# PHYS 321: PROBLEM SET 2

Due Feb 7 @ 02:30 pm

*Solve the problems listed below, and* ***write up your answers clearly and completely****. Do not turn in rough work – instead, make a clean copy after checking your calculations. Use English sentences and phrases to explain your solution and describe your answers step by step. Even if you did not get the correct answer, you may get partial credits for these steps!*

1. (2 credits) Integrate the Planck Function (differentiated in wavelength, i.e., Eq. 3.22 in your textbook) over all wavelengths, angle, and surface area of a star with radius $R$ to recover the Stefan-Boltzmann Equation (Eq. 3.17 in textbook). Write the Stefan-Boltzmann constant in terms of basic physical constants including $k$, $c$, and $h$. Hint: $\int_0^\infty x^3 dx/(e^x - 1) = \pi^4/15$.

2. (3 credits) Barnard's star, named after the American astronomer Edward E. Barnard (1857?1923), is an orange star in the constellation Ophiuchus. It has the largest known proper motion ($\mu = 10.3577''$ yr$^{-1}$) and the fourth-largest parallax angle ($p = 0.54901''$). Only the stars in the triple system $\alpha$ Centauri have larger parallax angles. In the spectrum of Barnard's star, the H$\alpha$ absorption line is observed to have a wavelength of 656.034 nm when measured from the ground.
   (a) Determine the radial velocity of Barnard's star.
   (b) Determine the transverse velocity of Barnard's star.
   (c) Calculate the speed of Barnard's star through space.

3. (2 credits) Find the shortest vacuum-wavelength photon emitted by a downward electron transition in the Lyman, Balmer, and Paschen series. These wavelengths are known as the *series limits*. In which regions of the electromagnetic spectrum are these wavelengths found?

4. (3 credits) An electron spends roughly $10^{-8}$ s in the first excited state of the hydrogen atom before making a spontaneous downward transition to the ground state.
   (a) Use Heisenberg's uncertainty principle (Eq. 5.20 in the textbook) to determine the uncertainty $\Delta E$ in the energy of the first excited state.
   (b) Calculate the uncertainty $\lambda$ in the wavelength of the photon involved in a transition (either upward or downward) between the ground and first excited states of the hydrogen atom. (Hint: You can assume that $\Delta E = 0$ for the ground state. But explain why.) This increase in the width of a spectral line is called *natural broadening*.