Inductance

- Capacitor stores energy via separation of charges.

  Inductor stores energy via alignment of magnetic dipoles, which are tiny magnets created by moving electrons (spin + orbital motion).

- In materials with unpaired electrons in outer shell, magnetic dipoles exist, which get aligned in presence of a magnetic field, (provided they aren’t already aligned as in case of permanent magnets). The alignment goes away when magnetic field is removed.

- Amount of alignment is measured as magnetic flux, \( \phi \), which is magnetic field integrated over the cross-sectional area.

\[
\phi = \int B \, ds
\]

- Magnetic field is created by moving charges (or moving electric field)

  Current (moving charges) through coil wrapped around magnetic core create a magnetic field which aligns the magnetic dipoles of the core. The amount of alignment as measured in terms of flux is proportional to applied current:

\[
\phi \propto i \quad \Rightarrow \quad \phi = L \cdot i
\]

  \( L \) is constant of proportionality and called inductance.

  Unit for \( L \): Tesla - m² - sec / Coulomb = Henry.
Inductance (ctnd.)

- A change in magnetic field gives rise to an electric field, which by Faraday's law satisfies,

\[ \frac{d\Phi}{dt} = \mathbf{v} = -\int \mathbf{E} \cdot d\mathbf{l} \]

\( L \) → changing magnetic flux
\( E \) → strength of induced field
\( \mathbf{v} \) → amount of work done in moving unit charge against the field along the curve \( C \) enclosing surface \( S \) over which flux \( \Phi \) is measured.

- Since for an inductor, \( \Phi = LI \),

\[ \frac{d\Phi}{dt} = \frac{d}{dt}(LI) = L \frac{dI}{dt} \]

We have:

\[ \mathbf{v} = L \frac{dI}{dt} \]

(Changing current = \( \Phi \) changing, flux = \( \Phi \) EMF opposing current change)

Units: Volts = Joules/Coulomb (energy required to move unit charge between two points)

Flux: Weber = Volts-sec (amount of flux change required per second to induce a unit voltage)

Magnetic field: Tesla = Weber/m² (amount of flux per unit area)

Inductance: Henry = Volts-sec/Ampere

Physical characteristics: For a solenoid inductor,

\[ L = \frac{\mu N^2 A}{l} \]

\( \mu \) → permeability (ability of magnetization)

\( N \) → no. of turns of coil

\( A \) → cross-section area of each turn

\( l \) → total length of coil

\( \mu_0 \) → permeability of vacuum

\( \mu_0 = 4\pi \times 10^{-7} \text{ H/m} \)