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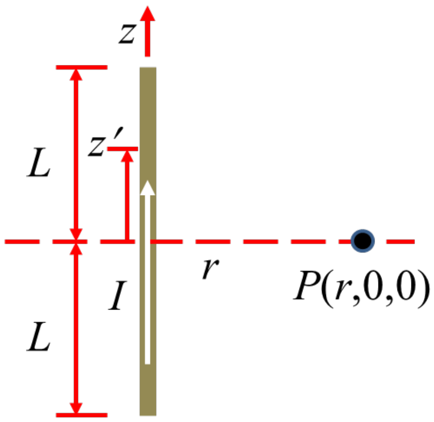
*EE214000 Electromagnetics, Fall 2020*

Your name: ________________ ID: _________________ Dec. 14th, 2020

EE214000 Electromagnetics, Fall, 2020
Quiz #14-1, Open books, notes (25 points), due 11 pm, Wednesday, Dec. 16th, 2020
(submission through iLMS)

Late submission won't be accepted!

1. Explain why you can't use the Ampere's law $\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I$ to calculate the magnetic flux density at $P(r,\phi,0)$? Of course, you could try it to get a different answer but the answer is wrong (why?). (5 points)




Ans: To answer it, one has to go back to take a look at how we came up with the surface integration in the Ampere's law, or

$$\int_s \nabla\times\vec{B}\cdot d\vec{s} = \oint_C \vec{B}\cdot d\vec{l} = \mu_0\int_s \vec{J}\cdot d\vec{s} = \mu_0 I\ .$$

To use it, the surface can be a flat surface bounced by C or a curved one bounded by C. Either choice has to give the same answer when calculating the circulation of the magnetic field. If one chooses a curved surface that excludes the current terminated at z′= ±L, the calculation of the magnetic circulation will end up with zero, which conflicts with the calculation for a surface intercepting the current element. Therefore, we cannot use the Ampere's law to do the calculation in this case.

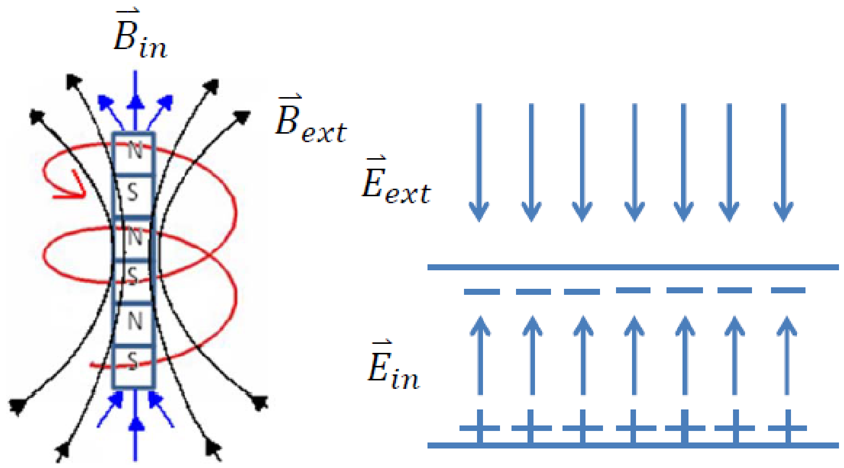
2. Step by step, write down the derivation of the far-zone magnetic flux density for a magnetic dipole. (6 points)

3. Explain why the magnetic flux density $B$ can be greatly increased nearby or inside a ferromagnetic material subject to an external current (6 points); whereas the electric field intensity $E$ is usually reduced inside a dielectric material given an external charge. (3 points) Graphic illustrations along with text explanations are encouraged

Ans: Refer to the plot on the right. An external current generates an external magnetic field that aligns the magnetic dipoles in a ferromagnetic material. Since the magnetic field enters *S* pole and exits *N* pole of the aligned dipoles, the external field and the dipole field are aligned along the same direction or

$$\vec{B}_{net} = \vec{B}_{ext} + \vec{B}_{in}.$$

The net effect is an increase of the *B* field.




$\vec{B}_{net}$=$\vec{B}_{ext}$+$\vec{B}_{in}$ $\vec{E}_{net}$= $\vec{E}_{ext}$- $\vec{E}_{in}$

Refer to the top right figure. The external external field $E_{ext}$ will also align the electric dipoles in a dielectric material in a way that the induced electric field in the material is along the opposite direction of the external field. As a result, the net field in the material is reduced according to $\vec{E}_{net} = \vec{E}_{ext} - \vec{E}_{in}$.

4. In electrostatics, you learned that the electric field lines entering a perfect conductor along the surface normal of the conductor. How does the magnetic field lines in vacuum enter a non-conducting magnetic material with $\mu_r \to \infty$? (5 points)

Ans: Refer to Page 24 of the slides, the relationship between the incident and transmission angles at a boundary is

$$\tan\theta_2 = \frac{H_{2t}}{H_{2n}} = \frac{\mu_2}{\mu_1}\tan\theta_1 = \mu_r \tan\theta_1 .$$

For any finite value of $\theta_2$, $\tan\theta_1 = \frac{\tan\theta_2}{\mu_r} \Rightarrow \theta_1 \xrightarrow[\mu_r \to \infty]{} 0$. Therefore, the magnetic field lines enter a "perfect" magnetic material along the surface normal on the boundary.

You are welcome to present a better insight for such a phenomenon.