**Lab Exercises**

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**Lab Exercise 1 — String Concatenation**

**I Lab Objectives**

In this lab, you will practice:

1. Overloading the + operator to allow String objects to be concatenated.
2. Writing function prototypes for overloaded operators.
3. Using overloaded operators.

**II Description of the Problem**

String **concatenation（连接）**requires two operands—the two strings that are to be concatenated. In the String case study, we showed how to implement an overloaded concatenation operator that concatenates the second String object to the right of the first String object, thus modifying the first String object. In some applications, it is desirable to produce a concatenated String object without modifying the String arguments. Implement operator+ to allow operations such as

string1 = string2 + string3;

in which neither operand is modified.

**III Sample Output**



**IV Problem-Solving Tips**

1. The overloaded + operator should be a member function of class String and should take one parameter, a const reference to a String.
2. The + operator function should use return type String.
3. The strcat function can be used to concatenate pointer-based strings.

**V Your Solution**

// Lab 1: String.h

// Header file for class String.

#ifndef STRING\_H

#define STRING\_H

#include <iostream>

#include <cstring>

#include <cassert>

using namespace std;

class String

{

friend ostream &operator<<( ostream &output, const String &s );

public:

String( const char \* const = "" ); // conversion constructor

String( const String & ); // copy constructor

~String(); // destructor

const String &operator=( const String & );

/\* Write a prototype for the operator+ member function \*/

const String operator+( const String &);

private:

char \*sPtr; // pointer to start of string

int length; // string length

}; // end class String

#endif

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else

cout << "Attempted assignment of a String to itself\n";

return \*this; // enables concatenated assignments

} // end function operator=

// concatenate right operand and this object and store in temp object

/\* Write the header for the operator+ member function \*/

const String String::operator+( const String &right )

{

/\* Declare a temporary String variable named temp \*/

String temp;

/\* Set temp’s length to be the sum of the two argument Strings’ lengthes \*/

temp.length = right.length + length;

/\* Allocate memory for temp.length + 1 chars and assign the pointer to temp.sPtr \*/

temp.sPtr = new char[ temp.length + 1 ];

assert( temp.sPtr != 0 ); // terminate if memory not allocated

/\* Copy the left String argument’s contents into temp.sPtr \*/

strcpy(temp.sPtr, sPtr);

/\* Write a call to strcat to concatenate the string in right

onto the end of the string in temp \*/

strcat(temp.sPtr, right.sPtr);

/\* Return the temporary String \*/

return temp;

} // end function operator+

// overloaded output operator

ostream & operator<<( ostream &output, const String &s )

{

output << s.sPtr;

return output; // enables concatenation

} // end function operator<<

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// Lab 1: String.cpp

// Member-function definitions for String.cpp

#include <iostream>

#include <cstring> // strcpy and strcat prototypes

#include <string>

#include <cstdlib>

#include "String.h" // String class definition

using namespace std;

// conversion constructor: convert a char \* to String

String::String( const char \* const zPtr )

{

length = strlen( zPtr ); // compute length

sPtr = new char[ length + 1 ]; // allocate storage

assert( sPtr != 0 ); // terminate if memory not allocated

strcpy( sPtr, zPtr ); // copy literal to object

} // end String conversion constructor

// copy constructor

String::String( const String &copy )

{

length = copy.length; // copy length

sPtr = new char[ length + 1 ]; // allocate storage

assert( sPtr != 0 ); // ensure memory allocated

strcpy( sPtr, copy.sPtr ); // copy string

} // end String copy constructor

// destructor

String::~String()

{

delete [] sPtr; // reclaim string

} // end destructor

// overloaded = operator; avoids self assignment

const String &String::operator=( const String &right )

{

if ( &right != this ) // avoid self assignment

{

delete [] sPtr; // prevents memory leak

length = right.length; // new String length

sPtr = new char[ length + 1 ]; // allocate memory

assert( sPtr != 0 ); // ensure memory allocated

strcpy( sPtr, right.sPtr ); // copy string

}

// Lab 1: StringCat.cpp

// Demonstrating overloaded + operator that does not modify operands

#include <iostream>

using namespace std;

#include "String.h"

int main()

{

String string1, string2( "The date is" );

String string3( " August 1, 1993" );

// test overloaded operators

cout << "string1 = string2 + string3\n";

/\* Write a statement to concatenate string2 and string3,

and assign the result to string1 \*/

string1 = string2 + string3;

cout << "\"" << string1 << "\" = \"" << string2 << "\" + \""

<< string3 << "\"" << endl;

} // end main

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运行截图：



**Lab Exercise 2 — Huge Integer**

**I Lab Objectives**

In this lab, you will practice:

1. Overloading arithmetic and comparison operators to enhance a huge integer class, HugeInt**.**
2. Writing function prototypes for overloaded operators.
3. Calling overloaded operator functions.

**II Description of the Problem**

A machine with 32-bit integers can represent integers in the range of approximately –2 billion to +2 billion. This fixed-size restriction is rarely troublesome, but there are applications in which we would like to be able to use a much wider range of integers. This is what C++ was built to do, namely, create powerful new data types. Consider class HugeInt of **Figs. 10.17–10.19.** Study the class carefully, then overload the relational and equality operators. [Note: We do not show an assignment operator or copy constructor for class HugeInt, because the assignment operator and copy constructor provided by the compiler are capable of copying the entire array data member properly.]

**III Sample Output**



**IV Problem-Solving Tips**

You can implement the !=, >, >= and <= operators in terms of the overloaded == and < operators.

**V Your Solution**

// Lab 2: Hugeint.h

// HugeInt class definition.

#ifndef HUGEINT\_H

#define HUGEINT\_H

#include <iostream>

using namespace std;

class HugeInt

{

friend ostream &operator<<( ostream &, const HugeInt & );

public:

HugeInt( long = 0 ); // conversion/default constructor

HugeInt( const char \* ); // conversion constructor

// addition operator; HugeInt + HugeInt

HugeInt operator+( const HugeInt & ) const;

// addition operator; HugeInt- HugeInt

HugeInt operator-( const HugeInt & ) const;

// addition operator; HugeInt + int

HugeInt operator+( int ) const;

// addition operator; HugeInt - int

HugeInt operator-( int ) const;

// addition operator;

// HugeInt + string that represents large integer value

HugeInt operator+( const char \* ) const;

/\* Write prototypes for the six relational and equality operators \*/

bool operator== ( const HugeInt & );

bool operator!= ( const HugeInt & );

bool operator< ( const HugeInt & );

bool operator<= ( const HugeInt & );

bool operator> ( const HugeInt & );

bool operator>= ( const HugeInt & );

int getLength() const;

private:

short integer[ 30 ];

}; // end class HugeInt

#endif

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// Lab 2: Hugeint.cpp

// HugeInt member-function and friend-function definitions.

#include <iostream>

#include <cctype> // isdigit function prototype

#include <cstring> // strlen function prototype

using namespace std;

#include "Hugeint.h" // HugeInt class definition

// default constructor; conversion constructor that converts

// a long integer into a HugeInt object

HugeInt::HugeInt( long value )

{

// initialize array to zero

for ( int i = 0; i <= 29; i++ )

integer[ i ] = 0;

// place digits of argument into array

for ( int j = 29; value != 0 && j >= 0; j-- )

{

integer[ j ] = value % 10;

value /= 10;

} // end for

} // end HugeInt default/conversion constructor

// conversion constructor that converts a character string

// representing a large integer into a HugeInt object

HugeInt::HugeInt( const char \*string )

{

// initialize array to zero

for ( int i = 0; i <= 29; i++ )

integer[ i ] = 0;

// place digits of argument into array

int length = strlen( string );

for ( int j = 30 - length, k = 0; j <= 29; j++, k++ )

if ( isdigit( string[ k ] ) )

integer[ j ] = string[ k ] - '0';

} // end HugeInt conversion constructor

// get function calculates length of integer

int HugeInt::getLength() const

{

int i;

for ( i = 0; i <= 29; i++ )

if ( integer[ i ] != 0 )

break; // break when first digit is reached

return 30 - i; // length is from first digit (at i) to end of array

} // end function getLength

// addition operator; HugeInt + HugeInt

HugeInt HugeInt::operator+( const HugeInt &op2 ) const

{

HugeInt temp; // temporary result

int carry = 0;

for ( int i = 29; i >= 0; i-- )

{

temp.integer[ i ] =

integer[ i ] + op2.integer[ i ] + carry;

// determine whether to carry a 1

if ( temp.integer[ i ] > 9 )

{

temp.integer[ i ] %= 10; // reduce to 0-9

carry = 1;

} // end if

else // no carry

carry = 0;

} // end for

return temp; // return copy of temporary object

} // end function operator+

HugeInt HugeInt::operator-( const HugeInt &op2 ) const

{

HugeInt temp; // temporary result

int carry = 0; for ( int i = 29; i >= 0; i-- )

{

temp.integer[ i ] =

integer[ i ] - op2.integer[ i ] - carry;

// determine whether to carry a 1

if ( temp.integer[ i ] < 0 )

{

temp.integer[ i ] = integer[ i ] - op2.integer[ i ] + 10; // reduce to 0-9

carry = 1;

} // end if

else // no carry

carry = 0;

} // end for

return temp; // return copy of temporary object

} // end function operator+

// addition operator; HugeInt + int

HugeInt HugeInt::operator+( int op2 ) const

{

// convert op2 to a HugeInt, then invoke

// operator+ for two HugeInt objects

return \*this + HugeInt( op2 );

} // end function operator+

// addition operator; HugeInt + int

HugeInt HugeInt::operator-( int op2 ) const

{

// convert op2 to a HugeInt, then invoke

// operator- for two HugeInt objects

return \*this - HugeInt( op2 );

} // end function operator-

// addition operator;

// HugeInt + string that represents large integer value

HugeInt HugeInt::operator+( const char \*op2 ) const

{

// convert op2 to a HugeInt, then invoke

// operator+ for two HugeInt objects

return \*this + HugeInt( op2 );

} // end function operator+

// equality operator; HugeInt == HugeInt

/\* Write a definition for the == operator \*/

bool HugeInt::operator== ( const HugeInt &op2 )

{

if(getLength()==op2.getLength())

{

for(int i=0; i<30; i++)

{

if(integer[i]!=op2.integer[i])

return false;

else

continue;

}

return true;

}else

return false;

}

// inequality operator; HugeInt != HugeInt

/\* Write a definition for the != operator

by calling the == operator \*/

bool HugeInt::operator!= ( const HugeInt &op2 )

{

if(getLength()==op2.getLength())

{

for(int i=0; i<30; i++)

{

if(integer[i]!=op2.integer[i])

return true;

else

continue;

}

return false;

}else

return true;

}

// less than operator; HugeInt < HugeInt

/\* Write a definition for the < operator \*/

bool HugeInt::operator< ( const HugeInt &op2 )

{

if(getLength()<op2.getLength())

{

return true;

}else if(getLength()>op2.getLength())

{

return false;

}else

{

for(int i=0; i<30; i++)

{

if(integer[i] < op2.integer[i])

return true;

else if(integer[i] > op2.integer[i])

return false;

else

continue;

}

return false;

}

}

// less than or equal operator; HugeInt <= HugeInt

/\* Write a definition for the <= operator

by calling the < and == operators \*/

bool HugeInt::operator<= ( const HugeInt &op2 )

{

if(getLength()<op2.getLength())

{

return true;

}else if(getLength()>op2.getLength())

{

return false;

}else

{

for(int i=0; i<30; i++)

{

if(integer[i] < op2.integer[i])

return true;

else if(integer[i] > op2.integer[i])

return false;

else

continue;

}

return true;

}

}

// greater than operator; HugeInt > HugeInt

/\* Write a definition for the > operator

by calling the <= operator \*/

bool HugeInt::operator> ( const HugeInt &op2 )

{

if(getLength()>op2.getLength())

{

return true;

}else if(getLength()<op2.getLength())

{

return false;

}else

{

for(int i=0; i<30; i++)

{

if(integer[i] > op2.integer[i])

return true;

else if(integer[i] < op2.integer[i])

return false;

else

continue;

}

return false;

}

}

// greater than or equal operator; HugeInt >= HugeInt

/\* Write a definition for the >= operator

by calling the > and == operators \*/

bool HugeInt::operator>= ( const HugeInt &op2 )

{

if(getLength()>op2.getLength())

{

return true;

}else if(getLength()<op2.getLength())

{

return false;

}else

{

for(int i=0; i<30; i++)

{

if(integer[i] > op2.integer[i])

return true;

else if(integer[i] < op2.integer[i])

return false;

else

continue;

}

return true;

}

}

// overloaded output operator

ostream& operator<<( ostream &output, const HugeInt &num )

{

int i;

for ( i = 0; ( num.integer[ i ] == 0 ) && ( i <= 29 ); i++ )

; // skip leading zeros

if ( i == 30 )

output << 0;

else

for ( ; i <= 29; i++ )

output << num.integer[ i ];

return output;

} // end function operator<<

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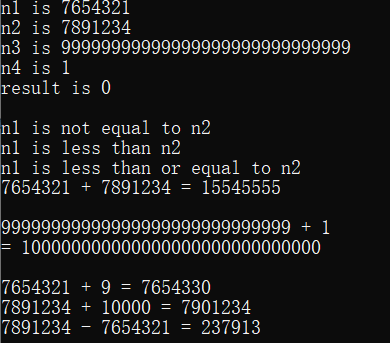
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运行截图：



**Lab Exercise 3 — Rational Numbers**

**I Lab Objectives**

In this lab, you will practice:

1. Overloading operators to create a class capable of storing rational numbers (fractions) and performing rational number arithmetic.
2. Writing function prototypes for overloaded operators.
3. Implementing overloaded operator functions.

The follow-up questions and activities also will give you practice:

1. Overloading the << operator.
2. Making a class more robust to prevent runtime errors.

**II Description of the Problem**

Create a classRationalNumber(fractions) with the following capabilities:

1. Create a constructor that prevents a 0 denominator in a fraction, reduces or simplifies fractions that are not in reduced form and avoids negative denominators.
2. Overload the addition, subtraction, multiplication and division operators for this class.
3. Overload the relational and equality operators for this class.

**III Sample Output**



**IV Problem-Solving Tips**

* 1. When comparing RationalNumbers, you can cast the numerator to a double and then divide by the denominator to determine the value of that RationalNumber as a double. The <=, >=, > and != operators can be implemented in terms of == and <.
  2. To implement the arithmetic operators, use the following formulas:

Addition: (a/b) + (c/d) = (ad + bc) / (bd).

Subtraction: (a/b)- (c/d) = (ad - bc) / (bd).

Multiplication: (a/b) \* (c/d) = (ac) / (bd).

Division: (a/b) / (c/d) = (ad) / (bc).

Remember to check for division by zero.

**V Your Solution**

// Lab 3: RationalNumber.h

// RationalNumber class definition.

#ifndef RATIONAL\_NUMBER\_H

#define RATIONAL\_NUMBER\_H

class RationalNumber

{

public:

RationalNumber( int = 0, int = 1 ); // default constructor

/\* Write prototype for operator + \*/

RationalNumber operator+ (const RationalNumber &) const;

/\* Write prototype for operator - \*/

RationalNumber operator- (const RationalNumber &) const;

/\* Write prototype for operator \* \*/

RationalNumber operator\* (const RationalNumber &) const;

/\* Write prototype for operator / \*/

RationalNumber operator/ (const RationalNumber &) const;

// relational operators

/\* Write prototype for operator > \*/

bool operator> (const RationalNumber &) const;

/\* Write prototype for operator < \*/

bool operator< (const RationalNumber &) const;

/\* Write prototype for operator >= \*/

bool operator>= (const RationalNumber &) const;

/\* Write prototype for operator <= \*/

bool operator<= (const RationalNumber &) const;

// equality operators

/\* Write prototype for operator == \*/

bool operator== (const RationalNumber &) const;

/\* Write prototype for operator != \*/

bool operator!= (const RationalNumber &) const;

void printRational() const; // display rational number

private:

int numerator; // private variable numerator

int denominator; // private variable denominator

void reduction(); // function for fraction reduction

}; // end class RationalNumber

#endif

// Lab 3: RationalNumber.cpp

// RationalNumber member-function definitions.

#include <cstdlib>

#include <iostream>

using namespace std;

#include "RationalNumber.h"

// RationalNumber constructor sets n and d and calls reduction

/\* Implement the RationalNumber constructor. Validate d first to ensure that

it is a positive number and set it to 1 if not. Call the reduction utility

function at the end \*/

RationalNumber::RationalNumber(int n, int d)

:numerator(n), denominator(d)

{

if(d <= 0)

d=1;

reduction();

}

// overloaded + operator

/\* Write definition for overloaded operator + \*/

RationalNumber RationalNumber::operator+ (const RationalNumber &op2) const

{

RationalNumber temp;

if(denominator == op2.denominator)

{

temp.denominator = denominator;

temp.numerator = numerator + op2.numerator;

}

else

{

temp.numerator = numerator\*op2.denominator + op2.numerator\*denominator;

temp.denominator = denominator \* op2.denominator;

}

temp.reduction();

return temp;

}

// overloaded - operator

/\* Write definition for overloaded operator - \*/

RationalNumber RationalNumber::operator- (const RationalNumber &op2) const

{

RationalNumber temp;

if(denominator == op2.denominator)

{

temp.denominator = denominator;

temp.numerator = numerator - op2.numerator;

}

else

{

temp.numerator = numerator\*op2.denominator - op2.numerator\*denominator;

temp.denominator = denominator \* op2.denominator;

}

temp.reduction();

return temp;

}

// overloaded \* operator

/\* Write definition for overloaded operator \* \*/

RationalNumber RationalNumber::operator\* (const RationalNumber &op2) const

{

RationalNumber temp;

temp.numerator = numerator \* op2.numerator;

temp.denominator = denominator \* op2.denominator;

temp.reduction();

return temp;

}

// overloaded / operator

/\* Write definition for overloaded operator /. Check if the client is

attempting to divide by zero and report an error message if so \*/

RationalNumber RationalNumber::operator/ (const RationalNumber &op2) const

{

RationalNumber temp;

if(op2.numerator <= 0)

{

throw invalid\_argument("denominator is 0, error!");

}

else

{

temp.numerator = numerator\*op2.denominator;

temp.denominator = denominator \* op2.numerator;

}

temp.reduction();

return temp;

}

// overloaded > operator

/\* Write definition for operator > \*/

bool RationalNumber::operator> (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

// overloaded > operator

/\* Write definition for operator > \*/

bool RationalNumber::operator> (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator > op2.numerator)

return true;

else

return false;

}else

{

if(numerator\*op2.denominator > op2.numerator\*denominator)

return true;

else

return false;

}

}

// overloaded < operator

/\* Write definition for operator < \*/

bool RationalNumber::operator< (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator < op2.numerator)

return true;

else

return false;

}else

{

if(numerator\*op2.denominator < op2.numerator\*denominator)

return true;

else

return false;

}

}

// overloaded >= operator

/\* Write definition for operator >= \*/

bool RationalNumber::operator>= (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator > op2.numerator || numerator == op2.numerator)

return true;

else

return false;

}else

{

if(numerator\*op2.denominator > op2.numerator\*denominator || numerator\*op2.denominator == op2.numerator\*denominator)

return true;

else

return false;

}

}

// overloaded <= operator

/\* Write definition for operator <= \*/

bool RationalNumber::operator<= (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator < op2.numerator || numerator == op2.numerator)

return true;

else

return false;

}else

{

if(numerator\*op2.denominator < op2.numerator\*denominator || numerator\*op2.denominator == op2.numerator\*denominator)

return true;

else

return false;

}

}

// overloaded == operator

/\* Write definition for operator == \*/

bool RationalNumber::operator== (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator == op2.numerator)

return true;

else

return false;

}else

{

if(numerator\*op2.denominator == op2.numerator\*denominator)

return true;

else

return false;

}

}

// overloaded != operator

/\* Write definition for operator != \*/

bool RationalNumber::operator!= (const RationalNumber &op2) const

{

if(denominator == op2.denominator)

{

if(numerator == op2.numerator)

return false;

else

return true;

}else

{

if(numerator\*op2.denominator == op2.numerator\*denominator)

return false;

else

return true;

}

}

// function printRational definition

void RationalNumber::printRational() const

{

if ( numerator == 0 ) // print fraction as zero

cout << numerator;

else if ( denominator == 1 ) // print fraction as integer

cout << numerator;

else

cout << numerator << '/' << denominator;

} // end function printRational

// function reduction definition

void RationalNumber::reduction()

{

int largest, gcd = 1; // greatest common divisor;

largest = ( numerator > denominator ) ? numerator: denominator;

for ( int loop = 2; loop <= largest; loop++ )

if ( numerator % loop == 0 && denominator % loop == 0 )

gcd = loop;

numerator /= gcd;

denominator /= gcd;

} // end function reduction

// Lab 3: RationalTest.cpp

// RationalNumber test program.

#include <iostream>

using namespace std;

#include "RationalNumber.h"

int main()

{

RationalNumber c( 7, 3 ), d( 3, 9 ), x;

c.printRational();

cout << " + ";

d.printRational();

cout << " = ";

x = c + d; // test overloaded operators + and =

x.printRational();

cout << '\n';

c.printRational();

cout << " - ";

d.printRational();

cout << " = ";

x = c - d; // test overloaded operators - and =

x.printRational();

cout << '\n';

c.printRational();

cout << " \* ";

d.printRational();

cout << " = ";

x = c \* d; // test overloaded operators \* and =

x.printRational();

cout << '\n';

c.printRational();

cout << " / ";

d.printRational();

cout << " = ";

x = c / d; // test overloaded operators / and =

x.printRational();

cout << '\n';

c.printRational();

cout << " is:\n";

// test overloaded greater than operator

cout << ( ( c > d ) ? " > " : " <= " );

d.printRational();

cout << " according to the overloaded > operator\n";

// test overloaded less than operator

cout << ( ( c < d ) ? " < " : " >= " );

d.printRational();

cout << " according to the overloaded < operator\n";

// test overloaded greater than or equal to operator

cout << ( ( c >= d ) ? " >= " : " < " );

d.printRational();

cout << " according to the overloaded >= operator\n";

// test overloaded less than or equal to operator

cout << ( ( c <= d ) ? " <= " : " > " );

d.printRational();

cout << " according to the overloaded <= operator\n";

// test overloaded equality operator

cout << ( ( c == d ) ? " == " : " != " );

d.printRational();

cout << " according to the overloaded == operator\n";

// test overloaded inequality operator

cout << ( ( c != d ) ? " != " : " == " );

d.printRational();

cout << " according to the overloaded != operator" << endl;

} // end main

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

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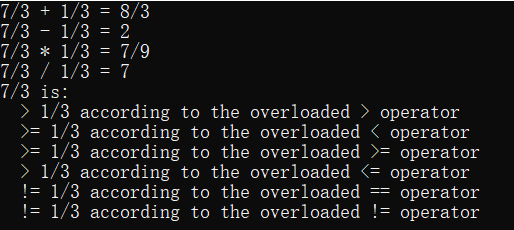
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运行截图：

**VI Follow-Up Questions and Activities**

1. Rewrite the printRational member function as an overloaded << friend function.

ostream& operator<< (ostream &output, const RationalNumber &num)

{

if ( num.numerator == 0 ) // print fraction as zero

output << num.numerator;

else if ( num.denominator == 1 ) // print fraction as integer

output << num.numerator;

else

output << num.numerator << '/' << num.denominator;

return output;

}

// function reduction definition

2. Make the RationalNumber class more robust by providing additional tests for division by zero in each of the relational operators that divides a numerator by a denominator.

It’s soluted.

3. Is it possible to add another overloaded operator> function that returns a pointer to the larger of the two rational numbers? Why or why not?

Cannot.