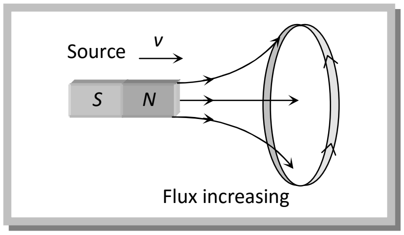
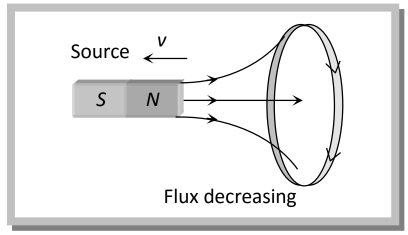
Faraday's Experiment and Laws.

(1) **First experiment**

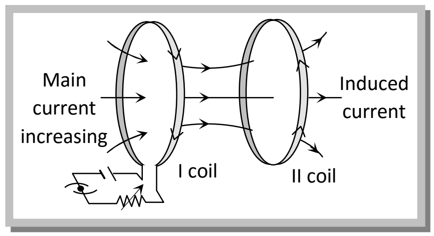
A coil is arranged to link some of the magnetic flux from a source S. If relative motion occurs between coil and source S such that flux linked with the coil changes, a current is induced in it.





(2) **Second experiment**

Two coils are arranged so that a steady current flows in one and some of its magnetic flux links with the other. If the current in the first coil changes a current is induced in the second.



(3) **Faradays first law**

Whenever the number of magnetic lines of force (magnetic flux) passing through a circuit changes (or a moving conductor cuts the magnetic flux) an emf is produced in the circuit (or emf induces across the ends of the conductor) called induced emf. The induced emf persists only as long as there is change or cutting of flux.

(4) **Faradays second law**

The induced emf is given by rate of change of magnetic flux linked with the circuit i.e. $e = -\frac{d\phi}{dt}$. For N turns $e = -\frac{N\,d\phi}{dt}$; Negative sign indicates that induced emf (e) opposes the change of flux.

(i) **Other forms :** We know that ϕ = BA cosθ ; Hence ϕ will change if either, B, A or θ will change

So $$e = -N\frac{d\phi}{dt} = -\frac{N(\phi_2 - \phi_1)}{\Delta t} = -\frac{NA(B_2 - B_1)\cos\theta}{\Delta t} = -\frac{NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$$

Note: Term $\frac{B_2 - B_1}{\Delta t}$ = rate of change of magnetic field, its unit is Tesla/sec

(ii) **Induced current:** If circuit is closed, then induced current is given by $i = \frac{e}{R} = -\frac{N}{R}.\frac{d\phi}{dt}$; where R is the resistance of circuit

(iii) **Induced charge:** If dq charge flows due to induction in time dtthen $i = \frac{dq}{dt}$; $dq = i\,dt = -\frac{N}{R} \cdot d\phi$ i.e. the charge induced does not depend on the time interval in which flux through the circuit changes. It simply depends on the net change in flux and resistance of the circuit.

(iv) **Induced power** : It exists when the circuit is open or closed $P = ei = \frac{e^2}{R} = i^2 R = \frac{N^2}{R}\left(\frac{d\phi}{dt}\right)^2$.

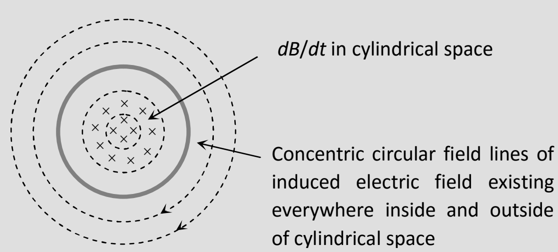
It depends on time and resistance

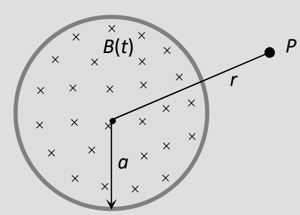
(5) **Induced electric field**

It is non-conservative and non-electrostatic in nature. Its field lines are concentric circular closed curves. A time varying magnetic field $\frac{dB}{dt}$ always produced induced electric field in all space surrounding it. Induced electric field is directly proportional to induced emf so $e = \oint \vec{E}_{in} \cdot d\vec{l}$ here $\vec{E}_{in} =$ induced electric field ......(i)

Also Induced emf from Faraday laws of EMI $e = -\frac{d\phi}{dt}$ ......(ii)

From (i) and (ii) $e = \oint \vec{E}_{in}.d\vec{l} = -\frac{d\phi}{dt}$ This is known as integral form of Faraday's laws of EMI.





A uniform but time varying magnetic field B(t) exists in a circular region of radius 'a' and is directed into the plane of the paper as shown, the magnitude of the induced electric field (E_{in}) at point P lies at a distance r from the centre of the circular region is calculated as follows.

So $\oint \vec{E}_{in} d\vec{l} = e = \frac{d\phi}{dt} = A\frac{dB}{dt}$ i.e. $E(2\pi r) = \pi a^2 \frac{dB}{dt}$ where r ≥ a or $E = \frac{a^2}{2r}\frac{dB}{dt}$; $\mathbf{E_{in}} \propto \frac{\mathbf{1}}{\boldsymbol{r}}$

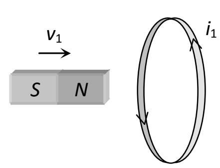
(6) **Change in induced parameter (e, i and q) with change in θ**

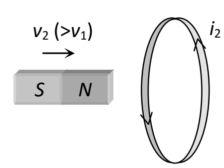
Suppose a coil having N turns, area of each turn is A placed in a transverse magnetic field B such that it's plane is perpendicular to the direction of magnetic field i.e. initially $\theta_1 = 0^o$. If R is the resistance of entire circuit and ϕ_1 = NBA cos 0^o = NBA, is initial flux linked with the coil then.

Change	**Final flux (ϕ_2)**	**Change in flux** $\Delta\phi = (\phi_2 - \phi_1)$	Time taken **(Δt)**	**Induced emf** $e = -\frac{\Delta\phi}{\Delta t}$	**Induced current** $i = \frac{e}{R}$	**Induced charge** $q = i\Delta t$
Coil turn through 180^o (end to end)	– NBA	– 2NBA	t	$\frac{2NBA}{t}$	$\frac{2NBA}{Rt}$	$\frac{2NBA}{R}$
Turn through 90^o	Zero	– NBA	t	$\frac{NBA}{t}$	$\frac{NBA}{Rt}$	$\frac{NBA}{R}$
Taken out of the field	Zero	– NBA	t	$\frac{NBA}{t}$	$\frac{NBA}{Rt}$	$\frac{NBA}{R}$

Concepts

☞ If a bar magnet moves towards a fixed conducting coil, then due to the flux changes an emf, current and charge induces in the coil. If speed of magnet increases then induced emf and induced current increases but induced charge remains same.





Induced parameter : e_1, i_1, q_1 Induced parameter : e_2 (> e_1), i_2(> i_1), q_2 (= q_1)

☞ Can ever electric lines of force be closed curve ? Yes, when produced by a changing magnetic field.

☞ It should be kept in mind that the total induced emf in a loop is not confined to any particular point but it is distributed around the loop in direct proportion to the resistance of it's parts.