Homework 4

Due **September 24 by 10:45am via Canvas upload**
Please show all work, writing solutions/explanations clearly, or no credit will be given. You are encouraged to work together, but everyone must turn in independent solutions; do not copy from others or from any other sources.

1. An interstellar cloud that is 50 pc thick along our line of sight absorbs 50% of the $\lambda = 550$ nm light passing through it.
   (a) What is the mean free path for photons of this wavelength in this cloud?
   (b) How thick would the cloud have to be in order to absorb only 25% of the $\lambda = 550$ nm light passing through it?
   (c) How thick would it have to be in order to absorb 99% of the light?

2. The average adult human eye can be approximated as a solid sphere, with a radius of 20 mm. Human body temperature is 98.5° F = 310 K.
   (a) In any 1 s interval, what is the total energy in your eye, due to the photons produced by your eyeball itself? Express your answer in Joules.
   (b) Staring at a normal 100 W lightbulb that is 1 meter away results in 8×10^{-15} J of energy inside your eye in any 1 s interval. Which contributes more energy to the interior of your eye: the lightbulb or your eye itself?
   (c) Why does it get dark when you close your eyes?

   (HINT: Think about how the energies of the photons from the different sources are distributed.)

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3. In the spectrum of a star, you measure the second line of the Balmer absorption series, also called H-β, to be at a wavelength of $\lambda = 4862.3$ Å.
   (a) Calculate the rest wavelength of this line, in Å.
   (b) Is the star moving towards you or away from you?
   (c) How quickly is it moving towards you or away from you?
   (d) Using only this information, and the fact that the star has a parallax angle of $\pi'' = 0.1''$, can you deduce anything about the star's sideways, or tangential, motion?

4. Assuming stars are spherical and emit radiation as perfect blackbodies:
   (a) From the wavelength equation of a blackbody's intensity, $I_\lambda(T)$, show that the most probable wavelength $\lambda_p = \frac{0.0029 \text{ m K}}{T}$.
   (HINT: you should end up with an expression that cannot be solved analytically and will need to compute it numerically, e.g., with a graphing calculator.)
   (b) For a star with a surface temperature $T = 7000$ K, at what wavelength are most of its photons being emitted? What visible color does this correspond to?
   (c) If the star has a parallax angle $\pi'' = 0.05''$ and a measured total flux (integrated over all wavelengths, also called the bolometric flux) of 3×10^{-9} J m^{-2} s^{-1}, estimate the radius of the star relative to the Sun's radius (i.e., in solar units $R_\odot$).