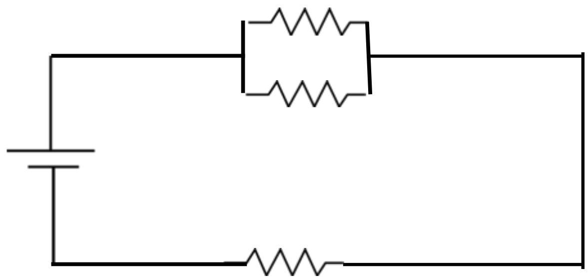
Name____

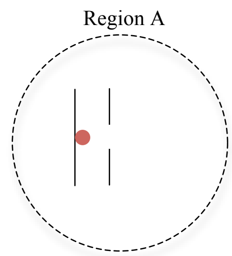
Physics 111 Quiz #4, February 8, 2013

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. _________________

Suppose that you are given the circuit below in which there is a battery ($V = 2.0kV$) connected to a collection of resistors, with each resistor 100Ω.





a. For this circuit above, what are R_{eq} and I_{total}?

For the two resistors in parallel we have an effective resistance given by $\frac{1}{R_{parallel}} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \rightarrow R_{parallel} = \frac{R}{2} = \frac{100\Omega}{2} = 50\Omega$. This equivalent resistor is in series with a 100Ω resistor. The equivalent resistance of the circuit is therefore $R_{eq} = R + R_{parallel} = 100\Omega + 50\Omega = 150\Omega$.

The current is given by Ohm's law and is $I_{total} = \frac{V}{R_{eq}} = \frac{2000V}{150\Omega} = 13.3A$ flowing clockwise in the circuit.

b. Suppose that in a region A of space (the dashed circle above), a small electron accelerator is placed. If the electrons (the red dot above) are accelerated through a potential difference of $\Delta V = 300V$ from rest, how fast will the electrons be moving when they leave the hole in the right plate?

The speed is given by the work-kinetic energy theorem.

$$W = -q\Delta V = -(-e)[V - 0] = \Delta KE = \tfrac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19}C \times 300V}{9.11 \times 10^{-31}kg}} = 1.03 \times 10^7 \tfrac{m}{s}$$

c. What is the magnetic field in the region A (assuming that it is uniform across the entire region A) if the center of region A is located $5cm$ from the right most wire in the circuit above?

Assuming that the right most wire in the circuit can be modeled as a long strait wire with a current I flowing clockwise in the circuit we have

$B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{4\pi \times 10^{-7} \frac{Tm}{A} \times 13.3A}{2\pi(0.05m)} = 5.32 \times 10^{-5} T$ pointing out of the page at region A.

d. Assuming, again, that this magnetic field is constant over region A, what is the orbital radius of the electron beam? Will the electron beam circulate clockwise or counterclockwise?

By the right hand rule, the electron beam will circulate counterclockwise with a radius given by

$F_B = qvB = F_C = \dfrac{mv^2}{R} \to R = \dfrac{mv}{qB} = \dfrac{9.11 \times 10^{-31} kg \times 1.03 \times 10^{7} \frac{m}{s}}{1.6 \times 10^{-19} C \times 5.32 \times 10^{-5} T} = 1.10m$. Of course since the magnetic field is not everywhere in space, the charge will only travel along part of an arc of this circle.

e. Suppose that instead of the setup located at region A, you remove the setup and now you have a proton moving out of the page at you (directed from the floor to the ceiling) at region A. The magnetic force causes the proton to

1. turn in a vertical circle of radius R in and out of the plane of this paper.
2. turn in a clockwise horizontal circle in the plane of the paper as you look down at the paper.
3. turn in a counterclockwise horizontal circle in the plane of the paper as you look down at the paper.
4. experience no change in its momentum and keep moving toward the ceiling along its original trajectory.

Since the magnetic field is pointing out of the page at region A and the proton's velocity is parallel to the magnetic field, the proton feels no magnetic force and therefore no change in its momentum.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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