ELEC 344
3rd Tutorial

Review Hysteresis & Eddy current
& Assignment #1

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Problem 1.1)

The long solenoid coil shown in Fig. P1.1 has 250 turns. As its length is much greater than its diameter, the field inside the coil may be considered uniform. Neglect the field outside.

a) Determine the field intensity (H) and flux density (B) inside the solenoid (i=100A)

b) Determine the inductance of the solenoid coil.

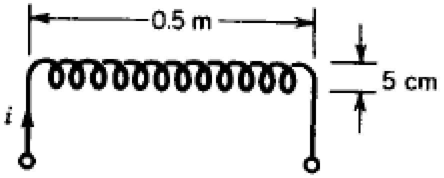


FIGURE P1.1

Problem 1.2)

In the magnetic system of Fig P1.2 two sides are thicker than the other two sides. The depth of the core is 10 cm, the relative permeability of the core is 2000, the number of turns is 300, and the current flowing through the coil is 1 A.

a) Determine the flux in the core

b) Determine the flux densities in the parts of the core

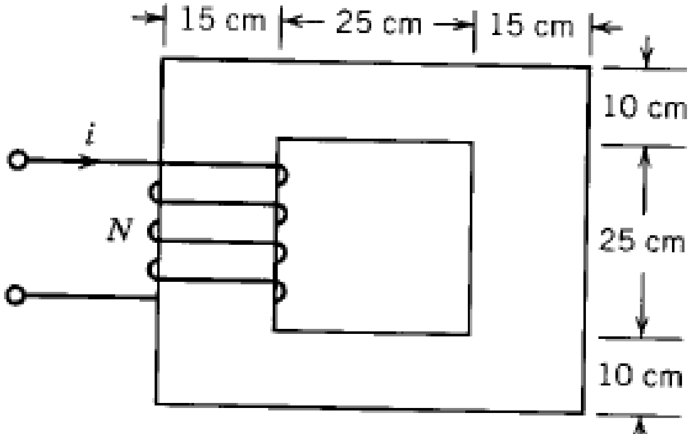


FIGURE P1.2

Problem 1.3)

For the magnetic system of Problem 1.2, find the current I in the coil to produce a flux 0.012 [Wb].

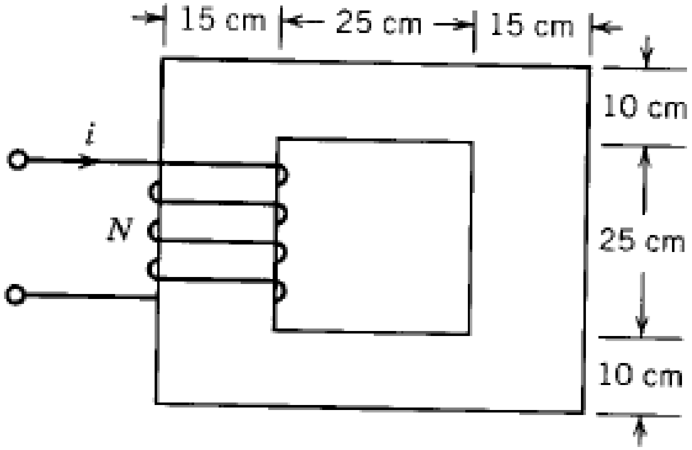


FIGURE P1.2

Problem 1.7)

A two-pole synchronous machine, as shown in Fig. P1.7, has the following dimensions:

Each air gap length, $l_g = 2.5$mm

Cross-sectional area of pole face, $A_g = 500$ cm^2

N = 500 turns

I = 5 A

Core permeability = infinity

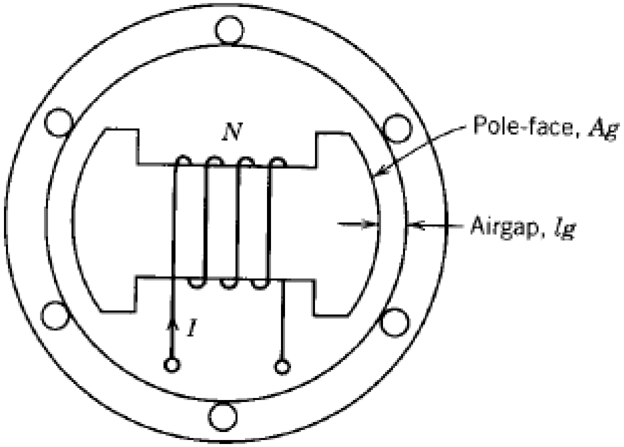


FIGURE P1.7

a) Draw the magnetic equivalent circuit

b) Find the flux density in the air gap.

Problem 1.8)

The electromagnet shown in Fig. P1.8 can be used to lift a length of steel strip. The coil has 500 turns and can carry a current of 20 amps without overheating. The magnetic material has negligible reluctance at flux densities up to 1.4 tesla. Determine the maximum air gap for which a flux density of 1.4 tesla can be established with a coil current of 20 amps. Neglect magnetic leakage and fringing of flux at the air gap.

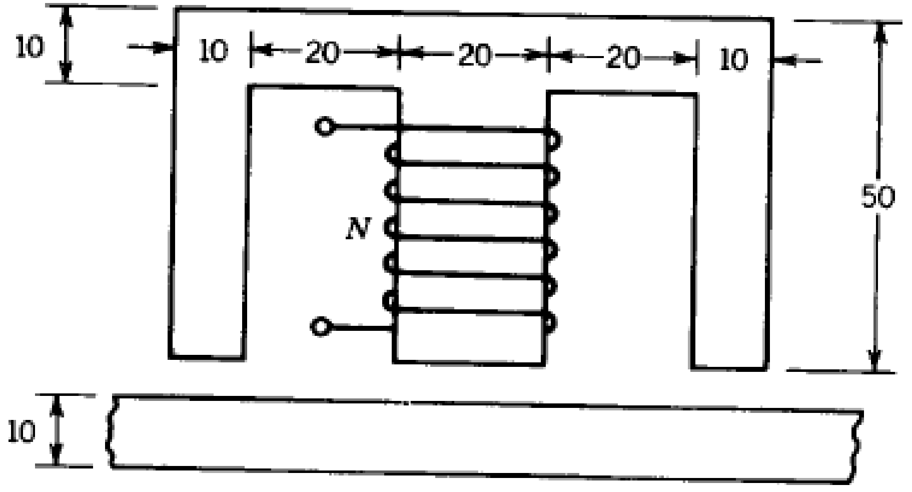


FIGURE P1.8

Hysteresis Loss

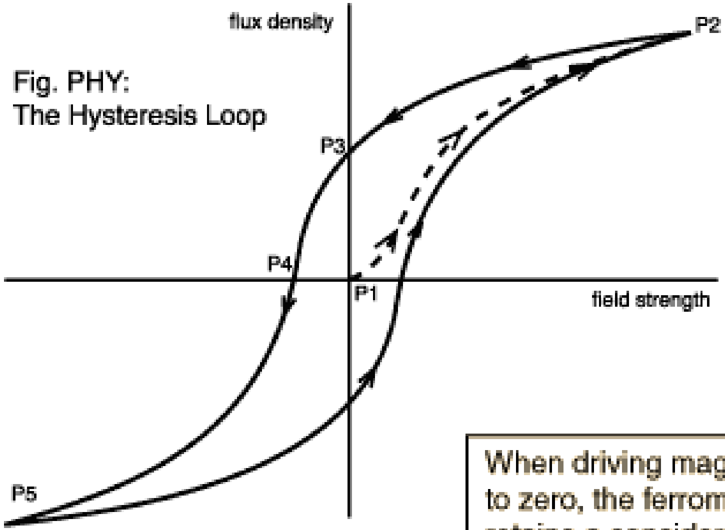
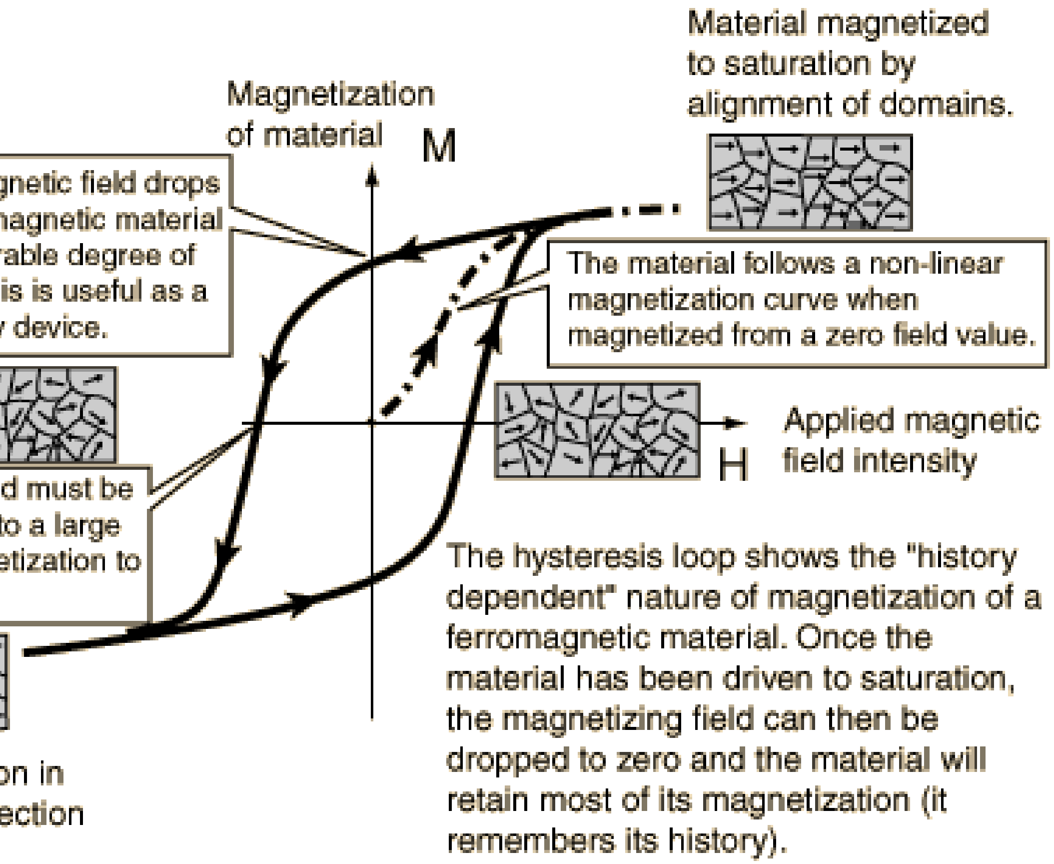


Fig. PHY:
The Hysteresis Loop



Material magnetized to saturation by alignment of domains.

When driving magnetic field drops to zero, the ferromagnetic material retains a considerable degree of magnetization. This is useful as a magnetic memory device.

The material follows a non-linear magnetization curve when magnetized from a zero field value.

The driving magnetic field must be reversed and increased to a large value to drive the magnetization to zero again.

Toward saturation in the opposite direction

The hysteresis loop shows the "history dependent" nature of magnetization of a ferromagnetic material. Once the material has been driven to saturation, the magnetizing field can then be dropped to zero and the material will retain most of its magnetization (it remembers its history).

Hysteresis Loss – Point by Point Explanation

a) ***P1 to P2***: The field strength is increased in the positive direction and the flux begins to grow along the dotted path until we reach P2. This is called the initial magnetization curve

b) ***P2 to P3***: If the field strength is now relaxed then some curious behavior occurs. Instead of retracing the initial magnetization curve the flux falls more slowly. In fact, even when the applied field is returned to zero there will still be a remaining (*remnant or remanent*) flux density at P3. It is this phenomenon which makes permanent magnets possible.

c) ***P3 to P4***: To force the flux to go back to zero we have to reverse the applied field (P4). The field strength here is called the *coercivity*.

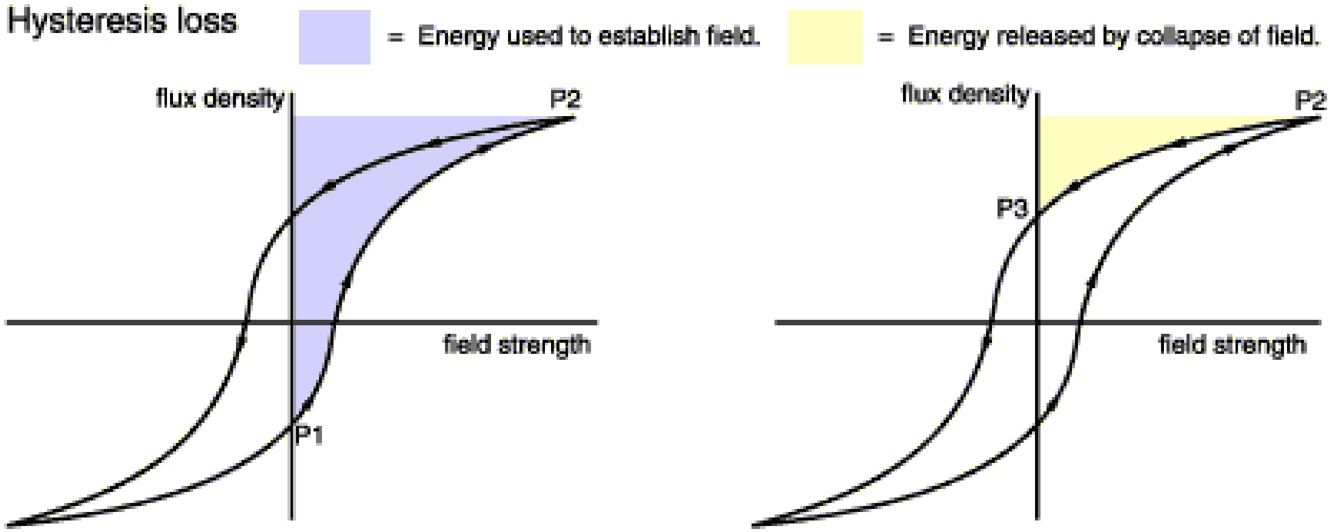
d) ***P4 to P5***: We can then continue reversing the field to get to P5, and so on round this type of magnetization curve called a *hysteresis loop*.

Hysteresis Loss – in terms of Power Loss

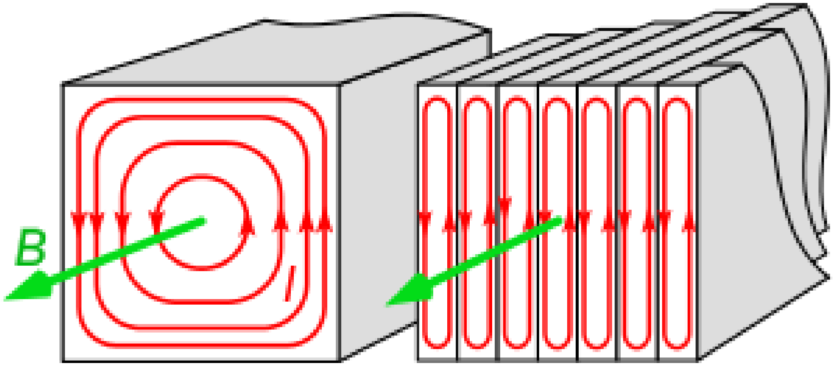
Q: What is the significance of this from the point of power losses?

A: It is that we have had to expend energy in order to set up the remnant flux. To show this more clearly we'll look at separate figures below. The area (shown shaded) between the B-H curve and the B axis represents the work done (per unit volume of material).

You can see that the energy required to 'pump up' the core by moving from P1 to P2 is more than that which it returns when going from P2 to P3. This is evocatively termed *inelastic* behavior.



Eddy Current Loss – and Lamination



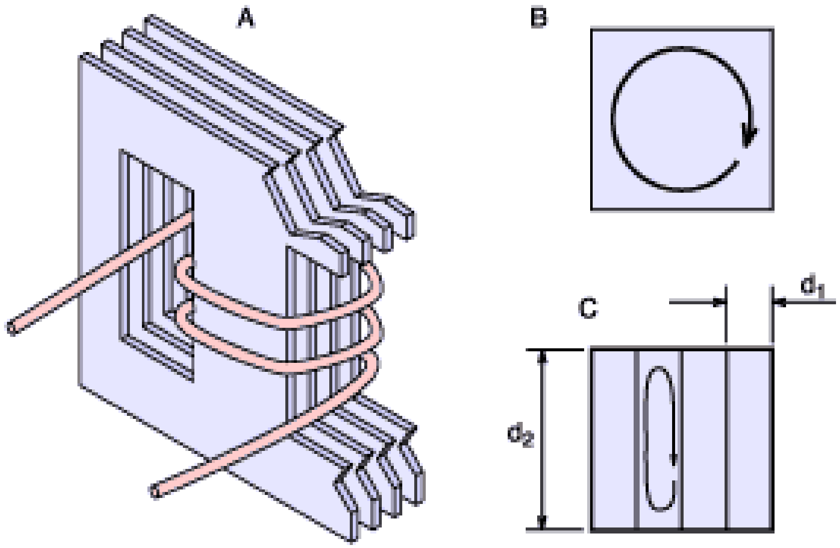


Figure PLM: Lamination

Eddy current losses occur whenever the core material is electrically conductive. Most ferromagnetic materials contain iron: a metal that has fairly low resistivity (roughly 10^{-7} Ω m).

The problem is intuitively obvious if you consider that the magnetic field is contained within a 'circuit' or loop formed by the periphery of the core in the same way as it is contained within a turn on the windings. Around that periphery a current will be induced in the same way as it is in an ordinary turn which is shorted at its ends.

Eddy Current Loss – Power loss

Under certain assumptions (uniform material, uniform magnetic field, no skin effect, etc.) the power lost due to eddy currents per unit mass for a thin sheet or wire can be calculated from the following equation:

$$P = \frac{\pi^2 B_p^2 d^2 f^2}{6k\rho D}$$

where
P is the power lost per unit mass (W/kg),
B_p is the peak magnetic field (T),
d is the thickness of the sheet or diameter of the wire (m),
f is the frequency (Hz),
k is a constant equal to 1 for a thin sheet and 2 for a thin wire,
ρ is the resistivity of the material (Ω m), and
D is the density of the material (kg/m^3).

Eddy Current Loss *– How to reduce this loss*

$$P = \frac{\pi^2 B_p^2 d^2 f^2}{6k\rho D}$$

From the previous equation, we can reduce the eddy current loss

by reducing

- B_p, d, f

by increasing

- ρ, D

Then, what's the most practical way to reduce it?

"Yes, the Lamination"