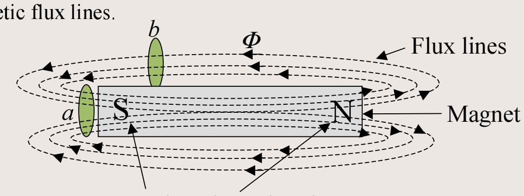
Magnetic Circuits

•Transformers, Motors, Generators, Computer and T.V. all employ magnetic effects to perform variety of important tasks.

•In the region surrounding a permanent magnet there exists a magnetic field, which can be represented by magnetic flux lines.



Areas *a* and *b* are the same but the flux density in area *a* is twice that in area *b*.

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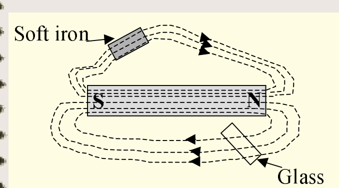
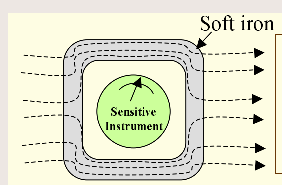
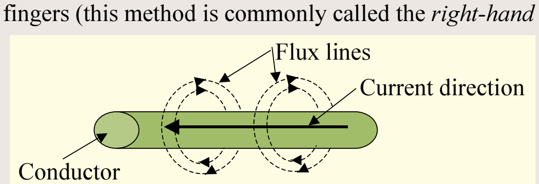
•If a magnetic material, such as soft iron, is placed in the flux path, the flux lines will pass through the soft iron rather than the surrounding air because flux lines pass with grate ease through the magnetic materials than through air.





Shielding of sensitive electrical elements and instruments that can be affected by stray magnetic fields.

- A magnetic field is present around every wire that carries an electric current.
- The direction of the magnetic flux lines can be found simply by placing the thumb of the right hand in the current direction and noting the direction of the other fingers (this method is commonly called the *right-hand rule*).



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Flux Density

It is the number of flux lines per unit area.

$$B = \frac{\Phi}{A}$$

B= Flux density (Teslas, T)
A= Cross-sectional area (m^2)
ϕ = Magnetic Flux (Webers)

Permeability

It is a measure of the ease with which magnetic flux line can be established in the material. Materials in which flux lines can easily be set up are said to be *magnetic* and to have *high permeability.*

The permeability of free space is $\mu_o = 4\pi \times 10^{-7}$

Relative permeability $$\mu_r = \frac{\mu}{\mu_o}$$

For ferromagnetic materials, $\mu_r \geq 100$, and for non magnetic materials, $\mu_r \geq 1$

- Materials with very high permeability are referred to as *ferromagnetic*.

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Reluctance

It is the opposition to the setting up of magnetic flux lines in the materials.

$$\Re = \frac{l}{\mu A}$$

- Obviously, materials with high permeability, such as ferromagnetic materials, have very small reluctances and will result in increased measure of flux through the core.

Magnetomotive Force

The mmf per unit length is called magnetizing force *H:*

$$F = NI = Hl = \Phi\Re$$

Magnetizing Force

$$H = \frac{F}{l} = \frac{NI}{l} \quad (At/m)$$
$$B = \mu H \quad (wb/m^2)$$

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Analogy Between Electric and Magnetic Circuits

Conductivity σ

Field intensity E

Current Density $J = \frac{I}{A} = \sigma E$

Electromotive Force (emf) V

Resistance R

Conductance $G = \frac{1}{R}$

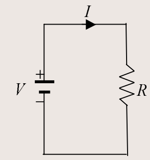
Ohm's Law $R = \frac{V}{I} = \frac{l}{\sigma A} = \frac{\rho l}{A}$

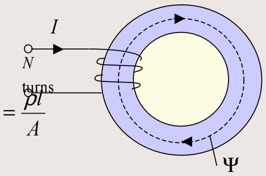
or $V = El = IR$

Kirchhoff's laws :

$\sum V = 0$

$\sum V - \sum RI = 0$





Permeability μ

Field intensity H

Flux Density $B = \frac{\Phi}{A} = \mu H$

Magnetomotive Force (mmf) F

Reluctance $\Re$

Permeance $P = \frac{1}{\Re}$

Ohm's Law $\Re = \frac{F}{\Phi} = \frac{l}{\mu A}$

or $F = Hl = \Phi\Re$

Kirchhoff's laws :

$\sum F = 0$

$\sum F - \sum \Re\Phi = 0$

! ***Differences are***: **1)** I flows but Ψ doesn't flow; **2)** σ independent of J but μ varies with B.

Kirchhoff's law applied to nodes and loops of a given magnetic circuits leads to:

Elements in Series

$$\Phi_1 = \Phi_2 = \Phi_3 = \cdots = \Phi_n$$

$$F_1 + F_2 + F_3 + \cdots + F_n = F$$

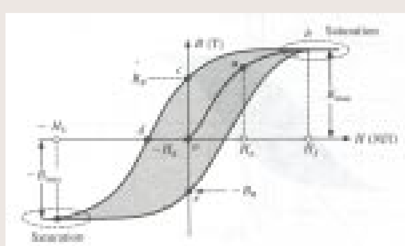
Elements in Parallel

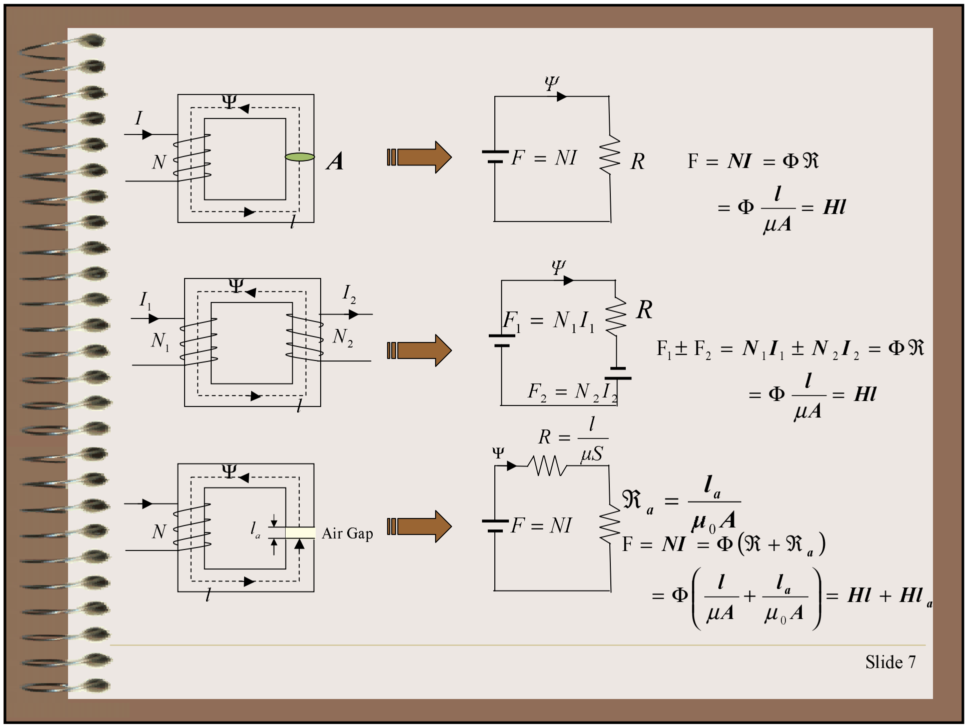
$$\Phi_1 + \Phi_2 + \Phi_3 + \cdots + \Phi_n = \Phi$$

$$F_1 = F_2 = F_3 = \cdots = F_n$$

Hysteresis

The entire curve shown is called the hysteresis curve. The area of the hysteresis loop represents the energy loss during one cycle in a unit cube of the core material.





Ψ
I
N
A
l
F = NI
R
$F = NI = \Phi \Re = \Phi \frac{l}{\mu A} = Hl$
I_1
I_2
N_1
N_2
$F_1 = N_1 I_1$
$F_2 = N_2 I_2$
$F_1 \pm F_2 = N_1 I_1 \pm N_2 I_2 = \Phi \Re = \Phi \frac{l}{\mu A} = Hl$
$R = \frac{l}{\mu S}$
l_a
Air Gap
F = NI
$\Re_a = \frac{l_a}{\mu_0 A}$
$F = NI = \Phi(\Re + \Re_a) = \Phi\left(\frac{l}{\mu A} + \frac{l_a}{\mu_0 A}\right) = Hl + Hl_a$
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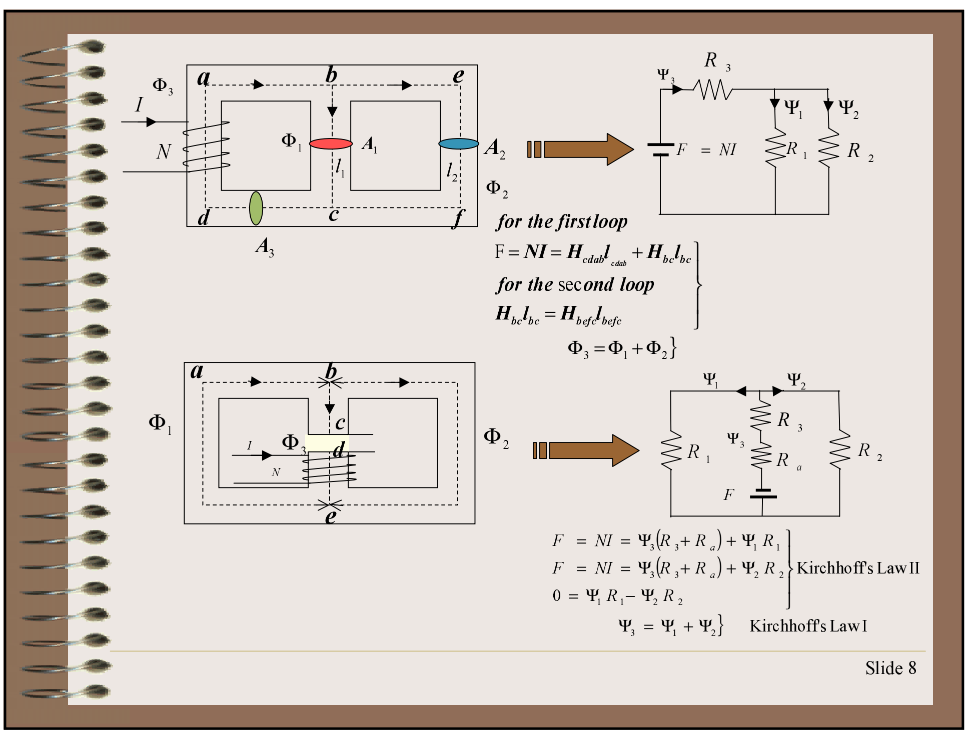

a b e
d c f
Φ_3
I
N
Φ_1
A_1
A_2
A_3
l_1
l_2
Φ_2
R_3
Ψ_3
Ψ_1
Ψ_2
F = NI
R_1
R_2
for the first loop
$F = NI = H_{cdab} l_{cdab} + H_{bc} l_{bc}$
for the second loop
$H_{bc} l_{bc} = H_{befc} l_{befc}$
$\Phi_3 = \Phi_1 + \Phi_2$
R_a
F
$F = NI = \Psi_3(R_3 + R_a) + \Psi_1 R_1$
$F = NI = \Psi_3(R_3 + R_a) + \Psi_2 R_2$
$0 = \Psi_1 R_1 - \Psi_2 R_2$
Kirchhoff's Law II
$\Psi_3 = \Psi_1 + \Psi_2$
Kirchhoff's Law I
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