Programming Design, Spring 2013
Midterm Exam

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Note 1. In total there are 110 points for this exam. If you get more than 100 points, your official score for this exam will only be 100.

Note 2. You do not need to return these problem sheets. Write down all your answers on the answer sheets provided to you.

1. (20 points; 2 points each) For the following statements, Write down "T" if one is true or "F" if it is false. DO NOT provide any explanation.

   (a) In C++, all the basic data types can be grouped into three different categories: integers, fractional numbers, and characters.

   (b) In C++, a `long int` variable can occupy the same number of bytes as a `int` variable does but a `short int` variable must occupy fewer bytes than a `int` variable does.

   (c) The division operator returns an integer if both the numerator and denominator are integers. As long as one of them is a fractional number, the division operator returns a fractional number. It is assumed that the denominator is not zero.

   (d) In C++, one `else` will be paired to the closest `if` that has not been paired with an `else`.

   (e) For the statement `if(a == b && c > d)`, if $a = 5$, $b = 7$, $c = 9$, $d = 6$, the returned value of the condition inside the `if` statement is false.

   (f) For the statement `if(a == b && c > d)`, if $a = 5$, $b = 7$, $c = 9$, $d = 6$, two comparisons and one "and" operation will be performed before the condition returns a value.

   (g) In a `switch` statement, if two values behind two `case` operators are identical, there will be a run time error.

   (h) A global variable can be accessed everywhere in the program it is defined.

   (i) To sort a very large single-dimensional array, merge sort is typically faster than insertion sort.

   (j) Given a statically allocated integer array `arr`, `sizeof{arr}` returns its length.

2. (15 points) Briefly answer the following questions. Your answers need to be precise but need not to be long.

   (a) (3 points) Why is a function signature designed not to include the return type of a function?

   (b) (3 points) Why the efficiency of insertion sort cannot be significantly improved by implementing the search part with the binary search algorithm?

   (c) (5 points) Suppose we do `double* ptr = new double[10]` to declare a dynamic memory allocation. What are the proper statements to release this dynamically allocated space? Why the computer cannot release this space automatically?
   Hint. The safest way of releasing this space requires two statements.

   (d) (4 points) Why in the C++ standard library `<ctime>` we do `typedef long int clock_t`?

3. (20 points) For the following program, write down the output of each `cout` statement. On your answer sheet, mark each output according to the English character after each `cout` statement. Write down "unpredictable" if the output is unpredictable.

```
char c1 = 'a';
char c2 = 'f';
cout << c2 - c1 << endl; // (a; 2 points)

char* ptrC1 = &c1;
char* ptrC2 = &c2;
cout << ptrC2 - ptrC1 << endl; // (b; 2 points)

double array[10];
cout << array[5] << endl; // (c; 2 points)

int value[10] = {-1};
cout << value[0] << endl; // (d; 2 points)
cout << value[5] << endl; // (e; 2 points)

int count = 0;
for(int i = 0; i < 5; i++);
    count++;
cout << count << endl; // (f; 4 points)

int sum = 100;
int loopCount = 0;
while (sum > 0)
{
    if (sum % 2 == 0)
        sum /= 2;
    else
        sum -= 5;
    loopCount++;
}
cout << loopCount << endl; // (g; 3 points)
cout << sum << endl; // (h; 3 points)
```

4. (15 points; 5 points each) One of your classmates does not have a good programming style and write a program shown below in Program (3a). Numbers in front of codes are not part of the program; they are just line numbers.

Program (3a):

```
 1: int a;
 2: cin >> a;
 3: if(a == 0)
 4: for(int i = 0; i < 10; i++)
 5: a += i;
 6: if(a > 10)
 7: a -= 10;
 8: if(a == 55)
 9: cout << a << endl;
10: else if(a < 55)
11: cout << a - 100 << endl;
12: else
13: cout << a + 100 << endl;
14: else
15: while(a > 0)
16: a -= 10;
17: cout << a + 1000 << endl;
```

Program (3b):

```
 1: int a;
 2: cin >> a;
 3: if(a == 0) {
 4: for(int i = 0; i <= 10; i++)
 5: a += i;
 6: if(a > 10)
 7: a -= 10;
 8: if(a == 55)
 9: cout << a << endl;
10: else if(a < 55)
11: cout << a - 100 << endl;
12: else
13: cout << a + 100 << endl; }
14: else
15: while(a > 0)
16: a -= 10;
17: cout << a + 1000 << endl;
```

(a) When you compile Program (3a) a compilation error occurs. Clearly indicate where the compilation error is and briefly explain why it happens.

(b) Your classmate modified the program into Problem (3b). Now there is no compilation error. If you enter 0 in the `cin` statement, what will be the output of this program?

(c) Rewrite the Program (3b) with proper indentations. Do not add any code or curly bracket. Your program will be graded according to the readability.

5. (20 points) Answer the following questions regarding binary search and sorting:

   (a) (5 points) For a sorted list $(2, 6, 9, 12, 16, 20, 21, 23, 27)$, write down all the numbers you need to compare with when you use binary search to search for 18. You need to write down these numbers in the order you perform comparisons.

   (b) (5 points) For a partially sorted list $(2, 6, 9, 12, 16, 7, 10, 15, 8)$, currently the first five values are sorted and the last four values are unsorted. Suppose you are going to apply the insertion sort to sort the whole list. For each of the four insertions you will perform, write down the resulting list. Please note that the first three lists will be partially sorted and the last list will be completely sorted.

   (c) (4 points) Suppose you are going to sort a set of distinct points on the Cartesian coordinate system. You know for a point (x, y) in the set, we have $0 \leq x \leq 100$ and $0 \leq y \leq 100$. The sorting rule is that (x_i, y_i) should be put in front of (x_j, y_j) if (1) $x_i < x_j$ or (2) $x_i = x_j$ and $y_i < y_j$. Describe a method, in words or in pseudocodes, that can sort these points according to the above rule.

   (d) For the following recursive function

```
int strange(int i)
{
    if(i <= 2)
        return 1;
    else
        return strange(i - 1) + 2 * strange(i - 2);
}
```

      i. (2 points) What is the returned value of `strange(6)`?

      ii. (4 points) Write a loop that can calculate `strange(6)`. Declare those variables you need. Indicate which variable contains the value of `strange(6)` after the execution of the loop.

6. (20 points; 5 points each) Suppose you are asked to write a software system that will process a lot of complex numbers. A complex number is generally expressed as $a + bi$, where a and b are two real numbers and $i = \sqrt{-1}$ is the imaginary unit. Two operations that may be performed on those complex numbers include:

   - Conjugation: The conjugation of $a + bi$ is $a - bi$.
   - Finding the absolute value: $|a + bi| = \sqrt{a^2 + b^2}$.

   Note that the former changes the complex number while the latter does not.

   (a) Based on the above definition, design a `struct` or a `class` that makes the implementation of the system as easy as possible. Clearly define member variables and member functions. Name them in a satisfactory way. For member functions, just define their headers. Do not implement them. You need to write down your definition in a way that can be compiled according to the C++ standard. Your definition will be graded based on the correctness, easiness-to-read, and easiness-to-use.

   (b) Implement the function that conjugates a complex number.

   (c) Implement a function that calculates the product of two complex numbers, where the multiplication of complex numbers $a + bi$ and $c + di$ is defined as

$$(a + bi)(c + di) = (ac - bd) + (bc + ad)i.$$

   Explain why you define it as a member function or not.

   (d) Implement a function that takes three real numbers a, b, and c as parameters and returns two complex numbers as the roots of the equation $ax^2 + bx + c = 0$.[1]

[1] Mathematically, it can be shown that the two roots of $ax^2 + bx + c = 0$ are

$$\frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad \text{and} \quad \frac{-b - \sqrt{b^2 - 4ac}}{2a}.$$