Data Structures Applications Laboratory (21EECF201/23EVTF203)

Name of the student: Varun Vivek Pai
USN: 01FE23BEC126
Div: C
Roll No: 332

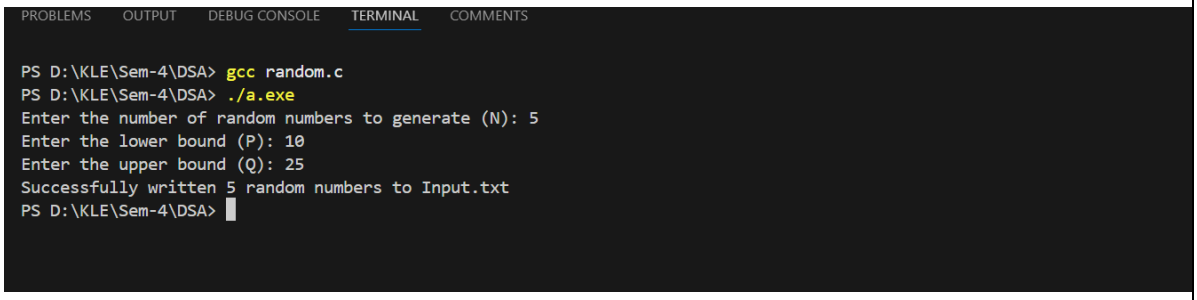
Task 1: Write a program to generate N random numbers between a given range of numbers (P, Q) and write it to a file (*Input.txt*).

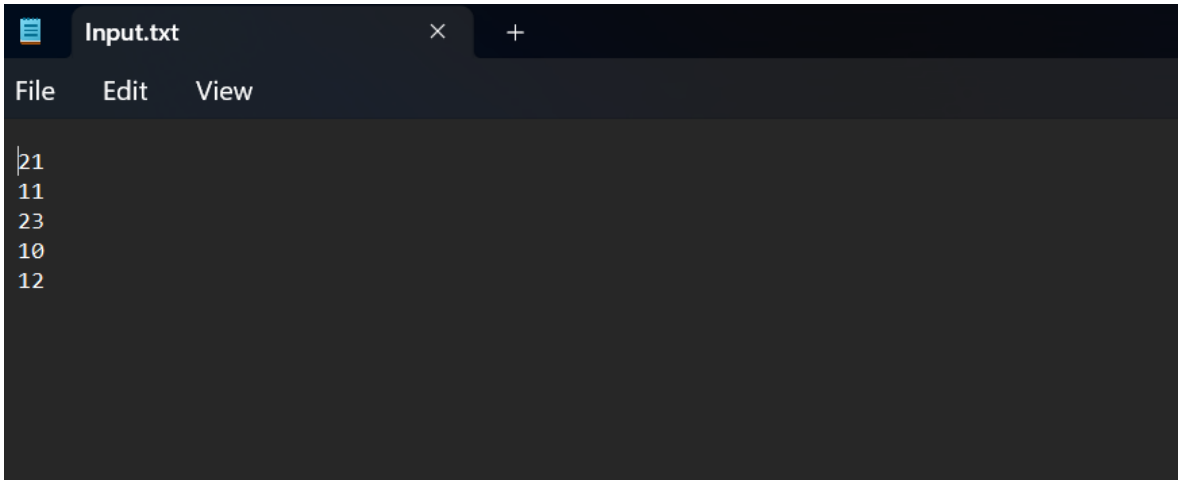
Code:

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

void random(int N, int P, int Q)
{
   int num, i;
   FILE *file = fopen("Input.txt", "w");
   if (file)
   {

      srand(time(NULL));
      for (i = 0; i < N; i++)
      {
         num = P + rand() % (Q - P + 1);
         fprintf(file, "%d\n", num);
      }
      fclose(file);
      printf("Successfully written %d random numbers to Input.txt\n", N);
   }
   else
      printf("Error opening file!\n");
}

int main()
{
   int N, P, Q;
   printf("Enter the number of random numbers to generate (N): ");
   scanf("%d", &N);
   printf("Enter the lower bound (P): ");
   scanf("%d", &P);
   printf("Enter the upper bound (Q): ");
   scanf("%d", &Q);
   if (P > Q)
```

```
        printf("Invalid range! P should be less than or equal to Q.\n");
    else
        random(N, P, Q);
    return 0;
}
```

Output: Put screenshots of the output





Task 2: List any 10 sorting algorithms. Describe the operation of each sorting algorithm in few sentences

1.Bubble Sort

2. Selection Sort
3. Insertion Sort
4.Merge Sort
5. Quick Sort
6. Heap Sort
7. Shell Sort
8.Counting Sort
9.Radix Sort
10. Bucket Sort

1. **Bubble Sort**: Repeatedly compares and swaps adjacent elements if they are in the wrong order, effectively "bubbling" larger elements to the end of the list.
2. **Selection Sort**: Identifies the smallest (or largest) element from the unsorted portion and swaps it with the first unsorted element, moving the boundary of the sorted section one element forward.
3. **Insertion Sort**: Builds a sorted list by taking each element from the unsorted portion and inserting it into its correct position within the sorted portion.
4. **Merge Sort**: Recursively divides the list into halves until each sublist contains a single element, then merges these sublists in a sorted manner to produce the final sorted list.
5. **Quick Sort**: Selects a pivot element, partitions the list into elements less than and greater than the pivot, and recursively applies the same process to the sublists.
6. **Heap Sort**: Transforms the list into a heap structure, repeatedly extracts the maximum (or minimum) element, and reconstructs the heap until the list is sorted.
7. **Shell Sort**: An extension of insertion sort that allows the exchange of items that are far apart by comparing elements separated by a gap, which decreases over successive passes.
8. **Counting Sort**: Counts the occurrences of each distinct element, calculates their positions, and places them into the output array accordingly, making it efficient for sorting integers within a specific range.
9. **Radix Sort**: Processes each digit of the numbers from least significant to most significant, grouping them by each digit, and combining the groups to form a sorted list.
10. **Bucket Sort**: Distributes elements into several 'buckets', sorts each bucket individually (often using another sorting algorithm), and then concatenates the sorted buckets to form the final sorted list.

Data Structures Applications Laboratory (21EECF201/23EVTF203)

Task 3: Use the file *Input.txt (output of Task1) and implement each of the sorting algorithms (implement all 10 algorithms) – Each of the sorting algorithm can be in a different table*

Code:

1. **Bubble Sort:**

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

#define MAX_SIZE 1000

void bubbleSort(int arr[], int n)
{
   int temp, i, j;
   for (i = 0; i < n - 1; i++) {
      for (j = 0; j < n - i - 1; j++) {
         if (arr[j] > arr[j + 1]) {
            temp = arr[j];
            arr[j] = arr[j + 1];
            arr[j + 1] = temp;
         }
      }
   }
}
```

```
int readNum(const char *filename, int arr[])
{
   FILE *file = fopen(filename, "r");
   int count = 0;
   if (file)
   {
      while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
         count++;
      fclose(file);
   }
   else
      printf("Error opening file: %s\n", filename);
   return count;
}

void writeFile(const char *filename, int arr[], int n)
{
   FILE *file = fopen(filename, "w");
   int count = 0, i;
   if (file)
   {
      for (i = 0; i < n; i++)
         fprintf(file, "%d\n", arr[i]);
      fclose(file);
      printf("Sorted numbers written to %s\n", filename);
   }
   else
      printf("Error opening file: %s\n", filename);
}

int main()
{
   int numbers[MAX_SIZE], count;
   count = readNum("Input.txt", numbers);
   if (count)
   {
      bubbleSort(numbers, count);
      writeFile("Sorted.txt", numbers, count);
      printf("Sorting complete. Check Sorted.txt for results.\n");
   }
   else
      printf("File is empty");
   return 0;
```

```
}
```

2. Selection Sort:

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

#define MAX_SIZE 1000

void selectionSort(int arr[], int n)
{
    int i, j, min, temp;
    for (i = 0; i < n - 1; i++)
    {
        min = i;
        for (j = i + 1; j < n; j++)
        {
            if (arr[j] < arr[min])
                min = j;
        }
        temp = arr[i];
        arr[i] = arr[min];
        arr[min] = temp;
    }
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
```

```
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
    }
    else
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        selectionSort(numbers, count);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
    }
    else
        printf("File is empty");
    return 0;
}
```

3. Insertion Sort:

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

#define MAX_SIZE 1000

void insertionSort(int arr[], int n)
{
    int i, j, key;
    for (i = 1; i < n; i++)
    {
        key = arr[i];
        for (j = i - 1; j >= 0 && arr[j] > key; j--)
            arr[j + 1] = arr[j];
```

```
        arr[j + 1] = key;
    }
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
    }
    else
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        insertionSort(numbers, count);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
```

```
    }
    else
        printf("File is empty");
    return 0;
}
```

4. Merge Sort:

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

#define MAX_SIZE 1000

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

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

```
}

int readNum(const char *filename, int arr[])
{
   FILE *file = fopen(filename, "r");
   int count = 0;
   if (file)
   {
      while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
         count++;
      fclose(file);
   }
   else
      printf("Error opening file: %s\n", filename);
   return count;
}

void writeFile(const char *filename, int arr[], int n)
{
   FILE *file = fopen(filename, "w");
   int i;
   if (file)
   {
      for (i = 0; i < n; i++)
         fprintf(file, "%d\n", arr[i]);
      fclose(file);
      printf("Sorted numbers written to %s\n", filename);
   }
   else
      printf("Error opening file: %s\n", filename);
}

int main()
{
   int numbers[MAX_SIZE], count;
   count = readNum("Input.txt", numbers);
   if (count)
   {
      mergeSort(numbers, 0, count - 1);
      writeFile("Sorted.txt", numbers, count);
      printf("Sorting complete. Check Sorted.txt for results.\n");
   }
   else
```

```
        printf("File is empty");
    return 0;
}
```

5. Quick sort:

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

#define MAX_SIZE 1000

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

int readNum(const char *filename, int arr[])
{
```

```
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
    }
    else
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        quickSort(numbers, 0, count - 1);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
    }
    else
        printf("File is empty");
    return 0;
}
```

6. Heap Sort:

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

#define MAX_SIZE 1000

void heapify(int arr[], int n, int i)
{
    int largest = i, left = 2 * i + 1, 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)
{
    int i, temp;
    for (i = n / 2 - 1; i >= 0; i--)
        heapify(arr, n, i);
    for (i = n - 1; i > 0; i--)
    {
        temp = arr[0];
        arr[0] = arr[i];
        arr[i] = temp;
        heapify(arr, i, 0);
    }
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
```

```
    while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
        count++;
    fclose(file);
  }
  else
    printf("Error opening file: %s\n", filename);
  return count;
}

void writeFile(const char *filename, int arr[], int n)
{
  FILE *file = fopen(filename, "w");
  int i;
  if (file)
  {
    for (i = 0; i < n; i++)
      fprintf(file, "%d\n", arr[i]);
    fclose(file);
    printf("Sorted numbers written to %s\n", filename);
  }
  else
    printf("Error opening file: %s\n", filename);
}

int main()
{
  int numbers[MAX_SIZE], count;
  count = readNum("Input.txt", numbers);
  if (count)
  {
    heapSort(numbers, count);
    writeFile("Sorted.txt", numbers, count);
    printf("Sorting complete. Check Sorted.txt for results.\n");
  }
  else
    printf("File is empty");
  return 0;
}
```

7. Shell Sort:

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

```
#define MAX_SIZE 1000

void shellSort(int arr[], int n)
{
    int i, j, temp;
    for (int gap = n / 2; gap > 0; gap /= 2)
    {
        for (i = gap; i < n; i++)
        {
            temp = arr[i];
            for (j = i; j >= gap && arr[j - gap] > temp; j -= gap)
                arr[j] = arr[j - gap];
            arr[j] = temp;
        }
    }
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
```

```
    }
    else
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        shellSort(numbers, count);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
    }
    else
        printf("File is empty");
    return 0;
}
```

8. Counting Sort:

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

#define MAX_SIZE 1000

int findMax(int arr[], int n)
{
    int max = arr[0], i;
    for (i = 1; i < n; i++)
    {
        if (arr[i] > max)
            max = arr[i];
    }
    return max;
}

void countingSort(int arr[], int n)
{
    int max, i, *count, *output;
    max =  findMax(arr, n);
    count = calloc(max + 1, sizeof(int));
```

```
    output = malloc(n * sizeof(int));

    for (i = 0; i < n; i++)
        count[arr[i]]++;
    for (i = 1; i <= max; i++)
        count[i] += count[i - 1];
    for (i = n - 1; i >= 0; i--)
    {
        output[count[arr[i]] - 1] = arr[i];
        count[arr[i]]--;
    }
    for (i = 0; i < n; i++)
        arr[i] = output[i];
    free(count);
    free(output);
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
    }
```

```
    else
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        countingSort(numbers, count);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
    }
    else
        printf("File is empty");
    return 0;
}
```

9. Radix Sort:

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

#define MAX_SIZE 1000

int findMax(int arr[], int n)
{
    int max = arr[0], i;
    for (i = 1; i < n; i++)
    {
        if (arr[i] > max)
            max = arr[i];
    }
    return max;
}

void countingSortByDigit(int arr[], int n, int exp)
{
    int output[n], count[10] = {0}, i;
    for (i = 0; i < n; i++)
        count[(arr[i] / exp) % 10]++;
    for (i = 1; i < 10; i++)
        count[i] += count[i - 1];
```

```
    for (i = n - 1; i >= 0; i--)
    {
        output[count[(arr[i] / exp) % 10] - 1] = arr[i];
        count[(arr[i] / exp) % 10]--;
    }
    for (i = 0; i < n; i++)
        arr[i] = output[i];
}

void radixSort(int arr[], int n)
{
    int max = findMax(arr, n), exp;
    for (int exp = 1; max / exp > 0; exp *= 10)
        countingSortByDigit(arr, n, exp);
}

int readNum(const char *filename, int arr[])
{
    FILE *file = fopen(filename, "r");
    int count = 0;
    if (file)
    {
        while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
            count++;
        fclose(file);
    }
    else
        printf("Error opening file: %s\n", filename);
    return count;
}

void writeFile(const char *filename, int arr[], int n)
{
    FILE *file = fopen(filename, "w");
    int i;
    if (file)
    {
        for (i = 0; i < n; i++)
            fprintf(file, "%d\n", arr[i]);
        fclose(file);
        printf("Sorted numbers written to %s\n", filename);
    }
    else
```

```
        printf("Error opening file: %s\n", filename);
}

int main()
{
    int numbers[MAX_SIZE], count;
    count = readNum("Input.txt", numbers);
    if (count)
    {
        radixSort(numbers, count);
        writeFile("Sorted.txt", numbers, count);
        printf("Sorting complete. Check Sorted.txt for results.\n");
    }
    else
        printf("File is empty");
    return 0;
}
```

10. Bucket Sort:

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

#define MAX_SIZE 1000
#define BUCKET_SIZE 10

typedef struct {
    int *array, count;
} Bucket;

int findMax(int arr[], int n)
{
    int max = arr[0], i;
    for (i = 1; i < n; i++)
    {
        if (arr[i] > max)
            max = arr[i];
    }
    return max;
}

void insertionSort(int arr[], int n)
{
    int i, j, key;
```

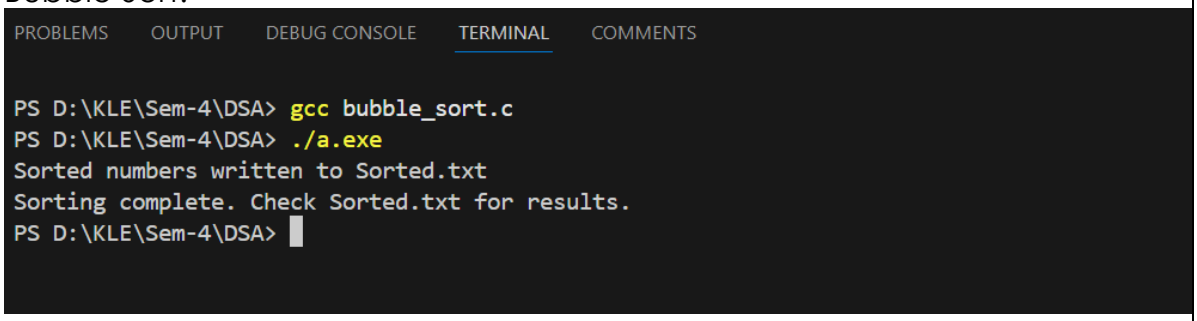
```
    for (i = 1; i < n; i++)
    {
        for (key = arr[i], j = i - 1; j >= 0 && arr[j] > key; j--)
            arr[j + 1] = arr[j];
        arr[j + 1] = key;
    }
}

void bucketSort(int arr[], int n)
{
    int max, min, i, j, range, bucketIndex, index;
    Bucket buckets[BUCKET_SIZE];
    if (n >= 0)
    {
        max = findMax(arr, n);
        min = arr[0];
        for (i = 1; i < n; i++)
        {
            if (arr[i] < min)
                min = arr[i];
        }
        range = (max - min) / BUCKET_SIZE + 1;
        for (i = 0; i < BUCKET_SIZE; i++)
        {
            buckets[i].array = (int *)malloc(n * sizeof(int));
            buckets[i].count = 0;
        }
        for (i = 0; i < n; i++)
        {
            bucketIndex = (arr[i] - min) / range;
            buckets[bucketIndex].array[buckets[bucketIndex].count++] = arr[i];
        }
        for (index = i = 0; i < BUCKET_SIZE; i++)
        {
            insertionSort(buckets[i].array, buckets[i].count);
            for (j = 0; j < buckets[i].count; j++)
                arr[index++] = buckets[i].array[j];
            free(buckets[i].array);
        }
    }
    else
        printf("No numbers to sort\n");
}
```

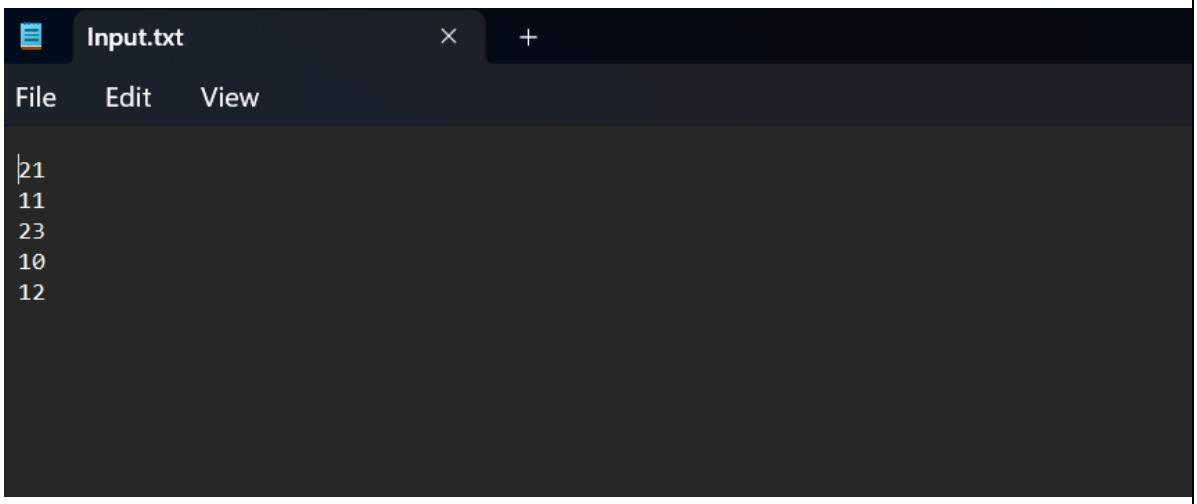
```
int readNum(const char *filename, int arr[])
{
   FILE *file = fopen(filename, "r");
   int count = 0;
   if (file)
   {
      while (fscanf(file, "%d", &arr[count]) != EOF && count < MAX_SIZE)
         count++;
      fclose(file);
   }
   else
      printf("Error opening file: %s\n", filename);
   return count;
}

void writeFile(const char *filename, int arr[], int n)
{
   FILE *file = fopen(filename, "w");
   int i;
   if (file)
   {
      for (i = 0; i < n; i++)
         fprintf(file, "%d\n", arr[i]);
      fclose(file);
      printf("Sorted numbers written to %s\n", filename);
   }
   else
      printf("Error opening file: %s\n", filename);
}

int main()
{
   int numbers[MAX_SIZE], count;
   count = readNum("Input.txt", numbers);
   if (count)
   {
      bucketSort(numbers, count);
      writeFile("Sorted.txt", numbers, count);
      printf("Sorting complete. Check Sorted.txt for results.\n");
   }
   else
      printf("File is empty");
```

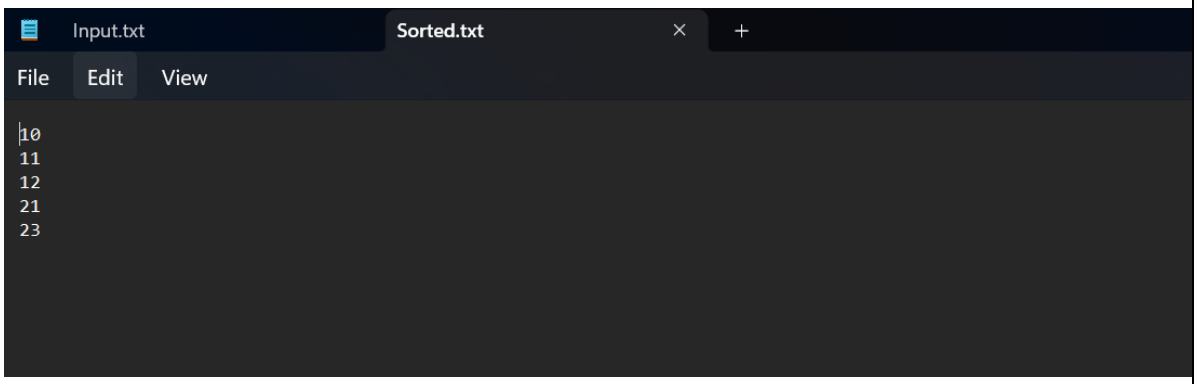
```
    return 0;
}
```

Output: Put screenshots of the output

Bubble Sort:

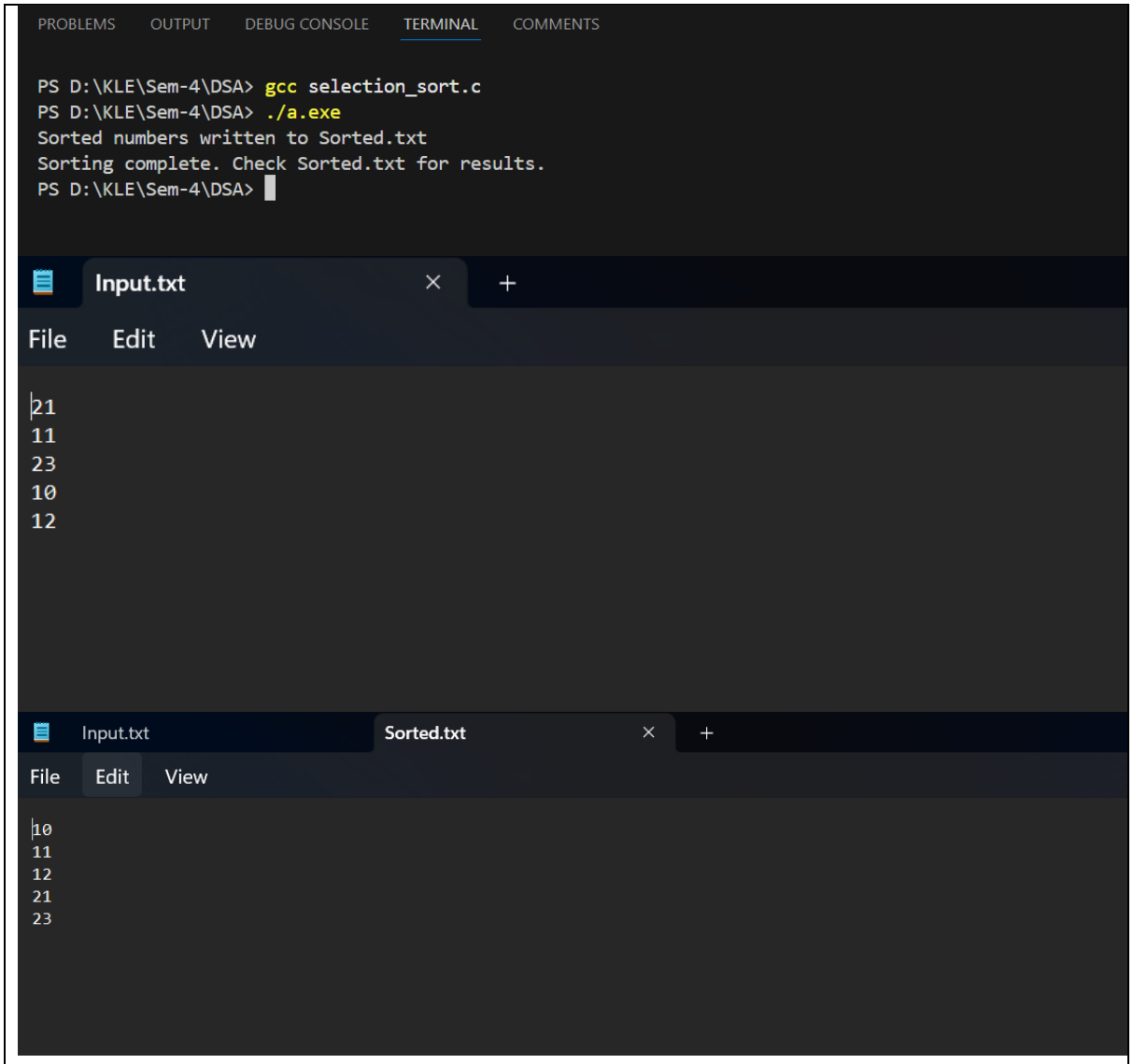




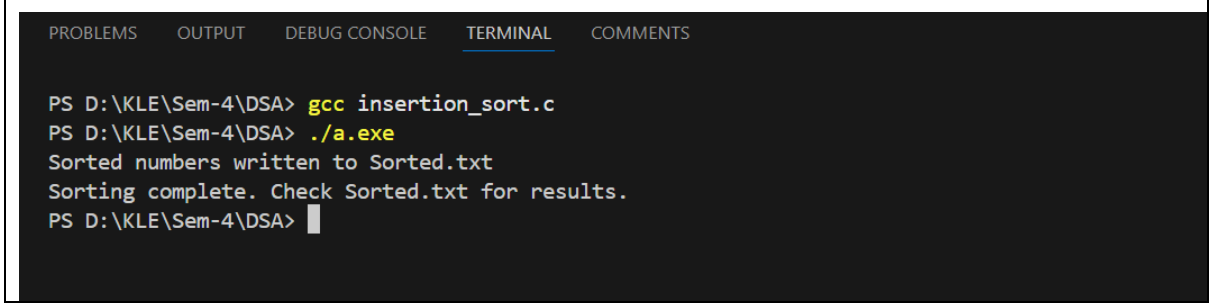


Selection Sort:

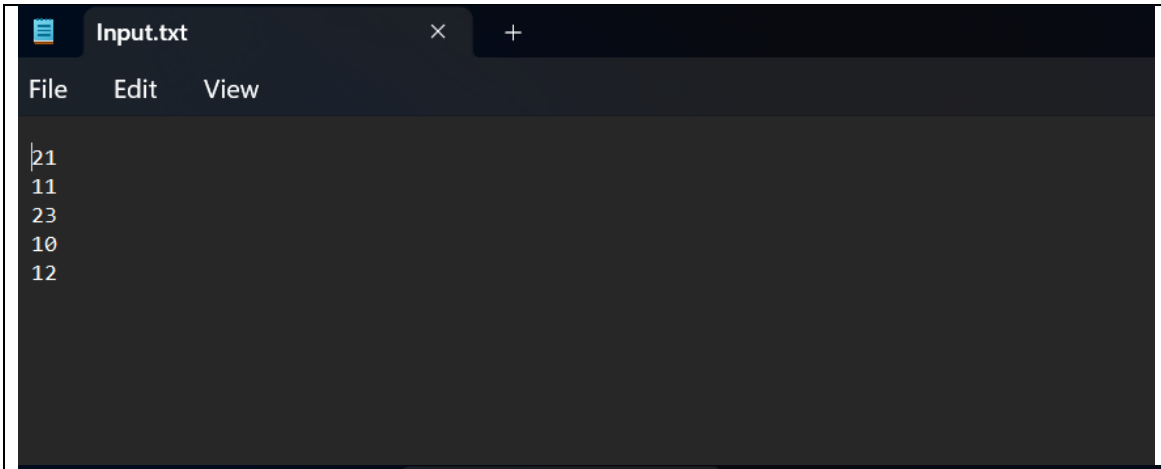
Data Structures Applications Laboratory (21EECF201/23EVTF203)

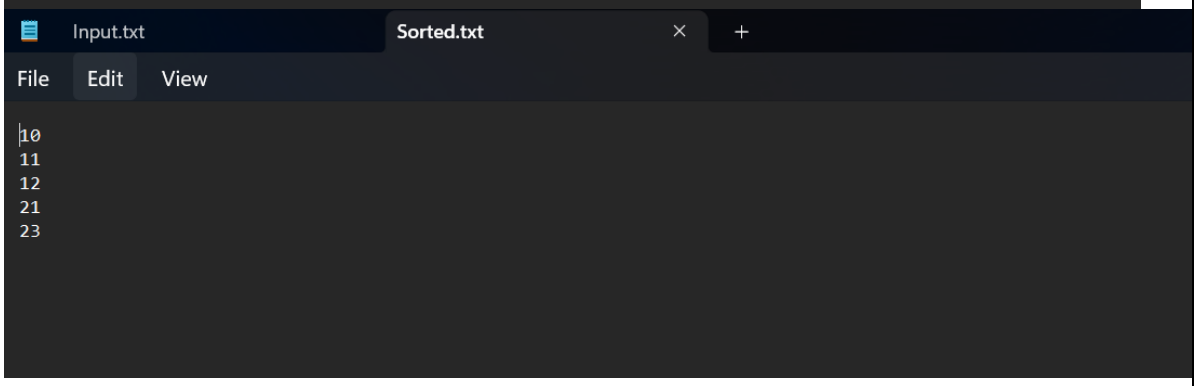


Insertion Sort:

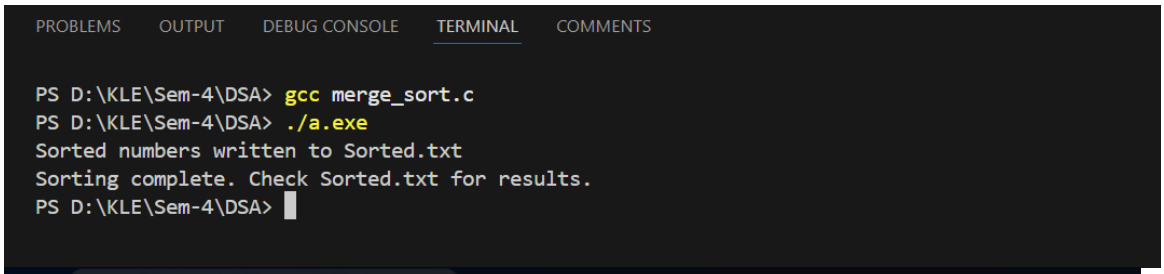


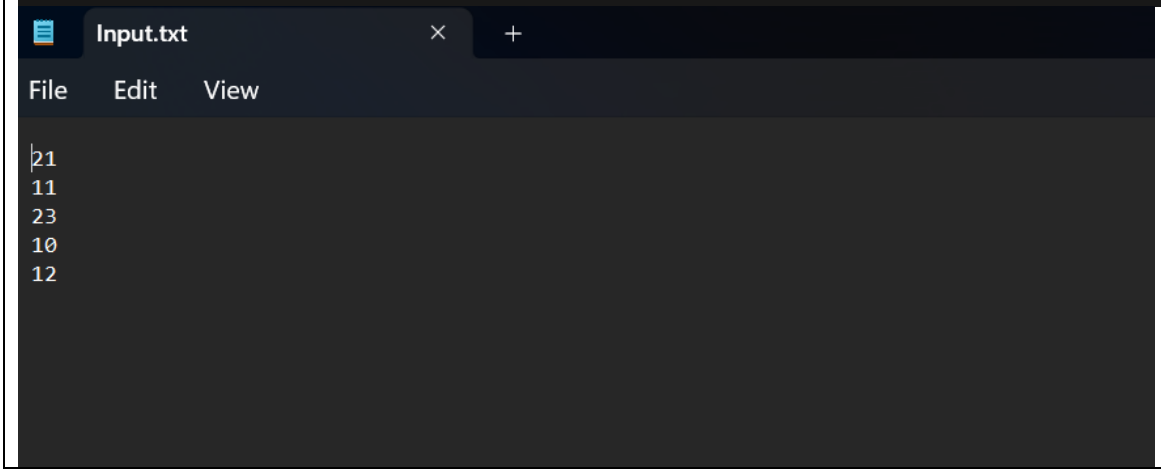
Data Structures Applications Laboratory (21EECF201/23EVTF203)



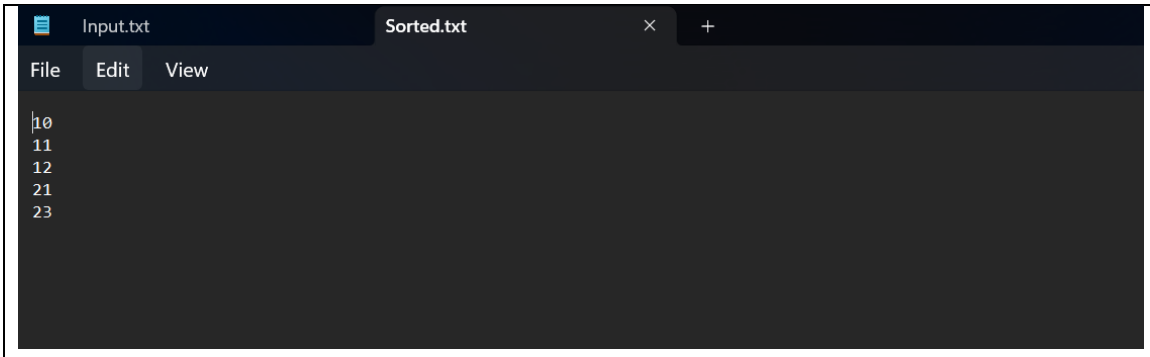


Merge Sort:

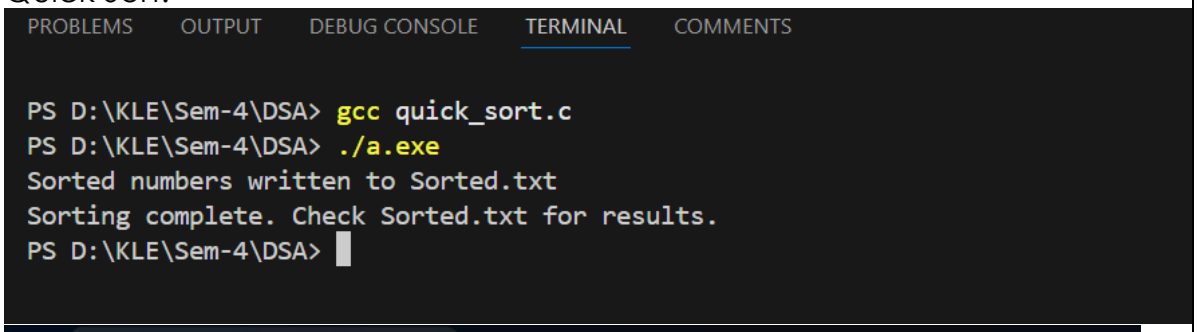


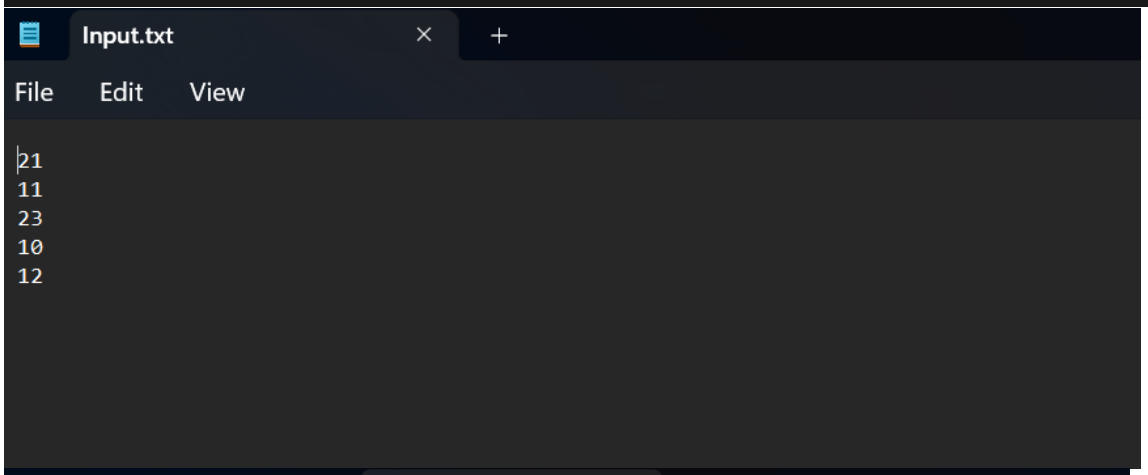


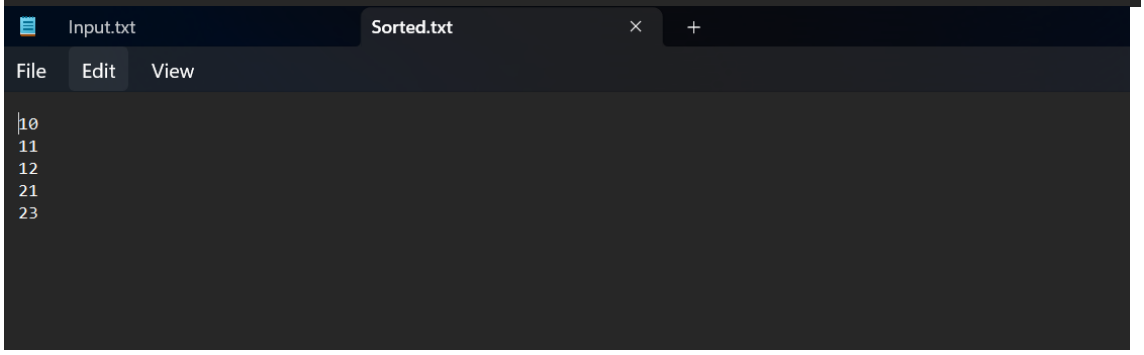
Data Structures Applications Laboratory (21EECF201/23EVTF203)



Quick Sort:







Heap Sort:

Data Structures Applications Laboratory (21EECF201/23EVTF203)

```
PROBLEMS  OUTPUT  DEBUG CONSOLE  TERMINAL  COMMENTS

PS D:\KLE\Sem-4\DSA> gcc heap_sort.c
PS D:\KLE\Sem-4\DSA> ./a.exe
Sorted numbers written to Sorted.txt
Sorting complete. Check Sorted.txt for results.
PS D:\KLE\Sem-4\DSA>
```

Input.txt

File Edit View

```
21
11
23
10
12
```

Input.txt Sorted.txt

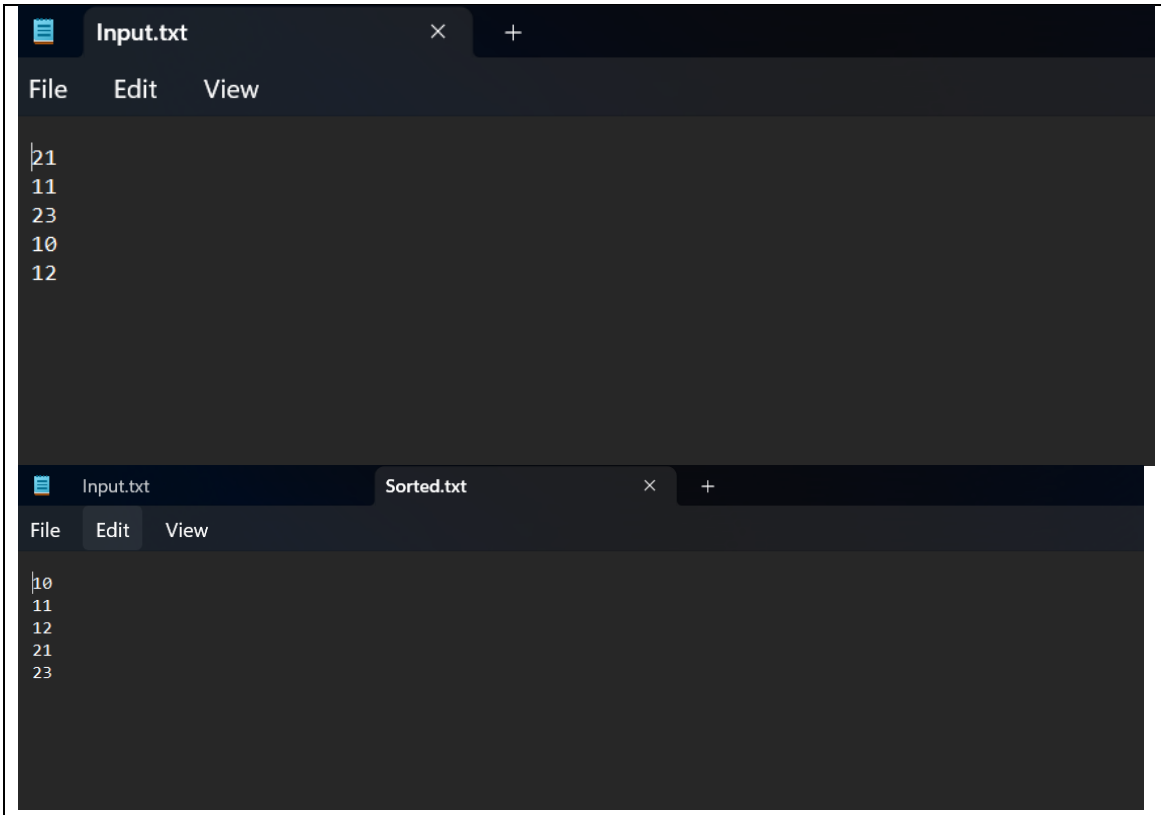
File Edit View

```
10
11
12
21
23
```

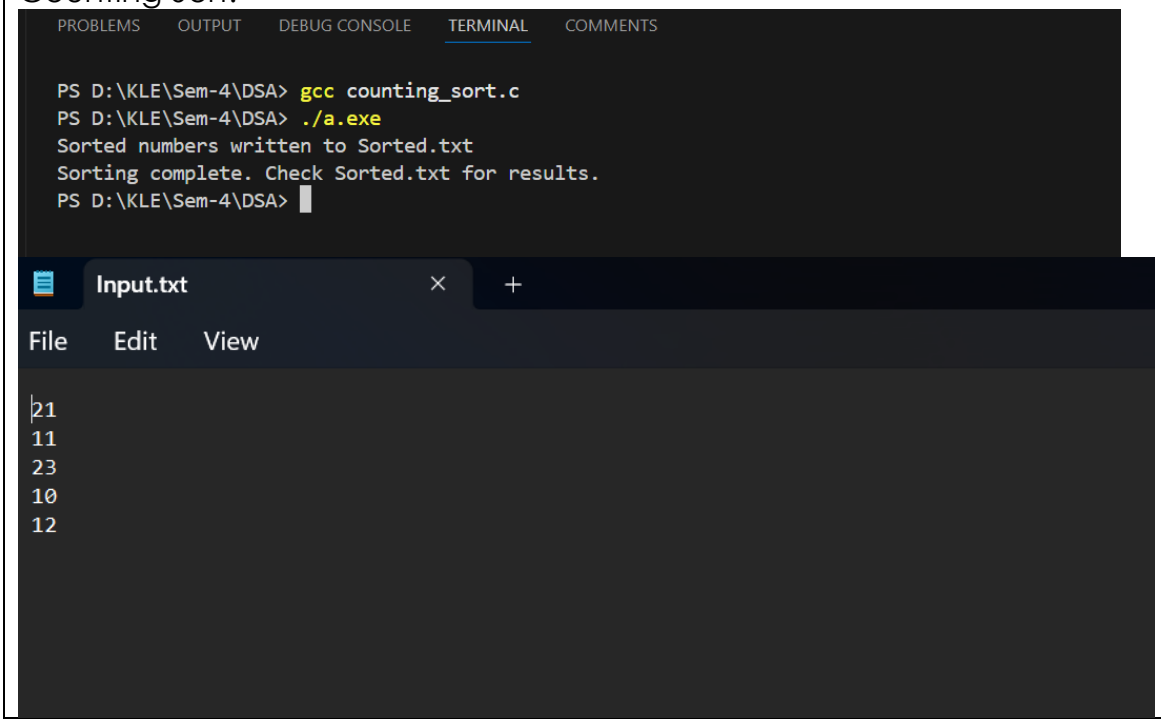
Shell sort:

```
PROBLEMS  OUTPUT  DEBUG CONSOLE  TERMINAL  COMMENTS

PS D:\KLE\Sem-4\DSA> gcc shell_sort.c
PS D:\KLE\Sem-4\DSA> ./a.exe
Sorted numbers written to Sorted.txt
Sorting complete. Check Sorted.txt for results.
PS D:\KLE\Sem-4\DSA>
```

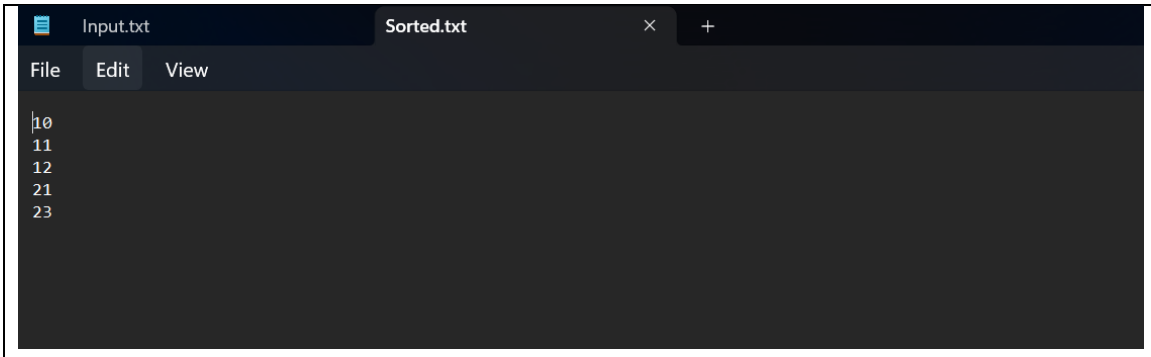
Data Structures Applications Laboratory (21EECF201/23EVTF203)



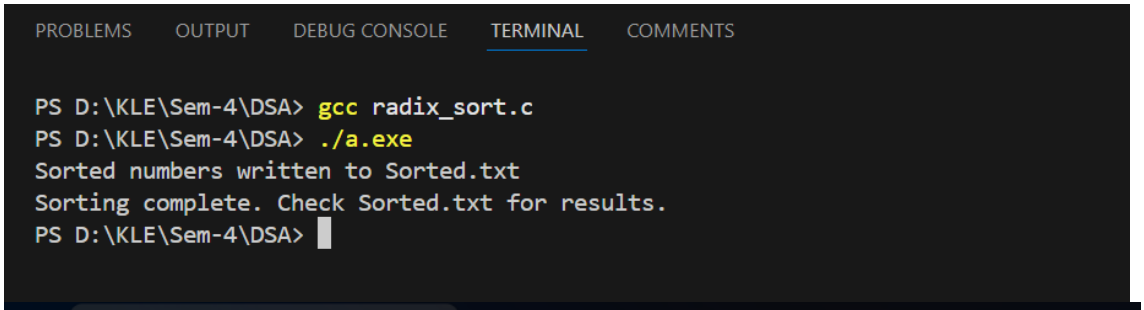
Counting Sort:

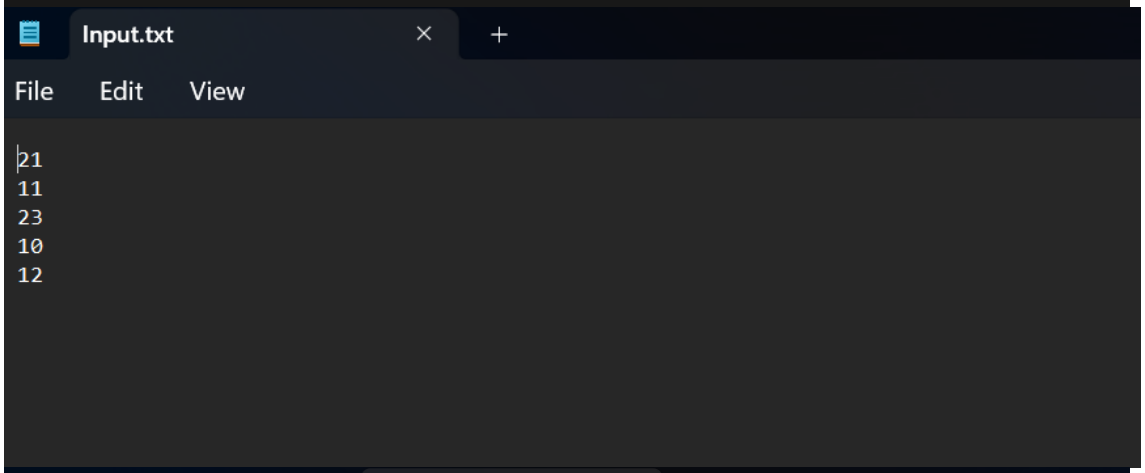


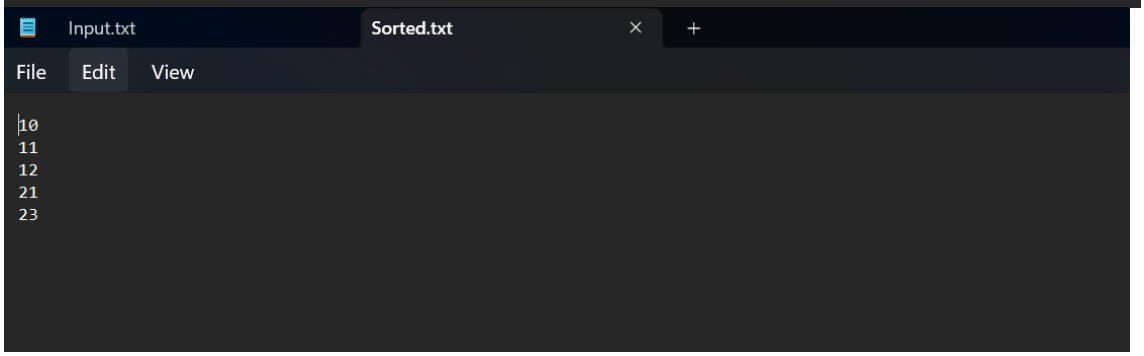
Data Structures Applications Laboratory (21EECF201/23EVTF203)



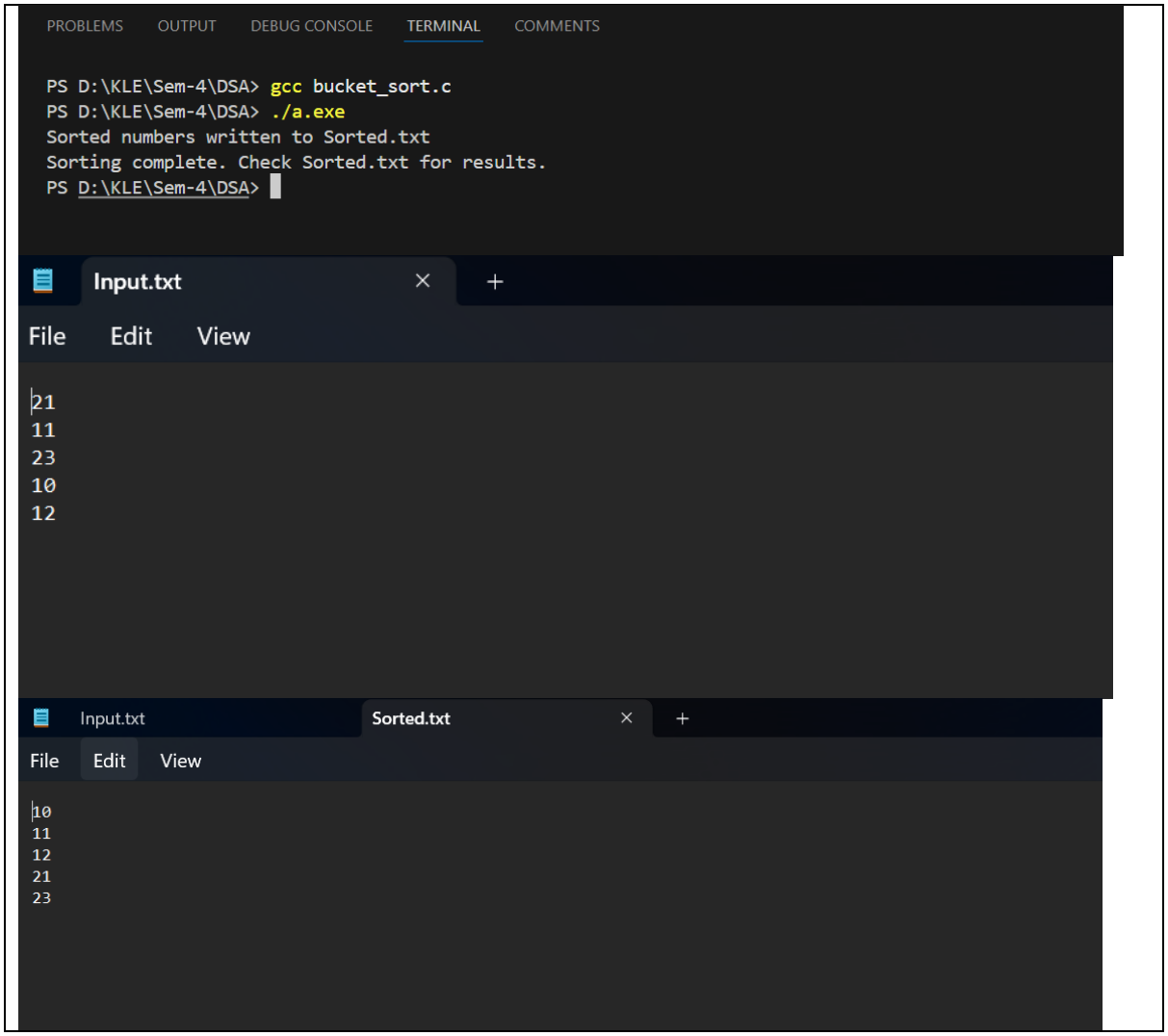
Radix Sort:







Bucket Sort:



Task 4:

	Time complexity		
Sorting algorithm	**Best case**	**Average case**	**Worst case**
Bubble Sort	**$O(n^2)$**	**$O(n^2)$**	**$O(n^2)$**
Selection Sort	**$O(n^2)$**	**$O(n^2)$**	**$O(n^2)$**
Insertion Sort	**$O(n)$**	**$O(n^2)$**	**$O(n^2)$**
Merge Sort	**$O(n \log n)$**	**$O(n \log n)$**	**$O(n^2)$**
Quick Sort	**$O(n \log n)$**	**$O(n \log n)$**	**$O(n \log n)$**
Heap Sort	**$O(n \log n)$**	**$O(n \log n)$**	**$O(n \log n)$**
Shell Sort	**$O(n \log n)$**	**$O(n \log^2 n)$**	**$O(n^2)$**
Counting Sort	**$O(n + k)$**	**$O(n + k)$**	**$O(n + k)$**
Radix Sort	**$O(nk)$**	**$O(nk)$**	**$O(nk)$**
Bucket Sort	**$O(n + k)$**	**$O(n + k)$**	**$O(n^2)$**