**Assignment One**
**Statistical Physics**
**Kigali Institute of Science and Technology**
December 2011

**This assignment is due at the beginning of class on Wednesday, 21 December.** Please let me know if you have questions on any of these problems. I am happy to meet and provide help. I probably will not be available over the weekend, however.

These exercises are based on problems 1.3, 1.4, 1.16, and 1.14 of Schroeder's book *An Introduction to Thermal Physics*. My shipment of these books has not yet arrived from the U.S., but I hope it will this week. I will let you know as soon as they arrive. In the mean time, there is one book you can consult in the department library.

1. Determine the kelvin temperature for each of the following

   (a) human body temperature
   (b) the boiling point of water at standard pressure
   (c) the melting point of lead ($327^o$ C)
   (d) -$7^o$ C. (this is how cold it is forecast to be in my hometown in a few days.)

2. Does it make sense to say that water at 80 degrees C is twice as hot as water at 40 degrees? Explain.

3. The exponential atmosphere. (We did part of this problem together in class last week.)

   (a) Consider a horizontal slab of air whose thickness is $dz$. The slab is at rest, to the force due to pressure on the bottom of the slab much be equal to the slab's weight and the force due to pressure on the top of the slab. Use this, along with the ideal gas law, to derive the following differential equation for the variation of pressure $P$ with height $z$:

   $$\frac{dP}{dz} = -\frac{mg}{kT}P \,, \tag{1}$$

   where $k$ is Boltzmann's constant, $T$ is the temperature, $g$ is the acceleration due to gravity, and $m$ is the average mass of an air molecule.
   (b) Write down the solution to Eq. (1).
   (c) Determine the average mass of an air molecule. Assume that air consists of 78% $N_2$, 23% $O_2$, and 1% argon.
   (d) Use your results to estimate the pressure in Kigali and on the top of Mount Kilimanjaro. Assume that the pressure is 1 atm at sea level.
   (e) The law you mentioned to me in class is Pascal's Law:

   $$\Delta P = \rho g \delta z \tag{2}$$

   which states how pressure in a fluid changes with altitude. In this problem you will use your answer from problem 3b to derive Pascal's law. For small $z$, we know that

   $$P(z) = P(0) + P'(0)z \,. \tag{3}$$

   This is just the first-order Taylor expansion. (Or, the linear approximation at $z = 0$. Use $\Delta P = P(z) - P(0)$ and the ideal gas law to derive Pascal's law.