PHYS 321: PROBLEM SET 2

Due Feb 7, 2018 @ 11:30 am

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. (3 credits) Planck function and Rayleigh-Jeans Law
   (a) Derive the Rayleigh-Jeans Law from the expression for B_ν given in the lecture notes, by using the approximation $h\nu \ll kT$. (Hint: use Taylor expansion on e^x when $x \ll 1$ and ignore high-order terms.)
   (b) Use your favorite programming language, plot the Planck function B_λ and the Rayleigh-Jeans law for the Sun ($T_\odot = 5777$ K) on the same graph. At roughly what wavelength is the Rayleigh-Jeans value twice as large as the Planck function?

2. (2 credits) What is the luminosity of a star with absolute visual magnitude $M_V = 3.49$ and bolometric correction $BC = -0.11$, in units of the solar luminosity? The absolute bolometric magnitude of the Sun is $M_{bol,\odot} = 4.74$.

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 ΔE in the energy of the first excited state.
   (b) Calculate the uncertainty λ 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*.