CS 109 – C/C ++ Programming for Engineers w. MatLab– Fall 2009
Homework Assignment 1
Partial Pressures of Gas Mixtures

Due: **Wednesday 9 September, 11:59 p.m., via Blackboard.** Hard copy to be handed in during lab **MUST MATCH THE ELECTRONIC COPY EXACTLY.**

Overall Assignment

All branches of engineering occasionally need to determine the partial pressures of individual gases in a gas mixture, given the composition and the total pressure. For this assignment, you are to write a simple computer program that determines the partial pressures of oxygen and nitrogen breathed by a SCUBA diver, given the composition of gas in the diver's tank and the depth at which the diver is diving.

Background: SCUBA and Nitrox

SCUBA divers most commonly breath compressed air, which is a mixture of 21% oxygen and 79% nitrogen for our purposes. (Ignoring trace components.) This air is stored in a cylinder on the divers back at high pressures, normally up to 3000 psi, or about 200 atmospheres. The diver's regulator then reduces this pressure to exactly match the pressure of the water around the diver, so that the pressure inside the diver and the pressure outside the diver will exactly balance.

Unfortunately there are a number of dangers associated with breathing nitrogen at high pressures, most notably decompression sickness, also known as "the bends". The deeper a diver dives (and hence the higher the pressure of air that the diver breaths) and the longer the diver stays there, the more high-pressure nitrogen soaks into the diver's muscle tissues, and must be removed slowly by ascending slowly to the surface and possibly making a number of lengthy decompression stops.

One solution is to change the mix of the breathing gas, so that instead of breathing 21% oxygen 79% nitrogen, the diver breaths a mix that is 25 to 40% (or more) oxygen and the remainder nitrogen. These mixtures are known as "Nitrox".

Unfortunately there is also a danger with breathing oxygen at high pressures. Above 1.4 atmospheres of partial pressure, oxygen can cause what is known as "oxygen toxicity", resulting in seizures which lead to drowning when the diver loses their regulator. (The figure of 1.4 atm includes some margin for safety – Oxygen toxicity actually occurs at higher partial pressures, but the exact value will depend on a large number of factors including the particular diver's physiology.) For any particular mixture of Nitrox, there is a particular depth at which the partial pressure of oxygen delivered to the diver is exactly 1.4 atmospheres. That depth is known as the "Maximum Operating Depth", or MOD for that blend of Nitrox.

It is therefore very important for a diver breathing Nitrox to be able to calculate: (1) What is the partial pressure of oxygen for a given gas mixture at a given depth?, and (2) What is the Maximum Operating Depth for that blend of Nitrox?

Background: Partial Pressure Gas Calculations

- One atmosphere is defined as the pressure exerted by the atmosphere at sea level, and is equal to 33.89854205 feet of water. That is to say that a column of water 33.9 feet high will exert a pressure of 1 atmosphere, or more to the point for this assignment, for every 33.9 feet that a diver submerges below the surface, the pressure around them increases by 1 atmosphere. Plus we can't forget about the 1 atmosphere of pressure on the surface before the diver even submerges, which leads us to the following equation for the pressure exerted on the diver (and therefore the total pressure of the gas that the diver is breathing) as a function of the diver's depth below the surface:

$$P = 1 + \frac{depth}{33.89854205} \quad (1)$$

- For an ideal mixture of gases, the partial pressure of a particular gas is just the fraction of that gas in the mixture times the total pressure of the mixture, as given by:

$$P_i = x_i * P \quad (2)$$

  where x_i is the molar fraction of gas i in the mixture. When we refer to mixtures of Nitrox, the percentage of oxygen is given on a molar basis, so air is just a 21% Nitrox blend, having an oxygen mole fraction of 0.21.

- (Dalton's Law states that the total pressure of a gas mixture is equal to the sum of the partial pressures of the individual components, which should be obvious from the above definition of partial pressure.)

Program Details

For this assignment, you are to write a program that determines the partial pressure of oxygen for a diver breathing a given blend of Nitrox at a given planned dive depth, as well as the maximum safe depth (MOD) to which the diver can dive while breathing that gas mixture.

- Your program should first print out your name and ID, and explain to the user what the program does.

- Your program should then ask the user for the percentage oxygen mixture in the Nitrox, and the maximum depth to which the diver plans to dive.

- 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 maximum operating depth of the gas mixture. (Depth at which the partial pressure of oxygen will be 1.4 atm.)

  - The partial pressures of oxygen, nitrogen, and the total overall pressure at both the diver's planned depth and at the maximum operating depth of the gas.

- **Note:** 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.

What to Hand In:

1. Your code, **<u>including a readme file,</u>** should be handed in electronically using Blackboard.
2. The purpose of the readme file is to make it as easy as possible for the grader to understand your program. If the readme file is too terse, then (s)he can't understand your code; If it is overly verbose, then it is extra work to read the readme file. It is up to you to provide the most effective level of documentation.
3. If there are problems that you know your program cannot handle, it is best to document them in the readme file, rather than have the TA wonder what is wrong with your program.
4. 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.

- 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.
- Make the program more generic, to handle more than two components in the gas mixture. (Technical divers going beyond the bounds of Nitrox commonly breath ***trimix*** – a mixture of oxygen, nitrogen, and helium, in which the addition of helium allows the diver to keep the partial pressures of both nitrogen and oxygen lower than what they would be otherwise.)
- Other enhancements that you think of – Check with TA for acceptability.