El-Manzala Higher Institute of Engineering and Technology

Fundamentals of Electrical Engineering

First YEAR

By

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Inductor and Inductance

Chapter 7

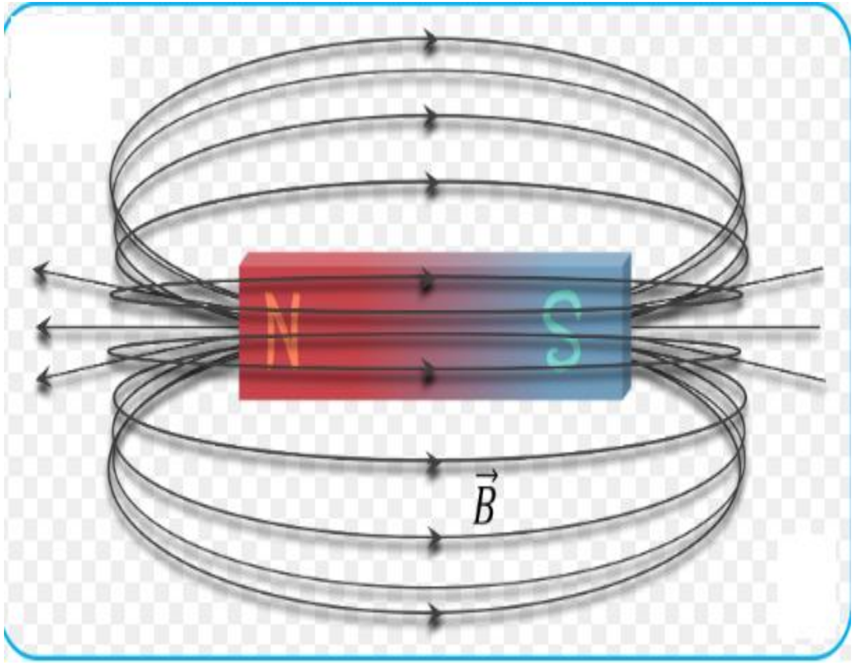
Chapter Content

CH7: Inductor and Inductance

MAGNETIC FLUX

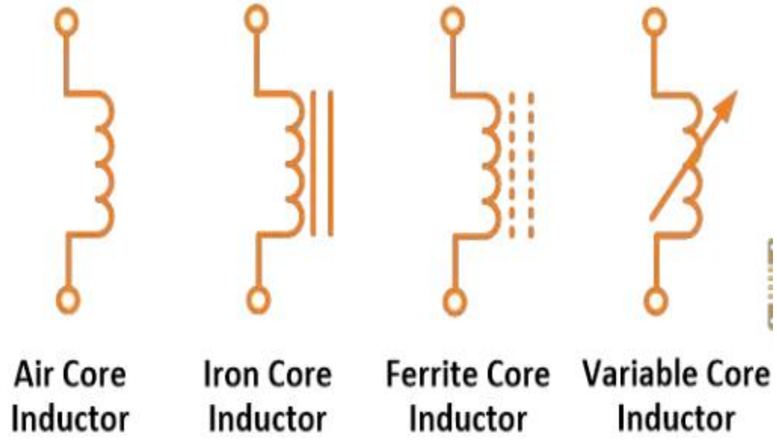
- Magnetic phenomena are explained using magnetic flux, or just flux, which relates to magnetic lines of force that, for a magnet, extend in continuous lines from the magnetic north pole to the south pole outside the magnet and from the south pole to the north pole inside the magnet.

- The SI unit of flux is the **Weber** ,with unit symbol (Wb).



2. INDUCTANCE AND INDUCTOR

- **Inductor**: is an electrical component formed by a coil of a wire



2. INDUCTANCE AND INDUCTOR

- A current through the coil produces an electromagnetic field.
- When the current changes, the electromagnetic field also changes.
- The change of electromagnetic field causes an induced voltage across the coil in a direction to oppose the change of current.

$$e = -N \cdot (d\varphi / dt)$$

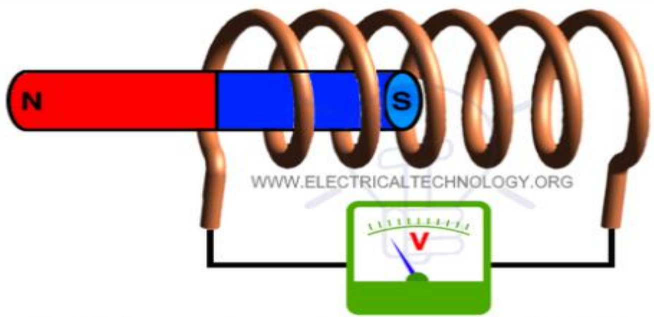


Fig 1.A: As magnet moves to the right, magnetic field is changing with respect to the coil, and EMF is induced.

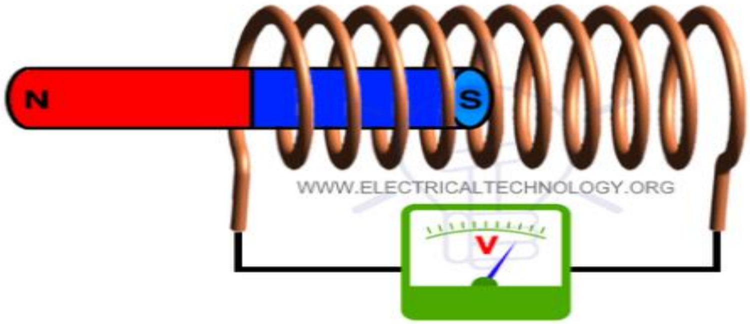


Fig 1.B: As magnet moves more rapidly to the right, magnetic field is changing more rapidly with respect to the coil and a greater EMF is induced.

2. INDUCTANCE AND INDUCTOR

- For most coils, a current i produces a flux linkage **NΦ** that is proportional to I.

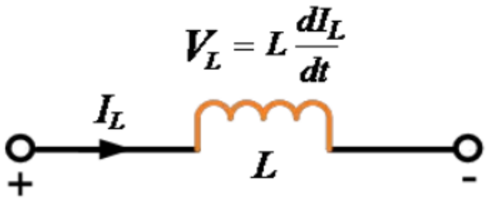
$$I \propto N\Phi$$

$$I = (1/L)\, N\Phi = N\Phi / L$$

$$L = N\Phi / I$$

The constant of proportionality L that is the inductance of the coil.

- The voltage across an inductor is directly proportional to the rate of change of the electric current flowing through the inductor.
- Mathematically, the voltage across the inductor can be expressed as: $$v_L = L\frac{di_L}{dt}$$



Voltage Across an Inductor

2. INDUCTANCE AND INDUCTOR

- EX: Find the voltage induced in a 150-mH coil when the current is constant at 4 A. Also, find the voltage when the current is changing at a rate of 4 A/s.

SOL:

If the current is constant, di/dt = 0 and so the coil voltage is zero. For a rate of change of di /d t =4 A/s

$$v = L\frac{di}{dt} = (150 \times 10^{-3})(4) = 0.6\ \text{V}$$

Permeability

- **Permeability**, with quantity symbol μ, is *a measure of this flux-enhancing property*.
- It has an SI unit of henry per meter and a unit symbol of **H/m**.
- Henry, with unit symbol H, is the SI unit of inductance.
- The permeability of vacuum, designated by μ_o , is 0.4π μH/m.
- Permeability of other materials are related to that of vacuum by a factor called the relative Permeability, with symbol μ_r

$$\mu = \mu_0 \mu_r$$

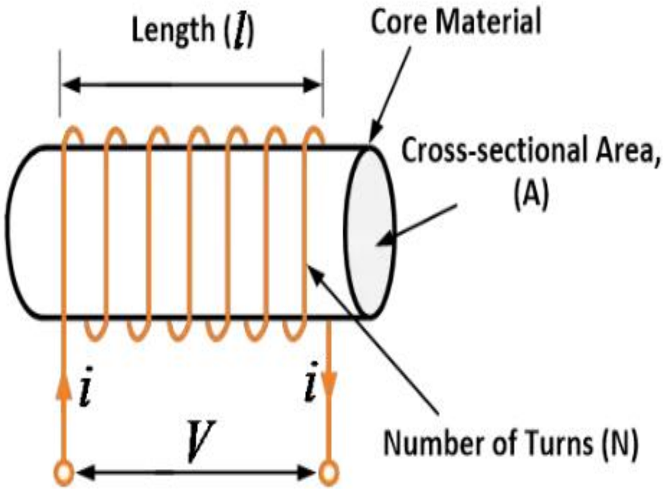
- Most materials have relative permeability close to 1.
- Pure iron has them in the range of 6000 to 8000.
- Nickel has them in the range of 400 to 1000.
- Alloys السبائك has a relative permeability of over 80 000.

2. INDUCTANCE AND INDUCTOR

- The inductance of a coil depends on the shape of the coil (A, L), the permeability of the surrounding material (μ), the number of turns (N), the spacing of the turns, and other factors.

$$L = N^2 \cdot \mu \cdot A / l$$

where **N** is the number of turns of wire, **A** is the core cross-sectional area in square meters, **l** is the coil length in meters, and **μ** is the core permeability.



3. ENERGY STORAGE

- The energy stored in an inductor is: $W_L = \frac{1}{2} LI^2$

where W is in joules, L is in Henrys, and I is in Amperes.

- This energy is considered to be stored in the magnetic field surrounding the inductor.

4.TOTAL INDUCTANCE

- the current is same in all three inductors,

$$I_1 = I_2 = I_3$$

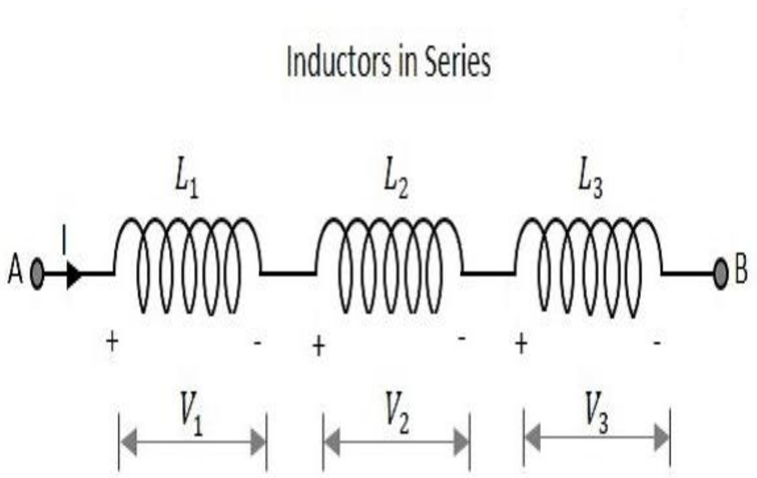
- Also, we know that the voltage through a inductor is given by $V = L\ (di/dt)$

$$V = V_{L1} + V_{L2} + V_{L3}$$

$$L_T \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt}$$

Series Inductances

$$L_{total} = L_1 + L_2 + \ldots L_n$$



4.TOTAL INDUCTANCE

- the Voltage is same in all three inductors,

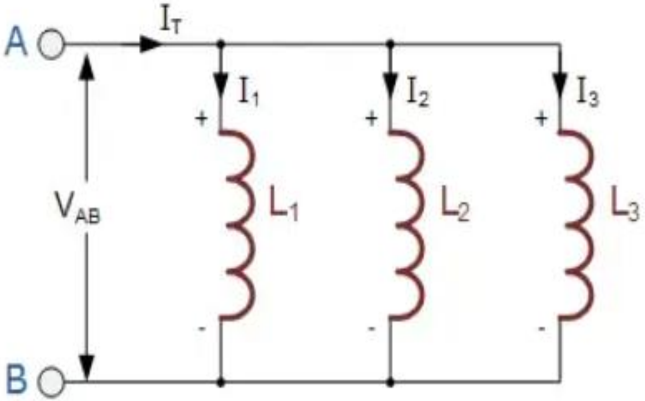
$$V_1 = V_2 = V_3$$

- Also, we know that the voltage through an inductor is given by $V = L\,(di/dt)$

$$I = I_1 + I_2 + I_3$$

$$v = L_T \frac{d}{dt}(i_1 + i_2 + i_3) = L_T\left(\frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt}\right)$$

$$v = L_T\left(\frac{v}{L_1} + \frac{v}{L_2} + \frac{v}{L_3}\right)$$



Parallel Inductances

$$\mathbf{L}_{\text{total}} = \frac{1}{\frac{1}{\mathbf{L}_1} + \frac{1}{\mathbf{L}_2} + \dots \frac{1}{\mathbf{L}_n}}$$

ENERGY STORAGE

EX: Find the total inductance of three parallel inductors having inductances of 45, 60, and 75 mH.

SOL:

$$L_T = \frac{1}{1/45 + 1/60 + 1/75} = 19.1 \text{ mH}$$

End of Lecture 9