Physics 3P41/5P11 Assignment 1

Due: Wednesday October 23, 2019 in drop box across from MC B210a by 12:00 noon.

1. The Nuclear Magnetic Resonance (NMR) technique is used to obtain information about internal magnetic fields in solids. For nuclei of non-zero spin the degeneracy of energy levels with respect to the orientation of the nuclear spin is lifted by the magnetic field. A resonance absorption of electromagnetic power occurs when photons bombarding the solid have the proper energy to excite transitions between these levels. The strength of the absorption depends on the difference in population of the levels involved. Calculate the percentage difference between the populations of two levels at 20.0^o C if the resonant absorption is detected at a frequency of 9.5 MHz.

2. A thin-walled vessel containing 1.0 L of CO_2 is kept at T=0^o C. The gas slowly leaks through a circular hole of diameter 100.0 μm. The outside pressure is low enough that leakage back into the vessel is negligible. The diameter of a CO_2 molecule is approximately 4.6 $\mathring{A}$ and its molecular mass is 44 g/mole.

   (a) Estimate the upper limit of the pressure in the container for effusion to occur through the hole.

   (b) Find an expression for the time dependence of the pressure inside an oven of Volume V with a hole of area A, containing hot gas of molecular mass m at temperature T.

   (c) Calculate the time, starting at the pressure of part (a), for the pressure to drop to one-half its initial value.

3. A diffuse cloud of neutral Hydrogen atoms in space has a temperature of 50 K and number density 500 cm^{-3}.

   (a) Estimate the mean scattering time (in years) between Hydrogen atoms in the cloud. Take the atomic radius of a Hydrogen atom to be 0.79 $\mathring{A}$.

   (b) Estimate the mean free path in astronomical units. (An astronomical unit is the Earth-Sun distance).

4. The space between two concentric cylinders is filled with material of thermal conductivity κ. The inner cylinder has radius r_1 and is maintained at temperature T_1, while the outer cylinder has radius r_2 and is maintained at temperature T_2. Derive an expression for the heat flow per unit length between the cylinders