Ph. D. Qualifying Exam Questions in Electrophysics

Spring 2017

Force per unit length is
2 Mu_o / (15 pi) Nt/m in negative y-direction

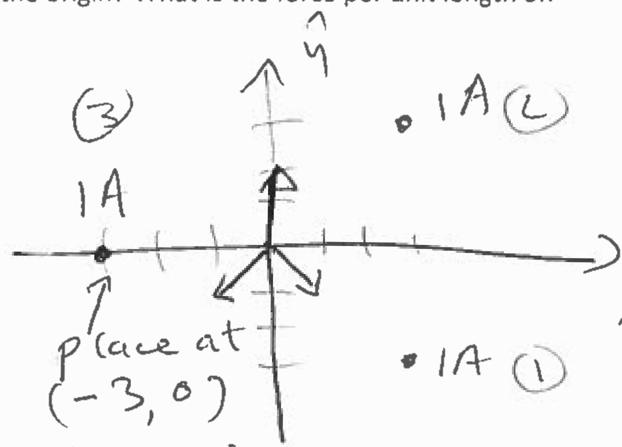
1. Consider three infinite line currents, all with one amp flowing in the +z direction. One current passes through x=3 & y=3. Another passes through x=3 & y=-3. Where can you place the third line current so that the magnetic field is zero at the origin? What is the force per unit length on that third line? (6 points)

At origin

$$B_{(1)} = \frac{\mu_0}{2\pi(3\sqrt{2})}\left(-\frac{\hat{x}}{\sqrt{2}} - \frac{\hat{y}}{\sqrt{2}}\right)$$

$$B_{(2)} = \frac{\mu_0}{2\pi(3\sqrt{2})}\left(\frac{\hat{x}}{\sqrt{2}} - \frac{\hat{y}}{\sqrt{2}}\right)$$

Answer $\Rightarrow$ $$B_{(3)} = \frac{\mu_0}{2\pi(3)}\hat{y}$$



so $B_{(1)} + B_{(2)} + B_{(3)} = 0$ at origin

2. An infinite plane wave traveling in free space in the –z direction has an electric field in the +x direction with an amplitude of 10 V/m. Write the time-averaged Poynting vector for this wave. (3 points)

$$\langle \vec{S} \rangle = \frac{1}{2}\vec{E} \times \vec{H}^*$$

$$\vec{E} = 10e^{jkz}\hat{x}\left(\frac{V}{m}\right);\quad \vec{H} = \frac{10}{377}e^{jkz}(-\hat{y})\left(\frac{A}{m}\right)$$

$$\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 377$$

$$\langle \vec{S} \rangle = \frac{50}{377}e^{jkz}e^{-jkz}\,\hat{x}\times(-\hat{y})\ \frac{W}{m}$$

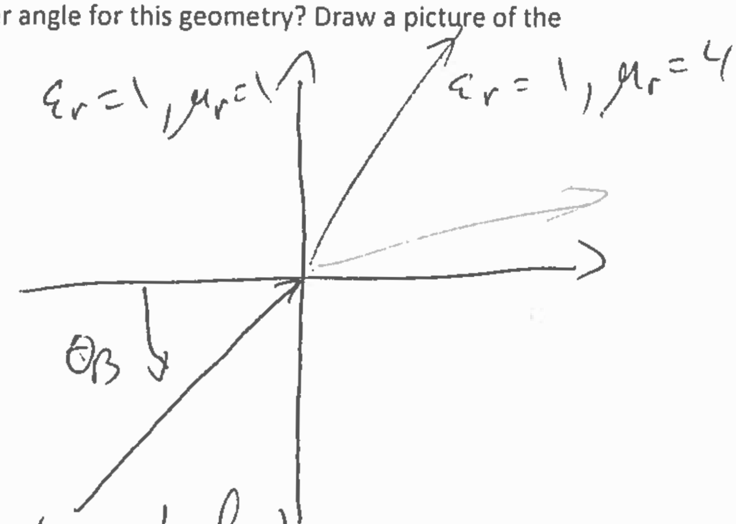
$$\boxed{\langle \vec{S} \rangle = (-\hat{z})\frac{50}{377}\left(\frac{W}{m^2}\right)}$$

3. Space is divided in two regions with a boundary at z=0. Region 1 (z<0) is vacuum and Region 2 (z>0) has ε_r = 1 and μ_r = 4. What is the Brewster angle for this geometry? Draw a picture of the scenario to get full points. (3 points)

$$\Theta_B = \tan^{-1}\left(\frac{n_2}{n_1}\right)$$

$$n_{1,2} = \sqrt{\mu_{1,2}\varepsilon_{1,2}}$$

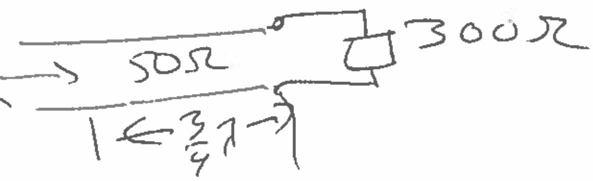
$$\text{so, } \Theta_B = \tan^{-1}(2) = 63.43°$$



Answer via calculator

4. A transmission line with a 50 Ohm characteristic impedance is terminated with a 300 Ohm load. What is the input impedance if the line is ¾ of a wavelength in length? (4 points)

$$\beta = \frac{2\pi}{\lambda} \quad \beta l = \left(\frac{2\pi}{\lambda}\right)\left(\frac{3}{4}\lambda\right) = \frac{3}{2}\pi$$

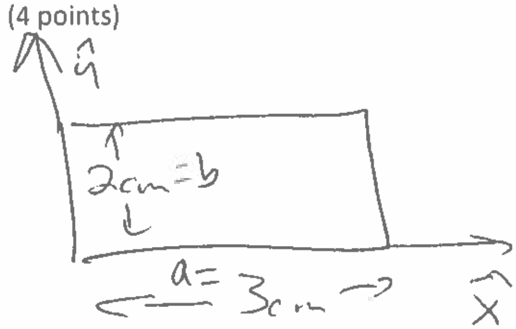


$$Z_{in} = Z_0 \left[\frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}\right]$$

$$= 50 \left[\frac{300 + j50 \tan(3\pi/2)}{50 + j300 \tan(3\pi/2)}\right] \rightarrow \frac{(50)^2}{300} = \frac{50}{6} = 8.33\,\Omega$$

5. A rectangular waveguide has a width of 3 cm and a height or 2 cm. What are the four lowest distinct cutoff frequencies if the waveguide is filled with dry air? (4 points)

$$f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$



m	n	$f_{c\,TE_{mn}}$	
1	0	5 GHz ($c/6$)	#1
0	1	7.5 GHz ($c/4$)	#2
2	0	10 GHz ($c/3$)	#4
1	1	9.01 GHz ($c\frac{\sqrt{13}}{12}$)	#3