Lab-10

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Aim: **Write a program to implement DES cipher.**

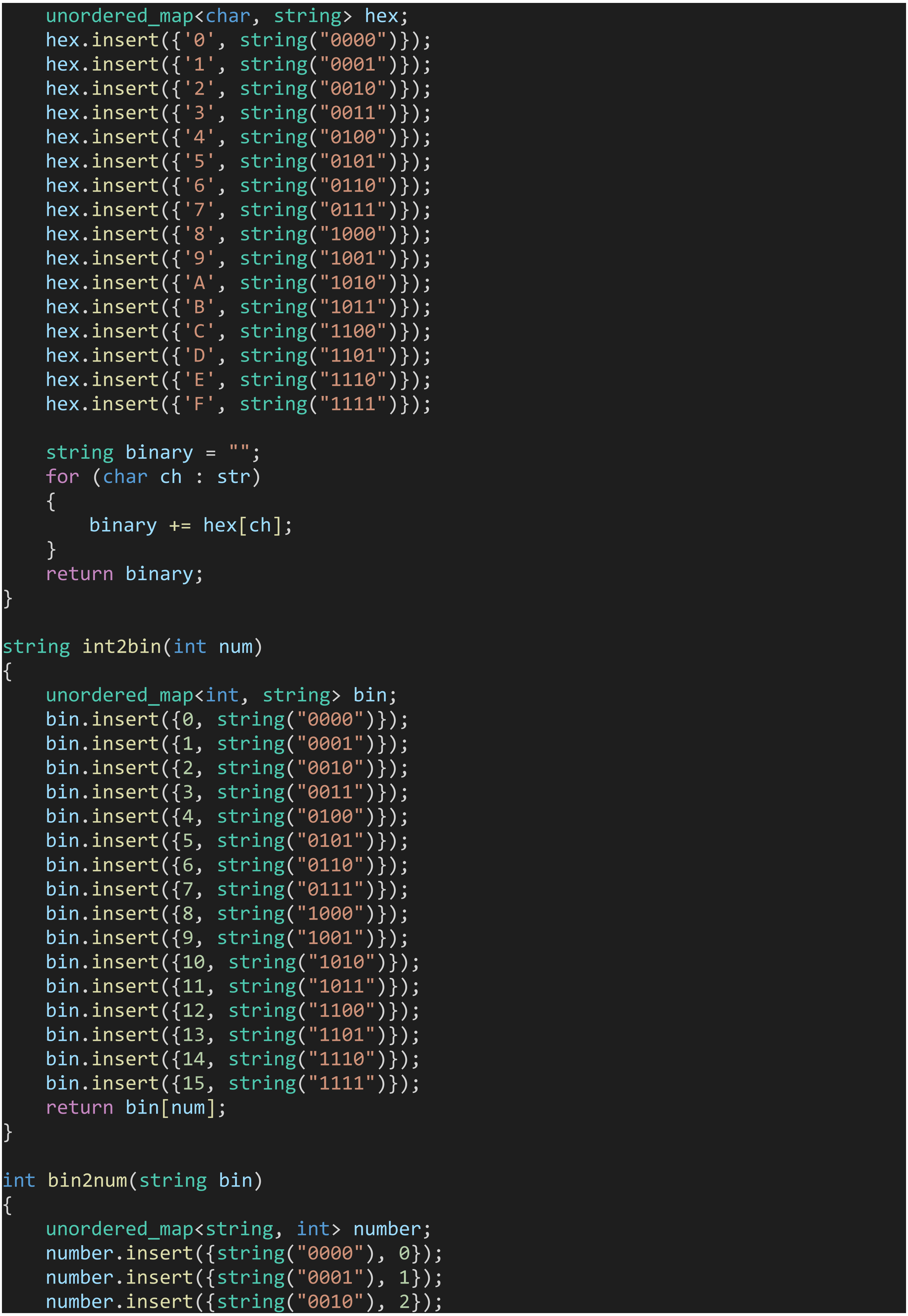
- **Round Function Implementation**

Source Code:

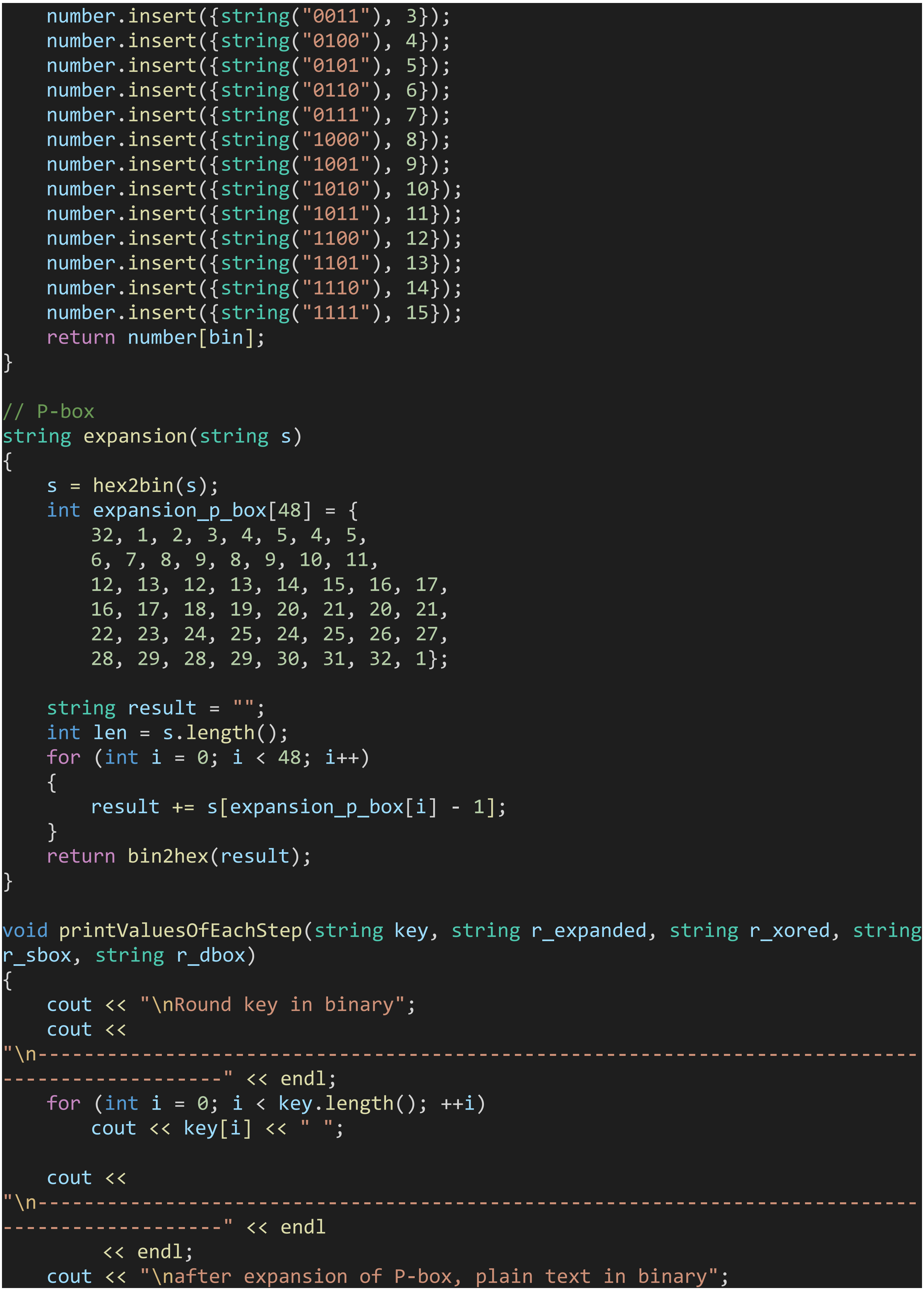
Programming Language : C++

Ans:

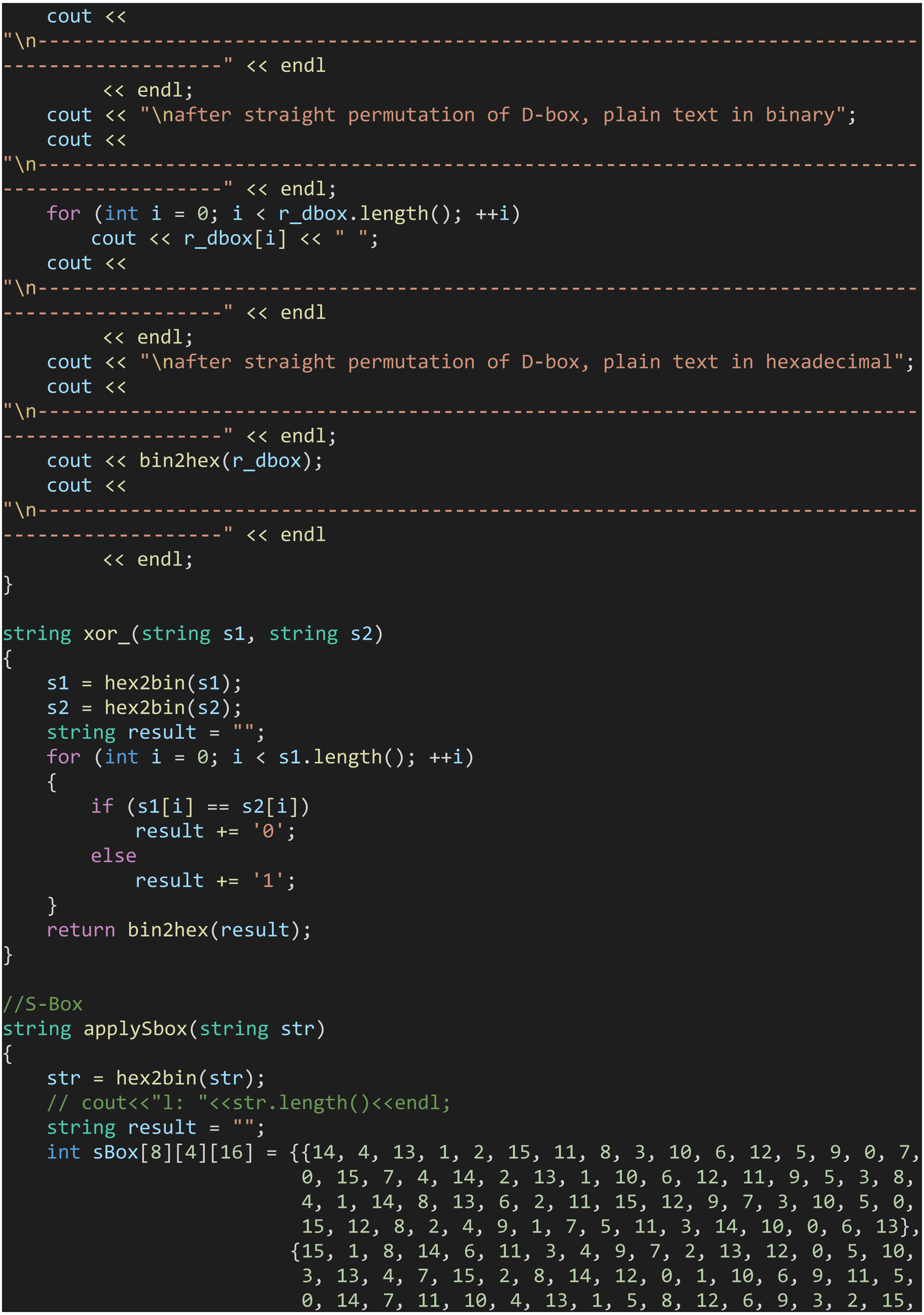
```
#include "../functions.h"

string bin2hex(string str)
{
    unordered_map<string, char> bin;
    bin.insert({string("0000"), '0'});
    bin.insert({string("0001"), '1'});
    bin.insert({string("0010"), '2'});
    bin.insert({string("0011"), '3'});
    bin.insert({string("0100"), '4'});
    bin.insert({string("0101"), '5'});
    bin.insert({string("0110"), '6'});
    bin.insert({string("0111"), '7'});
    bin.insert({string("1000"), '8'});
    bin.insert({string("1001"), '9'});
    bin.insert({string("1010"), 'A'});
    bin.insert({string("1011"), 'B'});
    bin.insert({string("1100"), 'C'});
    bin.insert({string("1101"), 'D'});
    bin.insert({string("1110"), 'E'});
    bin.insert({string("1111"), 'F'});

    string hex = "";
    for (int i = 0; i <= (str.length() - 3); i += 4)
    {
        string temp = str.substr(i, 4);
        hex += bin[temp];
    }
    return hex;
}

string hex2bin(string str)
{
```



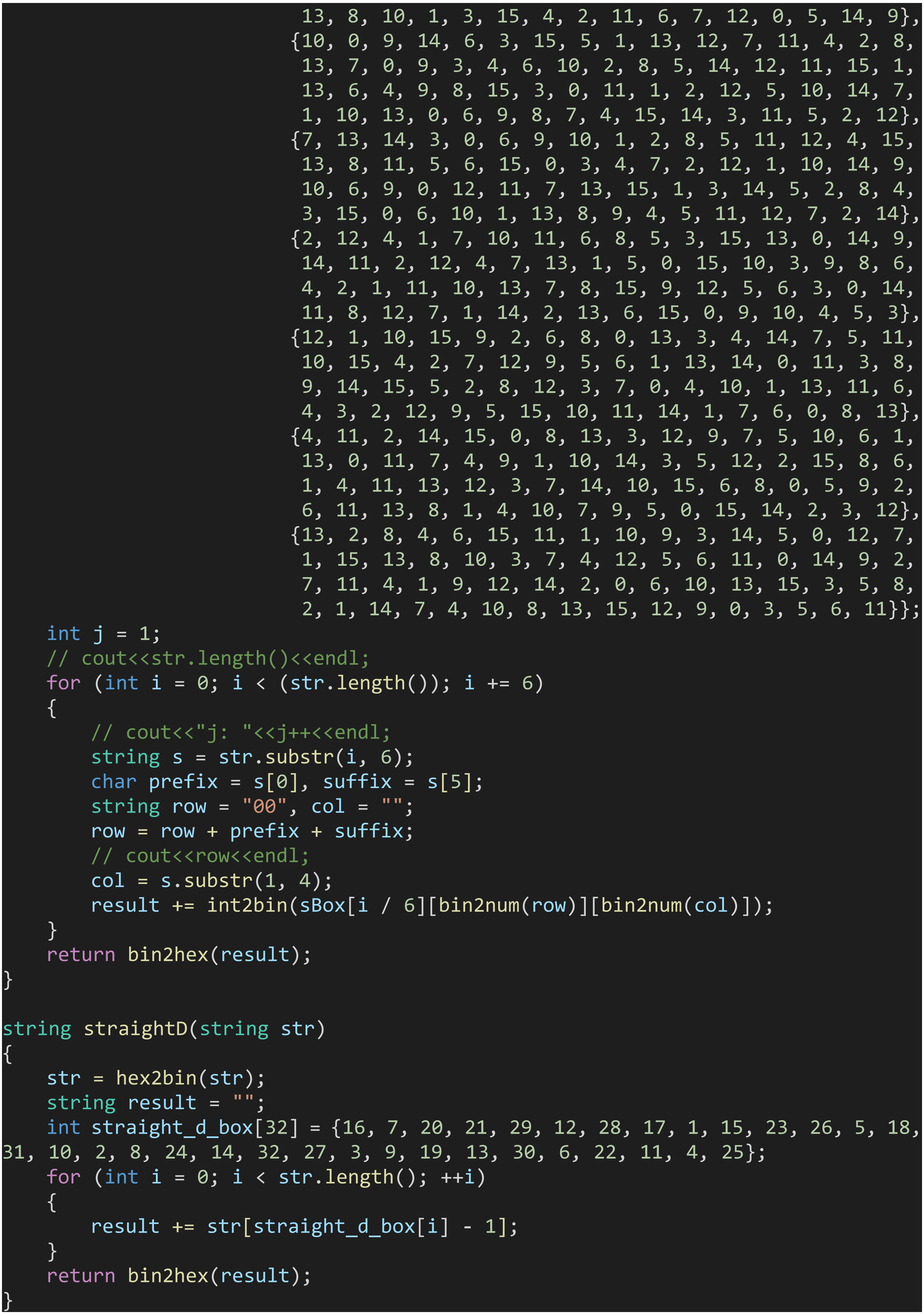
```
    unordered_map<char, string> hex;
    hex.insert({'0', string("0000")});
    hex.insert({'1', string("0001")});
    hex.insert({'2', string("0010")});
    hex.insert({'3', string("0011")});
    hex.insert({'4', string("0100")});
    hex.insert({'5', string("0101")});
    hex.insert({'6', string("0110")});
    hex.insert({'7', string("0111")});
    hex.insert({'8', string("1000")});
    hex.insert({'9', string("1001")});
    hex.insert({'A', string("1010")});
    hex.insert({'B', string("1011")});
    hex.insert({'C', string("1100")});
    hex.insert({'D', string("1101")});
    hex.insert({'E', string("1110")});
    hex.insert({'F', string("1111")});

    string binary = "";
    for (char ch : str)
    {
        binary += hex[ch];
    }
    return binary;
}

string int2bin(int num)
{
    unordered_map<int, string> bin;
    bin.insert({0, string("0000")});
    bin.insert({1, string("0001")});
    bin.insert({2, string("0010")});
    bin.insert({3, string("0011")});
    bin.insert({4, string("0100")});
    bin.insert({5, string("0101")});
    bin.insert({6, string("0110")});
    bin.insert({7, string("0111")});
    bin.insert({8, string("1000")});
    bin.insert({9, string("1001")});
    bin.insert({10, string("1010")});
    bin.insert({11, string("1011")});
    bin.insert({12, string("1100")});
    bin.insert({13, string("1101")});
    bin.insert({14, string("1110")});
    bin.insert({15, string("1111")});
    return bin[num];
}

int bin2num(string bin)
{
    unordered_map<string, int> number;
    number.insert({string("0000"), 0});
    number.insert({string("0001"), 1});
    number.insert({string("0010"), 2});
```



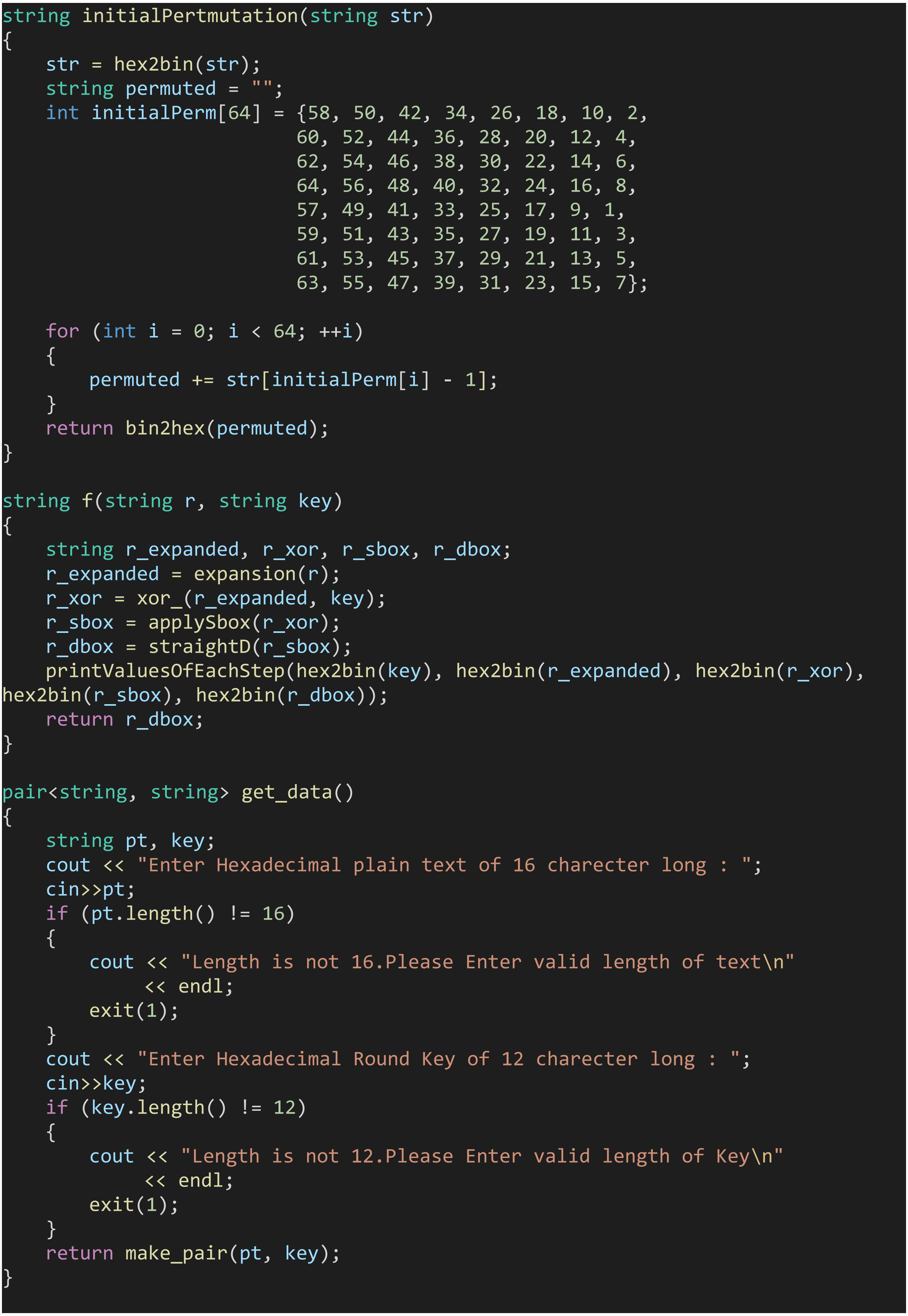
```
    number.insert({string("0011"), 3});
    number.insert({string("0100"), 4});
    number.insert({string("0101"), 5});
    number.insert({string("0110"), 6});
    number.insert({string("0111"), 7});
    number.insert({string("1000"), 8});
    number.insert({string("1001"), 9});
    number.insert({string("1010"), 10});
    number.insert({string("1011"), 11});
    number.insert({string("1100"), 12});
    number.insert({string("1101"), 13});
    number.insert({string("1110"), 14});
    number.insert({string("1111"), 15});
    return number[bin];
}

// P-box
string expansion(string s)
{
    s = hex2bin(s);
    int expansion_p_box[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};

    string result = "";
    int len = s.length();
    for (int i = 0; i < 48; i++)
    {
        result += s[expansion_p_box[i] - 1];
    }
    return bin2hex(result);
}

void printValuesOfEachStep(string key, string r_expanded, string r_xored, string
r_sbox, string r_dbox)
{
    cout << "\nRound key in binary";
    cout <<
"\n-------------------------------------------------------------------------------
--------------------" << endl;
    for (int i = 0; i < key.length(); ++i)
        cout << key[i] << " ";

    cout <<
"\n-------------------------------------------------------------------------------
--------------------" << endl
         << endl;
    cout << "\nafter expansion of P-box, plain text in binary";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    for (int i = 0; i < r_expanded.length(); ++i)
        cout << r_expanded[i] << " ";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter expansion of P-box, plain text in hexadecimal";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    cout << bin2hex(r_expanded);
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter xor with round key, plain text in binary";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    for (int i = 0; i < r_xored.length(); ++i)
        cout << r_xored[i] << " ";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter xor with round key, plain text in hexadecimal";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    cout << bin2hex(r_xored);
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter applying S-box, plain text in binary";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    for (int i = 0; i < r_sbox.length(); ++i)
        cout << r_sbox[i] << " ";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter applying S-box, plain text in hexadecimal";
    cout <<
"\n-------------------------------------------------------------------------------
-------------------" << endl;
    cout << bin2hex(r_sbox);
```



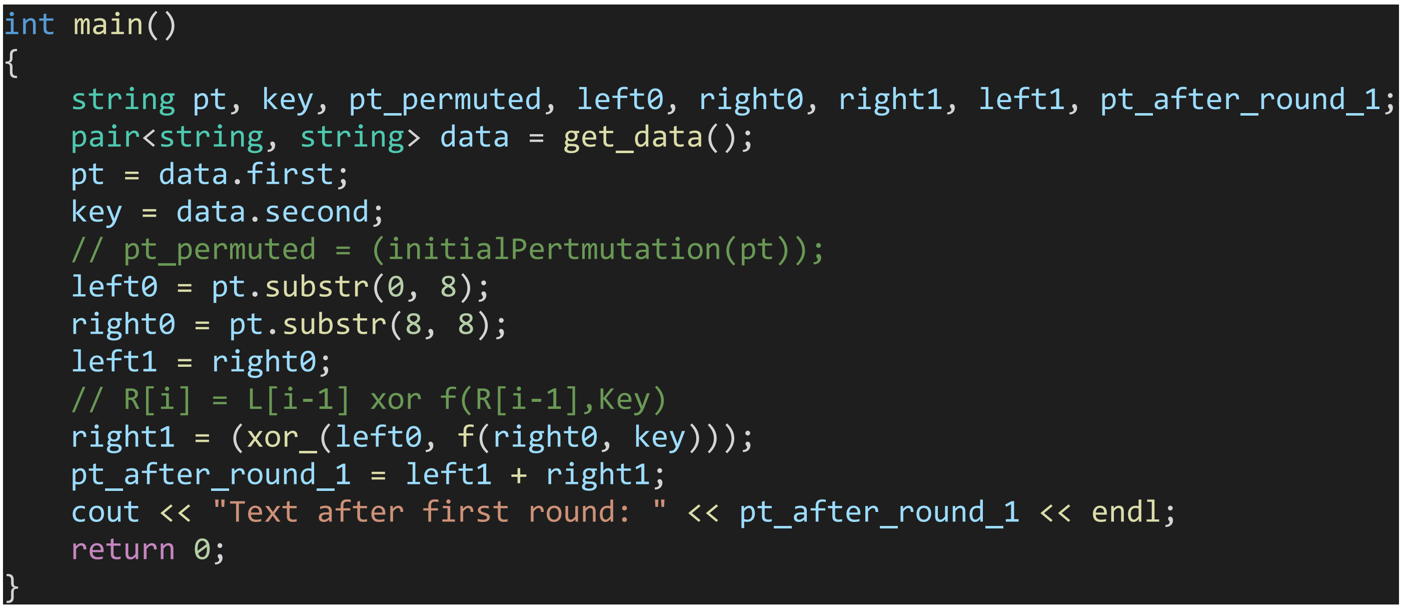
```
    cout <<
"\n----------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter straight permutation of D-box, plain text in binary";
    cout <<
"\n----------------------------------------------------------------------------
-------------------" << endl;
    for (int i = 0; i < r_dbox.length(); ++i)
        cout << r_dbox[i] << " ";
    cout <<
"\n----------------------------------------------------------------------------
-------------------" << endl
         << endl;
    cout << "\nafter straight permutation of D-box, plain text in hexadecimal";
    cout <<
"\n----------------------------------------------------------------------------
-------------------" << endl;
    cout << bin2hex(r_dbox);
    cout <<
"\n----------------------------------------------------------------------------
-------------------" << endl
         << endl;
}

string xor_(string s1, string s2)
{
    s1 = hex2bin(s1);
    s2 = hex2bin(s2);
    string result = "";
    for (int i = 0; i < s1.length(); ++i)
    {
        if (s1[i] == s2[i])
            result += '0';
        else
            result += '1';
    }
    return bin2hex(result);
}

//S-Box
string applySbox(string str)
{
    str = hex2bin(str);
    // cout<<"l: "<<str.length()<<endl;
    string result = "";
    int sBox[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 j = 1;
    // cout<<str.length()<<endl;
    for (int i = 0; i < (str.length()); i += 6)
    {
        // cout<<"j: "<<j++<<endl;
        string s = str.substr(i, 6);
        char prefix = s[0], suffix = s[5];
        string row = "00", col = "";
        row = row + prefix + suffix;
        // cout<<row<<endl;
        col = s.substr(1, 4);
        result += int2bin(sBox[i / 6][bin2num(row)][bin2num(col)]);
    }
    return bin2hex(result);
}

string straightD(string str)
{
    str = hex2bin(str);
    string result = "";
    int straight_d_box[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};
    for (int i = 0; i < str.length(); ++i)
    {
        result += str[straight_d_box[i] - 1];
    }
    return bin2hex(result);
}
```



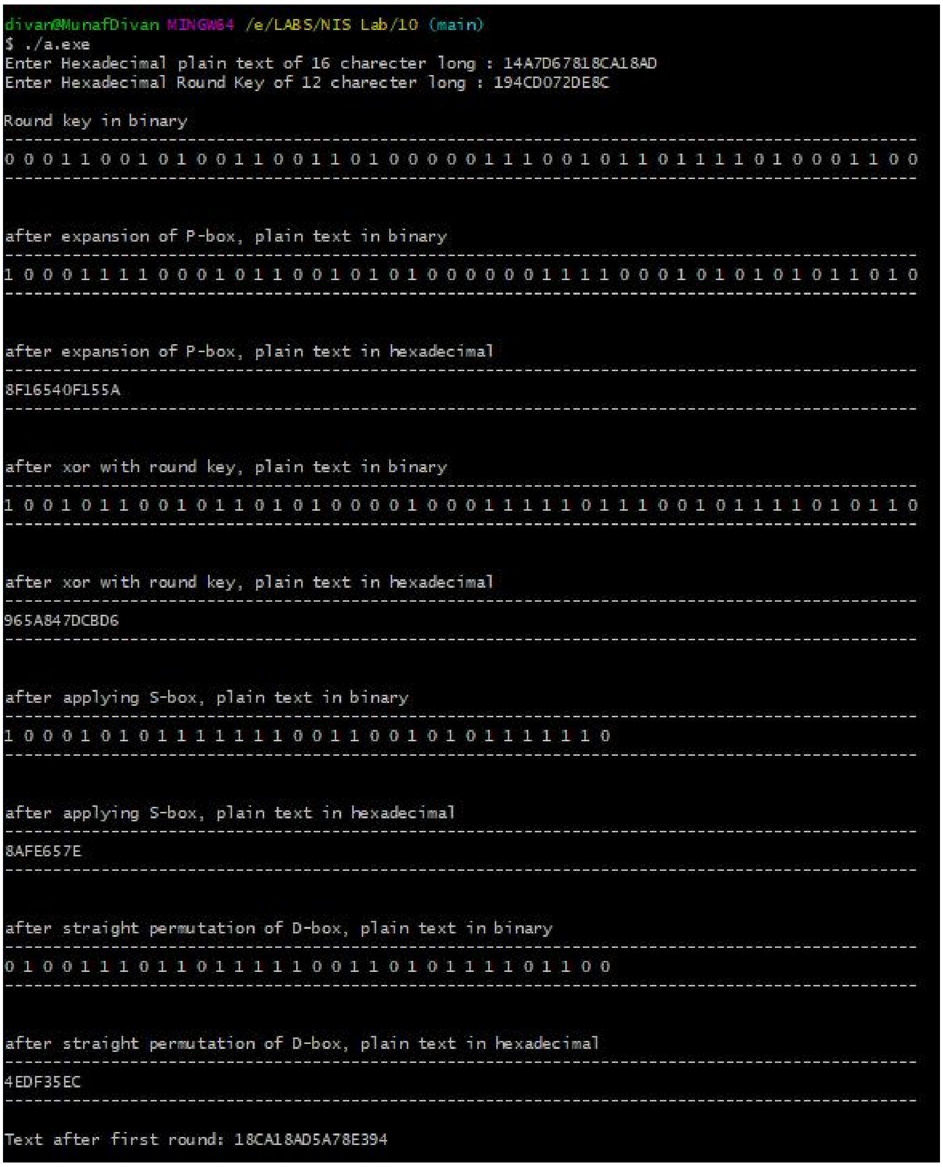
```
string initialPertmutation(string str)
{
    str = hex2bin(str);
    string permuted = "";
    int initialPerm[64] = {58, 50, 42, 34, 26, 18, 10, 2,
                           60, 52, 44, 36, 28, 20, 12, 4,
                           62, 54, 46, 38, 30, 22, 14, 6,
                           64, 56, 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};

    for (int i = 0; i < 64; ++i)
    {
        permuted += str[initialPerm[i] - 1];
    }
    return bin2hex(permuted);
}

string f(string r, string key)
{
    string r_expanded, r_xor, r_sbox, r_dbox;
    r_expanded = expansion(r);
    r_xor = xor_(r_expanded, key);
    r_sbox = applySbox(r_xor);
    r_dbox = straightD(r_sbox);
    printValuesOfEachStep(hex2bin(key), hex2bin(r_expanded), hex2bin(r_xor),
hex2bin(r_sbox), hex2bin(r_dbox));
    return r_dbox;
}

pair<string, string> get_data()
{
    string pt, key;
    cout << "Enter Hexadecimal plain text of 16 charecter long : ";
    cin>>pt;
    if (pt.length() != 16)
    {
        cout << "Length is not 16.Please Enter valid length of text\n"
             << endl;
        exit(1);
    }
    cout << "Enter Hexadecimal Round Key of 12 charecter long : ";
    cin>>key;
    if (key.length() != 12)
    {
        cout << "Length is not 12.Please Enter valid length of Key\n"
             << endl;
        exit(1);
    }
    return make_pair(pt, key);
}
```



```cpp
int main()
{
    string pt, key, pt_permuted, left0, right0, right1, left1, pt_after_round_1;
    pair<string, string> data = get_data();
    pt = data.first;
    key = data.second;
    // pt_permuted = (initialPertmutation(pt));
    left0 = pt.substr(0, 8);
    right0 = pt.substr(8, 8);
    left1 = right0;
    // R[i] = L[i-1] xor f(R[i-1],Key)
    right1 = (xor_(left0, f(right0, key)));
    pt_after_round_1 = left1 + right1;
    cout << "Text after first round: " << pt_after_round_1 << endl;
    return 0;
}
```

Input & Output Screenshots:

1)



```
divan@MunafDivan MINGW64 /e/LABS/NIS Lab/10 (main)
$ ./a.exe
Enter Hexadecimal plain text of 16 charecter long : 14A7D67818CA18AD
Enter Hexadecimal Round Key of 12 charecter long : 194CD072DE8C

Round key in binary
-----------------------------------------------------------------------------------------------
0 0 0 1 1 0 0 1 0 1 0 0 1 1 0 0 1 1 0 1 0 0 0 0 0 1 1 1 0 0 1 0 1 1 0 1 1 1 1 0 1 0 0 0 1 1 0 0
-----------------------------------------------------------------------------------------------


after expansion of P-box, plain text in binary
-----------------------------------------------------------------------------------------------
1 0 0 0 1 1 1 1 0 0 0 1 0 1 1 0 0 1 0 1 0 1 0 0 0 0 0 0 1 1 1 1 0 0 0 1 0 1 0 1 0 1 0 1 1 0 1 0
-----------------------------------------------------------------------------------------------


after expansion of P-box, plain text in hexadecimal
-----------------------------------------------------------------------------------------------
8F16540F155A
-----------------------------------------------------------------------------------------------


after xor with round key, plain text in binary
-----------------------------------------------------------------------------------------------
1 0 0 1 0 1 1 0 0 1 0 1 1 0 1 0 1 0 0 0 0 1 0 0 0 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 1 1 0 1 0 1 1 0
-----------------------------------------------------------------------------------------------


after xor with round key, plain text in hexadecimal
-----------------------------------------------------------------------------------------------
965A847DCBD6
-----------------------------------------------------------------------------------------------


after applying S-box, plain text in binary
-----------------------------------------------------------------------------------------------
1 0 0 0 1 0 1 0 1 1 1 1 1 1 1 0 0 1 1 0 0 1 0 1 0 1 1 1 1 1 1 0
-----------------------------------------------------------------------------------------------


after applying S-box, plain text in hexadecimal
-----------------------------------------------------------------------------------------------
8AFE657E
-----------------------------------------------------------------------------------------------


after straight permutation of D-box, plain text in binary
-----------------------------------------------------------------------------------------------
0 1 0 0 1 1 1 0 1 1 0 1 1 1 1 1 0 0 1 1 0 1 0 1 1 1 1 0 1 1 0 0
-----------------------------------------------------------------------------------------------


after straight permutation of D-box, plain text in hexadecimal
-----------------------------------------------------------------------------------------------
4EDF35EC
-----------------------------------------------------------------------------------------------

Text after first round: 18CA18AD5A78E394
```