Name_____

Physics 111 Quiz #6, November 6, 2020

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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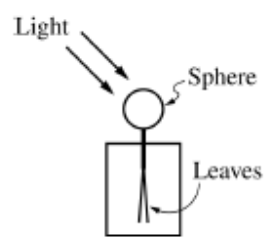
1. Suppose green light ($\lambda_g = 545nm$) is shown onto a cesium surface at a rate of $1 \times 10^{12}\,\frac{photons}{s}$. Electrons are ejected from the surface and a potential difference applied across the system brings the ejected electrons to rest from a, initial speed $v = 0.00084c$. What is the work function of cesium?

$$K = hf - \phi \rightarrow \phi = hf - K = \frac{hc}{\lambda} - \frac{1}{2}mv^2$$

$$\phi = \left[\left(\frac{6.63 \times 10^{-34}Js \times 3 \times 10^8\,\frac{m}{s}}{545 \times 10^{-9}m}\right) \times \frac{1eV}{1.6 \times 10^{-19}J}\right] - \frac{1}{2}\left(0.511 \times 10^6\,\frac{eV}{c^2}\right)(0.00084c)^2$$

$$\phi = 2.2809eV - 0.1804eV = 2.10eV$$

2. The figure on the right shows an electroscope. A metal sphere is connected by a vertical metal bar to the leaves, which are thin strips of metal. The electroscope initially has a negative charge, so the leaves of the electroscope are separated. The green light from the experiment in part a is shown on the sphere and the electroscope leaves do not move. However, when ultraviolet light is shown on the electroscope leaves, the leaves of the electroscope move closer together. Explain in complete sentences why this occurs.



This is an example of the photoelectric effect. Initially the leaves are separated since the leaves have a negative charge on them. Green light is unable to eject electrons so there is no loss of charge and the leaves do not move. However, when UV light is used, we eject electrons from the electroscope and the net charge on the electroscope decreases. Since the net charge decreases, the net repulsive force decreases, and the leaves move closer together.

3. X-rays with energy $E = 5179.6875eV$ are used in a Compton effect experiment. An x-ray detector is placed at an angle ϕ measured with respect to the direction of the incident beam (taken as $\phi = 0^0$) with counterclockwise indicating an increasing angle from the beam. If the scattered x-rays measured on this detector have an energy $E' = 5153.9179eV$, at what angle ϕ to the incident beam was the detector placed?

$$\lambda' = \lambda + \frac{h}{mc}(1 - \cos\phi) \rightarrow \frac{\lambda'}{hc} = \frac{\lambda}{hc} + \frac{1}{mc^2}(1 - \cos\phi) \rightarrow \frac{1}{E} = \frac{1}{E'} + \frac{1-\cos\phi}{mc^2}$$

$$\cos\phi = 1 - mc^2\left(\frac{1}{E} - \frac{1}{E'}\right) = 1 - \left(0.511 \times 10^6 \frac{eV}{c^2}\right)c^2\left[\frac{1}{5179.6875eV} - \frac{1}{5153.9179eV}\right]$$

$$\cos\phi = 0.5067 \rightarrow \phi = 59.6^0$$

4. What is the momentum of the recoiling electron in $\frac{keV}{c}$?

$$E = E' + K \rightarrow K = E - E' = (\gamma - 1)mc^2 \rightarrow \gamma = 1 + \frac{E-E'}{mc^2} = 1 + \frac{5179.6875eV - 5153.9179eV}{\left(0.511\times10^6\frac{eV}{c^2}\right)c^2}$$

$$\gamma = 1.0000504 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \rightarrow v = \sqrt{1 - \frac{1}{\gamma^2}}c = \sqrt{1 - \frac{1}{(1.0000504)^2}}c = 0.01c$$

$$p = \gamma mv = 1.0000504 \times 511\frac{keV}{c^2} \times 0.01c = 5.13\frac{keV}{c}$$

5. At what angle θ, measured with respect to the incident x-ray beam, does the electron scatter? Make sure you specify clearly what you've measured your angle with respect to.

$$x\text{:}\ \frac{h}{\lambda} = \frac{h}{\lambda'}\cos\phi + p_e\cos\theta \rightarrow p_{ex} = p_e\cos\theta$$

$$p_{ex} = p_e\cos\theta = \frac{E}{c} - \frac{E'}{c} = \frac{5179.6875eV - 5153.9179eV\cos 59.6}{c} = 2571.6\frac{eV}{c}$$

$$y\text{:}\ 0 = p_e\sin\theta - \frac{h}{\lambda'}\sin\phi \rightarrow p_{ey} = p_e\sin\theta = \frac{hc}{\lambda' c}\sin\phi$$

$$p_{ey} = p_e\sin\theta = \frac{E'}{c}\sin\phi = \frac{5153.9179eV\sin 59.6}{c} = 4445.3\frac{eV}{c}$$

$\tan\theta = \frac{-p_{ey}}{p_{ex}} \rightarrow \theta = \tan^{-1}\left(\frac{-4445.3\frac{ev}{c}}{2571.6\frac{eV}{c}}\right) = -60^0$ or 60^0 below the direction of the incident x-rays.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W = -q\Delta V_{f,i}$$

Magnetic Forces and Fields

$$F = qvB\sin\theta$$

$$F = IlB\sin\theta$$

$$\tau = NIAB\sin\theta = \mu B\sin\theta$$

$$PE = -\mu B\cos\theta$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$g = 9.8\,\frac{m}{s^2}$

$1e = 1.6\times10^{-19}C$

$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\frac{C^2}{Nm^2}$

$\varepsilon_o = 8.85\times10^{-12}\,\frac{Nm^2}{C^2}$

$1eV = 1.6\times10^{-19}J$

$\mu_o = 4\pi\times10^{-7}\,\frac{Tm}{A}$

$c = 3\times10^8\,\frac{m}{s}$

$h = 6.63\times10^{-34}Js$

$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$

$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$

$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$

$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$

$N_A = 6.02\times10^{23}$

$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = neAv_d$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{charge}(t) = Q_{max}\left(1-e^{-\frac{t}{RC}}\right)$$

$$Q_{discharge}(t) = Q_{max}e^{-\frac{t}{RC}}$$

$$C_{parallel} = \sum_{i=1}^{N} C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{max} = hf - \phi = eV_{stop}$$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

$$E_{total}^2 = p^2c^2 + m^2c^4$$

$$E_{rest} = mc^2$$

$$KE = (\gamma - 1)mc^2$$

Geometry

$Circles\ C = 2\pi r = \pi D \qquad A = \pi r^2$

$Triangles\ A = \tfrac{1}{2}bh$

$Spheres\ A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$

$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_o}$$

$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{max}^2 = c\frac{B_{max}^2}{2\mu_o}$$

$$P = \frac{S}{c} = \frac{Force}{Area}\ ;\ P = \frac{2S}{c}$$

$$S = S_o\cos^2\theta$$

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$

$$\theta_{inc} = \theta_{refl}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$M_{total} = \prod_{i=1}^{N} M_i$$

$$S_{out} = S_{in}e^{-\sum_i \mu x_i}$$

$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$

$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$