Collegedunia NCERT Formula Sheet

The Ultimate Formula Reference for Class 12 Physics

Chapter 6: Electromagnetic Induction

Constant / Unit	Value
Permeability of free space, μ_0	$4\pi \times 10^{-7}$ T·m/A
Weber (Wb)	1 Wb = 1 T·m^2 = 1 V·s
Henry (H)	1 H = 1 Wb/A = 1 V·s/A
Volt (V)	1 V = 1 Wb/s

1 Magnetic Flux & Faraday's Law

A changing magnetic flux through a circuit drives a current — the discovery that links electricity and magnetism into one phenomenon (NCERT 6.2–6.4).

Electromagnetic induction

A current is induced in a closed circuit whenever the **magnetic flux through the circuit changes**. Flux can change three ways: (i) the field changes, (ii) the area changes, (iii) the orientation between $\vec{B}$ and the area vector changes.

Magnetic flux

$$\Phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$$

General: $\Phi_B = \int \vec{B} \cdot d\vec{A}$ (Wb)

where θ = angle between $\vec{B}$ and $\vec{A}$ (outward normal).

Maximum when $\vec{B}$ is perpendicular to the surface ($\theta = 0$); zero when $\vec{B}$ is parallel to the surface ($\theta = 90°$).

Faraday's law of induction

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

For N turns: $\varepsilon = -N\frac{d\Phi_B}{dt}$

Induced EMF is proportional to the **rate of change** of flux. Faster change $\Rightarrow$ larger EMF. Sign of ε is given by Lenz's law (next).

Lenz's law

The induced current flows in a direction such that its own magnetic field **opposes the change** in the flux that produced it. This is a statement of **energy conservation**: nature does not give you a free push.

2 Motional EMF

When a conductor moves through a magnetic field, the magnetic force on its free charges drives a current — a special case of Faraday's law where the area changes (NCERT 6.5).

Motional EMF (straight rod)

$\varepsilon = Bvl$

where l = length of rod; v = speed perpendicular to $\vec{B}$ and l.

Microscopically, the magnetic force qvB on each free electron pushes them along the rod, building up an EMF. Direction by right-hand rule.

Induced current and power

Current: $I = \dfrac{\varepsilon}{R} = \dfrac{Bvl}{R}$

Force needed to maintain v: $F_{\text{ext}} = BIl = \dfrac{B^2 l^2 v}{R}$

Power dissipated: $P = Fv = \dfrac{B^2 l^2 v^2}{R}$

Mechanical work done by the external force **equals** the electrical power dissipated — energy conservation in action.

Rotational EMF (rod about one end)

$\varepsilon = \dfrac{1}{2} B\omega l^2$

where ω = angular velocity; l = length of rod.

Different speeds at different points along the rod; integration gives the factor of $1/2$. Used in homopolar generators.

3 Eddy Currents

When bulk conductors experience changing flux, induced currents flow in closed loops within the metal — usually a nuisance, but sometimes useful (NCERT 6.6).

Eddy currents

Closed-loop currents induced in the bulk of a conductor when the flux through it changes. They dissipate energy as heat (**wasteful** in transformer cores — minimised by lamination) or apply braking force (**useful** in induction brakes, induction cooktops, metal detectors).

4 Self & Mutual Inductance

A coil with changing current induces an EMF in itself (self-inductance) and in nearby coils (mutual inductance) (NCERT 6.7–6.8).

Self-inductance

$\Phi_B = LI$

$\varepsilon = -L\dfrac{dI}{dt}$

where L = self-inductance (H = Wb/A).

L depends only on **geometry** and the medium — never on I. A coil's "electrical inertia": it resists changes in current, just as mass resists changes in velocity.

Self-inductance of a long solenoid

$L = \mu_0 n^2 A l = \mu_0 \dfrac{N^2 A}{l}$

where n = turns per unit length; A = cross-section; l = length; $N = nl$.

Quadratic in turns (N^2) — doubling turns quadruples L. Insert ferromagnetic core to multiply L by μ_r (often hundreds).

Mutual inductance

$\Phi_{2(1)} = MI_1$

$\varepsilon_2 = -M\dfrac{dI_1}{dt}$

$M_{12} = M_{21} = M$ (reciprocity)

M links coil 1's current to coil 2's flux. Reciprocity: a given pair of coils has **one** mutual inductance, regardless of which one drives.

Coupled coil relation

$M = k\sqrt{L_1 L_2}$

where $0 \le k \le 1$ is the **coupling coefficient**.

$k = 1$ for perfectly coupled coils (all flux linked); $k = 0$ if coils don't influence each other. Transformers are designed to maximise k.

5 Energy Stored in an Inductor

The work done against the back-EMF while building up a current is stored as energy in the magnetic field (NCERT 6.7 cont.).

Energy stored

$$U = \frac{1}{2}LI^2$$

Compare with capacitor's $U = (1/2)CV^2$. Energy is stored in the **magnetic field** inside the coil, not in the wire itself.

Energy density of $\vec{B}$ field

$$u_B = \frac{B^2}{2\mu_0} \quad \text{(J/m}^3\text{)}$$

Magnetic analogue of $u_E = (1/2)\epsilon_0 E^2$. Wherever $\vec{B}$ exists, energy is stored at this density.

JEE/NEET Extension: Inductors in series & parallel

Series (no mutual coupling): $L_{\text{eq}} = L_1 + L_2$.

Parallel: $\frac{1}{L_{\text{eq}}} = \frac{1}{L_1} + \frac{1}{L_2}$.

With mutual coupling, add or subtract $\pm 2M$ depending on flux direction. Same combinatorial rules as resistors.

Sign of induced EMF

The minus sign in Faraday's law is **Lenz's law**, not just a sign convention. If a calculation gives a positive EMF in your assumed direction, the induced current flows that way. Always cross-check: the induced current's $\vec{B}$ **must oppose** the original change in flux.

Three flux changes

Flux changes when: (i) **B changes** (transformer EMF), (ii) **Area changes** (motional EMF in a rod), (iii) **Angle changes** (rotating loop in a generator). All three obey the same Faraday formula — only the dominant term differs.

Quick Reference — Electromagnetic Induction

Quantity / Configuration	Expression	Notes
Magnetic flux	$\vec{B} \cdot \vec{A} = BA\cos\theta$	Wb
Faraday's law	$\varepsilon = -d\Phi_B/dt$	Sign $=$ Lenz
Faraday (N turns)	$-N\,d\Phi_B/dt$	Adds linearly
Motional EMF (straight)	Bvl	Rod $\perp$ to $\vec{v}$, $\vec{B}$
Motional EMF (rotational)	$\frac{1}{2}B\omega l^2$	About one end
Self-inductance (def.)	$\Phi_B = LI$	Geometry only
Solenoid inductance	$\mu_0 N^2 A/l$	Quadratic in N
Mutual inductance (def.)	$\Phi_{2(1)} = MI_1$	Reciprocal
Coupling	$M = k\sqrt{L_1 L_2}$	$0 \le k \le 1$
Energy in inductor	$\frac{1}{2}LI^2$	In magnetic field
Magnetic energy density	$\frac{B^2}{2\mu_0}$	Per unit volume
Force on motional rod	$\frac{B^2 l^2 v}{R}$	Opposes motion
Power (motional)	$\frac{B^2 l^2 v^2}{R}$	$= Fv$