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**on**

**Design & Analysis of Algorithms**

**LAB**

**( PCS 409)**

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**Submitted to:                             Submitted by:**

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PROGRAM 1

I. Given an array of nonnegative integers, design a linear algorithm and implement it using a program to find whether given key element is present in the array or not. Also, find total number of comparisons for each input case. (Time Complexity = O(n), where n is the size of input).

**Algorithm :**

Algorithm linearSearch(a[0…n-1],n,key)

{

no\_of\_comparisons = 0

for i=0 to n

{

no\_of\_comparisons++

if(a[i] == key)

Print “ key is found”

return no\_of\_comparisons

}

if(i==n)

Print “ key is NOT found”

return no\_of\_comparisons

}

**Complexity Analysis :**

**Time Complexity :**

Worst Case: T(n) = θ(𝑛)

Best Case: T(n)= Ω(1)

Average Case:T(n) = θ(𝑛)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1)

**Source Code :**

#include <iostream>

using namespace std;

int main()

{

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

    int key;

    cout<<"enter the key"<<endl;

    cin>>key;

    int c=0,f=0;

    for(int i=0;i<n;i++)

    { c++;

        if(arr[i]==key)

        {

            cout<<key<<" found"<<endl;

            cout<<"number of comparision"<<endl;

            cout<<c;

            f=1;

            break;

        }

    }

    if(f==0)

    cout<<key<<" not found"<<endl;

    t--;

 }

    return 0;

}

**OUTPUT**

Text

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PROGRAM 2

2. Given an already sorted array of positive integers, design an algorithm and implement it using a program to find whether given key element is present in the array or not. Also, find total number of comparisons for each input case. (Time Complexity = O(logn), where n is the size of input).

**Algorithm:**

Binary\_Search(a, lower\_bound, upper\_bound, val)

Step 1: set beg = lower\_bound, end = upper\_bound, pos = - 1

Step 2: repeat steps 3 and 4 while beg <=end

Step 3: set mid = (beg + end)/2

Step 4: if a[mid] = val

set pos = mid

print pos

go to step 6

else if a[mid] > val

set end = mid - 1

else

set beg = mid + 1

[end of if]

[end of loop]

Step 5: if pos = -1

print "value is not present in the array"

[end of if]

Step 6: exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θlog(𝑛)

Best Case: T(n)= Ω(1)

Average Case:T(n) = θlog(𝑛)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code :**

#include <iostream>

using namespace std;

void binary(int \*arr,int n,int key)

{

    int l=0,r=n-1;

    int c=0;

    while(l<r)

    {

        int mid=(l+r)/2;

        c++;

        if(arr[mid]==key)

        {

            cout<<key<<" found"<<endl;

            cout<<"number of comparision"<<endl;

            cout<<c;

            return ;

        }

        if(arr[mid]>key)

          r=mid-1;

        else

          l=mid+1;

    }

    cout<<key<<" not found"<<endl;

    cout<<"number of comparision"<<endl;

    cout<<c;

    return ;

}

int main()

{

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

    int key;

    cout<<"enter the key"<<endl;

    cin>>key;

    int c=0;

    binary(arr,n,key);

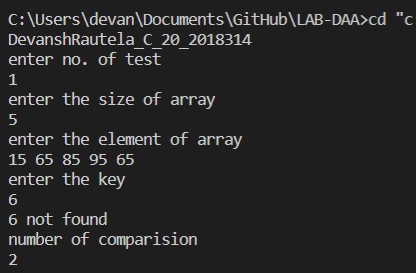
    t--;

 }

    return 0;

}

**OUTPUT**

****

PROGRAM 3

3. Given an already sorted array of positive integers, design an algorithm and implement it using a program to find whether a given key element is present in the sorted array or not. For an array arr[n], search at the indexes arr[0], arr[2], arr[4],. ,arr[2 k ] and so on. Once the interval (arr[2 k ] < key < arr[ 2 k+1 ] ) is found, perform a linear search operation from the index 2 k to find the element key. (Complexity < O(n), where n is the number of elements need to be scanned for searching): (Jump Search)

**Algorithm:**

Algorithm JumpSearch(a[0…n-1],n,key)

Step 1: set r=2^1,i=1

Step 2: repeat steps 3 and 4 while r <=n

Step 3: if a[r]<key

for j=i-1 to r

if a[j]== key

print found

exit

Step 4:i=r, r=2^i

Step 5:if r>n then

for j=i-1 to n

if a[j]== key

print found

exit

Step 6:print not found

Step 7:exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(sqrt 𝑛)

Best Case: T(n)= Ω(sqrt n)

Average Case:T(n) = θ(sqrt 𝑛)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1)

**Source code :**

#include <iostream>

#include <math.h>

using namespace std;

void jumpsearch(int \*arr,int n,int key)

{int r=pow(2,1);

  int l=0;

  int i=1;

  int c=0;

  while(r<=n)

  {

      c++;

      if(arr[r]<arr[i])

      {

        for(int j=l;j<=r;j++)

        {

        c++;

        if(arr[j]==key)

        {

            cout<<key<<" found"<<endl;

            cout<<"number of comparision"<<endl;

            cout<<c;

            return ;

        }

        }

      }

      i++;

      l=r;

      r=pow(2,i);

  }

  if(r>n){

        for(int j=l;j<n;j++){

        c++;

        if(arr[j]==key) {

            cout<<key<<" found"<<endl;

            cout<<"number of comparision"<<endl;

            cout<<c;

            return ;

        }  }  }

    cout<<key<<" not found"<<endl;

    cout<<"number of comparision"<<endl;

    cout<<c;

    return ;}

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0) {

    int n, key;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

    cout<<"enter the key"<<endl;

    cin>>key;

    jumpsearch(arr,n,key);

    t--;

 } return 0;

}

OUTPUT

Text

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PROGRAM 4

4. Given a sorted array of positive integers containing few duplicate elements, design an algorithm and implement it using a program to find whether the given key element is present in the array or not. If present, then also find the number of copies of given key. (Time Complexity = O(log n))

**Algorithm:**

Step 1: find fist occurance of key using binary search

Step 2:find last occurance of key using binary search

Step 3: set freq=last occurance – first occurance +1

Step 4: if freq >1

Print freq

Else

Print no duplicate

Step 5 exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θlog(𝑛)

Best Case: T(n)= Ω(1)

Average Case:T(n) = θlog(𝑛)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code** :

#include <iostream>

using namespace std;

int first(int \*arr,int l,int r,int key,int n)

{

    if(l<=r)

    {

        int mid1=l+(r-l)/2;

        if((mid1==0||arr[mid1-1]<key)&&arr[mid1]==key)

           return mid1;

        else if(arr[mid1]<key)

           return first(arr,mid1+1,r,key,n);

        else

          return first(arr,l,mid1-1,key,n);

    }

    return -1;

}

int last(int  \*arr,int l,int r,int key,int n)

{

    if(l<=r)

    {

        int mid2=l+(r-l)/2;

        if((mid2==n-1||arr[mid2+1]>key)&&arr[mid2]==key)

           return mid2;

        else if(arr[mid2]>key)

           return last(arr,l,mid2-1,key,n);

        else

          return last(arr,mid2+1,r,key,n);

    }

    return -1;

}

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

    int key;

    cout<<"enter the key"<<endl;

    cin>>key;

    int diff=last(arr,0,n-1,key,n)-first(arr,0,n-1,key,n)+1;

    if(diff>0)

    {

        cout<<key<<"-"<<diff<<endl;

    }

    else

       cout<<key<<" not found"<<endl;

    t--;

}

}

**OUTPUT**

**Text

Description automatically generated**

PROGRAM 5

5. Given a sorted array of positive integers, design an algorithm and implement it using a program to find three indices i, j, k such that arr[i] + arr[j] = arr[k].

**Algorithm:**

Step 1: for i=0 to n-2

for j=i+1 to n-1

for k=j+1 to n

if arr[i]+arr[j]==arr[k]

print i j k

exit

Step 2: print not found

Step 3: exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛^3)

Best Case: T(n)= Ω(n^3)

Average Case:T(n) = θ(𝑛^3)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code:**

#include <iostream>

using namespace std;

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

      int f=0;

    for(int i=0;i<n-2;i++)

    {

        for(int j=i+1;j<n-1;j++)

        {

            for(int k=j+1;k<n;k++)

            {

                if(arr[i]+arr[j]==arr[k])

                {

                    cout<<i<<" "<<j<<" "<<k;

                    f=1;

                    break;

                }

            }

            if(f==1)

              break;

        }

        if(f==1)

         break;

    }

    if(f==0)

     cout<<"not found";

     t--;

 }

}

**OUTPUT**

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PROGRAM 6

6. Given an array of nonnegative integers, design an algorithm and a program to count the number of pairs of integers such that their difference is equal to a given key, K.

**Algorithm:**

Step 1: for i=0 to n-1

for j=i+1 to n

if arr[i]+arr[j]==key

print arr[i] arr[j]

Step 2: print not such pair

Step 3 : exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛^2)

Best Case: T(n)= Ω(n^2)

Average Case:T(n) = θ(𝑛^2)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code :**

#include <iostream>

using namespace std;

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0){

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    cout<<"enter the element of array"<<endl;

    int arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

      int f=0;

      int k;

      cout<<"enter key"<<endl;

      cin>>k;

      for(int i=0;i<n-1;i++)

      {

          for(int j=i+1;j<n;j++)

          {

              if(arr[i]-arr[j]==k||arr[j]-arr[i]==k)

               f++;

          }

      }

      cout<<f;

      t--;

 }

}

**OUTPUT**

**Text

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PROGRAM 7

7. Given an unsorted array of integers, design an algorithm and a program to sort the array using insertion sort. Your program should be able to find number of comparisons and shifts ( shifts - total number of times the array elements are shifted from their place) required for sorting the array.

**Algorithm:**

Step 1 - If the element is the first element, assume that it is already sorted. Return 1.

Step2 - Pick the next element, and store it separately in a key.

Step3 - Now, compare the key with all elements in the sorted array.

Step 4 - If the element in the sorted array is smaller than the current element, then move to the next element. Else, shift greater elements in the array towards the right.

Step 5 - Insert the value.

Step 6 - Repeat until the array is sorted.

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛^2)

Best Case: T(n)= Ω(n)

Average Case:T(n) = θ(𝑛^2)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code** :

#include <iostream>

#include <algorithm>

using namespace std;

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 int c=0,s=0;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

     int temp=arr[i];

     j=i-1;

     while(j>=0&&temp<arr[j])

     {

         arr[j+1]=arr[j];

         c++;

         s++;

         j--;

     }

     arr[j+1]=temp;

     s++;

 }

  for(int i=0;i<n;i++)

 {

     cout<<arr[i]<<" ";

 }

 cout<<"comparision "<<c<<endl;

 cout<<"shifts "<<s-1<<endl;

 t--;

 }

}

**OUTPUT**

**Text

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PROGRAM 8

8. Given an unsorted array of integers, design an algorithm and implement a program to sort this array using selection sort. Your program should also find number of comparisons and number of swaps required.

**Algorithm:**

Step 1 − Set MIN to location 0

Step 2 − Search the minimum element in the list

Step 3 − Swap with value at location MIN

Step 4 − Increment MIN to point to next element

Step 5 − Repeat until list is sorted

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛^2)

Best Case: T(n)= Ω(n^2)

Average Case:T(n) = θ(𝑛^2)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code :**

#include <iostream>

#include <algorithm>

using namespace std;

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

 int t;

cout<<"enter no. of test"<<endl;

cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 int c=0,s=0;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

 for(int i=0;i<n;i++)

 {

     int k=i;

     for(int j=i+1;j<n;j++)

     {

         c++;

         if(arr[k]>arr[j])

           k=j;

     }

     s++;

     swap(arr[i],arr[k]);

 }

  for(int i=0;i<n;i++)

 {

     cout<<arr[i]<<" ";

 }

 cout<<"comparision "<<c<<endl;

 cout<<"swaps "<<s-1<<endl;

 t--;

 }

}

**OUTPUT**

**Text

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PROGRAM 9

9. Given an unsorted array of positive integers, design an algorithm and implement it using a program to find whether there are any duplicate elements in the array or not. (use sorting) (Time Complexity = O(n log n))

**Algorithm:**

Step1: sort the array using merge sort

Step2:repeat for i=0 to n

If array[i]==array[i+1] then

Print duplicate found

Jump to step 4

Step3: print no duplicate found

Step4:exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛logn)

Best Case: T(n)= Ω(nlogn)

Average Case:T(n) = θ(nlogn)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(n) [ Constant ]

**Source code :**

#include <iostream>

#include <algorithm>

using namespace std;

void merge(int \*arr,int l,int e,int mid)

{

    int i=0,j=0,k=l;

    int n1=mid-l+1;

    int n2=e-mid;

    int L[n1];

    int R[n2];

    for(int i=0;i<n1;i++)

    {

        L[i]=arr[l+i];

    }

    for(int i=0;i<n2;i++)

    {

        R[i]=arr[mid+1+i];

    }

    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 l,int e)

{

    if(l<e)

    {

        int mid=l+(e-l)/2;

        mergesort(arr,l,mid);

        mergesort(arr,mid+1,e);

        merge(arr,l,e,mid);

    }

}

int main(){

cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

 int t;

 cout<<"enter no. of test"<<endl;

 cin>>t;

 while(t!=0)

 {

 int n;

 cin>>n;

 int arr[n];

 int j;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

   mergesort(arr,0,n-1);

   int f=1;

  for(int i=0;i<n;i++)

 {

    if(arr[i]==arr[i+1])

    {

        cout<<"yes"<<endl;

        f=0;

        break;

    }

 }

 if(f==1)

 {

     cout<<"no"<<endl;

 }

 t--;

 }

}

**OUTPUT**

**Text

Description automatically generated**

PROGRAM 10

10. Given an unsorted array of integers, design an algorithm and implement it using a program to sort an array of elements by dividing the array into two subarrays and combining these subarrays after sorting each one of them. Your program should also find number of comparisons and inversions during sorting the array. ( Merge sort)

**Algorithm:**

Step 1 − divide the list recursively into two halves until it can no more be divided.

MERGE\_SORT(arr, beg, end)

if beg < end

set mid = (beg + end)/2

MERGE\_SORT(arr, beg, mid)

MERGE\_SORT(arr, mid + 1, end)

MERGE (arr, beg, mid, end)

end of if

END MERGE\_SORT

Step 2 − merge the smaller lists into new list in sorted order.

while (i < n1 && j < n2)

if (LeftArray[i] <= RightArray[j]) then

a[k] = LeftArray[i];

i++;

else then

a[k] = RightArray[j];

j++; k++;

end of while

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛logn)

Best Case: T(n)= Ω(nlogn)

Average Case:T(n) = θ(𝑛logn)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(n)

**Source code :**

#include <bits/stdc++.h>

using namespace std;

int \_mergeSort(int arr[], int temp[], int left, int right,int \*c);

int merge(int arr[], int temp[], int left, int mid,int right,int \*c);

int mergeSort(int arr[], int array\_size,int \*c)

{

    int temp[array\_size];

    return \_mergeSort(arr, temp, 0, array\_size - 1,c);

}

int \_mergeSort(int arr[], int temp[], int left, int right,int \*c)

{

    int mid, inv\_count = 0;

    if (right > left) {

        mid = (right + left) / 2;

        inv\_count += \_mergeSort(arr, temp, left, mid,c);

        inv\_count += \_mergeSort(arr, temp, mid + 1, right,c);

        inv\_count += merge(arr, temp, left, mid + 1, right,c);

    }

    return inv\_count;

}

int merge(int arr[], int temp[], int left, int mid,int right,int \*c)

{

    int i, j, k;

    int inv\_count = 0;

    i = left;

    j = mid;

    k = left;

    while ((i <= mid - 1) && (j <= right)) {

        \*c=\*c+1;

        if (arr[i] <= arr[j]) {

            temp[k++] = arr[i++];

        }

        else {

            temp[k++] = arr[j++];

            inv\_count = inv\_count + (mid - i);

        }

    }

    while (i <= mid - 1)

        temp[k++] = arr[i++];

    while (j <= right)

        temp[k++] = arr[j++];

    for (i = left; i <= right; i++)

        arr[i] = temp[i];

    return inv\_count;

}

int main(){

 cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

 cout<<"enter no. of test"<<endl;

 cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 int c=0;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

    int s = mergeSort(arr, n,&c);

    for(int i=0;i<n;i++)

      cout<<arr[i]<<" ";

    cout<<"comparision "<<c<<endl;

    cout << "inversions " <<s<<endl;

  t--;

}

}

**OUTPUT**

**Text

Description automatically generated**

PROGRAM 11

11. Given an unsorted array of integers, design an algorithm and implement it using a program to sort an array of elements by partitioning the array into two subarrays based on a pivot element such that one of the sub array holds values smaller than the pivot element while another sub array holds values greater than the pivot element. Pivot element should be selected randomly from the array. Your program should also find number of comparisons and swaps required for sorting the array. ( Randomised QuickSort)

**Algorithm:**

QUICKSORT (array A, start, end)

{

1 if (start < end)

2 {

3 p = partition(A, start, end)

4 QUICKSORT (A, start, p - 1)

5 QUICKSORT (A, p + 1, end)

6 }

}

PARTITION (array A, start, end)

{

1 pivot ? A[end]

2 i ? start-1

3 for j ? start to end -1 {

4 do if (A[j] < pivot) {

5 then i ? i + 1

6 swap A[i] with A[j]

7 }}

8 swap A[i+1] with A[end]

9 return i+1

}

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛^2)

Best Case: T(n)= Ω(nlogn)

Average Case:T(n) = θ(𝑛logn)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(nlogn)

**Source code :**

#include<iostream>

#include<algorithm>

using namespace std;

int partition(int \*arr,int l,int r,int \*c,int \*s){

    int piovt=arr[r];

    int i=l-1;

    for(int j=l;j<=r-1;j++)

    {

       (\*c)++;

        if(arr[j]<=piovt)

        {

           i++;

           swap(arr[i],arr[j]);

           (\*s)++;

        }

    }

    swap(arr[i+1],arr[r]);

    (\*s)++;

    return (i+1);

}

void quicksort(int \*arr,int l,int r,int \*c,int \*s)

{

if(l<r)

{

int p=partition(arr,l,r,c,s);

quicksort(arr,l,p-1,c,s);

quicksort(arr,p+1,r,c,s);

}

}

int main(){

 cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

 cout<<"enter no. of test"<<endl;

 cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 int s=0,c=0;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

   quicksort(arr,0,n-1,&c,&s);

  for(int i=0;i<n;i++)

 {

     cout<<arr[i]<<" ";

 }

 cout<<"comparision "<<c<<endl;

 cout<<"swaps "<<s<<endl;

 t--;

}

}

**OUTPUT**

Text

Description automatically generated

PROGRAM 12

12. Given an unsorted array of integers, design an algorithm and implement it using a program to find Kth smallest or largest element in the array. (Worst case Time Complexity = O(n))

**Algorithm:**

function quickSelect(list, left, right, k)

if left = right

return list[left]

Select a pivotIndex between left and right

pivotIndex := partition(list, left, right,pivotIndex)

if k = pivotIndex

return list[k]

else if k < pivotIndex

right := pivotIndex - 1

else

left := pivotIndex + 1

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛logn)

Best Case: T(n)= Ω(n)

Average Case:T(n) = θ(𝑛^2)

**Space Complexity:**

Worst Case= θ(n)

Best Case = Average case = θ(logn)

**Source code:**

#include<iostream>

#include<algorithm>

using namespace std;

int partition(int \*arr,int l,int r)

{

    int pivot=arr[r];

    int i=l-1;

    for(int j=l;j<=r-1;j++)

    {

        if(arr[j]<pivot)

        {

            i++;

            swap(arr[j],arr[i]);

        }

    }

    swap(arr[i+1],arr[r]);

    return i+1;

}

int quickselect(int \*arr,int l,int r,int k)

{

    if(k>0&&k<=r-l+1)

    {

        int p=partition(arr,l,r);

        if(p-l==k-1)

          return arr[p];

        if(p-l>k-1)

          return quickselect(arr,l,p-1,k);

          return quickselect(arr,p+1,r,k-p+l-1);

    }

return INT\_MAX;

}

int main(){

 cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

 cout<<"enter no. of test"<<endl;

 cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

 int k;

 cout<<"enter key"<<endl;

 cin>>k;

   int s=quickselect(arr,0,n-1,k);

   cout<<s<<endl;

   t--;

 }

}

**OUTPUT**

Text

Description automatically generated

PROGRAM 13

13. Given an unsorted array of alphabets containing duplicate elements. Design an algorithm and implement it using a program to find which alphabet has maximum number of occurrences and print it. (Time Complexity = O(n)) (Hint: Use counting sort)

**Algorithm:**

countingSort(array, n)

max = find maximum element in the given array

create count array with size maximum + 1

Initialize count array with all 0's

for i = 0 to n

find the count of every unique element and

store that count at ith position in the count array

for j = 1 to max

Now, find the cumulative sum and store it in count array

for i = n to 1

Restore the array elements

Decrease the count of every restored element by 1

end countingSort

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛+k)

Best Case: T(n)= Ω(n+k)

Average Case:T(n) = θ(𝑛+k)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(k)

**Source code :**

#include<bits/stdc++.h>

using namespace std;

int main(){

    cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

    cout<<"enter no. of test"<<endl;

    cin>>t;

    while(t!=0)

    {

    int n;

    cout<<"enter the size of array"<<endl;

    cin>>n;

    char arr[n];

    for(int i=0;i<n;i++)

      cin>>arr[i];

    int count[26];

    memset(count,0,sizeof(count));

    for(int i=0;i<n;++i)

    {

        int k=arr[i];

        ++count[k-97];

    }

    int l=count[0],j=0;

    for(int i=1;i<26;i++)

    {

        if(l<count[i])

        {

          l=count[i];

          j=i;

        }

    }

    if(l>1)

    {

        char a='a'+j;

        cout<<a<<"-"<<l;

    }

    else

    {

       cout<<"no duplicate found"<<endl;

    }

    t--;

    }

}

**OUTPUT**

Text

Description automatically generated

PROGRAM 14

14. Given an unsorted array of integers, design an algorithm and implement it using a program to find whether two elements exist such that their sum is equal to the given key element. (Time Complexity = O(n log n))

**Algorithm:**

Step 1 − divide the list recursively into two halves until it can no more be divided.

MERGE\_SORT(arr, beg, end)

if beg < end

set mid = (beg + end)/2

MERGE\_SORT(arr, beg, mid)

MERGE\_SORT(arr, mid + 1, end)

MERGE (arr, beg, mid, end)

end of if

END MERGE\_SORT

Step 2 − merge the smaller lists into new list in sorted order.

while (i < n1 && j < n2)

if (LeftArray[i] <= RightArray[j]) then

a[k] = LeftArray[i];

i++;

else then

a[k] = RightArray[j];

j++; k++;

end of while

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛logn)

Best Case: T(n)= Ω(nlogn)

Average Case:T(n) = θ(𝑛logn)

**Space Complexity:**

Worst Case=Best Case = Average case = θ(n)

**Source Code :**

#include <iostream>

#include <algorithm>

using namespace std;

void merge(int \*arr,int l,int e,int mid)

{

    int i=0,j=0,k=l;

    int n1=mid-l+1;

    int n2=e-mid;

    int L[n1];

    int R[n2];

    for(int i=0;i<n1;i++)

    {

        L[i]=arr[l+i];

    }

    for(int i=0;i<n2;i++)

    {

        R[i]=arr[mid+1+i];

    }

    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 l,int e)

{

    if(l<e)

    {

        int mid=l+(e-l)/2;

        mergesort(arr,l,mid);

        mergesort(arr,mid+1,e);

        merge(arr,l,e,mid);

    }

}

int main(){

 cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

 cout<<"enter no. of test"<<endl;

 cin>>t;

 while(t!=0)

 {

 int n;

 cout<<"enter the size of array"<<endl;

 cin>>n;

 int arr[n];

 int j;

 cout<<"enter the element of array"<<endl;

 for(int i=0;i<n;i++)

 {

     cin>>arr[i];

 }

 int key;

 cout<<"enter key"<<endl;

 cin>>key;

  mergesort(arr,0,n-1);

  int l=0,r=n-1,f=0;

  while(l<r)

  {

      if(arr[l]+arr[r]==key)

      {

          cout<<arr[l]<<" "<<arr[r]<<endl;

          f=1;

          l++,r--;

      }

      else if(arr[l]+arr[r]<key)

        l++;

      else

        r--;

  }

  if(f==0)

    cout<<"no such pairs"<<endl;

  t--;

 }

}

**OUTPUT**

**Text

Description automatically generated**

PROGRAM 15

15. You have been given two sorted integer arrays of size m and n. Design an algorithm and implement it using a program to find list of elements which are common to both. (Time Complexity = O(m+n))

**Algorithm:**

Function intersection(arr1,arr2,m,n)

Step 1 set i=0,j=0

Step 2  while(i<m&&j<n)

        {

            if(arr1[i]==arr2[j]&&(arr1[i-1]!=arr1[i]||arr2[j-1]!=arr2[j])) then

            {

              cout<<arr1[i]<<" ";

              i++;

              j++;

            }

            else if(arr1[i]>arr2[j])

              j++;

            else

              i++;

        }

Step 3 exit

**Complexity Analysis:**

**Time Complexity:**

Worst Case: T(n) = θ(𝑛) [ Linear]

Best Case: T(n)= Ω(1) [ Constant]

Average Case:T(n) = θ(𝑛) [ Linear]

**Space Complexity:**

Worst Case=Best Case = Average case = θ(1) [ Constant ]

**Source code :**

#include<iostream>

using namespace std;

int main(){

    cout<<”DevanshRautela\_C\_20\_2018314”<<endl;

int t;

    cout<<"enter no. of test"<<endl;

    cin>>t;

    while(t!=0)

    {

        int m;

        cout<<"enter the size of array"<<endl;

        cin>>m;

        int arr1[m];

        cout<<"enter the element of array"<<endl;

        for(int i=0;i<m;i++)

        {

            cin>>arr1[i];

        }

        int n;

        cout<<"enter the size of array"<<endl;

        cin>>n;

        int arr2[n];

        cout<<"enter the element of array"<<endl;

        for(int i=0;i<n;i++)

        {

            cin>>arr2[i];

        }

        int i=0,j=0;

        while(i<m&&j<n)

        {

            if(arr1[i]==arr2[j]&&(arr1[i-1]!=arr1[i]||arr2[j-1]!=arr2[j]))

            {

              cout<<arr1[i]<<" ";

              i++;

              j++;

            }

            else if(arr1[i]>arr2[j])

              j++;

            else

              i++;

        }

        t--;

    }

}

**OUTPUT**

**Text

Description automatically generated**