# unit - IV Electromagnetic Induction

மின்காந்தத் தூண்டல்

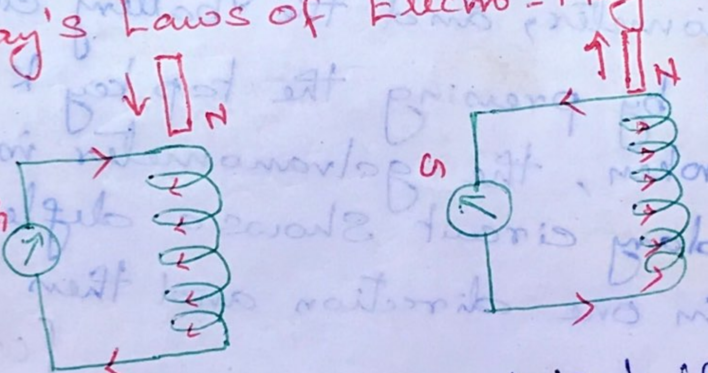
Laws of electromagnetic induction - (2) Self induction - (10) Rayleigh's methods mutual induction - experimental determination of mutual induction (5)(10) - A c and Dc circuits - (5) Growth and decay of current in an LR (10) circuit - Series and parallel in a CR circuit (LCR) applied with AC - (5 mark) Sharpness of resonance - (2) power factor. - (5)

(self - inductance of a Solenoid) 2mark

## Electromagnetic Induction. (is the generation of electrical energy using magnetisms (magnetic fields) in the process

மின்காந்தத் தூண்டல் விதிகள்

## (2 mark) Faraday's Laws of Electro - Magnetic Induction

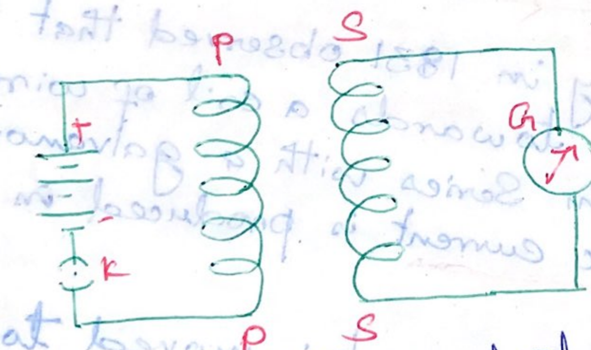



- Faraday in 1831 observed that if a magnet is moved towards a coil of wire (Solenoid) connected in series with a galvanometer, an electric current is produced in the circuit.

- when the magnet is moved towards the Solenoid, the galvanometer shows deflection in one direction and when the magnet is moved away from the Solenoid, the galvanometer shows deflection in the other direction.

- when the magnet is stationary, there is no deflection in the galvanometer.
- Similar results are obtained when the magnet is kept stationary and the coil is moved.
- when the magnet is moved fast, the deflection in the galvanometer is large and when it is moved slowly the deflection is small.
- It was also found that if there are two closed circuits in close proximity, one containing a battery and other a galvanometer, and the battery circuit is closed by pressing the tap key K, and then broken, the galvanometer in the secondary circuit shows a deflection first in one direction and then in the other.

[circuit open - no way for the electr flow. It is turned off
circuit closed - full way for the electr flow




- It is observed that no deflection is produced in the galvanometer if the current in the primary circuit flows continuously

• ~~the deflection is produced in the galvanometer if the current in the primary circuit flows continuously,~~

The deflection is produced in the galvanometer only at make of break of the current in the primary circuit.

Faraday summed up the experimental results in the form of the following laws:

①, whenever there is a change in the magnetic lines of forces (or) magnetic flux, an induced current is produced in the circuit.

②, the induced current (or) EMF lasts only for the time of for which the lines of force (or) magnetic flux is actually changing.

③, the magnitude of the induced EMF depends upon the rate at which the magnetic lines of force (or) magnetic flux changes.

• Suppose, the total flux in the circuit = $\phi$ and the induced emf = e

then $e \propto \frac{d\phi}{dt}$

Also, increase in magnetic flux produces an inverse current and decrease in magnetic flux produces a direct current,
(Increase - Inverse, Decrease - Direct)

## Lenz's law. லென்ஸ் விதி

- The direction of the induced EMF (தூண்டு மின்னியக்கு விசையின் திசையினை) is given by Lenz's law.

- It states that the direction of the induced EMF is such that it opposes the change (or) the movement, that is producing it.

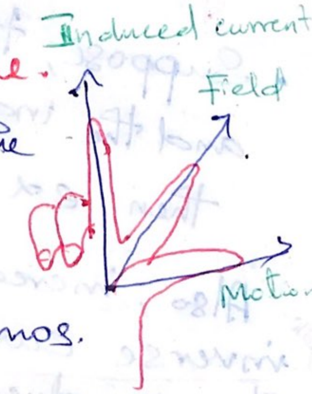
- If the current in the primary is increasing, the direction of the induced current in the secondary will be in the opposite direction and tries to decrease the magnetic flux in the circuit.

- When a magnet is moved towards the solenoid, the direction of the induced current is such that it tries to oppose the movement of the magnet towards the solenoid.

- ~~Len'z~~ Lenz's law is in accordance with the law of conservation of energy.

- The induced EMF is produced at the cost of mechanical work.

## Fleming's Right hand rule. ஃபிளமிங் வலக்கை விதி




- This rule is applied when the current is induced in a single circuit and is useful in the case of generators and dynamos.

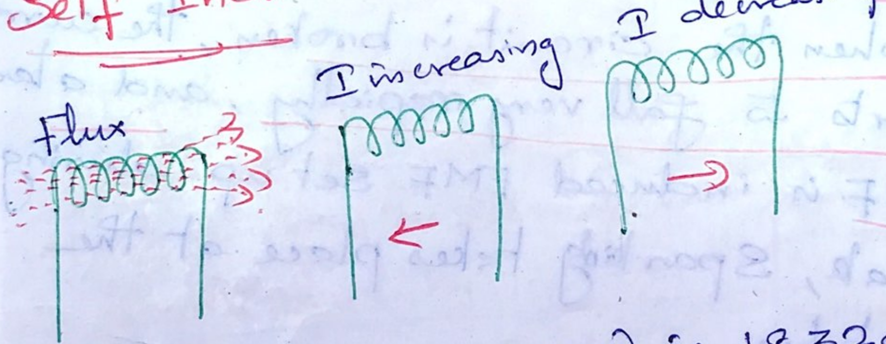
. Fleming's right hand rule is also know as generator rule.

. Stretch the thumb, the forefinger and the middle finger of the right hand mutually perpendicular to one another.

. If the thumb represents the direction of motion of the conductor, the forefinger the direction of the magnetic field, then the middle finger points in the direction in which current is induced in the circuit

(Fore - field, thumb - Motion, Middle - Induced current)

## Self Induction தன்மின் தூண்டல்




. Joseph Henry (American) in 1832 discovered the phenomenon of Self-Induction on theoretical considerations,

. When a current flows through a coil, a magnetic field is set up in it.

. If the current passing through the coil is changed, the total flux linked with the coil changes and an induced EMF will be such as to opposing the current when the current is increasing and in the direction of the current when the current is decreasing.

- The property of an electric circuit by virtue of which any change in the magnetic flux linked with it, induces an EMF in it, is called inductance.
- The EMF induced is called back EMF.
- Self inductance opposes the growth of current in a circuit when the current is switched on, and also it opposes the decay of current when it is switched off.
- When the circuit is broken, the current starts to fall very rapidly, and a large EMF is induced EMF set up during the break, sparking takes place at the switches.
- This energy which appears in the form of heat and light at the time of break is stored in the magnetic field during the growth of current in the circuit.

• Thus, it is clear that in the case of an inductive circuits, while the flux is increasing during the growth of current, energy is stored up magnetically as long as the flux remains constant.

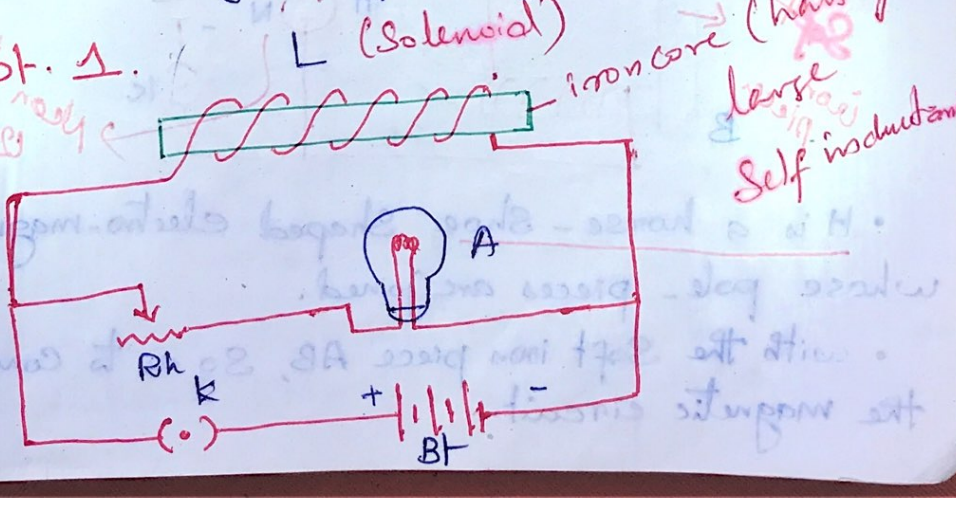
• When the current is switched off, the flux decreases and the energy is given back in the form of Spark.

• The Switches at the power stations are usually oil immersion type to avoid sparking and damage to the machinery.

Thus, Self-Inductance of a circuit is that property whereby any change in the current flowing in that circuit induces an EMF opposing the change and by virtue of which energy is stored in the magnetic field established by the current.

The effect of self-induction can be demonstrated by the following experiments.

Expt. 1.



• Take a Solenoid L having a large number of turns wound on an iron core so as to have a large Self- ~~induction~~ inductance.

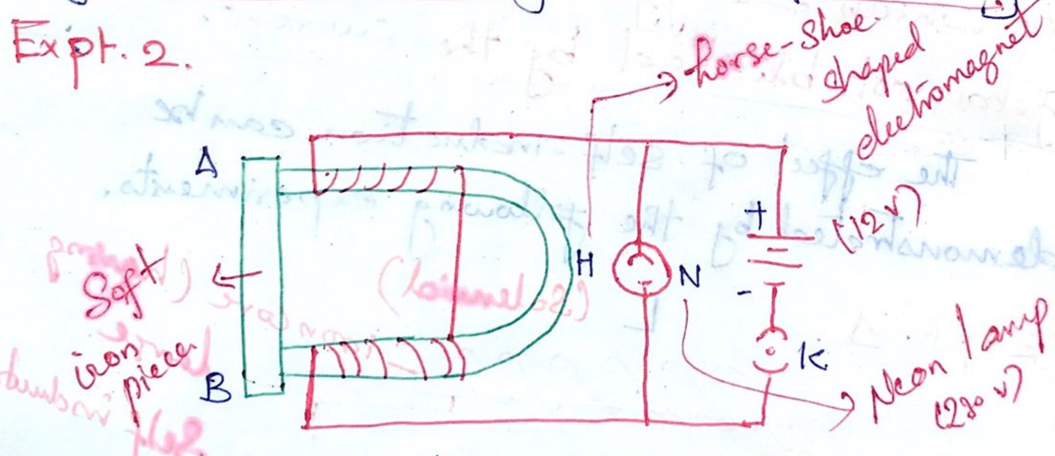
• Such a Solenoid is known as a ~~chocke~~ choke coil.

• The key K is pressed and the rheostat R is adjusted so that the bulb A just begins to glow.

• On Switching off the key K, the bulb A Suddenly glows very brightness in this case is greater than what it was at the time of make.

• This shows that the induced EMF due to Self-inductance in L at the time of break is greater than the original EMF of the battery.

Expt. 2.




• H is a horse-shoe shaped electro-magnet whose pole- pieces are joined.

• with the Soft iron piece AB, So as to complete the magnetic circuit.

- A neon lamp-N which works on 230 volts is connected as shown in fig.
- The EMF of the battery is a about 12 volts.
- when the circuit is closed with the key K, the lamp just glows.
- On the other hand, when the circuit is broken, the lamp flashes indicating that the momentary EMF ~~induction~~ induced at the time of break is more than 230 volts.
- This shows that the EMF induced at make (or) break is due to self-inductance of the coil.

co-efficient of Self-inductance
## Units of Self-inductance (தன் மின் நிலைம எண்)

- Consider a coil of N turns (சுற்றுக்களின் எண்ணிக்கை) carrying a current I.
- then the total magnetic flux (காந்தப்பாயம்) (or) linkage

$\phi \propto I$,

(or) $\phi = LI$ —— ①.

Differentiating eq ① with respect to time

$$\frac{d\phi}{dt} = L\frac{dI}{dt}$$

and back EMF, தூண்டு மின்னியக்கு விசை

$$e = -\frac{d\phi}{dt}$$

$$= -L\frac{dI}{dt} \quad —— ②$$

- The negative sign indicates that the direction of the induced EMF is such that it opposes the change, (i.e.), if the current is increasing $\frac{dI}{dt}$ is positive and the induced EMF, e is in the opposite direction

- If the current is decreasing, $\frac{dI}{dt}$ is negative and the induced EMF e is the same direction as the current.

From eq (i) if $I = 1$, then, $\boxed{\phi = L}$

Therefore, the co-efficient of self-inductance of a circuit is the total magnetic flux linked with it when a unit current passes through it.

From eq (ii), if $\frac{dI}{dt} = 1$

$$\boxed{e = -L}$$

Therefore, the co-efficient of self-inductance is equal to the induced emf in the circuit if the rate of change of current in the circuit is unity.

The rationalised MKS units (or) SI units of self-inductance is henry.

If $\frac{dI}{dt} = 1$ ampere/second

and $e = 1$ volt

then $L = 1$ henry

## Henry.

A coil has a self-inductance of one henry if the back EMF in it is one volt, when the current through it is changing at the rate of 1 ampere per second.

Equation (ii) then becomes,

$$e(\text{volt}) = -L(\text{henry}) \times \frac{dI}{dt} \text{ ampere/second.}$$

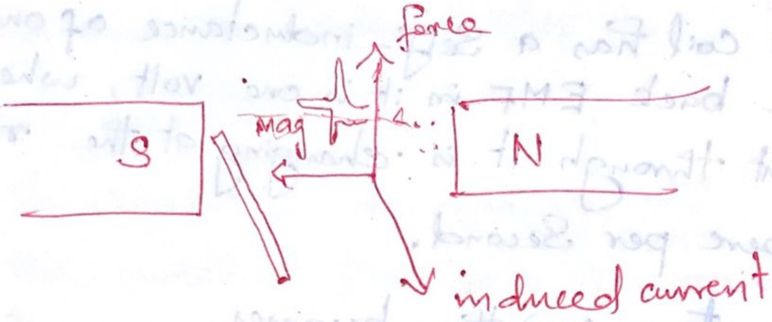
For practical purposes,

1 milli-henry = $10^{-3}$ henry.

1 micro-henry = $10^{-6}$ henry.

## Non-Inductive Coils.

- In bridge circuits, self-inductance is a drawback when resistance is to be measured.
- To minimise the effect of self-inductance in resistance coils, the coils are wound so as to set up extremely small magnetic fields.
- In this case the wire is doubly wound on itself before being coiled up.
- Such a coil is said to be non-inductive
- Each turn is in close contact with a similar turn carrying current in the opposite direction.
- The magnetic effect of one turn is completely neutralized by the other.




∴ The Conductor is Stationary there is no force and no induced current.

→ thus, the resultant magnetic flux and the self-inductance are negligibly small

In the case of a post office box and resistance box, all the resistance coils are non-inductively wound on bobbin