

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 **CHITRASHREE K(1BM23CS081)**, 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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GITHUB LINK : <https://github.com/Chitrashree-tech/ADA>

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 1.1:

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

Program full details

Code

```
#include <stdio.h>

#include <stdbool.h>

#define MAX 100

int graph[MAX][MAX];

bool visited[MAX];

int stack[MAX];

int top = -1;

int n;

void push(int v) {
    stack[++top] = v;
}

void dfs(int node) {
    visited[node] = true;
    for (int i = 0; i < n; i++) {
        if (graph[node][i] == 1 && !visited[i]) {
            dfs(i);
        }
    }
}
```

```
    push(node);  
}
```

```
void topologicalSort() {
```

```
    for (int i = 0; i < n; i++) {  
        visited[i] = false;  
    }
```

```
    for (int i = 0; i < n; i++) {  
        if (!visited[i]) {  
            dfs(i);  
        }  
    }
```

```
    printf("Topological Order: ");
```

```
    while (top != -1) {  
        printf("%d ", stack[top--]);  
    }
```

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

```
}
```

```
int main() {
```

```
    printf("Enter number of vertices: ");
```

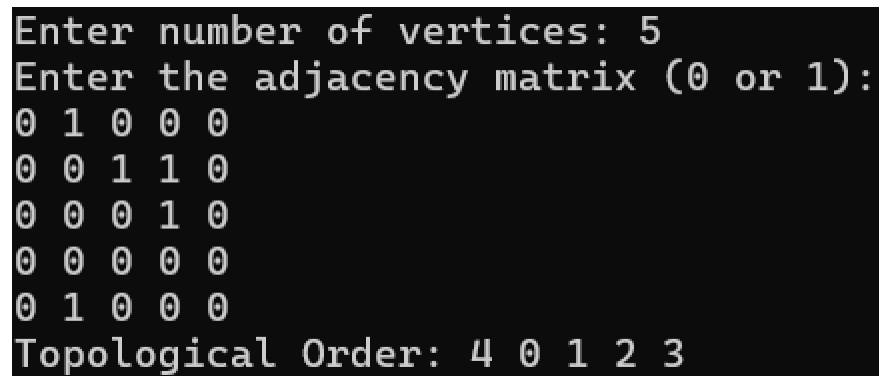
```
    scanf("%d", &n);
```

```
    printf("Enter the adjacency matrix (0 or 1):\n");
```

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

```
        scanf("%d", &graph[i][j]);  
    }  
}  
topologicalSort();  
return 0;  
}
```

Screenshot of Output



```
Enter number of vertices: 5  
Enter the adjacency matrix (0 or 1):  
0 1 0 0 0  
0 0 1 1 0  
0 0 0 1 0  
0 0 0 0 0  
0 1 0 0 0  
Topological Order: 4 0 1 2 3
```

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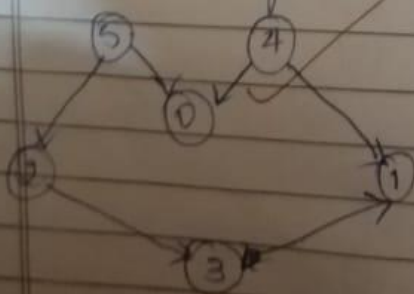
LAB-3

Topological sorting of vertices in a given digraph.
Algorithm and step wise explanation.

Algorithm

- Step 1. Create a graph with n vertices and m -directed edges
- Step 2. Initialize a stack and a visited array of size n .
- Step 3. for each unvisited vertex in the graph, do the following:
 - Call the dfs function with the vertex as the parameter.
 - In the dfs function, mark the vertex as visited and recursively call the dfs function for all unvisited neighbors of the vertex.
 - Once all the neighbors have been visited, push the vertex onto the stack.
- Step 4. After all, vertices have been visited, pop elements from the stack and append them to the output list until the stack is empty.
- Step 5. The resulting list is the topologically sorted order of the graph.

ex: Consider graph



visited[] =

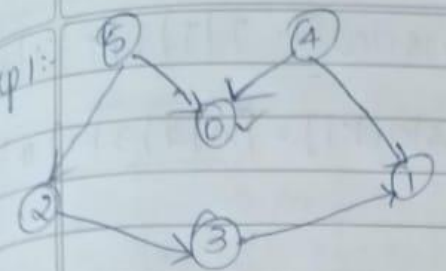
0	1	2	3	4	5
F	F	F	F	F	F

stack[] =

--	--	--	--	--	--

↑_{top}

Step 1:-



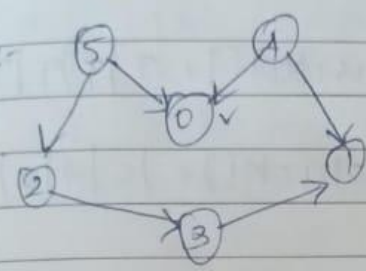
visited[] =

0	1	2	3	4	5
T	F	F	F	F	F

stack[] =

--	--	--	--	--	--

Step 2:-



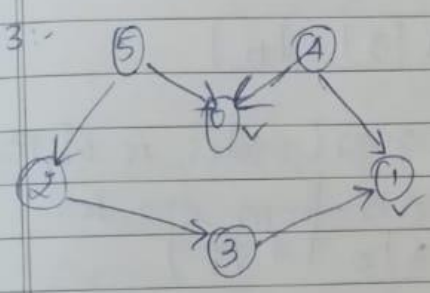
visited[] =

0	1	2	3	4	5
T	F	F	F	F	F

stack[] =

0					
---	--	--	--	--	--

Step 3:-



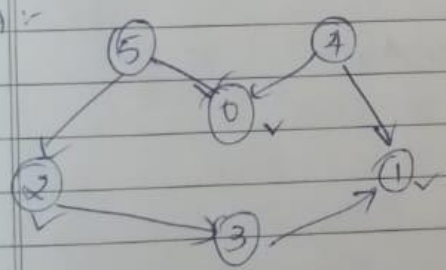
visited[] =

0	1	2	3	4	5
T	T	F	F	F	F

stack[] =

1	0				
---	---	--	--	--	--

Step 4:-



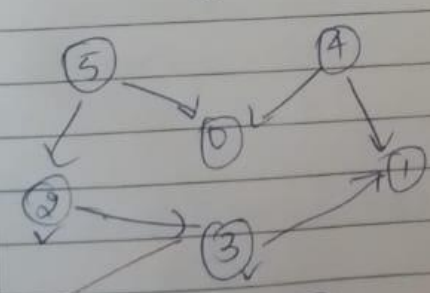
visited[] =

0	1	2	3	4	5
T	T	T	F	F	F

stack[] =

1	0	1	1	1	1
---	---	---	---	---	---

Step 5:-



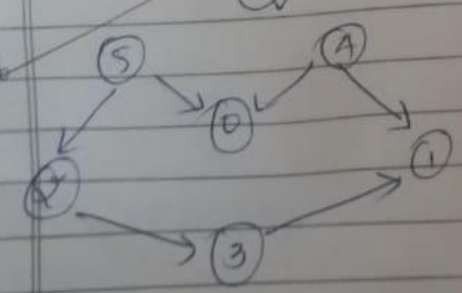
visited[] =

0	1	2	3	4	5
T	T	T	T	F	F

stack[] =

1	0	1	1	1	1
---	---	---	---	---	---

Step 6:-



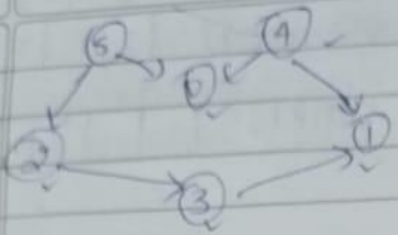
visited[] =

0	1	2	3	4	5
T	T	T	T	T	T

stack[] =

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

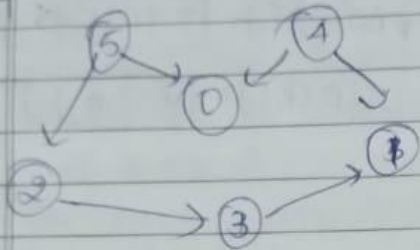
step 1



visited[] = T | T | T | T | T | F

stack[] = 4 | 2 | 3 | 1 | 0 | 1

step 2



visited[] = T | T | T | T | T | T

stack[] = 5 | 4 | 2 | 3 | 1 | 0

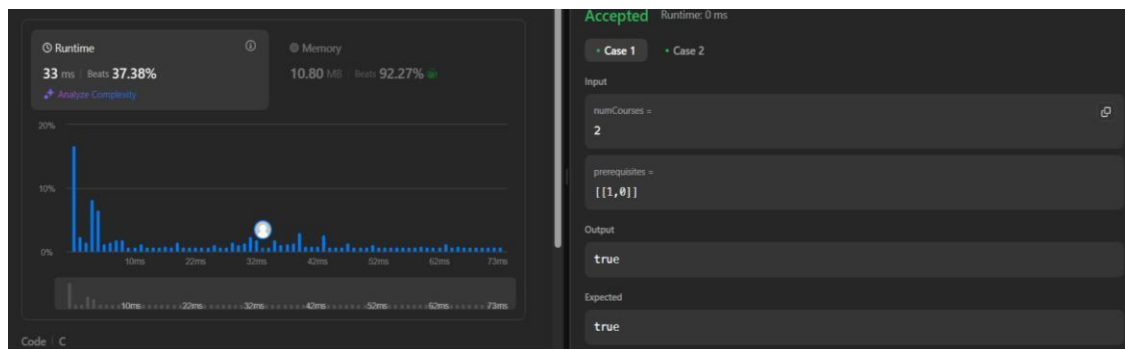
∴ in stack 5 | 4 | 2 | 3 | 1 | 0

∴ the final topological order is obtained
by popping elements from stack
ie, 0 | 1 | 3 | 2 | 4 | 5

Output:- 0, 1, 3, 2, 4, 5

Lab program 1.2:

```
class Solution {
public:
    bool canFinish(int numCourses, vector<vector<int>>& prerequisites) {
        vector<vector<int>> graph(numCourses);
        vector<int> indegree(numCourses, 0);
        for (const auto& pre : prerequisites) {
            graph[pre[1]].push_back(pre[0]);
            indegree[pre[0]]++;
        }
        queue<int> q;
        for (int i = 0; i < numCourses; ++i) {
            if (indegree[i] == 0) q.push(i);
        }
        int count = 0;
        while (!q.empty()) {
            int curr = q.front(); q.pop();
            count++;
            for (int next : graph[curr]) {
                indegree[next]--;
                if (indegree[next] == 0) q.push(next);
            }
        }
        return count == numCourses;
    }
};
```



Lab program 2:

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.

Code

```
#include <stdio.h>

#include <stdlib.h>

#include <time.h>

void merge(int arr[], int left, int right, int mid) {

    int i, j, k;

    int n1 = mid - left + 1;

    int n2 = right - mid;

    int L[n1], R[n2];

    for(i = 0; i < n1; i++) {

        L[i] = arr[left + i];

    }

    for(j = 0; j < n2; j++) {

        R[j] = arr[mid + 1 + j];

    }

    i = 0;

    j = 0;
```

```
k = left;
```

```
while(i < n1 && j < n2) {
```

```
    if(L[i] <= R[j]) {
```

```
        arr[k] = L[i];
```

```
        i++;
```

```
    } else {
```

```
        arr[k] = R[j];
```

```
        j++;
```

```
    }
```

```
    k++;
```

```
}
```

```
while(i < n1) {
```

```
    arr[k] = L[i];
```

```
    i++;
```

```
    k++;
```

```
}
```

```
while(j < n2) {
```

```
    arr[k] = R[j];
```

```
    j++;
```

```
    k++;
```

```
}
```

```
}
```

```
void mergeSort(int arr[], int left, int right) {
```

```
    if(left < right) {
```

```
        int mid = left + (right - left) / 2;
```

```
        mergeSort(arr, left, mid);
        mergeSort(arr, mid + 1, right);
        merge(arr, left, right, mid);
    }
}
```

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

```
int main() {
    int n;
    clock_t start, end;

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

    int arr[n];

    srand(time(NULL));

    for(int i = 0; i < n; i++) {
        arr[i] = rand() % 1000;
    }
}
```

```
}
```

```
printf("Original Array: ");
```

```
print(arr, n);
```

```
start = clock();
```

```
mergeSort(arr, 0, n - 1);
```

```
end = clock();
```

```
printf("Sorted Array: ");
```

```
print(arr, n);
```

```
printf("Time taken: %f seconds\n", 1000 * (double)(end - start) / CLOCKS_PER_SEC);
```

```
return 0;
```

```
}
```

Screenshot of Output

```
Time taken: 1.000000 seconds
```


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LAB-01 Sort a given set of N integer elements using Merge Sort Technique and compute its time taken. Run the program for diff^r values of N and record the time taken to sort.

Merge sort

```
- #include <stdio.h>
void merge(int arr[], int left, int mid, int right) {
    int i, j, k;
    int n1 = mid - left + 1;
    int n2 = right - mid;
    int L[n1], R[n2];
    for (int i = 0; i < n1; ++i)
        L[i] = arr[left + i];
    for (int j = 0; j < n2; ++j)
        R[j] = arr[mid + 1 + j];
    i = 0; j = 0; k = left;
    while (i < n1 && j < n2)
        if (L[i] <= R[j]) { arr[k] = L[i]; ++i; }
        else { arr[k] = R[j]; ++j; }
        ++k;
    while (j < n2) {
        arr[k] = R[j];
        ++j; ++k;
    }
    while (i < n1) {
        arr[k] = L[i];
        ++i; ++k;
    }
}
```

```

void merge-sort(int arr[], int left, int right) {
    if (left < right) {
        int mid = left + (right - left) / 2;
        merge-sort(arr, left, mid);
        merge-sort(arr, mid + 1, right);
        merge(arr, left, mid, right);
    }
}

```

```

}
void run_exp(int n) {
    int arr[MAX_SIZE];
    for (int i = 0; i < n; ++i) {
        arr[i] = rand() % 1000;
    }
    clock_t start_time = clock();
    merge-sort(arr, 0, n - 1);
    clock_t end_time = clock();
    double time_taken = (double)(end_time - start_time) / CLOCKS_PER_SEC;
    printf("N: %d, Time taken: %.6f sec\n",
           n, time_taken);
}

```

```

int main() {
    srand(time(NULL));
    int n_values[10];
    printf("Enter no. of elements: ");
    scanf("%d", &n);
    printf("Enter elements: ");
    for (int i = 0; i < n; ++i) {
        scanf("%d", &n_values[i]);
    }
    merge-sort(n_values, 0, n);
}

```

Output: $N = 10$ - execution time = 0.00002 sec
 $N = 20$ - 0.000010 sec
 $N = 50$ - 0.000025 sec
 $N = 200$ - 0.000105 sec
 $N = 500$ - 0.000310 sec
 $N = 2000$ - 0.001502 sec
 $N = 5000$ - 0.003902 sec
 $N = 10000$ - 0.009804 sec

Algorithm:

Mergesort($A[0 \dots n-1]$)

if ($n > 1$)

copy $A[0 \dots [n/2]-1]$ to $B[0 \dots [n/2]-1]$

copy $A[n/2 \dots n-1]$ to $C[0 \dots [n/2]-1]$

Mergesort($B[0 \dots n/2-1]$)

Merge($C[0 \dots n/2-1]$)

Merge(B, C, A)

Merge($B[0 \dots p-1], C[0 \dots q-1], A[0 \dots p+q-1]$)

$i \leftarrow 0; j \leftarrow 0; k \leftarrow 0$

while $i < p, j < q$ do

if $B[i] \leq C[j]$

$A[k] \leftarrow B[i]; i \leftarrow i+1$

else $A[k] \leftarrow C[j]; j \leftarrow j+1$

$k \leftarrow k+1;$

if $i = p$

copy $C[j \dots q-1]$ to $A[k \dots p+q-1]$

else copy $B[i \dots p-1]$ to $A[k, p+q-1]$

Enter no of element: 5

array of element: 61 25 43 26 34 43 61

Sort array: 25 26 34 43 61

left : 61 25 43

left : 61

right : 25 43

left : 25

right 43

merge [25 43]

merge [25 43 61]

right 26 34

left 26

Right 34

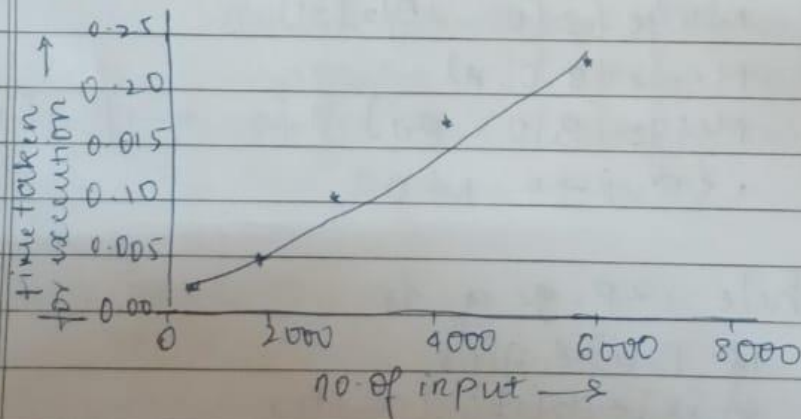
merge [25 43]

merge [25 43 61]

merge [25 43 61] [26 34]

final array [25 26 34 43 61]

Graph



Lab program 3:

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

Code

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

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

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

```
int partition(int arr[], int low, int high) {
```

```
    int pivot = arr[high];
```

```
    int i = low - 1;
```

```
    for (int j = low; j <= high - 1; j++) {
```

```
        if (arr[j] < pivot) {
```

```
            i++;
```

```
            int temp = arr[i];
```

```
            arr[i] = arr[j];
```

```
            arr[j] = temp;
```

```
        }
```

```
}
```

```
int temp = arr[i + 1];
```

```
arr[i + 1] = arr[high];
```

```
arr[high] = temp;
```

```
return (i + 1);
```

```
}
```

```
void quickSort(int arr[], int low, int high) {
```

```
    if (low < high) {
```

```
        int pi = partition(arr, low, high);
```

```
        quickSort(arr, low, pi - 1);
```

```
        quickSort(arr, pi + 1, high);
```

```
    }
```

```
}
```

```
void print(int arr[], int size) {
```

```
    for (int i = 0; i < size; i++) {
```

```
        printf("%d ", arr[i]);
```

```
    }
```

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

```
}
```



```
int main() {  
    int n;  
    clock_t start, end;  
  
    printf("Enter the number of elements in the array: ");  
    scanf("%d", &n);  
  
    int arr[n];  
  
    srand(time(NULL));  
  
    for (int i = 0; i < n; i++) {  
        arr[i] = rand() % 1001;  
    }  
  
    printf("Original Array: ");  
    print(arr, n);  
  
    start = clock();  
  
    quickSort(arr, 0, n - 1);
```

[illegible]

04/09/25
LAB-02

Quick Sort

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```
Code: #include <stdio.h>
void swap(int *a, int *b){
    int temp = *a;
    *a = *b;
    *b = temp;
}

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

void quicksort(int arr[], int low, int high){
    if (low < high){
        int pi = partition(arr, low, high);
        quicksort(arr, low, pi-1);
        quicksort(arr, pi+1, high);
    }
}

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

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Tra

```

int main() {
    int n;
    printf("Enter no. of elements: ");
    scanf("%d", &n);
    int arr[n];
    printf("Enter the elements: ");
    for (int i = 0; i < n; ++i) {
        scanf("%d", &arr[i]);
    }
    quicksort(arr, 0, n-1);
    printf("Sorted Array: \n");
    printArray(arr, n);
    return 0;
}

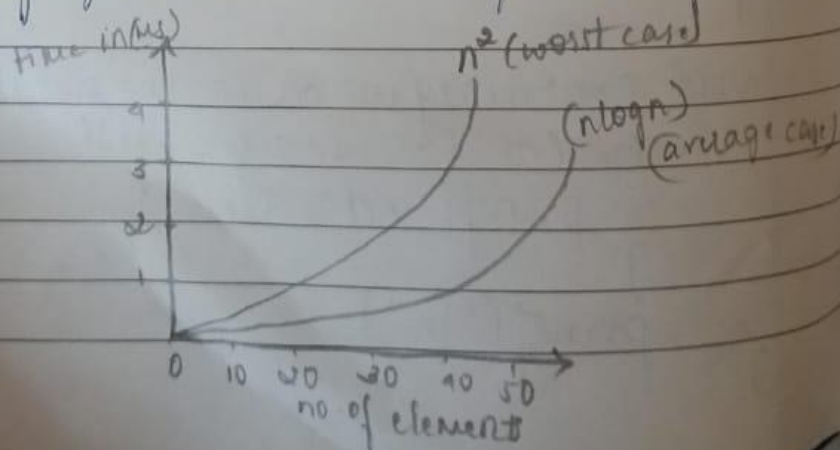
```

Output: Enter no. of elements: 9
 Enter elements: 20 2 9 7 12 15 1 6 8
 Sorted array:
 1 2 6 7 8 9 12 15 20

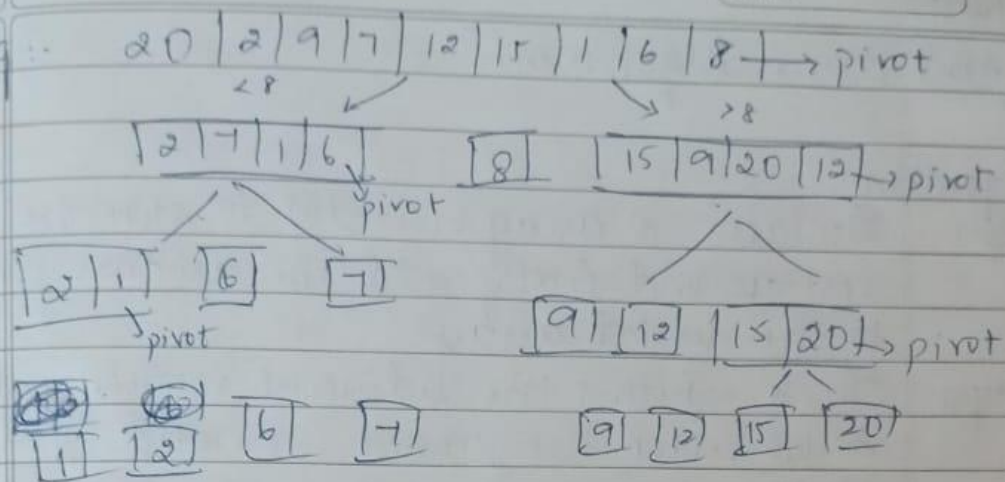
Algorithm:-

- step 1: Choose a pivot element
- step 2: Partition the array
 * Elements smaller to pivot move to its left.
 * Elements greater to pivot move to its right.
- step 3: Recursively apply quick sort
 apply quick sort on the left and right sequentially.

Graph



Traing ::



sorted array = $\{1, 2, 6, 7, 9, 12, 15, 20\}$

Lab program 4:

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

Code

```
#include<stdio.h
```

```

#include<conio.h>

int cost[10][10],vt[10],et[10][10],vis[10],j,n;

int sum=0;

int x=1;

int e=0;

void prims();

void main()
{
    int i;

    printf("enter the number of vertices\n");
    scanf("%d",&n);
    printf("enter the cost adjacency matrix\n");
    for(i=1;i<=n;i++)
    {
        for(j=1;j<=n;j++)
        {
            scanf("%d",&cost[i][j]);
        }
        vis[i]=0;
    }
    prims();
    printf("edges of spanning tree\n");
    for(i=1;i<=e;i++)
    {
        printf("%d,%d\t",et[i][0],et[i][1]);
    }
}

```

$$\}$$
$$\{$$
$$vt[x]=1;$$

```
for(s=1;s<n;s++)
```

$$\{$$

```
min=999;
```

$$\{$$

```
for(m=2;m<=n;m++)
```

$$\{$$
$$\{$$
$$j^{--};$$

```
}  
vt[++x]=v;  
et[s][0]=u;  
et[s][1]=v;  
e++;  
vis[v]=1;  
sum=sum+min;  
}  
}
```

Screenshot of Output

```
enter the number of vertices  
5  
enter the cost adjacency matrix  
999 2 999 6 999  
2 999 3 8 5  
999 3 999 999 7  
6 8 999 999 9  
999 5 7 9 999  
edges of spanning tree  
1,2      2,3      2,5      1,4      weight=16
```

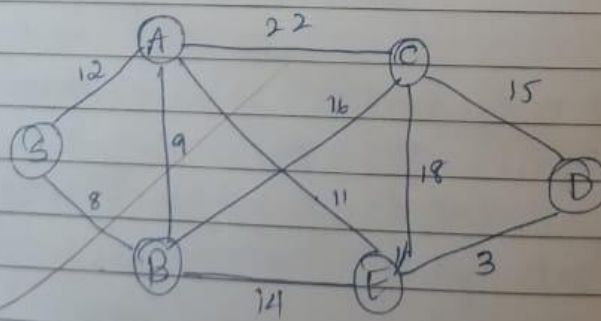
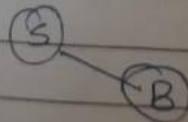
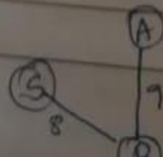

04/04/25

LAB 0 Prime algorithm.

Algorithm:

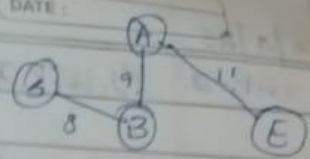
- step 1: Declare an array visited[] to store the visited vertices and firstly, add the arbitrary root to the visited array.
- step 2: Check whether the adjacent vertices of the last visited vertex are present in visited [] or not.
- step 3: If the vertices are not in the visited [] array, compare the cost of edges and add the least cost edge to output spanning tree.
- step 4: The adjacent unvisited vertex with the least cost edge is added into the visited [] array and the least cost edge is added to minimum spanning tree output.
- step 5: Steps 2 & 4 are repeated for all the unvisited in the graph to obtain the full minimum spanning tree output for the given graph.
- step 6: Calculate the cost of the minimum spanning tree obtained.

input graph

 $V = \{S\} : S \rightarrow B = 8$ $V = \{S, B\}$  $B \rightarrow A = 9 : B \rightarrow C = 16 : B \rightarrow E = 14$ $V = \{S, B, A\}$ 

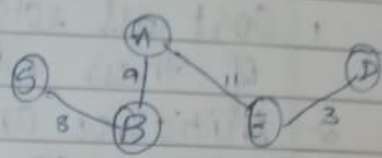
$A \rightarrow C = 20$; $A \rightarrow B = 9$; $A \rightarrow E = 11$

$V = \{S, B, A, E\}$



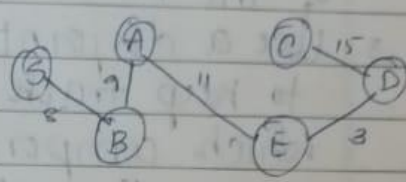
$E \rightarrow C = 18$; $E \rightarrow D = 3$

$V = \{S, B, A, E, D\}$

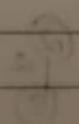
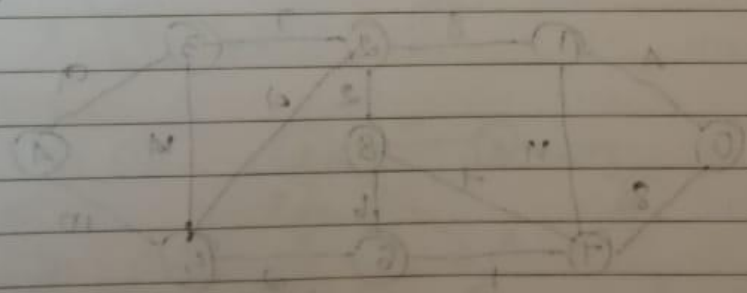


$D \rightarrow C = 15$; $E \rightarrow D = 3$

$V = \{S, B, A, E, D, C\}$



Split



Lab program 5:

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

Code

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

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

```
int find(int v,int parent[10])
```

```
{
```

```
    while(parent[v]!=v)
```

```
    {
```

```
        v=parent[v];
```

```
    }
```

```
    return v;
```

```
}
```

```
void union1(int i,int j,int parent[10])
```

```
{
```

```
    if(i<j)
```

```
        parent[j]=i;
```

```
    else
```

```
        parent[i]=j;
```

```
}
```

```
void kruskal(int n,int a[10][10])
```

```
{
```

```
    int count,k,min,sum,i,j,t[10][10],u,v,parent[10];
```

```
    count=0;
```

```
    k=0;
```

```
    sum=0;
```

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

```
        parent[i]=i;
```

```
    while(count!=n-1)
```

```
    {
```

```
        min=999;
```

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

```
        {
```

```
            for(j=0;j<n;j++)
```

```
            {
```

```
                if(a[i][j]<min && a[i][j]!=0)
```

```
                {
```

```
                    min=a[i][j];
```

```
                    u=i;
```

```
                    v=j;
```

```
                }
```

```

        }
    }
    i=find(u,parent);
    j=find(v,parent);
    if(i!=j)
    {
        union1(i,j,parent);
        t[k][0]=u;
        t[k][1]=v;
        k++;
        count++;
        sum=sum+a[u][v];
    }
    a[u][v]=a[v][u]=999;
}
if(count==n-1)
{
    printf("spanning tree\n");
    for(i=0;i<n-1;i++)
    {
        printf("%d %d\n",t[i][0],t[i][1]);
    }
    printf("cost of spanning tree=%d\n",sum);
}
else
    printf("spanning tree does not exist\n");
}

```

```

void main()
{
    int n,i,j,a[10][10];

```

```
clrscr();

printf("enter the number of nodes\n");

scanf("%d",&n);

printf("enter the adjacency matrix\n");

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

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

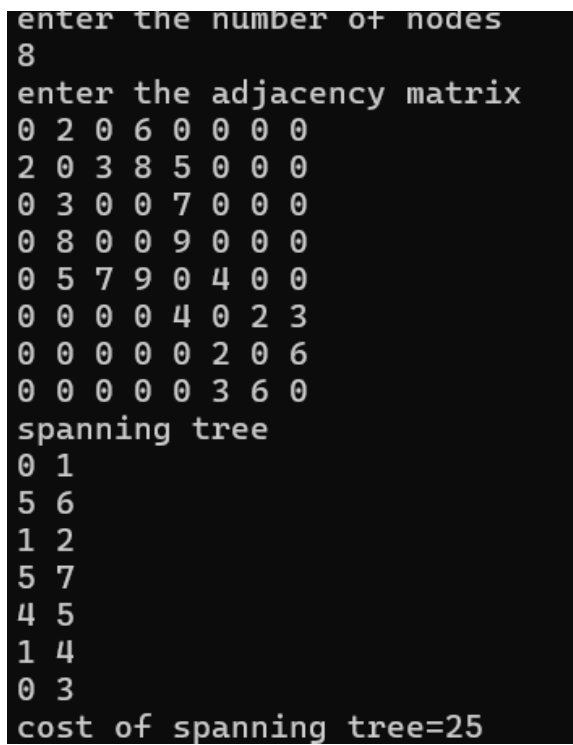
        scanf("%d",&a[i][j]);

kruskal(n,a);

getch();

}
```

Screenshot of Output



```
enter the number of nodes
8
enter the adjacency matrix
0 2 0 6 0 0 0 0
2 0 3 8 5 0 0 0
0 3 0 0 7 0 0 0
0 8 0 0 9 0 0 0
0 5 7 9 0 4 0 0
0 0 0 0 4 0 2 3
0 0 0 0 0 2 0 6
0 0 0 0 0 3 6 0
spanning tree
0 1
5 6
1 2
5 7
4 5
1 4
0 3
cost of spanning tree=25
```

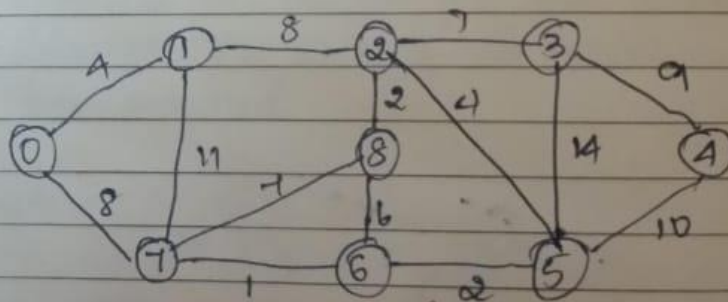
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LAB-2

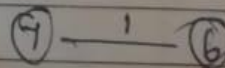
Kruskal's Algorithm

1. Sort all edges in non-decreasing order of their weights.
2. Initialize an empty set to store the edges of the MST.
3. Use a disjoint set (union-find) data structure to keep track of which vertices are in which components.
4. Iterate through the sorted edges:
 - For each edge (u, v) :
 - if u & v belong to different components include this edge in MST and union the components.
 - if they are in same component, skip the edge.
5. Stop when the MST has $(v-1)$ edges.

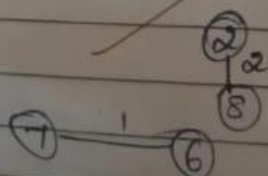
ex:-



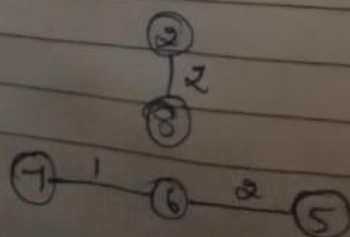
step 1:-



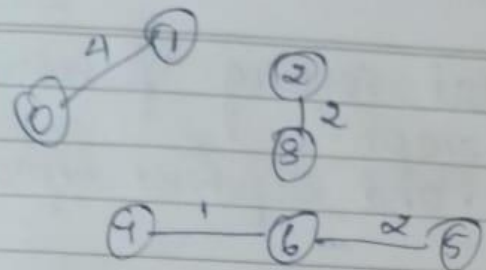
step 2:-



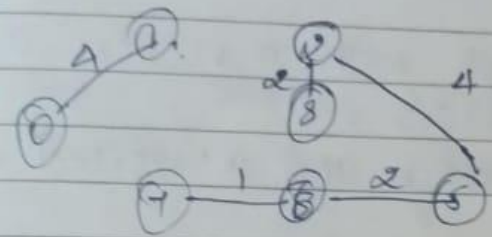
step 3:-



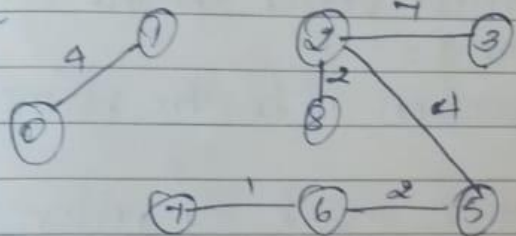
step 4:-



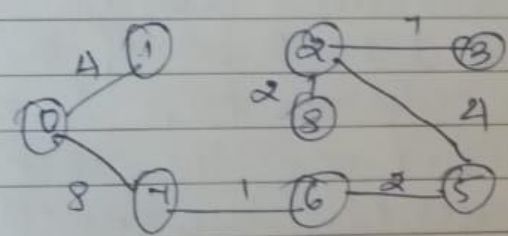
step 5:-



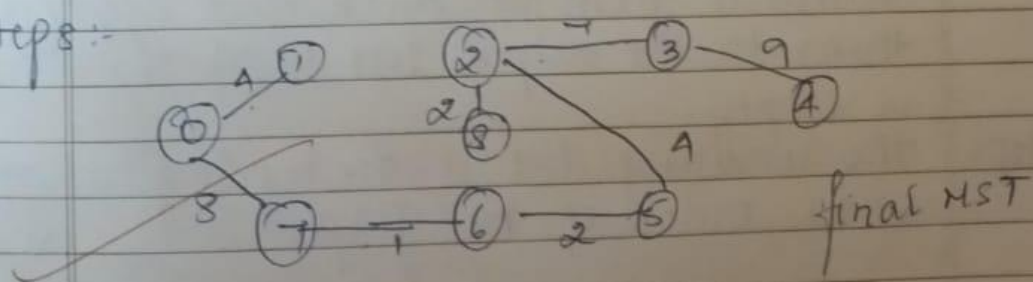
step 6:-



step 7:-



step 8:-



Lab program 6:

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

Code

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



```
#define INF 999
```

```
void dijkstra(int n, int cost[10][10], int src) {
```

```
    int i, j, u, dis[10], vis[10], min;
```

```
    // Initialize distances and visited flags
```

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

```
        dis[i] = cost[src][i];
```

```
        vis[i] = 0;
```

```
    }
```

```
    vis[src] = 1;
```

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

```
        min = INF;
```

```
        u = -1;
```

```
        // Find the unvisited vertex with the smallest distance
```

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

```
            if (vis[j] == 0 && dis[j] < min) {
```

```
                min = dis[j];
```

```
                u = j;
```

```
            }
```

```
        }
```

```
        if (u == -1) break; // All reachable vertices visited
```

```
        vis[u] = 1;
```

```

// Update distances to neighboring vertices
for (j = 1; j <= n; j++) {
    if (vis[j] == 0 && dis[u] + cost[u][j] < dis[j]) {
        dis[j] = dis[u] + cost[u][j];
    }
}

printf("Shortest paths from vertex %d:\n", src);
for (i = 1; i <= n; i++) {
    if (dis[i] == INF)
        printf("%d -> %d = INF\n", src, i);
    else
        printf("%d -> %d = %d\n", src, i, dis[i]);
}

}

int main() {
    int src, j, cost[10][10], n, i;

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

    printf("Enter the cost adjacency matrix (use 999 for no connection):\n");
    for (i = 1; i <= n; i++) {
        for (j = 1; j <= n; j++) {
            scanf("%d", &cost[i][j]);
        }
    }
}

```

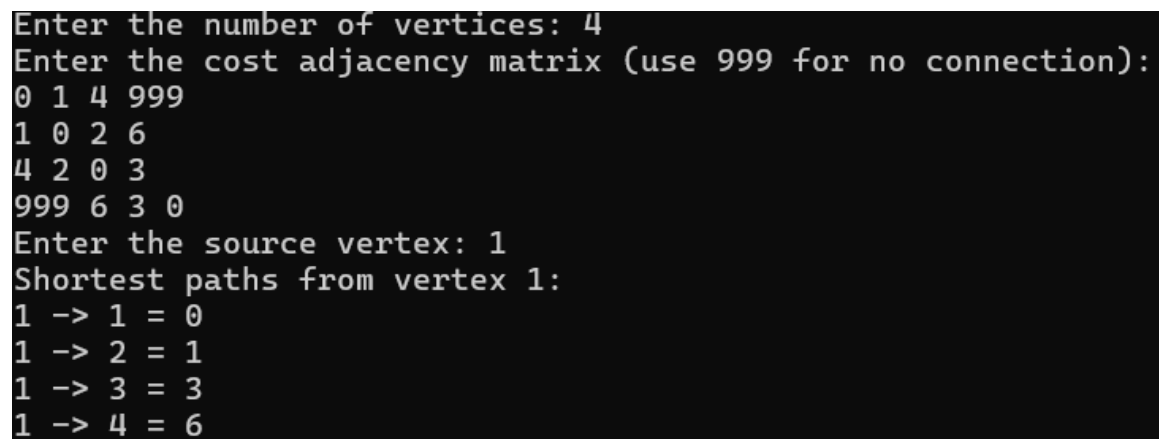
```
}

printf("Enter the source vertex: ");
scanf("%d", &src);

dijkstra(n, cost, src);

return 0;
}
```

Screenshot of Output



```
Enter the number of vertices: 4
Enter the cost adjacency matrix (use 999 for no connection):
0 1 4 999
1 0 2 6
4 2 0 3
999 6 3 0
Enter the source vertex: 1
Shortest paths from vertex 1:
1 -> 1 = 0
1 -> 2 = 1
1 -> 3 = 3
1 -> 4 = 6
```

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

Algorithm.

step 1: set $\text{dist}[\text{source}] = 0$ and all other distances as infinity.

step 2: Push the source node into the min heap as a pair $\langle \text{distance}, \text{node} \rangle$ i.e., $\langle 0, \text{source} \rangle$

step 3: Pop the top element (node with the smallest distance)

1. For each adjacent neighbor of the current node:

2. Calculate the distance using the formula:

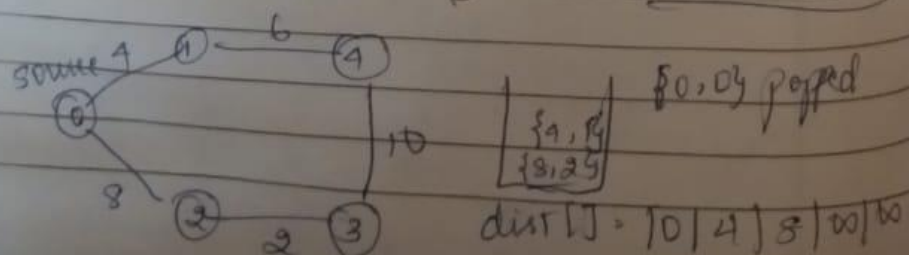
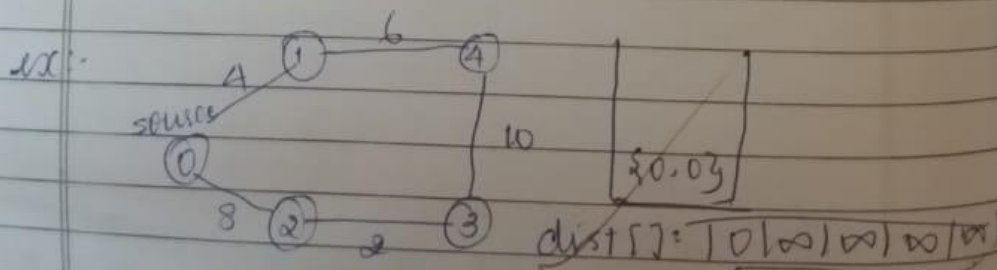
$$\text{dist}[v] = \text{dist}[u] + \text{weight}[u][v]$$

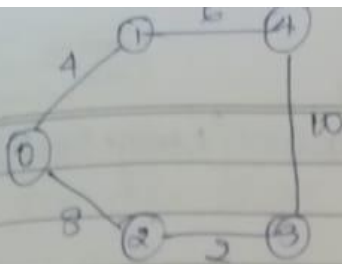
- if this new distance is shorter than the current $\text{dist}[v]$, update it.

- push the updated pair $\langle \text{dist}[v], v \rangle$ into the min heap.

step 4: Repeat step 3 until the min heap is empty

step 5: Return the distance array, which holds the shortest distance from the source to all nodes.

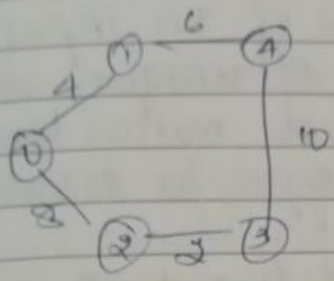




$\{3, 2\}$
 $\{10, 4\}$

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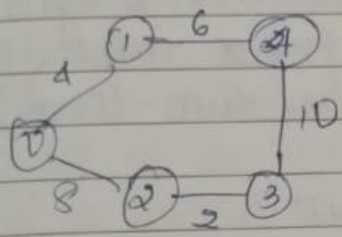
$dist[] = [0, 4, 8, \infty, 10]$



$\{10, 3\}$
 $\{10, 4\}$

$\{3, 2\}$ pop

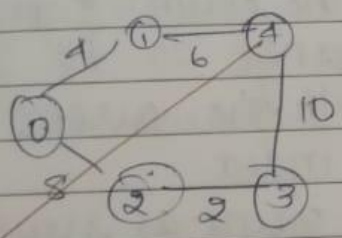
$dist[] = [0, 4, 8, 10, 10]$



$\{10, 4\}$

$\{10, 3\}$ pop

$dist[] = [0, 4, 8, 10, 10]$



$\{10, 4\}$ pop

$dist[] = [0, 4, 8, 10, 10]$

Q. 8
 19/5/21

Lab program 7:

Implement Johnson Trotter algorithm to generate permutations.

Code

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

```
#define LEFT_TO_RIGHT 1
```

```
#define RIGHT_TO_LEFT 0
```

```

int searchArr(int a[], int n, int mobile) {
    for (int i = 0; i < n; i++)
        if (a[i] == mobile)
            return i + 1;
    return -1;
}

```

```

int getMobile(int a[], int dir[], int n) {
    int mobile_prev = 0, mobile = 0;

    for (int i = 0; i < n; i++) {
        if (dir[a[i] - 1] == RIGHT_TO_LEFT && i != 0) {
            if (a[i] > a[i - 1] && a[i] > mobile_prev) {
                mobile = a[i];
                mobile_prev = mobile;
            }
        }

        if (dir[a[i] - 1] == LEFT_TO_RIGHT && i != n - 1) {
            if (a[i] > a[i + 1] && a[i] > mobile_prev) {
                mobile = a[i];
                mobile_prev = mobile;
            }
        }
    }

    return mobile;
}

```

```

void printOnePerm(int a[], int dir[], int n) {

```

```
int mobile = getMobile(a, dir, n);
```

```
int pos = searchArr(a, n, mobile);
```

```
if (mobile == 0) return;
```

```
if (dir[a[pos - 1] - 1] == RIGHT_TO_LEFT) {
```

```
    int temp = a[pos - 1];
```

```
    a[pos - 1] = a[pos - 2];
```

```
    a[pos - 2] = temp;
```

```
} else if (dir[a[pos - 1] - 1] == LEFT_TO_RIGHT) {
```

```
    int temp = a[pos];
```

```
    a[pos] = a[pos - 1];
```

```
    a[pos - 1] = temp;
```

```
}
```

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

```
    if (a[i] > mobile) {
```

```
        dir[a[i] - 1] = !dir[a[i] - 1]; // toggle direction
```

```
    }
```

```
}
```

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

```
    printf("%d", a[i]);
```

```
    printf(" ");
```

```
}
```

```
int fact(int n) {
```

```
    int res = 1;
```

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



```

        res = res * i;

    return res;
}

void printPermutation(int n) {
    int a[n], dir[n];

    for (int i = 0; i < n; i++) {
        a[i] = i + 1;
        printf("%d", a[i]);
    }

    printf("\n");

    for (int i = 0; i < n; i++)
        dir[i] = RIGHT_TO_LEFT;

    for (int i = 1; i < fact(n); i++)
        printOnePerm(a, dir, n);
}

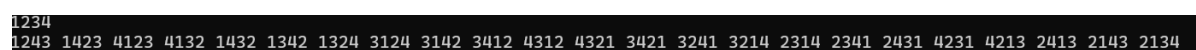
int main() {
    int n = 4;

    printPermutation(n);

    return 0;
}

```

Screenshot of Output



```

1234
1243 1423 4123 4132 1432 1342 1324 3124 3142 3412 4312 4321 3421 3241 3214 2314 2341 2431 4231 4213 2413 2143 2134

```

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Implement Johnson Trotter algorithm to generate permutations.

Algorithm

- Step 1: Find out the largest mobile integer in a particular sequence. A directed integer is said to be mobile if it is greater than its immediate neighbour in the direction it is looking at.
- Step 2: Switch this mobile integer and the adjacent integer to which its direction points.
- Step 3: Switch the direction of all the elements whose value is greater than the mobile integer value.
- Step 4: Repeat the step 1 until unless there is no mobile integer left in the sequence.

Ex: $\leftarrow 1 \leftarrow 2 \leftarrow 3$

Iteration 1 $\rightarrow \leftarrow 1 \leftarrow 2 \leftarrow 3$
 2 $\rightarrow \leftarrow 1 \leftarrow 3 \leftarrow 2$
 3 $\rightarrow \leftarrow 3 \leftarrow 1 \leftarrow 2$
 4 $\rightarrow \leftarrow 3 \leftarrow 2 \leftarrow 1$
 5 $\rightarrow \leftarrow 2 \leftarrow 3 \leftarrow 1$
 6 $\rightarrow \leftarrow 2 \leftarrow 1 \leftarrow 3$

\therefore Output: $\begin{matrix} 1 & 2 & 3 \\ 1 & 3 & 2 \\ 3 & 1 & 2 \\ 3 & 2 & 1 \\ 2 & 3 & 1 \\ 2 & 1 & 3 \end{matrix}$

program 8.1:

Implement Fractional Knapsack using Greedy technique.

Code

```
#include <stdio.h>

int main() {
    float weight[50], profit[50], ratio[50];
    float Totalvalue = 0.0, temp, capacity, amount;
    int n, i, j;

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

    for (i = 0; i < n; i++) {
        printf("Enter Weight and Profit for item[%d]:\n", i);
        scanf("%f %f", &weight[i], &profit[i]);
    }

    printf("Enter the capacity of knapsack:\n");
    scanf("%f", &capacity);

    // Calculate profit/weight ratio
    for (i = 0; i < n; i++)
        ratio[i] = profit[i] / weight[i];

    // Sort items by descending ratio
    for (i = 0; i < n; i++) {
        for (j = i + 1; j < n; j++) {
            if (ratio[i] < ratio[j]) {
```

```

        // Swap ratio
        temp = ratio[i];
        ratio[i] = ratio[j];
        ratio[j] = temp;

        // Swap weight
        temp = weight[i];
        weight[i] = weight[j];
        weight[j] = temp;

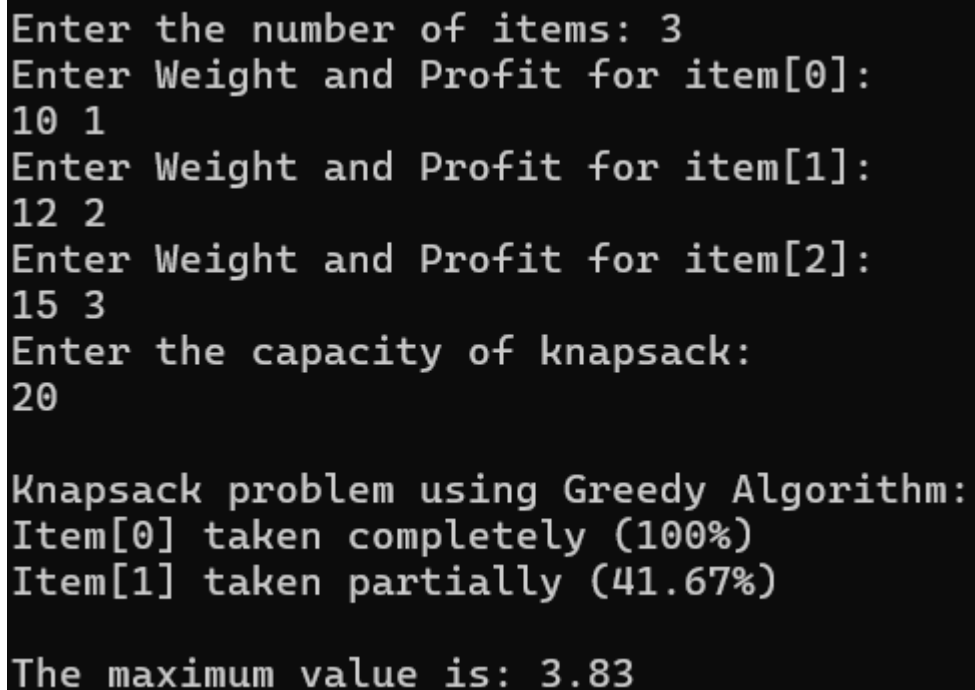
        // Swap profit
        temp = profit[i];
        profit[i] = profit[j];
        profit[j] = temp;
    }
}

printf("\nKnapsack problem using Greedy Algorithm:\n");
for (i = 0; i < n; i++) {
    if (weight[i] <= capacity) {
        // Take full item
        printf("Item[%d] taken completely (100%%)\n", i);
        Totalvalue += profit[i];
        capacity -= weight[i];
    } else {
        // Take fraction of item
        float fraction = capacity / weight[i];
        Totalvalue += profit[i] * fraction;
    }
}

```

```
        printf("Item[%d] taken partially (%.2f%%)\n", i, fraction * 100);  
        break; // Knapsack is now full  
    }  
}  
  
printf("\nThe maximum value is: %.2f\n", Totalvalue);  
return 0;  
}
```

Screenshot of Output



```
Enter the number of items: 3  
Enter Weight and Profit for item[0]:  
10 1  
Enter Weight and Profit for item[1]:  
12 2  
Enter Weight and Profit for item[2]:  
15 3  
Enter the capacity of knapsack:  
20  
  
Knapsack problem using Greedy Algorithm:  
Item[0] taken completely (100%)  
Item[1] taken partially (41.67%)  
  
The maximum value is: 3.83
```

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Implement Fractional knapsack using Greedy technique.

Algorithm:

step 1: Calculate the ratio (profit/weight) for each item.

step 2: Sort all the items in decreasing order of the ratio.

step 3: Initialize res = 0, current capacity = given capacity.

step 4: Do the following for every item i in the sorted order:

* if the weight of the current item is less than or equal to the remaining capacity then add the value of that item into the result.

* Else add the current item as much as we can and break out of the loop.

step 5: Return res.

Ex: val[] = [60, 100, 120]

wt[] = [10, 20, 30] capacity = 50

Sorting \Rightarrow $\{60, 10\}, \{100, 20\}, \{120, 30\}$

iteration: $i = 0$ weight = 10 < 50 \rightarrow add to the knapsack profit = 60 \rightarrow remaining cap =

$i = 1$: weight = 20 < 40 profit = 60 + 100 = 160

remaining capacity = 40 - 20 = 20

$i = 2$: weight = 30 > 20 \therefore fraction = $20/30 = 2/3 \times 120$
= 80 \therefore profit = 160 + 80 = 240 capacity

\therefore the final profit after capacity full is 240

Output: 240

Lab program 8.2:

LeetCode Program related to Greedy Technique algorithms

Code

```
char* largestOddNumber(char* num) {  
    int len = strlen(num);
```

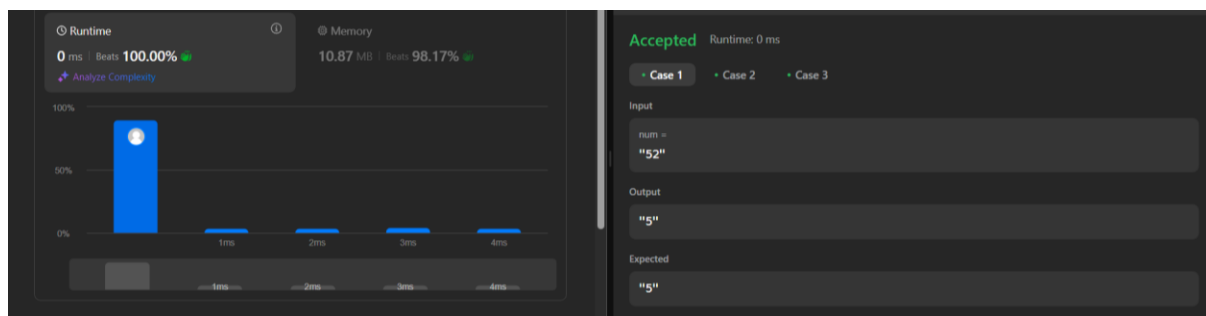
```

for (int i = len - 1; i >= 0; i--) {
    if ((num[i] - '0') % 2 == 1) {
        num[i + 1] = '\0'; // Truncate string at that position
        return num; // Return the longest odd-suffix (greedy)
    }
}

return ""; // No odd digit found
}

```

Screenshot of Output



Lab program 9.1:

Implement 0/1 Knapsack problem using dynamic programming.

Code

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

```
// Function to return the maximum of two numbers
```

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

```
// Function to solve the 0/1 Knapsack problem
```



```

int knapsack(int weight[], int profit[], int n, int capacity) {
    int i, w;
    int K[n + 1][capacity + 1];

    // Build the DP table K[][] bottom up
    for (i = 0; i <= n; i++) {
        for (w = 0; w <= capacity; w++) {
            if (i == 0 || w == 0)
                K[i][w] = 0;
            else if (weight[i - 1] <= w)
                K[i][w] = max(profit[i - 1] + K[i - 1][w - weight[i - 1]], K[i - 1][w]);
            else
                K[i][w] = K[i - 1][w];
        }
    }

    // Optional: Print the items included
    printf("\nItems included:\n");
    w = capacity;
    for (i = n; i > 0 && w > 0; i--) {
        if (K[i][w] != K[i - 1][w]) {
            printf("Item %d (Weight: %d, Profit: %d)\n", i, weight[i - 1], profit[i - 1]);
            w -= weight[i - 1];
        }
    }

    return K[n][capacity];
}

```

```
int main() {  
    int n, capacity;  
    int weight[50], profit[50];  
    int i;  
  
    printf("Enter number of items: ");  
    scanf("%d", &n);  
  
    printf("Enter weight and profit for each item:\n");  
    for (i = 0; i < n; i++) {  
        printf("Item[%d] - Weight Profit: ", i + 1);  
        scanf("%d %d", &weight[i], &profit[i]);  
    }  
  
    printf("Enter the capacity of knapsack: ");  
    scanf("%d", &capacity);  
  
    int maxProfit = knapsack(weight, profit, n, capacity);  
  
    printf("\nMaximum profit: %d\n", maxProfit);  
    return 0;  
}
```

Screenshot of Output

```
Enter number of items: 4
Enter weight and profit for each item:
Item[1] - Weight Profit: 2 12
Item[2] - Weight Profit: 3 15
Item[3] - Weight Profit: 1 25
Item[4] - Weight Profit: 2 10
Enter the capacity of knapsack: 4

Items included:
Item 3 (Weight: 1, Profit: 25)
Item 2 (Weight: 3, Profit: 15)

Maximum profit: 40
```

18/9/25
11B-3

Implement 0/1 knapsack problem using dynamic programming.

Algorithm

Step 1. Create dp table: Initialize a $(n+1) \times (\text{capacity} + 1)$ table with zeroes.

Step 2. Fill dp table.

- For each item i from $1 \rightarrow n$:

For each capacity w from 1 to capacity:

- if $\text{weight}[i-1] \leq w$ then

$\text{dp}[i][w] = \max(\text{value}[i-1] + \text{dp}[i-1][w - \text{weight}[i-1]], \text{dp}[i-1][w])$

- else: $\text{dp}[i][w] = \text{dp}[i-1][w]$

Step 3. Backtrack for items:-

- initialize $\text{included}[]$, $\text{current_capacity} = \text{capacity}$, $i = n$.

- while $i > 0$ and $\text{current_capacity} > 0$

- if $\text{dp}[i][\text{current_capacity}] \neq \text{dp}[i-1][\text{current_capacity}]$

- add $i-1$ to included .

- $\text{current_capacity} -= \text{weight}[i-1]$

- decrement i

Step 4. Return: $\text{dp}[n][\text{capacity}]$ and included .

Ex:-

weights	values
2	300
1	200
5	400
3	500

capacity = 10;

Output :- Tabulation Table :-

Weight	0	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	300	300	300	300	300	300	300	300	300
1	0	200	300	500	500	500	500	500	500	500	500
5	0	200	300	500	500	500	600	1000	900	900	900
3	0	200	300	500	700	800	1000	1000	1000	1000	1200

Maximum value in knapsack = 1200

Included item indices (0-based) : 0 2 3

Included items:

Value : 300 , Weight : 2

Value : 400 , Weight : 5

Value : 500 , Weight : 3

Here:

- $dp[4][10] = 1200$, $dp[3][10] = 900$ different so weight 3 is included. More to $dp[3][10-3] = dp[3][7]$
 - $dp[3][7] = 100$, $dp[2][7] = 500$ diff so weight 5 is included. More to $dp[2][7-5] = dp[2][2]$
 - $dp[2][2] = 300$, $dp[1][2] = 300$ same not included more to $dp[1][2] = 300$
 - $dp[1][2] = 300$, $dp[0][2] = 0$ diff so included weight 2. More to $dp[0][0]$
- Backtracking complete.

Lab program 9.2:

Code

```
class Solution(object):
```

```
    def fib(self, n):
```

```
        if n == 0:
```

```
            return 0
```

```
        if n == 1:
```

```
            return 1
```

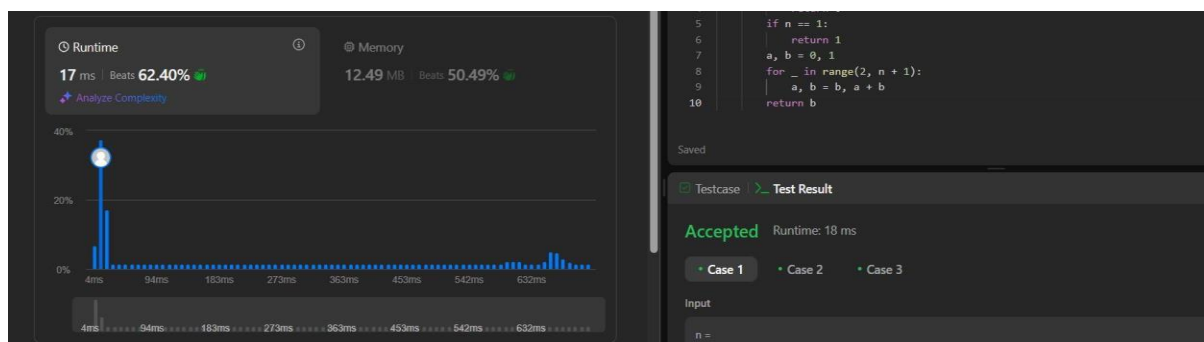
```
        a, b = 0, 1
```

```
        for _ in range(2, n + 1):
```

```
            a, b = b, a + b
```

```
        return b
```

Screenshot of Output



Lab program 10:

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

Code

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

void heapify(int arr[], int n, int i) {
    int largest = i;
    int left = 2 * i + 1;
    int right = 2 * i + 2;

    if (left < n && arr[left] > arr[largest])
        largest = left;

    if (right < n && arr[right] > arr[largest])
        largest = right;

    if (largest != i) {
        int temp = arr[i];
        arr[i] = arr[largest];
        arr[largest] = temp;

        heapify(arr, n, largest);
    }
}

void heapSort(int arr[], int n) {
    for (int i = n / 2 - 1; i >= 0; i--)
        heapify(arr, n, i);

    for (int i = n - 1; i >= 0; i--) {
        int temp = arr[0];
        arr[0] = arr[i];
        arr[i] = temp;

        heapify(arr, i, 0);
    }
}
```

```

int main() {
    int arr[1000], n;
    clock_t start, end;
    double time_taken;

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

    printf("Enter %d integer elements:\n", n);
    for (int i = 0; i < n; i++)
        scanf("%d", &arr[i]);

    start = clock();

    heapSort(arr, n);

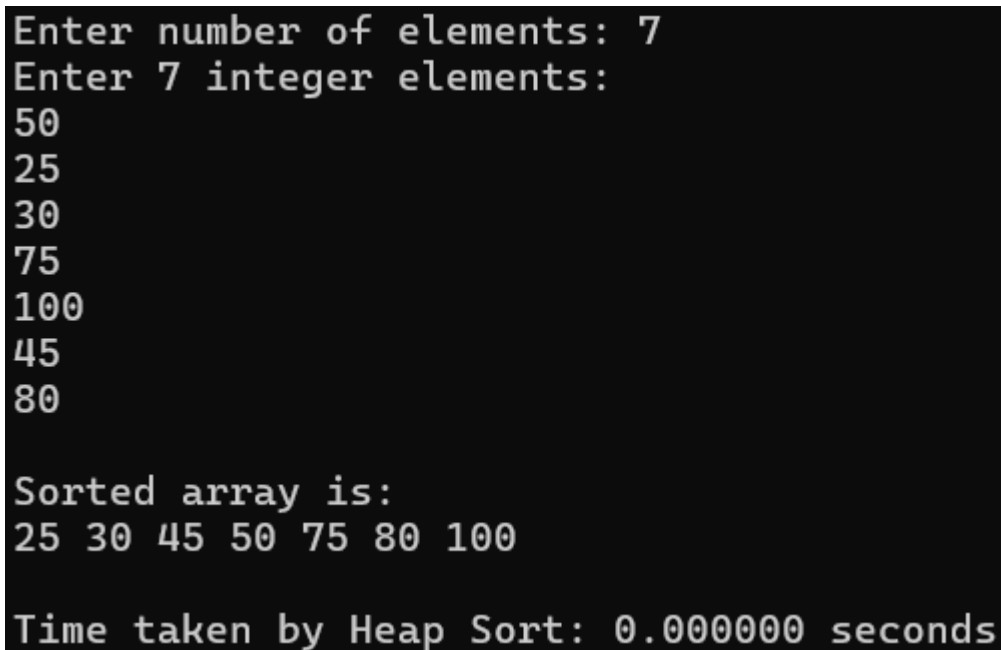
    end = clock();
    time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;
    printf("\nSorted array is:\n");
    for (int i = 0; i < n; i++)
        printf("%d ", arr[i]);

    printf("\n\nTime taken by Heap Sort: %f seconds\n", time_taken);

    return 0;
}

```

Screenshot of Output



```

Enter number of elements: 7
Enter 7 integer elements:
50
25
30
75
100
45
80

Sorted array is:
25 30 45 50 75 80 100

Time taken by Heap Sort: 0.000000 seconds

```


8/15/25

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

Algorithm:

Step 1: Rearrange array elements so that they form a Max Heap

Step 2: Repeat the following steps until the heap contains only one element:

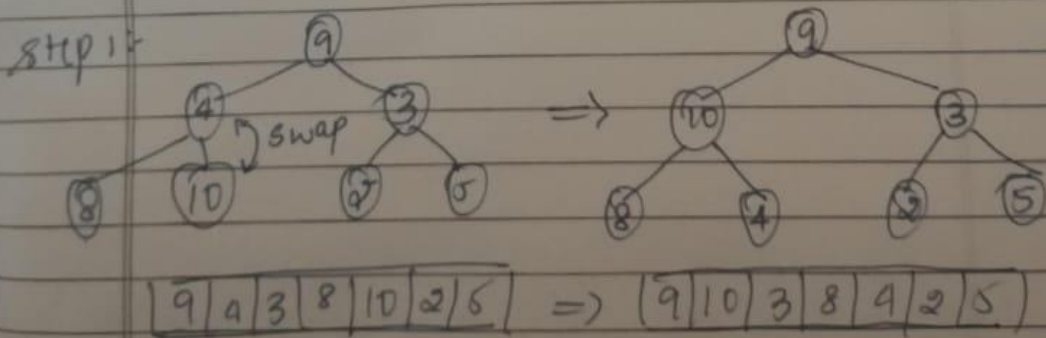
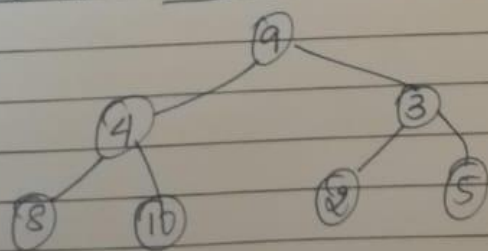
* Swap the root element of the heap (which is the largest element in current heap) with the last element of the heap.

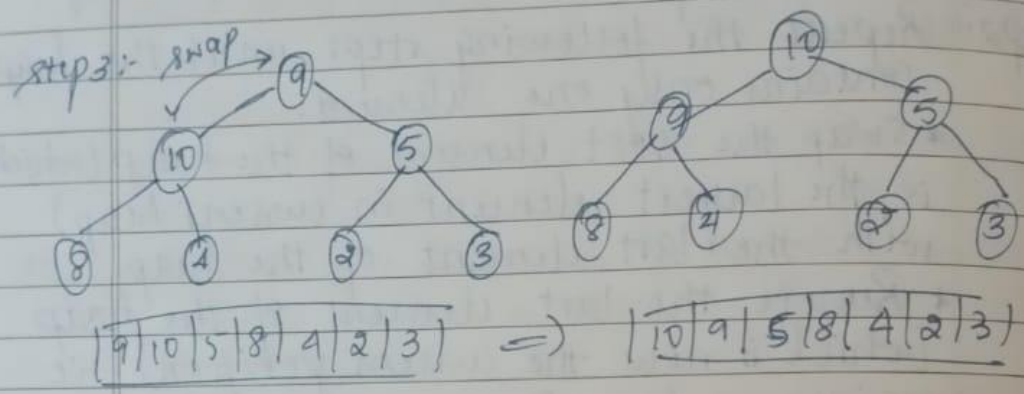
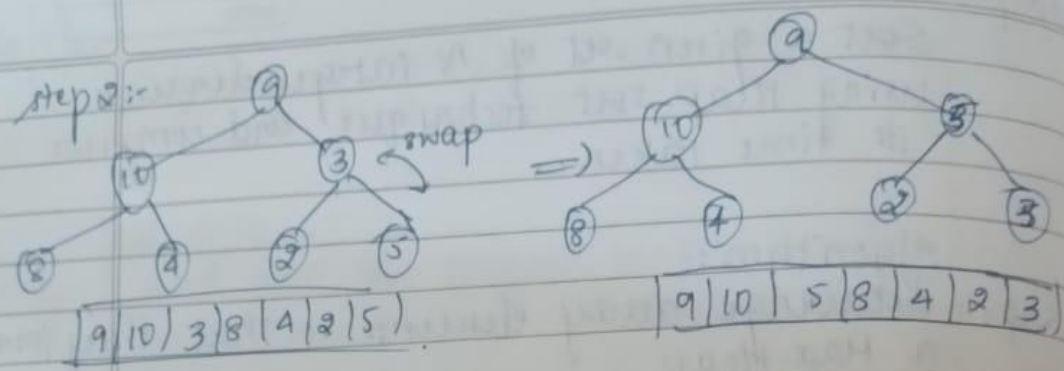
* Remove the last element of the heap (which is now the current position). We mainly reduce heap size and do not remove element from the actual array.

* Heapify the remaining elements of heap

Step 3: Finally we get the sorted array.

Ex: arr[] = [9, 4, 3, 8, 10, 2, 5]





Output: Sorted array is
2 3 4 5 8 9 10

Lab program 11.1:

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

Code

```
#include <stdio.h>

#define INF 99999 // Use a large number to represent infinity
#define MAX 100

void floydWarshall(int graph[MAX][MAX], int n) {
    int dist[MAX][MAX];
    int i, j, k;

    // Initialize the solution matrix same as input graph
    for (i = 0; i < n; i++)
        for (j = 0; j < n; j++)
            dist[i][j] = graph[i][j];

    // Floyd-Warshall algorithm
    for (k = 0; k < n; k++) {
        for (i = 0; i < n; i++) {
            for (j = 0; j < n; j++) {
                if (dist[i][k] + dist[k][j] < dist[i][j])
                    dist[i][j] = dist[i][k] + dist[k][j];
            }
        }
    }

    // Print the final shortest distance matrix
```

```

printf("\nAll-Pairs Shortest Paths (Floyd-Warshall):\n");

for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        if (dist[i][j] == INF)
            printf("INF ");
        else
            printf("%3d ", dist[i][j]);
    }
    printf("\n");
}

int main() {
    int graph[MAX][MAX], n;

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

    printf("Enter the adjacency matrix (use 99999 for no direct path):\n");
    for (int i = 0; i < n; i++) {
        for (int j = 0; j < n; j++) {
            scanf("%d", &graph[i][j]);
        }
    }

    floydWarshall(graph, n);

    return 0;
}

```

Screenshot of Output

```
Enter number of vertices: 4
Enter the adjacency matrix (use 99999 for no direct path):
0 4 3 9
99 0 1 99
99 990 99999
5 2 6 0
2 99 99999 99999
```

All-Pairs Shortest Paths (Floyd-Warshall):

0	4	3	8
8	0	1	6
7	11	5	5
2	6	0	2

15/5/25

Q3 Implement all pair shortest paths problem using Floyd's algorithm.

Algorithm :-

Step 1: Use a matrix $dist[i][j]$ where $dist[i][j]$ holds the shortest distance from vertex i to vertex j .

Step 2: Initialize $dist[i][j]$ with:

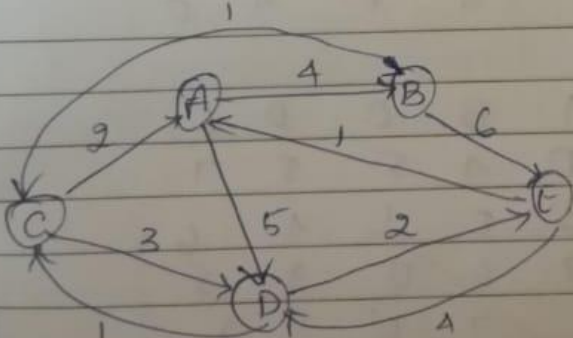
- 0 if $i = j$
- weight of edge (i, j) if it exists
- ∞ if no direct edge exists

Step 3: update $dist[i][j]$ by considering each vertex k as an intermediate vertex.

```

for k from 0 to v-1;
  for i from 0 to v-1;
    for j from 0 to v-1;
      if  $dist[i][k] + dist[k][j] < dist[i][j]$ 
         $dist[i][j] = dist[i][k] + dist[k][j]$ 
  
```

ex:-



Step 1:

initial matrix :-

	A	B	C	D	E
A	0	4	∞	5	∞
B	∞	0	1	∞	6
C	2	∞	0	3	∞
D	∞	∞	1	0	2
E	1	∞	∞	4	0

Step 2: (A)

	A	B	C	D	E		A	B	C	D	E
A	0	4	5	7		A	0	4	5	7	
B	4	0	1	6		B	4	0	1	6	
C	5	1	0	3		C	5	6	0	3	
D	7	6	3	0	2	D	7	1	0	2	
E	1	6	4	2	0	E	1	5	3	1	0

Step 3: (B)

	A	B	C	D	E
A	0	4	5	5	10
B	4	0	1	6	6
C	5	6	0	3	12
D	7	1	0	0	2
E	1	5	6	4	0

Step 4: (C)

	A	B	C	D	E
A	0	4	5	5	10
B	3	0	1	4	6
C	2	6	0	3	12
D	3	7	1	0	2
E	1	5	6	4	0

Step 5: (D)

	A	B	C	D	E
A	0	4	5	5	7
B	3	0	1	4	6
C	2	6	0	3	5
D	3	7	1	0	2
E	1	5	5	4	0

Step 6: (E)

	A	B	C	D	E
A	0	4	5	5	7
B	3	0	1	4	6
C	2	6	0	3	5
D	3	7	1	0	2
E	1	5	5	4	0

Step ① Since all nodes have been treated as an intermediate node
∴ final result after applying algorithm

Output:-

	A	B	C	D	E
A	0	4	5	5	7
B	3	0	1	4	6
C	2	6	0	3	5
D	3	7	1	0	2
E	1	5	5	4	0

Sgt
16/5/25

Lab program 11.2:

LeetCode Program related to shortest distance calculation

Code

class Solution:

```
def shortestPathLength(self, graph: List[List[int]]) -> int:
```

```
    n=len(graph)
```

```
    queue=deque([(i,1<<i) for i in range(n)])
```

```
    seen=set(queue)
```

```
    ans=0
```

```
    while queue:
```

```
        for _ in range(len(queue)):
```

```
            u,m=queue.popleft()
```

```
            if m==(1<<n)-1:
```

```
                return ans
```

```
            for v in graph[u]:
```

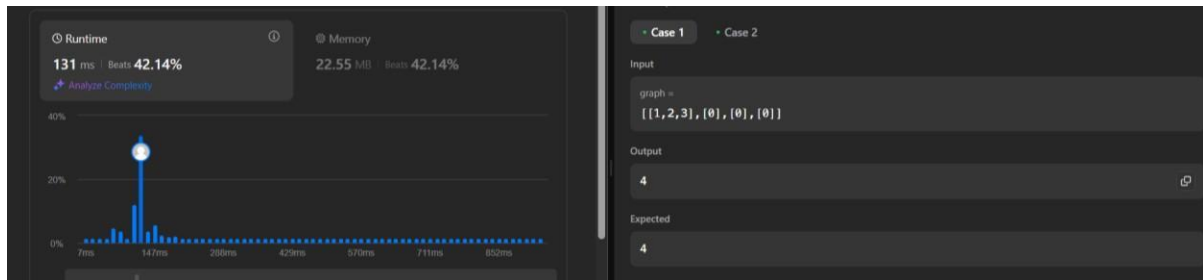
```
                if (v,m|1<<v) not in seen:
```

```
                    queue.append((v,m|1<<v))
```

```
                    seen.add((v,m|1<<v))
```

```
            ans+=1
```

Screenshot of Output



Lab program 12:

Implement “N-Queens Problem” using Backtracking.

Code

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

```
#include <math.h>
```

```
#define MAX 20
```

```
int board[MAX];
```

```
int found = 0;
```

```
// Function to print one solution
```

```
void printSolution(int n) {
```

```
    printf("One solution for %d-Queens:\n", n);
```

```
    for (int i = 1; i <= n; i++) {
```

```
        for (int j = 1; j <= n; j++) {
```

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

```
                printf("Q ");
```

```
            else
```

```

        printf(". ");
    }
    printf("\n");
}
found = 1;
}

// Check if placing queen at (k, i) is safe
int isSafe(int k, int i) {
    for (int j = 1; j < k; j++) {
        if (board[j] == i || fabs(board[j] - i) == fabs(j - k))
            return 0;
    }
    return 1;
}

// Recursive backtracking to find one solution
void nQueens(int k, int n) {
    for (int i = 1; i <= n && !found; i++) {
        if (isSafe(k, i)) {
            board[k] = i;
            if (k == n)
                printSolution(n);
            else
                nQueens(k + 1, n);
        }
    }
}
}

```

```

int main() {
    int n;

    printf("Enter number of queens (N): ");
    scanf("%d", &n);

    if (n < 1 || n > MAX) {
        printf("Please enter N between 1 and %d.\n", MAX);
        return 1;
    }

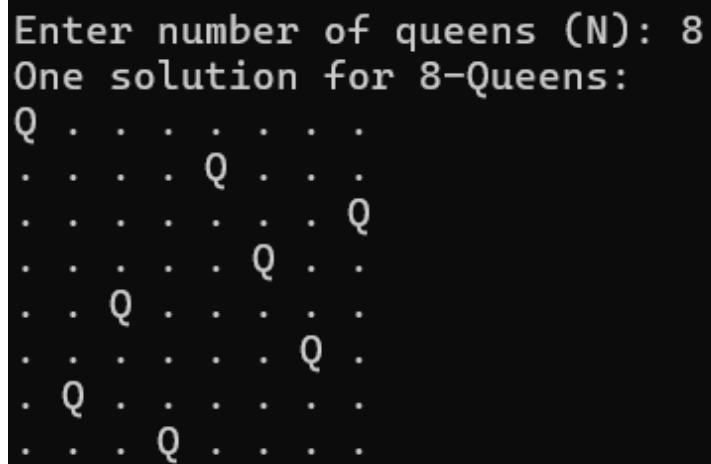
    nQueens(1, n);

    if (!found)
        printf("No solution exists for N = %d\n", n);

    return 0;
}

```

Screenshot of Output



```

Enter number of queens (N): 8
One solution for 8-Queens:
Q . . . . . . .
. . . . Q . . .
. . . . . . . Q
. . . . Q . . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .

```

23/05/20

PAGE NO.:

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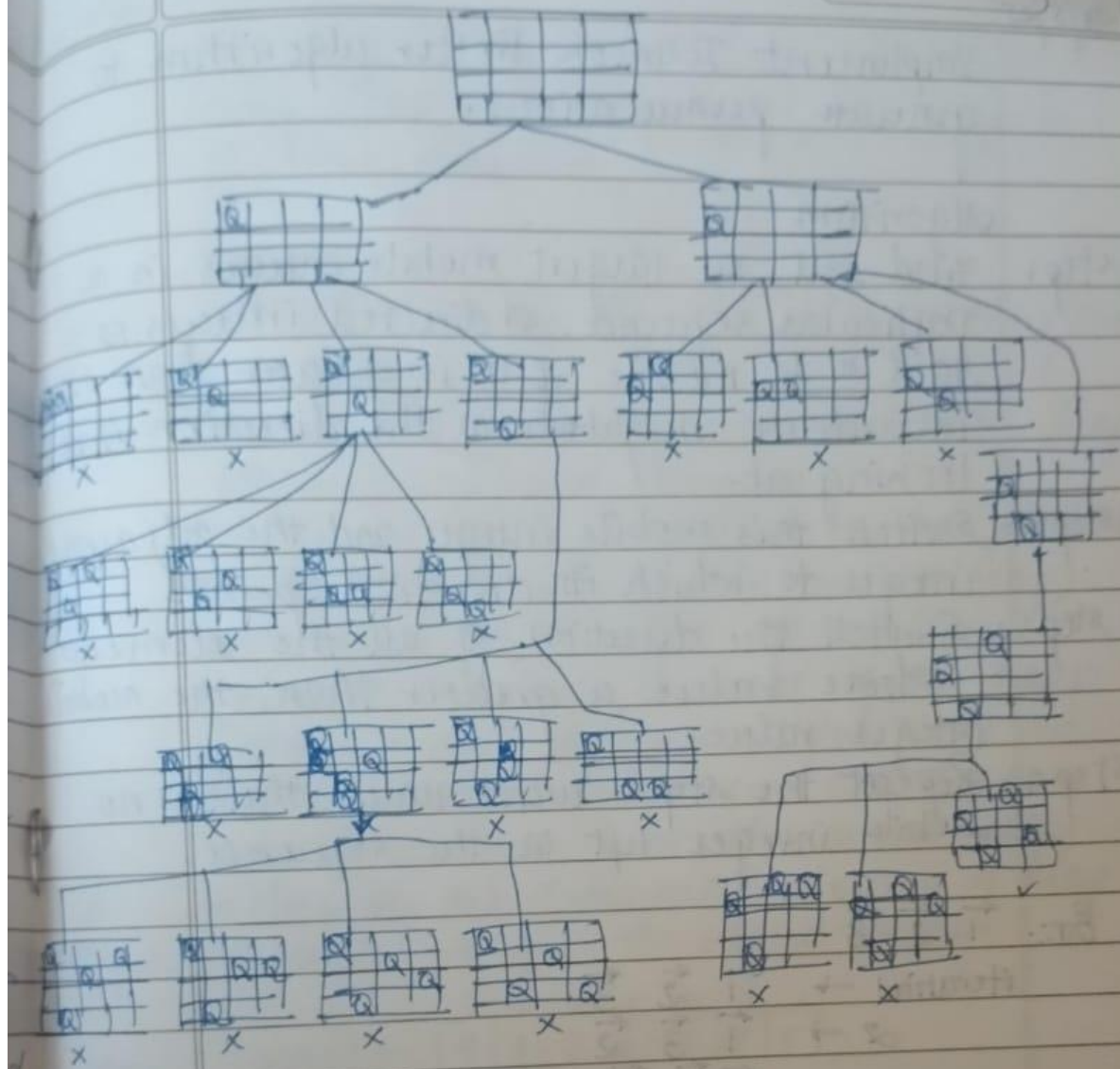
Implement 'N-Queens Problem' using Backtracking.

Algorithm:

- Step 1: Start from the leftmost column (column 0)
- Step 2: Try placing a queen in each row one by one in the current column.
- Step 3: For each placement, check if it's safe:
- * No queen in the same row to the left.
 - * No queen in the upper left diagonal.
 - * No queen in the lower left diagonal.
- Step 4: If it's safe, place the queen and move to the next column recursively.
- Step 5: If placing queen in any row in the current column leads to solution, return true.
- Step 6: If no row is safe in this column, backtrack: remove the queen and try it the next row.
- Step 7: Continue this until all N queens are placed.

Input: $n = 4$

Output: 2 4 1 3



\therefore final matrix is

		Q	
Q			
	Q		Q

4 2 4 1 3