PH2400 Exam 1, Spring 2015

Show your work for full credit.

1. The light intensity incident on a metallic surface with a work function of 3 eV produces photoelectrons with a maximum kinetic energy of 2 eV. The frequency of the light is then doubled. Determine the maximum kinetic energy of the resulting photoelectrons, in eV. (5 points)

\[ K.E_1 = h f_1 - 3 \text{ eV} = 2 \text{ eV} \Rightarrow h f_1 = 5 \text{ eV} \]

Then, \( h f_2 = 2 h f_1 \) so \( K.E_2 = 10 \text{ eV} - 3 = 7 \text{ eV} \)

2. If the interplanar spacing of NaCl is \( 2.814 \times 10^{-10} \text{ m} \), what is the predicted angle at which x-rays of wavelength 0.14\( \times 10^{-10} \) m will be diffracted in a first-order maximum? (5 points)

An ambiguous question. Could have been interpreted as scattering between layers (Fig. 3.20), Bragg's law,

\[ n \lambda = 2 d \sin \theta \]

Then \( n \lambda = 2 d \sin \theta \), \( n = 1 \), \( d = 2.81 \times 10^{-10} \)

\[ \sin \theta = \frac{0.14 \times 10^{-10}}{5.62 \times 10^{-10}} \Rightarrow \theta = 14.9^\circ \]

Or Davisson-Germer (Fig 5.6)

\[ n \lambda = d \sin \phi \], \( n = 1 \), \( d = 2.81 \times 10^{-10} \text{ m} \)

\[ 0.14 \times 10^{-9} = \sin \phi \Rightarrow \phi = 29.8^\circ \]

(either answer accepted)
3. A spaceship moves at a speed of 0.95c away from the earth. It shoots a torpedo toward the earth at a speed of 0.9c relative to the ship. What is the velocity of the torpedo relative to the earth? (5 points)

\[
\alpha = \frac{0.9c - 0.95c}{1 - (0.9c)(0.9c)} = -0.3\sqrt{5}c
\]

4. Electrons are accelerated through a voltage, \(V\), towards a collection of hydrogen atoms all in the ground state. What is the minimum value of \(V\) in order to excite the hydrogen atoms to the \(n=3\) state? (5 points)

\[
eV_{n=3} = 13.6 \left( \frac{1}{1^2} - \frac{1}{3^2} \right) = 12.1 [eV]
\]

\[
\therefore \ V_{n=3} = 12.1 \text{ Volts}
\]
5. A photon whose energy is $8 \times 10^{-15}$ J is scattered off an electron at an angle of 90°. What is the wavelength of the scattered wave? (5 points)

$$\lambda' - \lambda = \frac{h}{mc} \left(1 - c^2 \sin^2 \theta \right)$$

$$\lambda' = \lambda \cdot \frac{h}{mc} = \frac{hc}{E} + \frac{h}{mc}$$

$$= 6.63 \times 10^{-34} \text{ J s} \left( \frac{3.7 \times 10^{15} \text{ rad}}{3 \times 10^8 \text{ cm/s}} \right)$$

$$= 2.73 \times 10^{-11} \text{ m}$$