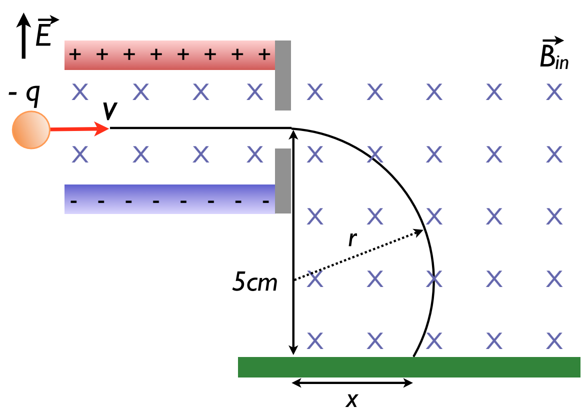
Name ______________________ Date ____________

PH 102 Exam II

INSTRUCTIONS

1. **Solve 8 problems out of the 12 below.** All problems have equal weight.
2. Clearly mark the problems you choose by filling in the adjacent circle.
3. **Show as much work as possible for partial credit.**
4. Solve the problems on separate sheets. Staple your sheets to the exam when finished.
5. You are allowed 2 sides of a standard 8.5x11 in piece of paper with notes/formulas and a calculator.

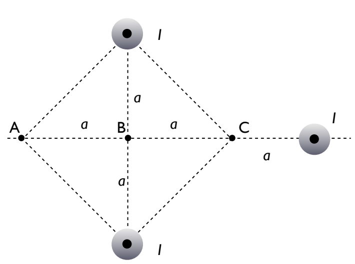
5Nov07 LeClair



◯ **1**. Consider the mass spectrometer shown at left. The electric field between the plates of the velocity selector is $|\vec{\mathbf{E}}| = 1000\,\text{V/m}$, and the magnetic fields in both the velocity selector and the deflection chamber have magnitudes of 0.1 T.

Calculate the *position* x at which a singly charged ion with mass $m = 7.3 \times 10^{-26}\,\text{kg}$ (corresponding to CO_2) will hit the detector plate.

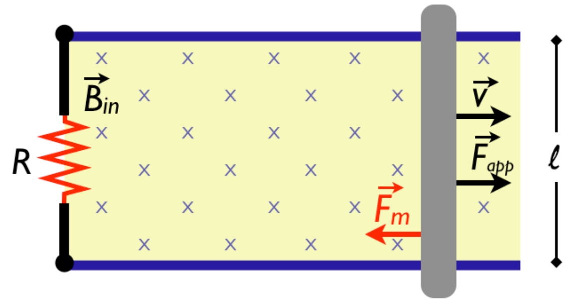
◯ 2. A wire with a *weight* per unit length of 0.10 N/m is suspended directly above a second wire. The top wire carries a current of 30 A and the bottom wire carries a current of 60 A. Find the distance of separation between the wires so that the top wire will be held in place by magnetic repulsion.



◯ 3. Three long parallel conductors carry currents coming *out of the page* of $I = 2.8\,\text{A}$, as shown in the figure at left. Given $a = 2.0\,\text{cm}$, find the magnitude and direction of the magnetic field at all three points A, B, and C.

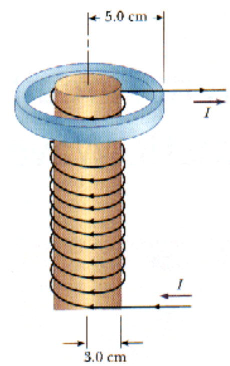
◯ 4. A circular coil enclosing an area of $105\,\text{cm}^2$ is made of 200 turns of copper wire. The wire making up the coil has resistance of $7.0\,\Omega$, and the ends of the wire are connected to form a closed circuit. Initially, a 2.0 T uniform magnetic field points perpendicularly upward through the plane of the coil. The direction of the field then reverses so that the final magnetic field has a magnitude of 2.0 T and points downward through the coil. If the time required for the field to reverse directions is 0.15 s, what average current flows through the coil during that time?

◯ 5. A conducting rod of length l moves on two (frictionless) horizontal rails, as shown to the right. A constant force of magnitude $|\vec{\mathbf{F}}_{\text{app}}| = 1.0\,\text{N}$ moves the bar at a uniform speed of $|\vec{\mathbf{v}}| = 2.0\,\text{m/s}$ through a magnetic field $\vec{\mathbf{B}}$ directed into the page. The resistor has a value $R = 8.0\,\Omega$.



(a) What is the current through the resistor R?
(b) What is the mechanical power delivered by the constant force?

◯ 6. An aluminum ring of radius 5.0 cm and resistance $1.0 \times 10^{-4}\,\Omega$ is placed around the top of a long air-core solenoid with $n = 996$ turns per meter and a smaller radius of 3.0 cm, as in the figure. If the current in the solenoid is increasing at a constant rate of 266 A/s, what is the induced current in the ring?



Assume that the magnetic field produced by the solenoid over the area at the end of the solenoid is one-half as strong as the field at the center of the solenoid. Assume also that the solenoid produces a negligible field outside its cross-sectional area.

◯ 7. A helium-neon laser delivers 1.05×10^{18} photons/sec in a beam diameter of 1.75 mm. Each photon has a wavelength of 601 nm.

(a) Calculate the amplitudes of the electric and magnetic fields inside the beam.
(b) If the beam shines perpendicularly onto a perfectly reflecting surface, what force does it exert?
(c) If the perfectly reflecting surface is a block of aluminum with mass $m = 1\,\text{g}$, how long will it take for the incident photons to accelerate it to a velocity of 1 m/s? Assume the beam does not diverge, air resistance and gravity can be neglected.

◯ 8. You are given 2 resistors, 1 capacitor, and 1 inductor.

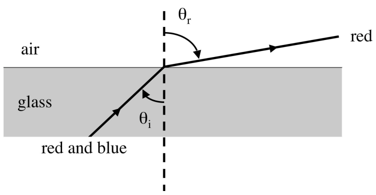
(a) Using only these components, construct both a low and high pass filter.
(b) Sketch the frequency response for each.

◯ 9. A cylindrical cistern, constructed below ground level, is 2.9 m in diameter and 2.0 m deep and is filled to the brim with a liquid whose index of refraction is 1.5. A small object rests on the bottom of the cistern at its center. How far from the edge of the cistern can a girl whose eyes are 1.2 m from the ground stand and still see the object?

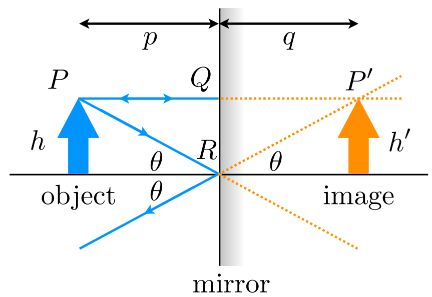
◯ 10. Refer to the figure below. Red and blue light are incident on a glass-air interface, from the glass side, at an angle of incidence θ_i. The index of refraction for red light is $n_{\text{red}} = 1.50$ and $n_{\text{blue}} = 1.52$ for blue light. If θ_i is greater than some critical angle θ_c, the transmitted beam contains only red light.

(a) What is the minimum angle of incidence θ_c such that only red light emerges?

(b) What is the corresponding minimum *refracted* angle θ_r?



◯ 11. Use the figure at right to give a geometrical proof that the virtual image formed by a flat mirror is the same distance behind the mirror as the object is in front of it, and of the same height as the object.



◯ 12. While looking at her image in a cosmetic mirror, Dina notes that her face is highly magnified when she is close to the mirror, but as she backs away from the mirror, her image first becomes blurry, then disappears when she is about 38.0 cm from the mirror, and then inverts when she is beyond 38.0 cm.

(a) What type of mirror does Dina have?

(b) What is the focal length of the mirror?

(c) What is the radius of curvature of the mirror?

Useful Things

Constants:

$$\mu_0 \equiv 4\pi \times 10^{-7}\,\mathrm{T \cdot m/A}$$
$$e = 1.602 \times 10^{-19}\,\mathrm{C}$$
$$\epsilon_0 = 8.85 \times 10^{12}\,\mathrm{C^2/N \cdot m^2}$$
$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792 \times 10^{8}\mathrm{m/s}$$
$$h = 6.63 \times 10^{-34}\mathrm{J \cdot s}$$
$$m_{e^-} = 9.11 \times 10^{-31}\,\mathrm{kg}$$
$$m_{p^+} = 1.67 \times 10^{-27}\,\mathrm{kg}$$

Magnetism

$$|\vec{\mathbf{F}}_B| = q|\vec{\mathbf{v}}||\vec{\mathbf{B}}|\sin\theta_{vB} \text{ charge } q$$
$$|\vec{\mathbf{F}}_B| = BIl\sin\theta \text{ wire}$$
$$|\vec{\tau}| = BIAN\sin\theta \text{ torque current loop}$$
$$\vec{\mathbf{B}} = \frac{\mu_0 I}{2\pi r}\hat{\theta} \text{ wire}$$
$$\vec{\mathbf{B}} = \mu_0 \frac{N}{L} I\,\hat{\mathbf{z}} \equiv \mu_0 n I\,\hat{\mathbf{z}} \text{ solenoid}$$
$$\frac{|\vec{\mathbf{F}}_{12}|}{l} = \frac{\mu_0 I_1 I_2}{2\pi d} \text{ 2 wires, force per length}$$

Electricity

$$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$$
$$\tau = RC \text{ time const}$$
$$\Delta V = IR$$
$$\mathscr{P} = I^2 R = IV \text{ power}$$

Induction:

$$\Phi_B = B_\perp A = BA\cos\theta_{BA}$$
$$\Delta V = -N\frac{\Delta\Phi_B}{\Delta t}$$
$$L = N\frac{\Delta\Phi_B}{\Delta I} = \frac{N\Phi_B}{I}$$
$$\Delta V = |\vec{\mathbf{v}}||\vec{\mathbf{B}}|l = |\vec{\mathbf{E}}|l \text{ motional voltage}$$

Quadratic formula:

$$ax^2 + bx^2 + c = 0$$
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Basic Equations:

$$\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}} \text{ Newton's Second Law}$$
$$\vec{\mathbf{F}}_{\text{centr}} = \frac{mv^2}{r}$$
$$\text{KE} = \frac{1}{2}mv^2 \text{ Kinetic energy}$$
$$\text{KE}_{\text{initial}} + \text{PE}_{\text{initial}} = \text{KE}_{\text{final}} + \text{PE}_{\text{final}}$$

Optics:

$$\mathscr{E} = hf = \frac{hc}{\lambda}$$
$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}$$
$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \text{ refraction}$$
$$\lambda_1 n_1 = \lambda_2 n_2 \text{ refraction}$$
$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \text{ Snell's refraction}$$
$$n_1 \sin\theta_c = n_2 \sin 90^\circ = n_2 \text{ total internal refl.}$$

ac Circuits

$$\tau = L/R \text{ RL circuit}$$
$$X_C = \frac{1}{2\pi f C} \text{ “resistance” of a capacitor for ac}$$
$$X_L = 2\pi f L \text{ “resistance” of an inductor for a}$$

EM Waves:

$$c = \lambda f = \frac{|\vec{\mathbf{E}}|}{|\vec{\mathbf{B}}|}$$
$$\mathcal{I} = \left[\frac{\text{photons}}{\text{time}}\right]\left[\frac{\text{energy}}{\text{photon}}\right]\left[\frac{1}{\text{Area}}\right]$$
$$\mathcal{I} = \frac{\text{energy}}{\text{time} \cdot \text{area}} = \frac{E_{\max}B_{\max}}{2\mu_0} = \frac{\text{power } (\mathscr{P})}{\text{area}} = \frac{E_{\max}^2}{2\mu_0 c}$$

$\uparrow$ radiation intensity