Name_______________________________________

Physics 121 Quiz #4, February 5, 2016

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 small cylindrical piece of gold wire ($L = 0.1m;\ \ r = 0.5mm$) carries an unknown conventional current I flowing to the left. The wire lies along the x-axis with its center at the origin. (Some pertinent data for gold: $m_{Au} = 0.197\,\frac{kg}{mol}$, $\rho_{Au} = 1.93\times10^{4}\,\frac{kg}{m^3}$, and $\mu = 8.5\times10^{-3}\,\frac{m/s}{N/C}$)

a. What is the number density for electrons in gold?

$$n = 1\,\tfrac{e^-}{atom}\times 6.02\times10^{23}\,\tfrac{atoms}{mol}\times\tfrac{1mol}{0.197kg}\times1.93\times10^{4}\,\tfrac{kg}{m^3} = 5.9\times10^{28}\,\tfrac{e^-}{m^3}$$

b. Suppose that a potential difference of $\Delta V = 9.0\times10^{-4}V$ existed across the wire, what magnitude of current would flow in the piece of wire?

$$I = n|e|Av_d = 5.9\times10^{28}m^{-3}\times1.6\times10^{-19}C\times\pi\left(0.5\times10^{-3}m\right)\times7.65\times10^{-5}\,\tfrac{m}{s}$$
$$I = 0.567A$$

where the drift velocity of electrons in gold is determined by

$$v_d = \mu E = \mu\frac{\Delta V}{\Delta x} = 8.5\times10^{-3}\,\tfrac{m/s}{N/C}\times\left(\frac{9.0\times10^{-4}V}{0.1m}\right) = 7.65\times10^{-5}\,\tfrac{m}{s}$$

c. What is the magnitude of the magnetic field at a point $\langle 0,0.1,0\rangle m$?

$$\left|\vec{B}_{wire}\right| = \frac{\mu_o LI}{4\pi r\sqrt{\left(\frac{L}{2}\right)^2 + r^2}} = \frac{1\times 10^{-7}\,\frac{Tm}{A}\times 0.1m\times 0.567A}{0.1m\sqrt{\left(\frac{0.1m}{2}\right)^2 + (0.1m)^2}} = 1.11\times 10^{-4}T$$

d. Suppose that a compass was placed above the wire at the point $\langle 0,0.1,0\rangle m$ and further suppose that the current in the wire was flowing in the northerly direction (that is the negative x-axis points north). The magnetic field due to the wire produces a deflection of the compass needle that points

1. north.
2. south.

[✓ 3.] east.

4. west.

Physics 121 Equation Sheet

Electricity & Magnetism

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r};\quad \hat{r} = \frac{\vec{r}_o - \vec{r}_s}{\left|\vec{r}_o - \vec{r}_s\right|}$$

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

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

$$\vec{p} = q\vec{s} = \alpha\vec{E}$$

$$\left|\vec{E}_{\parallel}\right| = \frac{2kqs}{r^3};\ \text{dipole}\ \ r >> s$$

$$\left|\vec{E}_{\perp}\right| = \frac{kqs}{r^3};\ \text{dipole}\ \ r >> s$$

$$\left|\vec{E}_{rod}\right| = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{r\sqrt{r^2 + \left(L/2\right)^2}}\right];\quad \left|\vec{E}_{rod}\right| \sim \frac{1}{4\pi\varepsilon_0}\left(\frac{2Q}{rL}\right)\quad L >> r$$

$$\left|\vec{E}_{ring}\right| = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qz}{\left(R^2 + z^2\right)^{\frac{3}{2}}}\right]$$

$$\left|\vec{E}_{disk}\right| = \frac{Q}{2\pi\varepsilon_0 R^2}\left[1 - \frac{z}{\sqrt{R^2 + z^2}}\right];\quad \left|\vec{E}_{disk}\right| \sim \frac{Q}{2\varepsilon_0 A}\left[1 - \frac{z}{R}\right]\quad z << R;\quad \left|\vec{E}_{disk}\right| \sim \frac{Q}{2\varepsilon_0 A}\quad z << R$$

$$\left|\vec{E}_{capacitor}\right| \sim \frac{Q}{\varepsilon_0 A};\quad \left|\vec{E}_{fringe}\right| \sim \frac{Q}{2\varepsilon_0 A}\left(\frac{s}{R}\right)$$

$$W = -q\Delta V = -\Delta U = \Delta K;\quad U = \sum_{i \neq j}\frac{kQ_iQ_j}{r_{ij}};$$

$$V_Q = \frac{kQ}{r};\quad V_{Q's} = \sum_i \frac{kQ_i}{r_i}$$

$$\Delta V = -\int \vec{E}\cdot d\vec{r}$$

$$E_x = -\frac{\Delta V}{\Delta x};\quad E_y = -\frac{\Delta V}{\Delta y};\quad E_z = -\frac{\Delta V}{\Delta z};\quad \vec{E} = -\left\langle \frac{dV}{dx}, \frac{dV}{dy}, \frac{dV}{dz}\right\rangle$$

$$Q = \left(\frac{\varepsilon_0 A}{s}\right)\Delta V$$

$$I = \frac{\Delta Q}{\Delta t} = i\left|e\right| = n\left|e\right|Av_d;\quad \vec{v}_d = \mu\vec{E}$$

$$\vec{B} = \frac{\mu_o}{4\pi}\left(\frac{q\vec{v}\times\hat{r}}{r^2}\right)$$

$$d\vec{B} = \frac{\mu_o I}{4\pi}\left(\frac{d\vec{l}\times\hat{r}}{r^2}\right)$$

$$\left|\vec{B}_{wire}\right| = \frac{\mu_o LI}{4\pi r\sqrt{\left(\frac{L}{2}\right)^2 + r^2}};\quad \left|\vec{B}_{wire}\right| \approx \frac{\mu_o I}{2\pi r}\quad L >> r$$

$$\left|\vec{B}_{ring}\right| = \frac{\mu_o IR^2}{2\left(z^2 + R^2\right)^{\frac{3}{2}}};\ \left|\vec{B}_{ring}\right| \approx \frac{\mu_o IR^2}{2z^3}\quad z << R$$

Constants

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

$B_{Earth,H} = 2\times10^{-5}\,T$

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

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

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

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