Operator Overloading

Operator "overloading" is one way in which C++ supports the object-oriented principle of *ad hoc polymorphism*. Polymorphism is derived from the Greek words "poly" ("many") and "morph" ("form"). *Ad hoc polymorphism* refers to the notion that the actual *operation* performed for any *operator* is entirely dependent on the form (*type*) of its *operands*. For example, the division operator / results in different operations for floating-point operands vs. integer operands.

Operator overloading is useful when constructing complex classes. At a minimum, most user-defined classes should include overloaded stream *input* and *output* operators ( >> and << ) to support debugging and file I/O. In this lab exercise, we continue to develop our understanding of class construction by extending the work from the previous lab by including overloaded operators.

**Warm-up**

Complete the following paper/pencil exercises. First, do these individually. Then you and your partner should share your answers and make any needed corrections, making sure you both understand the solutions. Then you both should discuss your answers with one of your TA.

1) Consider the following class declaration:

```c++
class Point
{
  public:
    Point( );
    Point(int xval, int yval);
    friend Point operator +(Point, Point);
  private:
    int  xloc;
    int  yloc;
};
```

a. Write the function definition for the overloaded + operator that will produce the sum of the x values and the sum of the y values of two *Point* objects.

b. Rewrite the *Point* class interface to make the overloaded + operator a public member function of the class.

c. Provide the function definition for the overloaded + *member* operator of the *Point* class.

d. Describe what the overloaded output operator ( e.g., << ) return-type must be and why. *(Hint: consider how the following statement is evaluated:)*

```c++
    cin >> some_object >> some_other_object;
```

e. In order to overload the output operator for a class we make it a non-member *friend* function of the class and not a member function. Explain why.

f. Overload the output operator for the point class to output a point object as follows:

```c++
    x, y
```

where x and y are the coordinate values for the point, separated by a comma.
Stretch

1) Complex Number Class

Extend the Complex class that you completed in last week's Lab Exercises. Recall that a complex number is of the form $a + bi$ where $a$ and $b$ are real numbers and $i^2 = -1$. For example, $2.4 + 5.2i$ and $5.73 - 6.9i$ are complex numbers. $a$ is referred to as the real part of the complex number and $bi$ the imaginary part.

Make the following changes to the Complex class definition:

a) Add a constructor that will take two double arguments and initialize the real and imaginary components respectively.

b) Replace the input and output methods with overloaded $\gg$ and $\ll$ operators, respectively, that are friend functions of the class. The output should be $\text{realValue} + \text{imaginaryValue}i$ e.g.,:

$$9.3 + 5.7i \quad 12.4 - 8.4i$$

If the imaginaryValue component is zero, simply output the realValue as a 'regular' floating-point value. Also, if the imaginaryValue is negative, replace the '+' symbol with '-'. You may input the complex value in any format you wish.

c) Provide an overloaded addition operator that will return the sum of two Complex objects. For complex numbers $a + bi$ and $c + di$, addition is defined as

$$(a+c) + (b+d)i.$$ 

4) Provide an overloaded negation operator (unary -) that will negate both the real and imaginary parts of a complex number. For example if $z$ is the complex number $3 - 2i$, then $-z$ should return a complex number $-3 + 2i$.

Thoroughly test your Complex number class by writing a test program that constructs various Complex values and displays the results until you are convinced that it is operating correctly. Include the following statements in your test program and show the results to a TA:

```
Complex c1,c2,c3;
cout << "Enter two complex values: ";
cin >> c1 >> c2;
c3 = c1+c2;
cout << "The sum is: " << c3 << endl;
cout << "and negating the sum yields: " << -c3 << endl;
```
Workout

1) Quadratic Polynomials

Write a program that will output the sum of two quadratic polynomials. Your program must do the following:

1. Define an abstract data type, Poly with three private data members a, b and c (type double) to represent the coefficients of a quadratic polynomial in the form: \( ax^2 + bx + c \)
2. Include a constructor in the Poly class to initialize all private data members with caller-supplied values (in addition to the default constructor!)
3. Overload the addition operator to return the sum of two Poly objects.
4. Overload the \( << \) (output) operator to output Poly objects in the following format, e.g.,:
   \[
   ax^2 + bx + c
   \]
   Where a, b and c are the coefficients of the Poly object. Do not display the a or b terms if they have zero coefficients. Moreover, if any coefficient is negative it should be precede by a minus sign, and not a plus sign.
5. In your main() function, declare and initialize two Poly objects, q1 and q2, to represent the following polynomials: \( 3x^2 + 4x – 2 \) and \( -4x + 10 \). Also declare a third, un-initialized Poly object named sum.
6. Output the sum of the two polynomials to the console using the following C++ code exactly as it appears:

   ```cpp
   sum = q1 + q2;
   cout << q1 << " : q1
   cout << q2 << " : q2
   cout << sum << " : q1+q2
   ```

2) More Polynomial Methods

Extend the Poly class to support the evaluation of quadratic polynomials as follows:

1. Add a member function named eval that takes a single double argument representing the 'x' value and returns the result (type double) of evaluating the polynomial at x.
2. Add a void member function named roots that will take two reference arguments of type Complex (use your Complex class), then compute and provide both roots of a quadratic polynomial object. Recall that the roots are given by the quadratic equation:

   \[
   x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
   \]

   The expression under the radical is referred to as the discriminant. If the discriminant is negative, the roots must be expressed as imaginary values using Complex numbers as follows:

   \[
   x = \frac{-b}{2a} \pm \frac{\sqrt{4ac - b^2}}{2a}i
   \]

   The roots method should first determine if the roots are real or imaginary based on the value of the discriminant. If the roots are real, return them as complex values with the imaginary component set to zero, if the roots are imaginary, return them in complex form using the absolute value of the discriminant.
3. Overload the >> (input) operator to input a Poly object in the following format:
   
   
   (a, b, c)
   
   Where a, b and c are the data values of the poly object. The input will include the parentheses and commas as shown.

Now, write a main program that will evaluate the quadratic polynomial $2x^2 - 6x + 5$ at the integer values 0 through 10. Include the following C++ code:

```cpp
Poly inpoly;
cout << "Input a quadratic polynomial: ";
cin >> inpoly;
for( int i=0; i<= 10; i++)
    cout << "f(" << i << ") is: " << inpoly.eval(i) << endl;
Complex c1,c2;
inpoly.roots(c1,c2);
cout << "The roots of f(x) are " << c1 << "\t" << c2 << endl;
```

Check

Individually write down (a) one important thing you learned from this lab exercise, and (b) one question you still have. Then you and your partner should share and discuss what you both have written.

Challenge

1) Polynomial Evaluation

The current Poly::eval method takes a floating-point value for x and returns $f(x)$ as a double. Provide an overloaded Poly::eval method that will take a complex number as its argument and return a complex result.

To do this, you will need to add overloaded operators to your Complex class to support multiplication and subtraction. If this is done properly, the code for the floating-point Poly::eval method should be usable with very little (if any) modification.

2) Further Overloaded Operators

Add the following additional operators to your Complex number class:

- If you wrote your overloaded + operator as a friend function, write it as a non-member, non-friend function. (Hint: you will need to use accessor member functions in writing this.)
- Write an overloaded == operator that checks if two complex number objects have the same real and imaginary values.
- Write an overloaded += operator as a member function of the class. The statement $c_1 += c_2$ should add $c_1$ and $c_2$ together and store the result in $c_1$. 