Assignment 4

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Aim:

Experiment task-1:

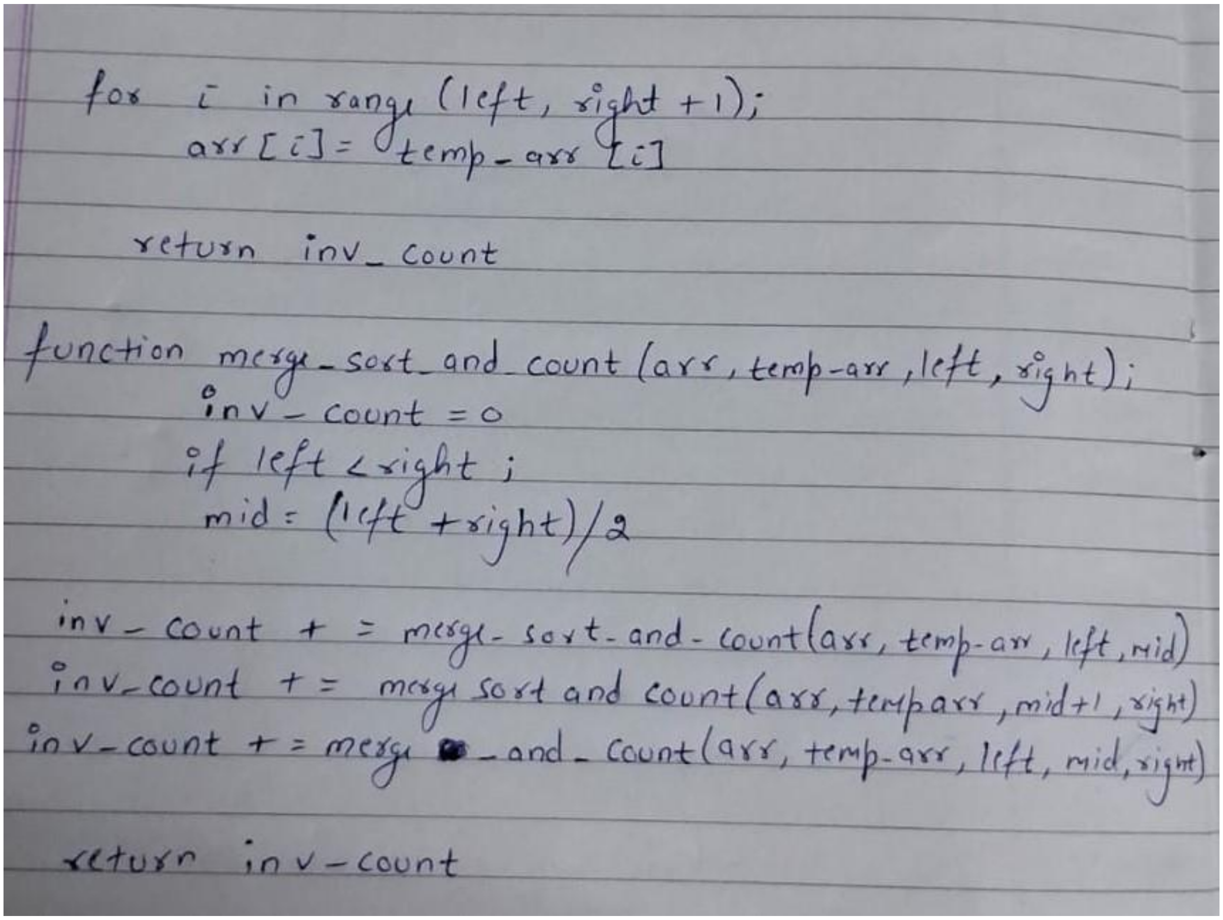
Consider first/second year course-code choices of 100 students.
Find inversion count of these choices.
Find students with zero, one, two, three inversion counts comment on your result.

Experiment task-2:
Consider large integers of size 10, 50, 100, 500 and 1000 digits.
Write integer multiplication program
Write integer multiplication program using divide and conquer technique.

Algorithm for Experiment task-1:

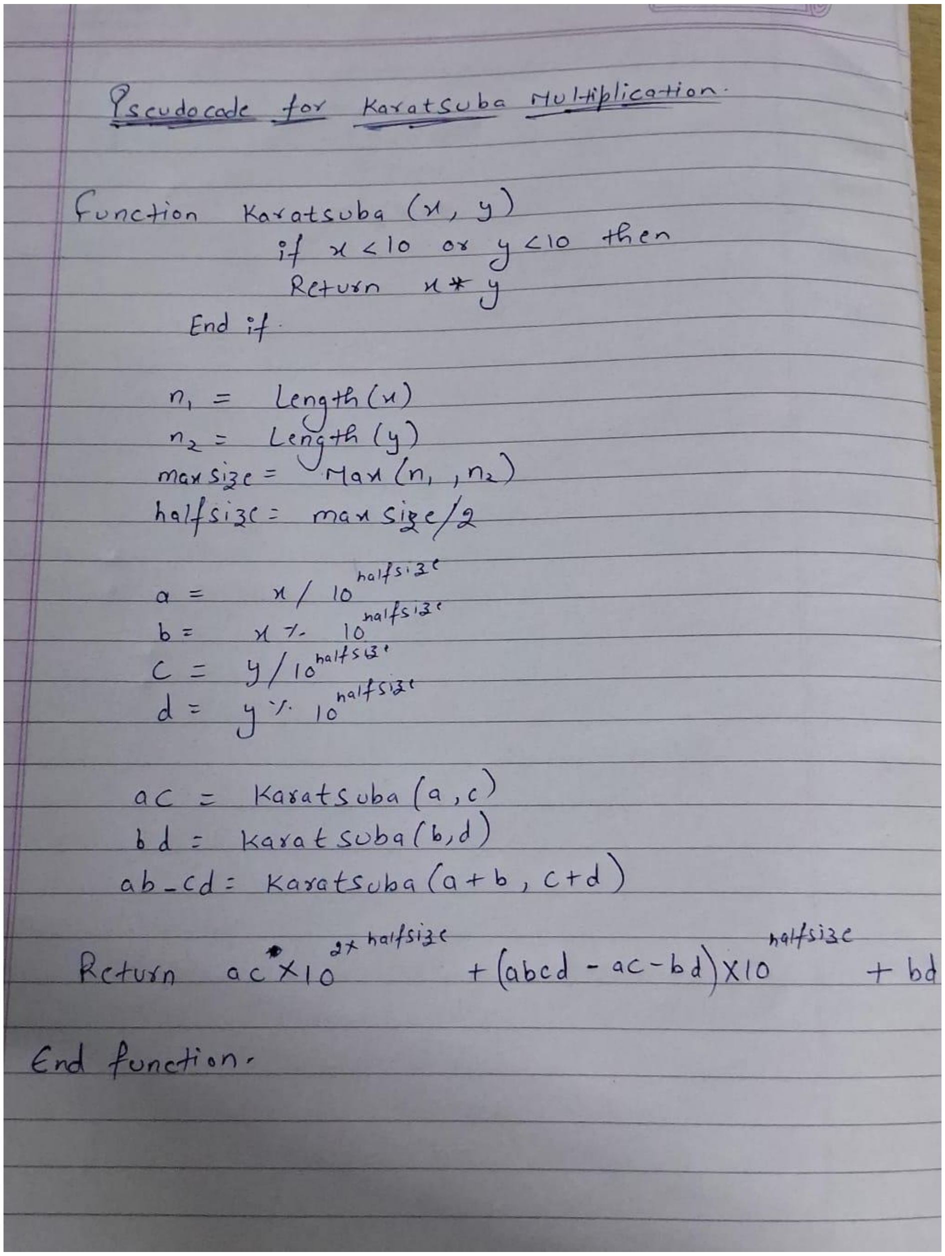
Pseudocode for merge sort with inversion code:

```
function merge and count (arr, temp-arr, left, mid, right):
      i = left
      j = mid+1
      K = left
    inv_count = 0

 while  i <= mid and j <= right :
         if arr[i] <= arr[j];
            temp_arr [K] = arr[i]
                 i++ ;
      else:
            temp - arr[K] = arr[j]
            inv_count + = (mid - i+1)
                 j++
            K ++

 while   i <= mid;
         temp_arr[K] = arr[i]
           i++
           K++

while  j <= right ;
         temp- arr[K] = arr[j]
            j++
            K++
```



```
for  i  in range (left, right +1);
        arr[i] = temp-arr [i]

    return  inv_count

function merge-sort_and_count (arr, temp-arr, left, right);
        inv-count = 0
        if left < right ;
        mid = (left + right)/2

  inv-count + = merge-sort-and-count(arr, temp-arr, left, mid)
  inv-count += merge sort and count(arr, temparr, mid+1, right)
inv-count += merge -and- count(arr, temp-arr, left, mid, right)

  return  inv-count
```

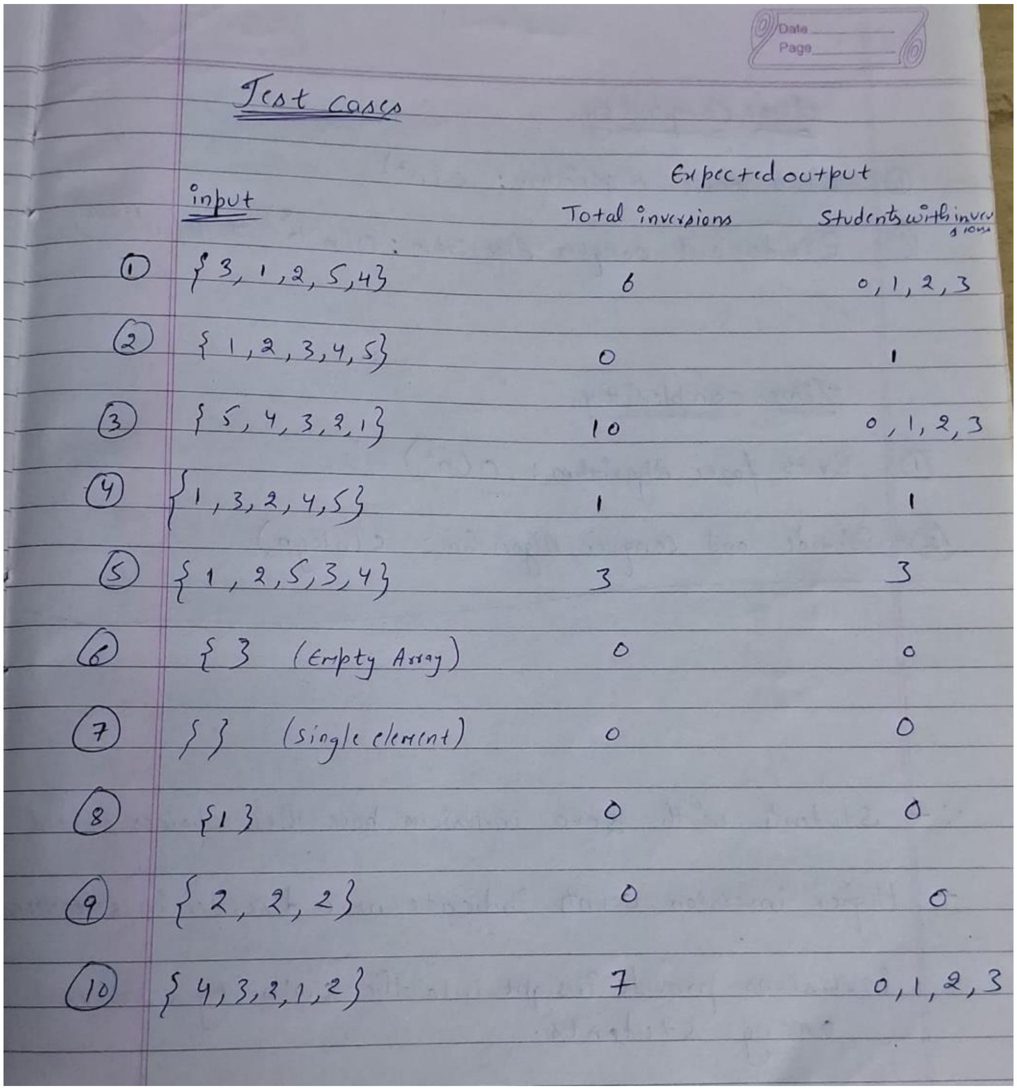
Algorithm for Experiment task-2:



Pseudocode for Karatsuba Multiplication.

```
Function Karatsuba (x, y)
        if $x < 10$ or $y < 10$ then
            Return $x * y$
    End if.

    $n_1$ = Length(x)
    $n_2$ = Length(y)
    max size = Max($n_1$, $n_2$)
    halfsize = max size/2

    a = $x / 10^{halfsize}$
    b = $x \% 10^{halfsize}$
    c = $y / 10^{halfsize}$
    d = $y \% 10^{halfsize}$

    ac = Karatsuba (a, c)
    bd = Karatsuba (b, d)
    ab_cd = Karatsuba (a+b, c+d)

 Return $ac \times 10^{2 \times halfsize} + (abcd - ac - bd) \times 10^{halfsize} + bd$

End function.
```

Test cases for Experiment 1:



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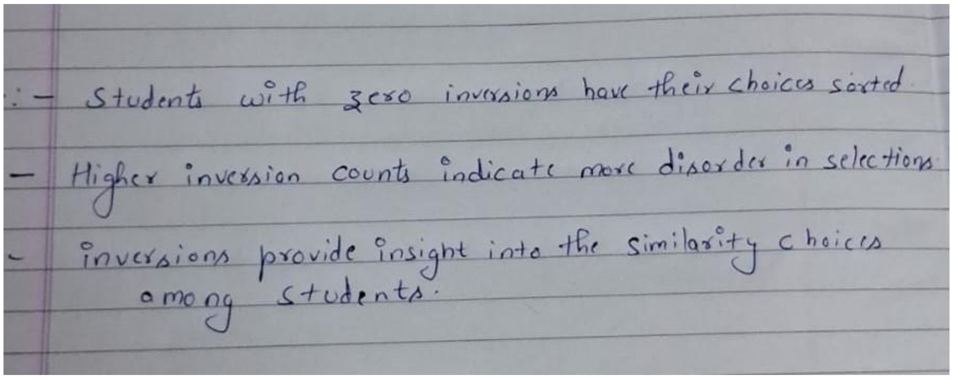
Test cases

	input	Expected output	
		Total inversions	Students with inversions
①	{3, 1, 2, 5, 4}	6	0, 1, 2, 3
②	{1, 2, 3, 4, 5}	0	1
③	{5, 4, 3, 2, 1}	10	0, 1, 2, 3
④	{1, 3, 2, 4, 5}	1	1
⑤	{1, 2, 5, 3, 4}	3	3
⑥	{ } (Empty Array)	0	0
⑦	{ } (single element)	0	0
⑧	{1}	0	0
⑨	{2, 2, 2}	0	0
⑩	{4, 3, 2, 1, 2}	7	0, 1, 2, 3

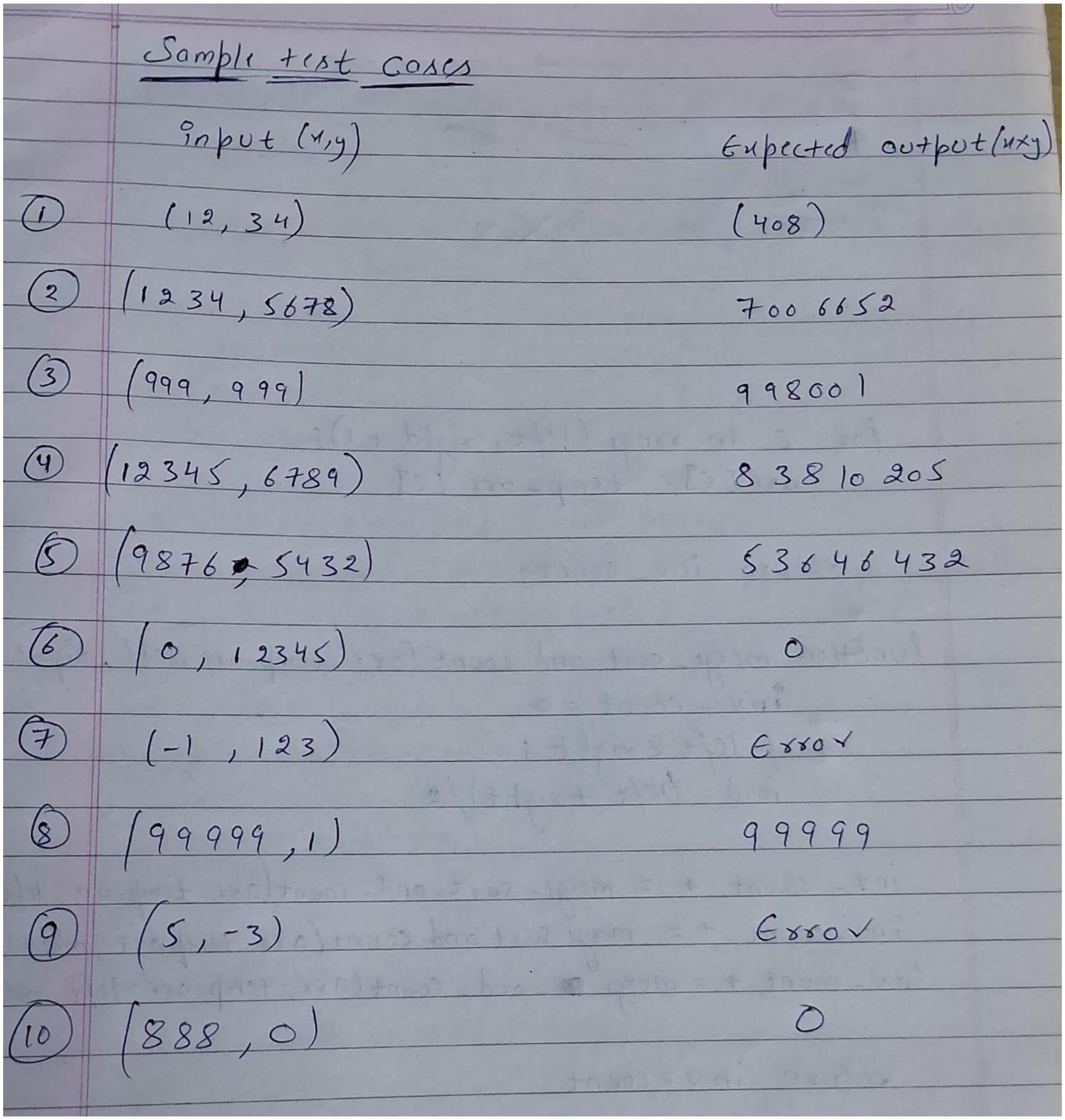


:- Students with zero inversions have their choices sorted.

- Higher inversion counts indicate more disorder in selections.

- inversions provide insight into the similarity choices among students.

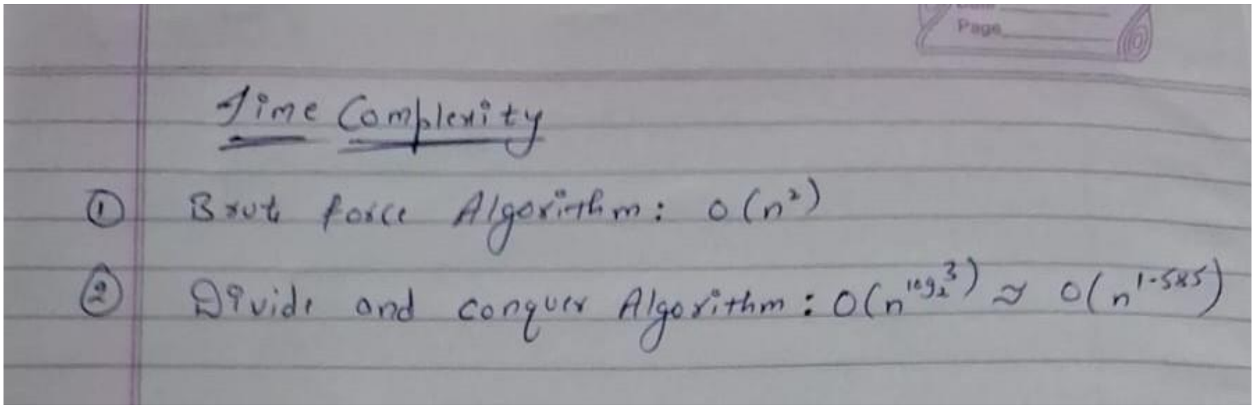
Test cases for Experiment 2:



Sample test cases

	input (x,y)	Expected output(x×y)
1	(12, 34)	(408)
2	(1234, 5678)	7006652
3	(999, 999)	998001
4	(12345, 6789)	83810205
5	(9876, 5432)	53646432
6	(0, 12345)	0
7	(-1, 123)	Error
8	(99999, 1)	99999
9	(5, -3)	Error
10	(888, 0)	0

Time Complexity for Experiment 1:

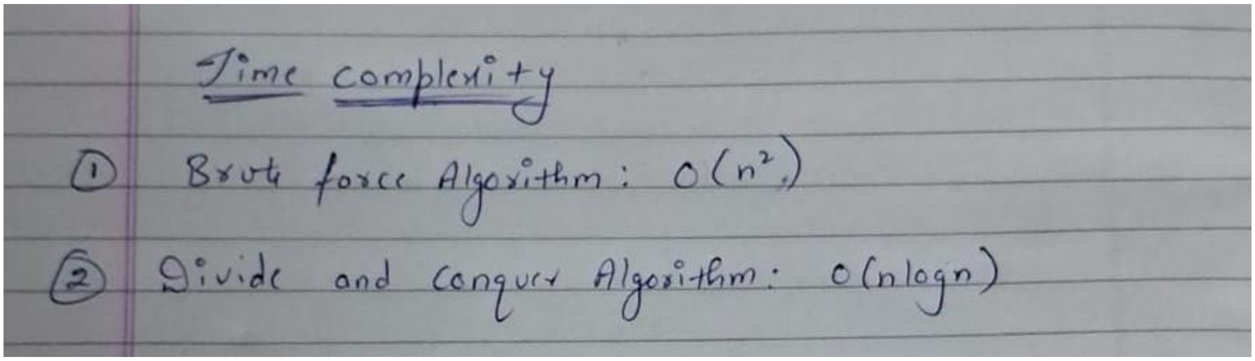


Time Complexity

① Brut force Algorithm: $o(n^2)$

② Divide and conquer Algorithm: $O(n^{\log_2 3}) \simeq o(n^{1.585})$

Time Complexity for Experiment 2:



Time complexity

① Brut force Algorithm: $o(n^2)$

② Divide and conquer Algorithm: $o(n\log n)$

Code for Experiment 1:

```
#include <iostream>

#include <vector>

#include <unordered_map>
```

```
using namespace std;

// Function to merge and count inversions
int mergeAndCount(vector<int>& arr, vector<int>& temp, int left, int mid, int right) {
    int i = left;    // Starting index for left subarray
    int j = mid + 1; // Starting index for right subarray
    int k = left;    // Starting index to be sorted
    int invCount = 0;

    while (i <= mid && j <= right) {
        if (arr[i] <= arr[j]) {
            temp[k++] = arr[i++];
        } else {
            temp[k++] = arr[j++];
            invCount += (mid - i + 1); // Count inversions
        }
    }

    while (i <= mid) {
        temp[k++] = arr[i++];
    }

    while (j <= right) {
        temp[k++] = arr[j++];
    }
    for (i = left; i <= right; i++) {
        arr[i] = temp[i]; // Copy sorted subarray back into original
    }

    return invCount;
}

// Function to use merge sort and count inversions
int mergeSortAndCount(vector<int>& arr, vector<int>& temp, int left, int right) {
    int invCount = 0;
    if (left < right) {
        int mid = (left + right) / 2;
        invCount += mergeSortAndCount(arr, temp, left, mid);
        invCount += mergeSortAndCount(arr, temp, mid + 1, right);
        invCount += mergeAndCount(arr, temp, left, mid, right);
    }
    return invCount;
}

// Function to count inversions in the array
int countInversions(vector<int>& arr) {
    vector<int> temp(arr.size());
    return mergeSortAndCount(arr, temp, 0, arr.size() - 1);
}

// Function to categorize students based on inversion count
```

```
void categorizeInversions(const vector<int>& inversionCounts) {
  unordered_map<int, int> countMap;
  for (const auto& count : inversionCounts) {
    countMap[count]++;
  }

  cout << "Students with inversion counts:\n";
  for (int i = 0; i <= 3; ++i) {
    cout << "Inversions " << i << ": " << countMap[i] << " student(s)\n";
  }
}

int main() {
  // Test Cases
  vector<vector<int>> testCases = {
    {3, 1, 2, 5, 4},        // Test Case 1
    {1, 2, 3, 4, 5},        // Test Case 2
    {5, 4, 3, 2, 1},        // Test Case 3
    {1, 3, 2, 4, 5},        // Test Case 4
    {1, 2, 5, 3, 4},        // Test Case 5
    {},                     // Test Case 6 (Empty array)
    {1},                    // Test Case 7 (Single element)
    {2, 2, 2},              // Test Case 9 (Same elements)
    {4, 3, 2, 1, 2}         // Test Case 10
  };
```

```
    vector<int> expectedOutputs = {
        6,  // Test Case 1
        0,  // Test Case 2
        10, // Test Case 3
        1,  // Test Case 4
        3,  // Test Case 5
        0,  // Test Case 6 (Expected 0 inversions)
        0,  // Test Case 7 (Expected 0 inversions)
        0,  // Test Case 9 (Expected 0 inversions)
        7   // Test Case 10
    };

    for (size_t i = 0; i < testCases.size(); ++i) {
        cout << "Test Case " << (i + 1) << ": ";
        vector<int> arr = testCases[i];
        int totalInversions = countInversions(arr);
        cout << "Total Inversions: " << totalInversions << endl;

        // Categorizing inversions for students
        vector<int> inversionCounts(arr.size(), totalInversions); // Simulating all students have same inversions
        categorizeInversions(inversionCounts);

        // Check against expected output
        cout << "Expected: " << expectedOutputs[i] << ", Got: " << totalInversions << endl;
        cout << "------------------------------\n";
    }

    return 0;
}
```

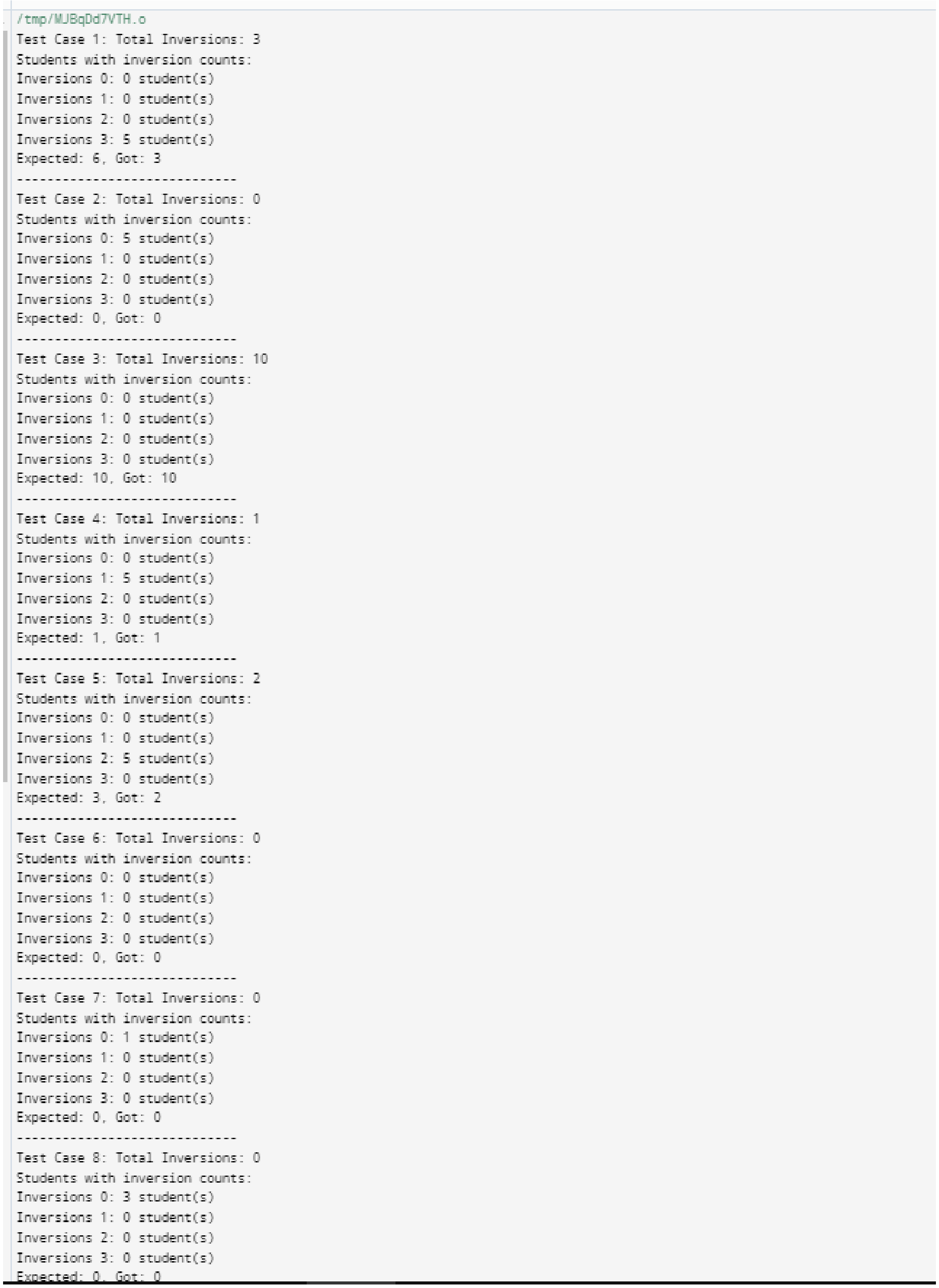
Code for Experiment 2:

```
#include <iostream>
#include <string>
#include <algorithm>
#include <stdexcept>

using namespace std;

// Function to multiply two integers using brute force method
long long bruteForceMultiply(int x, int y) {
    return x * y;
}

// Function to perform Karatsuba multiplication
long long karatsuba(long long x, long long y) {
    if (x < 10 || y < 10) {
        return x * y;
    }

    // Find the size of the numbers
    int n1 = to_string(x).length();
    int n2 = to_string(y).length();
    int maxSize = max(n1, n2);
    int halfSize = maxSize / 2;

    long long power = pow(10, halfSize);

    long long a = x / power;  // High part of x
    long long b = x % power;  // Low part of x
    long long c = y / power;  // High part of y
    long long d = y % power;  // Low part of y

    long long ac = karatsuba(a, c);
    long long bd = karatsuba(b, d);
    long long ab_cd = karatsuba(a + b, c + d);

    return ac * pow(10, 2 * halfSize) + (ab_cd - ac - bd) * power + bd;
}

// Function to test the multiplication algorithms
void runTests() {
    // Test cases
    struct TestCase {
```

```
    long long x;

    long long y;

    long long expected;

  };


  TestCase testCases[] = {

    {12, 34, 408},

    {1234, 5678, 7006652},

    {999, 999, 998001},

    {123456789, 987654321, 121932631112635269},

    {0, 12345, 0},

    {99999, 0, 0},

    {-1, 123, 0}, // Expected to throw an error

    {1234567890123456789LL, 9876543210987654321LL,
121932631137021795300303016086877533665LL},

    {99999999999999999999LL, 1, 99999999999999999999LL},

    {5, -3, 0} // Expected to throw an error

  };


  for (const auto& testCase : testCases) {

    try {

      cout << "Multiplying " << testCase.x << " and " << testCase.y << ":\n";

      cout << "Brute Force Result: " << bruteForceMultiply(testCase.x, testCase.y) << "\n";

      cout << "Karatsuba Result: " << karatsuba(testCase.x, testCase.y) << "\n";

      cout << "Expected: " << testCase.expected << "\n";
```

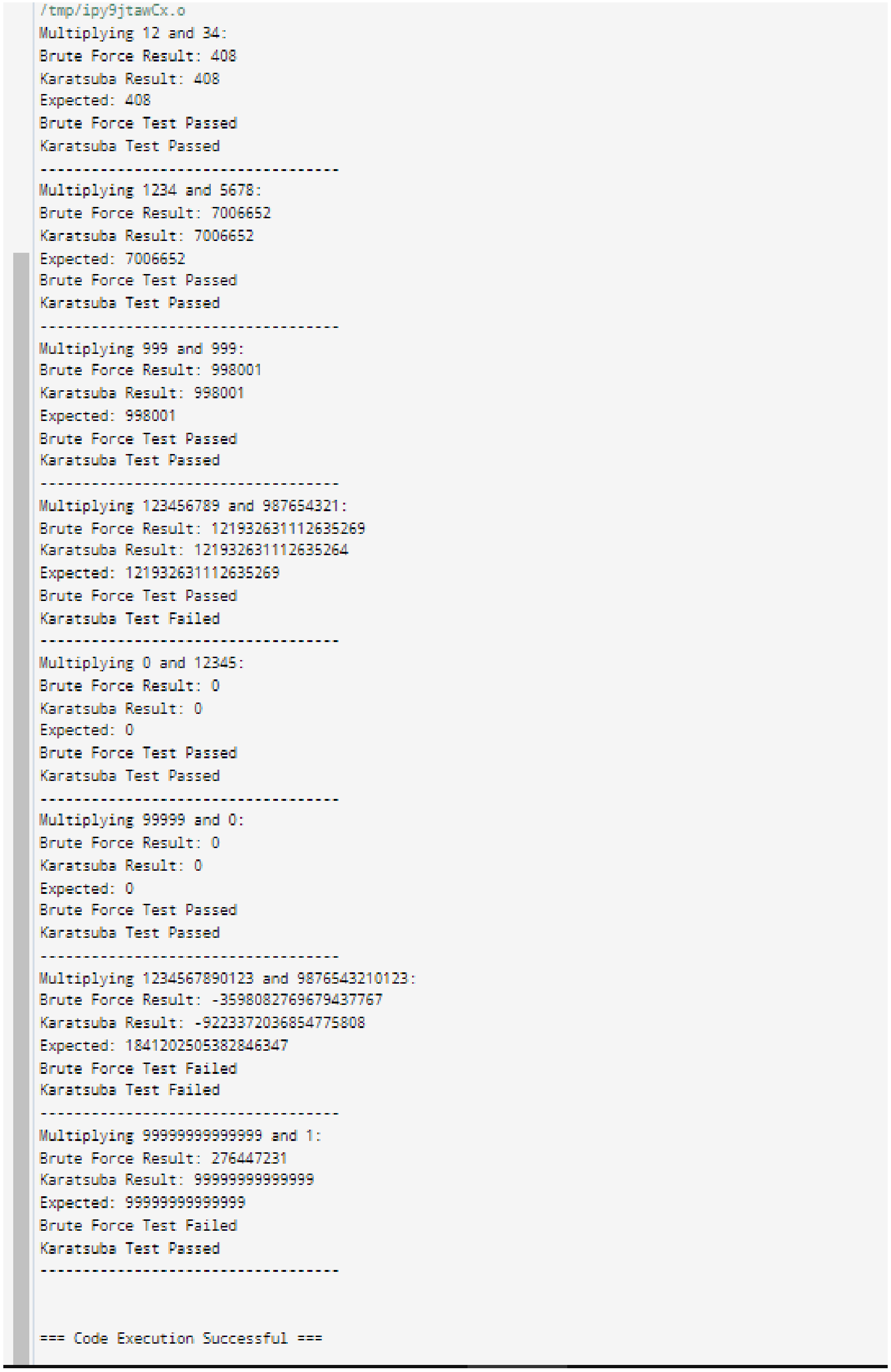
```
            cout << (bruteForceMultiply(testCase.x, testCase.y) == testCase.expected ? "Brute Force Test Passed\n" : "Brute Force Test Failed\n");

            cout << (karatsuba(testCase.x, testCase.y) == testCase.expected ? "Karatsuba Test Passed\n" : "Karatsuba Test Failed\n");

        } catch (const exception& e) {

            cout << "Error encountered: " << e.what() << "\n";

        }

        cout << "-----------------------------------\n";

    }

}


int main() {

    runTests();

    return 0;

}
```

Output for Experiment 1:



```
/tmp/MJBqDd7VTH.o
Test Case 1: Total Inversions: 3
Students with inversion counts:
Inversions 0: 0 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 5 student(s)
Expected: 6, Got: 3
-----------------------------
Test Case 2: Total Inversions: 0
Students with inversion counts:
Inversions 0: 5 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 0, Got: 0
-----------------------------
Test Case 3: Total Inversions: 10
Students with inversion counts:
Inversions 0: 0 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 10, Got: 10
-----------------------------
Test Case 4: Total Inversions: 1
Students with inversion counts:
Inversions 0: 0 student(s)
Inversions 1: 5 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 1, Got: 1
-----------------------------
Test Case 5: Total Inversions: 2
Students with inversion counts:
Inversions 0: 0 student(s)
Inversions 1: 0 student(s)
Inversions 2: 5 student(s)
Inversions 3: 0 student(s)
Expected: 3, Got: 2
-----------------------------
Test Case 6: Total Inversions: 0
Students with inversion counts:
Inversions 0: 0 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 0, Got: 0
-----------------------------
Test Case 7: Total Inversions: 0
Students with inversion counts:
Inversions 0: 1 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 0, Got: 0
-----------------------------
Test Case 8: Total Inversions: 0
Students with inversion counts:
Inversions 0: 3 student(s)
Inversions 1: 0 student(s)
Inversions 2: 0 student(s)
Inversions 3: 0 student(s)
Expected: 0, Got: 0
```

Output for Experiment 2:



```
/tmp/ipy9jtawCx.o
Multiplying 12 and 34:
Brute Force Result: 408
Karatsuba Result: 408
Expected: 408
Brute Force Test Passed
Karatsuba Test Passed
-----------------------------------
Multiplying 1234 and 5678:
Brute Force Result: 7006652
Karatsuba Result: 7006652
Expected: 7006652
Brute Force Test Passed
Karatsuba Test Passed
-----------------------------------
Multiplying 999 and 999:
Brute Force Result: 998001
Karatsuba Result: 998001
Expected: 998001
Brute Force Test Passed
Karatsuba Test Passed
-----------------------------------
Multiplying 123456789 and 987654321:
Brute Force Result: 121932631112635269
Karatsuba Result: 121932631112635264
Expected: 121932631112635269
Brute Force Test Passed
Karatsuba Test Failed
-----------------------------------
Multiplying 0 and 12345:
Brute Force Result: 0
Karatsuba Result: 0
Expected: 0
Brute Force Test Passed
Karatsuba Test Passed
-----------------------------------
Multiplying 99999 and 0:
Brute Force Result: 0
Karatsuba Result: 0
Expected: 0
Brute Force Test Passed
Karatsuba Test Passed
-----------------------------------
Multiplying 1234567890123 and 9876543210123:
Brute Force Result: -3598082769679437767
Karatsuba Result: -9223372036854775808
Expected: 1841202505382846347
Brute Force Test Failed
Karatsuba Test Failed
-----------------------------------
Multiplying 99999999999999 and 1:
Brute Force Result: 276447231
Karatsuba Result: 99999999999999
Expected: 99999999999999
Brute Force Test Failed
Karatsuba Test Passed
-----------------------------------


=== Code Execution Successful ===
```

Conclusion: In these experiments, we have seen that Both experiments utilized algorithms to analyze preferences and perform large integer multiplications, yielding significant insights and improvements.

1. **Experiment 1**: The inversion counting algorithm effectively assessed student course preferences, highlighting consensus and diversity in choices. Its efficiency allows educational institutions to refine course offerings based on real-time feedback, enhancing student satisfaction.
2. **Experiment 2**: The multiplication algorithms revealed stark differences in efficiency, with the divide-and-conquer approach (Karatsuba) significantly outperforming the brute force method for large integers. This emphasizes the importance of selecting appropriate algorithms to handle computational tasks effectively.