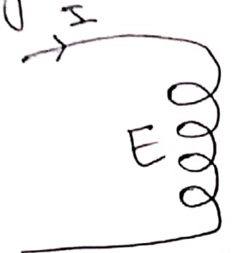
Faraday's Law of Electromagnetic Induction:-

Faradays performed a number of experiments after which he derived two important laws. These two laws are explained below:-

i).: **Faraday's First Law:-**

" whenever the magnetic lines of force passing through a circuit changes, an emf is induced."



Consider that the current flowing in the above coil is variable (i.e changing), then the flux produced by this current will be also variable because flux (ϕ) is given by:-

$$\phi = \frac{mmf}{S} = \frac{NI}{S}$$

→ Hence from the above relation, we can conclude that if current (I) is changing, then the respective flux (ϕ) produced by it will be also changing.

→ Note that from the above relation, we can see that No. of turns (N) and reluctance (S) for a coil will be constant.

→ Hence to vary flux (ϕ), current (I) should be varied.

→ Now according to Faraday's 1st law, this changing flux (ϕ) will produce the emf (E) in the coil.

The variable flux (ϕ) will be written as:-

$$\frac{d\phi}{dt}$$

Now to find out how much emf will be induced in the given ckt, Faraday's 2nd law explains it.

2):- Faraday's Second Law:-

"Induced emf will be directly proportional to the rate of change of flux" i.e

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

$$\boxed{e = N\frac{d\phi}{dt}}$$

Where N = No. of turns of the coil

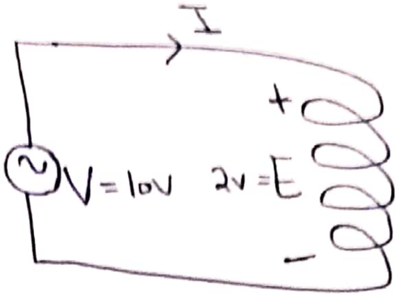
→ Hence in 1st law, Faraday said that emf is induced and in 2nd law, he concluded that how much emf is induced (i.e magnitude of the emf).

Lenz's Law:-

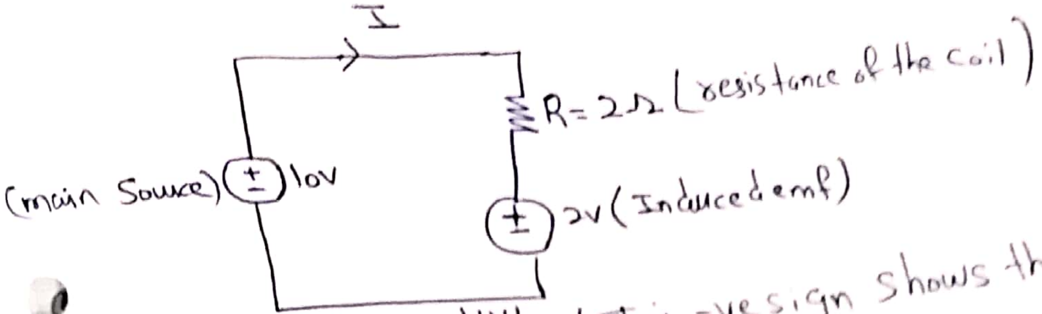
"The induced emf is such that it will oppose the cause which has produced it."

→ means that the induced emf will produce a current which will flow in opposite direction to the Source which has produced it.

Suppose we have a ckt as shown below:-



The above ckt can also be shown as:-

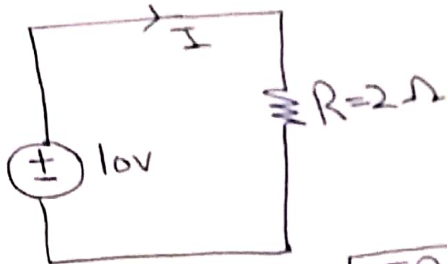


Applying KVL (This -ve sign shows the opposition)

$$10 - 2I - 2 = 0$$

$$8 = 2I \Rightarrow \boxed{I = 4A}$$

→ Suppose if we don't consider the induced emf (2V), then:-



Now $I = \frac{10}{2} = \boxed{5A}$

It means that induced emf is opposing the main Source i.e it has decreased the current from the main Source (∴ from 5A to 4A)

→ Lenz law basically gives the polarity of the induced emf.

Types of Induced Emf:-

1):- Dynamically Induced Emf.
2):- Stationary Induced Emf
a). Mutually Induced Emf
b). Self Induced Emf.

i):- Dynamically Induced EMF:-

• "when magnetic field is stationary and conductor cuts across it, the emf induced is known as dynamically induced emf".

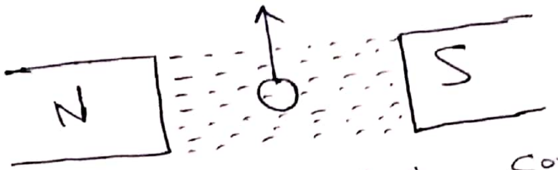
→ In the above case, the magnetic field is stationary.
• Now to induce emf in the conductor, we have to move it up and down (i.e at right and to the field) in order to induce the emf across it.

→ Note that in order to induce maximum emf, the angle b/w the field and movement of conductor should be 90°.

Fleming's Right Hand Rule:-

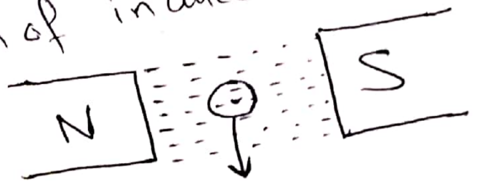
"When a conductor moves in a uniform magnetic field and cuts the magnetic lines of force, an emf is induced."

Thumb = Force
First finger = Field
middle finger = Induced Emf (or current)



→ Suppose motion of the conductor (o) is upward. Then, according to Fleming's R.H.R, direction of induced emf (or current) will be inward i.e $\{ \oplus \uparrow I \}$

→ Suppose if motion of the conductor is downward. Then, direction of induced emf will be outward. i.e $\{ \ominus \downarrow \}$



Equation of Emf induced in a moving conductor in a uniform magnetic Field:-

Suppose we move the conductor by a small distance (dx) in a uniform magnetic field (B). Then movement of conductor is:-

movement $= dx$

also length of the conductor $= L$

Total area covered by the conductor $= L\,dx$

Also, flux density $(\phi) = B \cdot A$

$= B(L\,dx)$

also, $e = N \dfrac{d\phi}{dt}$

Here $N = 1$ (As we have considered only 1 conductor).

Hence $e = BL\frac{dx}{dt}$

Also velocity $= \frac{\text{distance}}{\text{time}}$

So the velocity of the conductor $= \frac{dx}{dt}$

Hence $e = BLV\sin\theta$

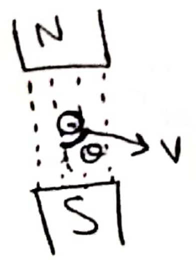
where θ is the angle b/w B & L and e will be maximum when $\theta = 90°$.

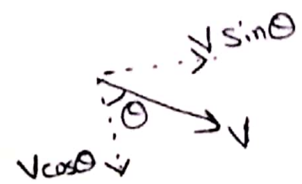
$$\boxed{e = BLV}$$

Why $\sin\theta$?

→ The equation $e = BLV$ is the induced emf when plane of motion is exactly perpendicular to the plane of flux.

→ But if conductor is moving with a velocity (v) but at a certain angle (θ) measured with respect to the plane of the flux as shown below:





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Then the component of the velocity which is, $V\sin\theta$, is perpendicular to the direction of flux and hence is responsible for the induced emf.

→ The other component, $V\cos\theta$, is parallel to the plane of the flux and hence, will not contribute to the dynamically induced emf.

under this condition, magnitude of induced emf is, thus, given by:-

$$\boxed{e = BLV\sin\theta}$$

Q:- A conductor of 2m moves with a uniform velocity of 1.27m/s under a magnetic field having a flux density of 1.2wb/m². If conductor moves, calculate the magnitude of induced emf.

a):- at right angle to the axis of field.

b):- at an angle 60° to the direction of field.

Given Data:-

$L = 2m$

$V = 1.27 m/s$

$B = 1.2 wb/m^2$

a):- $\theta = 90°$ b) $\theta = 60°$

Required:-

$e = ?$

Solution:-

a):: for $\theta = 90^\circ$

$e = BLV \sin\theta$

$e = (1.2)(2)(1.27) \sin 90^\circ$

$\boxed{e = 3.048V}$

b):: for $\theta = 60^\circ$

$e = (1.2)(2)(1.27) \sin 60^\circ$

$\boxed{e = 2.6397V}$