Cryptography & Network Security Lab

Assignments

Name- Aniket Tatoba Mane

PRN-2020BTECS00020

Batch – B7

ASSIGNMENT NO: 1

Title: Encryption and Decryption using Caesar cipher.

Aim: To Study and Implement Encryption and Decryption using Caesar cipher Technique.

Caesar Cipher:

Caesar Cipher, also known as the Shift Cipher, is one of the simplest and oldest encryption techniques used to secure information.

It is a type of substitution cipher where each letter in the plaintext is shifted a certain number of places down or up the alphabet.

The number of positions a letter is shifted is determined by a key.

Encryption:

In Encryption, input is a Plain text and output is a Cipher text.

Step 1: Choose a secret key (a positive integer).

Step 2: Take the plaintext message you want to encrypt.

Step 3: Shift each letter in the message forward in the alphabet by the key positions.

Step 4: Non-alphabetical characters remain unchanged.

Step 5: The result is the ciphertext, the encrypted message.

Decryption:

In Decryption, input is a Cipher text and output is a Plain text.

Step 1: Have the same key used for encryption.

Step 2: Take the ciphertext (the encrypted message).

Step 3: Shift each letter in the ciphertext backward in the alphabet by the key positions.

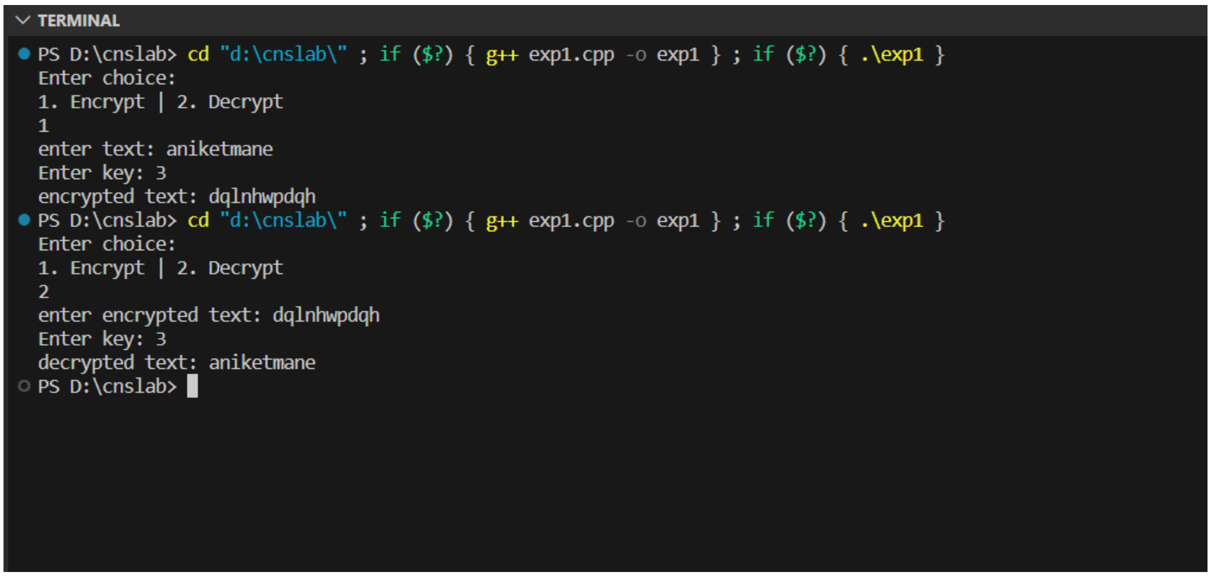
Step 4: Non-alphabetical characters remain unchanged.

Step 5: The result is the plaintext, the original message.

Code:

```cpp
#include <bits/stdc++.h>
using namespace std;
char shift_char(char c, int shift, char op)
{
    if (isalpha(c) && op == 'e')
    {
        char base = islower(c) ? 'a' : 'A';
        return char((c - base + shift) % 26 + base);
    }
    else if (isalpha(c) && op == 'd')
    {
        char base = islower(c) ? 'a' : 'A';
        return char((c - base - shift + 26) % 26 + base);
    }
    return c;
}
string encrypt_text(string text, int key)
{
    string encrypted = "";
    for (char c : text)
    {
        encrypted += shift_char(c, key, 'e');
    }
    return encrypted;
}
string decrypt_text(string text, int key)
{
    string decrypted = "";
    for (char c : text)
    {
        decrypted += shift_char(c, key, 'd');
    }
    return decrypted;
}
int main(int argc, char const *argv[])
{
    int choice, key;
    string text;
    cout << "Enter choice: ";
    cout << endl
         << "1. Encrypt | 2. Decrypt" << endl;
    cin >> choice;
    cin.get();
    if (choice == 1)
    {
        cout << "enter text: ";
        getline(cin, text);
        cout << "Enter key: ";
        cin >> key;
        string result = encrypt_text(text, key);
        cout << "encrypted text: " << result << endl;
    }
    else if (choice == 2)
    {
        cout << "enter encrypted text: ";
        getline(cin, text);
        cout << "Enter key: ";
        cin >> key;
        string result = decrypt_text(text, key);
        cout << "decrypted text: " << result << endl;
    }
    else
    {
        cout << "not a valid choice!" << endl;
    }
    return 0;
}
```

Output:



```
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ exp1.cpp -o exp1 } ; if ($?) { .\exp1 }
Enter choice:
1. Encrypt | 2. Decrypt
1
enter text: aniketmane
Enter key: 3
encrypted text: dqlnhwpdqh
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ exp1.cpp -o exp1 } ; if ($?) { .\exp1 }
Enter choice:
1. Encrypt | 2. Decrypt
2
enter encrypted text: dqlnhwpdqh
Enter key: 3
decrypted text: aniketmane
PS D:\cnslab>
```

ASSIGNMENT NO: 2

Title: Encryption and Decryption using Transposition cipher.

Aim: To Study and Implement Encryption and Decryption using Transposition cipher technique.

Transposition Cipher:

1. Railfence Transposition

The Rail Fence Transposition Cipher, also known as the Zigzag Cipher, is a simple columnar transposition cipher technique.

It involves arranging the plaintext characters in a zigzag pattern across multiple rows, known as "rails," and then reading them off row by row to create the encrypted message.

While this cipher is easy to understand and implement, it lacks strong security and is mainly used for educational purposes or simple puzzles.

Encryption:

- Choose the number of rails (rows) for the zigzag pattern.

- Write the message diagonally across the rails, moving up and down.

- Read the characters row by row to form the encrypted message.

Decryption:

- Create the zigzag pattern with the chosen number of rails.

- Leave blank spaces in the pattern for characters to be placed.

- Fill in the blanks with the encrypted characters, row by row.

- Read the characters diagonally to retrieve the original message.

Advantages:

- Easy to understand and implement.

- Provides basic encryption and breaks up character repetition.

Disadvantages:

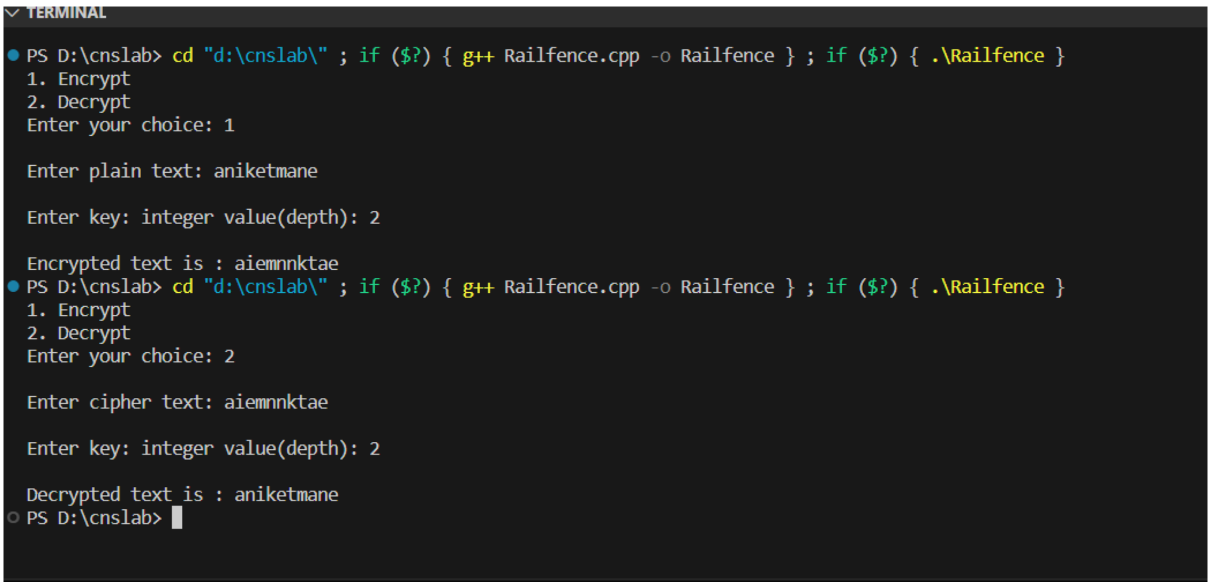
- Not secure against modern cryptanalysis.

- Security depends on the number of rails, making it less practical for strong encryption.

Code:

```
#include <bits/stdc++.h>
using namespace std;
string format(string &str)
{
    for (char c : str)
    {
        if (isalpha(c))
        {
            c += tolower(c);
        }
    }
    return str;
}
string encrypt(string &plain, int key)
{
    vector<vector<char>> matrix(key);
    int rowNumber = 0;
    int flag = 1;
    for (int i = 0; i < plain.size(); i++)
    {
        matrix[rowNumber].push_back(plain[i]);
        rowNumber += flag;
        if (rowNumber == 0)
            flag = 1;
        if (rowNumber == key - 1)
            flag = -1;
    }
    string cipher;
    for (int i = 0; i < key; i++)
    {
        for (int j = 0; j < matrix[i].size(); j++)
            cipher += matrix[i][j];
    }
    return cipher;
}
string decrypt(string &cipher, int key)
{
    vector<vector<int>> matrixDecry(key);
    int rowNumber = 0;
    int flag = 1;
    int n = cipher.length();
    for (int i = 0; i < n; i++)
    {
        matrixDecry[rowNumber].push_back(i);
        rowNumber += flag;
        if (rowNumber == (key - 1))
            flag = -1;
        if (rowNumber == 0)
            flag = 1;
    }
    vector<int> mapping;
    for (int i = 0; i < key; i++)
    {
        for (int j = 0; j < matrixDecry[i].size(); j++)
            mapping.push_back(matrixDecry[i][j]);
    }
    map<int, char> m;
    for (int i = 0; i < n; i++)
        m[mapping[i]] = cipher[i];
    string plain;
    for (int i = 0; i < n; i++)
        plain += m[i];
    return plain;
}
int main()
{
    int choice;
    cout << "1. Encrypt\n2. Decrypt\nEnter your choice: ";
    cin >> choice;
    cin.get();
    if (choice == 1)
    {
        string plain;
        int key;
        cout << "\nEnter plain text: ";
        getline(cin, plain);
        plain = format(plain);
        cout << "\nEnter key: integer value(depth): ";
        cin >> key;
        string cipher = encrypt(plain, key);
        cout << "\nEncrypted text is : " << cipher << endl;
    }
    else if (choice == 2)
    {
        string cipher;
        int key;
        cout << "\nEnter cipher text: ";
        getline(cin, cipher);
        cipher = format(cipher);
        cout << "\nEnter key: integer value(depth): ";
        cin >> key;
        string plain = decrypt(cipher, key);
        cout << "\nDecrypted text is : " << plain << endl;
    }
    return 0;
}
```

Output:



```
TERMINAL

PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ Railfence.cpp -o Railfence } ; if ($?) { .\Railfence }
1. Encrypt
2. Decrypt
Enter your choice: 1

Enter plain text: aniketmane

Enter key: integer value(depth): 2

Encrypted text is : aiemnnktae
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ Railfence.cpp -o Railfence } ; if ($?) { .\Railfence }
1. Encrypt
2. Decrypt
Enter your choice: 2

Enter cipher text: aiemnnktae

Enter key: integer value(depth): 2

Decrypted text is : aniketmane
PS D:\cnslab>
```

2. Row/Columnar Transposition

The Columnar Transposition Cipher is a more advanced transposition cipher technique that involves reordering the characters of a message based on a chosen keyword or key phrase.

It provides a higher level of security compared to simpler ciphers like the Rail Fence Cipher. Here is how the Columnar Transposition Cipher works:

Encryption:

- Choose a keyword or key phrase. The unique characters of the keyword determine the order of columns in the transposition grid.
- Write the message row by row into a grid, using the keyword to determine the order of columns.
- Read the characters column by column to obtain the encrypted message.

Decryption:

- Use the keyword to determine the order of columns in the transposition grid.
- Write the encrypted message into the grid column by column.
- Read the characters row by row to retrieve the original plaintext.

Advantages:

- Offers stronger security compared to simpler ciphers.
- Security depends on the length and uniqueness of the keyword.

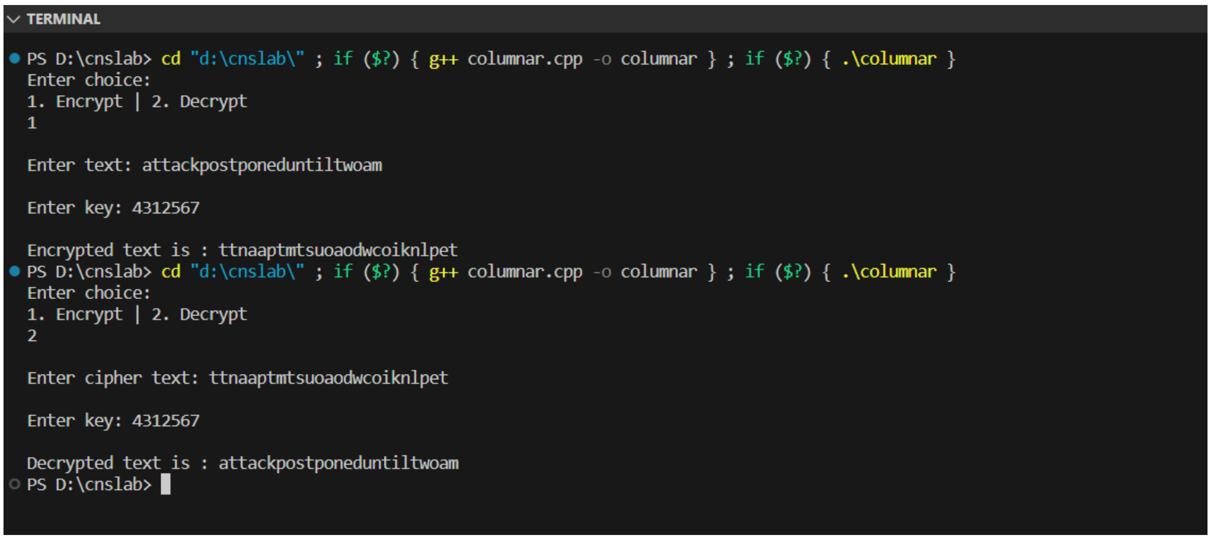
Disadvantages:

- Can be vulnerable to attacks if the keyword is short or easily guessed.
- May require additional padding characters for messages that don't fit evenly into the grid.

Code:

```cpp
#include <bits/stdc++.h>
using namespace std;
string alpha_lower(string text)
{
    for (char c : text)
    {
        if (isalnum(c))
        {
            c = tolower(c);
        }
    }
    return text;
}
string encrypt(string text, string key)
{
    map<char, vector<char>> mp;
    int cnt = 0;
    for (int i = 0; i < text.size(); i++)
    {
        if (cnt == key.size())
            cnt = 0;
        mp[key[cnt++]].push_back(text[i]);
    }
    string encrypted;
    for (auto i : mp)
    {
        for (auto j : i.second)
        {
            encrypted += j;
        }
    }
    return encrypted;
}
string decrypt(string cipher, string key)
{
    map<int, int> map1;
    int common = cipher.size() / key.size();
    int extra = cipher.size() % key.size();
    for (int i = 0; i < key.size(); i++)
    {
        if (i < extra)
            map1[i] = common + 1;
        else
            map1[i] = common;
    }
    map<int, vector<char>> map2;
    int start = 0;
    string sortedKey = key;
    sort(sortedKey.begin(), sortedKey.end());
    for (int i = 0; i < sortedKey.size(); i++)
    {
        for (int j = 0; j < key.size(); j++)
        {
            if (sortedKey[i] == key[j])
            {
                for (int k = 0; k < map1[j]; k++)
                {
                    map2[key[j]].push_back(cipher[start++]);
                }
            }
        }
    }
    string plain;
    vector<int> counters(key.size(), 0);
    while (plain.size() < cipher.size())
    {
        for (int i = 0; i < key.size(); i++)
        {
            if (counters[i] < map1[i])
                plain += map2[key[i]][counters[i]++];
        }
    }
    return plain;
}
int main()
{
    int choice;
    cout << "Enter choice: ";
    cout << endl
         << "1. Encrypt | 2. Decrypt" << endl;
    cin >> choice;
    cin.get();
    if (choice == 1)
    {
        string text, key;
        cout << "\nEnter text: ";
        getline(cin, text);
        text = alpha_lower(text);
        cout << "\nEnter key: ";
        getline(cin, key);
        alpha_lower(key);
        string cipher = encrypt(text, key);
        cout << "\nEncrypted text is : " << cipher << endl;
    }
    else if (choice == 2)
    {
        string cipher, key;
        cout << "\nEnter cipher text: ";
        getline(cin, cipher);
        cipher = alpha_lower(cipher);
        cout << "\nEnter key: ";
        getline(cin, key);
        alpha_lower(key);
        string text = decrypt(cipher, key);
        cout << "\nDecrypted text is : " << text << endl;
    }
    return 0;
}
```

Output:



```
TERMINAL
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ columnar.cpp -o columnar } ; if ($?) { .\columnar }
Enter choice:
1. Encrypt | 2. Decrypt
1

Enter text: attackpostponeduntiltwoam

Enter key: 4312567

Encrypted text is : ttnaaptmtsuoaodwcoiknlpet
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ columnar.cpp -o columnar } ; if ($?) { .\columnar }
Enter choice:
1. Encrypt | 2. Decrypt
2

Enter cipher text: ttnaaptmtsuoaodwcoiknlpet

Enter key: 4312567

Decrypted text is : attackpostponeduntiltwoam
PS D:\cnslab>
```

Conclusion: Studied and implemented encryption and decryption of Transposition cipher.

ASSIGNMENT NO: 3

Title: Encryption and Decryption using Playfair cipher.

Aim: To Study and Implement Encryption and Decryption using Playfair cipher technique.

Playfair Cipher:

The Playfair Cipher Technique is a substitution cipher that encrypts pairs of characters (digraphs) from the plaintext using a 5x5 key square matrix.

The matrix is constructed from a keyword, with duplicate letters removed and the

keyword letters placed at the beginning.

Encryption involves applying rules based on the positions of the letters within the

key square.

If the letters are in the same row, column, or form a rectangle, they are replaced by specific neighbouring letters.

Encryption:

Divide the plaintext into digraphs.

Apply rules based on the positions of letters in the key square to replace each digraph.

Decryption:

Divide the ciphertext into digraphs.

Apply the rules in reverse to each digraph to retrieve the original plaintext.

Advantages:

Enhanced security due to digraphs and key square usage.

Reduces susceptibility to frequency analysis.

Key square generation is straightforward using a keyword.

Disadvantages:

Complexity increases with handling various cases (same row, column, rectangle).

Security depends on the keyword and arrangement of the key square.

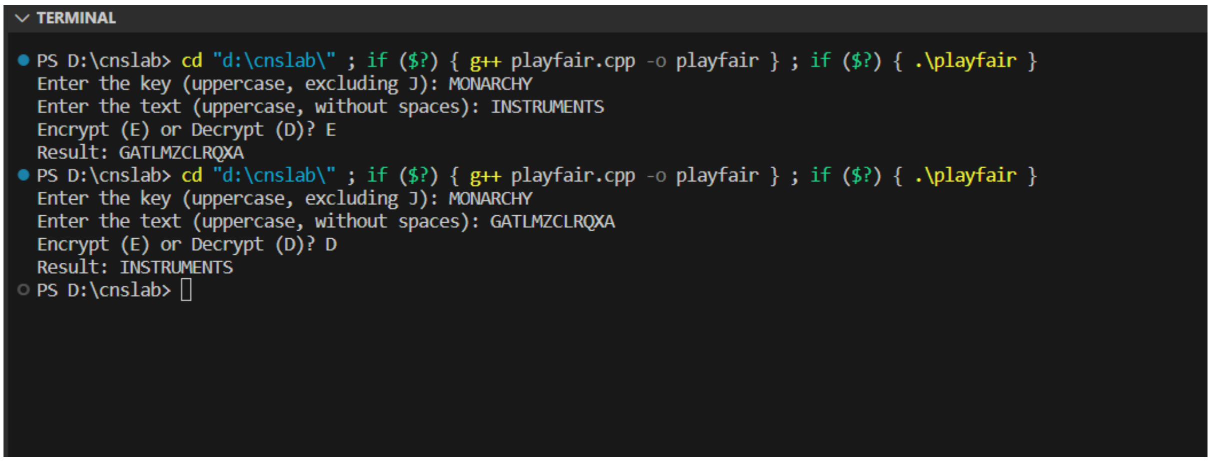
Code:

```cpp
#include <iostream>
#include <string>
using namespace std;
const int SIZE = 5;
void generateMatrix(string key, char matrix[SIZE][SIZE])
{
    string keyWithoutDuplicates = "";
    bool used[26] = {false};
    for (char c : key)
    {
        if (c != 'J' && !used[c - 'A'])
        {
            keyWithoutDuplicates += c;
            used[c - 'A'] = true;
        }
    }
    int index = 0;
    for (int i = 0; i < SIZE; i++)
    {
        for (int j = 0; j < SIZE; j++)
        {
            if (index < keyWithoutDuplicates.length())
            {
                matrix[i][j] = keyWithoutDuplicates[index++];
            }
            else
            {
                for (char c = 'A'; c <= 'Z'; c++)
                {
                    if (c != 'J' && !used[c - 'A'])
                    {
                        matrix[i][j] = c;
                        used[c - 'A'] = true;
                        break;
                    }
                }
            }
        }
    }
```

```
}
void findPosition(char matrix[SIZE][SIZE], char c, int &row, int &col)
{
    if (c == 'J')
        c = 'I';
    for (int i = 0; i < SIZE; i++)
    {
        for (int j = 0; j < SIZE; j++)
        {
            if (matrix[i][j] == c)
            {
                row = i;
                col = j;
                return;
            }
        }
    }
}
string encryptDigraph(char matrix[SIZE][SIZE], char a, char b)
{
    int rowA, colA, rowB, colB;
    findPosition(matrix, a, rowA, colA);
    findPosition(matrix, b, rowB, colB);
    if (rowA == rowB)
    {
        return string(1, matrix[rowA][(colA + 1) % SIZE]) + string(1,
                                                                   matrix[rowB
][(colB + 1) % SIZE]);
    }
    if (colA == colB)
    {
        return string(1, matrix[(rowA + 1) % SIZE][colA]) + string(1,
                                                                   matrix[(row
B + 1) % SIZE][colB]);
    }
    return string(1, matrix[rowA][colB]) + string(1, matrix[rowB][colA]);
}
string decryptDigraph(char matrix[SIZE][SIZE], char a, char b)
{
    int rowA, colA, rowB, colB;
    findPosition(matrix, a, rowA, colA);
    findPosition(matrix, b, rowB, colB);
    if (rowA == rowB)
    {
        return string(1, matrix[rowA][(colA - 1 + SIZE) % SIZE]) + string(1,
                                                                          matr
ix[rowB][(colB - 1 + SIZE) % SIZE]);
    }
```

```cpp
    if (colA == colB)
    {
        return string(1, matrix[(rowA - 1 + SIZE) % SIZE][colA]) + string(1,
                                                                          matr
ix[(rowB - 1 + SIZE) % SIZE][colB]);
    }
    return string(1, matrix[rowA][colB]) + string(1, matrix[rowB][colA]);
}
int main()
{
    string key, text;
    char matrix[SIZE][SIZE];
    cout << "Enter the key (uppercase, excluding J): ";
    cin >> key;
    generateMatrix(key, matrix);
    cout << "Enter the text (uppercase, without spaces): ";
    cin >> text;
    string result;
    char choice;
    cout << "Encrypt (E) or Decrypt (D)? ";
    cin >> choice;
    if (choice == 'E' || choice == 'e')
    {
        string preparedText = "";
        for (int i = 0; i < text.length(); i += 2)
        {
            if (i + 1 < text.length())
            {
                if (text[i] == text[i + 1])
                {
                    preparedText += text[i];
                    preparedText += 'X';
                    i--;
                }
                else
                {
                    preparedText += text.substr(i, 2);
                }
            }
            else
            {
                preparedText += text[i];
                preparedText += 'X';
            }
        }
        for (int i = 0; i < preparedText.length(); i += 2)
        {
            char a = preparedText[i];
            char b = preparedText[i + 1];
            result += encryptDigraph(matrix, a, b);
        }
    }
    else if (choice == 'D' || choice == 'd')
    {
        for (int i = 0; i < text.length(); i += 2)
        {
            char a = text[i];
            char b = text[i + 1];
            result += decryptDigraph(matrix, a, b);
        }
        string cleanedText = "";
        for (int i = 0; i < result.length(); i++)
        {
            if (result[i] != 'X')
            {
                cleanedText += result[i];
            }
        }
        result = cleanedText;
    }
    else
    {
        cout << "Invalid choice. Please enter 'E' for Encrypt or 'D' for
Decrypt" << endl;
        return 1;
    }
    cout << "Result: " << result << endl;
    return 0;
}
```

Output:



```
TERMINAL
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ playfair.cpp -o playfair } ; if ($?) { .\playfair }
Enter the key (uppercase, excluding J): MONARCHY
Enter the text (uppercase, without spaces): INSTRUMENTS
Encrypt (E) or Decrypt (D)? E
Result: GATLMZCLRQXA
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ playfair.cpp -o playfair } ; if ($?) { .\playfair }
Enter the key (uppercase, excluding J): MONARCHY
Enter the text (uppercase, without spaces): GATLMZCLRQXA
Encrypt (E) or Decrypt (D)? D
Result: INSTRUMENTS
PS D:\cnslab>
```

Conclusion: Studied and implemented encryption and decryption of Playfair cipher.

ASIGNMENT NO: 4

Title: Encryption and Decryption using Vigenere cipher.

Aim: To Study and Implement Encryption and Decryption using Vigenere cipher technique.

Vigenere Cipher:

The Vigenere Cipher Technique is a polyalphabetic substitution cipher that adds an extra layer of complexity to encryption by using a keyword or key phrase to determine the shifts applied to the plaintext letters.

Unlike monoalphabetic ciphers, where each letter is replaced with a fixed substitution, the Vigenere Cipher employs multiple alphabets with different shifts, making it more secure against frequency analysis.

Key Setup:

Choose a keyword or key phrase.

Replicate the keyword to match the length of the plaintext, repeating it as needed.

Convert the keyword letters to their corresponding numerical values (A=0, B=1, ..., Z=25).

Encryption:

Divide the plaintext into individual letters and convert them to numerical values.

For each letter, determine the shift value using the corresponding keyword letter.

Shift the plaintext letter by the calculated shift value (mod 26).

Convert the shifted numerical value back to a letter to create the ciphertext.

Decryption:

Divide the ciphertext into individual letters and convert them to numerical values.

For each letter, determine the shift value using the corresponding keyword letter.

Reverse the shift (subtract the shift value, mod 26).

Convert the shifted numerical value back to a letter to retrieve the original

plaintext.

Advantages:

Stronger security due to polyalphabetic nature and keyword-driven shifts.

Reduces susceptibility to frequency analysis.

Key space increases with keyword length, enhancing security.

Disadvantages:

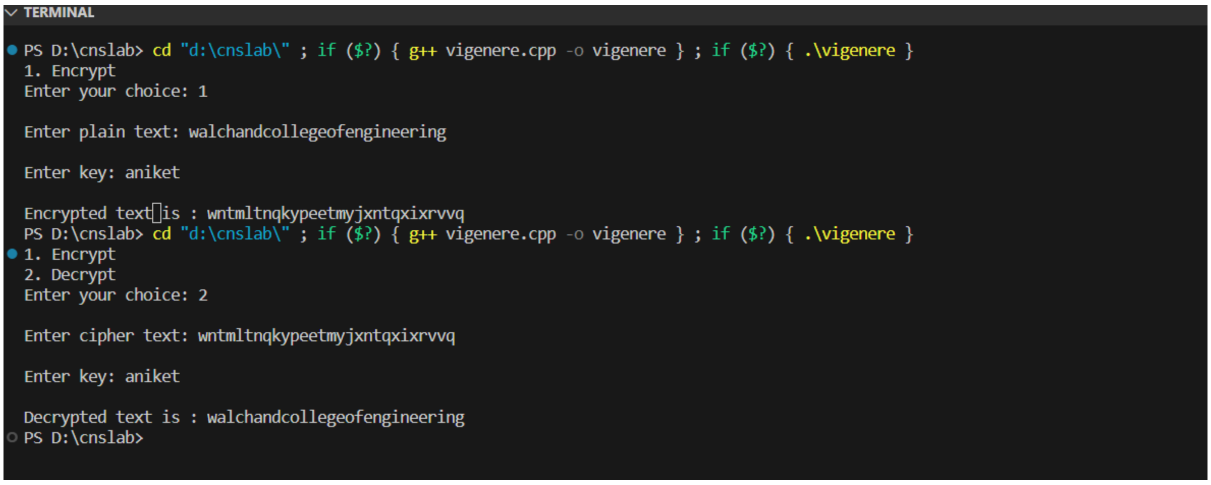
Vulnerable to key length repetition for shorter keywords.

Security can weaken if the keyword is short or predictable.

Code:

```
#include <bits/stdc++.h>
using namespace std;
string alpah_lower(string str)
{
    for (char c : str)
    {
        if (isalpha(c))
        {
            c += tolower(c);
        }
    }
    return str;
}
string encrypt(string text, string key)
{
    string cipher;
    for (int i = 0; i < text.size(); i++)
    {
        int val = text[i] - 'a' + key[i % (key.size())] - 'a';
        cipher += ('a' + (val % 26));
    }
    return cipher;
}
string decrypt(string cipher, string key)
{
    string text;
    for (int i = 0; i < cipher.size(); i++)
    {
        int val = cipher[i] - 'a' - (key[i % (key.size())] - 'a');
        text += ('a' + (val + 26) % 26);
    }
    return text;
}
int main()
{
    int choice;
    cout << "1. Encrypt\n2. Decrypt\nEnter your choice: ";
    cin >> choice;
    cin.get();
    if (choice == 1)
    {
        string plain, key;
        cout << "\nEnter plain text: ";
        getline(cin, plain);
        plain = alpah_lower(plain);
        cout << "\nEnter key: ";
        getline(cin, key);
        string cipher = encrypt(plain, key);
        cout << "\nEncrypted text is : " << cipher << endl;
    }
    else if (choice == 2)
    {
        string cipher, key;
        cout << "\nEnter cipher text: ";
        getline(cin, cipher);
        cipher = alpah_lower(cipher);
        cout << "\nEnter key: ";
        getline(cin, key);
        string plain = decrypt(cipher, key);
        cout << "\nDecrypted text is : " << plain << endl;
    }
    return 0;
}
```

Output:



```
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ vigenere.cpp -o vigenere } ; if ($?) { .\vigenere }
1. Encrypt
Enter your choice: 1

Enter plain text: walchandcollegeofengineering

Enter key: aniket

Encrypted text is : wntmltnqkypeetmyjxntqxixrvvq
PS D:\cnslab> cd "d:\cnslab\" ; if ($?) { g++ vigenere.cpp -o vigenere } ; if ($?) { .\vigenere }
1. Encrypt
2. Decrypt
Enter your choice: 2

Enter cipher text: wntmltnqkypeetmyjxntqxixrvvq

Enter key: aniket

Decrypted text is : walchandcollegeofengineering
PS D:\cnslab>
```

Conclusion: Studied and implemented encryption and decryption of Vigenere cipher.

DES Algorithm:

The Data Encryption Standard (DES) is a symmetric-key block cipher algorithm that was widely used for secure data encryption before being replaced by more secure algorithms like AES (Advanced Encryption Standard). Here are the steps involved in the DES algorithm:

1. Key Generation:

• Start with a 64-bit encryption key. However, only 56 bits of this key are used directly; the remaining 8 bits are used for error detection and do not affect the encryption process.

• Perform a key permutation, called the "Initial Permutation (IP)", to create two 28-bit subkeys, one for each half of the data.

2. Data Preparation:

• The plaintext message is divided into 64-bit blocks.

• An initial permutation, similar to the one used for the key, is applied to the 64-bit plaintext block.

3. Initial Round:

• The 64-bit plaintext block is divided into two 32-bit halves, referred to as the "left half" (L0) and the "right half" (R0).

• The right half (R0) is expanded to 48 bits using an expansion permutation (E-box).

• The expanded right half (E(R0)) is then XORed with the 48-bit subkey generated from the key in the first round (K1).

• The result is passed through the S-boxes (Substitution Boxes), which substitute 48 bits with 32 bits according to predefined tables.

• The output from the S-boxes is subjected to a permutation (P-box).

• The output from the P-box is then XORed with the left half (L0).

• Swap the left half (L0) and the right half (R0) to prepare for the next round.

4. Iterative Rounds:

• DES uses a total of 16 rounds with each round using a different 48-bit subkey (K2 to K16) derived from the original key using a process that involves key rotation and permutation.

• For rounds 2 to 16, the same process as the initial round is repeated, including the expansion, S-box substitution, permutation, and XOR operations.

• After each round, the left and right halves are swapped.

5. Final Round:

• After the 16th round, the left and right halves are swapped one more time.

6. Final Permutation:

• A final permutation, the inverse of the initial permutation, is applied to the data. This effectively reverses the initial permutation and produces the 64-bit ciphertext block.

7. Repeat for Multiple Blocks:

• If there are additional 64-bit plaintext blocks to encrypt, repeat the above steps for each block using the same key.

8. Decryption:

• To decrypt the ciphertext, the same steps are applied in reverse order using the same key schedule. The ciphertext is first subjected to the initial permutation, and then the rounds are applied in reverse order using the subkeys in reverse order.

Advantages:

1. Standardization: A widely accepted encryption standard.
2. Efficiency: Designed for efficient implementation.
3. Symmetric Key: Uses the same key for encryption and decryption.
4. Proven Security (in its time): Considered secure when initially introduced.
5. Compact: Uses small key and block sizes.
6. Historical Significance: Paved the way for modern cryptography.

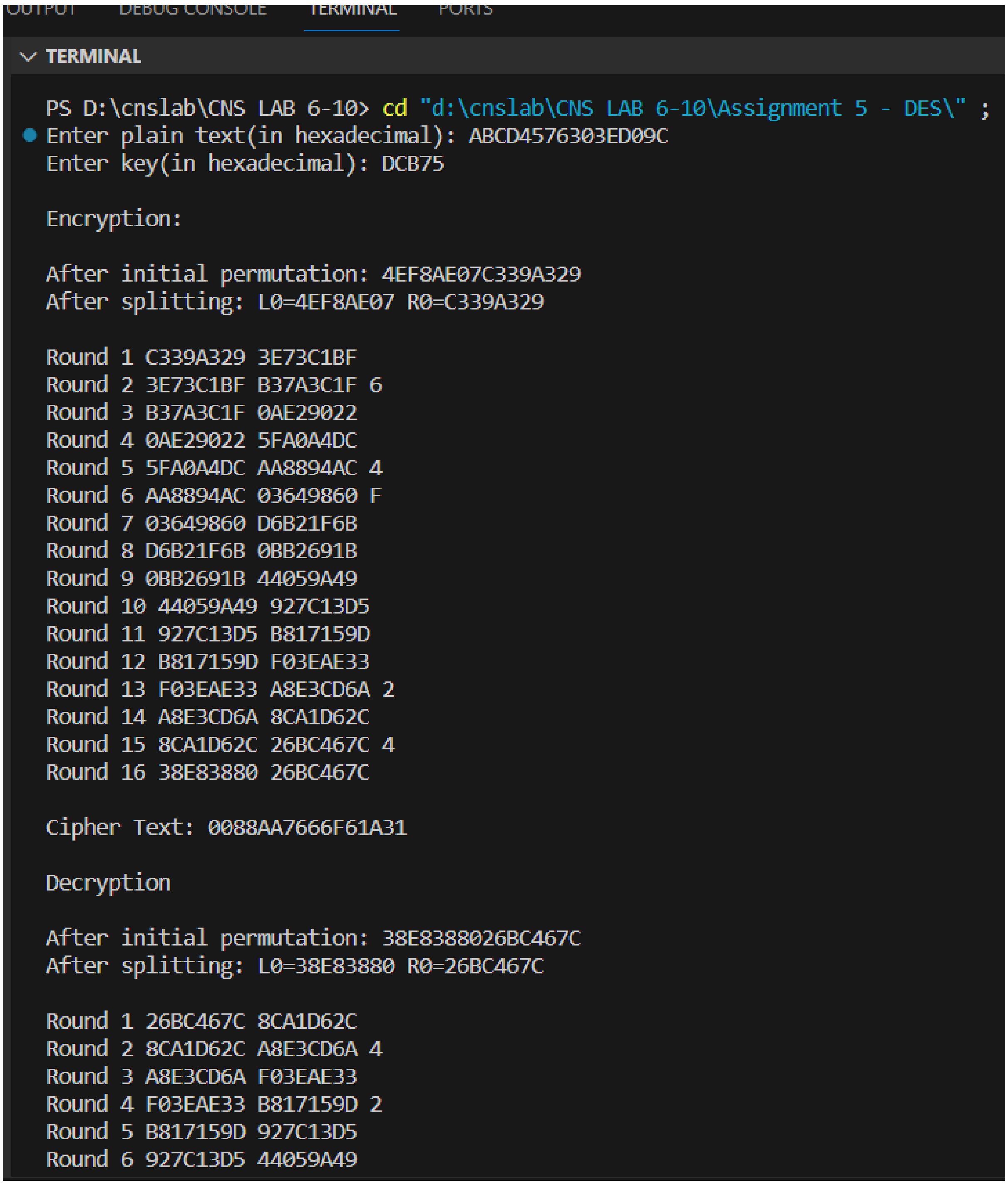
Disadvantages:

1. Small Key Size: 56-bit key vulnerable to brute-force attacks.
2. Outdated Security: Ineffective against modern threats.
3. Cryptanalysis Vulnerabilities: Susceptible to certain attack methods.
4. Fixed Block Size: Limited adaptability to varying data sizes.
5. No Longer Recommended: Replaced by more secure encryption standards.

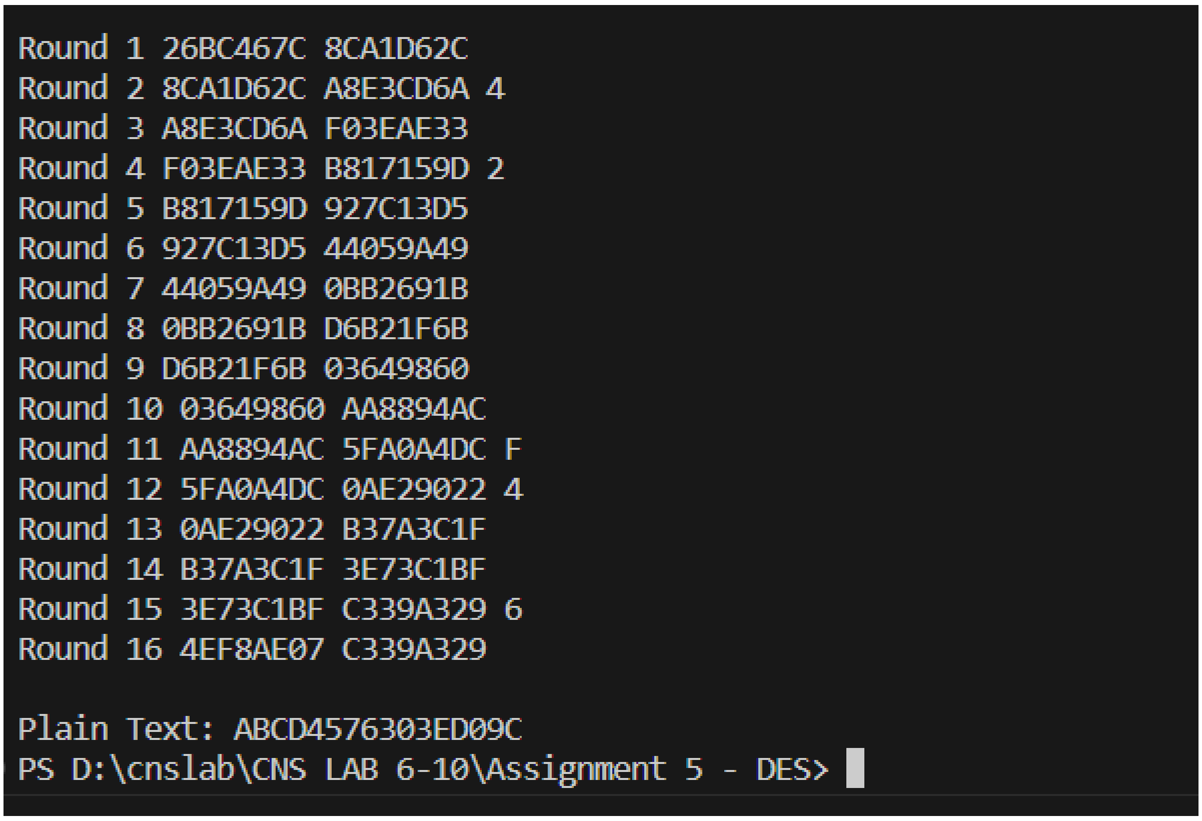
Code:

```
#include <bits/stdc++.h>
using namespace std;

string hex2bin(string s)
{
    unordered_map<char, string> mp;
    mp['0'] = "0000";
    mp['1'] = "0001";
    mp['2'] = "0010";
    mp['3'] = "0011";
    mp['4'] = "0100";
    mp['5'] = "0101";
    mp['6'] = "0110";
    mp['7'] = "0111";
    mp['8'] = "1000";
    mp['9'] = "1001";
    mp['A'] = "1010";
    mp['B'] = "1011";
    mp['C'] = "1100";
    mp['D'] = "1101";
    mp['E'] = "1110";
    mp['F'] = "1111";
    string bin = "";
    for (int i = 0; i < s.size(); i++)
    {
        bin += mp[s[i]];
    }
    return bin;
}
string bin2hex(string s)
{
    unordered_map<string, string> mp;
    mp["0000"] = "0";
    mp["0001"] = "1";
    mp["0010"] = "2";
    mp["0011"] = "3";
    mp["0100"] = "4";
    mp["0101"] = "5";
    mp["0110"] = "6";
    mp["0111"] = "7";
    mp["1000"] = "8";
    mp["1001"] = "9";
    mp["1010"] = "A";
    mp["1011"] = "B";
    mp["1100"] = "C";
    mp["1101"] = "D";
    mp["1110"] = "E";
    mp["1111"] = "F";
    string hex = "";
    for (int i = 0; i < s.length(); i += 4)
    {
        string ch = "";
        ch += s[i];
        ch += s[i + 1];
        ch += s[i + 2];
        ch += s[i + 3];
        hex += mp[ch];
    }
    return hex;
}

string permute(string k, int *arr, int n)
{
    string per = "";
    for (int i = 0; i < n; i++)
    {
        per += k[arr[i] - 1];
    }
    return per;
}

string shift_left(string k, int shifts)
{
    string s = "";
    for (int i = 0; i < shifts; i++)
    {
        for (int j = 1; j < 28; j++)
        {
            s += k[j];
        }
        s += k[0];
        k = s;
        s = "";
    }
    return k;
}

string xor_(string a, string b)
{
    string ans = "";
    for (int i = 0; i < a.size(); i++)
    {
        if (a[i] == b[i])
        {
            ans += "0";
        }
        else
        {
            ans += "1";
        }
    }
    return ans;
```

```
}
string encrypt(string pt, vector<string> rkb,
               vector<string> rk)
{
    pt = hex2bin(pt);

    int initial_perm[64] = {58, 50, 42, 34, 26, 18, 10, 2, 60, 52, 44,
                            36, 28, 20, 12, 4, 62, 54, 46, 38, 30, 22,
                            14, 6, 64, 56, 48, 40, 32, 24, 16, 8, 57,
                            49, 41, 33, 25, 17, 9, 1, 59, 51, 43, 35,
                            27, 19, 11, 3, 61, 53, 45, 37, 29, 21, 13,
                            5, 63, 55, 47, 39, 31, 23, 15, 7};
    pt = permute(pt, initial_perm, 64);
    cout << "After initial permutation: " << bin2hex(pt)
         << endl;

    string left = pt.substr(0, 32);
    string right = pt.substr(32, 32);
    cout << "After splitting: L0=" << bin2hex(left)
         << " R0=" << bin2hex(right) << endl;

    int exp_d[48] = {32, 1, 2, 3, 4, 5, 4, 5, 6, 7, 8, 9,
                     8, 9, 10, 11, 12, 13, 12, 13, 14, 15, 16, 17,
                     16, 17, 18, 19, 20, 21, 20, 21, 22, 23, 24, 25,
                     24, 25, 26, 27, 28, 29, 28, 29, 30, 31, 32, 1};

    int s[8][4][16] = {
        {14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5,
         9, 0, 7, 0, 15, 7, 4, 14, 2, 13, 1, 10, 6,
         12, 11, 9, 5, 3, 8, 4, 1, 14, 8, 13, 6, 2,
         11, 15, 12, 9, 7, 3, 10, 5, 0, 15, 12, 8, 2,
         4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13},
        {15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12,
         0, 5, 10, 3, 13, 4, 7, 15, 2, 8, 14, 12, 0,
         1, 10, 6, 9, 11, 5, 0, 14, 7, 11, 10, 4, 13,
         1, 5, 8, 12, 6, 9, 3, 2, 15, 13, 8, 10, 1,
         3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9},

        {10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12,
         7, 11, 4, 2, 8, 13, 7, 0, 9, 3, 4,
         6, 10, 2, 8, 5, 14, 12, 11, 15, 1, 13,
         6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12,
         5, 10, 14, 7, 1, 10, 13, 0, 6, 9, 8,
         7, 4, 15, 14, 3, 11, 5, 2, 12},
        {7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11,
         12, 4, 15, 13, 8, 11, 5, 6, 15, 0, 3, 4, 7,
         2, 12, 1, 10, 14, 9, 10, 6, 9, 0, 12, 11, 7,
         13, 15, 1, 3, 14, 5, 2, 8, 4, 3, 15, 0, 6,
         10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14},
        {2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13,
         0, 14, 9, 14, 11, 2, 12, 4, 7, 13, 1, 5, 0,
         15, 10, 3, 9, 8, 6, 4, 2, 1, 11, 10, 13, 7,
         8, 15, 9, 12, 5, 6, 3, 0, 14, 11, 8, 12, 7,
         1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3},
        {12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14,
         7, 5, 11, 10, 15, 4, 2, 7, 12, 9, 5, 6, 1,
         13, 14, 0, 11, 3, 8, 9, 14, 15, 5, 2, 8, 12,
         3, 7, 0, 4, 10, 1, 13, 11, 6, 4, 3, 2, 12,
         9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13},
        {4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5,
         10, 6, 1, 13, 0, 11, 7, 4, 9, 1, 10, 14, 3,
         5, 12, 2, 15, 8, 6, 1, 4, 11, 13, 12, 3, 7,
         14, 10, 15, 6, 8, 0, 5, 9, 2, 6, 11, 13, 8,
         1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12},
        {13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5,
         0, 12, 7, 1, 15, 13, 8, 10, 3, 7, 4, 12, 5,
         6, 11, 0, 14, 9, 2, 7, 11, 4, 1, 9, 12, 14,
         2, 0, 6, 10, 13, 15, 3, 5, 8, 2, 1, 14, 7,
         4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11}};

    int per[32] = {16, 7, 20, 21, 29, 12, 28, 17, 1, 15, 23,
                   26, 5, 18, 31, 10, 2, 8, 24, 14, 32, 27,
                   3, 9, 19, 13, 30, 6, 22, 11, 4, 25};

    cout << endl;
    for (int i = 0; i < 16; i++)
    {
        string right_expanded = permute(right, exp_d, 48);

        string x = xor_(rkb[i], right_expanded);

        string op = "";
        for (int i = 0; i < 8; i++)
        {
            int row = 2 * int(x[i * 6] - '0') + int(x[i * 6 + 5] - '0');
            int col = 8 * int(x[i * 6 + 1] - '0') + 4 * int(x[i * 6 + 2] -
'0') + 2 * int(x[i * 6 + 3] - '0') + int(x[i * 6 + 4] - '0');
            int val = s[i][row][col];
            op += char(val / 8 + '0');
            val = val % 8;
            op += char(val / 4 + '0');
            val = val % 4;
            op += char(val / 2 + '0');
            val = val % 2;
            op += char(val + '0');
        }
        op = permute(op, per, 32);

        x = xor_(op, left);

        left = x;

        if (i != 15)
        {
            swap(left, right);
        }
        cout << "Round " << i + 1 << " " << bin2hex(left)
             << " " << bin2hex(right) << " " << rk[i]
             << endl;
    }

    string combine = left + right;

    int final_perm[64] = {40, 8, 48, 16, 56, 24, 64, 32, 39, 7, 47,
                          15, 55, 23, 63, 31, 38, 6, 46, 14, 54, 22,
                          62, 30, 37, 5, 45, 13, 53, 21, 61, 29, 36,
                          4, 44, 12, 52, 20, 60, 28, 35, 3, 43, 11,
                          51, 19, 59, 27, 34, 2, 42, 10, 50, 18, 58,
                          26, 33, 1, 41, 9, 49, 17, 57, 25};

    string cipher = bin2hex(permute(combine, final_perm, 64));
    return cipher;
}

int main()
{
    string pt, key;
    cout << "Enter plain text(in hexadecimal): ";
    cin >> pt;
    cout << "Enter key(in hexadecimal): ";
    cin >> key;

    key = hex2bin(key);

    int keyp[56] = {57, 49, 41, 33, 25, 17, 9, 1, 58, 50, 42, 34,
                    26, 18, 10, 2, 59, 51, 43, 35, 27, 19, 11, 3,
                    60, 52, 44, 36, 63, 55, 47, 39, 31, 23, 15, 7,
                    62, 54, 46, 38, 30, 22, 14, 6, 61, 53, 45, 37,
                    29, 21, 13, 5, 28, 20, 12, 4};

    key = permute(key, keyp, 56);

    int shift_table[16] = {1, 1, 2, 2, 2, 2, 2, 2,
                           1, 2, 2, 2, 2, 2, 2, 1};
    int key_comp[48] = {14, 17, 11, 24, 1, 5, 3, 28,
                        15, 6, 21, 10, 23, 19, 12, 4,
                        26, 8, 16, 7, 27, 20, 13, 2,
                        41, 52, 31, 37, 47, 55, 30, 40,
                        51, 45, 33, 48, 44, 49, 39, 56,
                        34, 53, 46, 42, 50, 36, 29, 32};

    string left = key.substr(0, 28);
    string right = key.substr(28, 28);

    vector<string> rkb;
    vector<string> rk;
    for (int i = 0; i < 16; i++)
    {
        left = shift_left(left, shift_table[i]);
        right = shift_left(right, shift_table[i]);

        string combine = left + right;

        string RoundKey = permute(combine, key_comp, 48);

        rkb.push_back(RoundKey);
        rk.push_back(bin2hex(RoundKey));
    }

    cout << "\nEncryption:\n\n";
    string cipher = encrypt(pt, rkb, rk);
    cout << "\nCipher Text: " << cipher << endl;

    cout << "\nDecryption\n\n";
    reverse(rkb.begin(), rkb.end());
    reverse(rk.begin(), rk.end());
    string text = encrypt(cipher, rkb, rk);
    cout << "\nPlain Text: " << text << endl;
}
```



```
PS D:\cnslab\CNS LAB 6-10> cd "d:\cnslab\CNS LAB 6-10\Assignment 5 - DES\" ;
Enter plain text(in hexadecimal): ABCD4576303ED09C
Enter key(in hexadecimal): DCB75

Encryption:

After initial permutation: 4EF8AE07C339A329
After splitting: L0=4EF8AE07 R0=C339A329

Round 1 C339A329 3E73C1BF
Round 2 3E73C1BF B37A3C1F 6
Round 3 B37A3C1F 0AE29022
Round 4 0AE29022 5FA0A4DC
Round 5 5FA0A4DC AA8894AC 4
Round 6 AA8894AC 03649860 F
Round 7 03649860 D6B21F6B
Round 8 D6B21F6B 0BB2691B
Round 9 0BB2691B 44059A49
Round 10 44059A49 927C13D5
Round 11 927C13D5 B817159D
Round 12 B817159D F03EAE33
Round 13 F03EAE33 A8E3CD6A 2
Round 14 A8E3CD6A 8CA1D62C
Round 15 8CA1D62C 26BC467C 4
Round 16 38E83880 26BC467C

Cipher Text: 0088AA7666F61A31

Decryption

After initial permutation: 38E8388026BC467C
After splitting: L0=38E83880 R0=26BC467C

Round 1 26BC467C 8CA1D62C
Round 2 8CA1D62C A8E3CD6A 4
Round 3 A8E3CD6A F03EAE33
Round 4 F03EAE33 B817159D 2
Round 5 B817159D 927C13D5
Round 6 927C13D5 44059A49
```



```
Round 1 26BC467C 8CA1D62C
Round 2 8CA1D62C A8E3CD6A 4
Round 3 A8E3CD6A F03EAE33
Round 4 F03EAE33 B817159D 2
Round 5 B817159D 927C13D5
Round 6 927C13D5 44059A49
Round 7 44059A49 0BB2691B
Round 8 0BB2691B D6B21F6B
Round 9 D6B21F6B 03649860
Round 10 03649860 AA8894AC
Round 11 AA8894AC 5FA0A4DC F
Round 12 5FA0A4DC 0AE29022 4
Round 13 0AE29022 B37A3C1F
Round 14 B37A3C1F 3E73C1BF
Round 15 3E73C1BF C339A329 6
Round 16 4EF8AE07 C339A329

Plain Text: ABCD4576303ED09C
PS D:\cnslab\CNS LAB 6-10\Assignment 5 - DES>
```

Advanced Encryption Standard:

The Advanced Encryption Standard (AES) is a widely used symmetric encryption algorithm that provides strong data security. Here are the algorithm steps, advantages, and disadvantages of AES:

Algorithm:

• The AES algorithm begins with a key expansion phase, where the original encryption key is expanded into a set of round keys. These round keys are used in the subsequent encryption rounds.

• Initial Round (Add Round Key): The plaintext data is divided into blocks. In the initial round, the round key is added to the plaintext using a bitwise XOR operation.

• AES operates in a fixed number of rounds, which depends on the key size. For AES-128, there are 10 rounds; for AES-192, there are 12 rounds; and for

AES-256, there are 14 rounds. Each round consists of the following operations:

- SubBytes: Substitutes each byte in the block with a corresponding byte from the S-Box, a fixed substitution table.
- ShiftRows: Shifts the rows of the block to the left by different offsets.
- MixColumns: Mixes the columns of the block using a mathematical transformation.
- AddRoundKey: Adds the round key to the block using a bitwise XOR operation.

• In the final round, the SubBytes, ShiftRows, and MixColumns operations are performed, followed by adding the final round key.

• The result after the final round is the ciphertext.

Advantages:

• AES is widely considered to be highly secure and is used by governments, organizations, and individuals for protecting sensitive information.

• AES is a fast and efficient encryption algorithm, making it suitable for a wide range of applications, including secure communication and data storage.

• AES has been standardized by the National Institute of Standards and Technology (NIST) and is widely adopted and accepted in the security community.

• AES supports multiple key lengths (128, 192, and 256 bits), allowing users to choose the level of security they need.

• AES has withstood extensive cryptanalysis and has not been found to have any significant vulnerabilities.

Disadvantages:

• AES is a symmetric encryption algorithm, which means that both the sender and receiver need to possess the same key. Secure key distribution can be a challenge, especially over insecure channels.

• While AES is highly secure, it may not be the best choice for all encryption scenarios. For example, it may not be suitable for public-key encryption or digital signatures, which require asymmetric cryptography.

• While AES is generally efficient, it can introduce some performance overhead, particularly for very resource-constrained devices or when using large key sizes.

• Like many cryptographic algorithms, AES can be vulnerable to side-channel attacks (e.g., timing or power analysis attacks) if not properly implemented and protected.

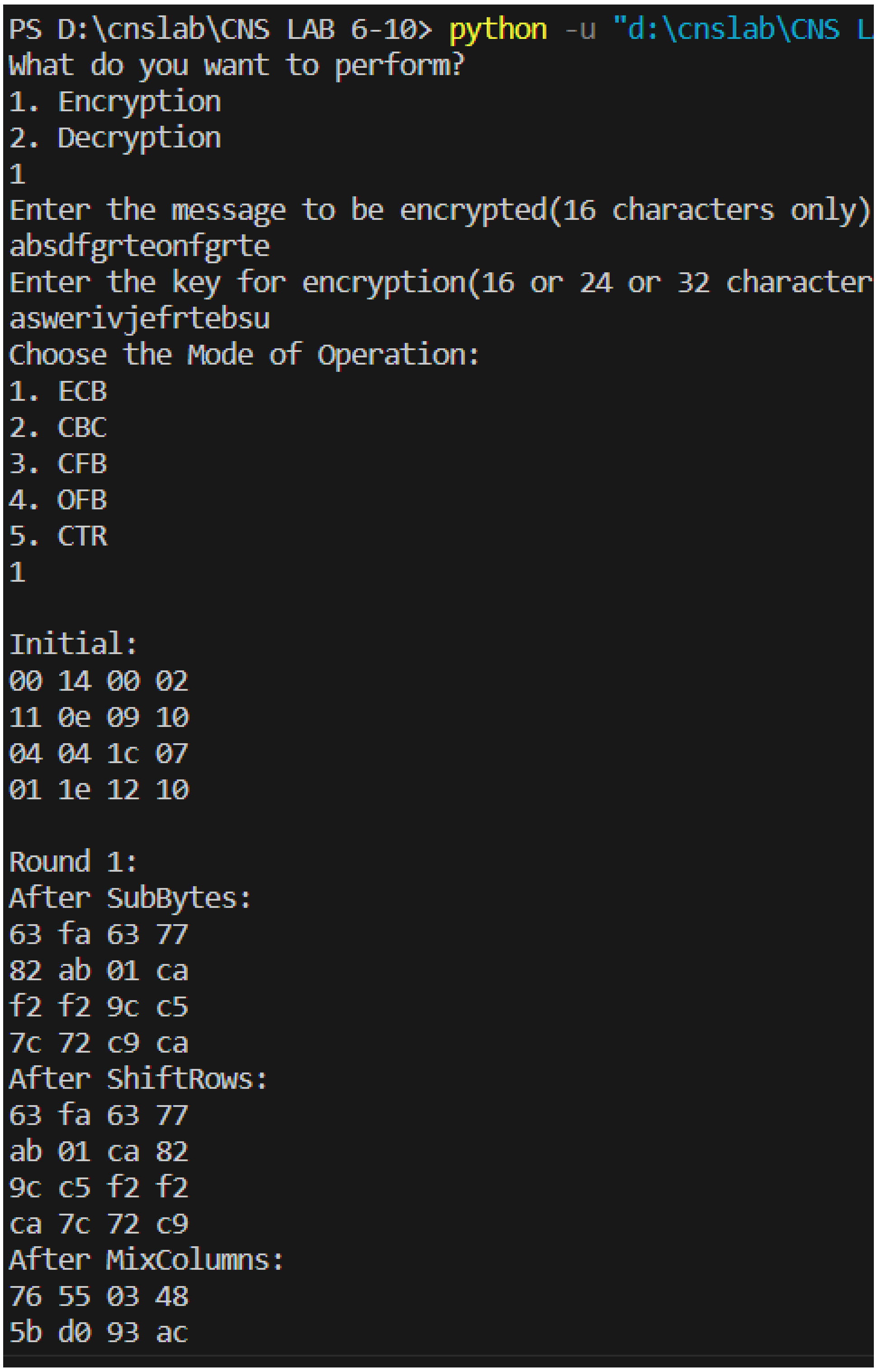
Code:

```
from block_cipher import BlockCipher, BlockCipherWrapper
from block_cipher import MODE_ECB, MODE_CBC, MODE_CFB, MODE_OFB, MODE_CTR

def print_str_into_AES_matrix(str):
    characters = ' '.join([str[i:i+2] for i in range(0, len(str), 2)]).split()
    matrix = [[characters[i] for i in range(j, j + 4)] for j in range(0,
len(characters), 4)]

    for col in range(4):
        for row in range(4):
            print(matrix[row][col], end=" ")
        print()

__all__ = [
    'new', 'block_size', 'key_size',
    'MODE_ECB', 'MODE_CBC', 'MODE_CFB', 'MODE_OFB', 'MODE_CTR'
]


SBOX = (
    0x63, 0x7c, 0x77, 0x7b, 0xf2, 0x6b, 0x6f, 0xc5,
    0x30, 0x01, 0x67, 0x2b, 0xfe, 0xd7, 0xab, 0x76,
    0xca, 0x82, 0xc9, 0x7d, 0xfa, 0x59, 0x47, 0xf0,
    0xad, 0xd4, 0xa2, 0xaf, 0x9c, 0xa4, 0x72, 0xc0,
    0xb7, 0xfd, 0x93, 0x26, 0x36, 0x3f, 0xf7, 0xcc,
    0x34, 0xa5, 0xe5, 0xf1, 0x71, 0xd8, 0x31, 0x15,
    0x04, 0xc7, 0x23, 0xc3, 0x18, 0x96, 0x05, 0x9a,
    0x07, 0x12, 0x80, 0xe2, 0xeb, 0x27, 0xb2, 0x75,
    0x09, 0x83, 0x2c, 0x1a, 0x1b, 0x6e, 0x5a, 0xa0,
    0x52, 0x3b, 0xd6, 0xb3, 0x29, 0xe3, 0x2f, 0x84,
    0x53, 0xd1, 0x00, 0xed, 0x20, 0xfc, 0xb1, 0x5b,
    0x6a, 0xcb, 0xbe, 0x39, 0x4a, 0x4c, 0x58, 0xcf,
    0xd0, 0xef, 0xaa, 0xfb, 0x43, 0x4d, 0x33, 0x85,
    0x45, 0xf9, 0x02, 0x7f, 0x50, 0x3c, 0x9f, 0xa8,
    0x51, 0xa3, 0x40, 0x8f, 0x92, 0x9d, 0x38, 0xf5,
    0xbc, 0xb6, 0xda, 0x21, 0x10, 0xff, 0xf3, 0xd2,
    0xcd, 0x0c, 0x13, 0xec, 0x5f, 0x97, 0x44, 0x17,
    0xc4, 0xa7, 0x7e, 0x3d, 0x64, 0x5d, 0x19, 0x73,
    0x60, 0x81, 0x4f, 0xdc, 0x22, 0x2a, 0x90, 0x88,
    0x46, 0xee, 0xb8, 0x14, 0xde, 0x5e, 0x0b, 0xdb,
    0xe0, 0x32, 0x3a, 0x0a, 0x49, 0x06, 0x24, 0x5c,
    0xc2, 0xd3, 0xac, 0x62, 0x91, 0x95, 0xe4, 0x79,
    0xe7, 0xc8, 0x37, 0x6d, 0x8d, 0xd5, 0x4e, 0xa9,
    0x6c, 0x56, 0xf4, 0xea, 0x65, 0x7a, 0xae, 0x08,
    0xba, 0x78, 0x25, 0x2e, 0x1c, 0xa6, 0xb4, 0xc6,
    0xe8, 0xdd, 0x74, 0x1f, 0x4b, 0xbd, 0x8b, 0x8a,
    0x70, 0x3e, 0xb5, 0x66, 0x48, 0x03, 0xf6, 0x0e,
    0x61, 0x35, 0x57, 0xb9, 0x86, 0xc1, 0x1d, 0x9e,
    0xe1, 0xf8, 0x98, 0x11, 0x69, 0xd9, 0x8e, 0x94,
    0x9b, 0x1e, 0x87, 0xe9, 0xce, 0x55, 0x28, 0xdf,
    0x8c, 0xa1, 0x89, 0x0d, 0xbf, 0xe6, 0x42, 0x68,
    0x41, 0x99, 0x2d, 0x0f, 0xb0, 0x54, 0xbb, 0x16,
)
INV_SBOX = (
    0x52, 0x09, 0x6a, 0xd5, 0x30, 0x36, 0xa5, 0x38,
    0xbf, 0x40, 0xa3, 0x9e, 0x81, 0xf3, 0xd7, 0xfb,
    0x7c, 0xe3, 0x39, 0x82, 0x9b, 0x2f, 0xff, 0x87,
    0x34, 0x8e, 0x43, 0x44, 0xc4, 0xde, 0xe9, 0xcb,
    0x54, 0x7b, 0x94, 0x32, 0xa6, 0xc2, 0x23, 0x3d,
    0xee, 0x4c, 0x95, 0x0b, 0x42, 0xfa, 0xc3, 0x4e,
    0x08, 0x2e, 0xa1, 0x66, 0x28, 0xd9, 0x24, 0xb2,
    0x76, 0x5b, 0xa2, 0x49, 0x6d, 0x8b, 0xd1, 0x25,
    0x72, 0xf8, 0xf6, 0x64, 0x86, 0x68, 0x98, 0x16,
    0xd4, 0xa4, 0x5c, 0xcc, 0x5d, 0x65, 0xb6, 0x92,
    0x6c, 0x70, 0x48, 0x50, 0xfd, 0xed, 0xb9, 0xda,
    0x5e, 0x15, 0x46, 0x57, 0xa7, 0x8d, 0x9d, 0x84,
    0x90, 0xd8, 0xab, 0x00, 0x8c, 0xbc, 0xd3, 0x0a,
    0xf7, 0xe4, 0x58, 0x05, 0xb8, 0xb3, 0x45, 0x06,
    0xd0, 0x2c, 0x1e, 0x8f, 0xca, 0x3f, 0x0f, 0x02,
    0xc1, 0xaf, 0xbd, 0x03, 0x01, 0x13, 0x8a, 0x6b,
    0x3a, 0x91, 0x11, 0x41, 0x4f, 0x67, 0xdc, 0xea,
    0x97, 0xf2, 0xcf, 0xce, 0xf0, 0xb4, 0xe6, 0x73,
    0x96, 0xac, 0x74, 0x22, 0xe7, 0xad, 0x35, 0x85,
    0xe2, 0xf9, 0x37, 0xe8, 0x1c, 0x75, 0xdf, 0x6e,
    0x47, 0xf1, 0x1a, 0x71, 0x1d, 0x29, 0xc5, 0x89,
    0x6f, 0xb7, 0x62, 0x0e, 0xaa, 0x18, 0xbe, 0x1b,
    0xfc, 0x56, 0x3e, 0x4b, 0xc6, 0xd2, 0x79, 0x20,
    0x9a, 0xdb, 0xc0, 0xfe, 0x78, 0xcd, 0x5a, 0xf4,
    0x1f, 0xdd, 0xa8, 0x33, 0x88, 0x07, 0xc7, 0x31,
    0xb1, 0x12, 0x10, 0x59, 0x27, 0x80, 0xec, 0x5f,
    0x60, 0x51, 0x7f, 0xa9, 0x19, 0xb5, 0x4a, 0x0d,
    0x2d, 0xe5, 0x7a, 0x9f, 0x93, 0xc9, 0x9c, 0xef,
    0xa0, 0xe0, 0x3b, 0x4d, 0xae, 0x2a, 0xf5, 0xb0,
    0xc8, 0xeb, 0xbb, 0x3c, 0x83, 0x53, 0x99, 0x61,
    0x17, 0x2b, 0x04, 0x7e, 0xba, 0x77, 0xd6, 0x26,
    0xe1, 0x69, 0x14, 0x63, 0x55, 0x21, 0x0c, 0x7d,
)

round_constants = (0x01, 0x02, 0x04, 0x08, 0x10, 0x20, 0x40, 0x80, 0x1b, 0x36)

block_size = 16
key_size = None


def new(key, mode, IV=None, **kwargs) -> BlockCipherWrapper:

    if mode in (MODE_CBC, MODE_CFB, MODE_OFB) and IV is None:
        raise ValueError("This mode requires an IV")

    cipher = BlockCipherWrapper()
    cipher.block_size = block_size
    cipher.IV = IV
    cipher.mode = mode
    cipher.cipher = AES(key)

    if mode == MODE_CFB:
        cipher.segment_size = kwargs.get('segment_size', block_size * 8)
    elif mode == MODE_CTR:
        counter = kwargs.get('counter')
        if counter is None:
            raise ValueError("CTR mode requires a callable counter object")
        cipher.counter = counter

    return cipher


class AES(BlockCipher):

    def __init__(self, key: bytes):

        self.key = key
        self.Nk = len(self.key) // 4  # words per key
        if self.Nk not in (4, 6, 8):
            raise ValueError("Invalid key size")
        self.Nr = self.Nk + 6
        self.Nb = 4  # words per block
        self.state: list[list[int]] = []
        # raise NotImplementedError
        # key schedule
        self.w: list[list[int]] = []
        for i in range(self.Nk):
            self.w.append(list(key[4*i:4*i+4]))
        for i in range(self.Nk, self.Nb*(self.Nr+1)):
            tmp: list[int] = self.w[i-1]
            q, r = divmod(i, self.Nk)
            if not r:
                tmp = self.sub_word(self.rot_word(tmp))
                tmp[0] ^= round_constants[q-1]
            elif self.Nk > 6 and r == 4:
                tmp = self.sub_word(tmp)
            self.w.append(
                [a ^ b for a, b in zip(self.w[i-self.Nk], tmp)]
            )

    def encrypt_block(self, block: bytes) -> bytes:

        self.set_state(block)

        self.add_round_key(0)
        print("\nInitial:")
        print_str_into_AES_matrix(self.get_state().hex())

        for r in range(1, self.Nr):
            print(f"\nRound {r}:")

            self.sub_bytes()
            print("After SubBytes:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.shift_rows()
            print("After ShiftRows:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.mix_columns()
            print("After MixColumns:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.add_round_key(r)
            print("After AddRoundKey:")
            print_str_into_AES_matrix(self.get_state().hex())
```

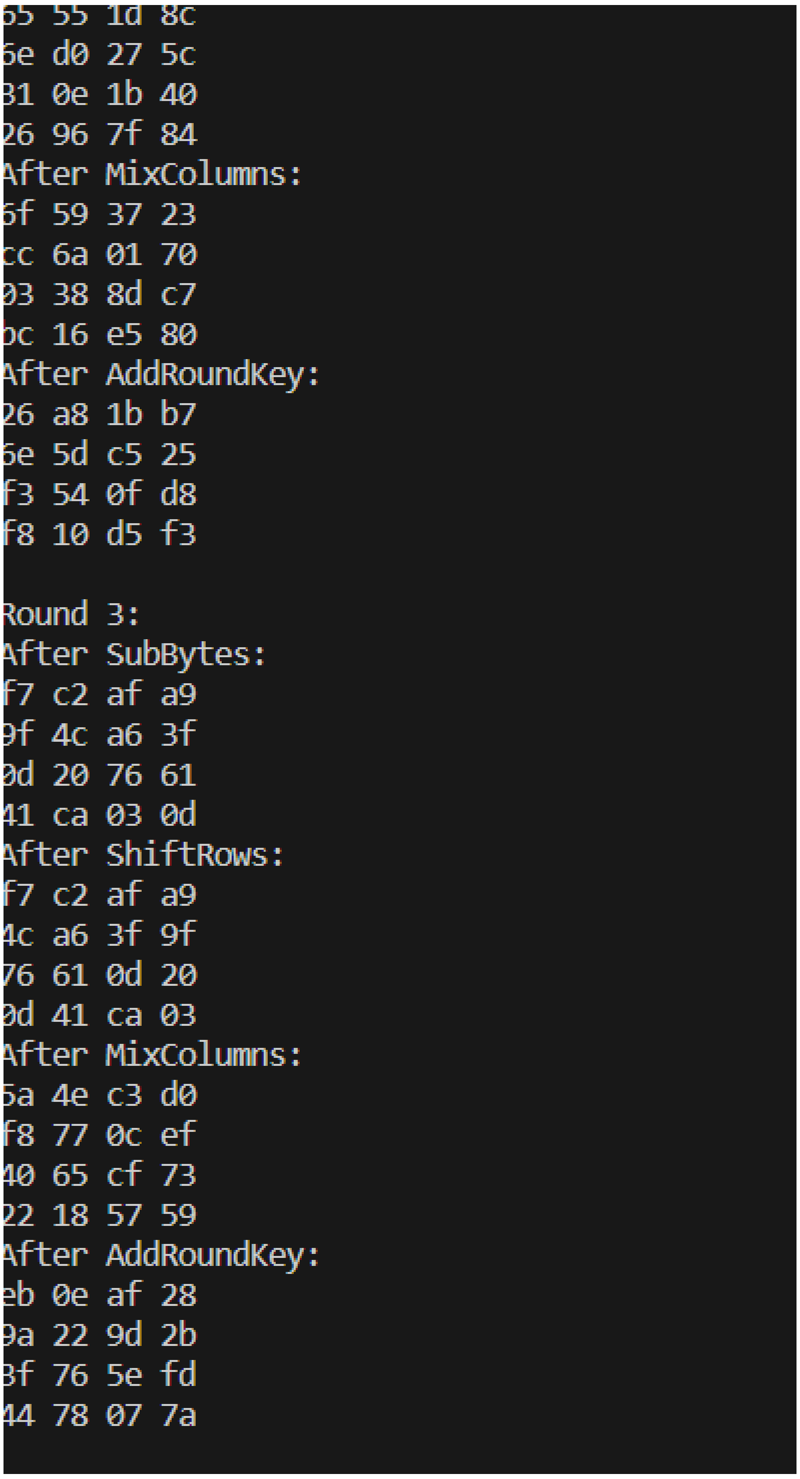
```python
        print(f"\nFinal Round {r+1}:")
        self.sub_bytes()
        print("After SubBytes:")
        print_str_into_AES_matrix(self.get_state().hex())

        self.shift_rows()
        print("After ShiftRows:")
        print_str_into_AES_matrix(self.get_state().hex())

        self.add_round_key(self.Nr)
        print("After AddRoundKey:")
        print_str_into_AES_matrix(self.get_state().hex())

        return self.get_state()

    def decrypt_block(self, block: bytes) -> bytes:

        self.set_state(block)
        print("\nInitial:")
        print_str_into_AES_matrix(self.get_state().hex())


        self.add_round_key(self.Nr)
        for r in range(self.Nr-1, 0, -1):
            print(f"\nRound {r}:")

            self.inv_shift_rows()
            print("After Inverse ShiftRows:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.inv_sub_bytes()
            print("After Inverse SubBytes:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.add_round_key(r)
            print("After AddRoundKey:")
            print_str_into_AES_matrix(self.get_state().hex())

            self.inv_mix_columns()
            print("After Inverse MixColumns:")
            print_str_into_AES_matrix(self.get_state().hex())

        print(f"\nFinal Round {r}:")
        self.inv_shift_rows()
        print("After Inverse ShiftRows:")
        print_str_into_AES_matrix(self.get_state().hex())

        self.inv_sub_bytes()
        print("After Inverse SubBytes:")
        print_str_into_AES_matrix(self.get_state().hex())

        self.add_round_key(0)
        print("After AddRoundKey:")
        print_str_into_AES_matrix(self.get_state().hex())

        return self.get_state()

    @staticmethod
    def rot_word(word: list[int]):
        # for key schedule
        return word[1:] + word[:1]

    @staticmethod
    def sub_word(word: list[int]):
        # for key schedule
        return [SBOX[b] for b in word]

    def set_state(self, block: bytes):

        self.state = [
            list(block[i:i+4])
            for i in range(0, 16, 4)
        ]

    def get_state(self) -> bytes:

        return b''.join(
            bytes(col)
            for col in self.state
        )

    def add_round_key(self, r: int):

        round_key = self.w[r*self.Nb:(r+1)*self.Nb]
        for col, word in zip(self.state, round_key):
            for row_index in range(4):
                col[row_index] ^= word[row_index]

    def mix_columns(self):

        for i, word in enumerate(self.state):
            new_word = []
            for j in range(4):
                # element wise cl mul with constants 2, 3, 1, 1
                value = (word[0] << 1)
                value ^= (word[1] << 1) ^ word[1]
                value ^= word[2] ^ word[3]
                # polynomial reduction in constant time
                value ^= 0x11b & -(value >> 8)
                new_word.append(value)
                # rotate word in order to match the matrix multiplication
                word = self.rot_word(word)
            self.state[i] = new_word

    def inv_mix_columns(self):

        for i, word in enumerate(self.state):
            new_word = []
            for j in range(4):
                # element wise cl mul with constants 0xe, 0xb, 0xd, 0x9
                value = (word[0] << 3) ^ (word[0] << 2) ^ (word[0] << 1)
                value ^= (word[1] << 3) ^ (word[1] << 1) ^ word[1]
                value ^= (word[2] << 3) ^ (word[2] << 2) ^ word[2]
                value ^= (word[3] << 3) ^ word[3]
                # polynomial reduction in constant time
                value ^= (0x11b << 2) & -(value >> 10)
                value ^= (0x11b << 1) & -(value >> 9)
                value ^= 0x11b & -(value >> 8)
                new_word.append(value)
                # rotate word in order to match the matrix multiplication
                word = self.rot_word(word)
            self.state[i] = new_word

    def shift_rows(self):

        for row_index in range(4):
            row = [
                col[row_index] for col in self.state
            ]
            row = row[row_index:] + row[:row_index]
            for col_index in range(4):
                self.state[col_index][row_index] = row[col_index]

    def inv_shift_rows(self):

        for row_index in range(4):
            row = [
                col[row_index] for col in self.state
            ]
            row = row[-row_index:] + row[:-row_index]
            for col_index in range(4):
                self.state[col_index][row_index] = row[col_index]

    def sub_bytes(self):
        for col in self.state:
            for row_index in range(4):
                col[row_index] = SBOX[col[row_index]]

    def inv_sub_bytes(self):

        for col in self.state:
            for row_index in range(4):
                col[row_index] = INV_SBOX[col[row_index]]

    def print_state(self):
        # debug function
        for row_index in range(4):
            print(' '.join(f'{col[row_index]:02x}' for col in self.state))
        print()

# Main Code
ch = int(input("What do you want to perform?\n1. Encryption\n2.
Decryption\n"))

if(ch == 1):
    msg = str(input("Enter the message to be encrypted(16 characters
only):\n"))
    if(len(msg) != 16):
        print("Invalid Message size!")
        exit()

    key = str(input("Enter the key for encryption(16 or 24 or 32
characters):\n"))
    key_length = len(key)
    if (key_length!=16 and key_length!=24 and key_length!=32):
        print("Invalid Key size!")
        exit()

    mode = int(input("Choose the Mode of Operation:\n1. ECB\n2. CBC\n3.
CFB\n4. OFB\n5. CTR\n"))

    iv = None
    if mode == 1:
        AES_MODE = MODE_ECB
    elif mode == 2:
        AES_MODE = MODE_CBC
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 3:
        AES_MODE = MODE_CFB
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 4:
        AES_MODE = MODE_OFB
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 5:
        AES_MODE = MODE_CTR
    else:
        print("Invalid choice !!")
        exit()

    key = bytes.fromhex(key.encode('utf-8').hex())
    plain_text = bytes.fromhex(msg.encode('utf-8').hex())
    if iv is not None:
        iv = bytes.fromhex(iv.encode('utf-8').hex())

    cipher = new(key, AES_MODE, IV=iv)
    cipher_text = cipher.encrypt(plain_text)

    print(f"\nCiphertext is: {cipher_text.hex()}")

elif(ch == 2):
    c_txt = str(input("Enter the ciphertext to be decrypted(16 characters) [in
hex format]:\n"))
    if(len(c_txt) != 32):
        print("Invalid Cipher text size!")
        exit()

    key = str(input("Enter the key for decryption(16 or 24 or 32
characters):\n"))
    key = bytes.fromhex(key.encode('utf-8').hex())
    key_length = len(key)
    if (key_length!=16 and key_length!=24 and key_length!=32):
        print("Invalid Key size!")
        exit()

    mode = int(input("Choose the Mode of Operation used:\n1. ECB\n2. CBC\n3.
CFB\n4. OFB\n5. CTR\n"))
```

```
    iv = None
    if mode == 1:
        AES_MODE = MODE_ECB
    elif mode == 2:
        AES_MODE = MODE_CBC
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 3:
        AES_MODE = MODE_CFB
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 4:
        AES_MODE = MODE_OFB
        iv = str(input("Enter the Initialization Vector(IV) [16
characters]:\n"))
        if(len(iv) != 16):
            print("Invalid IV size!")
            exit()
    elif mode == 5:
        AES_MODE = MODE_CTR
    else:
        print("Invalid choice !!")
        exit()

    if iv is not None:
        iv = bytes.fromhex(iv.encode('utf-8').hex())

    cipher = new(key, AES_MODE, IV=iv)
    dec_bytes = cipher.decrypt(bytes.fromhex(c_txt))
    dec_txt = dec_bytes.decode('utf-8')

    print(f"\nDecrypted message is: {dec_txt}")

else:
    print("Invalid input!")
```

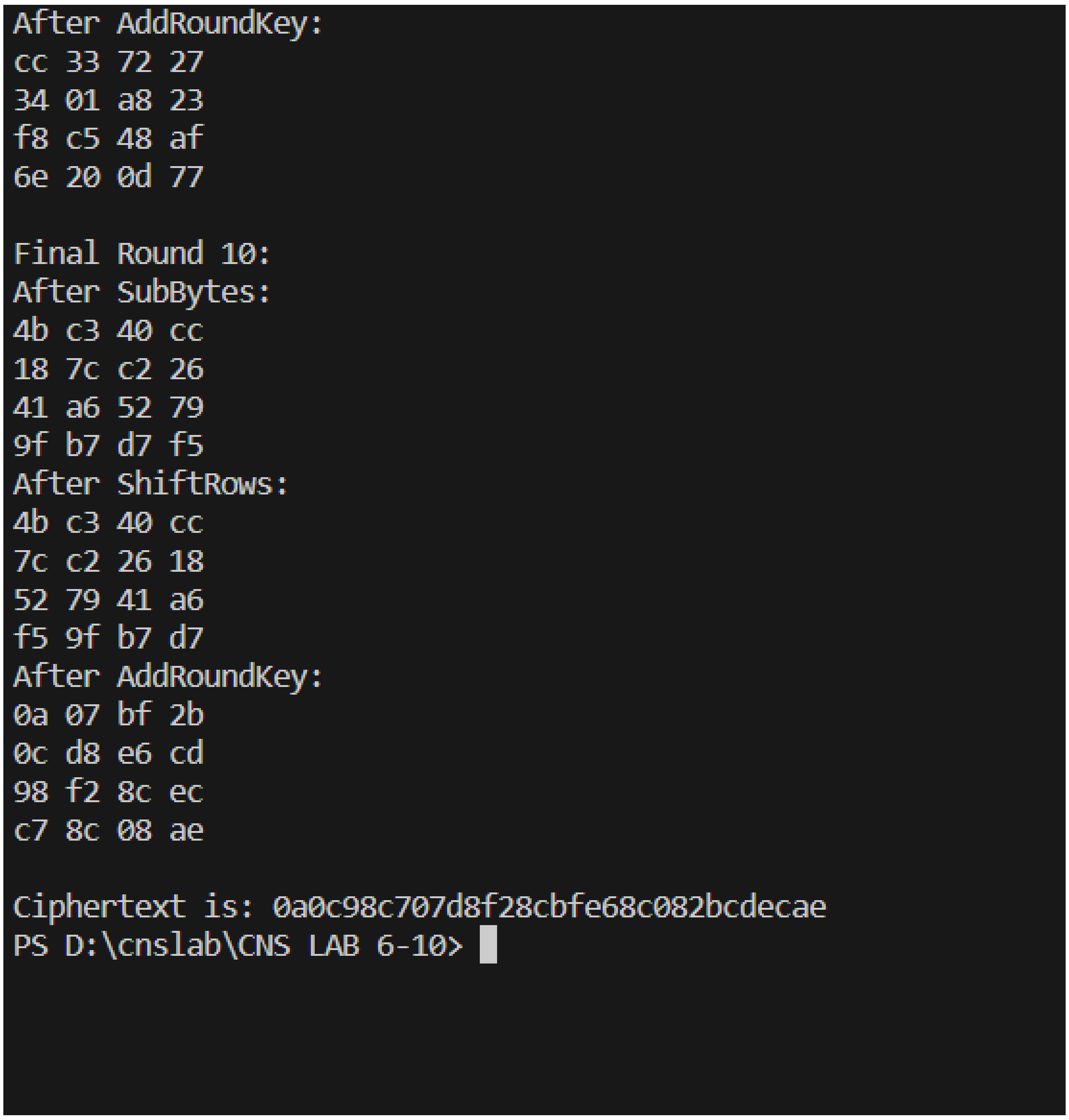
output:



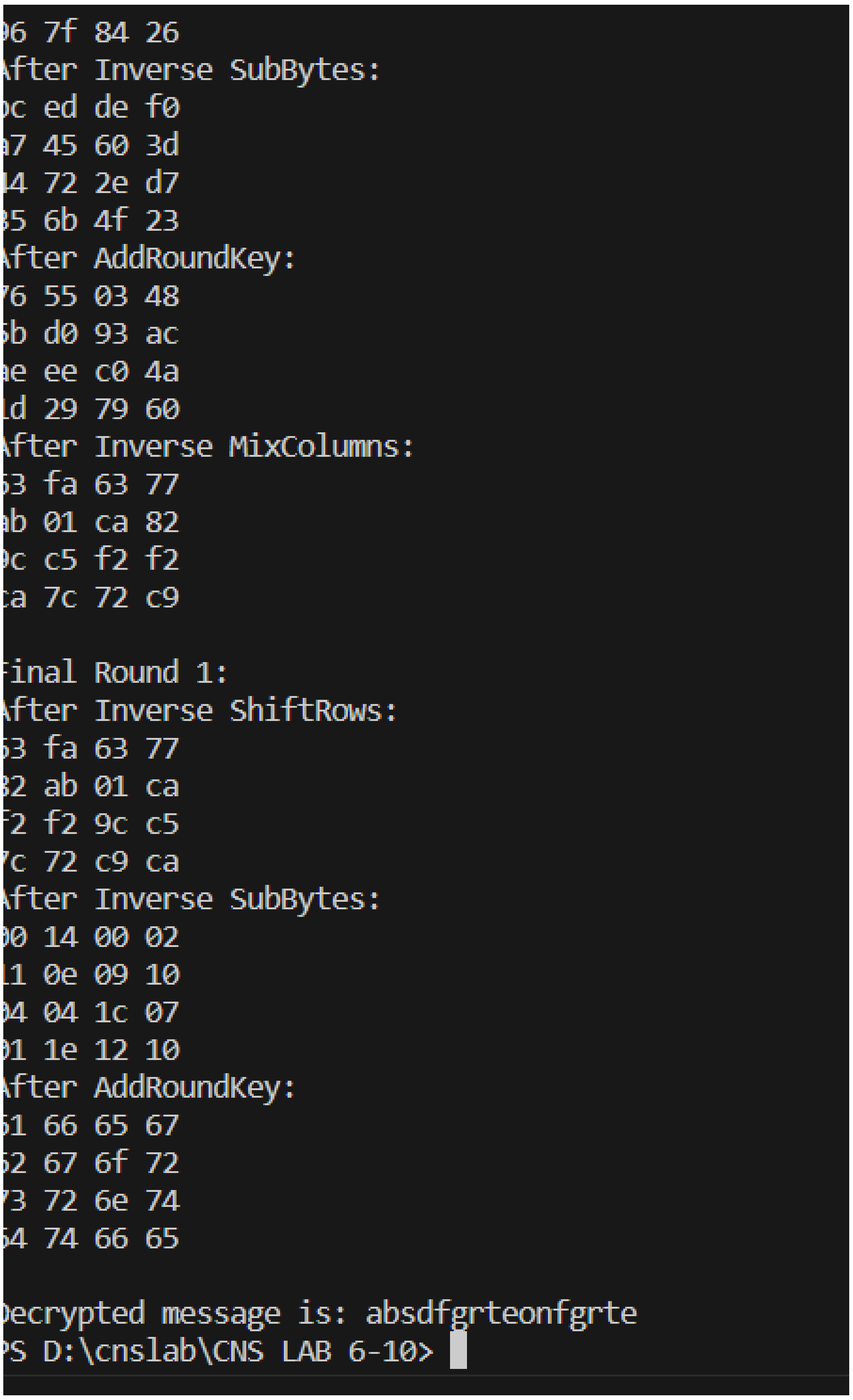
```
PS D:\cnslab\CNS LAB 6-10> python -u "d:\cnslab\CNS L
What do you want to perform?
1. Encryption
2. Decryption
1
Enter the message to be encrypted(16 characters only)
absdfgrteonfgrte
Enter the key for encryption(16 or 24 or 32 character
aswerivjefrtebsu
Choose the Mode of Operation:
1. ECB
2. CBC
3. CFB
4. OFB
5. CTR
1

Initial:
00 14 00 02
11 0e 09 10
04 04 1c 07
01 1e 12 10

Round 1:
After SubBytes:
63 fa 63 77
82 ab 01 ca
f2 f2 9c c5
7c 72 c9 ca
After ShiftRows:
63 fa 63 77
ab 01 ca 82
9c c5 f2 f2
ca 7c 72 c9
After MixColumns:
76 55 03 48
5b d0 93 ac
```



```
65 55 1d 8c
6e d0 27 5c
31 0e 1b 40
26 96 7f 84
After MixColumns:
6f 59 37 23
cc 6a 01 70
03 38 8d c7
bc 16 e5 80
After AddRoundKey:
26 a8 1b b7
6e 5d c5 25
f3 54 0f d8
f8 10 d5 f3

Round 3:
After SubBytes:
f7 c2 af a9
9f 4c a6 3f
0d 20 76 61
41 ca 03 0d
After ShiftRows:
f7 c2 af a9
4c a6 3f 9f
76 61 0d 20
0d 41 ca 03
After MixColumns:
5a 4e c3 d0
f8 77 0c ef
40 65 cf 73
22 18 57 59
After AddRoundKey:
eb 0e af 28
9a 22 9d 2b
3f 76 5e fd
44 78 07 7a
```



```
After AddRoundKey:
cc 33 72 27
34 01 a8 23
f8 c5 48 af
6e 20 0d 77

Final Round 10:
After SubBytes:
4b c3 40 cc
18 7c c2 26
41 a6 52 79
9f b7 d7 f5
After ShiftRows:
4b c3 40 cc
7c c2 26 18
52 79 41 a6
f5 9f b7 d7
After AddRoundKey:
0a 07 bf 2b
0c d8 e6 cd
98 f2 8c ec
c7 8c 08 ae

Ciphertext is: 0a0c98c707d8f28cbfe68c082bcdecae
PS D:\cnslab\CNS LAB 6-10>
```



```
)6 7f 84 26
\fter Inverse SubBytes:
)c ed de f0
a7 45 60 3d
14 72 2e d7
35 6b 4f 23
\fter AddRoundKey:
76 55 03 48
5b d0 93 ac
ae ee c0 4a
ld 29 79 60
\fter Inverse MixColumns:
53 fa 63 77
ab 01 ca 82
)c c5 f2 f2
ca 7c 72 c9

Final Round 1:
\fter Inverse ShiftRows:
53 fa 63 77
32 ab 01 ca
f2 f2 9c c5
7c 72 c9 ca
\fter Inverse SubBytes:
)0 14 00 02
11 0e 09 10
)4 04 1c 07
)1 1e 12 10
\fter AddRoundKey:
51 66 65 67
52 67 6f 72
73 72 6e 74
54 74 66 65

)ecrypted message is: absdfgrteonfgrte
>S D:\cnslab\CNS LAB 6-10>
```

RSA :

Algorithm:

1. Select Primes: Choose two distinct large prime numbers, p and q.

2. Compute Modulus: Calculate n, where n = p * q. This becomes the modulus

for the public and private keys.

3. Calculate Euler's Totient: Compute $\phi(n)$ where $\phi(n) = (p - 1)(q - 1)$.

4. Choose Public Key: Select a number e such that $1 < e < \phi(n)$ and e is coprime to $\phi(n)$.

5. Compute Private Key: Determine d as the modular multiplicative inverse of e modulo $\phi(n)$ $(d * e) \mod \phi(n) = 1$.

Encryption:

6. Represent Message: Represent the message as an integer m, where $0 < m < n$.

7. Compute Cipher: Encrypt the message using the public key: $c = m^e \mod n$.

Decryption:

8. Compute Message: Decrypt the ciphertext using the private key: $m = c^d \mod n$.

Advantages:

• Enables secure transmission of data over insecure networks.

• Uses public and private keys for encryption and decryption, enhancing security.

• Facilitates the creation and verification of digital signatures for data integrity and authenticity.

Disadvantages:

• Larger keys are needed for higher security, leading to increased computational load.

• RSA operations, particularly with larger keys, can be computationally intensive, affecting performance.

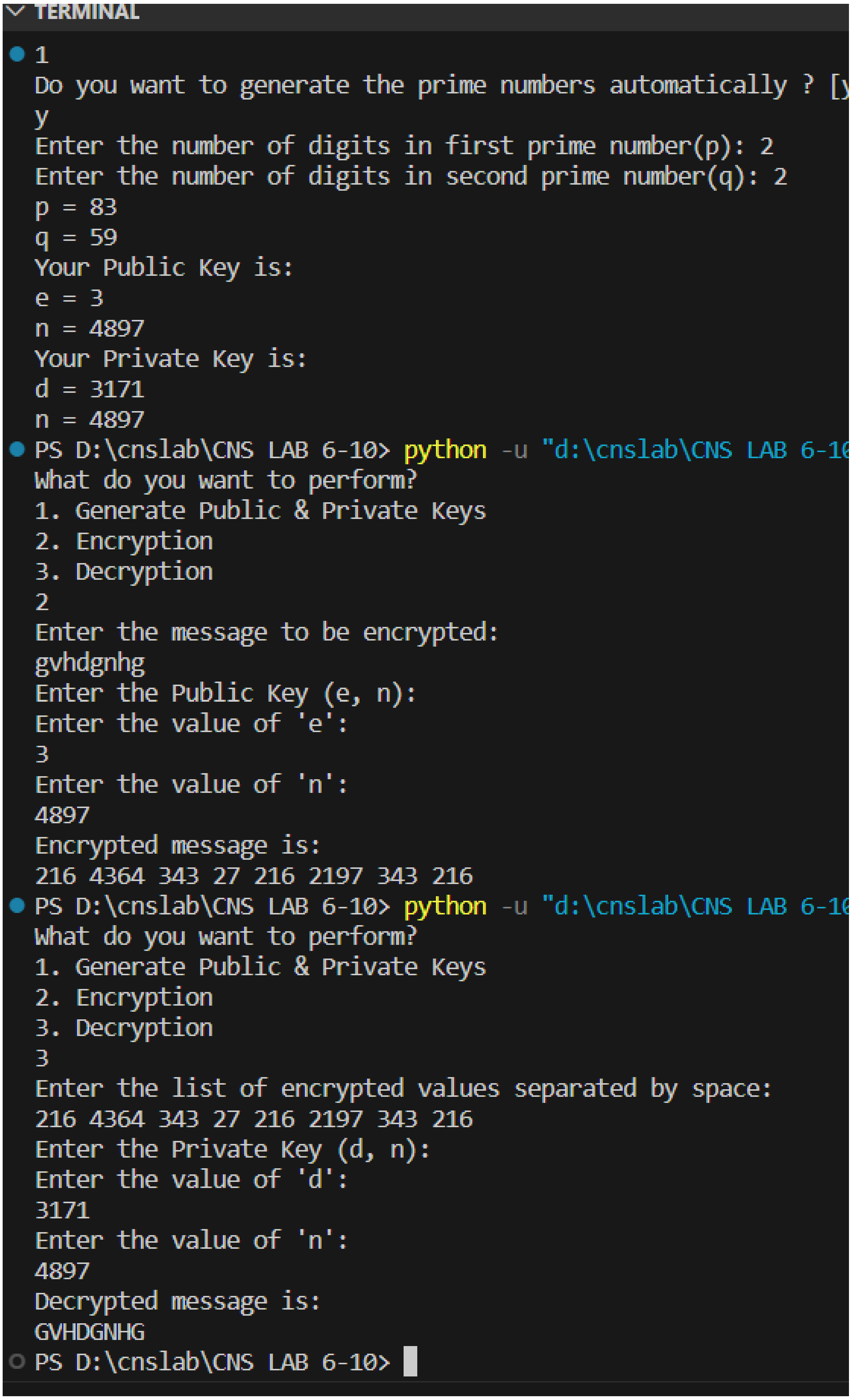
• Weaknesses in random number generation could compromise security.

Code:

```python
from generate_prime import generate_prime_no, is_prime

# Function to find mod: a^m mod n


def findExpoMod(a, m, n):
    return pow(a, m, n)


def mod_inverse(a, m):
    m0, x0, x1 = m, 0, 1
    while a > 1:
        q = a // m
        m, a = a % m, m
        x0, x1 = x1 - q * x0, x0
    return x1 + m0 if x1 < 0 else x1


def gcd(a, h):
    temp = 0
    while (1):
        temp = a % h
        if (temp == 0):
            return h
        a = h
        h = temp


def gen_keys(p, q):
    n = p*q
    phi = (p-1)*(q-1)

    e = 2
    while (e < phi):
        if (gcd(e, phi) == 1):
            break
        else:
            e += 1

    d = mod_inverse(e, phi)

    print(f"Your Public Key is:\ne = {str(e)}\nn = {str(n)}")
    print(f"Your Private Key is:\nd = {str(d)}\nn = {str(n)}")


def encrypt(message, e, n):
    # Convert alphabetic input to numerical values
    numerical_message = [ord(char) - ord('A') for char in message.upper()]

    # Encryption: C = (M ^ e) % n
    encrypted_message = [findExpoMod(char, e, n) for char in
numerical_message]
    return encrypted_message


def decrypt(encrypted_message, d, n):
    # Decryption: M = (C ^ d) % n
    decrypted_numerical_message = [findExpoMod(
        char, d, n) for char in encrypted_message]

    # Convert back to alphabetic characters
    decrypted_message = ''.join(chr(char + ord('A'))
                                for char in decrypted_numerical_message)
    return decrypted_message


# Main Code
ch = int(input("What do you want to perform?\n1. Generate Public & Private
Keys\n2. Encryption\n3. Decryption\n"))

if (ch == 1):
    gen_r = input(
        "Do you want to generate the prime numbers automatically ? [y/n]\n")
    if gen_r == 'y':
        dig_p = int(
            input("Enter the number of digits in first prime number(p): "))
        p = generate_prime_no(dig_p)
        dig_q = int(
            input("Enter the number of digits in second prime number(q): "))
        q = generate_prime_no(dig_q)

        print(f"p = {p}")
        print(f"q = {q}")

        gen_keys(p, q)

    elif gen_r == 'n':
        p = int(input("Enter first large prime number(p):\n"))
        if not is_prime(p):
            print(f"Entered number is not prime!")
            exit()

        q = int(input("Enter second large prime number(q):\n"))
        if not is_prime(q):
            print(f"Entered number is not prime!")
```

```python
            exit()

        gen_keys(p, q)

    else:
        print("Invaild choice!")
        exit()

elif (ch == 2):
    message = input("Enter the message to be encrypted:\n")
    print("Enter the Public Key (e, n):")
    e = int(input("Enter the value of 'e':\n"))
    n = int(input("Enter the value of 'n':\n"))

    encrypted_message = encrypt(message, e, n)
    print(f"Encrypted message is:\n{' '.join(map(str, encrypted_message))}")

elif (ch == 3):
    encrypted_message = list(map(int, input(
        "Enter the list of encrypted values separated by space:\n").split()))
    print("Enter the Private Key (d, n):")
    d = int(input("Enter the value of 'd':\n"))
    n = int(input("Enter the value of 'n':\n"))

    decrypted_message = decrypt(encrypted_message, d, n)

    ans = ""
    for a in decrypted_message:
        if (a < 'A' or a > 'Z'):
            ans += " "
        else:
            ans += a

    print(f"Decrypted message is:\n{ans}")

else:
    print("Invalid input!")
```

Output:



```
1
Do you want to generate the prime numbers automatically ? [y
y
Enter the number of digits in first prime number(p): 2
Enter the number of digits in second prime number(q): 2
p = 83
q = 59
Your Public Key is:
e = 3
n = 4897
Your Private Key is:
d = 3171
n = 4897
PS D:\cnslab\CNS LAB 6-10> python -u "d:\cnslab\CNS LAB 6-1
What do you want to perform?
1. Generate Public & Private Keys
2. Encryption
3. Decryption
2
Enter the message to be encrypted:
gvhdgnhg
Enter the Public Key (e, n):
Enter the value of 'e':
3
Enter the value of 'n':
4897
Encrypted message is:
216 4364 343 27 216 2197 343 216
PS D:\cnslab\CNS LAB 6-10> python -u "d:\cnslab\CNS LAB 6-1
What do you want to perform?
1. Generate Public & Private Keys
2. Encryption
3. Decryption
3
Enter the list of encrypted values separated by space:
216 4364 343 27 216 2197 343 216
Enter the Private Key (d, n):
Enter the value of 'd':
3171
Enter the value of 'n':
4897
Decrypted message is:
GVHDGNHG
PS D:\cnslab\CNS LAB 6-10>
```

RSA Factorization:

```
#include <bits/stdc++.h>
using namespace std;
int m = 1e9+7;
pair<long long, long long> factorize(long long n){
for(long long i=2; i*i<=n; i++){
if(n % i == 0){
return {i,n/i};
}
}
return {0,0};
}
int main()
{
cout<<"Enter long number which is multiplication of 2 prime numbers :";
long long n;
cin>>n;
auto ans = factorize(n);
if(ans.first == 0 && ans.second == 0){
cout<<"Enter number which is multiplication of 2 prime numbers \n";
}else{
cout << 1LL*n << " is multiplication of "<<ans.first << " and
"<<ans.second<<endl;
}
return 0;
}
```

Output:

Diffie Hellman using socket programming

The Diffie-Hellman key exchange is a method used to securely establish a

shared secret key between two parties over an insecure communication channel.

Here is an outline of the Diffie-Hellman algorithm:

1. Setup:

2. Key Exchange:

a. Public Value Calculation:

Alice computes her public value (A): A=ga mod p

Bob computes his public value (B): B=gbmod p

Alice and Bob exchange their calculated public values (A and B).

b. Shared Secret Key Generation:

Alice uses Bob's public value and her private key to compute the shared secret: s=Ba mod p

Bob uses Alice's public value and his private key to compute the same shared secret: s=Ab mod p

3. Result: Both Alice and Bob now possess a shared secret key (s) that is identical.

4. Usage of Shared Key: The shared secret key (s) can be utilized for further secure communication, such as symmetric encryption or decryption.

Advantages:

• Facilitates secure exchange of cryptographic keys over an insecure communication channel.

• Uses public and private keys, ensuring a shared secret key without directly transmitting the private keys.

• Prevents eavesdroppers from deriving the shared secret key, as it's computationally difficult to deduce from exchanged public values.

Disadvantages:

• Vulnerable to potential man-in-the-middle attacks where an intruder intercepts and alters the exchanged public keys.

• Diffie-Hellman only provides a method for secure key exchange, lacking built-in authentication mechanisms to verify the identity of the parties involved.

• If a private key is compromised, it can compromise the secrecy of the shared key in subsequent communications.

Code:

Client:

```python
import socket

# Function to find mod: a^m mod n
def findExpoMod(a, m, n):
    # Decimal to binary conversion
    m_bin = bin(m).replace("0b", "")

    # Convert it into list (individual characters)
    m_bin_lst = [int(i) for i in m_bin]

    # Initialize the list
    a_lst = [a]

    # Functions to perform operations
    # If next value = 0
    def oneOperation(num):
        return (num*num) % n

    # If next value = 1
    def twoOperation(num):
        return (a * oneOperation(num)) % n

    for j in range(len(m_bin_lst)):
        if j+1 == len(m_bin_lst):
            break

        if(m_bin_lst[j+1] == 0):
            a_lst.append(oneOperation(a_lst[j]))
        else:
            a_lst.append(twoOperation(a_lst[j]))

    return a_lst[-1]

HOST = 'localhost'
PORT = 12345
client_socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
server_address = (HOST, PORT)  # Server address and port
client_socket.connect(server_address)
print(f"Connected to server at: {HOST}:{PORT}")

# Receive the server's public key, q, alpha
received_Ya = client_socket.recv(1024)
Ya = int(received_Ya.decode())
print(f"Received server's public key as: {Ya}")
```

```python
received_q = client_socket.recv(1024)
q = int(received_q.decode())
print(f"Received large prime as: {q}")

received_alpha = client_socket.recv(1024)
alpha = int(received_alpha.decode())
print(f"Received alpha as: {alpha}")

# Client's Private Key
Xb = int(input(f"Enter the private key for B (Xb) [less than {q}]:\n"))
if Xb >= q:
    print("Private key must be less than choosen prime!")
    exit()

# Client's Public Key
Yb = findExpoMod(alpha, Xb, q)
print(f"Client's Public key is: {Yb}")

# Send this to Server
print("Sending Client's Public Key to Server...")
send_Yb = str(Yb).encode()
client_socket.sendall(send_Yb)

# Receive Server's Shared key
received_Ks = client_socket.recv(1024)
Ks = int(received_Ks.decode())
print(f"Received Server's Shared key as: {Ks}")

# Compute shared key and send to server
Kc = findExpoMod(Ya, Xb, q)
print(f"Client's Shared key is: {Kc}")

print("Sending it to server...")
send_Kc = str(Kc).encode()
client_socket.sendall(send_Kc)

if Kc == Ks:
    print("Both shared keys are equal\nKeys exchanged successfully!")
else:
    print("Both shared keys aren't equal.\nKey exchange failed!")

client_socket.close()
```

server:

```python
from generate_prime import is_prime, generate_prime_no
import socket

```

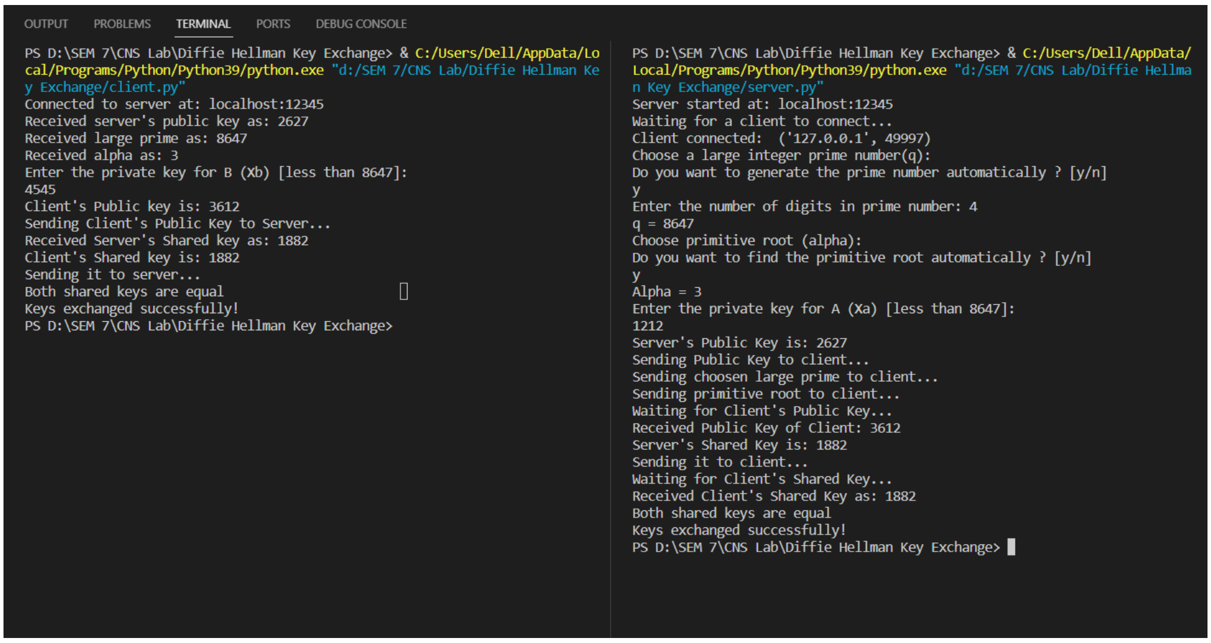
```python
# Function to find mod: a^m mod n
def findExpoMod(a, m, n):
    # Decimal to binary conversion
    m_bin = bin(m).replace("0b", "")

    # Convert it into list (individual characters)
    m_bin_lst = [int(i) for i in m_bin]

    # Initialize the list
    a_lst = [a]

    # Functions to perform operations
    # If next value = 0
    def oneOperation(num):
        return (num*num) % n

    # If next value = 1
    def twoOperation(num):
        return (a * oneOperation(num)) % n

    for j in range(len(m_bin_lst)):
        if j+1 == len(m_bin_lst):
            break

        if(m_bin_lst[j+1] == 0):
            a_lst.append(oneOperation(a_lst[j]))
        else:
            a_lst.append(twoOperation(a_lst[j]))

    return a_lst[-1]

def is_primitive_root(alpha, q):
    L = []

    for i in range(1, q):
        L.append(findExpoMod(alpha, i, q))

    for i in range(1, q):
        if L.count(i) > 1:
            L.clear()
            return False

        return True

# Initialize Socket
HOST = 'localhost'
PORT = 12345
server_socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
```

```python
server_address = (HOST, PORT)  # Server address and port
server_socket.bind(server_address)
server_socket.listen(1)
print(f"Server started at: {HOST}:{PORT}")

print("Waiting for a client to connect...")
client_socket, client_address = server_socket.accept()
print("Client connected: ", client_address)

# DH Key-exchange
# Choose prime no. 'q'
print("Choose a large integer prime number(q):")
gen_r = input("Do you want to generate the prime number automatically ?
[y/n]\n")
if gen_r == 'y':
    dig_p = int(input("Enter the number of digits in prime number: "))
    q = generate_prime_no(dig_p)
    print(f"q = {q}")
elif gen_r == 'n':
    q = int(input("Enter a large prime number:\n"))
    if not is_prime(q):
        print(f"Entered number is not prime!")
        exit()
else:
    print("Invaild choice!")
    exit()

# Choose primitive root 'alpha'
print("Choose primitive root (alpha):")
gen_pr = input("Do you want to find the primitive root automatically ?
[y/n]\n")
if gen_pr == 'y':
    for a in range(2, q):
        if is_primitive_root(a, q):
            alpha = a
            break
    print(f"Alpha = {alpha}")
elif gen_pr == 'n':
    alpha = int(input(f"Enter the primiitive root of {q}:\n"))
    if not is_primitive_root(alpha, q):
        print(f"This is not the primitive root!")
        exit()
else:
    print("Invaild choice!")
    exit()

# Server's Private key
Xa = int(input(f"Enter the private key for A (Xa) [less than {q}]:\n"))
```

```python
if Xa >= q:
    print("Private key must be less than choosen prime!")
    exit()

# Server's Public Key
Ya = findExpoMod(alpha, Xa, q)

# Send this data to client
print(f"Server's Public Key is: {Ya}")
print("Sending Public Key to client...")
send_Ya = str(Ya).encode()
client_socket.sendall(send_Ya)

print("Sending choosen large prime to client...")
send_q = str(q).encode()
client_socket.sendall(send_q)

print("Sending primitive root to client...")
send_alpha = str(alpha).encode()
client_socket.sendall(send_alpha)

print("Waiting for Client's Public Key...")

# Receive Client's Public Key
received_Yb = client_socket.recv(1024)
Yb = int(received_Yb.decode())
print(f"Received Public Key of Client: {Yb}")

# Compute shared key and send to client
Ks = findExpoMod(Yb, Xa, q)
print(f"Server's Shared Key is: {Ks}")

print("Sending it to client...")
send_Ks = str(Ks).encode()
client_socket.sendall(send_Ks)

# Receive Client's Shared Key
print("Waiting for Client's Shared Key...")
received_Kc = client_socket.recv(1024)
Kc = int(received_Kc.decode())
print(f"Received Client's Shared Key as: {Kc}")

if Ks == Kc:
    print("Both shared keys are equal\nKeys exchanged successfully!")
else:
    print("Both shared keys aren't equal.\nKey exchange failed!")

client_socket.close()
```

```
server_socket.close()
```

output:



```
PS D:\SEM 7\CNS Lab\Diffie Hellman Key Exchange> & C:/Users/Dell/AppData/Lo
cal/Programs/Python/Python39/python.exe "d:/SEM 7/CNS Lab/Diffie Hellman Ke
y Exchange/client.py"
Connected to server at: localhost:12345
Received server's public key as: 2627
Received large prime as: 8647
Received alpha as: 3
Enter the private key for B (Xb) [less than 8647]:
4545
Client's Public key is: 3612
Sending Client's Public Key to Server...
Received Server's Shared key as: 1882
Client's Shared key is: 1882
Sending it to server...
Both shared keys are equal
Keys exchanged successfully!
PS D:\SEM 7\CNS Lab\Diffie Hellman Key Exchange>
```

```
PS D:\SEM 7\CNS Lab\Diffie Hellman Key Exchange> & C:/Users/Dell/AppData/
Local/Programs/Python/Python39/python.exe "d:/SEM 7/CNS Lab/Diffie Hellma
n Key Exchange/server.py"
Server started at: localhost:12345
Waiting for a client to connect...
Client connected:  ('127.0.0.1', 49997)
Choose a large integer prime number(q):
Do you want to generate the prime number automatically ? [y/n]
y
Enter the number of digits in prime number: 4
q = 8647
Choose primitive root (alpha):
Do you want to find the primitive root automatically ? [y/n]
y
Alpha = 3
Enter the private key for A (Xa) [less than 8647]:
1212
Server's Public Key is: 2627
Sending Public Key to client...
Sending choosen large prime to client...
Sending primitive root to client...
Waiting for Client's Public Key...
Received Public Key of Client: 3612
Server's Shared Key is: 1882
Sending it to client...
Waiting for Client's Shared Key...
Received Client's Shared Key as: 1882
Both shared keys are equal
Keys exchanged successfully!
PS D:\SEM 7\CNS Lab\Diffie Hellman Key Exchange>
```

Euclidean Algorithm

The Euclidean Algorithm is a fundamental mathematical algorithm used to find the greatest common divisor (GCD) of two integers. It has various applications in number theory, cryptography, and computer science. Here are the algorithm steps, advantages, and disadvantages of the Euclidean Algorithm:

Algorithm:

• Start with two integers, 'a' and 'b,' where 'a' is greater than or equal to 'b.'

• Divide 'a' by 'b' to obtain a quotient 'q' and a remainder 'r,' such that:

a=b*q+r

• Set 'a' to 'b' and 'b' to 'r,' then repeat the division and remainder calculation until 'b' becomes zero.

• The algorithm terminates when 'b' becomes zero. The GCD is then the value of 'a' at this point.

Advantages:

• The Euclidean Algorithm is highly efficient for finding the GCD of two integers, and its time complexity is proportional to the number of bits in the input values.

• It can be applied to both positive and negative integers and is not limited to just two values; it can find the GCD of multiple integers.

• Mathematical Simplicity: The algorithm is based on simple mathematical operations (division and remainder), making it easy to understand and implement.

• Basis for Other Algorithms: The Euclidean Algorithm serves as the basis for various other algorithms, including the Extended Euclidean Algorithm used in modular arithmetic and modular inverses.

Disadvantages:

• The algorithm works well for integers, but it may not handle very large numbers efficiently due to limitations in computational resources and time.

• The Euclidean Algorithm is designed for integers and cannot be directly applied to non-integer data types.

• If implemented recursively, the algorithm may lead to a stack overflow for extremely large input values. To avoid this, an iterative version is often preferred for practical applications.

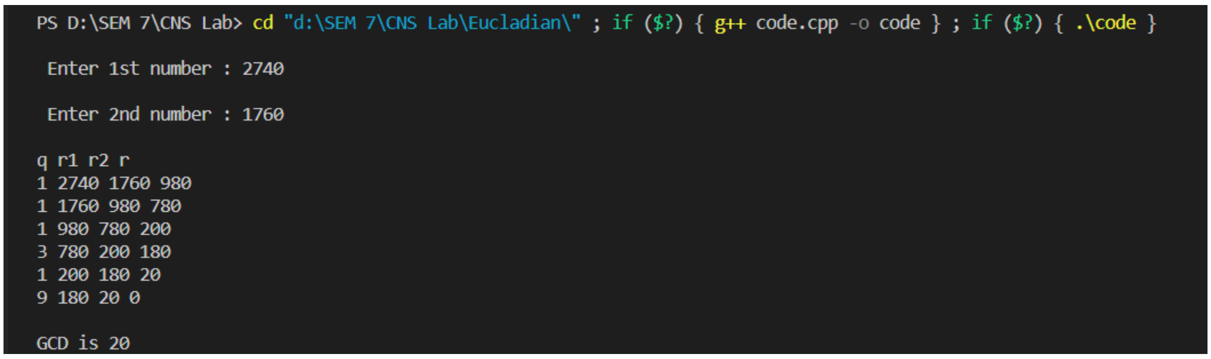
• The Euclidean Algorithm does not directly factor numbers or provide information about prime factorization, which may be needed in some applications.

Code:

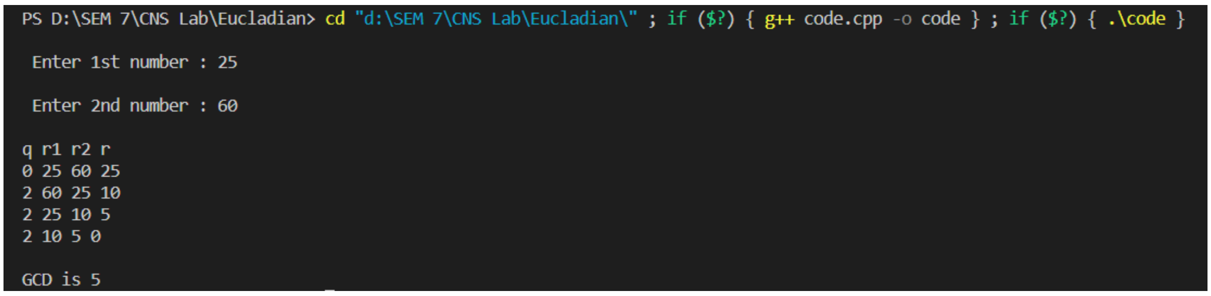
```
#include <bits/stdc++.h>
```

```cpp
using namespace std;

int ansS, ansT;

int findGcdExtended(int r1, int r2)
{
    // Base Case
    if (r2 == 0)
    {
        return r1;
    }

    int q = r1 / r2;
    int r = r1 % r2;

    cout << q << " " << r1 << " " << r2 << " " << r << endl;

    return findGcdExtended(r2, r);
}

int main()
{
    int num1, num2;
    cout << "\n Enter 1st number : ";
    cin >> num1;

    cout << "\n Enter 2nd number : ";
    cin >> num2;

    cout<<endl<< "q r1 r2 r" << endl;
    int gcd = findGcdExtended(num1, num2);
    cout <<endl<< "GCD is " << gcd << endl;
    return 0;
}
```

Output:



```
PS D:\SEM 7\CNS Lab> cd "d:\SEM 7\CNS Lab\Eucladian\" ; if ($?) { g++ code.cpp -o code } ; if ($?) { .\code }

 Enter 1st number : 2740

 Enter 2nd number : 1760

q r1 r2 r
1 2740 1760 980
1 1760 980 780
1 980 780 200
3 780 200 180
1 200 180 20
9 180 20 0

GCD is 20
```



```
PS D:\SEM 7\CNS Lab\Eucladian> cd "d:\SEM 7\CNS Lab\Eucladian\" ; if ($?) { g++ code.cpp -o code } ; if ($?) { .\code }

 Enter 1st number : 25

 Enter 2nd number : 60

q r1 r2 r
0 25 60 25
2 60 25 10
2 25 10 5
2 10 5 0

GCD is 5
```

Extended Euclidean Algorithm

The Extended Euclidean Algorithm is an extension of the Euclidean Algorithm that not only calculates the greatest common divisor (GCD) of two integers but also finds the Bézout coefficients, which are used to compute the modular inverse of an integer.

Algorithm:

1. Start with two integers 'a' and 'b,' where 'a' is greater than or equal to 'b.'
2. Initialize two sets of variables: 'x0,' 'x1,' 'y0,' and 'y1.' Set 'x0' and 'y1' to 1, and 'x1' and 'y0' to 0.
3. Divide 'a' by 'b' to obtain a quotient 'q' and a remainder 'r,' such that:
4. a = b * q + r
5. Update Variables: Update 'a' to 'b' and 'b' to 'r.' Then update the sets of variables as follows:

- 'x0' becomes 'x1.'
- 'x1' becomes 'x0 - q * x1.'
- 'y0' becomes 'y1.'
- 'y1' becomes 'y0 - q * y1.'

6. Repeat steps 3 and 4 until 'b' becomes zero.
7. At this point, 'a' is the GCD of the original 'a' and 'b,'. x0 and y0 (also called as Bézout coefficients) can be used to find the modular inverse of 'a' modulo

'b' if 'a' and 'b' are coprime (GCD = 1).

Advantages:

• The Extended Euclidean Algorithm not only finds the GCD of two integers but also computes the Bézout coefficients, which are useful for solving linear Diophantine equations and calculating modular inverses.

• It is an efficient algorithm for finding both the GCD and the Bézout coefficients. Its time complexity is proportional to the number of bits in the input values.

• The algorithm can handle both positive and negative integers, making it suitable for various applications in number theory and cryptography.

• The Bézout coefficients obtained from the Extended Euclidean Algorithm are used in modular arithmetic to find the modular inverse of an integer.

Disadvantages:

• Like the Euclidean Algorithm, the Extended Euclidean Algorithm may not handle very large numbers efficiently due to computational resource limitations.

• It is designed for integers and may not be directly applied to non-integer data types.

• While the algorithm itself is conceptually straightforward, the implementation can become complex, especially in coding the updates to the variables, leading to potential programming errors.

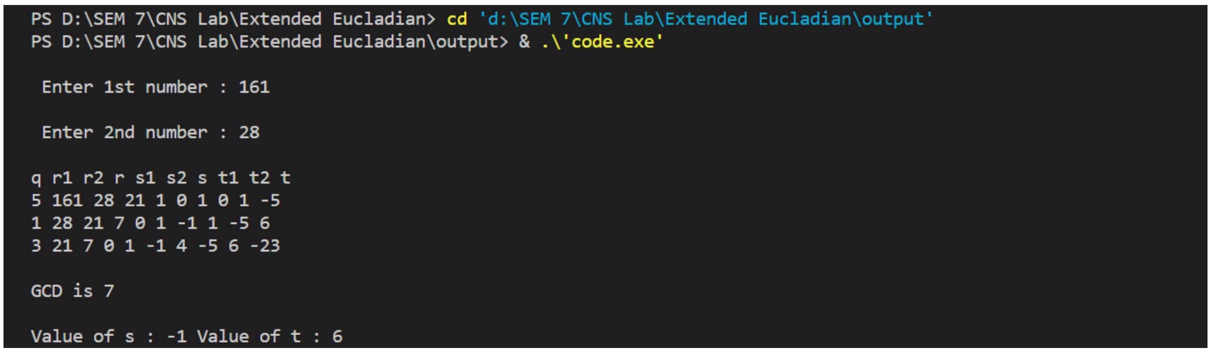
• The algorithm is primarily used for finding modular inverses and solving linear Diophantine equations. It may not be the best choice for other mathematical operations.

Code:

```cpp
#include <bits/stdc++.h>
using namespace std;
```

```cpp
int ansS, ansT;

int findGcdExtended(int r1, int r2, int s1, int s2, int t1, int t2)
{
    // Base Case
    if (r2 == 0)
    {
        ansS = s1;
        ansT = t1;
        return r1;
    }

    int q = r1 / r2;
    int r = r1 % r2;

    int s = s1 - q * s2;
    int t = t1 - q * t2;

    cout << q << " " << r1 << " " << r2 << " " << r << " " << s1 << " " << s2
<< " " << s << " " << t1 << " " << t2 << " " << t << endl;

    return findGcdExtended(r2, r, s2, s, t2, t);
}

int main()
{
    int num1, num2;
    cout << "\n Enter 1st number : ";
    cin >> num1;

    cout << "\n Enter 2nd number : ";
    cin >> num2;

    cout<<endl<< "q r1 r2 r s1 s2 s t1 t2 t" << endl;
    int gcd = findGcdExtended(num1, num2, 1, 0, 0, 1);
    cout <<endl<< "GCD is " << gcd << endl;
    cout <<endl<< "Value of s : "<<ansS << " " <<"Value of t : "<<ansT <<
endl;

    return 0;
}
```

Output:


```
PS D:\SEM 7\CNS Lab\Extended Eucladian> cd 'd:\SEM 7\CNS Lab\Extended Eucladian\output'
PS D:\SEM 7\CNS Lab\Extended Eucladian\output> & .\'code.exe'

 Enter 1st number : 161

 Enter 2nd number : 28

q r1 r2 r s1 s2 s t1 t2 t
5 161 28 21 1 0 1 0 1 -5
1 28 21 7 0 1 -1 1 -5 6
3 21 7 0 1 -1 4 -5 6 -23

GCD is 7

Value of s : -1 Value of t : 6
```

Chinese Remainder Theorem

The Chinese Remainder Theorem (CRT) is a mathematical technique used in number theory and cryptography. It is primarily used in modular arithmetic to speed up certain calculations. Here are the algorithm steps, advantages, and disadvantages of the CRT:

Algorithm:

1. Suppose you have a large integer 'N' that you want to work with and perform calculations modulo 'N.' You can break this down into simpler calculations by using the CRT.

2. First, you need to find the prime factorization of 'N.' You express 'N' as a product of its prime factors: N = p1^e1 * p2^e2 * ... * pk^ek, where p1, p2, ..., pk are distinct prime numbers, and e1, e2, ..., ek are their respective exponents.

3. For a given number 'x,' you calculate its remainders when divided by each of the prime factors. This means computing x mod p1, x mod p2, ..., x mod pk.

4. Inverse Modulus: You then calculate the modular inverse of each prime factor, which is the number 'y' such that (p1^e1 * p2^e2 * ... * pk^ek) * y ≡ 1 (mod pi) for each prime factor pi.

5. Using the remainders and the modular inverses, you can calculate the value of 'x' modulo 'N' as follows:

6. x mod N = (x mod p1) * (p1^e1 * y1) + (x mod p2) * (p2^e2 * y2) + ... + (x mod pk) * (pk^ek * yk).

Advantages:

• CRT allows you to perform modular arithmetic operations more efficiently by breaking them down into smaller computations.

• You can perform the CRT calculations for different primes in parallel, which can significantly speed up the process.

• The CRT can reduce the space needed to store large numbers in some applications.

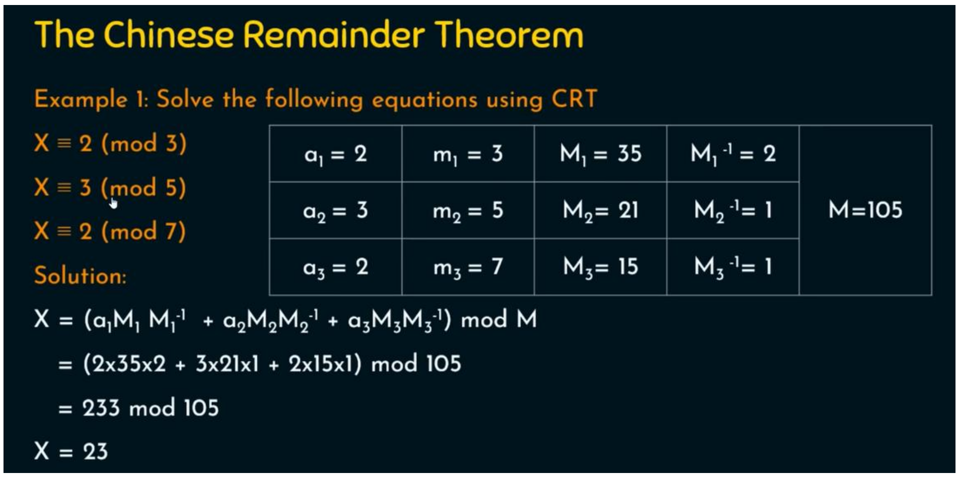
Disadvantages:

• The CRT algorithm can be complex and requires knowledge of prime factorization and modular inverses.

• CRT is applicable when you can factor 'N' into its prime factors. In cases where 'N' is not factorizable, CRT cannot be used.

• The CRT can introduce errors if not implemented carefully due to the risk of overflow or precision issues in intermediate calculations.

• In cryptography, the CRT can potentially be vulnerable to attacks if not implemented properly, leading to information leaks.



The Chinese Remainder Theorem

Example 1: Solve the following equations using CRT

$X \equiv 2 \pmod 3$

$X \equiv 3 \pmod 5$

$X \equiv 2 \pmod 7$

Solution:

$a_1 = 2$	$m_1 = 3$	$M_1 = 35$	$M_1^{-1} = 2$	
$a_2 = 3$	$m_2 = 5$	$M_2 = 21$	$M_2^{-1} = 1$	M=105
$a_3 = 2$	$m_3 = 7$	$M_3 = 15$	$M_3^{-1} = 1$	

$X = (a_1M_1 M_1^{-1} + a_2M_2M_2^{-1} + a_3M_3M_3^{-1}) \bmod M$

$= (2x35x2 + 3x21x1 + 2x15x1) \bmod 105$

$= 233 \bmod 105$

$X = 23$

Code:

```
#include<iostream>
#include<bits/stdc++.h>

using namespace std;
long long find_multiplicative_inverse(long long a, long long b) {
    long long q, r, t1 = 0, t2 = 1, t, main_a = a;

    while (b > 0) {
        q = a / b;
        r = a % b;
        t = t1 -  (t2 * q );

        a = b;
        b = r;
        t1 = t2;
        t2 = t;
    }

    if (t1 < 0) {
        t1 += main_a;
    }
    return t1;
}
int main()
{

    cout<<"________________________________________________________\n";
    cout<<"Chinese Remainder Theorem Problem  \n";
    cout<<"________________________________________________________\n";

    cout<<"Suppose that equation needs to be in form of X = a (mod m)\n";

    cout<<"How many equations you want to perfrom : \t";
    int count;
    cin>>count;
     cout<<"\n________________________________________________________\n";
    int M=1;
    vector<int> a,m;
    for(int i=0;i<count;i++)
    {
        cout<<"Equation No : \t"<<i+1<<endl;
        cout<<"Enter a :\t";
        int a_data;
        cin>>a_data;
        cout<<"Enter m :\t";
        int m_data;
        cin>>m_data;
        a.push_back(a_data);
        m.push_back(m_data);
         cout<<"\n____________________________________________________________
________________________\n";
        M=M*m_data;
   }
    cout<<"\nValue of M  :\t"<<M<<endl;
    vector<long long > M_vector,M_inverse_vector;

    for(int i=0;i<count;i++)
    {
        M_vector.push_back(M/m[i]);

    }

    for(int i=0;i<count;i++)
    {
        M_inverse_vector.push_back(find_multiplicative_inverse(m[i],M_vector[i
]));

    }

    long long sum=0;
    for(int i=0;i<count;i++)
    {
        sum+=(a[i] * M_vector[i] * M_inverse_vector[i]);
    }
    long long ans=sum%M;
    cout<<"\nAfter calculations :\n";
    cout <<
"_____________________________________________________________________________
_________________\n";
    cout << "|\tEq. No\t|\ta[i]\t|\tm[i]\t|\tM[i]\t|\tM_inverse[i]\t|\n";
    cout <<
"_____________________________________________________________________________
_________________\n";

    for(int i=0;i<count;i++)
    {
            cout<<"|\t"<<i+1<<"\t|\t"<<a[i]<<"\t|\t"<<m[i]<<"\t|\t"<<M_vector[
i]<<"\t|\t"<<M_inverse_vector[i]<<"\t\t|\n";
            cout <<
"_____________________________________________________________________________
_________________\n";

    }
    cout<<"\nUsing formula X= E (a[i]*m[i]*m^-1[i]) mod M \n";
    cout<<"Value of X is approximate equal to  :  "<<ans;
    return 0;
}
```

Output: