Name____

Physics 111 Quiz #3, February 2, 2018

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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Suppose that you have two ions (${}^{64}_{30}Zn^{+2}$ and ${}^{66}_{30}Zn^{+2}$) that are accelerated through a potential difference of $|10kV|$ and enter a region of space that contains a uniform $10T$ magnetic field pointing down into the plane of the paper.

1. What are the speeds of each ion after they were accelerated? Hint: Assume that the mass of the proton is the same as the mass of the neutron and that the charges initially start from rest.

$$W = -q\Delta V = \Delta K = \tfrac{1}{2} m v_f^2 \rightarrow v_f = \sqrt{\frac{-2q\Delta V}{m}}$$

$$v_{f,{}^{64}Zn} = \sqrt{\frac{-2q\Delta V}{m_{{}^{64}Zn}}} = \sqrt{\frac{-2\left(2\times1.6\times10^{-19}C\right)\left(-10000V\right)}{64\times1.67\times10^{-27}kg}} = 2.45\times10^{5}\,\tfrac{m}{s}$$

$$v_{f,{}^{66}Zn} = \sqrt{\frac{-2q\Delta V}{m_{{}^{66}Zn}}} = \sqrt{\frac{-2\left(2\times1.6\times10^{-19}C\right)\left(-10000V\right)}{66\times1.67\times10^{-27}kg}} = 2.41\times10^{5}\,\tfrac{m}{s}$$

2. What is the ratio (${}^{66}_{30}Zn^{+2}$ / ${}^{64}_{30}Zn^{+2}$) of the radii for each ion and what direction do the ions bend in this magnetic field? Assume that the velocity is perpendicular to the magnetic field and that the charges are moving to the right across the page as they enter the magnetic field.

$$F_B = qvB = m\frac{v^2}{R} \rightarrow R = \frac{mv}{qB}$$

$$R_{{}^{64}Zn} = \frac{m_{{}^{64}Zn} v_{{}^{64}Zn}}{qB}$$

$$R_{{}^{66}Zn} = \frac{m_{{}^{66}Zn} v_{{}^{66}Zn}}{qB}$$

$$\frac{R_{{}^{66}Zn}}{R_{{}^{64}Zn}} = \frac{\dfrac{m_{{}^{66}Zn} v_{{}^{66}Zn}}{qB}}{\dfrac{m_{{}^{64}Zn} v_{{}^{64}Zn}}{qB}} = \frac{m_{{}^{66}Zn} v_{{}^{66}Zn}}{m_{{}^{64}Zn} v_{{}^{64}Zn}} = \frac{66\times2.41\times10^{5}\,\tfrac{m}{s}}{64\times2.45\times10^{5}\,\tfrac{m}{s}} = 1.01$$

By the right-hand rule, the charges will feel a force that causes them to move up the page.

3. Suppose that $6cm$ of wire were between the poles of a magnet of strength $2T$. The wire has a radius $0.5mm$ and is made out of aluminum with $\rho_{Al} = 2800\frac{kg}{m^3}$ and $M = 27\frac{g}{mol}$. If the wire is connected to a 200Ω resistor and a $12V$ battery, what is the drift velocity of the charge carriers in the wire?

$$n = \frac{\rho_{Al} N_A}{M_{Al}} = \frac{2800\frac{kg}{m^3} \times 6.02 \times 10^{23}}{0.027kg} = 6.24 \times 10^{28} m^{-3}$$

$$v_d = \frac{I}{nAe} = \frac{V}{RnAe} = \frac{12V}{200\Omega \times 6.24 \times 10^{28} m^{-3} \times \pi \left(0.5 \times 10^{-3} m\right)^2 \times 1.6 \times 10^{-19} C} = 7.65 \times 10^{-6} \frac{m}{s}$$

4. What magnitude of magnetic force would the wire feel in this magnetic field? Assume that $I \perp B$.

$$F = ILB = \frac{V}{R} LB = \frac{12V}{200\Omega} \times 0.06m \times 2T = 7.2 \times 10^{-3} N$$

5. A long straight wire carries a current I up the plane of this page. If a second wire were oriented perpendicular and to the right at a distance of r from the first wire but with its current (also given as I) flowing out of the plane of the page at the viewer, the magnetic force on the second wire would be given by which of the following?

   a. $F = 0$.

   b. $F = \dfrac{\mu_0 I^2}{2\pi r}$ directed up the page parallel to the first wire.

   c. $F = \dfrac{\mu_0 I^2}{2\pi r}$ directed down the page parallel to the first wire.

   d. $F = \dfrac{\mu_0 I^2}{2\pi r}$ directed to the right away from the first wire.

   e. $F = \dfrac{\mu_0 I^2}{2\pi r}$ directed to the left toward the first wire.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1 Q_2}{r^2}\hat{r}$$

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

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

$$PE = k\frac{Q_1 Q_2}{r}$$

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

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

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

Magnetic Forces and Fields

$$F = qvB\sin\theta$$

$$F = ILB\sin\theta$$

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

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

Constants

$$g = 9.8\tfrac{m}{s^2}$$

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

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

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

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

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

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

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

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

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

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

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

$$N_A = 6.02\times10^{23}$$

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

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = neAv_d;\ n = \frac{\rho N_A}{M}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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