Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.685 Electric Machines

Problem Set 1

Issued September 4, 2013
Due September 12, 2013

Reading Assignment: Course Notes, Chapters 1 and 2

Note: Ordinarily, homework is issued on Monday and due the following Wednesday (9 days later). Because of the start of term, this one is due in a little shorter time.

Problem 1: This is a kind of 'made up' problem designed to be tractible. A circular coil is wound on the inside of a cylindrical core as shown in Figure 1. The coil has radial thickness w with outer radius R and axial length h. Assume that the core has infinite permeability. The coil has N turns.

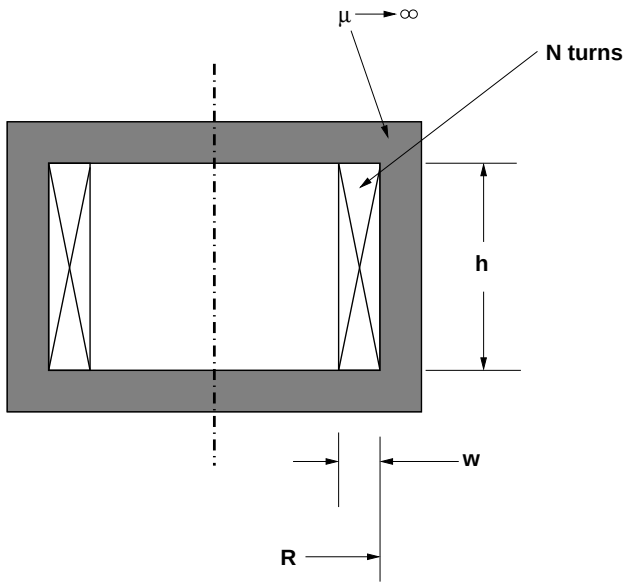

Figure 1: Coil in a Core

1. Calculate the inductance of this coil, assuming that the radial thickness w is very small.
2. Now, calculate the inductance of the coil, abandoning the assumption that the radial thickness is not negligible. You should be able to show that your answer approaches that of the first part as $w \to 0$

Problem 2: In the same setup as for Problem 1, a conductive cylinder is added. Assume the cylinder has *surface* conductivity $\sigma_c = \sigma t_c$, where σ is the conductivity of the cyliner material and t is its thickness, which you may asssume to be small.

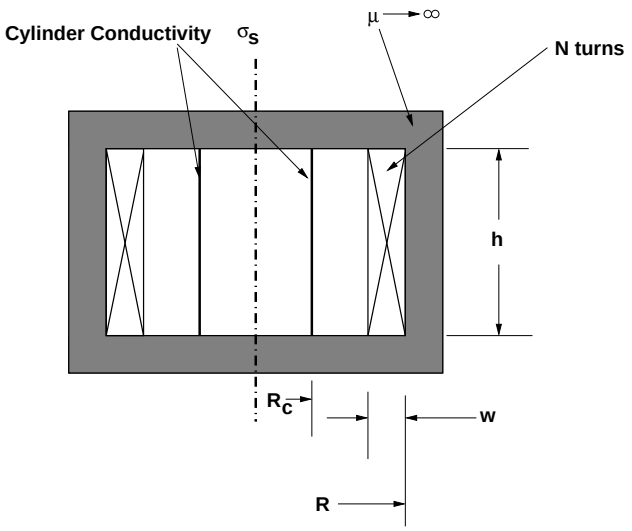

Figure 2: Conductive cylinder added

1. Find the magnetic field along the axis of the cylinder if the coil is driven by a steady (DC) current I_0. (Ignore any transients)
2. Now, find the magnetic field along the axis if the coil is driven by a *step* of current of magnitude I_0.
3. To give this one some numbers, assume that coil has 1,000 turns, the cylinder radius is $R_c = 10$ cm, the coil outer radius is $R = 20$ cm and the height is $h = 10$ cm. Assume, for the sake of nice numbers, that the cylinder thickness is 1 mm and its conductivity is 6×10^7 S/m. The coil is driven by current as shown in Figure 3. Find the magnetic field inside the cylinder.
4. For the same current drive as in the previous part, find coil voltage. You will need to estimate coil resistance and inductance. Assume that the coil thickness $w = 1$ cm, that its *winding factor* (the ratio of conductor area to total area) is $\lambda_w = 0.5$ and its conductivity is the same as that of the shell.

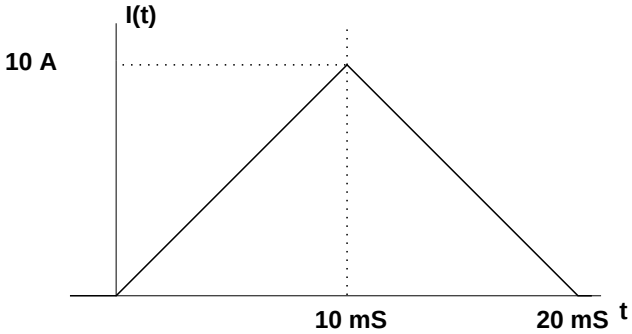

Figure 3: Coil current

Problem 4: The objective of this problem is to do a rough sizing of the rotor of an electric motor. the machine in question is to be rated at 10 kilowatts at a speed of 10,000 RPM. Assuming that the machine develops a shear stress of 10 kPa.

1. What is the rotor volume of the machine?
2. Assuming that your rotor tip speed is limited to 230 meters per second, what would be the diameter and length of the rotor?

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