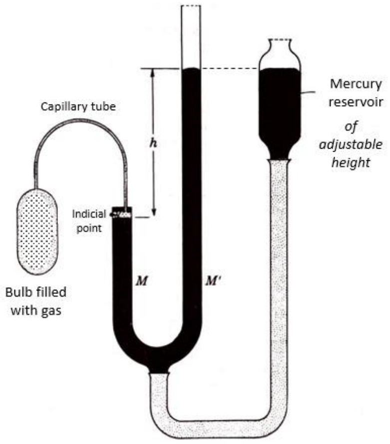
Thermodynamics. Problems. Sheet 1.

1. Classify each property as extensive or intensive: a) temperature; b) mass; c) density; d) electric field intensity; e) coefficient of thermal expansion; f) refractive index.

2. Identify whether the following systems are open, closed, or isolated: a) coffee in a high-quality thermos; b) gasoline in the tank of a running car; c) mercury in a mercury thermometer; d) a plant in a greenhouse.

3. A constant-volume gas thermometer is placed in contact with a system of unknown temperature and then in contact with water at its triple point (273.16 K). The mercury column reaches a height of -10.7 and -15.5 cm respectively. What is the system temperature? The barometric pressure is 0.980 bar, and the thermometer contains hydrogen.

   The density of mercury is 13.546 g cm^{-3}.



4. The Maxwellian distribution function of velocities of particles of a gas in equilibrium at a temperature T (constant), moving in one direction (x), has the form:

$$f(v_x) = \left(\frac{m}{2\pi k_B T}\right)^{1/2} e^{-mv_x^2/2k_BT}$$

   where m is the mass of a single particle, T is the absolute temperature, and k_B Boltzmann's constant. Use this to prove that the distribution function of *speeds* v of the particles (v being the modulus of the velocity vector) is:

$$f(v) = \left(\frac{m}{2\pi k_B T}\right)^{3/2} 4\pi v^2 e^{-mv^2/2k_BT}$$

   Here, $f(v)dv$ is the probability of finding a particle with speed between v and $v + dv$.

5. Starting with the suitable Maxwellian distribution function (see problem 4), show that:

   5a. $< v >= \left(\frac{8k_BT}{\pi m}\right)^{1/2}$ (average gas particle speed)

   5b. $< v^2 >^{1/2}= \left(\frac{3k_BT}{m}\right)^{1/2}$ (root mean square of particle speeds)

   5c. $< v_z >= 0$

6. Show mathematically that the combination of Boyle's and Charles' laws, lead to $PV = kNT$, where k is a constant. (P = pressure; V = volume; N = moles; T = absolute temperature.)

7. Show that the van der Waals equation of state is a cubic function of V. Discuss whether all the terms scale the same way with the extension (size) of the system.

8. Find the expression for the second virial coefficient for a van der Waals gas.

9. Find the Boyle temperature of a van der Waals gas.