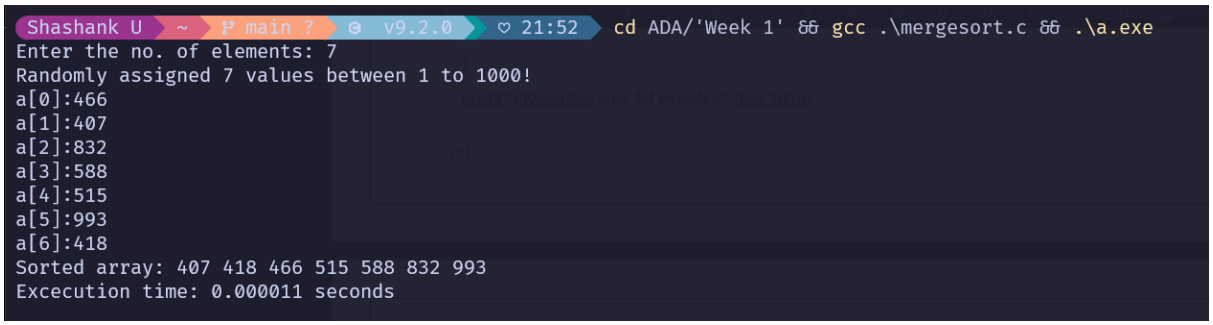
Sort a given set of N integer elements using Merge Sort technique and compute its time taken. Run the program for different values of N and record the time taken to sort.

```
#include <stdio.h>

#include <stdlib.h>

#include<time.h>

#include<windows.h>


void merge(int a[], int low, int mid, int high) {

   int *c = (int*)malloc( (high-low+1)*sizeof(int) );

   int i = low, j = mid+1, k = 0;

   while (i <=mid && j <=high) {

      if (a[i] <= a[j]) {

         c[k++] = a[i++];

      } else {

         c[k++] = a[j++];

      }

   }

   while (i <=mid) {

      c[k++] = a[i++];

   }

   while (j <=high) {

      c[k++] = a[j++];

   }

   for(i=0;i<high-low+1;i++){

         a[low+i]=c[i];

   }

   free(c);

}
```

```
void mergesort(int a[], int low, int high) {
    if (low < high) {
        int mid = (low + high) / 2;
        mergesort(a, low, mid);
        mergesort(a, mid + 1, high);
        merge(a, low, mid, high);
    }
}
int main() {
    int n, i;
    LARGE_INTEGER frequency, start, end;
    QueryPerformanceFrequency(&frequency);
    printf("Enter the no. of elements: ");
    scanf("%d", &n);
    int a[n];
    srand((unsigned int)time(NULL));
    printf("Randomly assigned %d values between 1 to 1000!\n",n);
    for(int i=0;i<n;i++){
        a[i] = (rand()%1000) + 1;
        printf("a[%d]:%d\n",i,a[i]);
    }
    QueryPerformanceCounter(&start);
    mergesort(a,0,n-1);
    QueryPerformanceCounter(&end);
    double time_taken = (double)(end.QuadPart - start.QuadPart) / frequency.QuadPart;
    printf("Sorted array: ");
    for (i = 0; i < n; i++) {
        printf("%d ", a[i]);
    }
    printf("\nExcecution time: %f seconds\n", time_taken);
```

```
    return 0;
}
```

OUTPUT:



Lab Program 4

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

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

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

int partition(int *arr, int low, int high) {
    int i = low + 1, j = high, pivot = arr[low];

    while (i <= j) {
        while (arr[i] <= pivot && i <= high) i++;
        while (arr[j] > pivot && j >= low) j--;
```

```
        if (i < j) swap(&arr[i], &arr[j]);
    }

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

void quicksort(int *arr, int low, int high) {
    if (low < high) {
        int pivot_pos = partition(arr, low, high);
        quicksort(arr, low, pivot_pos - 1);
        quicksort(arr, pivot_pos + 1, high);
    }
}

int main() {
    int n;
    printf("Enter array size: ");
    scanf("%d", &n);
    int arr[n];

    printf("Randomly assigned %d values between 1 to 1000!\n", n);
    for (int i = 0; i < n; i++) {
        arr[i] = (rand() % 1000) + 1;
        printf("arr[%d]: %d\n", i, arr[i]);
    }

    // Windows high-resolution timing
    LARGE_INTEGER frequency, start, end;
    QueryPerformanceFrequency(&frequency);
```

```
    QueryPerformanceCounter(&start);
    quicksort(arr, 0, n - 1);
   QueryPerformanceCounter(&end);
    double time_taken = (double)(end.QuadPart - start.QuadPart) / frequency.QuadPart;

    printf("Array after sorting:\n");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\nExecution time: %f sec\n", time_taken);
    return 0;
}
```

OUTPUT:

Lab Program 5:

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

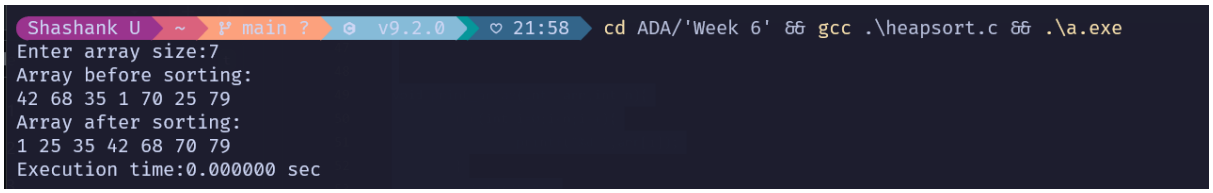
```
#include<stdio.h>
#include<stdlib.h>
#include<time.h>

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

```
}

//build a max-heap
void heapify(int* arr,int n,int i){
	int l = 2*i + 1, r = 2*i + 2;
	int largest = i;

	if(l<n && arr[l]>arr[largest]){
		largest = l;
	}

	if(r<n && arr[r]>arr[largest]){
		largest = r;
	}

	if(largest!=i){
		swap(&arr[largest],&arr[i]);
		//heapify the affected portion
		heapify(arr,n,largest);
	}
}


void heapsort(int* arr,int n){

	//swap the root with last element of heap
	//heapify the new heap

	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);
        }

}


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


int main(){
        int n;
        printf("Enter array size:");
        scanf("%d",&n);
        int arr[n];
        printf("Array before sorting:\n");
        for(int i=0;i<n;i++){
                arr[i]=(rand()%100) + 1;
        }
        print_array(arr,n);
        printf("Array after sorting:\n");
        clock_t start,end;
```

```
	start = clock();
	heapsort(arr,n);
	end = clock();
	print_array(arr,n);
	printf("Execution time:%f sec\n",((float)end-start)/CLOCKS_PER_SEC);
	return 0;
}
```

OUTPUT:



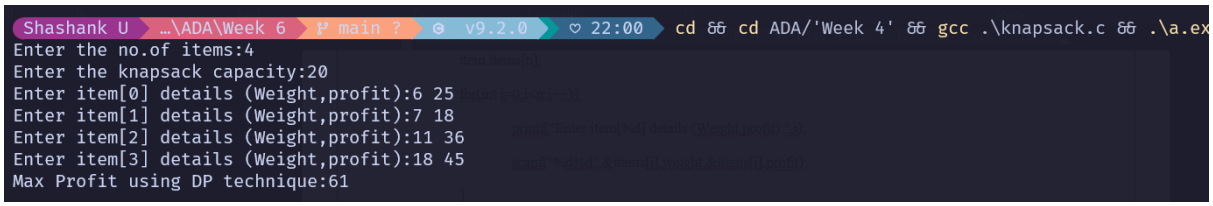
Lab Program 6:

Implement 0/1 Knapsack problem using dynamic programming.

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

typedef struct item{
	int weight,profit;
}item;

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

int knapsack(item* items,int capacity,int n){
	int dp[n+1][capacity+1];
	for(int i=0;i<=n;i++){
		for(int j=0;j<=capacity;j++){
			if(i==0 || j==0){
```

```
                    dp[i][j]=0;
                }else if(items[i-1].weight>j){
                    dp[i][j]=dp[i-1][j];
                }
            else{
dp[i][j]=max(items[i-1].profit + dp[i-1][j-items[i-1].weight],dp[i-1][j]);
                }
            }
        }
    return dp[n][capacity];
}


int main(){
        int n,w;
        printf("Enter the no.of items:");
        scanf("%d",&n);
        printf("Enter the knapsack capacity:");
        scanf("%d",&w);
        item items[n];
        for(int i=0;i<n;i++){
            printf("Enter item[%d] details (Weight,profit):",i);
            scanf("%d%d",&items[i].weight,&items[i].profit);
        }
        int max_profit = knapsack(items,w,n);
        printf("Max Profit using DP technique:%d\n",max_profit);
        return 0;
}
```

OUTPUT:



Lab Program 7:

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

```
#include<stdio.h>

#include<stdlib.h>

int min(int a,int b){

        return a<b?a:b;

}


int** read_data(int* n){

        printf("Enter no.of vertices:");

        scanf("%d",n);

        int **matrix = (int**)calloc(*n,sizeof(int*));

        for(int i=0;i<*n;i++){

                matrix[i]=(int*)calloc(*n,sizeof(int));

        }

        printf("Enter the values for cost adjacency matrix:\n");

        for(int i=0;i<*n;i++){

                for(int j=0;j<*n;j++){

                        printf("cost[%d][%d]:",i,j);

                        scanf("%d",&matrix[i][j]);

                }

        }

        return matrix;

}
```

```
void floyd(int **matrix,int n){
    for(int k=0;k<n;k++){
        for(int i=0;i<n;i++){
            for(int j=0;j<n;j++){
                matrix[i][j]=min(matrix[i][j],matrix[i][k]+matrix[k][j]);
            }
        }
    }
}

void print_data(int** matrix,int n){
        printf("Updated matrix:\n");
        for(int i=0;i<n;i++){
            for(int j=0;j<n;j++){
                printf("%d ",matrix[i][j]);
            }
            printf("\n");
        }
}

int main(){
        int n;
        int** cost = read_data(&n);
        printf("Before floyd the adjacency matrix is:\n");
        print_data(cost,n);
        printf("Cost matrix after floyd's algo is\n");
        floyd(cost,n);
        print_data(cost,n);
        return 0;
}
```

OUTPUT:

Lab Program 7

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

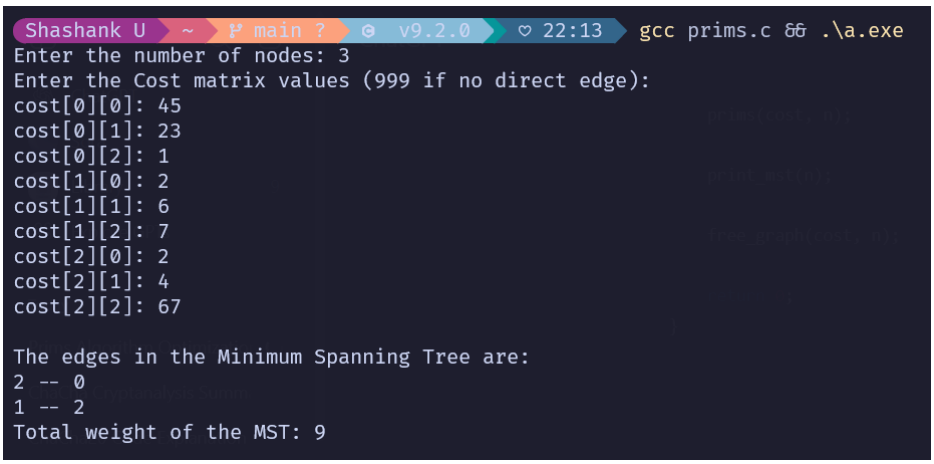
```
#include<stdio.h>

#include<stdlib.h>


int sum = 0;  // To store the total weight of MST

int t[10][2]; // To store the edges of MST


void prims(int cost[10][10], int n) {

    int i, j, u, v;

    int min, source;

    int p[10], d[10], s[10];  // Arrays to store parent, distance, and status

    min = 999;  // Initialize min to a large number (infinity)

    source = 0;  // Starting vertex (vertex 0)


    // Initialize arrays

    for (i = 0; i < n; i++) {

        d[i] = cost[source][i];  // Initialize distance to the source vertex

        s[i] = 0;  // Initially, no vertex is in the MST
```

```
    p[i] = source;  // Set the parent of each vertex to the source
}
s[source] = 1;  // Mark the source vertex as included in MST
sum = 0;  // Total weight of the MST
int k = 0;  // Counter for the number of edges in MST

// Main loop to find MST
for (i = 0; i < n - 1; i++) {  // Repeat for n-1 iterations
    min = 999;  // Reset min value for each iteration
    u = -1;  // Reset u (the vertex to be added to the MST)

    // Find the vertex with the minimum distance to the MST
    for (j = 0; j < n; j++) {
        if (s[j] == 0 && d[j] < min) {  // If vertex j is not in MST and has a smaller distance
            min = d[j];
            u = j;  // Select vertex u with the smallest edge
        }
    }

    if (u != -1) {
        // Add edge (u, p[u]) to MST
        t[k][0] = u;  // Store the edge
        t[k][1] = p[u];
        k++;  // Increment edge counter
        sum += cost[u][p[u]];  // Add the edge weight to the total sum
        s[u] = 1;  // Mark u as added to the MST

        // Update distances for adjacent vertices
        for (v = 0; v < n; v++) {
            if (s[v] == 0 && cost[u][v] < d[v]) {  // If v is not in MST and a shorter edge exists
```

```
                d[v] = cost[u][v];  // Update the distance to v
                p[v] = u;  // Set parent of v as u
            }
        }
    }
}

int** create_graph(int n) {
    int** cost = (int**)calloc(n, sizeof(int*));
    for (int i = 0; i < n; i++) {
        cost[i] = (int*)calloc(n, sizeof(int));
    }
    printf("Enter the Cost matrix values (999 if no direct edge)\n");
    for (int i = 0; i < n; i++) {
        for (int j = 0; j < n; j++) {
            printf("cost[%d][%d]:", i, j);
            scanf("%d", &cost[i][j]);
        }
    }
    return cost;
}

void print_mst(int n) {
    printf("The edges in the Minimum Spanning Tree are:\n");
    for (int i = 0; i < n - 1; i++) {
        printf("%d -- %d\n", t[i][0], t[i][1]);
    }
    printf("Total weight of the MST: %d\n", sum);
}
```

```
void free_graph(int** cost, int n) {
    for (int i = 0; i < n; i++) {
        free(cost[i]);
    }
    free(cost);
}

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

    int** cost = create_graph(n);

    prims(cost, n);

    print_mst(n);

    free_graph(cost, n);
    return 0;
}
```

OUTPUT:



Lab Program 8

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

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

#define INF 999

int find(int parent[], int i){
	if(parent[i] != i)
		parent[i] = find(parent, parent[i]);
	return parent[i];
}

int** create_graph(int n){
	int** cost = (int**)calloc(n, sizeof(int*));
	for(int i = 0; i < n; i++){
		cost[i] = (int*)calloc(n, sizeof(int));
	}

	printf("Enter the Cost matrix values (999 if no direct edge):\n");
	for(int i = 0; i < n; i++){
		for(int j = 0; j < n; j++){
			printf("cost[%d][%d]: ", i, j);
			scanf("%d", &cost[i][j]);
		}
	}
	return cost;
}

void kruskal(int** cost, int n){
```

```
int parent[10];
int t[10][2]; // MST edge list
int count = 0, sum = 0, k = 0;
int min, u, v;

// Initialize each node as its own parent
for(int i = 0; i < n; i++){
        parent[i] = i;
}

while(count < n - 1){
        min = INF;
        u = -1;
        v = -1;

        // Find the minimum weight edge that doesn't form a cycle
        for(int i = 0; i < n; i++){
                for(int j = 0; j < n; j++){
                        if(find(parent, i) != find(parent, j) && cost[i][j] < min){
                                min = cost[i][j];
                                u = i;
                                v = j;
                        }
                }
        }

        // Union the sets
        if(u != -1 && v != -1){
                int root_u = find(parent, u);
                int root_v = find(parent, v);
```

```
                parent[root_u] = root_v;

                t[k][0] = u;
                t[k][1] = v;
                sum += cost[u][v];
                k++;
                count++;
            }
        }

        // Print the MST
        printf("\nEdges in the Minimum Spanning Tree:\n");
        for(int i = 0; i < k; i++){
            printf("%d -- %d\n", t[i][0], t[i][1]);
        }
        printf("Total cost of MST: %d\n", sum);
}

void free_graph(int** cost, int n){
        for(int i = 0; i < n; i++){
            free(cost[i]);
        }
        free(cost);
}

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

```
    int** cost = create_graph(n);
    kruskal(cost, n);
    free_graph(cost, n);

    return 0;
}
```

OUTPUT:

Lab Program 9

Implement fractional knapsack problem using Greedy technique.

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

typedef struct {
    int cost;
    int weight;
    float ratio;
} Item;

void sort_items(Item* items, int n){
    for(int i=0;i<n-1;i++){
        for(int j=0;j<n-i-1;j++){
```

```
                if(items[j].ratio < items[j+1].ratio){
                        Item temp = items[j];
                        items[j] = items[j+1];
                        items[j+1] = temp;
                }
            }
        }
}

float fractional_knapsack(Item* items, int n, int capacity){
        float total_profit = 0.0;
        for(int i=0;i<n;i++){
            if(capacity >= items[i].weight){
                total_profit += items[i].cost;
                capacity -= items[i].weight;
            }else{
                total_profit += (float)items[i].cost * ((float)capacity / items[i].weight);
                break;
            }
        }
        return total_profit;
}

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

        Item* items = (Item*)calloc(n, sizeof(Item));
```

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

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

    sort_items(items, n);
    float max_profit = fractional_knapsack(items, n, cap);
    printf("Maximum profit = %.2f\n", max_profit);

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

OUTPUT:

```
Shashank U ~ main ? v9.2.0 22:18 cd ADA/'Week 4' && gcc .\fractional_knapsack.c && .\a.exe
Enter number of items: 5
Enter cost and weight of each item:
Item 0 cost: 32
Item 0 weight: 20
Item 1 cost: 6
Item 1 weight: 25
Item 2 cost: 7
Item 2 weight: 5
Item 3 cost: 65
Item 3 weight: 12
Item 4 cost: 35
Item 4 weight: 2
Enter knapsack capacity: 12
Maximum profit = 89.17
```

Lab Program 10

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

```
#include<stdio.h>

#include<stdlib.h>

#include<stdbool.h>

int** create_graph(int n){

        int** cost = (int**)calloc(n,sizeof(int*));

        for(int i=0;i<n;i++){

                cost[i]=(int*)calloc(n,sizeof(int));

        }

        printf("Enter the Cost matrix values (999 if no direct edge)\n");

        for(int i=0;i<n;i++){

                for(int j=0;j<n;j++){

                        printf("cost[%d][%d]:",i,j);

                        scanf("%d",&cost[i][j]);

                }

        }

        return cost;

}


int* djikstra(int** cost,int n,int source){

        int min,u;

        bool visited[n];

        int *sd = (int*)calloc(n,sizeof(int));

        //initialise visited and shortest distance array

        for(int j=0;j<n;j++){

                if(j==source){

                        visited[j]=true;

                        sd[j]=0;
```

```
            }else{
                visited[j]=false;
                sd[j]=cost[source][j];
            }
        }
        //Execute the algorithm
        for(int k=1;k<n;k++){
            min=999;
            //find out the unvisited edge with least updated distance from source
            for(int i=0;i<n;i++){
                if(!visited[i] && sd[i]<min){
                    min=sd[i];
                    u=i;
                }
            }
            visited[u]=true;
            //perform relaxation
            for(int j=0;j<n;j++){
                if(!visited[j]){
                    if(sd[u] + cost[u][j] < sd[j]){
                        sd[j] = sd[u] + cost[u][j];
                    }
                }
            }
        }

        return sd;
}

void print_distance(int *d,int n,int source){
```

```
	printf("Least distances from %d to other vertices are:\n",source);
	for(int i=0;i<n;i++){
		printf("%d--->%d: %d\n",source,i,d[i]);
	}
}

void free_graph(int** cost,int n){
	for(int i=0;i<n;i++){
	    free(cost[i]);
	}
	free(cost);
}

int main(){
	int n;
	printf("Enter no of nodes:");
	scanf("%d",&n);
	int** cost = create_graph(n);
start:
	int source;
	printf("Enter the source node:");
	scanf("%d",&source);
	if(source>=n || source<0) goto start;

	int* shortest_distance = djikstra(cost,n,source);
	print_distance(shortest_distance,n,source);
	free_graph(cost,n);
	free(shortest_distance);
	return 0;
}
```

OUTPUT:

Lab Program 11

Implement "N-Queens Problem" using Backtracking

```
#include <stdio.h>

#include <stdlib.h>

#include <stdbool.h>


// Function to print the chessboard

void print_board(int** board, int n) {

    for(int i = 0; i < n; i++) {

        for(int j = 0; j < n; j++) {

            if(board[i][j] == 1)

                printf("Q ");  // Queen is placed

            else

                printf(". ");  // Empty space

        }

        printf("\n");

    }

}


// Check if it's safe to place a queen at board[row][col]
```

```
bool is_safe(int** board, int row, int col, int n) {
    // Check column
    for(int i = 0; i < row; i++) {
        if(board[i][col] == 1)
            return false;
    }

    // Check upper-left diagonal
    for(int i = row-1, j = col-1; i >= 0 && j >= 0; i--, j--) {
        if(board[i][j] == 1)
            return false;
    }

    // Check upper-right diagonal
    for(int i = row-1, j = col+1; i >= 0 && j < n; i--, j++) {
        if(board[i][j] == 1)
            return false;
    }

    return true;
}

// Solve the N-Queens problem using backtracking
bool solve_n_queens(int** board, int row, int n) {
    // If all queens are placed, return true
    if(row >= n)
        return true;

    // Try all columns in the current row
    for(int col = 0; col < n; col++) {
```

```
        // Check if it's safe to place the queen
        if(is_safe(board, row, col, n)) {
            // Place queen
            board[row][col] = 1;

            // Recur to place the queen in the next row
            if(solve_n_queens(board, row + 1, n))
                return true;

            // If placing queen in this position doesn't lead to a solution, backtrack
            board[row][col] = 0;
        }
    }

    return false;
}

// Function to solve the N-Queens problem
void n_queens(int n) {
    // Create an empty board
    int** board = (int**)calloc(n, sizeof(int*));
    for(int i = 0; i < n; i++) {
        board[i] = (int*)calloc(n, sizeof(int));
    }

    // Try to solve the problem starting from the first row
    if(solve_n_queens(board, 0, n)) {
        print_board(board, n);
    } else {
        printf("Solution does not exist.\n");
```

```
    }

    // Free the memory for the board
    for(int i = 0; i < n; i++) {
        free(board[i]);
    }
    free(board);
}

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

    // Solve the N-Queens problem
    n_queens(n);

    return 0;
}
```

OUTPUT: