KEY - EXAM1

Problem1:

(II) In a photoelectric-effect experiment it is observed that no current flows unless the wavelength is less than 520 nm.

(*a*) What is the work function of this material?

17

$K = hf - \Phi$ $\lambda = 520$ nm is the thershold

$\Rightarrow K_{max} = 0$

$hf - \Phi = 0 \Rightarrow \Phi = hf$

$$\Rightarrow \Phi = \frac{hc}{\lambda} = \frac{1240\,eV \cdot nm}{520\,nm} = 2.38\,eV$$

(*b*) What is the stopping voltage required if light of wavelength 470 nm is used?

$\lambda = 470\,nm$

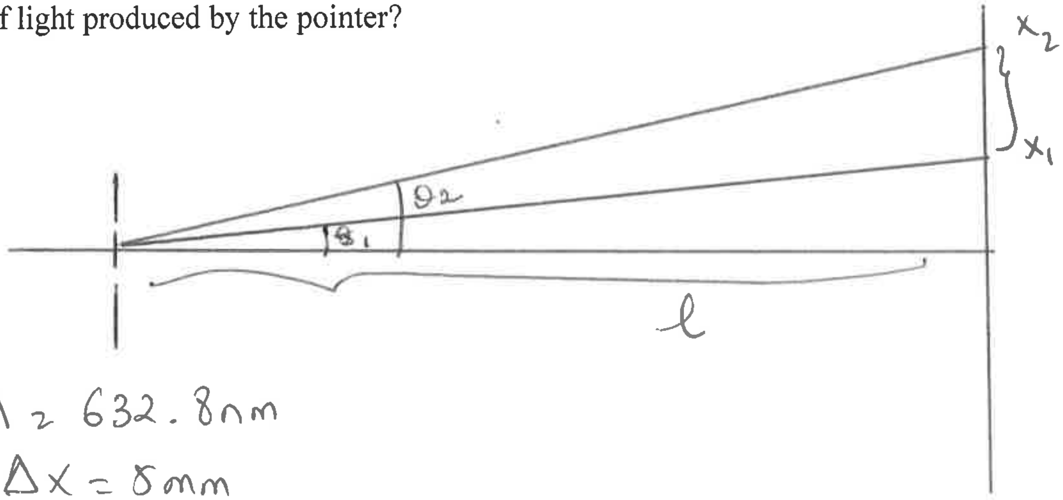
$K_{max} = 0.25\,eV$

$\Delta U = -\Delta K = -q\Delta V$

$\Delta K = -(-e\Delta V) = e\Delta V$

$$\Delta V = \frac{\Delta K}{e} = \frac{0.25\,eV}{e} = 0.25\,V$$

Problem 2: A red laser from the physics lab is marked as producing 632.8-nm light. When light from this laser falls on two closely spaced slits, an interference pattern formed on a wall several meters away has bright fringes spaced 5.00 mm apart near the center of the pattern. When the laser is replaced by a small laser pointer, the fringes are 5.14 mm apart. What is the wavelength of light produced by the pointer?



17

$X_2 - X_1 = \Delta x$

$\lambda = 632.8\,nm$

$\Delta x = 5\,mm$

λ_2? for $5.14\,mm$

$d \sin\theta = m\lambda$

$\tan\theta = \sin\theta \simeq \theta = \frac{x}{l}$

$m = 1$

$d \sin\theta = d\frac{x}{l} = m\lambda \Rightarrow \frac{x}{l} = \frac{m\lambda}{d}$; $x = \frac{m\lambda l}{d}$

$X_1 = \frac{\lambda_1 l}{d}$ & $X_2 = \frac{\lambda_2 l}{d} \Rightarrow \lambda_1 = \frac{X_1 d}{l}$ & $\lambda_2 = \frac{X_2 d}{l}$

$\frac{d}{l} = \frac{\lambda_1}{X_1} \Rightarrow \lambda_2 = \frac{X_2 \lambda_1}{X_1} = \frac{5.14\,nm}{5.0\,nm}(632.8\,nm)$

$= 650.52\,nm$

15

Problem 3: X-rays of wavelength λ=0.120nm are scattered from carbon. What is the expected Compton wavelength shift for photons detected at angles (relative to the incident beam) of exactly

(*a*) 60°,

$$\lambda' = \lambda + \frac{h}{m_e c}(1 - \cos 60^\circ)$$

$$\lambda' = 0.120\,nm + 0.00243\,nm\,[1 - \cos 60^\circ] = 0.1212\,nm$$

$$\Delta\lambda = 0.0012\,nm$$

(b)90°,

$$\lambda' = \lambda + \frac{h}{m_e c}(1 - \cos 90^\circ)$$

$$= 0.120\,nm + 0.00243\,nm\,[1 - \cancel{\cos 90^\circ}] = 0.12243\,nm$$

$$\Delta\lambda' = 0.00243$$ [same as the compton wavelength]

(a) 180°?

$$\lambda' = \lambda + \frac{h}{m_e c}[1 - \cos 180^\circ]$$

$$= 0.120\,nm + 0.00243\,nm\,[1 - \cos 180^\circ] = 0.1248\,nm$$

higher λ'

$$\Delta\lambda' = 0.005\,nm$$

Problem4:

15

What is the speed of a pion if its average lifetime is measured to be $4.40 \times 10^{-8} s$. At rest, its average lifetime is $2.60 \times 10^{-8} s$

the speed is determined from the time dilation relationship

$v = ?$

$$\Delta t_0 = \Delta t \sqrt{1 - \frac{v^2}{c^2}} \Rightarrow \frac{\Delta t_0}{\Delta t} = \sqrt{1 - \frac{v^2}{c^2}}$$

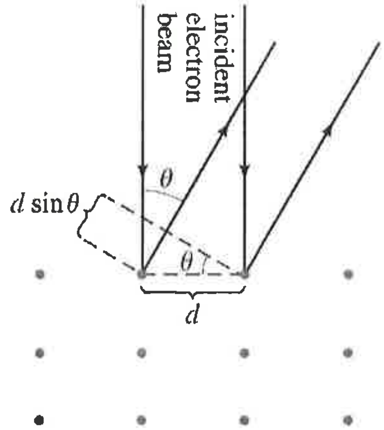
$$\Rightarrow \left(\frac{\Delta t_0}{\Delta t}\right)^2 = 1 - \frac{v^2}{c^2} \Rightarrow \frac{v^2}{c^2} = 1 - \left(\frac{\Delta t_0}{\Delta t}\right)^2$$

$$\Rightarrow v^2 = c^2 \left(1 - \left(\frac{\Delta t_0}{\Delta t}\right)^2\right) \Rightarrow v = c\sqrt{1 - \left(\frac{\Delta t_0}{\Delta t}\right)^2}$$

$$v = c\sqrt{1 - \left(\frac{2.60 \times 10^{-8} s}{4.40 \times 10^{-8} s}\right)^2} = 0.807c = 2.42 \times 10^8 \frac{m}{s}$$

Problem 5: 18

The wave nature of electrons is manifested in experiments where an electron beam interacts with the atoms on the surface of a solid. By studying the angular distribution of the diffracted electrons, one can indirectly measure the geometrical arrangement of atoms. Assume that the electrons strike perpendicular to the surface of a solid, and that their energy is low, K = 100 eV, so that they interact only with the surface layer of atoms. If the smallest angle at which a diffraction maximum occurs is at 24°, what is the separation d between the atoms on the surface?



$K = 100\,eV \qquad \theta = 24^\circ$

$d \sin\theta = m\lambda$

$P = \frac{h}{\lambda}$

$K = \frac{p^2}{2m_e} = \frac{h^2}{2m_e\lambda^2}$

$\Rightarrow \lambda^2 = \frac{h^2}{2m_e K^2} \Rightarrow \lambda = \frac{h}{\sqrt{2m_e K}}$

$$\Rightarrow \lambda = \frac{(6.63 \times 10^{-34}\,J.s)}{\sqrt{2(9.11 \times 10^{-31}\,kg)(100\,ev)(1.6 \times 10^{-19}\,\frac{J}{ev})}}$$

$\lambda = 0.123\,nm$

The spacing is :

$$d = \frac{m\lambda}{\sin\theta} = \frac{\lambda}{\sin\theta} = \frac{0.123\,nm}{\sin 24^\circ} = 0.30\,nm$$

Problem 6: Suppose you decide to travel to a star 65 light-years away at a speed that tells you the distance is only 25 light-years. How many years would it take you to make the trip?

18

The speed will be determined from the length contraction

$$l = l_0 \sqrt{1 - \frac{v^2}{c^2}} \Rightarrow \frac{l}{l_0} = \sqrt{1 - \frac{v^2}{c^2}}$$

$$\Rightarrow \left(\frac{l}{l_0}\right)^2 = 1 - \frac{v^2}{c^2} \Rightarrow \frac{v^2}{c^2} = 1 - \left(\frac{l}{l_0}\right)^2$$

$$\frac{v}{c} = \sqrt{1 - \left(\frac{l}{l_0}\right)^2} \Rightarrow v = c\sqrt{1 - \left(\frac{l}{l_0}\right)^2}$$

and $$t = \frac{l}{v} = \frac{l}{c\sqrt{1 - \left(\frac{l}{l_0}\right)^2}}$$

$$t = \frac{25\,ly}{c\sqrt{1 - \left(\frac{25\,ly}{65\,ly}\right)^2}} = \frac{(25\,y)c}{c(0.923)} = 27 \text{ years}$$