PHYS 122 | **EXAM III** | **December 3, 2009**
Prof. S.M. Bhagat

Name: Solution

(Sign in ink, print in pencil)

Notes

1. There are six (6) problems in this exam. Please make sure that your copy has all of them.
2. Please show your work indicating clearly what formula you used and what the symbols mean. Just writing the answer will not get you full credit. In stating vectors give both magnitude and direction.
3. Write your answers on the sheets provided.
4. Do not forget to write the units.
5. Do not hesitate to ask for clarification at any time during the exam. You may buy a formula at the cost of one point.

Best of Luck! God Bless You!

$\varepsilon_0 = 9 \times 10^{-12} F/m$

$\mu_0 = 4\pi \times 10^{-7} H/m$

Mass of proton = 1.6×10^{-27} kg

Charge of proton = 1.6×10^{-19} C

Mass of electron = 9×10^{-31} kg

Charge of electron = -1.6×10^{-19} C

Problem 1a (5)

Show that RC has the dimensions of time.

$$R = \frac{V}{I} \rightarrow \frac{VT}{Q}$$

$$C = \frac{Q}{V}$$

$$RC \rightarrow \frac{\cancel{V}T}{\cancel{Q}}\frac{\cancel{Q}}{\cancel{V}} \rightarrow T$$

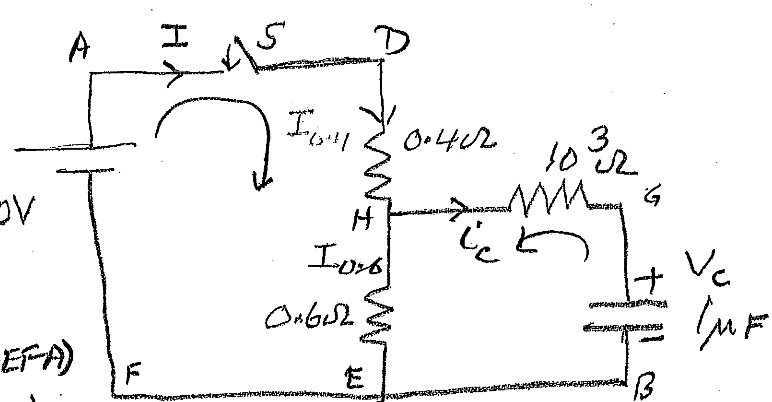
Problem 1b (7, 4)

In the circuit shown, S has been closed for a long time. (i) What is the charge on the capacitor? Why? (ii) What is the time constant of the discharge if you open S? Why?

If S has been closed for a long time, capacitor is fully charged:

$i_c = 0$,

$V_c = V_{0.6}$



Apply Loop Rule (ADEFA)

$10V - I(0.4+0.6) = 0$

$I = 10$ Amp $\qquad V_{0.6} = 6V. = V_c.$

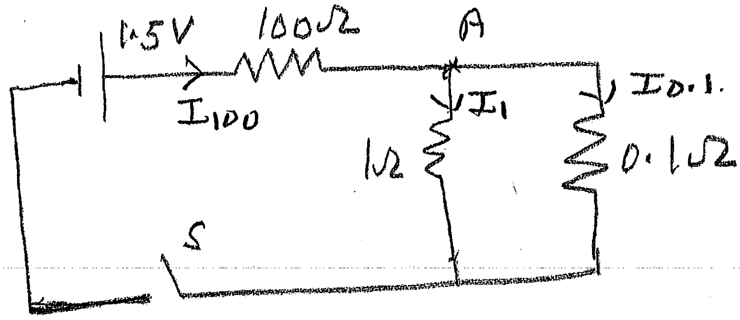
$Q = C V_c = 10^{-6} \times 6 = 6\mu C.$

When S is opened, capacitor will discharge throug BGHE

$RC = 10^3 \times 10^{-6} = 10^{-3}$ sec.

Problem 2 (16)

In the circuit shown, which resistor has the (i) largest current and (ii) smallest current when S is closed? Why?



In Resistors: Series: I is common, V's add so $R_S = \Sigma R_i$

Parallel: V is common, I's add $\frac{1}{R_P} = \Sigma \frac{1}{R_i}$

JUNCTION RULE $\Sigma I_{out} = \Sigma I_{in}$

LOOP RULE $\sum_{LOOP} \Delta U = 0.$

JUNCT. RULE AT A

$I_1 + I_{0.1} = I_{100}$

so I_{100} is largest.

1Ω + 0.1Ω are parallel $V_1 = V_{0.1} = V$

$I_1 = \frac{V}{1}$

$I_{0.1} = \frac{V}{0.1}$

SMALLEST.

Problem 3a (8)

How do you distinguish between a Coulomb $\underset{\rightarrow}{E}$-field and a non-Coulomb $\underset{\rightarrow}{E}$-field?

A Coulomb $\underset{\rightarrow}{E}$ is generated by a stationary charge

$$\underset{\rightarrow}{E} = \frac{Q}{4\pi \varepsilon_0 r^2} \hat{r}$$

Hence $\sum_c \underset{\rightarrow}{E} \cdot \Delta \underset{\rightarrow}{A} = \frac{1}{\varepsilon_0} \sum Q_i$ [Gauss' law].

A Non-Coulomb $\underset{\rightarrow}{E}_{NC}$ appears in every loop surrounding a region where flux of $\underset{\rightarrow}{B}$, $\phi_B = \underset{\rightarrow}{B} \cdot \underset{\rightarrow}{A}$ is changing with time. Lines of $\underset{\rightarrow}{E}_{NC}$ close on themselves so circulation of $\underset{\rightarrow}{E}_{NC}$ around a closed loop is determined by $\frac{\Delta \phi_B}{\Delta t}$,

$$\sum_c \underset{\rightarrow}{E}_{NC} \cdot \Delta \underset{\rightarrow}{l} = -\frac{\Delta \phi_B}{\Delta t}$$

The minus sign on the right ensures that sense of $\underset{\rightarrow}{E}_{NC}$ is such as to oppose the change in ϕ_B.

Problem 3b (8)

How do you distinguish between an $\underset{\rightarrow}{E}$-field and a $\underset{\rightarrow}{B}$-field?

In an $\underset{\rightarrow}{E}$ field a stationary charge experiences a force:

$$\underset{\rightarrow}{F}_E = q \underset{\rightarrow}{E}.$$

In a $\underset{\rightarrow}{B}$ field a moving charge experiences a force which is perpendicular both to its velocity and the $\underset{\rightarrow}{B}$ field

$$\underset{\rightarrow}{F}_B = q [\underset{\rightarrow}{v} \times \underset{\rightarrow}{B}]$$

Problem 4 (7, 5, 8)

A proton (q = 1.6 x 10^{-19} C) with a velocity of 100 km/s $\hat{y}$ is introduced in a region where there is a uniform $\underset{\rightarrow}{B}$ - field of $0 \cdot 5T\hat{z}$. (i) Show that it will move in a circular orbit in the xy – plane. (ii) How much work is done by the $\underset{\rightarrow}{B}$ - field during one circle? (iii) What is the angular velocity (magnitude and direction) of the proton? Why?

At $t=0$

$\underset{\rightarrow}{v} = 10^5 m/s\, \hat{y}$

$\underset{\rightarrow}{B} = 0.5T\, \hat{z}$

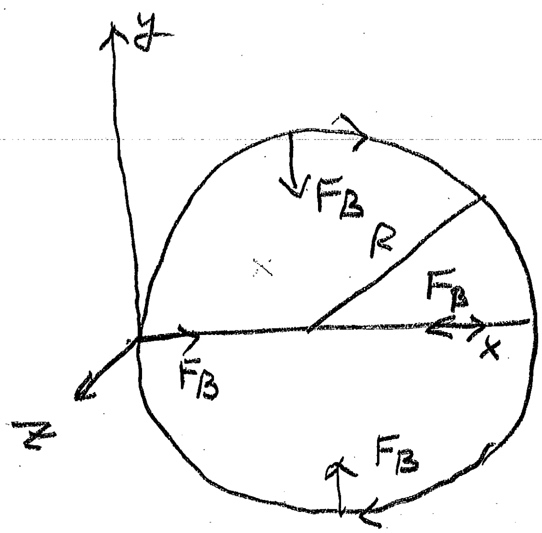
$q = +1.6\times10^{-19}C$

so

$\underset{\rightarrow}{F_B} = q[\underset{\rightarrow}{v}\times\underset{\rightarrow}{B}]$

$= qvB\,\hat{x}$

so proton turns right. Subsequently,



(i) $\underset{\rightarrow}{F_B} \perp \underset{\rightarrow}{v}$ at all times gives path shown.

(ii) → since $\underset{\rightarrow}{F_B} \perp \underset{\rightarrow}{v}$, no work is done hence magnitude of $\underset{\rightarrow}{v}$ is constant.

$\underset{\rightarrow}{F_B} = -qvB\hat{r}$ provides centripetal force for uniform circular motion

$\underset{\rightarrow}{F_c} = -\frac{Mv^2}{R}\hat{r}$ $\quad R = \frac{Mv}{qB}$.

Angular velocity vector

$\underset{\rightarrow}{\omega} = -\frac{v}{R}\hat{z} = -\frac{qB}{M}\hat{z}$ Rt. hand Rule.

$= \frac{-1.6\times10^{-19}\times0.5}{1.6\times10^{-27}}\hat{z}$

$= -5\times10^{7}$ rad/s $\hat{z}$

Problem 5

Why do two anti-parallel currents repel one another?

The current-current force arises b/c

i) A current creates a $\vec{B}$ field which circulates around it

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

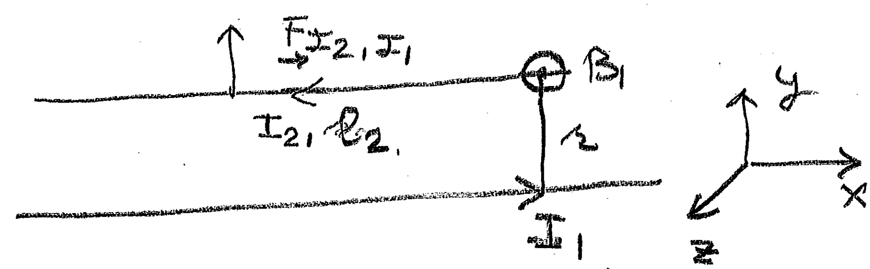
and

(ii) A current experiences a force in a $\vec{B}$-field

$$\vec{F}_I = I\left[\Delta \vec{\ell} \times \vec{B}\right].$$

Take current I_1, At r it produces a field

$$\vec{B}_1 = \frac{\mu_0 I_1}{2\pi r}\hat{z}$$



Locate I_2, force on I_2 by right hand rule $\Delta \vec{\ell}_2 \times \vec{B}$ $\left[-\hat{x} \times \hat{z}\right]$ is $+\hat{y}$

(Thumb $\parallel -\hat{x}$ $\quad \vec{F}_I \perp$ Palm $\hat{y}$]

Fingers $\parallel \hat{z}$

$$\vec{F}_{I_2, I_1} = \frac{\mu_0 I_1 I_2 \ell_2}{2\pi r}\hat{y}$$

Problem 6a (8)

Write down Ampere's law in your own words, defining the terms clearly.

The circulation of $\underset{\rightarrow}{B}$ around a closed loop is determined by the currents threading (going through) the surface on which the loop is drawn. Only currents within the loop contribute:

$$\sum_{C} \underset{\rightarrow}{B} \cdot \Delta \underset{\rightarrow}{l} = \mu_0 \sum I_i$$

Problem 6b (8)

Why does the total flux of the $\underset{\rightarrow}{B}$ - field through a closed surface always equal zero (0)?

Firstly, as we saw in Prb. 6a, $\underset{\rightarrow}{B}$ field lines circulate & close on themselves (closed loops), secondly, elementary generators of $\underset{\rightarrow}{B}$ are magnetic dipoles having no spatial extent (+ & − coincide). Hence

$$\sum_{C} \underset{\rightarrow}{B} \cdot \Delta \underset{\rightarrow}{A} = 0$$