Name____

Physics 121 Quiz #7, March 4, 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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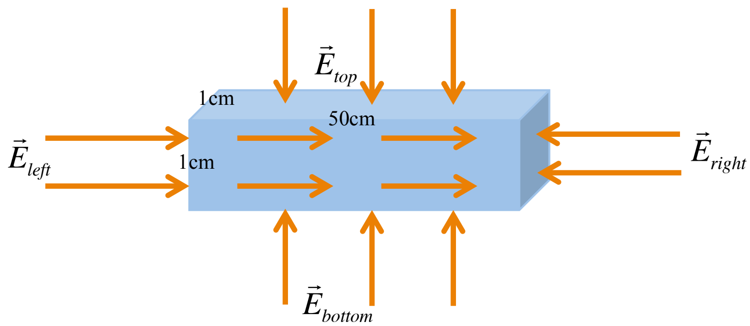
1. Suppose that you have the blue box shown below in which there is some electric charge inside. The electric field vectors are shown and $\left|\vec{E}_{left}\right| = 3\times10^4\,\frac{N}{C}$, $\left|\vec{E}_{right}\right| = 1\times10^4\,\frac{N}{C}$, $\left|\vec{E}_{front}\right| = \left|\vec{E}_{back}\right| = 2\times10^4\,\frac{N}{C}$, and $\left|\vec{E}_{top}\right| = \left|\vec{E}_{bottom}\right| = 2\times10^4\,\frac{N}{C}$. What is the net electric flux through the surface of the box?

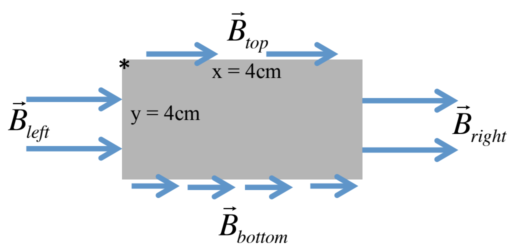


$$\phi_E = \vec{E}\cdot\hat{n}dA = \left|\vec{E}\right|\left|dA\right|\cos\theta$$
$$\phi_{left} = E_{left}A\cos(180) = -E_{left}A = -3\times10^4\,\tfrac{N}{C}\times(0.01m)^2 = -3Vm$$
$$\phi_{right} = E_{right}A\cos(180) = -E_{right}A = -1\times10^4\,\tfrac{N}{C}\times(0.01m)^2 = -1Vm$$
$$\phi_{left} = E_{front}A\cos(90) = 0Vm$$
$$\phi_{back} = E_{back}A\cos(90) = 0Vm$$
$$\phi_{top} = E_{top}A\cos(180) = -E_{top}A = -2\times10^4\,\tfrac{N}{C}\times(0.01m\times0.5m) = -100Vm$$
$$\phi_{bottom} = E_{bottom}A\cos(180) = -E_{bottom}A = -2\times10^4\,\tfrac{N}{C}\times(0.01m\times0.5m) = -100Vm$$
$$\phi_{total} = \oint\vec{E}\cdot\hat{n}\,dA = (-3Vm)+(-1Vm)+(0Vm)+(0Vm)+(-100Vm)+(-100Vm) = -204Vm$$

2. What is the magnitude and sign of the net charge enclosed?

$$\oint\vec{E}\cdot\hat{n}\,dA = \frac{Q_{enclosed}}{\varepsilon_0} \rightarrow Q_{enclosed} = \varepsilon_0\phi_{total} = 8.85\times10^{-12}\,\tfrac{C^2}{Nm^2}\times(-204Vm) = -1.81\times10^{-9}C\,.$$

3. What is the magnitude and direction of the net current enclosed by the grey box? Assume that $\left|\vec{B}_{left}\right| = \left|\vec{B}_{right}\right| = 2\times10^{-5}T$, $\left|\vec{B}_{top}\right| = 1.5\times10^{-5}T$, and $\left|\vec{B}_{bottom}\right| = 0.8\times10^{-5}T$. (Hint: Start at the corner marked with the star * and go clockwise around the loop and note the box is not drawn to scale.)



$$\oint \vec{B}\cdot d\vec{l} = \mu_o I_{enclosed}$$

$$\left(\oint \vec{B}\cdot d\vec{l}\right)_{top} = B_{top}x\cos(0) = B_{top}x = 1.5\times10^{-5}T\times(0.04m) = 6\times10^{-7}Vs$$

$$\left(\oint \vec{B}\cdot d\vec{l}\right)_{right} = B_{right}y\cos(90) = 0Vs$$

$$\left(\oint \vec{B}\cdot d\vec{l}\right)_{bottom} = B_{bottom}x\cos(180) = -B_{bottom}x = -0.8\times10^{-5}T\times(0.04m) = -3.2\times10^{-7}Vs$$

$$\left(\oint \vec{B}\cdot d\vec{l}\right)_{left} = B_{left}y\cos(90) = 0Vs$$

$$\oint \vec{B}\cdot d\vec{l} = \left(\oint \vec{B}\cdot d\vec{l}\right)_{top} + \left(\oint \vec{B}\cdot d\vec{l}\right)_{right} + \left(\oint \vec{B}\cdot d\vec{l}\right)_{bottom} + \left(\oint \vec{B}\cdot d\vec{l}\right)_{left} = 2.8\times10^{-7}Vs = \mu_o I_{enclosed}$$

$$\therefore I_{enclosed} = \frac{1}{\mu_o}\oint \vec{B}\cdot d\vec{l} = \frac{2.8\times10^{-7}Vs}{4\pi\times10^{-7}\frac{Tm}{A}} = 0.22A$$

4. A square loop of wire lies in the plane of the page with its normal perpendicular to the page and pointing out at your face. A uniform magnetic field points out of the page towards your face through the loop of wire at an angle θ measured with respect to the normal to the loop of wire. The magnetic flux through the square loop of wire is

a. zero.
b. $\vec{B}\cdot\vec{A}_{loop}$.
c. $\left|\vec{B}\right|\left|\vec{A}_{loop}\right|\cos\theta$.
d. $\left|\vec{B}\right|\left|\vec{A}_{loop}\right|\sin\theta$.
e. $\left|\vec{B}\right|\left|\vec{A}_{loop}\right|$.

$$\phi_B = \vec{B}\cdot\hat{n}dA = \left|\vec{B}\right|\left|A_{loop}\right|\cos\theta$$

Physics 121 Equation Sheet

Electricity & Magnetism

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\left|\vec{B}_{wire}\right| = \frac{\mu_o LI}{\cdots};\quad \left|\vec{B}_{wire}\right| \approx \frac{\mu_o I}{\cdots}\quad L >> r$$

Constants

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

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

Loop Rule: $\sum_i \Delta V_i = \sum_i E_i\Delta l_i = 0$

Node Rule: $\sum I_{in} = \sum I_{out}$

$$V = IR;\quad R = \frac{\rho L}{A} = \frac{L}{\sigma A}$$

$$\left|\vec{J}\right| = \frac{I}{A} = \sigma\left|\vec{E}\right|$$

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

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

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

$$E = \tfrac{1}{2}qV = \tfrac{1}{2}CV^2 = \frac{q^2}{2C}$$

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

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

$$I(t) = I_{\max}e^{\frac{-t}{RC}}$$

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

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$$\vec{F} = q\vec{v} \times \vec{B}$$

$$d\vec{F} = Id\vec{l} \times \vec{B}$$

$$\vec{F}_{net} = \vec{F}_{\perp} + \vec{F}_{\parallel} = p\frac{d\hat{p}}{dt} + \hat{p}\frac{dp}{dt}; \quad \left|\vec{F}_{\perp}\right| = \frac{pv}{r}$$

$$\vec{F}_{Lorentz} = q\vec{E} + q\vec{v} \times \vec{B}$$

$$\omega = \frac{v}{r} = \frac{d\theta}{dt}; \quad \omega = \frac{qB}{\gamma m}$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$K = (\gamma - 1)mc^2$$

$$\vec{p} = \gamma m\vec{v}$$

$$\oint \vec{E} \cdot \hat{n}\, dA = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$\oint \vec{B} \cdot \hat{n}\, dA = 0$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$$