Name____

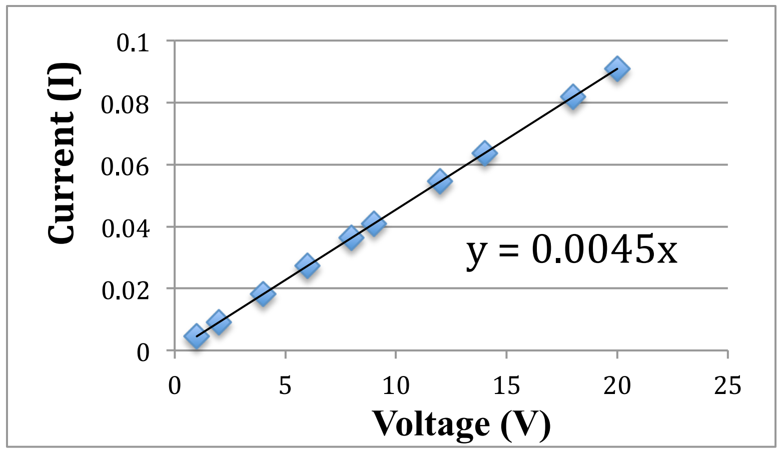
Physics 121 Quiz #4, February 9, 2018

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.

A 500 turn, $0.5mm$ diameter wire is wound into a cylindrical coil of wire with radius $56cm$ and the wire was used in an experiment. Data were taken on the potential difference across the wire as a function of the current through the wire and the data are shown in the graph below.

1. What is the resistivity of the wire?



From the graph, the slope is the inverse of the resistance, so $R = \frac{1}{0.0045}\Omega = 222\Omega$.

The resistivity is given by $R = \frac{\rho L}{A} \rightarrow \rho = \frac{RA}{L} = \frac{222\Omega \times \pi\left(0.25\times10^{-3}m\right)^2}{500\times 2\pi \times 0.56m} = 2.5\times10^{-8}\Omega m$

2. What is the magnitude of the assumed constant current density in the wire when the potential difference across the wire was $11V$?

$$J = \frac{I}{A} = \frac{11V/222\Omega}{\pi\left(0.25\times10^{-3}m\right)^2} = 2.5\times10^{5}\,\tfrac{A}{m^2}$$

3. The wire that was used in the experiment was gold with a density of $\rho = 19320\,\frac{kg}{m^3}$ and a molar mass of $197g$. What is the drift speed for charge carriers in gold? Assume that for each gold atom there is one free charge carrier.

$$n = \frac{\rho}{M}N_a = \frac{19320\,\frac{kg}{m^3}}{0.197kg}\times 6.02\times 10^{23} = 5.9\times 10^{28}\,m^{-3}$$

$$v_d = \frac{I}{nAe} = \frac{J}{ne} = \frac{2.5\times 10^5\,\frac{A}{m^2}}{5.9\times 10^{28}\,m^{-3}\times 1.6\times 10^{-19}C} = 2.6\times 10^{-5}\,\frac{m}{s}$$

4. What is the magnitude of the electric field in the sire when the potential difference across the wire was $11V$?

$$J = \tfrac{1}{\rho}E \rightarrow E = \rho J = 2.5\times 10^{-8}\Omega m\times 2.5\times 10^5\,\frac{A}{m^2} = 6.4\times 10^{-3}\,\frac{V}{m}$$

or

$$E = \left|-\frac{\Delta V}{\Delta x}\right| = \frac{11V}{500\times 2\pi\times 0.56m} = 6.4\times 10^{-3}\,\frac{V}{m}$$

5. When a current I flows through a wire, the drift velocity of the electrons is v_d. When a current $2I$ flows through another wire of the same material having double the length and double the cross-sectional area the drift velocity of the electrons will be

a. $\frac{v_d}{4}$.

b. $\frac{v_d}{2}$.

c. v_d.

d. $2v_d$.

e. $4v_d$.

Physics 121 Equation Sheet

Electric Forces, Fields and Potentials

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

$\vec{E}=\frac{\vec{F}}{q}=\int d\vec{E}=\int dE\hat{r}=\int\frac{kdq}{r^2}\hat{r}$

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

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

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

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

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

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

$|\vec{E}_{disk}|=\frac{Q}{2\pi\varepsilon_0R^2}\left[1-\frac{z}{\sqrt{R^2+z^2}}\right];\quad |\vec{E}_{disk}|\sim\frac{Q}{2\varepsilon_0A}\left[1-\frac{z}{R}\right]\quad z<<R;\quad |\vec{E}_{disk}|\sim\frac{Q}{2\varepsilon_0A}\quad z<<R$

$|\vec{E}_{capacitor}|\sim\frac{Q}{\varepsilon_0A};\quad |\vec{E}_{fringe}|\sim\frac{Q}{2\varepsilon_0A}\left(\frac{s}{R}\right)$

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

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

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

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

$Q=\left(\frac{\kappa\varepsilon_0A}{s}\right)\Delta V$

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

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

$I=\frac{dQ}{dt}=n|e|Av_d=\int\vec{J}\cdot d\vec{A}$

$n=\frac{\rho}{M}N_A$

$\vec{J}=n|e|\vec{v}_d=\sigma\vec{E}=\frac{1}{\rho}\vec{E}\rightarrow V=IR;\ R=\frac{\rho L}{A}$

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

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

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

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

Constants

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

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

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

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

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

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

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

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

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

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

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

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

$N_A=6.02\times10^{23}$

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