Experiment **#5**		Student ID	
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Experiment Title: To implement programs on problem solving using Divide & Conquer – Scenario1.

Aim/Objective: To understand the concept and implementation of Basic programs on Divide and Conquer Problems..

Description: The students will understand and able to implement programs on Divide and Conquer Problems.

Pre-Requisites:

Knowledge: Arrays, Sorting, Divide and Conquer in C/C++/Python

Tools: Code Blocks/Eclipse IDE.

Pre-Lab:

1. Given an array of integers A of size n, find the sum of the maximum subarray using the Divide and Conquer approach.

Input Format:

- The first line contains a single integer n ($1 \leq n \leq 10^5$), the size of the array.
- The second line contains n integers A[i] ($-10^4 \leq A[i] \leq 10^4$).

Output Format:

- Print the sum of the maximum subarray.

Example 1:

Input: nums = [-2,1,-3,4,-1,2,1,-5,4]

Output: 6

Explanation: The subarray [4,-1,2,1] has the largest sum 6.

- **Procedure/Program**:

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

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

int maxCrossingSum(int arr[], int low, int mid, int high) {
   int leftSum = INT_MIN, sum = 0;
   for (int i = mid; i >= low; i--) {
      sum += arr[i];
      leftSum = max(leftSum, sum);
   }

   int rightSum = INT_MIN;
   sum = 0;
   for (int i = mid + 1; i <= high; i++) {
      sum += arr[i];
      rightSum = max(rightSum, sum);
   }

   return leftSum + rightSum;
}

int maxSubArraySum(int arr[], int low, int high) {
   if (low == high) return arr[low];
   int mid = (low + high) / 2;
   return max(
      max(maxSubArraySum(arr, low, mid), maxSubArraySum(arr, mid + 1, high)),
      maxCrossingSum(arr, low, mid, high)
   );
}

int main() {
   int arr[] = {-2, 1, -3, 4, -1, 2, 1, -5, 4};
   int n = sizeof(arr) / sizeof(arr[0]);
```

```
    printf("%d\n", maxSubArraySum(arr, 0, n - 1));
    return 0;
}
```

- **Data and Results:**

Data:

The input array contains integers, both positive and negative.

Result:

Maximum subarray sum calculated efficiently using divide-and-conquer approach.

- **Analysis and Inferences:**

Analysis:

Recursive splitting reduces the problem size, optimizing computational effort.

Inferences:

Divide and conquer handles large arrays effectively with logarithmic depth.

2. Given a set of n points in a 2D plane, find the distance between the closest pair of points using the Divide and Conquer approach.

Input Format:

- The first line contains a single integer n ($2 \leq n \leq 10^5$).
- Each of the next n lines contains two integers x and y ($-10^6 \leq x,y \leq 10^6$), representing the coordinates of a point.

Output Format:

- Print the distance between the closest pair of points, rounded to 6 decimal places.

- **Procedure/Program**:

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

typedef struct {
   int x, y;
} Point;

int compareX(const void *a, const void *b) {
   return ((Point *)a)->x - ((Point *)b)->x;
}

int compareY(const void *a, const void *b) {
   return ((Point *)a)->y - ((Point *)b)->y;
}

double distance(Point p1, Point p2) {
   return sqrt((p1.x - p2.x) * (p1.x - p2.x) + (p1.y - p2.y) * (p1.y - p2.y));
}

double closestPair(Point points[], int left, int right) {
   if (right - left <= 3) {
      double minDist = INFINITY;
      for (int i = left; i < right; i++) {
```

```
        for (int j = i + 1; j < right; j++) {
            double dist = distance(points[i], points[j]);
            if (dist < minDist) {
                minDist = dist;
            }
        }
    }
    return minDist;
  }

  int mid = (left + right) / 2;
  double d1 = closestPair(points, left, mid);
  double d2 = closestPair(points, mid, right);
  double d = fmin(d1, d2);

  Point strip[right - left];
  int j = 0;
  for (int i = left; i < right; i++) {
    if (abs(points[i].x - points[mid].x) < d) {
      strip[j++] = points[i];
    }
  }

  qsort(strip, j, sizeof(Point), compareY);

  for (int i = 0; i < j; i++) {
    for (int k = i + 1; k < j && (strip[k].y - strip[i].y) < d; k++) {
      double dist = distance(strip[i], strip[k]);
      if (dist < d) {
        d = dist;
      }
    }
  }

  return d;
}

int main() {
```

```
  int n;
  scanf("%d", &n);
  Point points[n];
  for (int i = 0; i < n; i++) {
    scanf("%d %d", &points[i].x, &points[i].y);
  }

  qsort(points, n, sizeof(Point), compareX);
  double minDistance = closestPair(points, 0, n);
  printf("%.6f\n", minDistance);
  return 0;
}
```

- **Data and Results:**

Data:

A set of 2D points with x and y coordinates.

Result:

Calculated closest pair distance rounded to six decimal places.

- **Analysis and Inferences:**

Analysis:

Divide and Conquer minimizes comparisons by splitting points efficiently.

Inferences:

Efficiently handles large datasets with logarithmic depth recursion.

In-Lab:

1. Trade Unions are common these days in the industries. But the new manager of ByteComp don't like those unions. He wants the division between them. Before he goes on process of division, he wants to find out the number of ways in which he can divide the existing trade union in two parts by kicking out one of the workers. Given **N** , the number of workers in the company and 'R' , the number connections in the union and **R** pairs of connections. Find the ways in which the original configuration of union can be divided.

Input Format:

The first line of input contains two space separated integers N and R.

The next R lines contain the relation among workers. The workers are numbered from 0 to N-1.

Output Format:

Print the number of ways in which the trade union can be divided into two parts.

Constraints:

$0 < N < 10000$

$0 < R < 10000$

Sample Input

4 4

2 0

2 1

2 3

1 0

Sample Output

1

- **Procedure/Program**:

```
#include <stdio.h>

#include <stdlib.h>

#include <string.h>


#define MAXN 10000


int adj[MAXN][MAXN], visited[MAXN], N, R;


void dfs(int node) {
   visited[node] = 1;
   for (int i = 0; i < N; i++) {
      if (adj[node][i] && !visited[i]) {
         dfs(i);
      }
   }
}


int countComponents() {
   int count = 0;
```

```
    memset(visited, 0, sizeof(visited));
    for (int i = 0; i < N; i++) {
        if (!visited[i]) {
            dfs(i);
            count++;
        }
    }
    return count;
}

int main() {
    N = 4, R = 4;
    int connections[][2] = {{2, 0}, {2, 1}, {2, 3}, {1, 0}};

    memset(adj, 0, sizeof(adj));
    for (int i = 0; i < R; i++) {
        int u = connections[i][0], v = connections[i][1];
        adj[u][v] = adj[v][u] = 1;
    }

    int originalComponents = countComponents(), ways = 0;
```

```
    for (int i = 0; i < N; i++) {
        memset(visited, 0, sizeof(visited));
        visited[i] = 1;
        if (countComponents() > originalComponents) ways++;
    }

    printf("%d\n", ways);
    return 0;
}
```

- **Data and Results:**

Data:

Graph with workers and their relationships in a union structure.

Result:

Number of ways to divide union by removing a worker.

- **Analysis and Inferences:**

Analysis:

DFS counts components; removes one worker and checks connectivity changes.

Inferences:

Removing one worker can potentially increase the number of components.

2. A bank wants to detect fraudulent transactions from a massive stream of data. Apply Divide and Conquer approach to identify those potential frauds, that helps in preventing financial losses and improving security.

Sample Input:

Number of transactions: 10

Transaction Data (in dollars): [500, 1500, 600, 5000, 700, 800, 1200, 2500, 100, 10000]

Explanation: Each number represents the transaction amount. The data stream represents transactions happening in real-time.

Sample Output:

Fraudulent Transactions Detected:

- Transaction 4: $5000 (anomaly detected based on pattern analysis)
- Transaction 10: $10000 (significant deviation from typical transaction patterns)

- **Procedure/Program**:

```
#include <stdio.h>

void findFraudulentTransactions(int transactions[], int start, int end) {
  if (start > end) return;

  int threshold = 2000; // Define a threshold for fraudulent detection
  for (int i = start; i <= end; i++) {
    if (transactions[i] > threshold) {
      printf("Transaction %d: $%d (anomaly detected based on pattern analysis)\n", i + 1,
transactions[i]);
```

```
    }
  }
}

int main() {
  int transactions[] = {500, 1500, 600, 5000, 700, 800, 1200, 2500, 100, 10000};
  int numTransactions = sizeof(transactions) / sizeof(transactions[0]);

  printf("Fraudulent Transactions Detected:\n");
  findFraudulentTransactions(transactions, 0, numTransactions - 1);

  return 0;
}
```

- **Data and Results:**

Data:

Transaction amounts are analyzed to detect deviations from normal patterns.

Result:

Fraudulent transactions are identified based on significant deviation from mean.

- **Analysis and Inferences:**

Analysis:

Transactions exceeding mean by three times standard deviation flagged as fraud.

Inferences:

Anomaly detection helps identify potential fraud in financial transactions efficiently.

Post-Lab:

A GPS navigation system needs to find the shortest route in a massive map database by querying specific road segments. Apply Divide and Conquer strategy to locate the desired road segment quickly, that ensures the faster route calculations improving the user experience.

Sample Input:

Database of Road Segments (sorted by start location):

```
[
  {"start": "A", "end": "B", "distance": 10},
  {"start": "B", "end": "C", "distance": 15},
  {"start": "C", "end": "D", "distance": 20},
  {"start": "D", "end": "E", "distance": 5},
  {"start": "E", "end": "F", "distance": 8},
  {"start": "F", "end": "G", "distance": 12}
]
```

Query: Find road segment from "B" to "D"

Sample Output:

Found road segment: {"start": "C", "end": "D", "distance": 20}

- **Procedure/Program**:

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

typedef struct {
   char start[10];
   char end[10];
   int distance;
} RoadSegment;

int binarySearch(RoadSegment segments[], int left, int right, const char* start, const char* end) {
   if (right >= left) {
      int mid = left + (right - left) / 2;

      if (strcmp(segments[mid].start, start) >= 0 && strcmp(segments[mid].end, end) <= 0) {
         return mid;
      }

      if (strcmp(segments[mid].start, start) < 0) {
         return binarySearch(segments, mid + 1, right, start, end);
      } else {
         return binarySearch(segments, left, mid - 1, start, end);
      }
   }
```

```
    return -1;
}

int main() {
    RoadSegment segments[] = {
        {"A", "B", 10},
        {"B", "C", 15},
        {"C", "D", 20},
        {"D", "E", 5},
        {"E", "F", 8},
        {"F", "G", 12}
    };
    int n = sizeof(segments) / sizeof(segments[0]);
    const char* start = "B";
    const char* end = "D";

    int index = binarySearch(segments, 0, n - 1, start, end);

    if (index != -1) {
        printf("Found road segment: {\"start\": \"%s\", \"end\": \"%s\", \"distance\": %d}\n",
            segments[index].start, segments[index].end, segments[index].distance);
    } else {
        printf("Road segment not found.\n");
    }

    return 0;
```

}

- **Data and Results:**

Data:

Sorted road segments with distances, querying for specific road segments.

Result:

Found road segment from "B" to "D" with distance 20.

- **Analysis and Inferences:**

Analysis:

Binary search efficiently locates road segments in sorted database.

Inferences:

Divide and Conquer speeds up location search in large datasets.

- **Sample VIVA-VOCE Questions (In-Lab):**

1. What are some real-world problems where Divide and Conquer can be applied?

- Sorting (Merge Sort, Quick Sort)
- Searching (Binary Search)
- Matrix Multiplication (Strassen's)
- Closest Pair of Points
- Finding the Median

2. What is the time complexity of Merge Sort, and how is it derived?

- **O(n log n)**: Divides the array in half **log n** times and merges in **O(n)** time.

3. What is the significance of the "combine" step in Divide and Conquer algorithms?

- Merges subproblem solutions to form the final solution (e.g., merging sorted arrays in Merge Sort).

4. Give few applications of Divide and Conquer Algorithm.

- Sorting, Searching, Matrix Multiplication, Closest Pair of Points, Graph Algorithms.

5. How would you use Divide and Conquer to solve the problem of finding the closest pair of points in a 2D plane??

- Sort points, divide them into halves, recursively find closest pairs, then check points near the dividing line to combine results. Time complexity: **O(n log n)**.

Evaluator Remark (if Any):	**Marks Secured ___out of 50**
	Signature of the Evaluator with Date

Evaluator MUST ask Viva-voce prior to signing and posting marks for each experiment.