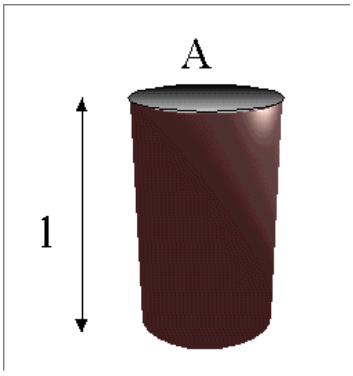
4. Magnetic circuits

- 4.1 Analogue of electric circuit.
- 4.2 Relationship to inductance.
- 4.3 Terminology
- 4.4 Magnetic materials

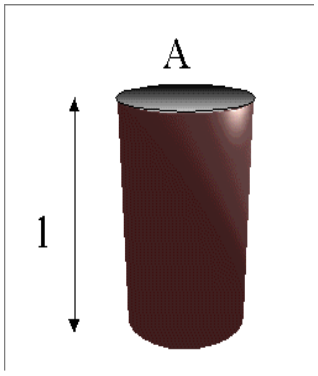
4.1 Electric circuit.

- Field equation in a resistor:
  - $J = \sigma E$
  - $I/A = \sigma V/l$
  - $I\, l/(\sigma A) = V$
  - $IR = V$
- Circuit equation
- Assume E, σ, J, A uniform



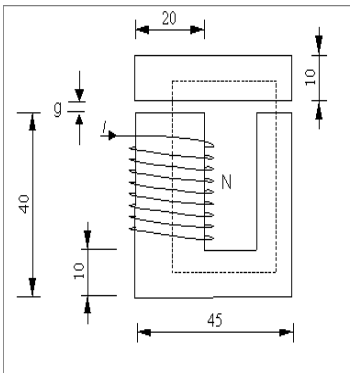
Magnetic circuit.

- Field equation in a iron:
  - $B = \mu H$
  - $\Phi/A = \mu \mathcal{F}/l$
  - $\Phi\, l/(\mu A) = \mathcal{F}$
  - $\Phi \mathcal{R} = \mathcal{F}$
    - $\mathcal{R} = l/(\mu A)$
- Circuit equation
- Assume B, μ, H, A uniform



Example

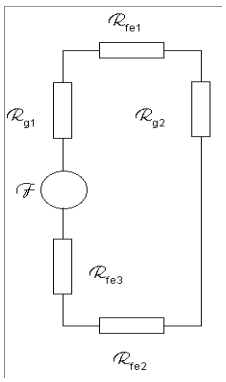
- Given:
  - N= 1000 turns,
  - I= 0.5 A,
  - g= 1.0mm
  - thickness=10mm,
  - μ_r =100 for core
- Determine the flux flowing in the airgaps.
- Determine the inductance of the coil.



Answer

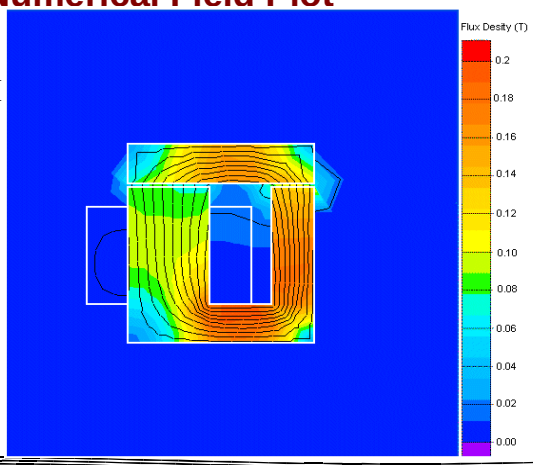
- $\Phi = \mathcal{F}/\mathcal{R}$
- $\mathcal{F}$=NI=500
- $\mathcal{R}=\mathcal{R}_{g1}+\mathcal{R}_{g2}+\mathcal{R}_{fe1}+\mathcal{R}_{fe2}+\mathcal{R}_{fe3}$
- $$\mathcal{R}=10^3\frac{1}{(\mu_0 20\cdot 10)}+\frac{1}{(\mu_0 10\cdot 10)}+\frac{(5+30+5)}{(\mu_r\mu_0 10\cdot 10)}+\frac{(35+30)}{(\mu_r\mu_0 10\cdot 10)}+\frac{35}{(\mu_r\mu_0 20\cdot 10)}=26.2\cdot 10^6$$

  Φ= 19.0 μWb; B= 0.19T (10x10)
- L=NΦ/I = 19.0 m/0.5 = 38 mH



Numerical Field Plot

- Using FEM

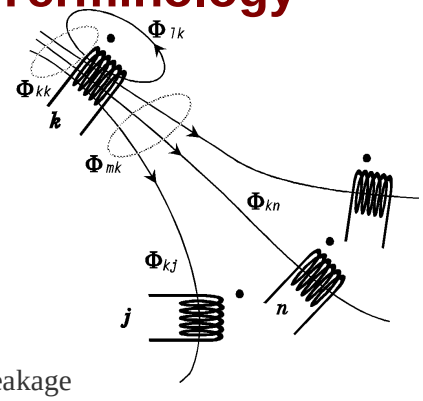


4.2 Relationship to inductance.

- $L=N\Phi/I$
  - $\Phi = \mathcal{F}/\mathcal{R} = NI/\mathcal{R}$
- $L = N^2/\mathcal{R}$
- Check Example:
  - $L = 1000^2/ (26.2\ 10^6) =$

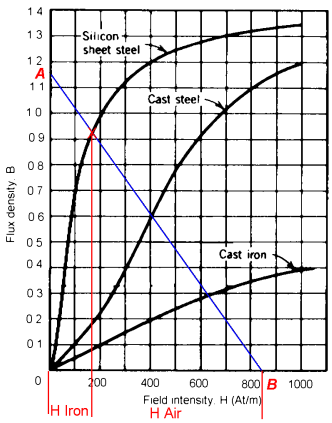
4.3 Terminology

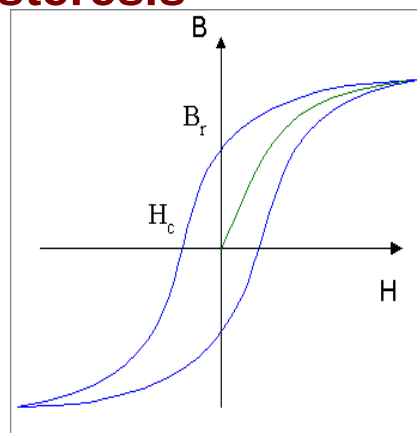
- Flux:
  - Self,
  - mutual,
  - leakage,
- Fringing
- Inductance:
  - Self, mutual, leakage



4.4 Magnetic materials

- Ferro-magnetic materials are non linear.
- __ is linear operating line of rest of cct.
- A is where B if only air. $\mu_r = 0$.
- B is total H available for iron. $\mu_r = \infty$
- X is operating point.



Hysteresis

- AC excitation.
- Produces loss
- Eddy currents also produce loss