University of Alabama
Department of Physics and Astronomy
PH 253-002 Spring 2019

Homework 2

Instructions:

1. Answer all questions below. Show your work for full credit.
2. All problems are due by 4:45pm on Mon 11 Feb as a hard copy, or by 11:59pm on Mon 11 Feb via Blackboard
3. You may collaborate, but everyone must turn in their own work.

1. Gamma rays of energy 0.657 MeV are Compton scattered. **(a)** What is the energy of the scattered photon observed at a scattering angle of 64.0°? **(b)** What is the kinetic energy of the scattered electrons?

2. An X-ray photon with $\lambda = 60\,\text{pm}$ is scattered over 150° by a target electron. **(a)** Find the change of its wavelength. **(b)** Find the angle between the directions of motion of the recoil electron and the incident photon. **(c)** Find the energy of the recoil electron.

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

4. An X-ray photon with wavelength 0.8 nm is scattered by an electron at rest. After the scattering the electron recoils with a speed equal to 1.4×10^6 m/s (non-relativistic case). *NOTE: in the following, do the calculations to at least 4-decimal place accuracy.* **(a)** Calculate the energy of the scattered photon in units eV (use conservation of energy). **(b)** Calculate the Compton shift in the photon's wavelength, in meters. **(c)** Calculate the angle through which the photon was scattered.

5. A particle of charge q and mass m has been accelerated from rest through a potential difference ΔV. Find an expression for its de Broglie wavelength.

6. Lithium, beryllium, and mercury have work functions of 2.30 eV, 3.90 eV, and 4.50 eV, respectively. If 400 nm light is incident on each of these metals, determine **(a)** which metals exhibit the photoelectric effect and **(b)** the maximum kinetic energy for the photoelectrons in each case.

7. **(a)** Show that the frequency f and wavelength λ of a freely moving particle are related by the expression

$$\left(\frac{f}{c}\right)^2 = \frac{1}{\lambda^2} + \frac{1}{\lambda_C^2} \tag{1}$$

where $\lambda_C = h/mc$ is the Compton wavelength of the particle. **(b)** Is it ever possible for a particle having nonzero mass to have the same wavelength *and* frequency as a photon? Explain.

8. The nucleus of an atom is on the order of 10^{-14} m in diameter. For an electron to be confined to a nucleus, its de Broglie wavelength would have to be of this order of magnitude or smaller. **(a)** What would be the kinetic energy of an electron confined to this region? **(b)** On the basis of this result, would you expect to find an electron in a nucleus? Explain.

9. What is the speed of en electron if its de Broglie wavelength equals its Compton wavelength?

10. The table below shows data obtained in a photoelectric experiment. Find the value of Planck's constant and the metal's work function implied by the data. By what percentage does the value for Planck's constant differ from the accepted value?

Wavelength (nm)	**Maximum KE of photoelectrons (eV)**
588	0.67
505	0.98
445	1.35
399	1.63