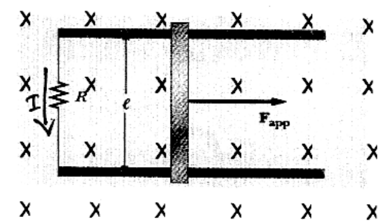
PHYS 142, EXAM 3 NAME: ______________________ SECTION: ________

$\varepsilon_o = 8.85\text{x}10^{-12}\ C^2/(Nm^2)$ $\mu_o = 4\pi\text{x}10^{-7}$ Tm/A $c = 3.0\text{x}10^8$ m/s

1. (10 pts) Consider a conducting bar (pictured below) which can freely move on top of two conducting wires. Assume that R = 6 Ω, l = 1.2 m, and a uniform 2.5 T magnetic field is directed into the page. (a)(4 pts) At what speed should the bar be moved to the right, in order to produce a current of 0.5 A in the resistor? (b)(2 pts) What direction will the current be through the resistor? (c)(4 pts) Calculate the applied force required to move the bar to the right at the constant speed of 2 m/s? (HINT: think about the force on a current due to magnetic field.)



$R = 6\Omega$ $I = 0.5A$
$\ell = 1.2m$
$B = 2.5T$

4 a) $I = \frac{\mathcal{E}}{R}$; $|\mathcal{E}| = v\ell B$

$\Rightarrow I = \frac{v\ell B}{R}$

$\Rightarrow v = \frac{IR}{\ell B}$

$v = \frac{(0.5)A\,(6)\Omega}{(1.2)m\,(2.5)T} = 1\ m/s$

4 c) $F_B = I\ell B$ - force on current due to mag. field

- this force opposes the motion (it's to the left)

need to apply force $F = -F_B$

$|F| = I\ell B \leftarrow I = \frac{v\ell B}{R}$

$\Rightarrow |F| = \frac{v\ell B\ell B}{R} = \frac{v\ell^2B^2}{R}$

$|F| = \frac{(2)(1.2)^2(2.5)^2}{(6)}$

$|F| = 3N$ (to the right)

2 b) Lenz's law:

- current in such a direction, that it creates $\vec{B}'$ inside the loop to oppose the change in the initial external mag. flux
- because I'm moving the rod to the right, the mag. flux in the loop is increasing into the ~~table~~ page ($\Phi_B = BA\cos\theta$) [I'm increasing A]

$\Rightarrow$ therefore my new $\vec{B}'$ must be out of the page, to counteract this change

$\Rightarrow$ by right-hand-rule: current must be counterclockwise

$\Rightarrow$ down through R.

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2. (10 pts) An AM news radio station broadcasts isotropically (equally in **all** directions) with an average total power of 4 kW. A receiving antenna 65 cm long is connected to the radio at your house, 4 km away from the station. (a)(2 pts) What is the intensity of the radio wave at the location of your house? (remember that intensity is power distributed over the total area) (b)(3 pts) What is the magnitude of the electric field (E_{max}) that is reaching your antenna? (c)(3 pts) What is the magnitude of the emf induced on the antenna by this electric field? (d)(2 pts) When you are listening to this radio station at home, by how much is the "instant news" they broadcast actually delayed by the time the radio waves reach your house? Is there a faster way to get the news to your house? (explain)
(NOTE: If you don't have an answer for a quantity you need in the next part, just leave it as a variable.)

$P = 4\ kW = 4000W$
$L = 65cm = 0.65\ m$
$r = 4\ km = 4000\ m$

2 a) $I = \frac{P}{A} = \frac{P}{4\pi r^2}$ ← the radio wave spreads in all directions (spherically), so by the time it gets to your house (4 km away) the total area the wave spreads over is $A = 4\pi r^2$

$I = \frac{4000\ W}{4\pi (4000)^2\ m^2}$

$I = \frac{1}{16\pi} \times 10^{-3} \frac{W}{m^2} = 2.0 \times 10^{-5} \frac{W}{m^2}$

3 b) $I = \frac{E_{max}^2}{2\mu_o c}$

$E_{max}^2 = 2\mu_o c I$

$E_{max} = \sqrt{\frac{2 \cdot 4\pi \times 10^{-7} \cdot 3\times 10^8}{16\pi} \times 10^{-3}}$

$E_{max} = \sqrt{\frac{3}{2} \times 10^{-2}}$

$E_{max} = \sqrt{\frac{3}{2}} \cdot 10^{-1} \frac{V}{m} = 0.122 \frac{V}{m}$

3 c) $\mathcal{E} = E_{max} \cdot L$

$\mathcal{E} = \sqrt{\frac{3}{2}} \cdot 10^{-1} \cdot 0.65$

$\mathcal{E} = 0.080\ V$

2 d) $\Delta t = \frac{r}{c}$ – time it takes the wave to get to your house

$\Delta t = \frac{4000m}{3 \times 10^8\ m/s}$

$\Delta t = \frac{4}{3} \times 10^{-5}\ s \approx 13\ \mu s$

this is THE FASTEST way to get the news

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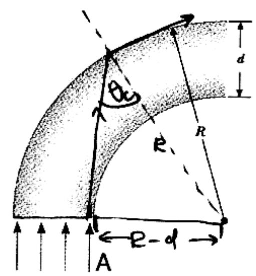
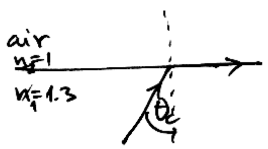
3. (10 pts) An optical fiber (shown below) has index of refraction n = 1.3 and diameter d = 2 mm, and it is surrounded by air. (a)(3 pts) For a light ray traveling inside this fiber, what is the maximum incident angle the ray can have at the fiber's boundary, before it is refracted out into the air? (b)(2 pts) Why do they say: "don't bend optical fiber cables"? (c)(5 pts) Calculate the smallest outer radius R permitted for a bend in the fiber if no light is to escape the fiber. (consider the ray labeled "A" in your calculation)



3 a)



– critical angle

$\sin\theta_c = \frac{n_2}{n_1} = \frac{1}{1.3}$

$\theta_c = \sin^{-1}\left(\frac{1}{1.3}\right) = 50.3°$

2 b) so that the signal doesn't escape from the fiber and so that you wouldn't break it! :)

5 c) $\sin\theta_c = \frac{R-d}{R}$ – from picture (for ray "A")

$\Rightarrow \frac{R-d}{R} = \frac{1}{1.3}$

$1 - \frac{d}{R} = \frac{1}{1.3}$

$\frac{d}{R} = 1 - \frac{1}{1.3}$

$R = \frac{d}{1-\frac{1}{1.3}}$

$R = \frac{2\text{ mm}}{\frac{1.3-1}{1.3}} = \frac{2.6}{0.3}$ mm

$R = 8.7$ mm

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4. (10 pts) A glass (n=1.5) converging thin lens is made with focal length of f=12cm. (a)(3 pts) If I place a small object on the table and place this lens 6cm above the object and look at the object through the lens, where exactly will the image of the object be (with respect to the lens)? (b)(2 pts) Will it be larger or smaller, and by what factor? (c)(1 pts) Is the image real or virtual? (d)(4 pts) Draw the light ray diagram of how the image of the object is formed in this case.

3 a) $p = 6$ cm
$f = 12$ cm

$\frac{1}{f} = \frac{1}{p} - \frac{1}{q}$

$q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{12} - \frac{1}{6}\right)^{-1} = \left(-\frac{1}{12}\right)^{-1}$

$q = -12$ cm ← same side as object (i.e. under the table)

2 b) $M = -\frac{q}{p} = -\frac{-12}{6}$

$M = +2$ - larger (twice)

1 c) image is virtual

4 d)