Name____

Physics 111 Quiz #6, March 3, 2017

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. Copper x-rays of energy $8.04 keV$ are completely backscattered from a thin carbon target. What is the energy of the backscattered x-rays?

$$E = \frac{hc}{\lambda} \rightarrow \lambda = \frac{hc}{E} = \frac{6.63\times10^{-34} Js \times 3\times10^{8} \frac{m}{s}}{8.04\times10^{3} eV \times \frac{1.6\times10^{-19} J}{1eV}} = 1.546\times10^{-10} m$$

$$\lambda' = \lambda + \frac{h}{m_e c}(1-\cos\phi) = \lambda + \frac{2h}{m_e c} = 1.546\times10^{-10} m + \frac{2\times6.63\times10^{-34} Js}{9.11\times10^{-31} kg \times 3\times10^{8} \frac{m}{s}} = 1.595\times10^{-10} m$$

$$E' = \frac{hc}{\lambda'} = \frac{6.63\times10^{-34} Js \times 3\times10^{8} \frac{m}{s}}{1.595\times10^{-10} m} \times \frac{1eV}{1.6\times10^{-19} J} = 7796.2 eV = 7.80 keV$$

2. What is the speed of the recoiling electron as a fraction of the speed of light?

$$E = E' + K \rightarrow K = E - E' = 8.04 keV - 7.80 keV = 0.24 keV$$

$$K = 0.24 keV = (\gamma - 1) m_e c^2 \rightarrow \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \left(\frac{K}{m_e c^2} + 1\right)$$

$$\gamma^2 = \frac{1}{1-\frac{v^2}{c^2}} = \left(\frac{K}{m_e c^2} + 1\right)^2 \rightarrow 1 - \frac{v^2}{c^2} = \frac{1}{\left(\frac{K}{m_e c^2} + 1\right)^2}$$

$$\rightarrow v = \sqrt{1 - \frac{1}{\left(\frac{K}{m_e c^2} + 1\right)^2}}\, c = \sqrt{1 - \frac{1}{\left(\frac{0.24 keV}{511 \frac{keV}{c^2} c^2} + 1\right)^2}}\, c = 0.031c$$

3. Ultraviolet photons ($\lambda = 210nm$) are incident on an aluminum surface ($\phi = 4.1eV$) at a rate of $4.7\times10^{15}\,\frac{photons}{\sec}$ and make a spot on the surface of area $A = 1mm^2$ and eject electrons (called photoelectrons) from the aluminum surface. What will be the speed of the ejected electrons as a fraction of the speed of light?

$$K = \frac{hc}{\lambda} - \phi = \left(\frac{6.63\times10^{-34}\,Js\times3\times10^{8}\,\frac{m}{s}}{210\times10^{-9}\,m}\times\frac{1eV}{1.6\times10^{-19}\,J}\right) - 4.1eV = 5.92eV - 4.1eV = 1.82eV$$

$$K = 1.82eV = \tfrac{1}{2}mv^2 = \tfrac{1}{2}\left(0.511\times10^{6}\,\tfrac{eV}{c^2}\right)v^2 \rightarrow v = 0.0027c$$

4. Suppose that instead of using ultraviolet light to illuminate your aluminum surface, you decide to use yellow light ($\lambda = 578nm$). The yellow light is incident on the same aluminum surface as in part 3 and the yellow light also makes a spot of area $A = 1mm^2$. If the rate of yellow photons incident were to increase to three times that of the ultraviolet photons, the number of photoelectrons ejected per second (assuming efficiency) would

a. increase because yellow photons produce photoelectrons more easily than ultraviolet photons.

b. increase because yellow photons are of a higher frequency than ultraviolet photons.

c. decrease because yellow photons produce photoelectrons less easily than ultraviolet photons.

d. would be zero because the wavelength of the yellow photons too small to produce photoelectrons.

e. would be zero because the wavelength of the yellow photons too large to produce photoelectrons.

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

$$g = 9.8\,\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}\,C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\tfrac{Nm^2}{C^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\,\tfrac{C^2}{Nm^2}$$
$$1eV = 1.6\times10^{-19}\,J$$
$$\mu_o = 4\pi\times10^{-7}\,\tfrac{Tm}{A}$$
$$c = 3\times10^8\,\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}\,Js$$
$$m_e = 9.11\times10^{-31}\,kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}\,kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}\,kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}\,kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$W = U = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

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

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$