Name______________________________________

Physics 111 Quiz #2, January 17, 2014

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.

____

A proton, initially very far from any charges, is accelerated to a speed of $v = 2\times 10^{7}\,\frac{m}{s}$. This proton is then directed toward a stationary copper nucleus. Copper has a charge of $Q_{Cu} = 29e$ and a mass of $m_{Cu} = 65m_p$. When the proton approaches the copper nucleus, it interacts with the electric field produced by the copper nucleus. This interaction of the proton with the electric field of the copper nucleus brings the proton momentarily to rest at some distance, known as the distance of closest approach, from the copper nucleus. Since the electric force on the proton does not dissipate, the proton is repelled from the copper nucleus back along its original path. This is called backscattering.

a. How much work was done in bringing the proton momentarily to rest?

$$W = \Delta KE = KE_f - KE_i = -KE_i = -\tfrac{1}{2}m_p v_i^2 = -\tfrac{1}{2}\times 1.67\times 10^{-27}\,kg\times\left(2\times 10^{7}\,\tfrac{m}{s}\right)^2 = -3.34\times 10^{-13}\,J.$$

b. When the proton momentarily comes to rest, what is the distance of closest approach? (Ignore the electrons that surround the copper nucleus. The proton is traveling so fast that it hardly notices the electrons and proceeds toward the nucleus unabated.)

$$W = -q\Delta V = -q\left[V_{Cu} - V_\infty\right] = -q\left(\frac{kQ_{Cu}}{r}\right)$$

$$\rightarrow r = -\frac{kqQ_{Cu}}{W} = -\frac{9\times 10^{9}\,\frac{Nm^2}{C^2}\times 1.6\times 10^{-19}\,C\times\left(29\times 1.6\times 10^{-19}\,C\right)}{-3.34\times 10^{-13}\,J} = 2\times 10^{-14}\,m$$

c. With what electric field would the proton interact (due to the copper nucleus) when the proton momentarily comes to rest at this distance of closest approach?

$$E_{net,r} = \frac{kQ_{Cu}}{r^2} = \frac{9\times 10^{9}\,\frac{Nm^2}{C^2}\times 29\times 1.6\times 10^{-19}\,C}{\left(2\times 10^{-14}\,m\right)^2} = 1.04\times 10^{20}\,\tfrac{N}{C}$$ directed radially away from the Cu atom.

d. What is the electric force exerted on the proton by the copper nucleus in this electric field?

$F_{p,Cu} = qE_{net,r} = 1.6\times10^{-19}C\times1.04\times10^{20}\,\tfrac{N}{C} = 16.7N$ directed radially away from the Cu atom.

e. Suppose that instead of a proton being fired at the copper nucleus, an alpha particle (a helium nucleus) were used. An alpha particle has a charge $Q_\alpha = 2e$ and a mass $m_\alpha = 4m_p$. If the alpha particle had the same initial speed as the proton, the distance of closest approach for the alpha particle would be

1. less, meaning the alpha particle would get closer to the copper nucleus than the proton.
2. the same as for the proton.
3. greater, meaning the alpha particle would not get as close to the copper nucleus as the proton.
4. unable to be determined since the force on the alpha particle is not known.

$$W = -q\Delta V = -q\left[V_{Cu} - V_\infty\right] = -q\left(\frac{kQ_{Cu}}{r_\alpha}\right) = -\tfrac{1}{2}m_\alpha v^2 \rightarrow -2e\left[\frac{29ke}{r_\alpha}\right] = -\tfrac{1}{2}\left(4m_p\right)v^2$$

$$\rightarrow r_\alpha = \frac{29ke^2}{m_p v^2}$$

$$W = -q\Delta V = -q\left[V_{Cu} - V_\infty\right] = -q\left(\frac{kQ_{Cu}}{r_p}\right) = -\tfrac{1}{2}m_p v^2 \rightarrow -e\left[\frac{29ke}{r_p}\right] = -\tfrac{1}{2}m_p v^2$$

$$\rightarrow r_p = 2\times\left[\frac{29ke^2}{m_p v^2}\right] = 2r_\alpha \Rightarrow r_\alpha = \frac{r_p}{2}$$

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

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

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

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

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

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

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

$$W_{A,B} = q\Delta V_{A,B}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

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

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

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

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

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

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

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

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

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

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

Light as a Particle & Relativity

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

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

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

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

$$p = \gamma mv$$

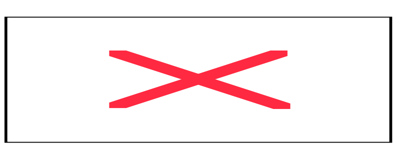
$$E_{total} = KE + E_{rest} = \gamma mc^2$$

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

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

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

Geometry



Light as a Wave

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

$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{max}^2 = c\frac{B_{max}^2}{2\mu_0}$$

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

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

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

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

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

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

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

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

$$d\sin\theta = m\lambda \text{ or } (m+\tfrac{1}{2})\lambda$$

$$a\sin\phi = m'\lambda$$

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

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

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

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

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

$$PE_{gravity} = mgy$$

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