Name____

Physics 111 Quiz #3, February 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. A long straight wire of length l lies in the plane of the page and has a current I flowing down the page from the top to the bottom. At a distance r to the right of the midpoint of the wire, a beam of electrons is fired into the page with a velocity v. The magnitude of the force on the beam of electrons is give by which of the following?

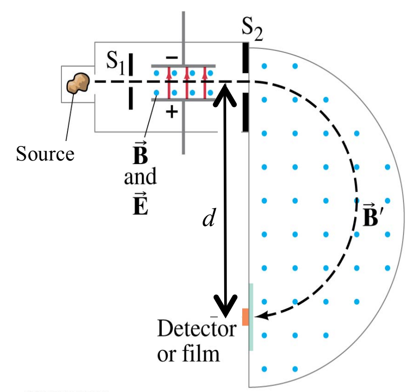
   a. $\left|\vec{F}\right| = \dfrac{mv^2}{r}$ to the right.

   b. $\left|\vec{F}\right| = \dfrac{\mu_0 evI}{2\pi r}$ to the left.

   c. $\left|\vec{F}\right| = \dfrac{\mu_0 I^2 l}{2\pi r}$ to the right.

   d. $\left|\vec{F}\right| = \dfrac{\mu_0 I^2 l}{2\pi r}$ to the left.

   e. $\left|\vec{F}\right| = 0$.



An unknown particle of mass m moves in a straight line from the source through a set of plates. The plates have crossed electric (E) and magnetic (B) fields as shown in the diagram. When the particle leaves the plates, the electric field vanishes and only a magnetic field (B') exists. The unknown particle bends in the direction shown and strikes a detector at a distance d below where it exits.

2. While the unknown charged particle is in between the plates, in the region of crossed electric and magnetic fields, derive an expression for the speed v of the particle if it is to travel a straight line from the source to the region of magnetic field B'. (Hint: Draw a force diagram for the particle between the plates and ignore the mass of the particle.)

$$F_{net,y} = F_E - F_B = 0 \rightarrow qE - qvB = 0$$

$$\therefore v = \frac{E}{B}$$

3. Using your result from part 2, derive an expression for the mass of the unknown charged particle in terms of q, E, B, and d. Let $B' = B$ and assume that the particle is singly charged, that is $q = e$.

$$F = qvB' = \frac{mv^2}{r} \rightarrow eB = \frac{mv}{r} = \frac{mE}{rB} = \frac{2mE}{dB}$$

$$m = \frac{eB^2 d}{2E}$$

4. Suppose that you had a second particle of the same mass but this time it was doubly charged. That is, $q = 2e$. What is the ratio of the distance from where the particle exits the plates and strikes the detector when doubly charged to the case when singly charged? In other words, calculate $\frac{d_{q=2e}}{d_{q=e}}$.

$$F = qvB' = \frac{mv^2}{r} \rightarrow r = \frac{d}{2} = \frac{mv}{eB} = \frac{mE}{eB^2}$$

$$\therefore d_{q=e} = \frac{2mE}{eB^2}$$

$$F = qvB' = \frac{mv^2}{r} \rightarrow r = \frac{d}{2} = \frac{mv}{eB} = \frac{mE}{eB^2}$$

$$\therefore d_{q=2e} = \frac{2mE}{2eB^2} = \frac{mE}{eB^2}$$

$$\frac{d_{q=2e}}{d_{q=e}} = \frac{mEeB^2}{eB^2 2mE} = \frac{1}{2}$$

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V}{\Delta x}$$
$$W = -q\Delta V_{f,i}$$

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 Wave

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

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$
$$KE_{\max} = hf - \phi = eV_{stop}$$
$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$
$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$p = \gamma mv$$
$$E_{total} = KE + E_{rest} = \gamma mc^2$$
$$E_{total}^2 = p^2c^2 + m^2c^4$$
$$E_{rest} = mc^2$$
$$KE = (\gamma-1)mc^2$$

Nuclear Physics

$$E_{binding} = \left(Zm_p + Nm_n - m_{rest}\right)c^2$$
$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$
$$A(t) = A_o e^{-\lambda t}$$
$$m(t) = m_o e^{-\lambda t}$$
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Geometry

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

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

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

Misc. Physics 110 Formulae

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