Modern Physics **EXAM 3** **Fall 2022**

Name KEY

Problem1:

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

17 points

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

$K = hf - \Phi$

$\lambda = 520\,nm$ is the threshold $K_{max} = 0$

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

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

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

$\lambda = 470\,nm$

$K_{max} = hf - \Phi = \frac{hc}{\lambda} - \Phi = \frac{1240\,eV.nm}{470\,nm} - 2.38\,eV$

$K_{max} = 0.25\,eV$

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

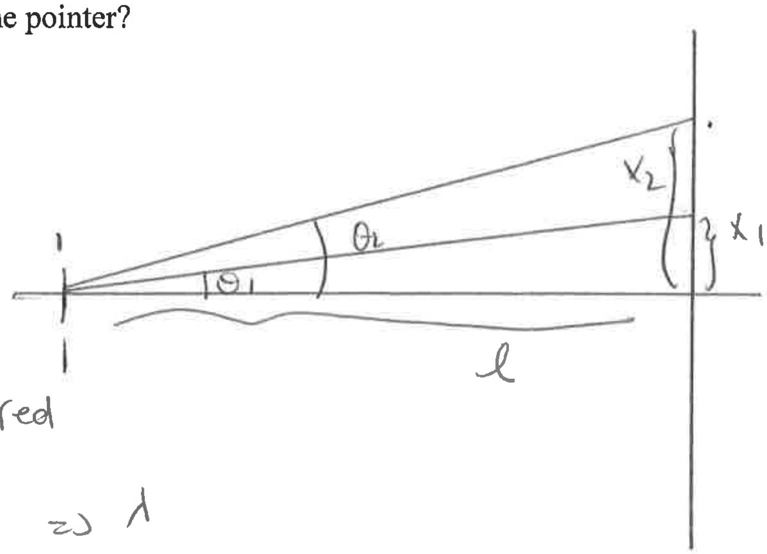
$\Delta K = -(-e\Delta V) = e\Delta V$

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

Name____________________________

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 points



$\Delta x = X_1 - X_2$

$\left.\begin{array}{l}\lambda = 632.8\,nm \\ \Delta x = 5\,mm\end{array}\right\}$ red

$\Delta x = 5.14\,mm \Rightarrow \lambda$

$d \sin\theta = m\lambda$

$\sin\theta \simeq \tan\theta \simeq \frac{x}{\ell}$

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

$X_1 = \frac{\lambda_1 \ell}{d} \Rightarrow \frac{X_1}{\lambda_1} = \frac{\ell}{d}$ (1) & $\frac{X_2}{\lambda_2} = \frac{\ell}{d}$ (2) $\Rightarrow \lambda_2 = \frac{X_2}{\ell} d$

from (1) & (2)

$\lambda_2 = \frac{X_2}{\ell} d = \frac{X_2 \lambda_1}{X_1} = \frac{5.14\,mm}{5.0\,mm}(632.8\,nm) = 650.52\,nm$

Name________________________________

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°,

15 points

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

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

$$\Delta\lambda = \lambda' - \lambda = 0.1212\,nm - 0.120\,nm = 0.0012\,nm$$

(b)90°,

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

$$= 0.120\,nm + 0.0243\,[1 - \cancel{\cos 90^\circ}] = 0.12243\,nm$$

$$\Delta\lambda = 0.12243 - 0.120 = 0.00243\,nm$$

(same as compton wavelength

(a) 180°?

$$\lambda' = \lambda + \frac{h}{m_e c}(1 - \cos 180)$$

$$= 0.120\,nm + 0.00243\,nm\,[1 - (-1)] = 0.1248\,nm$$

higher λ'

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

Name________________________________

Problem4: An electron moves in a straight line with a constant speed v = 1.10 x ~~10~~ 10^6 m/s, which has been measured to a precision of 0.10%. What is the maximum precision with which its position could be simultaneously measured?

15 points

$\frac{\Delta p}{p} = 0.10\% = 0.001$

$v = 1.10 \times 10^6$ m/s

$p = mv = (9.11 \times 10^{-31}\ \text{kg})(1.10 \times 10^6\ \text{m/s}) = 1.00 \times 10^{-24}\ \text{kg m/s}$

$\Delta p = 0.0010\,p = 0.0010 \times 1.00 \times 10^{-24}\ \text{kg m/s} = 1.00 \times 10^{-27}\ \text{kg m/s}$

& from the uncertainty principle the best position can be determined by

$\Delta x \Delta p \simeq \hbar \Rightarrow \Delta x = \frac{\hbar}{\Delta p} = \frac{1.055 \times 10^{-34}\ \text{J s}}{1.00 \times 10^{-27}} = 1.1 \times 10^{-7}\ \text{m}$

Name____________________________________

Problem 5:

18 points

What is the uncertainty in the mass of a muon (m=105.7MeV/c2) specified in eV/c2 given its lifetime of 2.20μs?

$m = 105 \frac{MeV}{c^2}$

$\Delta t = \tau$

$\Delta E = (\Delta m)c^2$

$\Delta E \Delta t \geq \frac{h}{2\pi} = \hbar \quad \Rightarrow \Delta E \geq \frac{\hbar}{\Delta t} \Rightarrow \Delta m c^2 \geq \frac{\hbar}{\Delta t}$

$\Delta m \geq \frac{\hbar}{(\Delta t) c^2} = \frac{\hbar}{c^2 \tau} = \frac{1.055 \times 10^{-34} \text{ J.s}}{c^2 (2.20 \times 10^{-6} s)}$

$\Delta m = \left(4.7955 \times 10^{-29} \frac{J}{c^2}\right)\left(\frac{1 \text{ eV}}{1.60 \times 10^{-19} J}\right)$

$\Delta m = 3.00 \times 10^{-10} \text{ eV}/c^2$

Modern Physics **EXAM 3** **Fall 2022**

Name_______________________________

18 points

Problem 6: An electron has a de Broglie wavelength of 6.0 Å

(a) What is its momentum?

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ J\cdot s}{6.0 \times 10^{-10}\ m} = 1.1 \times 10^{-24}\ kg\,m/s$$

(b) What is its speed? assume non relativistic case here

$$\lambda = \frac{h}{p} = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}\ J\cdot s}{(9.11 \times 10^{-31}\ kg)(6.0 \times 10^{-10}\ m)}$$

$$= 1.2 \times 10^{6}\ m/s$$

$\frac{v}{c} = 4.4 \times 10^{-3}$ so our assumption was valid

(c) What voltage was needed to accelerate it to this speed?

$$K = \frac{1}{2} m v^2 = \frac{1}{2} \frac{(9.11 \times 10^{-31}\ kg)(1.2 \times 10^{6}\ m/s)}{1.6 \times 10^{-19}\ J/eV} = 4.17\ eV$$

This is the energy gained by an electron if accelerated through a potential difference of 4.2 V