Name____

Physics 111 Quiz #3, October 5, 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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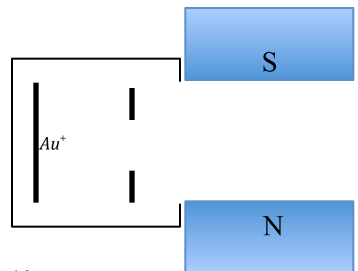
A gold ion ${}^{197}_{79}Au^{+}$ is accelerated from rest through a potential difference $\Delta V = 1000V$ and enters a region of magnetic field $|\vec{B}| = 1.6mT$ with its velocity perpendicular to the magnetic field. A schematic of the setup is shown below.



a. What is the orbital radius for the gold ion in the magnetic field

$$W = -q\Delta V = -e(-1000V) = 1000eV \times \frac{1.6\times10^{-19}J}{1eV} = 1.6\times10^{-16}J$$

$$W = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 \rightarrow v_f = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2\times1.6\times10^{-16}J}{197\times1.66\times10^{-27}kg}} = 3.1\times10^{4}\,\tfrac{m}{s}$$

$$F = qv_\perp B = m\frac{v_\perp^2}{R} \rightarrow R = \frac{mv}{qB} = \frac{197\times1.66\times10^{-27}kg\times3.1\times10^{4}\,\tfrac{m}{s}}{1.6\times10^{-19}C\times1.6\times10^{-3}T} = 39.6m$$

b. In what direction will the gold ion initially move when it leaves the accelerator and enters the magnetic field? To earn full credit, please justify your answer. Do not simply state a direction with no explanation.

By the right-hand rule, the magnetic force on the gold ion would cause it to initially move up out of the plane of the paper.

c. In one complete orbit about the magnetic field by the gold ion, how much work is done on the gold ion by the magnetic field?

1. $W = 0$.
2. $W = F\Delta x = 2\pi RF$.
3. $W = \Delta K = \frac{1}{2}mv_f^2$.
4. $W = -q\Delta V$.
5. There is not enough information to be able to answer this question.

d. Suppose that you make a circuit with $1mm$ diameter wires that are made out of gold. If the battery in your circuit produces a current of $3A$, what is the drift speed of electrons in the gold wire? Hints: Assume that the density of gold is $19300\frac{kg}{m^3}$ and that each gold nucleus contributes one electron to the current.

$$v_d = \frac{I}{nAe} = \frac{3A}{5.9\times10^{28}m^{-3}\times\pi\left(0.5\times10^{-3}m\right)^2\times1.6\times10^{-19}C} = 4.1\times10^{-4}\,\tfrac{m}{s} = 0.4\,\tfrac{mm}{s}$$

where, $n = \dfrac{\rho N_A}{M} = \dfrac{19300\frac{kg}{m^3}\times6.02\times10^{23}\frac{atoms}{mol}\times\frac{1e}{atom}}{0.197\frac{kg}{mol}} = 5.9\times10^{28}m^{-3}$

e. Two long straight parallel wires separated by a distance d have currents flowing in them in the same direction. The left wire has a current $I_L = I$ flowing up the plane of the page while the right wire has a current $I_R = \dfrac{I}{2}$ also flowing up the plane of the page. In terms of d, at what point(s), aside from very far away from the two wires, is the magnetic field zero?

The magnetic field will only vanish at a point in between the two wires. This can be seen using the right-hand rule for currents. Defining the distance r as the distance from the left wire to the point the magnetic field vanishes we have:

$$B_{net} = 0 = B_L - B_R = \frac{\mu_o I}{2\pi r} - \frac{\mu_o\left(\frac{I}{2}\right)}{2\pi\left(d-r\right)} \rightarrow r = 2d - 2r \rightarrow r = \frac{2}{3}d$$

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

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

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

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

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

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

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

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

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

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

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

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

Light as a 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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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