PHYS 2020: College Physics II

Midterm Number 2, Spring Semester 2008

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FAVORITE ~~ELECTRICAL PUN~~ EPISODE OF STAR TREK	CITY ON THE EDGE OF FOREVER

DO NOT OPEN THIS EXAM UNTIL YOU ARE TOLD TO START!

Welcome to Midterm 2! Take a deep breath, relax. You know how to do physics – this is simply covering material you already know how to do.

INSTRUCTIONS:

- ▷ You must show your work for full credit!
- ▷ Circle your final answers; make sure all your answers have been labeled **with units**!
- ▷ If you have questions, ask!

You may find some of the following formulae useful:

Charges in Magnetic Fields

$$F_{mag} = |q|vB\sin\theta \qquad r = \frac{mv}{|q|B}$$

Magnetic Forces on Currents

$$F = I\ell B\sin\theta \qquad B_{wire} = \frac{\mu_o I}{2\pi r}$$

Magnetic Fields & Loops

$$B_{loop} = N\frac{\mu_o I}{2R} \qquad B_{solenoid} = \left(\frac{N}{\ell}\right)\mu_o I$$

Magnetic Flux & Faraday's Law

$$\Phi_m = B\cdot A\cos\theta \qquad \mathcal{E}_{ind} = -N\frac{\Delta\Phi_m}{\Delta t} = L\frac{\Delta I}{\Delta t}$$

$$L = N\frac{\Delta\Phi_m}{\Delta I} \qquad L_{solenoid} = \mu_o A\left(\frac{N^2}{\ell}\right)$$

$$\mathcal{E}_{ind} = -N\frac{\Delta B}{\Delta t}A \qquad \mathcal{E}_{ind} = -N\frac{\Delta A}{\Delta t}B$$

$$\mathcal{E}_{ind} = B\ell v$$

Solenoids & Inductors

$$I(t) = I_{max}\left[1 - \exp(-t/\tau)\right] \qquad \tau = \frac{L}{R}$$

$$\frac{\mathcal{E}_p}{\mathcal{E}_s} = \frac{N_p}{N_s} \qquad \text{Transformer Equation}$$

Alternating Current

$$V(t) = V_{max}\sin(\omega t) \qquad I(t) = I_{max}\sin(\omega t) = \left(\frac{V_{max}}{R}\right)\sin(\omega t) \qquad I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$P = I^2R = I_{max}^2\sin^2(\omega t)R \qquad P = \frac{V^2}{R} = \frac{V_{max}^2}{R}\sin^2(\omega t)$$

$$P_{av} = \frac{1}{2}I_{max}^2R = I_{rms}^2R \qquad P_{av} = \frac{1}{2}\frac{V_{max}^2}{R} = \frac{V_{rms}^2}{R}$$

Impedance

$$Z_C = \frac{1}{\omega C} \qquad Z = \sqrt{R^2 + Z_C^2}$$

$$Z_L = \omega L \qquad Z = \sqrt{R^2 + Z_L^2}$$

$$Z = \sqrt{R^2 + (Z_L - Z_C)^2} \qquad \omega_o = \frac{1}{\sqrt{LC}} \qquad \text{Reasonant Frequency}$$

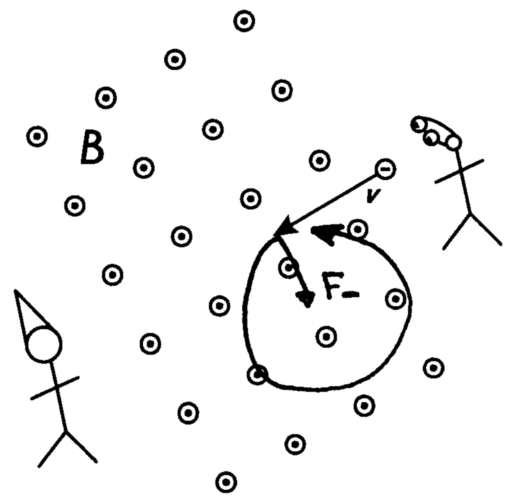
Some useful unit conversions and constants may be:

$\mu_o = 4\pi \times 10^{-7}$ T·m/A	$k = 8.99 \times 10^9$ N m^2/C^2	$\epsilon_o = 1/(4\pi k) = 8.85 \times 10^{-12}$ C^2/(N m^2)
	$e = 1.60 \times 10^{-19}$ C	
RHR 1a $\rightarrow \vec{F}_m \rightarrow \vec{v} \times \vec{B}$	RHR 1b $\rightarrow \vec{F}_m \rightarrow \vec{I} \times \vec{B}$	RHR 2 $\rightarrow$ get$\vec{B}$ direction from current

Good luck, and May the Force be with you!

⟨1⟩ **[30 pts total]** *The Bohr Atom*

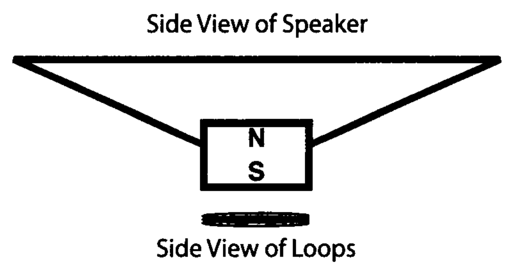
(a) **[15 pts]** One day, I'm floating in space near a uniform magnetic field, as shown. I'm minding my own business, when a wild Zeptonian appears and tries to shoot me with his electron beam. For the diagram shown, draw the *subsequent motion* of the electrons. Describe your reasoning below.



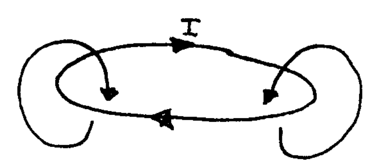
RHR 1 gives force on POSITIVE as CW deflection, so the electron (NEGATIVE) is CCW.

Resulting motion is circular since F is $\perp$ to v.

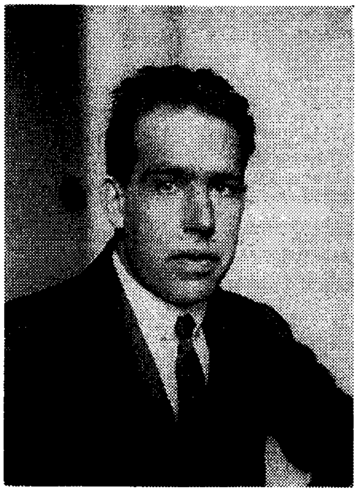
(b) **[15 pts]** Ever notice when you take a speaker apart there is a magnet inside? Sound is generated when small currents are run through a loop of wire near the magnet. Depending on the direction the current runs, it either attracts or pushes the magnet (attached to the speaker membrane) which generates sound. If you view the diagram shown at right *from above*, which direction does a CCW current in the loop push the magnet? Describe your reasoning below.



To PUSH the magnet up, the side of the loop closest should look like a S pole (to repulse the magnet's S). This means field lines due to current should be going IN to top of loops which means CW current viewed from above.



⟨2⟩ **[30 pts total]** *The Bohr Atom*



When we begin our study of atomic physics, our first model of the atom will be the *Bohr Model* proposed by Niels Bohr (pictured). In this model, the hydrogen atom is simply considered to be a proton, with the electron orbiting around it in a circular orbit.

(a) **[10 pts]** The electron has an orbital radius of 5.29×10^{-11} m, and an orbital speed of 2.19×10^{6} m/s. If I interpret the motion of the electron as a current, what is the current in amps?

Distance traveled in circular orbit: $\Delta x = 2\pi r$

Get time from speed and distance:

$$V = \frac{\Delta x}{\Delta t} \rightarrow \Delta t = \frac{\Delta x}{V}$$

Current: $I = \frac{q}{\Delta t} = q\left(\frac{V}{\Delta x}\right) = \frac{qV}{2\pi r}$

$$= \frac{(1.60\times10^{-19}C)(2.19\times10^{6} m/s)}{2\pi \cdot 5.29\times10^{-11} m} = \boxed{1.05\times10^{-3} \text{ Amps}}$$ (ANS)

(b) **[10 pts]** The orbit of the electron looks like a little current loop. What is the strength of the magnetic field produced by the electron at the location of the proton?

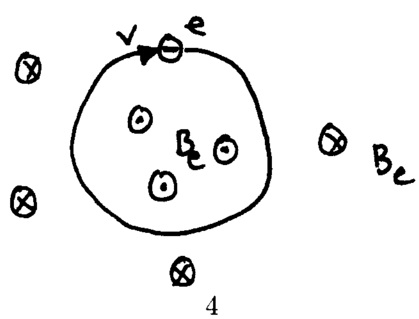
At the center of a loop:

$$B = \frac{\mu_0 I}{2r} = \frac{(4\pi\times10^{-7} Tm/A)(1.05\times10^{-3}A)}{2 \cdot 5.29\times10^{-11}m}$$

$$= \boxed{12.52 T}$$ (ANS)

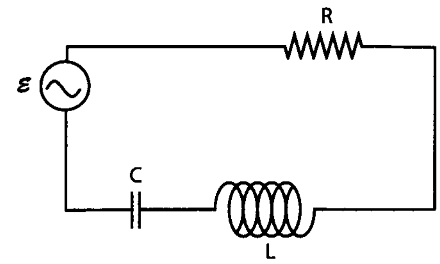
(c) **[10 pts]** Draw a sketch showing the electron's motion around the proton and the associated magnetic field.

VIEWED FROM ABOVE



RHR gives a B opposite this, but electron is NEGATIVE so direction is as shown.

⟨3⟩ **[20 pts total]** *The Crystal Radio Oscillator*



At the heart of a crystal radio set is an LC oscillator which sets the reception frequency of the radio. This type of radio is reasonably easy to construct from common household items. Even the electronic components can be improvised, as was readily shown by soldiers on the front lines in World War II, who built crystal radios in the field to listen to European radio. These radios were called *foxhole receivers*. Consider the oscillator in a crystal radio, shown here.

(a) **[10 pts]** If $C = 32.2\ \mu F$, $L = 0.250$ mH, and $R = 1.25\ \Omega$, what is the resonant frequency of the circuit (*i.e.* what frequency will the radio set tune to)?

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{(32.2 \times 10^{-6} F \cdot 0.250 \times 10^{-3} H)^{1/2}}$$

$$= \boxed{11.145 \text{ kHz}} \text{ (ANS)}$$

(b) **[10 pts]** The generator has a maximum EMF of $\mathcal{E} = 9.0V$. At the reasonance frequency, what is the RMS current in the circuit?

MAX EMF: $\mathcal{E}_{max} = 9.0V$ so// $\mathcal{E}_{RMS} = \frac{\mathcal{E}_{MAX}}{\sqrt{2}} = 6.36V$

AT REASONANCE $Z_L = Z_C$ so// $Z_{TOT} = \sqrt{R^2 + (Z_L - Z_C)^2} = R$

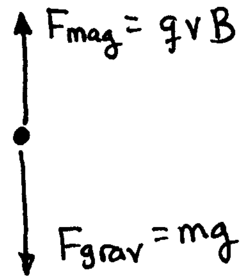
so//

$$\mathcal{E}_{RMS} = I_{RMS} \cdot Z_{TOT} \rightarrow I_{RMS} = \frac{\mathcal{E}_{RMS}}{R} = \frac{6.36V}{1.25\Omega} = \boxed{5.09A} \text{ (ANS)}$$

⟨4⟩ **[35 pts total]** *The Oil Drop Experiment*

One way to determine the charge to mass ratio of the electron, q/m, is to balance a charged object between forces exerted by gravity and magnetic fields. We will call this the *Larson Oil Drop Experiment.* In the Larson oil drop experiment, a charged oil drop is projected horizontally with a speed v into a uniform magnetic field. I adjust the speed so the particle travels *horizontally* without rising or falling.

(a) **[10 pts]** Draw a free body diagram for the oil drop. What must be true about the magnitudes of the forces in this diagram?



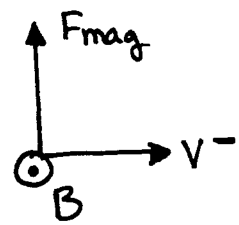
If particle travels horizontally, then there is no acceleration, so

$$\sum F = F_{NET} = 0$$

so// $F_{mag} = F_{grav}$.

(b) **[10 pts]** Considering the direction of the forces on your free body diagram, what direction must the magnetic field point? Describe how you know this.

RHR says for a NEGATIVE particle to have F_{mag} UP, B must be OUT of the page



(c) **[15 pts]** Suppose we inject an oil drop with 4.8×10^9 excess electrons into a 0.68 T field at a speed of 2.3×10^4 m/s, and it passes through the field horizontally. What was the mass of the oil drop when it entered the field?

From part (a): $F_{mag} = F_{grav}$

or// $mg = qvB$

so// $m = \frac{qvB}{g} = \frac{(4.8 \times 10^9 \cdot 1.60 \times 10^{-19} C)(2.3 \times 10^4 \frac{m}{s})(0.68 T)}{9.81 \, m/s^2}$

$$\boxed{m = 1.22 \times 10^{-6} \text{ kg}}$$

(ANS)