ELECTRO MAGNETIC INDUCTION

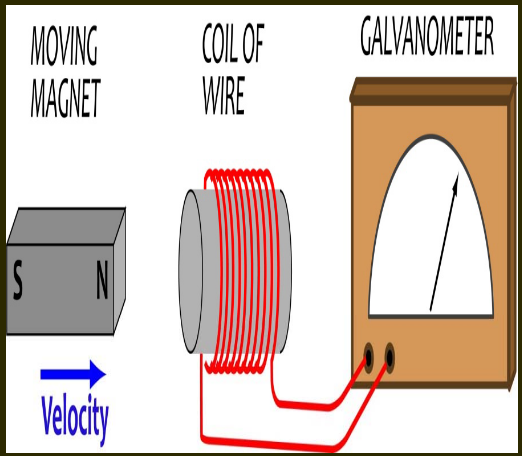
Electro magnetic induction

Faraday

1791 -1867

Henry

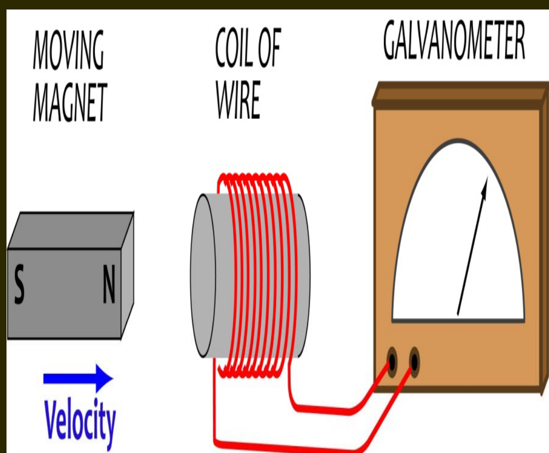
1797 –1878



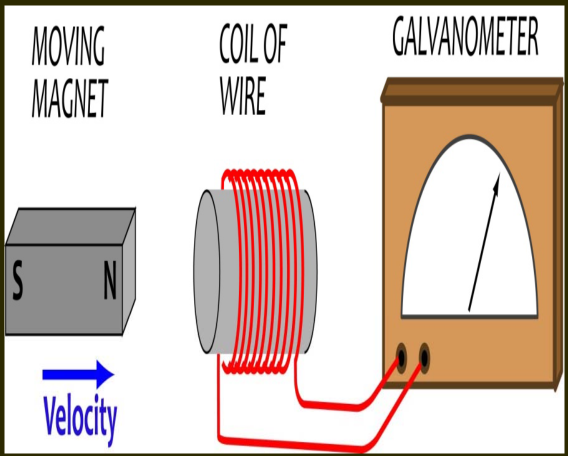
Laws:-

Faraday's Laws :-

1) When ever there is a <u>change</u> in magnetic flux linked with a coil, a current is generated in the coil.

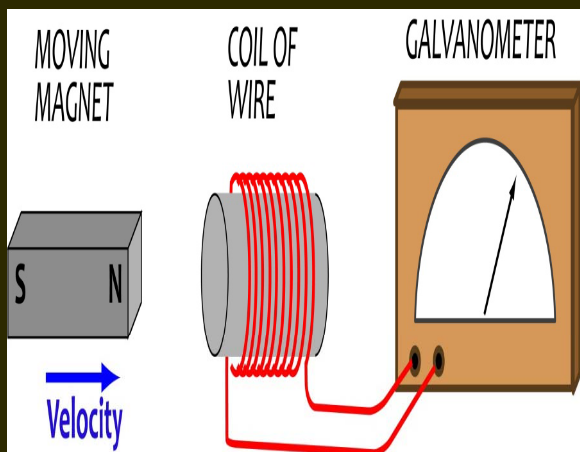


The current is called induced current and the emf responsible for the current is called induced emf. The phenomenon is called electro magnetic induction.



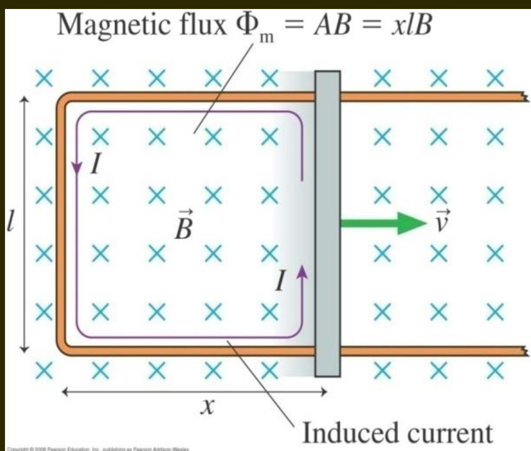
2) **The induced emf (the induced current) is directly proportional to the rate of <u>change</u> of magnetic flux. (The emphasis is on the change of flux)**

Lenz's Law:-



The direction of the induced current (induced emf) is always to oppose the cause for which it is due. (Emphasis is on cause)

Consequences of Electro magnetic induction.



<u>Motional emf, Self induction,mutual induction and Eddy currents.</u>

Motional emf = BLv volt.

self inductance of a coil is L = $\mu_0 \mu_r N^2 A$

(μ_r is the relative permeability of the core), μ_r = 1for air core

Mutual- induction: Between Pair of coils, $M = \mu_0 \mu_r N_1 N_2 A$ henry

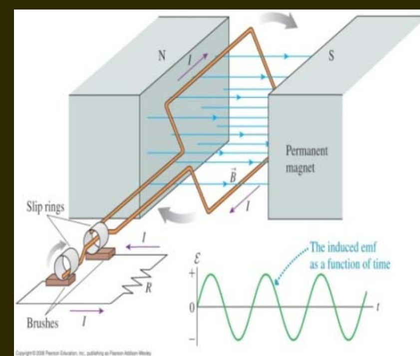
(μ_r is the relative permeability of the core $\mu_r = 1$, for air core.)

Eddy currents :-

They are cyclic currents also called focault current in the bulk of a metal in a direction perpendicular to the magnetic flux. They cause heating effect and dissipate energy. This can be minimized by using laminated plates.

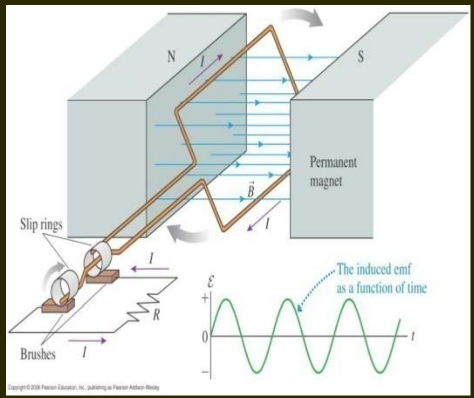
Alternating current
(Alternating voltage)

The current which oscillates between a positive maximum value and a negative minimum value is called alternating current(ac).The emf responsible is called alternating voltage.



$V = V_0 \sin\omega t$ is the expression for alt - voltage

$I = I_0 \sin\omega t$ is the expression for alt - current$_0$



e_0 and i_0 are the peak (max) values of the induced voltage and induced current respectively.

$\omega t = \sin^{-1} V/V_0$ or $\omega t = \sin^{-1} I/I_0$ is called the phase. If ωt is the same for current and voltage, then they are said to be in phase.

$$V_{ave} = (2/\pi)V_{0}, \quad I_{ave} = (2/\pi)I_{0}$$

$$V_{rms} = V_{0} /\sqrt{2} \qquad I_{rms} = I_{0} /\sqrt{2}$$

$$P_{rms} = V_{rms} I_{rms}$$

$$P_{rms} = (V_{0} /\sqrt{2}) \text{ X } (I_{0} /\sqrt{2}) = V_{0} I_{0} /2$$

is called half power point in ac circuits

AC applied to resistance, ideal inductance and ideal capacitance.

Ideal means inherent resistance of the circuit component is not considered for discussion. Power in AC circuits:- $P_{ac} = V\, I \cos\varphi$. V= P D measured. I= Current measured , φ is the phase difference between voltage and current .

cosφ is called the power factor in AC circuits because the magnitude of power transfer in AC circuits is dictated by cosφ .

AC applied to resistance

The behavior of resistance is identical for both AC and DC (we know that P_{dc} = Voltage x current)

The value of resistance is independent of frequency.

The voltage and current are always in phase in a resistance.

That means, in a purely resistive AC circuit ,ie., $\varphi = 0$, $\cos \varphi = 1$. $P_{ac} = V\,I$ watt. In other words For a resistance $P_{dc} = P_{ac}$

The behavior of inductance for DC is transient where as for AC it is perpetual. It offers Inductive reactance

$X_L = \omega L = 2\pi f L$ ohm to AC. $X_L \alpha f$, the frequency of the Applied AC.

The applied voltage and the resulting current through the pure inductance are not In phase $V = V_0 \sin \omega t$.

$I = I_0 \sin(\omega t - 90), \varphi = 90^0$

The current lags behind the voltage by 90^0.

$$P_{ac} = V\,I \cos \varphi = P_{ac} = V\,I \cos 90^0$$

$$P_{ac} = 0 \text{ watt}$$

The AC through an <u>ideal inductance</u> is called Watt less current.

The behavior of capacitance to DC is instantaneous where it gets charged to the potential of applied DC voltage. When Alternating voltage is applied across ‘C’ its action becomes perpetual. It offers a capacitive reactance.

$X_c = 1/\omega C = (1/2\pi f\ C)$ ohm.

ie, $X_c \ \alpha \ 1/f$

$V = V_0 \sin \omega t$

$I = I_0 \sin (\omega t + 90)$

The applied voltage and the resulting current are not in phase. The current leads the voltage by 90^0.

Series RLC circuit

Here a resistance, an ideal inductance and an ideal capacitance are connected in series with a plug key. When the key is closed the source drives a current through the series combination and maintains an effective voltage V across the combination.

The effective voltage can be obtained by a vector (phasor) diagram. $V = \sqrt{\{V^2_R + (V_L - V_C)^2\}}$

$V = I\sqrt{\{R^2 + (X_L - X_C)^2\}}$,

$V / I = Z$ ohm called the Impedance (Effective resistance offered to AC by the series RLC circuit). $Z = \sqrt{\{R^2 + (X_L - X_C)^2\}}$ ohm

Series resonant circuit

A series RLC circuit connected to an AC source of adjustable frequency (function generator) is called a series resonant circuit. When the circuit is switched on, it drives a current through the circuit. The magnitude of the current depends on the impedance Z.

But impedance depends on the values of R, X_L and, $X_{C.}$.

R is independent of frequency,

$X_L \alpha f$ and $X_C \alpha 1/f$.

$Z = \sqrt{\{R^2 + (X_L - X_C)^2\}}$ ohm.

At low frequencies of the applied AC ($X_C >> X_L$), $\sqrt{(X_L - X_C)^2}$ is very large , ‘ Z’ is large and ‘I’ is small

At high frequencies of the applied AC ($X_L >> X_C$), $\sqrt{(X_L - X_C)^2}$ is again very large, Z is large ‘I’ is small .

Therefore When frequency increases from a low value to a high value X_C decreases, X_L increases. At one particular frequency f_r , $X_L = X_{C,}$ $Z = Z_{min} = R$. I increases gradually And becomes maximum $I = I_{max}$ at f_r .

This point of $I = I_{max}$ is called electrical Resonance and that particular frequency is called resonant frequency f_r .

Resonant frequency.

At f_r, $X_L = X_C$, $Z = R$, Power factor

$\cos\varphi = R / Z$

$2\pi f_r L = 1/2\pi f_r C$ $f_r = 1/2\pi\sqrt{(L C)}$

Q factor :-

Q = (Voltage across L)/(Voltage across R)

at resonance.

$Q = (V_L / V_R) = IX_L / IR = X_L / R$

$Q = 2\pi f_r L/R$ But $2\pi f_r = 1/\sqrt{(L C)}$

$Q = (L/R) \times (1/\sqrt{(L C)}) = [\sqrt{(L/C)}] \times 1/R$

At half power frequency

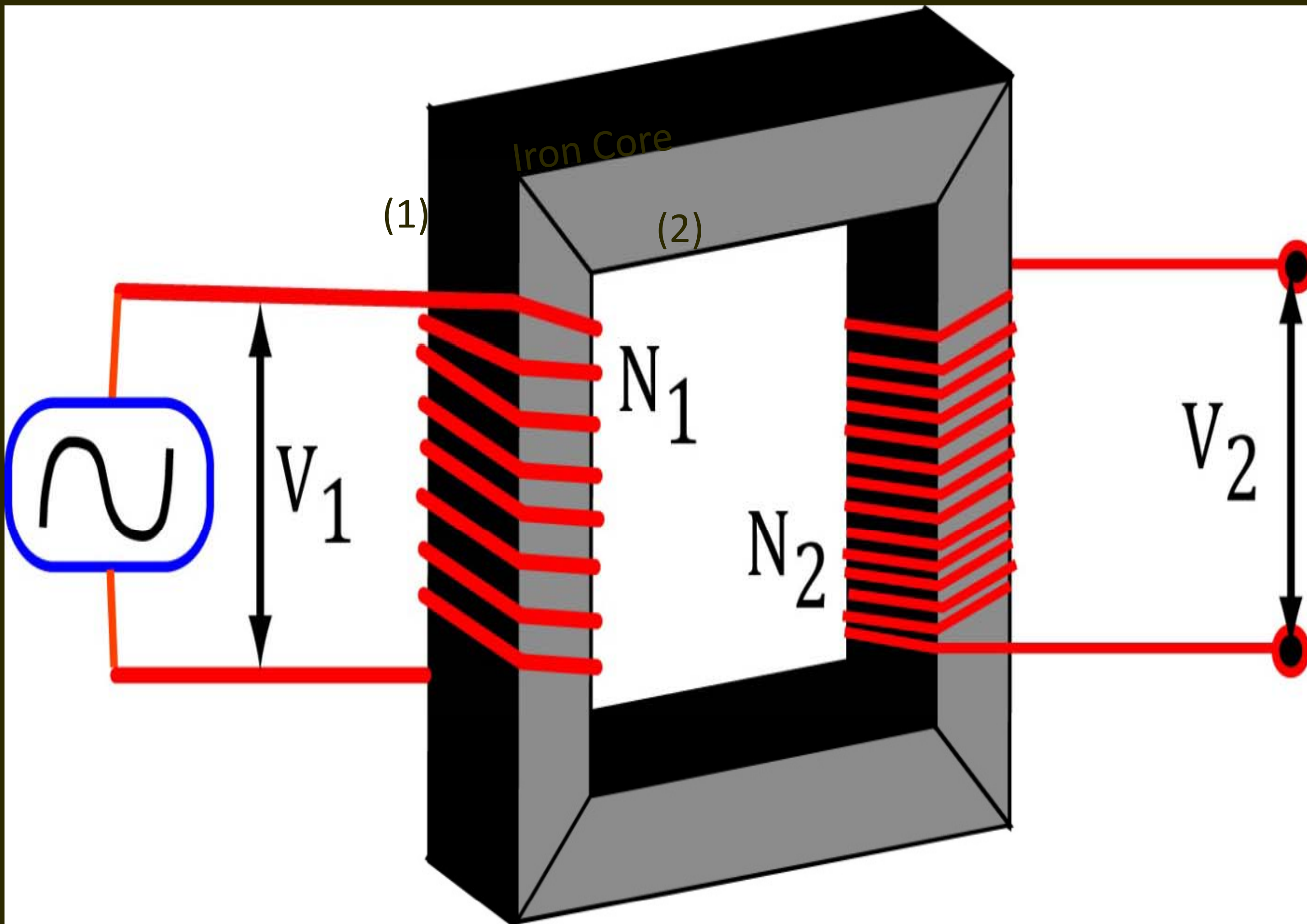
$I = (I_{max} / \sqrt{2})$. Band width = $f_2 - f_1$ and

$Q = f_r / (f_{2-} f_1)$. Q value is also called

the sharpness of resonance or

selectivity of the resonance circuit.

Q is large when R is small.



Iron Core
(1)
(2)
N_1
N_2
V_1
V_2

Transformer

For an ideal transformer,

$$(V_2/\ V_1) = (N_2/\ N_1) = K$$

K is called Transformer turn ratio.

$K > 1$ $N_2 > N_1$ it is called step up voltage transformer.

$K < 1$ $N_2 < N_1$ it is called step down voltage transformer.

$K = 1$ $N_2 = N_1$ it is called buffer transformer (Used in circuit isolation and impedance matching).

Input power = out put power

$$V_2 I_2 = V_1 I_1$$