

Initially, we want to construct a list of Roman denomination letters. Write the list in descending order, putting the largest denomination first and the smallest denomination last. Refer to table 1.

| Roman Denomination Letter | Roman Denomination Value | Roman Denomination Letter | Roman Denomination Value |
|---------------------------|--------------------------|---------------------------|--------------------------|
| M                         | 1000                     | X                         | 10                       |
| D                         | 500                      | V                         | 5                        |
| C                         | 100                      | I                         | 1                        |
| L                         | 50                       |                           |                          |

Table 1. Roman Denomination Letters

The algorithm for transforming a *decimal value* into Roman numerals is quite simple.

1. Traverse the list of Roman denomination pairs {(M,1000),(D,500),(C,100),(L,50),(X,10),(V,5),(I,1)}. The first value in the pair is the *Roman denomination letter*, the second is the *Roman denomination value*.
  - 1.1. **while** (*decimal value* >= Roman denomination value) {
    - 1.1.1. print the *Roman denomination letter*
    - 1.1.2. subtract the *Roman denomination value* from the *decimal value*

**Example:** Convert 4769 to Roman numerals.

|                                                                    |                  |                  |                  |                 |     |
|--------------------------------------------------------------------|------------------|------------------|------------------|-----------------|-----|
| Decimal Value                                                      | 4769             | 3769             | 2769             | 1769            | 769 |
| Is the decimal value >= 1000                                       | yes              | yes              | yes              | yes             | no  |
| Yes, print an <b>M</b><br>and subtract 1000 from the decimal value | <b>M</b><br>3769 | <b>M</b><br>2769 | <b>M</b><br>1769 | <b>M</b><br>769 |     |
| No, go on to next smaller Roman denomination                       |                  |                  |                  |                 |     |
| <b>4769=MMMM</b>                                                   |                  |                  |                  |                 |     |

|                                                                  |                 |     |  |  |  |
|------------------------------------------------------------------|-----------------|-----|--|--|--|
| Decimal Value                                                    | 769             | 269 |  |  |  |
| Is the decimal value >= 500                                      | yes             | no  |  |  |  |
| Yes, print a <b>D</b><br>and subtract 500 from the decimal value | <b>D</b><br>269 |     |  |  |  |
| No, go on to next smaller Roman denomination                     |                 |     |  |  |  |
| <b>4769=MMMMD</b>                                                |                 |     |  |  |  |

|                                                                  |                 |                |    |  |  |
|------------------------------------------------------------------|-----------------|----------------|----|--|--|
| Decimal Value                                                    | 269             | 169            | 69 |  |  |
| Is the decimal value >= 100                                      | yes             | yes            | no |  |  |
| Yes, print a <b>C</b><br>and subtract 100 from the decimal value | <b>C</b><br>169 | <b>C</b><br>69 |    |  |  |
| No, go on to next smaller Roman denomination                     |                 |                |    |  |  |
| <b>4769=MMMMDCC</b>                                              |                 |                |    |  |  |

|                                                                 |                |    |  |  |  |
|-----------------------------------------------------------------|----------------|----|--|--|--|
| Decimal Value                                                   | 69             | 19 |  |  |  |
| Is the decimal value >= 50                                      | yes            | no |  |  |  |
| Yes, print a <b>L</b><br>and subtract 50 from the decimal value | <b>L</b><br>19 |    |  |  |  |
| No, go on to next smaller Roman denomination                    |                |    |  |  |  |
| <b>4769=MMMMDCCCL</b>                                           |                |    |  |  |  |

|                                                                 |        |    |  |  |  |
|-----------------------------------------------------------------|--------|----|--|--|--|
| Decimal Value                                                   | 19     | 9  |  |  |  |
| Is the decimal value >= 10                                      | yes    | no |  |  |  |
| Yes, print a <b>X</b><br>and subtract 10 from the decimal value | X<br>9 |    |  |  |  |
| No, go on to next smaller Roman denomination                    |        |    |  |  |  |
| 4769=MMMMDCCLX                                                  |        |    |  |  |  |

|                                                                |        |    |  |  |  |
|----------------------------------------------------------------|--------|----|--|--|--|
| Decimal Value                                                  | 9      | 4  |  |  |  |
| Is the decimal value >= 5                                      | yes    | no |  |  |  |
| Yes, print a <b>V</b><br>and subtract 5 from the decimal value | V<br>4 |    |  |  |  |
| No, go on to next smaller Roman denomination                   |        |    |  |  |  |
| 4769=MMMMDCCLXV                                                |        |    |  |  |  |

|                                                                |        |        |        |        |    |
|----------------------------------------------------------------|--------|--------|--------|--------|----|
| Decimal Value                                                  | 4      | 3      | 2      | 1      | 0  |
| Is the decimal value >= 1                                      | yes    | yes    | yes    | yes    | no |
| Yes, print a <b>I</b><br>and subtract 1 from the decimal value | I<br>3 | I<br>2 | I<br>1 | I<br>0 |    |
| No, go on to next smaller Roman denomination                   |        |        |        |        |    |
| 4769=MMMMDCCLXVIII                                             |        |        |        |        |    |

```
#include <iostream>
#include <iomanip>
using namespace std;
int main()
{   int decimal_value=4769;

    char RDL[]="MDCLXVI";           //Roman Denomination Letters
    int RDV[]={1000,500,100,50,10,5,1}; //Roman Denomination Values

    cout << endl;
    cout << decimal_value << "=";
    for (int a=0;a<7;a++) {           //Traverse the list of Roman Denominations
        char rdl=RDL[a];              //Obtain the Roman denomination letter for this iteration
        int rdv=RDV[a];               //Obtain the Roman denomination value for this iteration
        while (decimal_value>=rdv) {  //Reduce the decimal_value < Roman denomination value
            cout << rdl;               //Print the Roman denomination letter
            decimal_value-=rdv;        //Subtract the Roman denomination value from the
        }                             //decimal_value
    }
    cout << endl;
    return 0;
}
```

Figure 1. Program p01 that converts 4769 to Roman numerals.

Program p01 prints:  
4769=MMMMDCCLXVIII

```
#include <iostream>
#include <iomanip>
using namespace std;
int RomanLetter(int d,int rdv,char rdl)
{   while (d>=rdv) {
        d=d-rdv;
        cout << rdl;
    }
    return d;
}
void RomanManager(int d)
{   cout << d << "=";
    d=RomanLetter(d,1000,'M');
    d=RomanLetter(d, 500,'D');
    d=RomanLetter(d, 100,'C');
    d=RomanLetter(d, 50,'L');
    d=RomanLetter(d, 10,'X');
    d=RomanLetter(d, 5,'V');
    d=RomanLetter(d, 1,'I');
}
int main()
{
    for (;;) {
        cout << "Enter a positive integer to be converted to Roman numerals. ";
        int d;
        cin >> d;
        if (d<1) break;
        cout << endl;
        RomanManager(d);
        cout << endl;
    }
    return 0;
}
```

Figure 2. Program **p02** converts any positive decimal value to Roman numerals.

Program **p02** prints:

Enter a positive integer to be converted to Roman numerals. 3452

3452=MMMCCCCLII

Enter a positive integer to be converted to Roman numerals. -1

Program **p02** notes:

1. Function *main* manages the interface to the user.
2. Function *RomanManager* traverses the list of Roman denominations.
3. Function *RomanLetter* prints one letter for each Roman denomination in the decimal value *d*.
4. The decimal value is converted to Roman numerals when its value is reduced to zero.
5. Decimal value *d* is passed “by value.”

```
#include <iostream>
#include <iomanip>
using namespace std;
int RomanLetter(int& d,int rdv,char rdl)
{   while (d>=rdv) {
        d=d-rdv;
        cout << rdl;
    }
}
void RomanManager(int d)
{   cout << d << "=";
    RomanLetter(d,1000,'M');
    RomanLetter(d, 500,'D');
    RomanLetter(d, 100,'C');
    RomanLetter(d, 50,'L');
    RomanLetter(d, 10,'X');
    RomanLetter(d, 5,'V');
    RomanLetter(d, 1,'I');
}
int main()
{
    for (;;) {
        cout << "Enter a positive integer to be converted to Roman numerals. ";
        int d;
        cin >> d;
        if (d<1) break;
        cout << endl;
        RomanManager(d);
        cout << endl;
    }
    return 0;
}
```

Figure 3. Program **p03** converts any positive value to Roman numerals.

Program **p03** prints:

Enter a positive integer to be converted to Roman numerals. 34

34=XXIIII

Enter a positive integer to be converted to Roman numerals. -1

Program **p03** notes:

1. Function *main* manages the interface to the user.
2. Function *RomanManger* traverses the list of Roman denominations.
3. Function *RomanLetter* prints one letter for each Roman denomination in the decimal value *d*.
4. The decimal value is converted to Roman numerals when its value is reduced to zero.
5. Decimal value *d* is passed “by reference.”

```
#include <iostream>
#include <iomanip>
using namespace std;
int RomanLetter(int& d,int rdv,char rdl)
{   while (d>=rdv) {
        d=d-rdv;
        cout << rdl;
    }
}
void RomanManager(int d)
{   cout << d << "=";
    string RDL="MDLCXVI";
    int RDV[]={1000,500,100,50,10,5,1};
    for (int a=0;a<RDL.length();a++) RomanLetter(d,RDL[a],RDL[a]);
}
int main()
{
    for (;;) {
        cout << "Enter a positive integer to be converted to Roman numerals. ";
        int d;
        cin >> d;
        if (d<1) break;
        cout << endl;
        RomanManager(d);
        cout << endl;
    }
    return 0;
}
```

Figure 3. Program p04 converts any positive value to Roman numerals.

Program p04 prints:

```
Enter a positive integer to be converted to Roman numerals. 134

134=CXXIIII
Enter a positive integer to be converted to Roman numerals. -1
```

Program p03 notes:

1. Function main manages the interface to the user.
2. Function *RomanManger* traverses the list of Roman denominations. Roman denominations are stored in two parallel arrays, *RDL* and *RDV*.
3. Function *RomanLetter* prints one letter for each Roman denomination in the decimal value *d*.
4. The decimal value is converted to Roman numerals when its value is reduced to zero.
5. Decimal value *d* is passed "by reference."