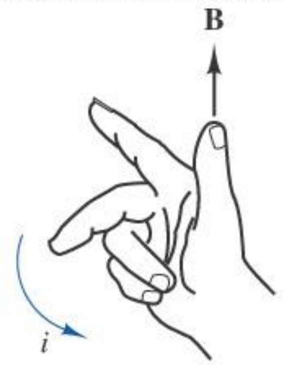
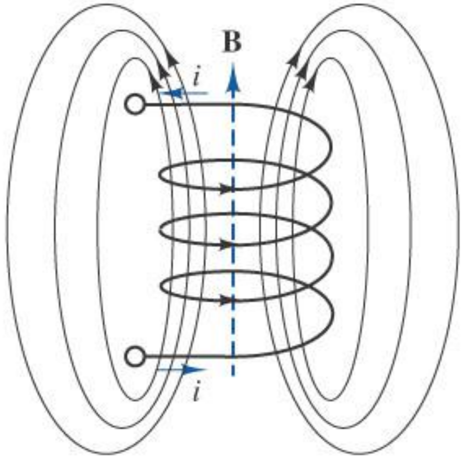
ELG2336: Magnetic Circuits



Right-hand rule



Flux lines

Magnetic Circuit Definitions

- Magnetomotive Force
  - The “driving force” that causes a magnetic field
  - Symbol, $\mathcal{F}$
  - Definition, $\mathcal{F} = \mathcal{N}I$
  - Units, Ampere-turns, (A-t)

Magnetic Circuit Definitions

- Magnetic Field Intensity
  - mmf gradient, or mmf per unit length
  - Symbol, H
  - Definition, $\mathcal{H} = \mathcal{F}/\ell = \mathcal{N}I/\ell$
  - Units, (A-t/m)

Magnetic Circuit Definitions

- Flux Density
  - he concentration of the lines of force in a magnetic circuit

  - Symbol, B
  - Definition, $B = \Phi/A$
  - Units, (Wb/m^2), or T (Tesla)

Magnetic Circuit Definitions

- Reluctance
  – The measure of “opposition” the magnetic circuit offers to the flux
  – The analog of Resistance in an electrical circuit

  – Symbol, $\mathcal{R}$
  – Definition, $\mathcal{R} = \mathcal{F}/\Phi$
  – Units, (A-t/Wb)

Magnetic Circuit Definitions

- Permeability
  - Relates flux density and field intensity

  - Symbol, μ
  - Definition, $\mu = B/H$
  - Units, (Wb/A-t-m)

Magnetic Circuit Definitions

- Permeability of free space (air)
  - Symbol, μ_0
  - $\mu_0 = 4\pi x 10^{-7}$ Wb/A-t-m

Definitions Combined

Φ (Unit is Weber (Wb)) = Magnetic Flux Crossing a Surface of Area 'A' in m^2.

B (Unit is Tesla (T)) = Magnetic Flux Density = Φ/A

H (Unit is Amp/m) = Magnetic Field Intensity = $\frac{B}{\mu}$

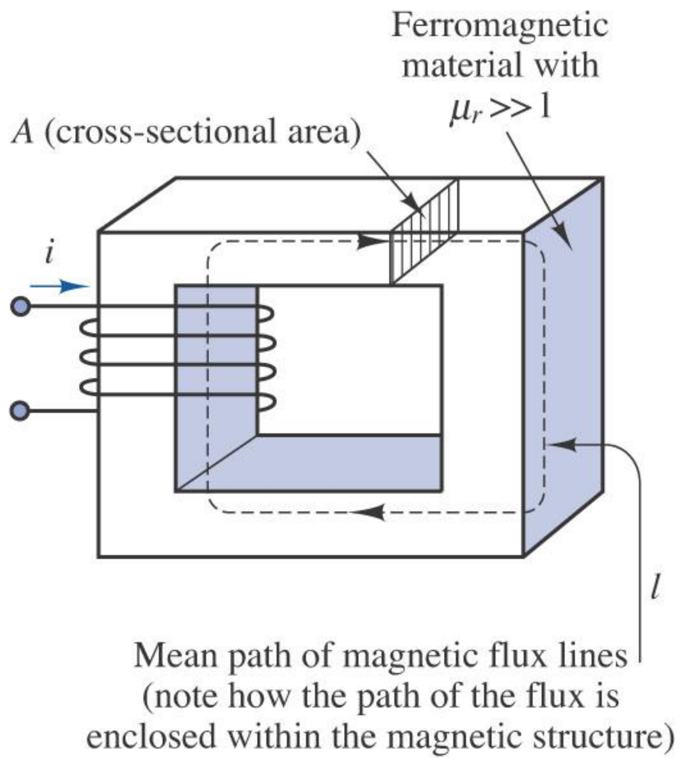
μ = permeability = $\mu_o \mu_r$

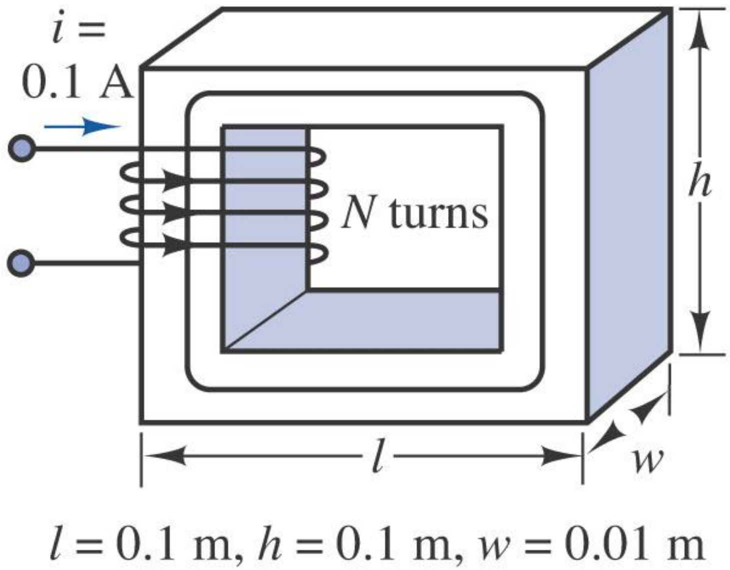
$\mu_o = 4\pi * 10^{-7}$ H/m (H $\Rightarrow$ Henry) = Permeability of free space (air)

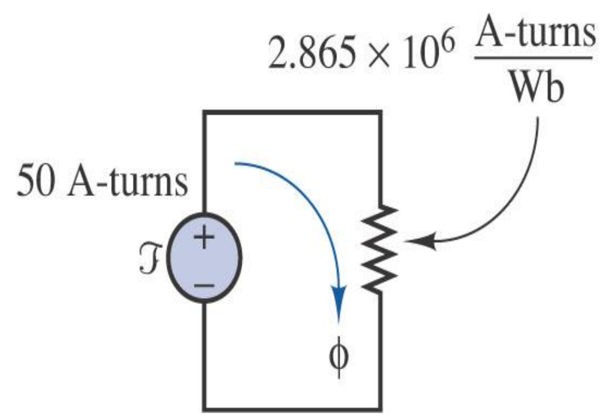
μ_r = Relative Permeability

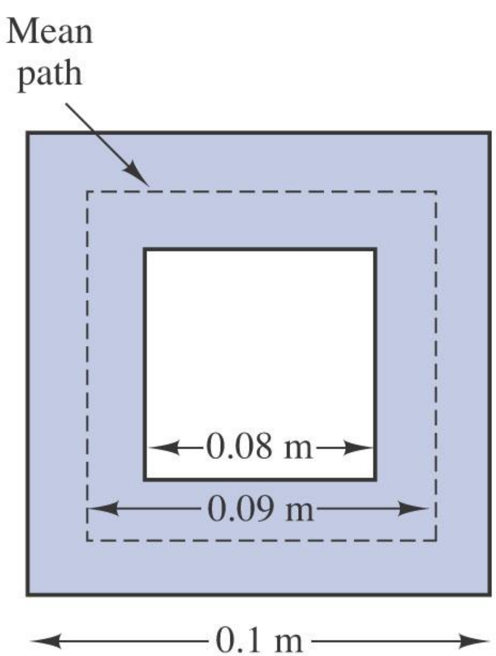
$\mu_r >> 1$ for Magnetic Material

Magnetic Circuit



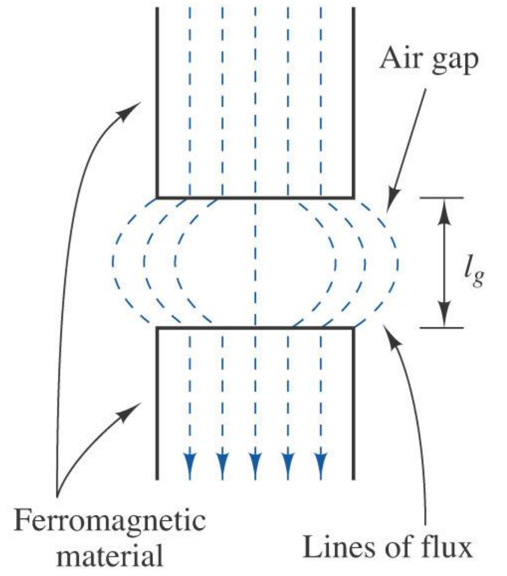

i =
0.1 A
N turns
h
l
w
l = 0.1 m, h = 0.1 m, w = 0.01 m

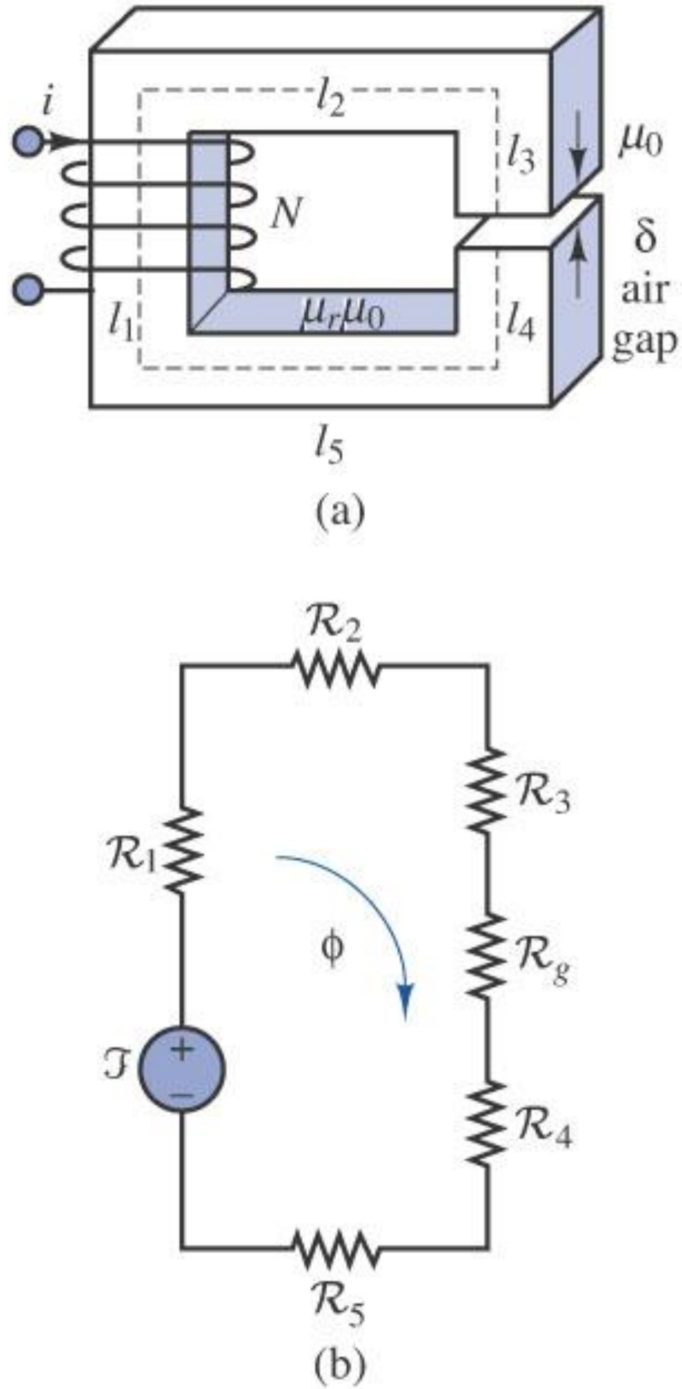

2.865 × 10^6 A-turns/Wb
50 A-turns
ℱ
+
−
ϕ


Mean
path
0.08 m
0.09 m
0.1 m

Air Gaps, Fringing, and Laminated Cores

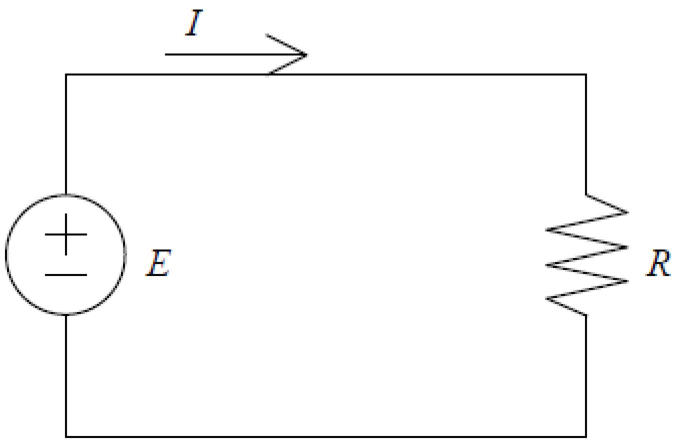
- Circuits with air gaps may cause fringing
- Correction
  - Increase each cross-sectior dimension of gap by the siz the gap
- Many applications use laminated cores
- Effective area is not as large as actual area




i
l_2
l_3
μ_0
N
δ
air
gap
l_1
$\mu_r\mu_0$
l_4
l_5
(a)
$\mathcal{R}_2$
$\mathcal{R}_3$
$\mathcal{R}_1$
ϕ
$\mathcal{R}_g$
$\mathcal{F}$
+
−
$\mathcal{R}_4$
$\mathcal{R}_5$
(b)

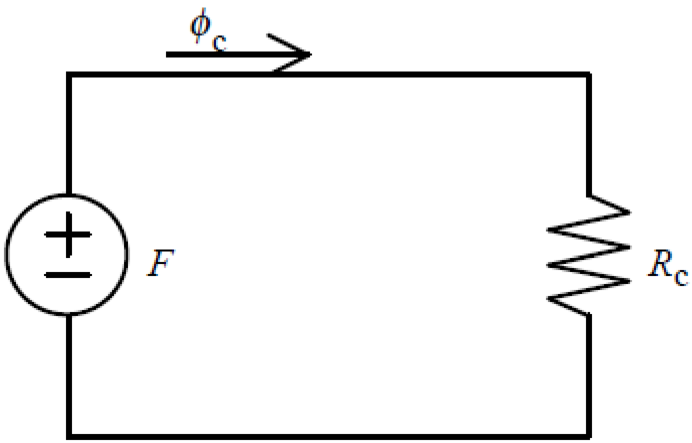
Electric and Magnetic Circuits

Electric Circuit



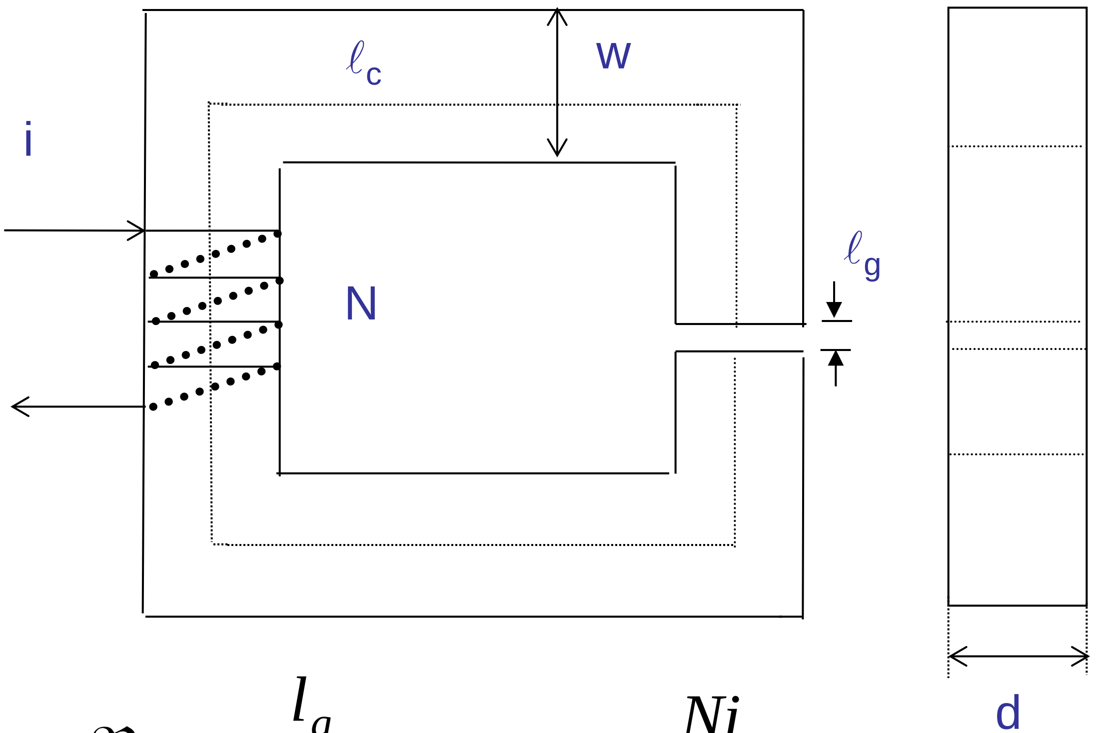
$$I = \frac{E}{R}$$

Magnetic Circuit



$$\phi_c = \frac{F}{R_c}$$

Magnetization Circuits with Air-Gap



$$\Re_c = \frac{l_c}{\mu_c A_c} \qquad \Re_g = \frac{l_g}{\mu_g A_g} \qquad \Phi = \frac{Ni}{\Re_c + \Re_g}$$

$$Ni = H_c l_c + H_g l_g \qquad A_c = A_g = wd \; (Neglecting \;\; fringing)$$

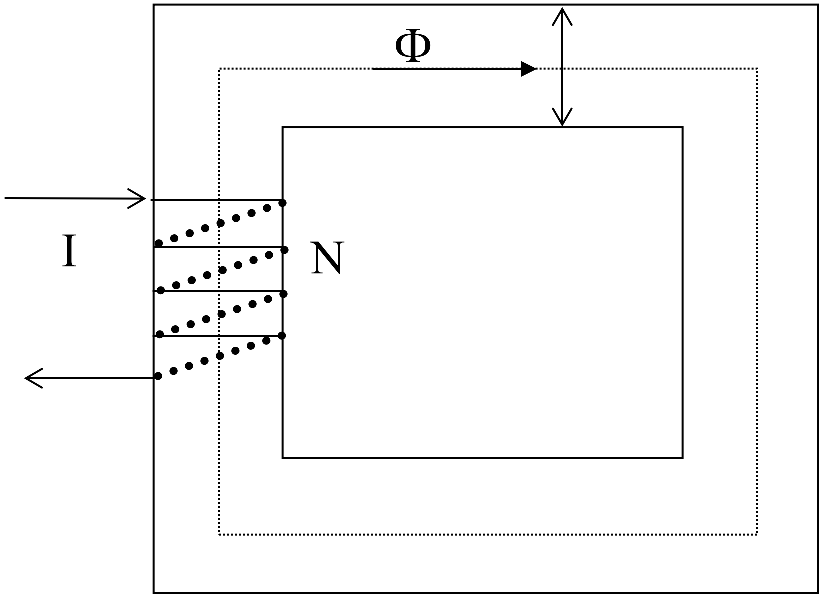
Inductance(L)

Definition: Flux Linkage(λ) per unit of current(I) in a magnetic circuit

$$L = \frac{\lambda}{I} = \frac{N\Phi}{I}$$

$$\Phi = \frac{NI}{\Re}$$

$$\therefore L = \frac{N^2}{\Re}$$



Thus inductance depends on the geometry of construction

Series Magnetic Circuits

- Solve a circuit where Φ is known
  - First compute B using Φ/A
  - Determine H for each magnetic section from B-H curves
  - Compute NI using Ampere’s circuital law
  - Use computed NI to determine coil current or turns as required

Series-Parallel Magnetic Circuits

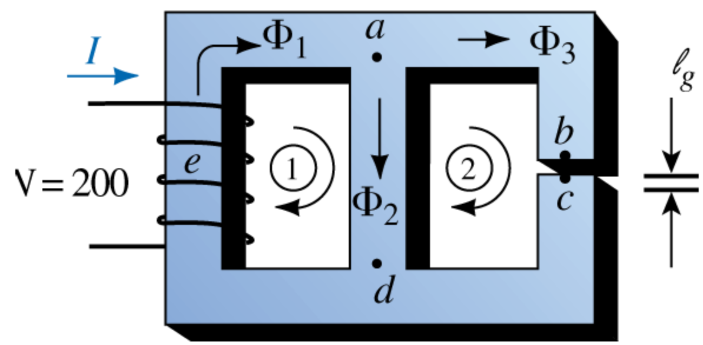
- Use sum of fluxes principle and Ampere's Law
- Find *B* and *H* for each section
- Then use Ampere's Law

Cast steel

$A = 2 \times 10^{-2}\,\text{m}^2$

$\ell_g = \ell_{bc} = 0.25 \times 10^{-3}\,\text{m}$

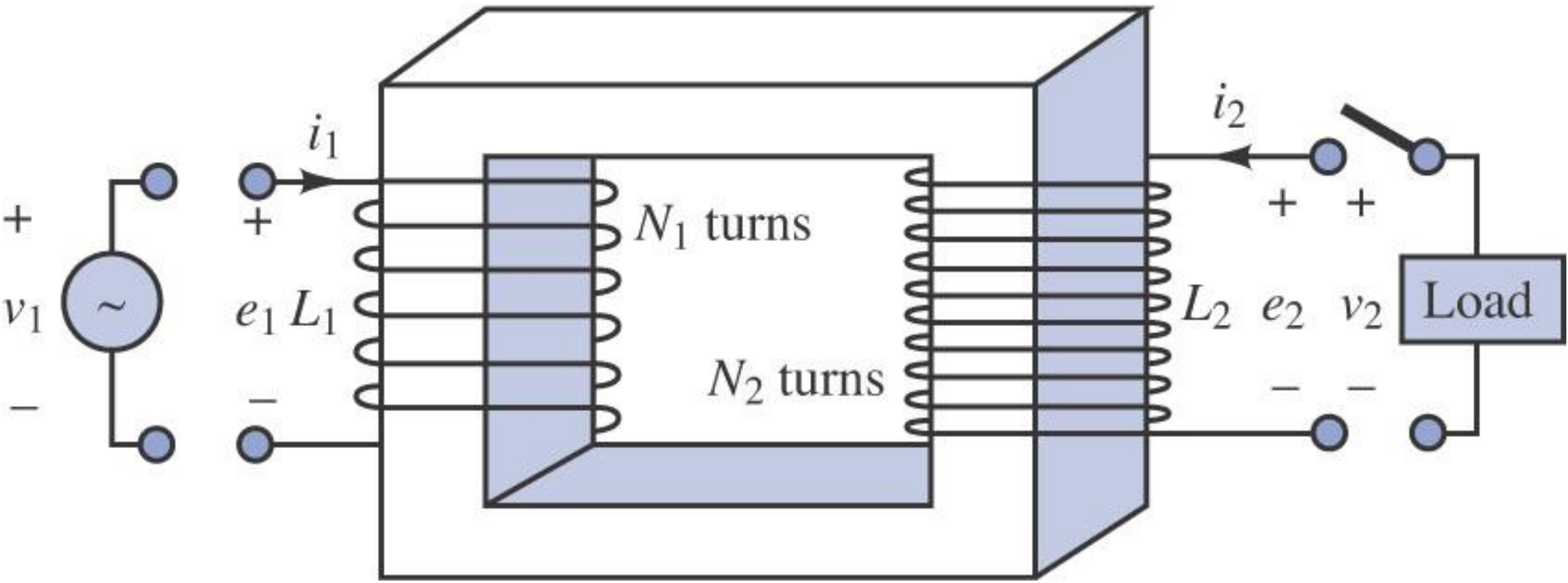
$\Phi_g = \Phi_3$

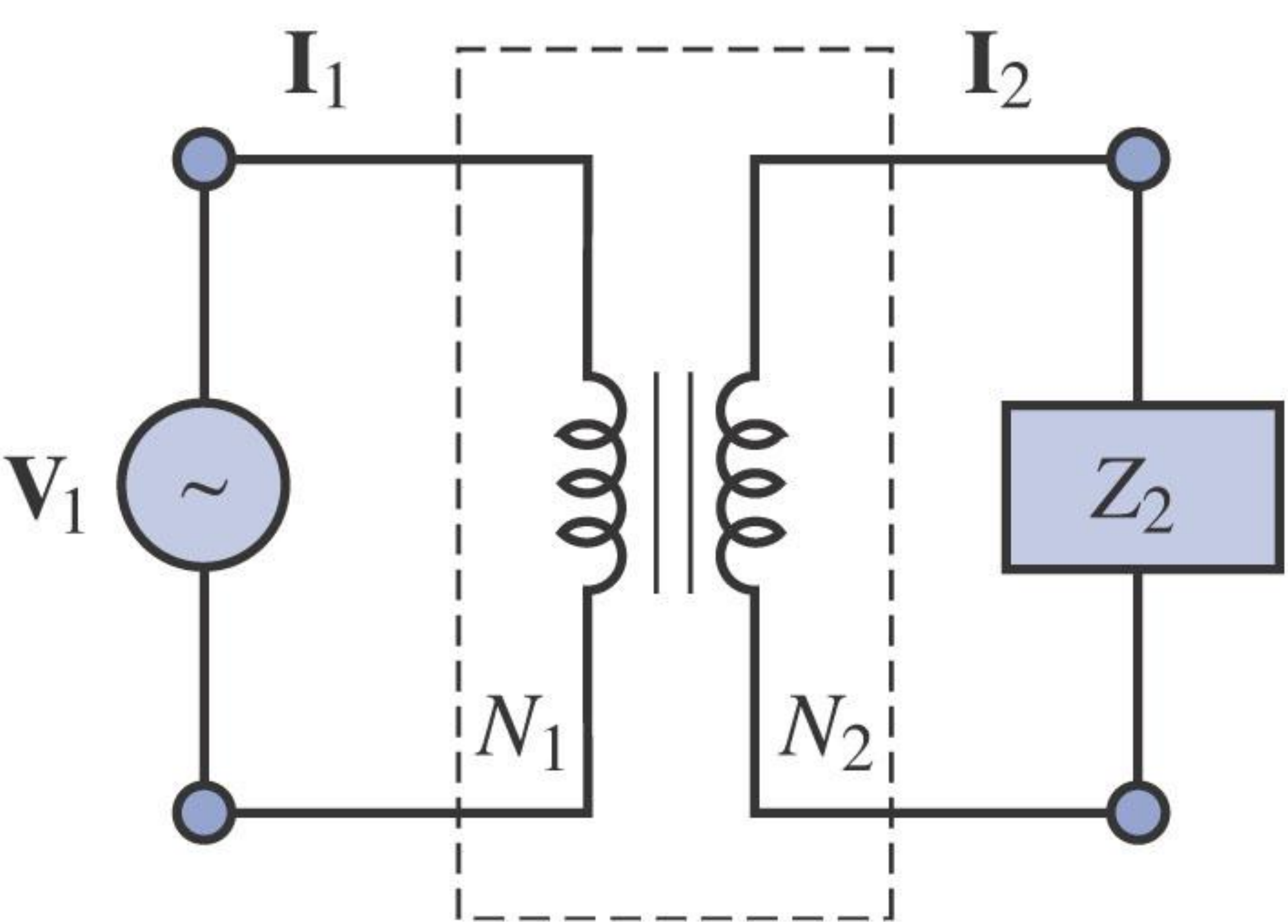


$\ell_{ab} = \ell_{cd} = 0.25\,\text{m}$ $\ell_{da} = 0.2\,\text{m}$

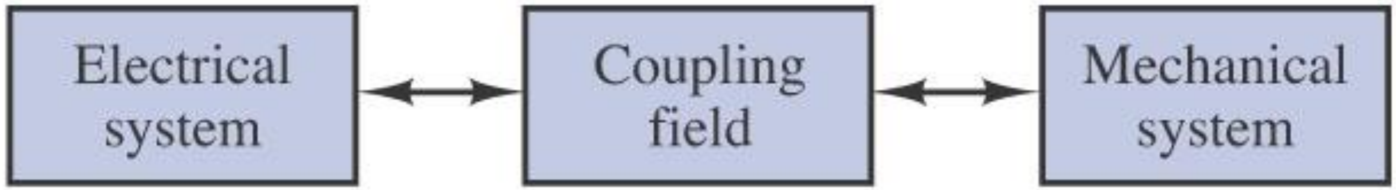
$\ell_{dea} = 0.35\,\text{m}$

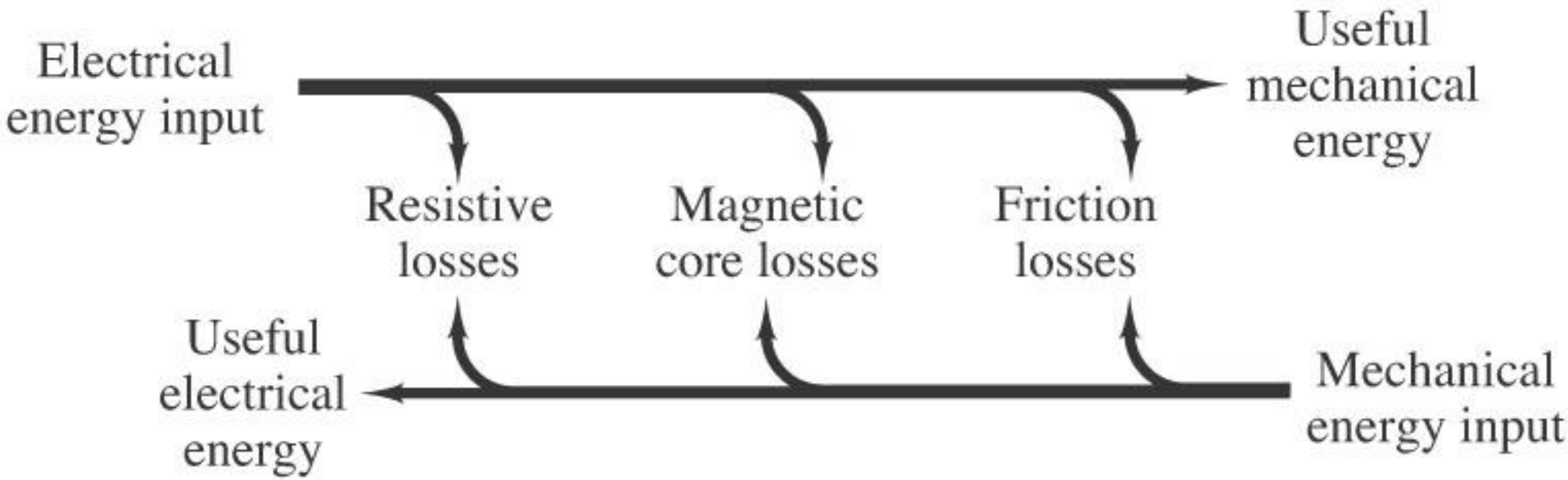
Structure of Transformer




I1
I2
V1
~
N1
N2
Z2

Electromechanical Energy Conversion





Reading

- Example 18.2
- Example 18.3
- Example 18.3
- Example 18.7