Astronomy 210 Spring 2005
Homework #4

Due in class: Friday, Feb. 25.

Problems

1. Tour of the electromagnetic spectrum.

   (a) (5 points) The highest energy γ-rays ever detected have a frequency of about 2×10^{26} Hz. Calculate the energy of this γ-ray in both ergs and eV (electron Volts). Compare the energy of one of these photons to the kinetic energy of a drop of water falling out of your kitchen faucet (make your own estimates for mass, speed, etc., and make sure you record your assumptions when you make the comparison).

   (b) (2 points) Find the wavelength of an X-ray with energy 1 keV, and compare this to the wavelength of visible light (i.e. just write down a typical wavelength for visible light).

   (c) (2 points) The Hubble space telescope routinely detects optical photons from galaxies so faint that only 10^{-10} ergs of visible light from the galaxy are captured by the telescope in the entire exposure. Approximately how many photons is this?

   (d) (2 points) A microwave oven typically operates at a frequency of 2.45 GHz (1 GHz $= 10^9$ Hz). What is the wavelength of the microwaves in your oven? Compare to the size of a slice of pizza.

   (e) (2 points) An AM radio operates at a typical frequency of 1 MHz (10^6 Hz). What is the corresponding wavelength?

2. The pupil of the eye has a diameter of about 7 mm.

   (a) (3 point) What is the angular resolution of your eye at a wavelength of 500 nm (green light)? Express your answer in radians and in arcsec.

   (b) (3 points) How much fainter a flux level can you detect looking through the mighty UofI 12-inch diameter telescope than with your eye alone?

3. Consider a $100\,M_\odot$ star which has surface ("effective") temperature $47,000$K, and radius 17 times that of the sun.

   (a) (3 points) Find the star's luminosity, assuming it radiates like a blackbody.

   (b) (2 points) Find the wavelength of peak emission.

   (c) (1 point) Find the frequency of peak emission.

4. Your average body temperature is approximately 37° C.

   (a) (1 point) What is this in absolute units (Kelvin)?

   (b) (1 point) What is the peak wavelength emitted by a person with this temperature?

   (c) (3 points) What region of the spectrum is this? Is this consistent with the observed fact that humans do not appear to glow (optically) in the dark? Wouldn't that be cool though?

   (d) (4 points) Estimate the surface area of your body (in m^2). You are welcome to make any reasonable assumptions and approximations, but be sure to state what these are.

   (e) (4 points) Assuming your body radiates like a blackbody (OK within a factor of 2-3), estimate the total power L radiated by your body in Watts. How does this compare to the power requirement of a typical light bulb?

   (f) (4 points) How much energy does your body radiate in one day? Express your answer in Joules, and then in Calories (the things that appear on food labels) where 1 Cal = 1 kcal = 10^3 cal = 4.2×10^3 J.

   (g) (5 points) The number in part (f) is higher than a typical dietary intake of about 2000 Cal per day. This is because we have neglected the radiative energy input from the environment! If room temperature is about 24° C, follow the steps above and find the power input into your body in Watts, and then the daily input in Cal.

   (h) (3 points)Find the *net* radiative energy output per day (i.e., the result from (3f) minus the result from (3g). If all has gone well, you will nd that this is about equal to the food energy intake per day, and you have shown that you conserve energy!