Thermodynamics & Statistical Mechanics PSet 12

1. **Book Problems:** 7.51, 7.52, 7.54, 7.64, 7.66, 7.72, 7.73

2. **Natural Units (Extra Credit):** The goal is to write some important quantities in 'natural' units, so we can better understand how material properties follow from fundamental physics. First show that if we work in units where $\hbar = c = 1$ (also $k_B = 1$) then temperature, energy, and momentum have the same units, while distance and time have units of 1/energy. So for example the electron mass m_e picks out a corresponding length scale $1/m_e$. Also, show that the fine structure constant $\alpha \equiv \frac{e^2}{4\pi\epsilon_0\hbar c}$ is dimensionless, so it's of the order of 10^{-2}, so it's meaningfully small. (This is a dimensionless sense in which the electromagnetic force between fundamental charges is weak.)

   With that established, write the Rydberg energy and Bohr radius in terms of m_e and α. Make a natural, rough guess for the average separation between atoms in a solid in terms of m_e and α, and then use this to make a rough estimate of the Fermi energy ϵ_F.

   Now try to make a guesstimate of the Debye energy T_D in terms of α, m_e, and the atomic mass M. How do you expect T_D to compare to T_F for a generic material?

   If you liked this problem, for fun you can try to re-write everything else you've ever studied in this way in order to try to better understand why some numbers are large and some are small. For example, determine the 'natural units' of the Newton constant G_N and compare its magnitude to some power of m_e. How does the magnitude of the gravitational force between two electrons compare to the electric force? Why are stars so big? You may have learned about white dwarves and neutron stars from other recent problems... it should be possible to write their size in terms of G_N and other fundamental parameters.

3. **Book Problem Extra Credit:** 7.50, 7.53, 7.70