Prof. Yen-Chieh Huang
Dept of Electrical Engineering
National Tsing-Hua University
office: Delta 856
ext: 62340
email:ychuang@ee.nthu.edu.tw
EE214000 Electromagnetics, Fall 2020

Your name: 王昱淳 ID: 107060013 Dec. 21st, 2020

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Quiz #15-1, Open books, notes (18 points), due 11 pm, Wednesday, Dec. 23rd, 2020
(submission through iLMS)

Late submission won't be accepted!

1. What is the reluctance of a piece of magnetic material of permeability μ, length l, and a constant cross section area S? Explain why the dependence of a reluctance is proportional to l and yet inversely proportional to μ and S. Don't just write a formula to show the dependences. Explain it from physical points of view. (5 points)

1. We know magnetic reluctance $R = \frac{l}{\mu S}$

Observe from physical points of view:

① If l increases, magnetic flux will suffer from more obstacles. $\Rightarrow R\uparrow$

② If μ increases, magnetic flux can response better. $\Rightarrow R\downarrow$

③ If S increases, there will be more magnetic flux. $\Rightarrow R\downarrow$

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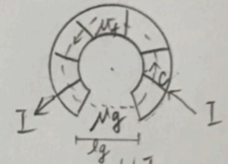
2. A thin ($r_0 >> a$ n Example 6-10) toroid is filled with a ferromagnetic core ($\mu_r >> 1$) and excited with mmf *NI*. There's a small air gap cut into the ferromagnetic core. How could the *B* in the air gap (having $\mu_r = 1$) be the same as the *B* in the ferromagnetic material (having $\mu_r >> 1$)? If the air gap is not "small", but is about, for instance, 1/3 of the toroid, would *B* remain the same over the whole axis of the toroid? (5 points)

$\oint_C \vec{H} \cdot d\vec{l} = NI \Rightarrow H_g l_g + H_f l_f = NI$

(g & f denote quantities in the gap and ferrite region.)



B.C. $\Rightarrow B_{1n} = B_{2n} \Rightarrow \mu_g H_g = \mu_f H_f \Rightarrow B_g = B_f = \dfrac{NI}{\dfrac{l_f}{\mu_f} + \dfrac{l_g}{\mu_g}}$

For the air gap is 1/3 of the toroid, B will remain the same on the whole axis of the toroid due to the contunity of B. Since B is continuous along the axis, there will be no leak of B.
The density might be a little different different. But, the whole B always keeps the same.

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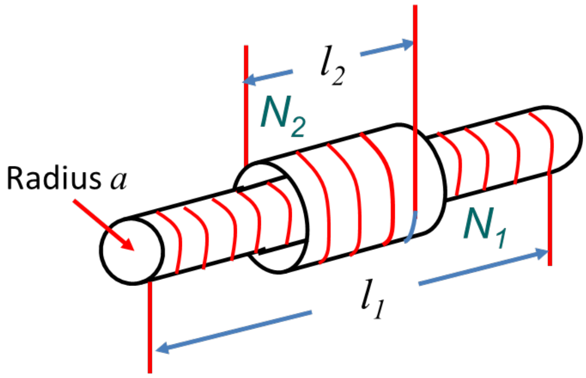
3. The textbook asserts that the mutual inductance $L_{12} = L_{21}$, but the following case gives you an answer of $L_{12} = \frac{\Lambda_{12}}{I_1} = \pi a^2 \frac{\mu_0 N_1 N_2}{l_1}$, which does not lead to $L_{12} = L_{21}$ when you swap the indices 1 and 2 in the expression. What has gone wrong with the calculation or the formula? (5 points)



$$L_{12} = \frac{\Lambda_{12}}{I_1} = \frac{\mu_0 N_1 N_2}{l_1} \pi a^2 \quad \text{—— ①}$$

$$L_{21} = \frac{\Lambda_{21}}{I_2} = \frac{\mu_0 N_1 N_2}{l_2} \pi a^2 \quad \text{—— ②}$$

If we switch all the indices "12" in ① into "21" in ②, the answer might be wrong since the flux won't cross. The magnetic will be continuous over l_1 instead of l_2, so we can't change all indices "12" into "21".

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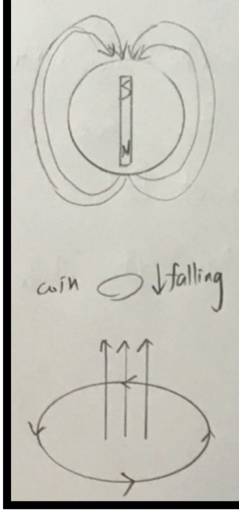
4. You fly over the north pole of the earth and drop a coin with its surface normal along the polar axis. Which direction, clockwise or counterclockwise, would the earth magnet induce a current on it when you look down the coin? (3 points)



At north pole, the magnetic flux will go into the ground. By Lenz's Law, there will be a B induced from the ground. So, the induced current is counter-clockwise.