PHYS-3301 Homework 12 NO DUE DATE

This homework is not to be turned in and will not be marked. It is solely for you to practice problems on statistical mechanics and Planck's law for the term test. Solutions will be posted on the course web site on Dec 3.

1. **Doppler Broadening** *from a question by Reif*

   Consider a thermal gas of atoms of mass m and temperature T. These atoms emit a spectral line of frequency ω_0 *when at rest.* Assuming the atoms move non-relativistically, what is the root-mean-square change in the observed frequency of the spectral line due to the thermal motion of the atoms? *Hint:* If the gas is located at the origin and the observer is a long distance away along the x axis, you only need to consider the motion in the x direction. *Second hint:* The root-mean-square value of something is the square root of the average of its square: $y_{rms} = \sqrt{\langle y^2 \rangle}$.

2. **Number of Photons** *based on Scherrer 1.10*

   (a) Using an argument very similar to our derivation of Planck's law, find the average number of photons in a wave mode with frequency ν.

   (b) Using your result, find the number density of photons per frequency interval.

   (c) Then integrate to show that the total number density of photons in a blackbody of temperature T is $n = \alpha(kT/hc)^3$, where α is a numerical constant (you do not need to evaluate α).

3. **Rayleigh-Jeans vs Planck** *based on Scherrer 1.4*

   Consider the Planck distribution as a function of $x = h\nu/kT$ and write the first two terms of its Taylor series around $x = 0$. Show that the leading term (the lowest order one) agrees with the Rayleigh-Jeans law. Then find the value of x when the first correction is 10% of the leading value.