VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

ANALYSIS AND DESIGN OF ALGORITHMS (23CS4PCADA)

Submitted by

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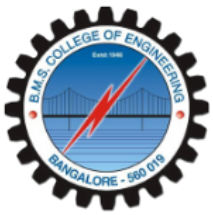
in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING



B.M.S. COLLEGE OF ENGINEERING
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BENGALURU-560019
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Bull Temple Road, Bangalore 560019
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Department of Computer Science and Engineering

This is to certify that the Lab work entitled **"Analysis and Design of Algorithms"** carried out by Shreyash Shaurya **(1BM23CS354)**, who is a 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 algorithm 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

1.1.1 Question

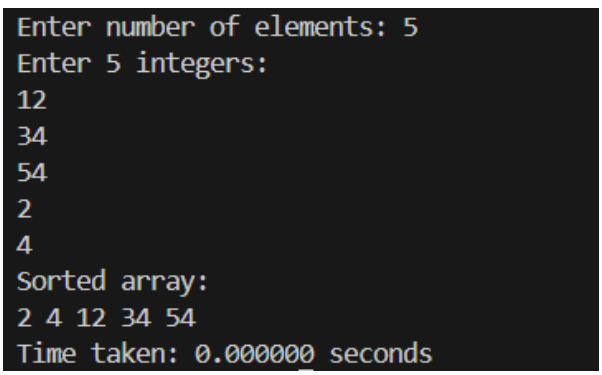
Sort a given set of N integer elements using Merge Sort technique and compute its time taken. Run the program for different values of N and record the time taken to sort.

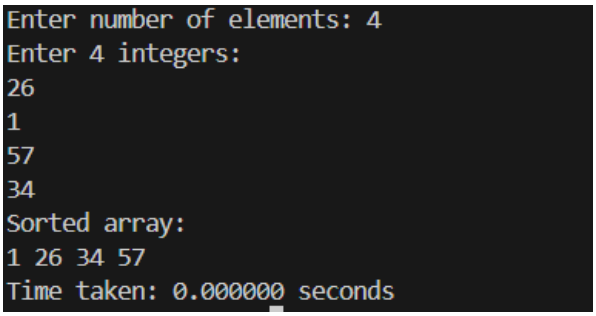
1.1.2 Code

```
#include <stdio.h>
#include <stdlib.h>
#include <time.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 = (int *)malloc(n1 * sizeof(int));
    int *R = (int *)malloc(n2 * sizeof(int));
    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) {
        arr[k++] = (L[i] <= R[j]) ? L[i++] : R[j++];
    }
    while (i < n1) arr[k++] = L[i++];
    while (j < n2) arr[k++] = R[j++];
    free(L);
    free(R);
}

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, mid, right);
    }
}

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

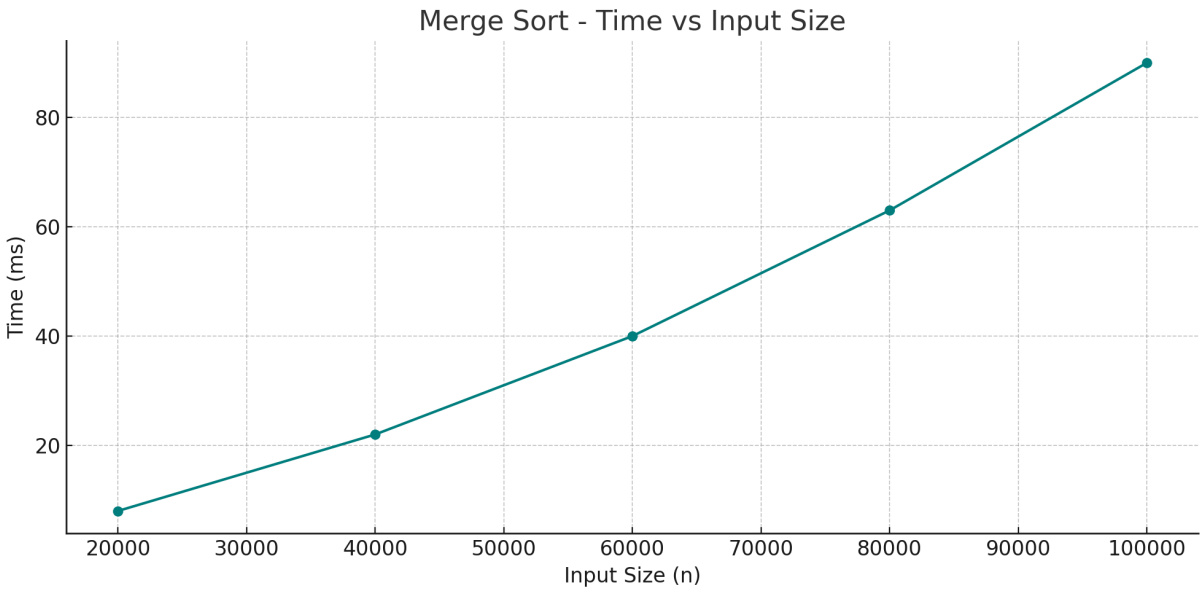
```
    int *arr = (int *)malloc(N * sizeof(int));
    if (arr == NULL) {
        printf("Memory allocation failed\n");
        return 1;
    }

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

    clock_t start = clock();
    mergeSort(arr, 0, N - 1);
    clock_t end = clock();

    double time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;

    printf("Sorted array:\n");
    for (int i = 0; i < N; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    printf("Time taken: %f seconds\n", time_taken);

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

1.1.3 Output





1.1.4 Graph


Merge Sort - Time vs Input Size
Time (ms)
20
40
60
80
20000
30000
40000
50000
60000
70000
80000
90000
100000
Input Size (n)

1.2.1 Leetcode Question
Count of Range Sum

1.2.2 Code

```
int countRangeSum(int* nums, int numsSize, int lower, int upper) {
    int count = 0;
    for (int i = 0; i < numsSize; i++) {
        long long sum = 0;
        for (int j = i; j < numsSize; j++) {
            sum += nums[j];
            if (sum >= lower && sum <= upper)
                count++;
        }
    }
    return count;
}
```

1.2.3 Output

Lab Program 2

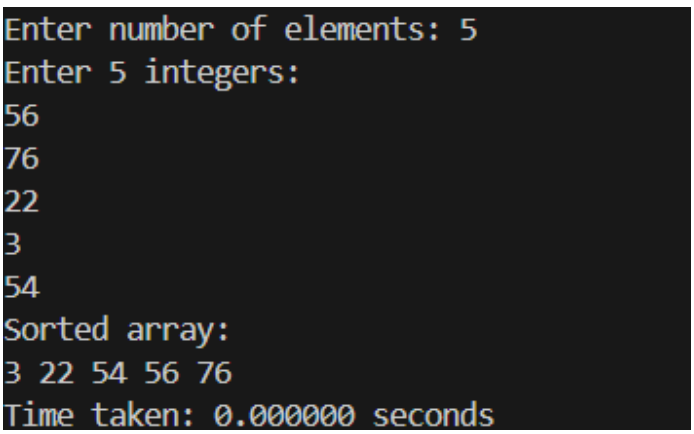
2.1.1 Question
Sort a given set of N integer elements using Quick Sort technique and compute its time taken.

2.1.2 Code

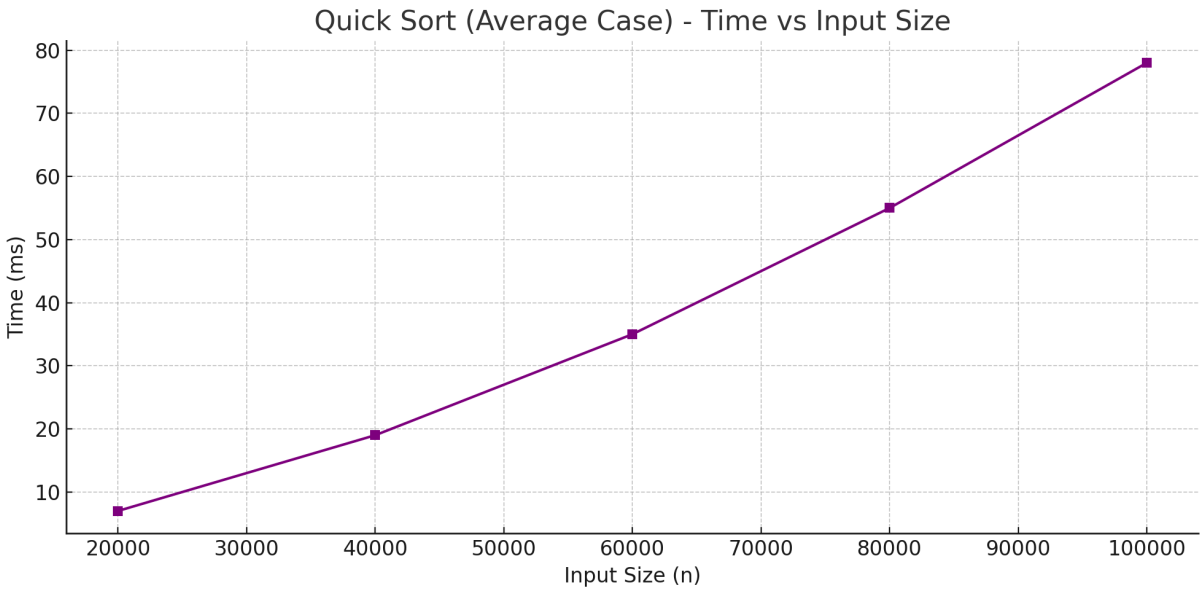
```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

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

int main() {
    int N;
    printf("Enter number of elements: ");
    scanf("%d", &N);

    int *arr = (int *)malloc(N * sizeof(int));
    if (arr == NULL) {
        printf("Memory allocation failed\n");
        return 1;
    }

    printf("Enter %d integers:\n", N);
    for (int i = 0; i < N; i++) {
```

```
        scanf("%d", &arr[i]);
    }

    clock_t start = clock();
    quickSort(arr, 0, N - 1);
    clock_t end = clock();

    double time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;

    printf("Sorted array:\n");
    for (int i = 0; i < N; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    printf("Time taken: %f seconds\n", time_taken);

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

2.1.3 Output



2.1.4 Graph

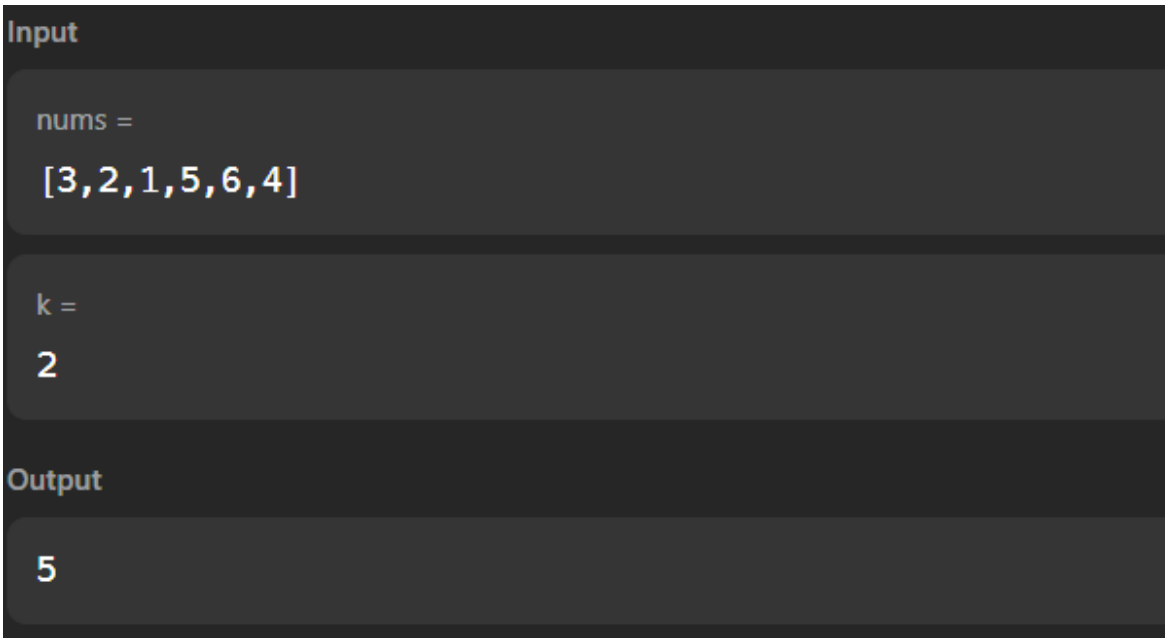

Quick Sort (Average Case) - Time vs Input Size
Time (ms)
Input Size (n)
10
20
30
40
50
60
70
80
20000
30000
40000
50000
60000
70000
80000
90000
100000

2.2.1 Leetcode Question
Kth Largest element in an array

2.2.2 Code

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

int partition(int arr[], int left, int right) {
   int pivot = arr[right];
   int i = left;
   for (int j = left; j < right; j++) {
      if (arr[j] <= pivot) {
         swap(&arr[i], &arr[j]);
         i++;
      }
   }
   swap(&arr[i], &arr[right]);
   return i;
}

int quickSelect(int arr[], int left, int right, int k) {
   if (left == right)
      return arr[left];

   int pivotIndex = partition(arr, left, right);

   if (k == pivotIndex)
      return arr[k];
   else if (k < pivotIndex)
      return quickSelect(arr, left, pivotIndex - 1, k);
   else
      return quickSelect(arr, pivotIndex + 1, right, k);
}

int findKthLargest(int arr[], int n, int k) {
   return quickSelect(arr, 0, n - 1, n - k);
}
```

2.2.3 Output



Lab Program 3

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

3.1.2 Code

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

#define MAX 100
#define INF 999999

int main() {
   int cost[MAX][MAX], visited[MAX];
   int n, i, j, min, u, v, total_cost = 0;

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

   printf("Enter the cost adjacency matrix (use %d for no edge):\n", INF);
   for (i = 0; i < n; i++) {
      for (j = 0; j < n; j++) {
         scanf("%d", &cost[i][j]);
         if (cost[i][j] == 0)
            cost[i][j] = INF;
      }
   }

   for (i = 0; i < n; i++)
      visited[i] = 0;

   visited[0] = 1;

   printf("Edges in the Minimum Cost Spanning Tree:\n");

   for (i = 0; i < n - 1; i++) {
      min = INF;
      for (j = 0; j < n; j++) {
         if (visited[j]) {
            for (int k = 0; k < n; k++) {
               if (!visited[k] && cost[j][k] < min) {
                  min = cost[j][k];
                  u = j;
                  v = k;
               }
```

```
            }
        }
    }
    visited[v] = 1;
    printf("%d - %d : %d\n", u, v, min);
    total_cost += min;
  }

  printf("Total cost of Minimum Spanning Tree: %d\n", total_cost);

  return 0;
}
```

3.1.3 Output

```
Enter number of vertices: 4
Enter the cost adjacency matrix (use 999999 for no edge):
0 3 999999 5
3 0 1 999999
999999 1 0 2
5 999999 2 0
Edges in the Minimum Cost Spanning Tree:
0 - 1 : 3
1 - 2 : 1
2 - 3 : 2
Total cost of Minimum Spanning Tree: 6
```

3.2.1 Question

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

3.2.2 Code

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

#define MAX 100
#define INF 999999

typedef struct {
   int u, v, w;
} Edge;

int parent[MAX];

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

void union_sets(int i, int j) {
   int a = find(i);
   int b = find(j);
   parent[a] = b;
}

void kruskal(Edge edges[], int n, int e) {
   int i, j;
   Edge temp;
   for (i = 0; i < e - 1; i++) {
      for (j = 0; j < e - i - 1; j++) {
         if (edges[j].w > edges[j + 1].w) {
            temp = edges[j];
            edges[j] = edges[j + 1];
            edges[j + 1] = temp;
         }
      }
   }

   for (i = 0; i < n; i++)
      parent[i] = i;

   int total_cost = 0;
```

```
    printf("Edges in the Minimum Cost Spanning Tree:\n");

    int count = 0;
    for (i = 0; i < e && count < n - 1; i++) {
        int u = edges[i].u;
        int v = edges[i].v;
        int w = edges[i].w;

        if (find(u) != find(v)) {
            union_sets(u, v);
            printf("%d - %d : %d\n", u, v, w);
            total_cost += w;
            count++;
        }
    }

    printf("Total cost of Minimum Spanning Tree: %d\n", total_cost);
}

int main() {
    int n, e;
    Edge edges[MAX];

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

    printf("Enter each edge as: u v weight\n");
    for (int i = 0; i < e; i++) {
        scanf("%d %d %d", &edges[i].u, &edges[i].v, &edges[i].w);
    }

    kruskal(edges, n, e);

    return 0;
}
```

3.2.3 Output

```
Enter number of vertices: 4
Enter number of edges: 5
Enter each edge as: u v weight
0 1 10
0 2 6
0 3 5
1 3 15
2 3 4
Edges in the Minimum Cost Spanning Tree:
2 - 3 : 4
0 - 3 : 5
0 - 1 : 10
Total cost of Minimum Spanning Tree: 19
```

Lab Program 4

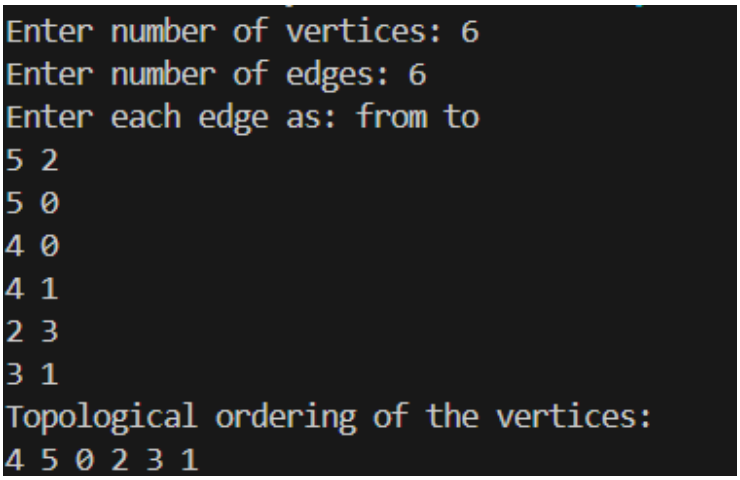
4.1.1 Question
Write a program to obtain the Topological ordering of vertices in a given digraph.

4.1.2 Code

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

#define MAX 100

int queue[MAX], front = -1, rear = -1;

void enqueue(int v) {
   if (rear == MAX - 1) return;
   if (front == -1) front = 0;
   queue[++rear] = v;
}

int dequeue() {
   if (front == -1 || front > rear) return -1;
   return queue[front++];
}

int isEmpty() {
   return (front == -1 || front > rear);
}

int main() {
   int n, e, i, j;
   int graph[MAX][MAX] = {0};
   int indegree[MAX] = {0};

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

   printf("Enter number of edges: ");
   scanf("%d", &e);

   printf("Enter each edge as: from to\n");
   for (i = 0; i < e; i++) {
      int u, v;
      scanf("%d %d", &u, &v);
      graph[u][v] = 1;
      indegree[v]++;
```

```
    }

    for (i = 0; i < n; i++) {
        if (indegree[i] == 0)
            enqueue(i);
    }

    int count = 0;
    int topo_order[MAX];

    while (!isEmpty()) {
        int u = dequeue();
        topo_order[count++] = u;

        for (j = 0; j < n; j++) {
            if (graph[u][j]) {
                indegree[j]--;
                if (indegree[j] == 0)
                    enqueue(j);
            }
        }
    }

    if (count != n) {
        printf("Cycle detected. Topological ordering not possible.\n");
    } else {
        printf("Topological ordering of the vertices:\n");
        for (i = 0; i < count; i++) {
            printf("%d ", topo_order[i]);
        }
        printf("\n");
    }

    return 0;
}
```

4.1.3 Output


Enter number of vertices: 6
Enter number of edges: 6
Enter each edge as: from to
5 2
5 0
4 0
4 1
2 3
3 1
Topological ordering of the vertices:
4 5 0 2 3 1

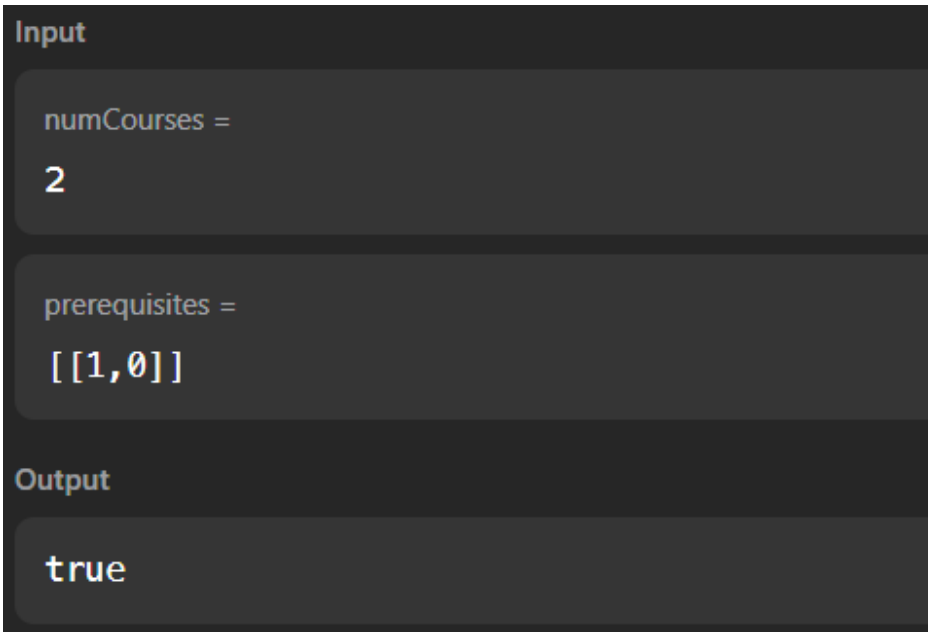
4.2.1 Leetcode Question
Course Schedule

4.2.2 Code

```
bool dfs(int node, int** graph, int* graphColSize, int* visited, int* inStack) {
    visited[node] = 1;
    inStack[node] = 1;

    for (int i = 0; i < graphColSize[node]; i++) {
        int neighbor = graph[node][i];
        if (!visited[neighbor]) {
            if (dfs(neighbor, graph, graphColSize, visited, inStack)) {
                return true;
            }
        } else if (inStack[neighbor]) {
            return true;
        }
    }

    inStack[node] = 0;
    return false;
}

bool canFinish(int numCourses, int** prerequisites, int prerequisitesSize, int*
prerequisitesColSize) {

    int** graph = (int**)malloc(numCourses * sizeof(int*));
    int* graphColSize = (int*)calloc(numCourses, sizeof(int));
    int* tempSizes = (int*)calloc(numCourses, sizeof(int));

    for (int i = 0; i < prerequisitesSize; i++) {
        int course = prerequisites[i][0];
        tempSizes[course]++;
    }

    for (int i = 0; i < numCourses; i++) {
        graph[i] = (int*)malloc(tempSizes[i] * sizeof(int));
    }

    for (int i = 0; i < prerequisitesSize; i++) {
        int course = prerequisites[i][0];
        int pre = prerequisites[i][1];
        graph[course][graphColSize[course]++] = pre;
    }
    int* visited = (int*)calloc(numCourses, sizeof(int));
```

```
    int* inStack = (int*)calloc(numCourses, sizeof(int));

    for (int i = 0; i < numCourses; i++) {
        if (!visited[i]) {
            if (dfs(i, graph, graphColSize, visited, inStack)) {

                for (int j = 0; j < numCourses; j++) free(graph[j]);
                free(graph); free(graphColSize); free(visited); free(inStack); free(tempSizes);
                return false;
            }
        }
    }

    for (int i = 0; i < numCourses; i++) free(graph[i]);
    free(graph); free(graphColSize); free(visited); free(inStack); free(tempSizes);
    return true;
}
```

4.2.3 Output



Lab Program 5

5.1.1 Question
Implement 0/1 Knapsack problem using dynamic programming.

5.1.2 Code

```
#include <stdio.h>

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

int knapsack(int W, int weights[], int values[], int n) {
   int dp[n + 1][W + 1];
   for (int i = 0; i <= n; i++) {
      for (int w = 0; w <= W; w++) {
         if (i == 0 || w == 0)
            dp[i][w] = 0;
         else if (weights[i - 1] <= w)
            dp[i][w] = max(values[i - 1] + dp[i - 1][w - weights[i - 1]], dp[i - 1][w]);
         else
            dp[i][w] = dp[i - 1][w];
      }
   }
   return dp[n][W];
}

int main() {
   int n, W;

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

   int values[n], weights[n];

   printf("Enter values of the items (space-separated): ");
   for (int i = 0; i < n; i++) scanf("%d", &values[i]);

   printf("Enter weights of the items (space-separated): ");
   for (int i = 0; i < n; i++) scanf("%d", &weights[i]);

   printf("Enter maximum capacity of knapsack: ");
   scanf("%d", &W);

   int result = knapsack(W, weights, values, n);
```

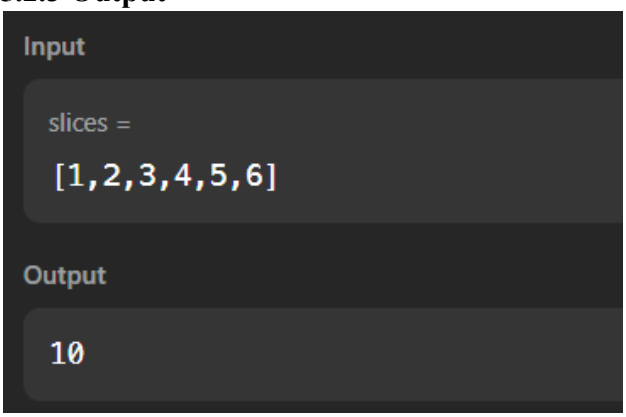
```
    printf("Maximum value in knapsack: %d\n", result);

    return 0;
}
```

5.1.3 Output

```
Enter number of items: 3
Enter values of the items (space-separated): 60 100 120
Enter weights of the items (space-separated): 10 20 30
Enter maximum capacity of knapsack: 50
Maximum value in knapsack: 220
```

5.2.1 Leetcode Question
Pizza With 3n slices

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

int maxSizeSlicesLinear(int* slices, int start, int end, int n) {
   int len = end - start + 1;
   int dp[len + 1][n + 1];

   for (int i = 0; i <= len; i++)
      for (int j = 0; j <= n; j++)
         dp[i][j] = 0;

   for (int i = 1; i <= len; i++) {
      for (int j = 1; j <= n; j++) {
         if (i == 1)
            dp[i][j] = slices[start + i - 1];
         else
            dp[i][j] = max(dp[i - 1][j], dp[i - 2][j - 1] + slices[start + i - 1]);
      }
   }
   return dp[len][n];
}

int maxSizeSlices(int* slices, int slicesSize) {
   int n = slicesSize / 3;
   int case1 = maxSizeSlicesLinear(slices, 0, slicesSize - 2, n);
   int case2 = maxSizeSlicesLinear(slices, 1, slicesSize - 1, n);
   return max(case1, case2);
}
```

5.2.3 Output


Lab program 6

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

6.1.2 Code

```
#include <stdio.h>

#define INF 1000000000

void floydWarshall(int n, int graph[100][100]) {
   int dist[100][100];

   for (int i = 0; i < n; i++)
      for (int j = 0; j < n; j++)
         dist[i][j] = graph[i][j];

   for (int k = 0; k < n; k++)
      for (int i = 0; i < n; i++)
         for (int j = 0; j < n; j++)
            if (dist[i][k] + dist[k][j] < dist[i][j])
               dist[i][j] = dist[i][k] + dist[k][j];

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

int main() {
   int n;
   int graph[100][100];

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

   printf("Enter the adjacency matrix (use %d to represent INF):\n", INF);
   for (int i = 0; i < n; i++)
      for (int j = 0; j < n; j++)
```

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

    floydWarshall(n, graph);

    return 0;
}
```

6.1.3 Output

```
Enter number of vertices: 4
Enter the adjacency matrix (use 1000000000 to represent INF):
0 5 1000000000 10
1000000000 0 3 1000000000
1000000000 1000000000 0 1
1000000000 1000000000 1000000000 0

All Pairs Shortest Distances:
  0   5   8   9
INF   0   3   4
INF INF   0   1
INF INF INF   0
```

6.2.1 Leetcode question
Number of ways to arrive at a destination.

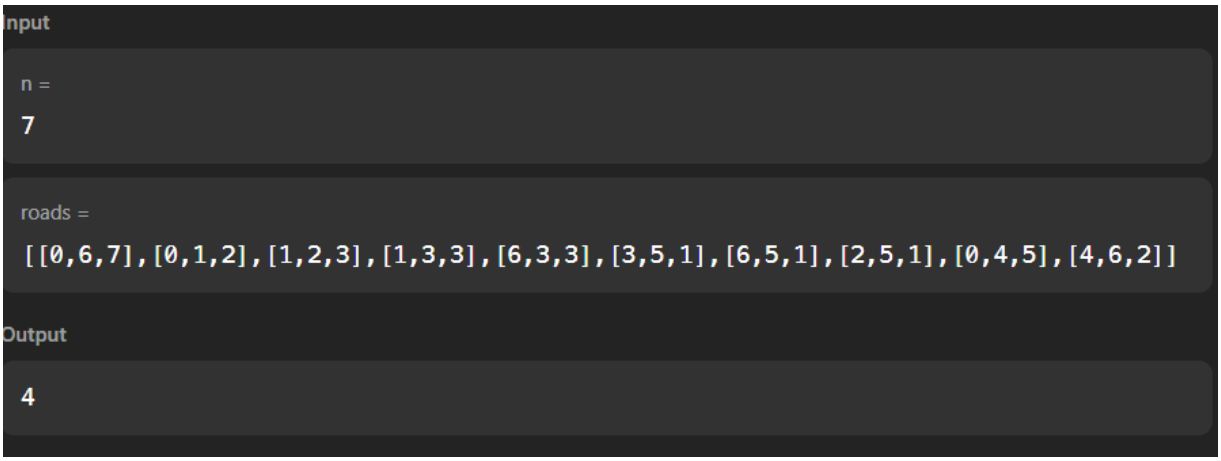
6.2.2 Code

```
#define MOD 1000000007
#define MAXN 100001
#define MAXEDGES 300000

int head[MAXN], to[MAXEDGES], cost[MAXEDGES], next[MAXEDGES], edgeCount;

int heap[MAXN], heapSize;
long long dist[MAXN];

int ways[MAXN];
int pos[MAXN];

void addEdge(int u, int v, int c) {
    to[edgeCount] = v;
    cost[edgeCount] = c;
    next[edgeCount] = head[u];
    head[u] = edgeCount++;
}

void swap(int i, int j) {
    int tmp = heap[i];
    heap[i] = heap[j];
    heap[j] = tmp;
    pos[heap[i]] = i;
    pos[heap[j]] = j;
}

void push(int node) {
    int i = heapSize++;
    heap[i] = node;
    pos[node] = i;
    while (i > 0 && dist[heap[i]] < dist[heap[(i - 1) / 2]]) {
        swap(i, (i - 1) / 2);
        i = (i - 1) / 2;
    }
}

int pop() {
    int top = heap[0];
    heap[0] = heap[--heapSize];
    pos[heap[0]] = 0;
```

```
    int i = 0;
    while (1) {
        int smallest = i, l = 2 * i + 1, r = 2 * i + 2;
        if (l < heapSize && dist[heap[l]] < dist[heap[smallest]]) smallest = l;
        if (r < heapSize && dist[heap[r]] < dist[heap[smallest]]) smallest = r;
        if (smallest == i) break;
        swap(i, smallest);
        i = smallest;
    }
    return top;
}

int countPaths(int n, int** roads, int roadsSize, int* roadsColSize) {
    for (int i = 0; i < n; i++) head[i] = -1;

    edgeCount = 0;
    for (int i = 0; i < roadsSize; i++) {
        int u = roads[i][0], v = roads[i][1], c = roads[i][2];
        addEdge(u, v, c);
        addEdge(v, u, c);
    }

    for (int i = 0; i < n; i++) {
        dist[i] = LLONG_MAX;
        ways[i] = 0;
        pos[i] = -1;
    }

    dist[0] = 0;
    ways[0] = 1;
    heapSize = 0;
    push(0);

    while (heapSize > 0) {
        int u = pop();
        for (int e = head[u]; e != -1; e = next[e]) {
            int v = to[e];
            long long d = dist[u] + cost[e];
            if (d < dist[v]) {
                dist[v] = d;
                ways[v] = ways[u];
                if (pos[v] == -1)
                    push(v);
                else {
                    int i = pos[v];
                    while (i > 0 && dist[heap[i]] < dist[heap[(i - 1) / 2]]) {
```

```
                swap(i, (i - 1) / 2);
                i = (i - 1) / 2;
            }
        }
    } else if (d == dist[v]) {
        ways[v] = (ways[v] + ways[u]) % MOD;
    }
  }
 }

 return ways[n - 1];
}
```

6.2.3 Output



Lab program 7

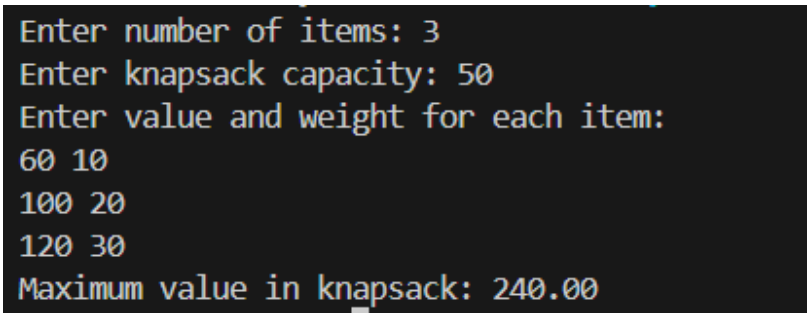
7.1.1 Question
Implement Fractional Knapsack using Greedy technique.

7.1.2 Code

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

typedef struct {
    int value;
    int weight;
    double ratio;
} Item;

int compare(const void *a, const void *b) {
    double r1 = ((Item *)b)->ratio;
    double r2 = ((Item *)a)->ratio;
    return (r1 > r2) - (r1 < r2);
}

int main() {
    int n;
    double capacity;

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

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

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

    qsort(items, n, sizeof(Item), compare);

    double totalValue = 0.0;

    for (int i = 0; i < n && capacity > 0; i++) {
        if (items[i].weight <= capacity) {
            totalValue += items[i].value;
```

```
            capacity -= items[i].weight;
        } else {
            totalValue += items[i].ratio * capacity;
            capacity = 0;
        }
    }

    printf("Maximum value in knapsack: %.2lf\n", totalValue);

    return 0;
}
```

7.1.3 Output



7.2.1 Leetcode Questions
Maximum units on a truck

7.2.2 Code

```
int compare(const void *a, const void *b) {
    int u1 = ((int **)b)[0][1];
    int u2 = ((int **)a)[0][1];
    return u1 - u2;
}

int maximumUnits(int** boxTypes, int boxTypesSize, int* boxTypesColSize, int truckSize) {
    qsort(boxTypes, boxTypesSize, sizeof(int *), compare);

    int totalUnits = 0;
    for (int i = 0; i < boxTypesSize && truckSize > 0; i++) {
        int boxesToTake = boxTypes[i][0] < truckSize ? boxTypes[i][0] : truckSize;
        totalUnits += boxesToTake * boxTypes[i][1];
        truckSize -= boxesToTake;
    }
    return totalUnits;
}
```

7.2.3 Output

Lab Program 8

8.1.1 Question
Dijkstra's Algorithm

8.1.2 Code

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

#define V 100  // Max number of vertices

int minDistance(int dist[], int visited[], int n) {
   int min = INT_MAX, min_index = -1;
   for (int v = 0; v < n; v++) {
      if (!visited[v] && dist[v] <= min) {
         min = dist[v];
         min_index = v;
      }
   }
   return min_index;
}

void dijkstra(int graph[V][V], int n, int src) {
   int dist[V];     // Shortest distance from src to i
   int visited[V];  // Visited vertices

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

   dist[src] = 0;

   for (int count = 0; count < n - 1; count++) {
      int u = minDistance(dist, visited, n);
      if (u == -1) break;  // All reachable nodes are processed

      visited[u] = 1;

      for (int v = 0; v < n; v++) {
         if (!visited[v] && graph[u][v] && dist[u] != INT_MAX &&
            dist[u] + graph[u][v] < dist[v]) {
            dist[v] = dist[u] + graph[u][v];
         }
      }
```

```
    }

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

int main() {
    int n, src;
    int graph[V][V];

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

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

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

    dijkstra(graph, n, src);

    return 0;
}
```

8.1.3 Output

```
Enter number of vertices: 5
Enter adjacency matrix (0 if no edge):
0 10 0 30 100
10 0 50 0 0
0 50 0 20 10
30 0 20 0 60
100 0 10 60 0
Enter source vertex: 0
Vertex   Distance from Source 0
0                0
1                10
2                50
3                30
4                60
```

Lab Program 9

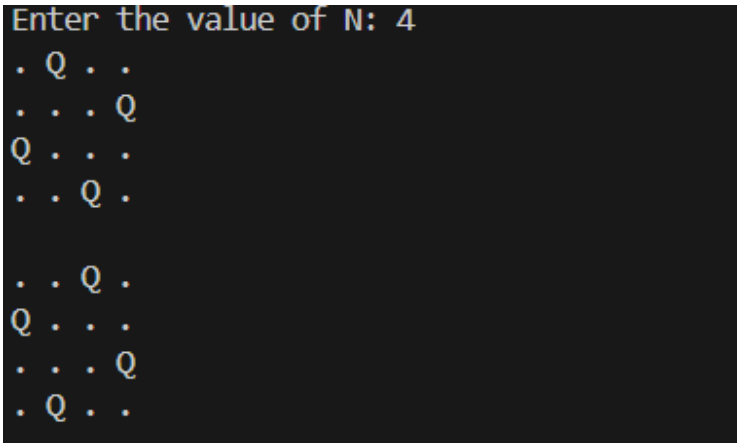
9.1.1 Question
N Queens

9.1.2 Code

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

int *board;
int N;

int isSafe(int row, int col) {
   for (int i = 0; i < row; i++) {
      if (board[i] == col ||
         abs(board[i] - col) == abs(i - row)) {
         return 0;
      }
   }
   return 1;
}

void printSolution() {
   for (int i = 0; i < N; i++) {
      for (int j = 0; j < N; j++) {
         if (board[i] == j)
            printf("Q ");
         else
            printf(". ");
      }
      printf("\n");
   }
   printf("\n");
}

void solveNQueens(int row) {
   if (row == N) {
      printSolution();
      return;
   }
   for (int col = 0; col < N; col++) {
      if (isSafe(row, col)) {
         board[row] = col;
         solveNQueens(row + 1);
```

```
        }
    }
}

int main() {
    printf("Enter the value of N: ");
    scanf("%d", &N);

    board = (int *)malloc(N * sizeof(int));

    solveNQueens(0);

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

9.1.3 Output



Lab Program 10

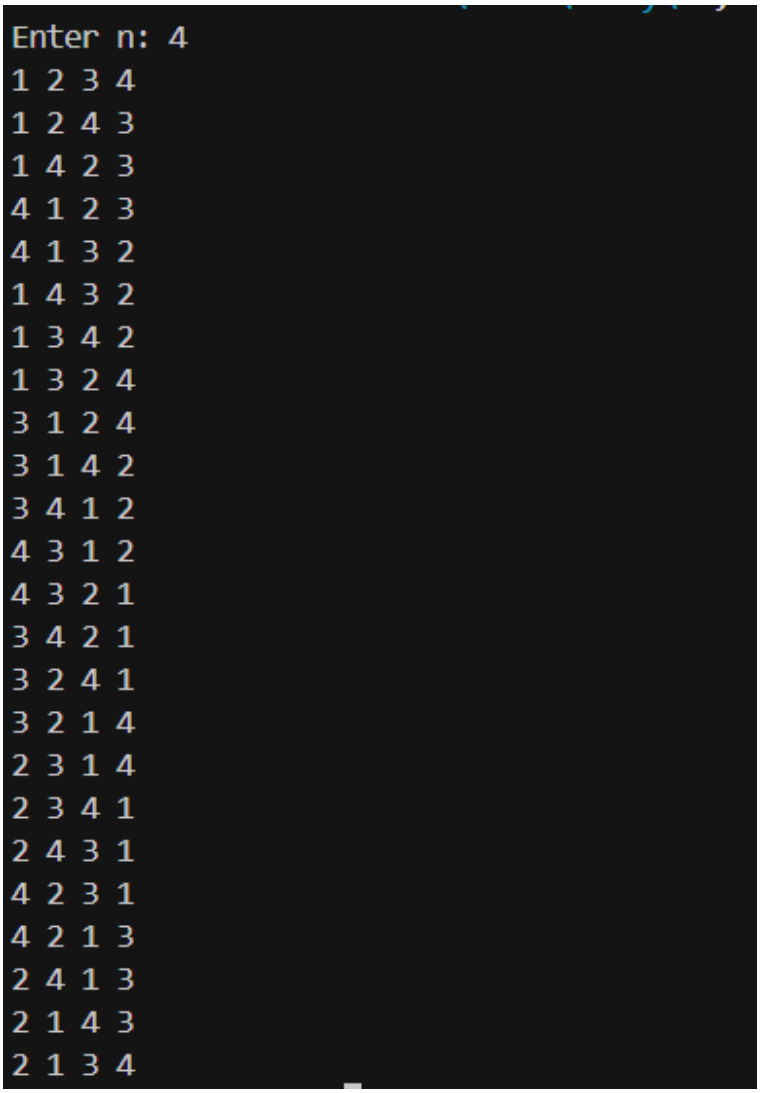
10.1.1 Question
Implement Johnson Trotter algorithm to generate permutations.

10.1.2 Code

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

#define LEFT 0
#define RIGHT 1

int n;

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

int getLargestMobile(int *arr, int *dir) {
   int largestMobileIndex = -1;
   int largestMobile = 0;

   for (int i = 0; i < n; i++) {
      int nextIndex = (dir[i] == LEFT) ? i - 1 : i + 1;

      if (nextIndex >= 0 && nextIndex < n) {
         if (arr[i] > arr[nextIndex] && arr[i] > largestMobile) {
            largestMobile = arr[i];
            largestMobileIndex = i;
         }
      }
   }
   return largestMobileIndex;
}

void johnsonTrotter() {
   int *arr = malloc(n * sizeof(int));
   int *dir = malloc(n * sizeof(int));

   for (int i = 0; i < n; i++) {
      arr[i] = i + 1;
      dir[i] = LEFT;
   }
```

```
    printPermutation(arr);

    while (1) {
        int largestMobileIndex = getLargestMobile(arr, dir);
        if (largestMobileIndex == -1)
            break; // No more mobile integer, done

        int swapIndex = (dir[largestMobileIndex] == LEFT) ? largestMobileIndex - 1 :
largestMobileIndex + 1;

        int temp = arr[largestMobileIndex];
        arr[largestMobileIndex] = arr[swapIndex];
        arr[swapIndex] = temp;

        temp = dir[largestMobileIndex];
        dir[largestMobileIndex] = dir[swapIndex];
        dir[swapIndex] = temp;

        largestMobileIndex = swapIndex;

        for (int i = 0; i < n; i++) {
            if (arr[i] > arr[largestMobileIndex]) {
                dir[i] = (dir[i] == LEFT) ? RIGHT : LEFT;
            }
        }

        printPermutation(arr);
    }

    free(arr);
    free(dir);
}

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

    johnsonTrotter();

    return 0;
}
```

10.1.3 Output


Enter n: 4
1 2 3 4
1 2 4 3
1 4 2 3
4 1 2 3
4 1 3 2
1 4 3 2
1 3 4 2
1 3 2 4
3 1 2 4
3 1 4 2
3 4 1 2
4 3 1 2
4 3 2 1
3 4 2 1
3 2 4 1
3 2 1 4
2 3 1 4
2 3 4 1
2 4 3 1
4 2 3 1
4 2 1 3
2 4 1 3
2 1 4 3
2 1 3 4

Lab Program 11

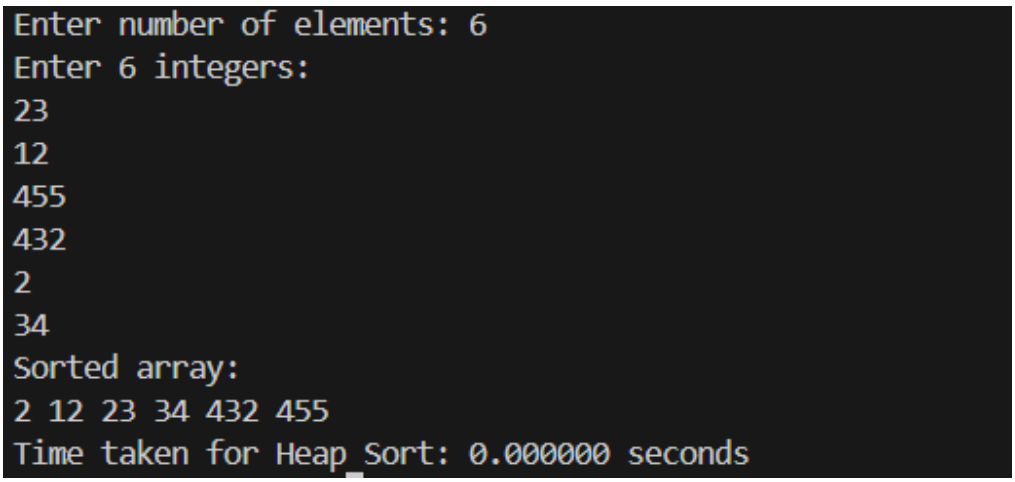
11.1.1 Question
Sort a given set of N integer elements using Heap Sort technique and compute its time taken.

11.1.2 Code

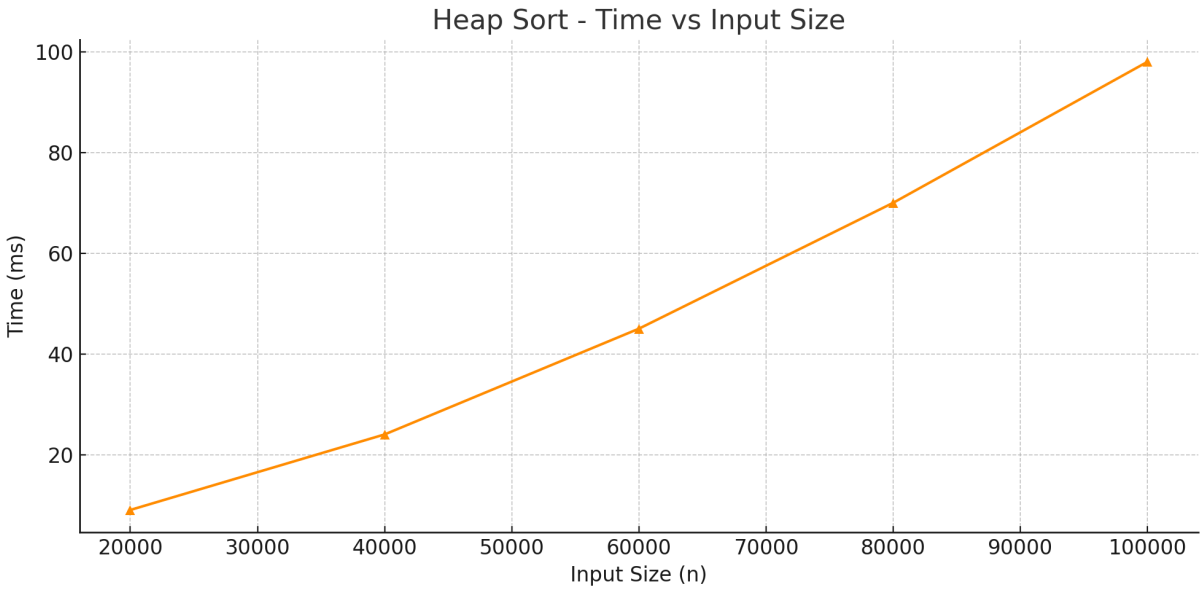
```
#include <stdio.h>
#include <time.h>

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 n;
```

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

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

    clock_t start = clock();
    heapSort(arr, n);
    clock_t end = clock();

    double time_taken = ((double)(end - start)) / CLOCKS_PER_SEC;

    printf("Sorted array:\n");
    for (int i = 0; i < n; i++)
        printf("%d ", arr[i]);
    printf("\n");

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

    return 0;
}
```

11.1.3 Output



11.1.4 Graph


Heap Sort - Time vs Input Size
Time (ms)
100
80
60
40
20
20000
30000
40000
50000
60000
70000
80000
90000
100000
Input Size (n)