Physics 252 – **Modern Physics**

Homework Assignment #2

Due Friday, February 2, 2007 at the beginning of class.

Reading: Feynman, chapters 1 and 2; Fowler, "Photoelectric Effect", "More on the Uncertainty Principle"

1. (a) If 5 percent of the power of a 100-W bulb is radiated in the visible spectrum, about how many visible photons are radiated per second? (b) If the bulb radiates equally in all directions, what is the flux of photons at a distance of $2\,m$? Flux is defined as number per unit time per unit area.

2. It takes $1.9\,eV$ to free an electron from cesium. (a) Find the longest-wavelength light which can free the electron. Find the potential required to stop the electron if the wavelength of the incident light is (b) $250\,nm$, and (c) $350\,nm$.

3. In the double-slit experiment (slits separated by a distance d) with a light bulb behind the slits, what momentum photons will disturb the interference pattern? What type of light is this (e.g. visible? X-ray?), if d is atomic size ?

4. A beam of electrons traveling in the x direction with speed $c/4$ passes through a slit of width $10^{-5}\,m$. Because of the uncertainty in the lateral position of the beam, there will be uncertainty in the transverse momentum as well ("Transverse" means perpendicular to the direction of motion.) Estimate this uncertainty, and use it to calculate approximately the spread of the image when it hits the backstop, which is $2.0\,m$ beyond the slit.

5. Another way of intuitively understanding the uncertainty principle is as a consequence of particles behaving as waves. Consider a particle whose probability amplitude is given by the wave packet in Fig. 2-1 of Feynman. The total number of waves N_w in the box is somewhat uncertain because of the way the amplitude falls off. For a region of size Δx, call the uncertainty in the number of waves ΔN_w.

   (a) Relate ΔN_w to the uncertainty in the wavelength $\Delta\lambda$. Assuming $\Delta N_w \sim \pm 1$, write this relation as an uncertainty principle relating Δx and $\Delta\lambda$.

   (b) Rewrite this in terms of Δp and Δx.

6. The argument of the last problem can be generalized to an uncertainty relation for energy as well. Assume we have a wave which now has a finite extent in time Δt. Count the number of wave peaks $\mathcal{P}$ which go by. Like with the last problem, because the wave packet falls off in time, you're not really certain exactly how may peaks have gone by, so call the uncertainty $\Delta\mathcal{P}$. Assume $\Delta\mathcal{P} \sim \pm 1$.

   (a) Relate the uncertainty in frequency $\Delta\nu$ to $\Delta\mathcal{P}$ and Δt.

   (b) Assume the particles are of a very small mass, so that you can use the formula $E = h\nu$ to relate frequency to energy. Use your result from part (a) to write down an uncertainty relation for ΔE and Δt.