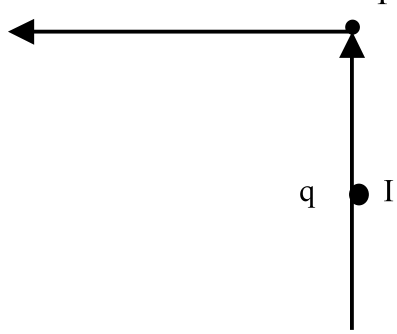
Physics 114 2001
Exam 3

The number of points for each section is noted in brackets, []. Choose a total of 35 points that will be graded – that is you may drop (not answer) a total of 25 points. **Clearly mark on the cover of your blue book, which ones are to be graded and not graded.** You must choose the twenty points worth that are not to be graded.

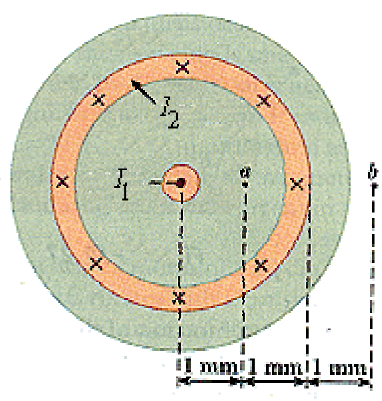
1. **Sources of Magnetic Fields.**

   a. [2.5 points] Consider a wire that is bent into a right angle at point P that carries a current I = 3A What is the magnitude of the magnetic field at the point P?

   b. [2.5 points] What is the magnitude and direction of the field at q, assuming q is 10 m from P and 1 mm from the vertical wire?

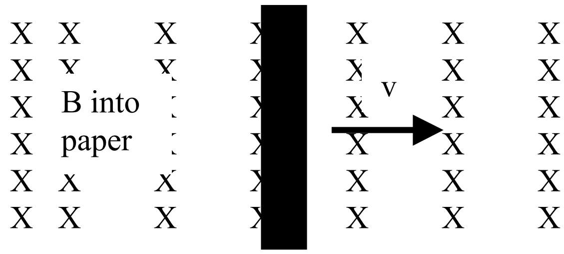


   c. [5 points] The figure below is a cross-sectional view of a coaxial cable. The center conductor is surrounded by a rubber layer, which is surrounded by an outer conductor, which is surrounded by another rubber layer. In a particular application, the current in the inner conductor is I_1 = 1.00 A out of the monitor, and the current in the outer conductor is I_2 = 3.00 A into the monitor. (1) Determine the magnitude and direction of the magnetic field at points a (2) Determine the magnitude direction of the magnetic field at point b.

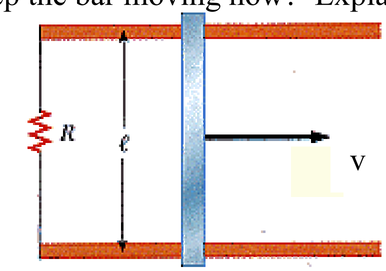


2. **Faraday's Law**

   a. [2.5 points] Imagine there is a uniform magnetic field pointing into the page. (1) If a conducting bar is moved in a magnetic field as shown below with a constant velocity v, is there an electric field set up in the bar? (2) If so, what is the direction of that field? (3) Is a force required to keep the bar moving? Explain.



b. [2.5 points] Imagine now that the same bar is moving in the same field (uniform into the page) but it is now moving along metallic rails as shown below. Would a force be required to keep the bar moving now? Explain.

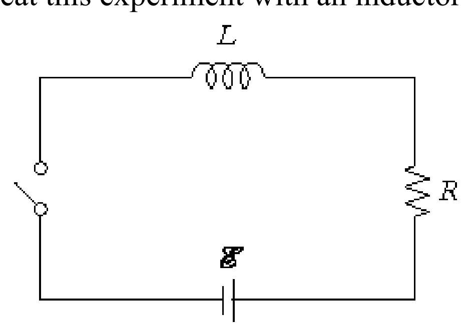


c. [5 points] Consider the arrangement shown above for part b. Assume that R = 6.00 , ℓ= 1.20 m, and a uniform 2.50 T magnetic field is directed into the page. (1) At what speed should the bar be moved to produce a current of 0.500 A in the resistor? (2) Will that current be clockwise or counter clockwise when viewed from above. (3) What is the time rate of change of the flux $\frac{d\Phi}{dt}$ through the closed circuit in the above picture?

3. Inductance

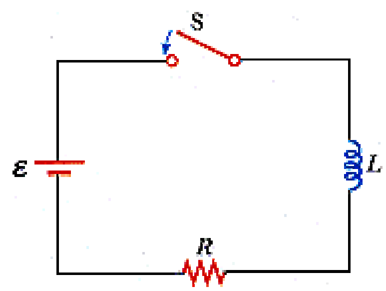
a. [2.5 points] A brass ring is placed on top of a coil of wire.(1) If a switch to a source of direct current is closed and charges start to flow in the coil, the ring springs upward. Explain. (2) The ring is then placed atop the coil once again, and the switch opened. The current in the coil rapidly dies out. What happens to the ring now? Explain.

b. [2.5 points] When the switch is closed, the current through the circuit shown below, exponentially approaches a value $I=E/R$. It takes a time t1 to each a current of I/2. If we repeat this experiment with an inductor having twice the number of



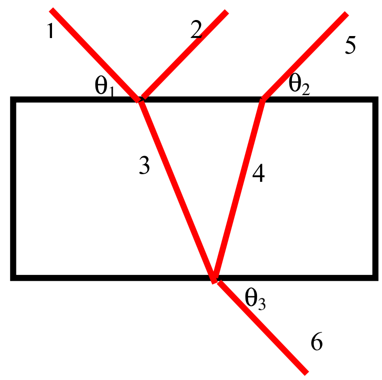
turns per unit length, what happens to the time it takes for the current to reach a value of $I/2$.

c. [5 points] Consider the circuit shown below, taking $\varepsilon = 6$ V, L = 8.00 mH, and R = 4.00 Ω. (1) What is the inductive time constant of the circuit? (2) Calculate the current in the circuit 250 μs after the switch is closed. (3) What is the value of the final steady-state current? (4) How long does it take the current to reach 80% of its maximum value?

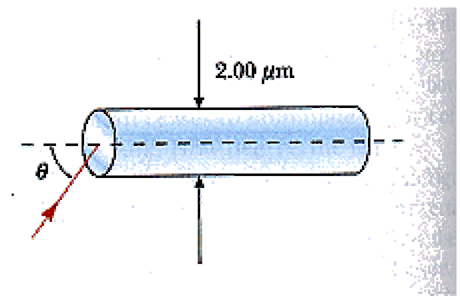


4. **Electromagnetic waves.**
   a. [2.5 points] (1) What is the phase difference between the electric and magnetic fields composing an electromagnetic wave? (2) Describe the physical significance of the Poynting vector, what is it and what information does it provide? (3) In space sailing, should your sail be reflective or absorptive to be most effective?
   b. [2.5 points] At a fixed point, *P*, the electric and magnetic field vectors in an electromagnetic wave oscillate at angular frequency w. At what angular frequency does the Poynting vector oscillate at that point?
   c. [5 points] In SI units, the electric field in an electromagnetic wave is described by $E_y = 100 \sin(1.00 \times 10^7 x - \omega t)$. (1) Calculate the amplitude of the corresponding magnetic field. (2) Find the wavelength , (3) Find the frequency f. (4) Also find an expression for the **vector** magnetic field.

5. **Nature of Light**
   a. [2.5 points] (1) As light travels from one medium to another, does it always bend toward the normal? (2) Does its frequency change? (3) Does its wavelength change? (4) Does its velocity change? Explain.
   b. [2.5 points] Consider a light ray of wavelength 6.33 nm (red) obliquely incident on a slab of glass as shown below (ray 1). (1) Which rays are due to reflection and which ones are due to refraction? (2) How does the angle that ray 1 makes with the horizontal (θ_1) compare to that which ray 5 makes with the horizontal (θ_2)? (3) How do these angles compare to the angle ray 6 makes with the horizontal (θ_3)? (4) How would these angles change (θ_2 and θ_3) if blue light were used instead of red? (5) What else, if anything would change in the picture?



c. [5 points] Consider light incident on the end of a pipe as shown below. Assume that the pipe has an index of refraction of 1.36 and the outside medium is air. (1) For the incident angle θ, what will be the initial angle of refraction in the pipe (in terms of θ)? (2) Determine the maximum angle θ for which the light rays incident on the end of the pipe are subject to total internal reflection along the walls of the pipe. (Hint – You need only examine the first time the ray goes from the pipe to air).



6. **Geometric Optics**

a. [2.5 points] (1) Draw the image formed of an object (consisting of an upright arrow) when it is placed 20 cm in front of a thin, convex lens of focal length 10 cm. Be sure to clearly show at least two rays forming the image. Don't worry about trying to draw distances exactly. (2) Now draw the image formed by this lens when the object is placed 5 cm from the lens.

b. [2.5 points] A thin lens is used to form a real image of a nearby object. If the object is moved closer to the lens, a new real image is observed. Does the new image differ from the old one (1) in position relative to the lens? (2) in size? (3) If it does differ in one of both of these, how so?

c. [5 points] A spherical mirror is to be used to form, on a screen located 5 m from the object, an image 5 times the size of the object. (1) Describe the type of mirror required. (2) Where should the mirror be placed relative to the object?

Possibly Useful Information

$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$

$\varepsilon_0 = 8.85 \text{ X } 10^{-12} (C^2 / N - m^2)$

$e = 1.6 \text{ X } 10^{-19}$ C

$\vec{E} = \vec{F}/q_0$

$E = \frac{|q|}{4\pi\varepsilon_0 r^2}$

$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E}.d\vec{A} = q_{enc}$

$\Delta x = x_2 - x_1,\ \Delta t = t_2 - t_1$

$\bar{v} = \Delta x / \Delta t$

$\bar{s}$ = (total distance) / Δt

$v = dx/dt$

$\bar{a} = \Delta v / \Delta t$

$a = dv/dt = d^2x/dt^2$

$v = v_o + at$

$g = 9.8\ m/s^2$

$x - x_o = v_o t + (½)at^2$

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

$v^2 = v_o^2 + 2a(x - x_o)$

$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$x - x_o = ½(v_o + v)t$

$\Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$

$x - x_o = vt - 1/2at^2$

$\bar{\vec{v}} = \Delta\vec{r} / \Delta t,\ \vec{v} = d\vec{r} / dt$

$\vec{a} = d\vec{v} / dt$

$\bar{\vec{a}} = \Delta\vec{v} / \Delta t$

$\Delta U = U_f - U_i = -W$

$\Delta V = V_f - V_i = -W/q_0 = \Delta U/q_0$

$U = -W_\infty$

$V = -W_\infty/q_0$

$V_f - V_i = -\int_i^f \vec{E}.d\vec{s}$

$V = -\int_i^f \vec{E}.d\vec{s}$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$

$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$

$E_s = \frac{\partial V}{\partial s}$

$E_x = \frac{\partial V}{\partial x}; E_y = \frac{\partial V}{\partial y}; E_z = \frac{\partial V}{\partial z}$

$E = \frac{\Delta V}{\Delta s}$

$U = -W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$

$Q = CV$

$C = \frac{\varepsilon_0 A}{d}$

$C = 2\pi\varepsilon_0 \frac{l}{\ln(b/a)}$

$C = 4\pi\varepsilon_0 \frac{ab}{b-a}$

$C = 4\pi\varepsilon_0 R$

$C_{eq} = \sum C_j$ (parallel)

$\frac{1}{C_{eq}} = \sum \frac{1}{C_j}$ (series)

$U = \frac{Q^2}{2C} = ½CV^2$

$u = \frac{1}{2}\varepsilon_0 E^2$

$C = \kappa C_0$

$I = dQ/dt$

$\rho = 1/\sigma$

$R = \rho L/A$

$V = IR$

$P = IV$

$P = I^2R = V^2/R$

$I = \varepsilon/(R + r)$

$P_{emf} = I\varepsilon$

$R_{eq} = \sum R_j$ (series)

$\frac{1}{R_{eq}} = \sum \frac{1}{R_j}$ (parallel)

$q(t) = Q(1-e^{-t/RC})$

$I = (\varepsilon/R)e^{-t/RC}$

$q(t) = Qe^{t/RC}$

$I = (Q/RC)e^{-t/RC}$, $I_0 = (Q/RC)$

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

$\vec{F} = I\vec{L} \times \vec{B}$

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

$\tau = \vec{\mu} \times \vec{B}$

$\vec{\mu} = NI\vec{A}$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{s} \times \vec{r}}{r^3}$, $\mu_0 = 4\pi \times 10^{-7}$ T·m/A

$B = \mu_0 I/2\pi r$

$B = \mu_0 nI$ (solenoid)

$F/l = (\mu_0 I_1 I_2)/2\pi a$

$\oint \vec{B}.d\vec{s} = \mu_0 I_{enc}$

$I_d = \varepsilon_0 d\Phi_E/dt$

$B = (\mu_0 IN)/(2\pi r)$ (toroid)

$\Phi_B = \int \vec{B}.d\vec{A}$

$L = N\Phi / I$

$\varepsilon = \oint \vec{E}.d\vec{s} - N\, d\Phi_B/dt$

$\varepsilon = -L\, dI/dt$

$L = \mu_0 n^2 A/l$

$I = I_0 e^{-t/\tau}$

$I = (\varepsilon/R)(1-e^{-t/\tau})$, $\tau = L/R$

$U_B = (1/2)LI^2$

$\mu_B = B^2/(2\mu_0)$

$c = \omega/k = E/B = 1/(\mu_0 \varepsilon_0)^{1/2} = 3.0 \times 10^8$ m/s $= \lambda f$, $\omega = 2\pi f$

$E = E_{max}\cos(kx-\omega t)$

$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$

$I = E_{max}^2/(2c\,\mu_0) = S_{av}$

$I = P_s/4\pi r^2$

$P = S/c$

$n = c/v$

$p_r = I/c$, $p_r = 2I/c$

$I = \frac{1}{2} I_0$, $I = I_0 \cos^2(\theta)$

$n_1\sin(\theta_1) = n_2\sin(\theta_2)$

$\theta_c = \sin^{-1}(n_2/n_1)$

$1/f = 1/p + 1/q = 2/R$

$n_1/p + n_2/q = (n_2 - n_1)/R$

$1/f = (n-1)(1/R_1 - 1/R_2)$

$M = -q/p$, $|M| = h'/h$

$n = \lambda_0/\lambda$