CS 109 – C/C ++ Programming for Engineers w. MatLab– Spring 2012
Homework Assignment 1
Speed of Sound and Distance in Fresh Water

Due: **Wednesday 18 January by 8:00 a.m., via Blackboard.** Optional hard copy may be turned in during labs.

Overall Assignment

For this assignment you are to write a simple computer program that calculates the speed of sound in fresh water, given the temperature of the water, and the distance to an object (e.g. the bottom of the lake), given the time it takes for a sonar echo to return at that temperature.

Background: Sonar

Sonar works by emitting a "ping" at a particular frequency, and then timing how long it takes to hear the echo reflected off of a distant object, such as the bottom of the lake or perhaps a shipwreck. In order to determine how far the sound travelled before being echoed back it is critical to know the speed of sound in the surrounding water. Del Grosso and Mader studied the speed of sound in fresh water in 1972, and reported that it could be estimated as a function of temperature as:

$$c = C_0 + C_1 T + C_2 T^2 + C_3 T^3 + C_4 T^4 + C_5 T^5 \quad (1)$$

where:

- c is the speed of sound in fresh water, in m/s,
- T is the temperature of the water, in degrees C in the range 0 to 95, and
- C_0 to C_5 are polynomial coefficients, reported as:

Coefficient	Value
C_0	1402.388
C_1	5.03711
C_2	-0.0580852
C_3	$0.3342 * 10^{-3}$
C_4	$-0.1478 * 10^{-5}$
C_5	$0.315 * 10^{-8}$

Then if one knows how long it takes a sound signal to travel an unknown distance, the distance can be calculated simply as time multiplied by speed, (taking care to convert units as necessary.)

Program Details

For this assignment you are to write a simple computer program that calculates the speed of sound in fresh water and the depth of the lake under the boat, given the temperature of the lake water and the time it takes for a sonar ping to travel to the lake bottom and back again.

- Your program should first print out your name and ACCC account name (e.g. astudent), and explain to the user what the program does.

- Your program should then ask the user to enter the temperature of the lake in degrees C and the time required for the sonar echo to return in milliseconds, **IN THAT ORDER**.

    - Each data item should be entered separately, with its own question and answer. I.e. with two data values to enter, your program should ask two separate questions and get a separate response for each one, rather than asking the user to enter two values in response to a single question.

- After performing the necessary calculations, the program should report the results, **including an echo of the user's input.** The specific results to be reported should include:

    - The speed of sound in fresh water at the given temperature, in m / sec.
    - The depth of water under the boat, in decimal feet. (E.g. 42.5 feet as opposed to 42 feet, 6 inches.)

Special Notes:

- **You should work out some sample problems by hand before writing any computer code.** As an example, if the water temperature is 15 degrees C (59 degrees F) and the sonar echo takes 17.465 milliseconds to return to the boat, the depth is approximately 42 feet. (You should verify this for yourself.)
- **You will need to pay attention to and report dimensional units.** For the computer program, that means you need to ask the user to enter their data in specific units, and you also need to specify the units when you report the results. You may or may not need to do some units conversions as part of the internal calculations.
- One foot = 0.3048 meters.
- C++ does not have an exponentiation operator. You can calculate T cubed as T * T * T.
- C++ does have exponential notation for constants. For example. 6.02E23 = $6.02 * 10^{23}$
- The basic assignment should not use any loops. You may use loops in your program only if you implement one of the optional enhancements (see below), e.g. to allow the user to solve multiple problems without restarting the program.
- Since you haven't learned how to test things yet, you can just assume that all of the user input is good.

What to Hand In:

- Your code, **<u>including a user documentation file,</u>** should be handed in electronically using Blackboard.
- The intended audience for the documentation file is a general end user, who might want to use this program to perform some work. They do not get to see the inner workings of the code, and have not read the homework assignment. You can assume, however, that they are familiar with the problem domain (e.g. sonar.)
- A secondary purpose of the documentation file is to make it as easy as possible for the grader to understand your program. If there is anything special the grader should know about your program, be sure to document it in the documentation file. In particular, if you do any of the optional enhancements, then you need to document what they are and anything special the TA needs to do to run your program and understand the results.
- If there are problems that you know your program cannot handle, it is best to document them as well, rather than have the TA wonder what is wrong with your program.
- Make sure that your name appears at the beginning of each of your files. Your program should also print this information when it runs.

Optional Enhancements:

It is course policy that students may go above and beyond what is called for in the base assignment if they wish. These optional enhancements will not raise any student's score above 100 for any given assignment, but they may make up for points lost due to other reasons.

- Perform the calculations using the **float** data type and again using the **double** data type, and compare the results found with each data type. You should be able to do this with a single program that originally reads in the data as doubles, and then later copies the data into float variables to perform the alternate calculations. In your documentation file you should discuss your findings. (Del Grosso and Mader report the accuracy of the estimation as ± 0.015 m/s. How does the error introduced by using floats instead of doubles compare to this level of accuracy?)
- Check the data entered to verify that it is valid.
- Ask the user if they would like to solve additional problems, and if so, repeat until they indicate they are done.
- Echo the input temperature in degrees F as well as degrees C, and report the speed and distance using both the metric system (meters) and the English system (feet.)
- Other enhancements that you think of – Check with TA for acceptability.