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## Problem Set #11

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In problems 1-3 compare the average number density  $\rho$  with the quantum number density

$$\rho_Q = g_s \left[ \frac{mc^2 k_B T}{2\pi(\hbar c)^2} \right]^{3/2}. \quad (\text{Note: } g_s = 2 \text{ for spin-1/2 fermions, } = 1 \text{ for spin-0 bosons.})$$

1. Solid copper ( $M = 64$ ) has a mass density of 8.96 gm/cc. Assuming that each atom in a piece of solid copper provides one electron to the conduction band determine the ratio  $\rho/\rho_Q$  at  $T = 300\text{K}$ . Are the electrons “hot,” “cold,” or “in between”?
2. A white dwarf is a smallish dense star that you can treat, to first order, as a plasma of protons and electrons. Assuming that the mass density of the star is  $10^6$  gm/cc at a temperature of 150,000 K, and that there is one electron for every proton, determine the ratio  $\rho/\rho_Q$  for the (a) protons and (b) electrons. State for each whether they are “hot,” “cold,” or “in between.”
3. Liquid helium ( $M = 4$ ) has a mass density of 0.146 gm/cc. Find the temperature at which the ratio  $\rho/\rho_Q = 1$  (i.e., “in between”).