University of Alabama
Department of Physics and Astronomy

PH 253 / LeClair — Spring 2010

Problem Set 3: Photons and Such

Instructions:

1. Answer all questions below.
2. Show your work for full credit.
3. All problems are due Thurs 4 February 2010 by the end of the day.
4. You may collaborate, but everyone must turn in their own work.

1. The energy required to break one O=O bond in ozone (O_3, O=O=O) is about 500 kJ/mol. What is the maximum wavelength of the photon that has enough energy to photodissociate ozone by breaking one of the O=O bonds?

$$O_3 \xrightarrow{hf} O + O_2$$

Note Avagadro's number is $N_A = 6.02 \times 10^{23}$ things/mol.

2. *Park 1.2* Show that it is impossible for a photon striking a free electron to be absorbed and not scattered.

3. *Park 1.3* What is the expected recoil velocity of a sodium atom which at rest emits a quantum of its $\lambda = 589.0$ nm radiation?

4. *Ohanian 37.48* Suppose that a photon is "Compton scattered" from a proton instead of an electron. What is the maximum wavelength shift in this case?

5. The Compton shift in wavelength $\Delta\lambda$ is independent of the incident photon energy $E_i = hf_i$. However, the Compton shift in *energy*, $\Delta E = E_f - E_i$ is strongly dependent on E_i. Find the expression for ΔE. Compute the fractional shift in energy for a 10 keV photon and a 10 MeV photon, assuming a scattering angle of 90°.

6. Show that the relation between the directions of motion of the scattered photon and the recoiling electron in Compton scattering is

$$\frac{1}{\tan(\theta/2)} = \left(1 + \frac{hf_i}{m_e c^2}\right) \tan\varphi \tag{1}$$

7. *French & Taylor 1.8* A radio station broadcasts at a frequency of 1 MHz with a total radiated power of 5 kW. **(a)** What is the wavelength of this radiation? **(b)** What is the energy (in electron volts) of the individual quanta that compose the radiation? How many photons are emitted per second? Per cycle of oscillation? **(c)** A certain radio receiver must have 2 μW of radiation power incident on its antenna in order to provide an intelligible reception. How many 1 MHz photons does this require per second? Per cycle of oscillation? **(d)** Do your answers for parts (b) and (c) indicate that the granularity of electromagnetic radiation can be neglected in these circumstances?

8. *French & Taylor 1.11* The clean surface of sodium metal (in vacuum) is illuminated with monochromatic light of various wavelengths and the retarding potentials required to stop the most energetic photoelectrons are observed as follows:

Wavelength (nm)	253.6	283.0	303.9	330.2	366.3	435.8
Stopping potential (V)	2.60	2.11	1.81	1.47	1.10	0.57

Plot these data in such a way as to show that they lie (approximately) on a straight line as predicted by the photoelectric equation, and obtain a value for h and the work function of sodium in electron volts.

9. *Ohanian 37.51* What is the maximum energy that a free electron (initially stationary) can acquire in a collision with a photon of energy 4 keV?