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Subject: CNS Lab
PRN: 2019BTECS00034

Assignment 7

Aim: To encrypt given plain text using DES algorithm.

Theory:
DES is a block cipher and encrypts data in blocks of size of 64 bits each, which means 64 bits of plain text go as the input to DES, which produces 64 bits of ciphertext. The same algorithm and key are used for encryption and decryption, with minor differences. The key length is 56 bits.

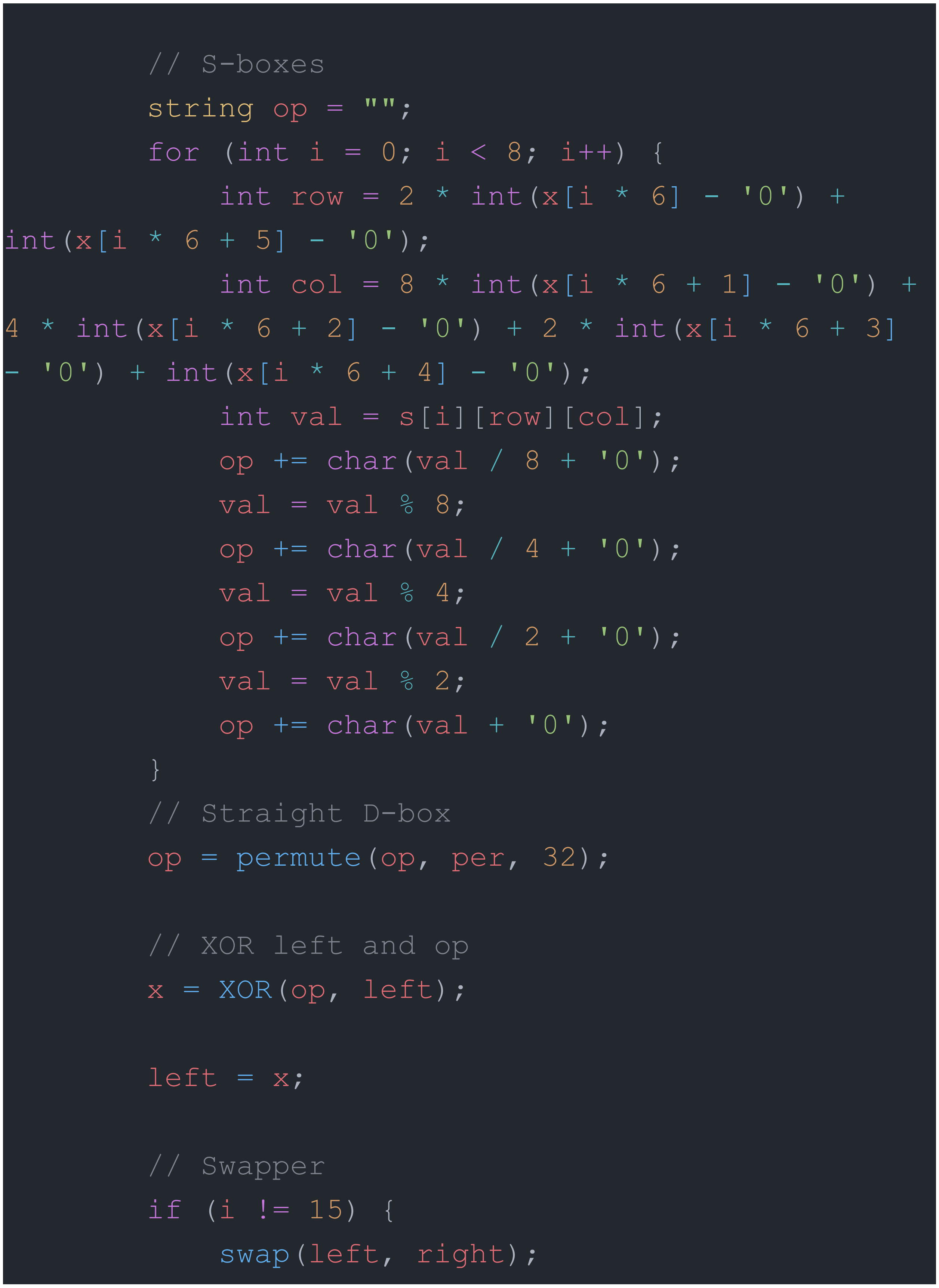
Code:

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

string hexToBin(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";
    stringstream bin;
    for (int i = 0; i < s.size(); i++) {
        bin << mp[s[i]];
    }
    return bin.str();
}
string binToHex(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";
```

```cpp
    stringstream hex;
    for (int i = 0; i < s.length(); i += 4) {
        string ch = s.substr(i, 4);
        hex << mp[ch];
    }
    return hex.str();
}

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

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

string encrypt(string plain, vector<string> rkb,
vector<string> rk) {
    // Hexadecimal to binary
    plain = hexToBin(plain);

    // Initial Permutation Table
    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};
    // Initial Permutation
    plain = permute(plain, initial_perm, 64);
    cout << "After initial permutation: " <<
binToHex(plain) << endl;

    // Splitting
    string left = plain.substr(0, 32);
    string right = plain.substr(32, 32);
    cout << "After splitting: L0=" <<
binToHex(left)
         << " R0=" << binToHex(right) << endl;

    // Expansion D-box Table
    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};
```

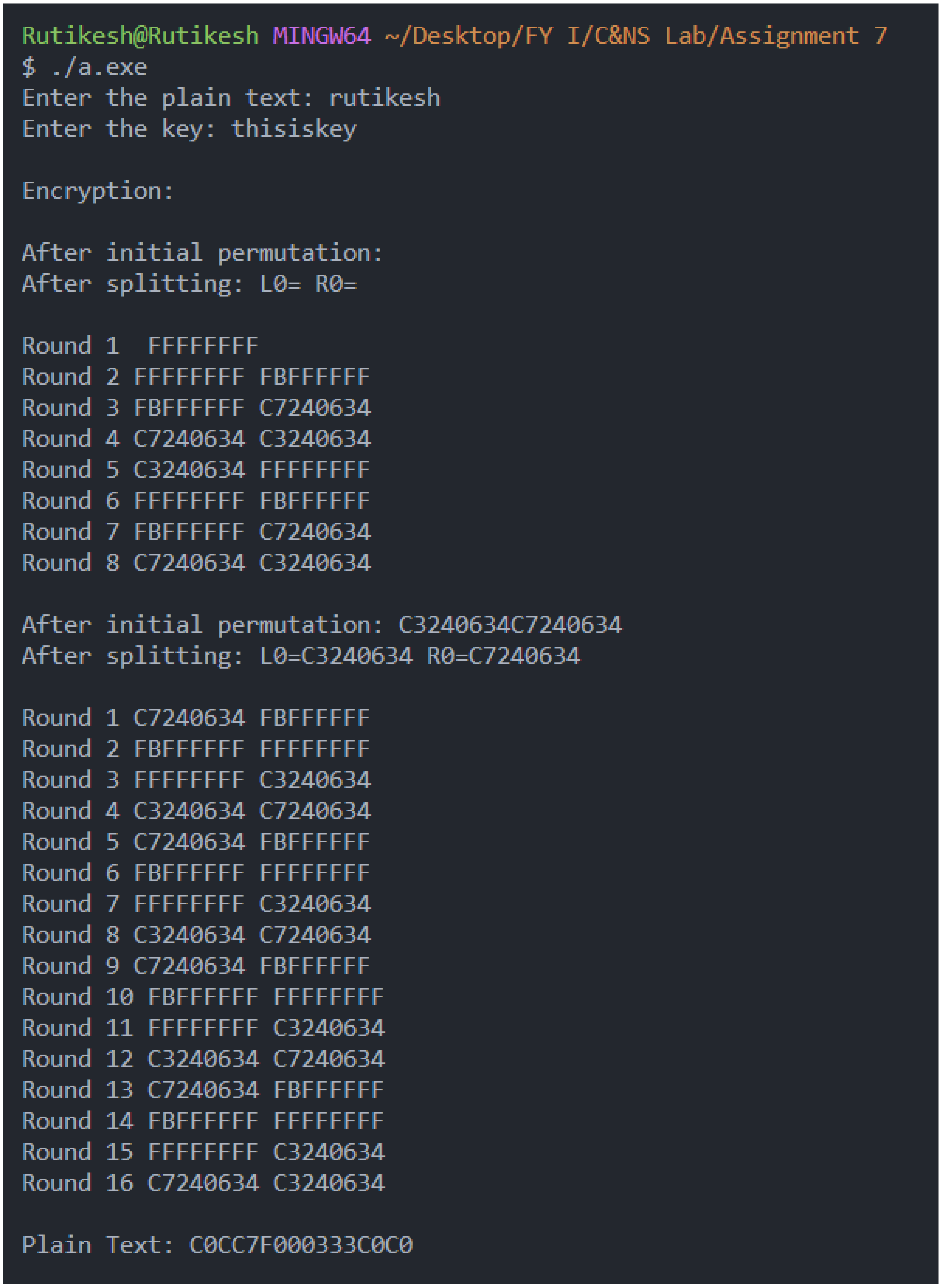
```
    // S-box Table
    int s[8][4][16] = {{14, 4, 13, 1, 2, 15, 11, 8,
3, 10, 6, 12, 5, 9, 0, 7,
                        0, 15, 7, 4, 14, 2, 13, 1,
10, 6, 12, 11, 9, 5, 3, 8,
                        4, 1, 14, 8, 13, 6, 2, 11,
15, 12, 9, 7, 3, 10, 5, 0,
                        15, 12, 8, 2, 4, 9, 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}};

    // Straight Permutation Table
    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++) {
        // Expansion D-box
        string right_expanded = permute(right,
exp_d, 48);

        // XOR RoundKey[i] and right_expanded
        string x = XOR(rkb[i], right_expanded);
```



```
        // S-boxes
        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');
        }
        // Straight D-box
        op = permute(op, per, 32);

        // XOR left and op
        x = XOR(op, left);

        left = x;

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

    // Combination
    string combine = left + right;

    // Final Permutation Table
    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};

    // Final Permutation
    string cipher = binToHex(permute(combine,
final_perm, 64));
    return cipher;
}
int main() {
    string plain, key;

    // plain = "This is a test text";
    // key = "this is a test";
    // Key Generation

    cout << "Enter the plain text: ";
    getline(cin, plain);
    cout << "Enter the key: ";
    getline(cin, key);

    // Hex to binary
    key = hexToBin(key);

    // Parity bit drop table
    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};
    // getting 56 bit key from 64 bit using the
parity bits
    key = permute(key, keyp, 56); // key without
parity

    // Number of bit shifts
    int shift_table[16] = {1, 1, 2, 2,
                           2, 2, 2, 2,
                           1, 2, 2, 2,
                           2, 2, 2, 1};

    // Key- Compression Table
    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};

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

    vector<string> rkb; // rkb for RoundKeys in
binary
    vector<string> rk;  // rk for RoundKeys in
hexadecimal
```

```
    for (int i = 0; i < 16; i++) {
        // Shifting
        left = shiftLeft(left, shift_table[i]);
        right = shiftLeft(right, shift_table[i]);

        // Combining
        string combine = left + right;

        // Key Compression
        string RoundKey = permute(combine,
key_comp, 48);

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

    cout << "\nEncryption:\n\n";
    string cipher = encrypt(plain, 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;
}
```

Output:



```
Rutikesh@Rutikesh MINGW64 ~/Desktop/FY I/C&NS Lab/Assignment 7
$ ./a.exe
Enter the plain text: rutikesh
Enter the key: thisiskey

Encryption:

After initial permutation:
After splitting: L0= R0=

Round 1  FFFFFFFF
Round 2 FFFFFFFF FBFFFFFF
Round 3 FBFFFFFF C7240634
Round 4 C7240634 C3240634
Round 5 C3240634 FFFFFFFF
Round 6 FFFFFFFF FBFFFFFF
Round 7 FBFFFFFF C7240634
Round 8 C7240634 C3240634

After initial permutation: C3240634C7240634
After splitting: L0=C3240634 R0=C7240634

Round 1 C7240634 FBFFFFFF
Round 2 FBFFFFFF FFFFFFFF
Round 3 FFFFFFFF C3240634
Round 4 C3240634 C7240634
Round 5 C7240634 FBFFFFFF
Round 6 FBFFFFFF FFFFFFFF
Round 7 FFFFFFFF C3240634
Round 8 C3240634 C7240634
Round 9 C7240634 FBFFFFFF
Round 10 FBFFFFFF FFFFFFFF
Round 11 FFFFFFFF C3240634
Round 12 C3240634 C7240634
Round 13 C7240634 FBFFFFFF
Round 14 FBFFFFFF FFFFFFFF
Round 15 FFFFFFFF C3240634
Round 16 C7240634 C3240634

Plain Text: C0CC7F000333C0C0
```