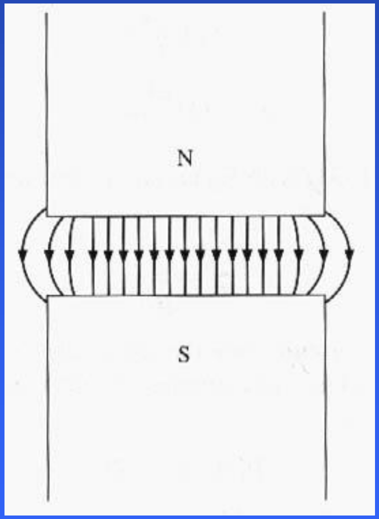
3. The magnetic field

Calculations of magnetic flux are **always** approximations!

$$F = \phi R$$

1. We assume that all flux is confined within the magnetic core but a leakage flux exists outside the core since permeability of air is non-zero!
2. A mean path length and cross-sectional area are assumed…
3. In ferromagnetic materials, the permeability varies with the flux.
4. In air gaps, the cross-sectional area is bigger due to the fringing effect.

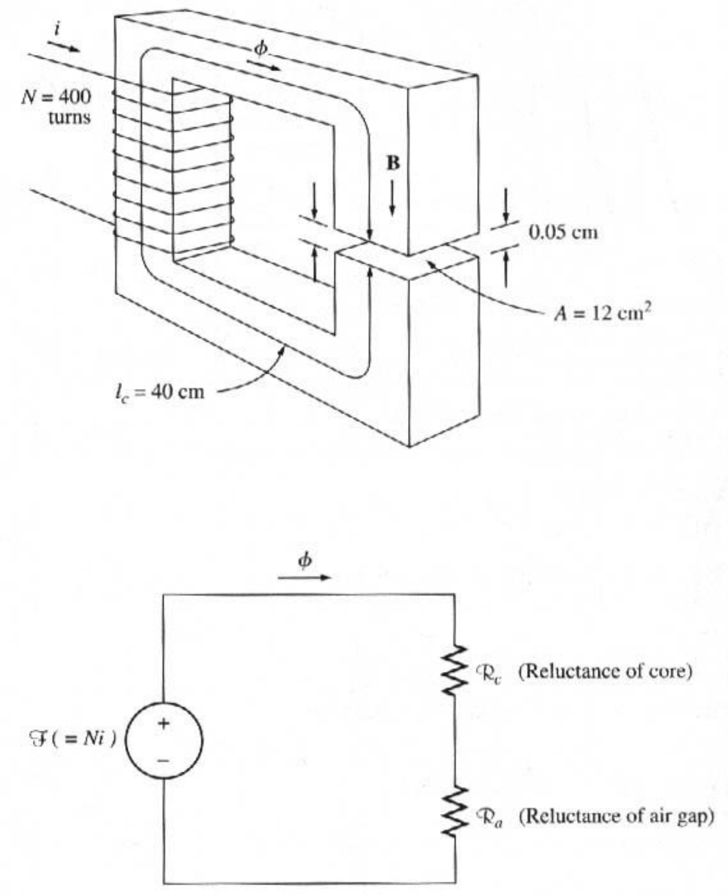


3. The magnetic field

Example 1: A ferromagnetic core with a mean path length of 40 cm, an air gap of 0.05 cm, a cross-section 12 cm^2, and μ_r=4000 has a coil of wire with 400 turns. Assume that fringing in the air gap increases the cross-sectional area of the gap by 5%, find (a) the total reluctance of the system (core and gap), (b) the current required to produce a flux density of 0.5 T in the gap.

$$F = \phi R$$

The equivalent circuit



3. The magnetic field

(a) The reluctance of the core:

$$\mathcal{R}_c = \frac{l_c}{\mu A_c} = \frac{l_c}{\mu_0 \mu_r A_c} = \frac{0.4}{4000 \cdot 4\pi \cdot 10^{-7} \cdot 0.0012} = 66\,300\ A-turns/Wb$$

Since the effective area of the air gap is 1.05 x 12 = 12.6 cm^2, its reluctance:

$$\mathcal{R}_a = \frac{l_a}{\mu_0 A_a} = \frac{0.0005}{4\pi \cdot 10^{-7} \cdot 0.00126} = 316\,000\ A-turns/Wb$$

The total reluctance:

$$\mathcal{R}_{eq} = \mathcal{R}_c + \mathcal{R}_a = 66300 + 316000 = 382\,300\ \ A-turns/Wb$$

The air gap contribute most of the reluctance!

3. The magnetic field

(b) The mmf:

$$\mathcal{F} = \phi\mathcal{R} = Ni = BA\mathcal{R}$$

Therefore:

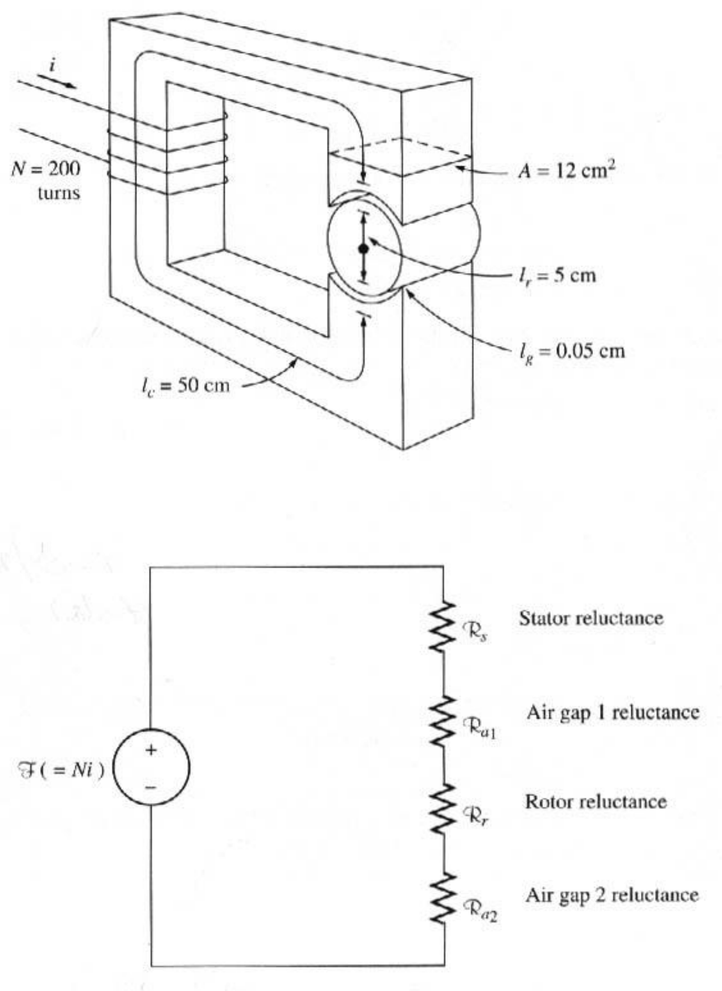
$$i = \frac{BA\mathcal{R}}{N} = \frac{0.5 \cdot 0.00126 \cdot 383200}{400} = 0.602\ A$$

Since the air gap flux was required, the effective area of the gap was used.

3. The magnetic field

Example 2: In a simplified rotor and stator motor, the mean path length of the stator is 50 cm, its cross-sectional area is 12 cm^2, and μ_r = 2000. The mean path length of the rotor is 5 cm and its cross-sectional area is also 12 cm^2, and μ_r = 2000. Each air gap is 0.05 cm wide, and the cross-section of each gap (including fringing) is 14 cm^2. The coil has 200 turns of wire. If the current in the wire is 1A, what will the resulting flux density in the air gaps be?

The equivalent circuit



3. The magnetic field

The reluctance of the stator is:

$$\mathcal{R}_s = \frac{l_s}{\mu_r \mu_0 A_s} = \frac{0.5}{2000 \cdot 4\pi \cdot 10^{-7} \cdot 0.0012} = 166000 \;\; A-turns/Wb$$

The reluctance of the rotor is:

$$\mathcal{R}_r = \frac{l_r}{\mu_r \mu_0 A_r} = \frac{0.05}{2000 \cdot 4\pi \cdot 10^{-7} \cdot 0.0012} = 16600 \;\; A-turns/Wb$$

The reluctance of each gap is:

$$\mathcal{R}_a = \frac{l_a}{\mu_0 A_a} = \frac{0.0005}{4\pi \cdot 10^{-7} \cdot 0.0014} = 284000 \;\; A-turns/Wb$$

The total reluctance is:

$$\mathcal{R}_{eq} = \mathcal{R}_s + \mathcal{R}_{a1} + \mathcal{R}_r + \mathcal{R}_{a2} = 751000 \;\; A-turns/Wb$$

3. The magnetic field

The net mmf is:

$$\mathcal{F} = Ni$$

The magnetic flux in the core is:

$$\phi = \frac{\mathcal{F}}{\mathcal{R}} = \frac{Ni}{\mathcal{R}}$$

Finally, the magnetic flux density in the gap is:

$$B = \frac{\phi}{A} = \frac{Ni}{\mathcal{R}A} = \frac{200 \cdot 1}{751000 \cdot 0.0014} = 0.19\,T$$