

1. (4 pts) A typical 100 Watt light bulb actually only puts out about 2 Watts of visible light. Assuming, for simplicity, that all of the visible light coming from such a bulb is yellow with a wavelength of 590 nm, how many photons exit the bulb per second? This explains why we didn't realize that light was quantized earlier! Remember that the frequency of light,  $\nu$ , is equal to  $c/\lambda$ .

The next three problems give some insight into blackbody radiation and light quantization. More importantly they will give you a glimpse into some of the things we will be doing later when we study quantum statistics. These problems may seem a bit difficult, but I think you will be glad to have seen this and had time to think about it before we dive into it full-force in the quantum statistics section!

2. (6 pts) What if the Rayleigh-Jeans equation were correct? Integrate the Rayleigh-Jeans equation to find the total amount of thermal light energy it predicts would be contained inside a one cubic cm cavity which is at a temperature of 300 K.
3. (6 pts) Now let's calculate the correct amount of energy using the Planck radiation law. To do this integral, first define  $x \equiv h\nu/kT$ , find  $d\nu$  in terms of  $x$  and  $dx$ , and write the integral in terms of  $x$  and  $dx$ . Here is the integral you will need:  $\int_0^\infty \frac{x^3}{e^x-1} dx = \frac{\pi^4}{15} = 6.494$ .
4. (6 pts) (a) If  $u(\nu)d\nu$  represents the blackbody energy per unit volume with a frequency between  $\nu$  and  $\nu + d\nu$ , write down a function  $n(\nu)d\nu$  which is the number of photons per unit volume with a frequency between  $\nu$  and  $\nu + d\nu$ . (b) Find the total number of photons in a one cubic cm cavity which is at 300 K. The integral you will need is  $\int_0^\infty \frac{x^2}{e^x-1} dx = 2.40411$ .
5. (4 pts) A stream of UV photons strikes a piece of aluminum and knocks electrons off of it. You find that a voltage of 4.19 volts is needed to deflect the electrons back to the aluminum. What is the wavelength of the photons. The work function for aluminum is 4.08 eV.
6. (4 pts) Explain how the Compton effect gives evidence that light is quantized.

**Extra problems I recommend you work (not to be turned in)**

- From Planck's radiation law, derive Wien's displacement law (including the constant).
- Starting from Planck's radiation law for  $u(\nu)d\nu$ , find  $u(\lambda)d\lambda$ , the energy per unit volume per with a wavelength between  $\lambda$  and  $\lambda + d\lambda$ . Now integrate this over all wavelengths to find the energy contained in a one cubic cm cavity at 300 K. You should get the same answer as you did in problem 3 (although this problem is a bit subtle — you have to convert  $d\nu$ , not just  $u(\nu)$ ).