Electrodynamics

In electrodynamics,
changing electric & magnetic field with time.
Now, the fields are time variable.
Static mag. field is produced by steady current.
" electric " " " charge at rest.

Steady Current – charges are not accumulating anywhere.
If current I is the fun^n of time then Magnetic field will also be the fun^n of time.

$$I(t) \longrightarrow B(t)$$

If Mag. field is time dependent then Mag. field & elec. field are dependent on each other.
Time dependent mag. field can produce time dependent Elec. field
" " Elec. " " " Mag. "

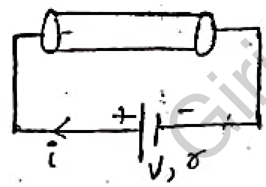
$$I(t) \longrightarrow B(t) \longrightarrow E(t)$$

ElectroMotive force (emf) :-

Electro motive force is Work done per unit charge.
emf is denoted by $\mathcal{E}$,

$$\mathcal{E} = -\int \vec{E}\cdot d\vec{l}$$

$\vec{F}\cdot d\vec{l}$ is Work done ~~/ unit charge~~
$\vec{E}\cdot d\vec{l}$ Work done per unit charge
If we have a wire connected to battery then it is conducting & battery supply the force then free charge in wire are in motion & produce Work. This work is done by battery. This work done is emf.
If battery pot^n is $V - iR$
Internal resistance is r

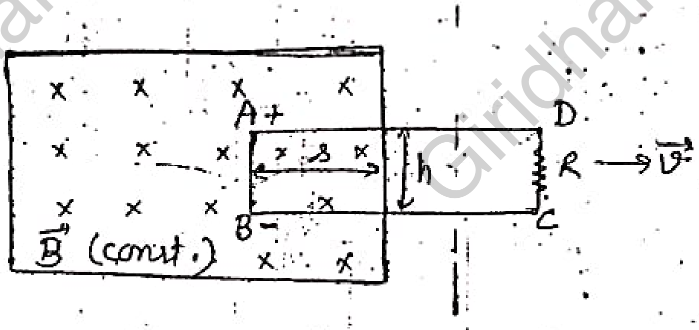


then By Battery do work by this potⁿ $V - iR$. So emf or work done per unit charge is $\Rightarrow$ emf $\varepsilon = V - ir$

Motional Electromotive force (emf) :-

Generators uses motional emf concept to generate power. This type of emf arrises when a conducting loop moves in a constant mag. field i.e. $\vec{B}$ remains constant with time.

Let us consider a wooden block. In this we have a closed loop. A resistance is connected with loop. If someone is pulling the loop then mag. flux changes.



Mag. flux passes through a closed surface is always zero.

$$\phi_m = \int_S \vec{B} \cdot d\vec{s} \qquad \left\{ \phi_m = \oint \vec{B} \cdot d\vec{s} = 0 \right.$$

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

This is closed loop but open surface bcoz closed surface bound some volume.

It works on Faraday's law.

Acc. to Faraday law,

Changing flux always induces the emf & dirⁿ of emf is s.t. it oppose the change.

If flux is ↑ then dirⁿ of emf is s.t. try to ↓ it. i.e. we take −ve sign.

i.e. $\boxed{\varepsilon = -\frac{d\phi_m}{dt}}$ → Faraday's law

⇒ Change in flux can be of 3 types.

(i) Either change $\vec{B}$, or (ii) change area ds or (iii) change the angle b/w $\vec{B}$ & $d\vec{s}$. $\phi_m = \int_S B\, ds \cos\theta$

In case of Motional emf,
B is always constant.
So flux can be changed due to either by changing area or by change angle b/w them.
If we pull the loop out then s will varry so area will change.
To find motional emf, we use formula,

$$\boxed{\varepsilon = \oint \vec{f}_{mag} \cdot d\vec{l}}$$

$\vec{f}_{mag} \rightarrow$ Magnetic force per unit charge.

$\Rightarrow$ In the present case, when loop is pulled with vel. $\vec{v}$ then amount of emf = ? Current in resistance & dir = ?
If a charge is moving with vel. $\vec{v}$ in mag. field $\vec{B}$ then force on charge

$$\vec{f}_{mag} = \vec{v} \times \vec{B} \quad \text{if charge is +ve}$$

$$f_{mag} = \vec{B} \times \vec{v} \quad \text{if " " -ve}$$

Here Consider charge is +ve. for +ve charge the dir^n of $\vec{f}_{mag}$ will be upward.
& force on e^- will be downward.

A → +ve
B → -ve

Current will flow due to motion of charges.
Now part AB will behave like a battery. & Current will flow from +ve to -ve terminal. i.e. A → B.
If AB is perfect conducting wire then its resistance = 0.
Hence AB part of loop is only contributing to the emf.

$$\varepsilon = \oint \vec{f}_{mag} \, d\vec{l}$$

$$= vB \int dl$$

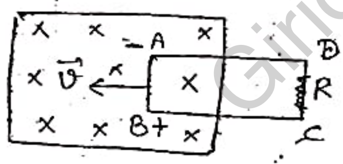
$$\boxed{V = \varepsilon = vBh}$$

& current $V = iR \Rightarrow i = \frac{V}{R}$

$$\boxed{i = \frac{vBh}{R}}$$

& dir^n of flow is from $D \to C$

- If loop is pulling in opposit dir^n



force on +ve charge downward

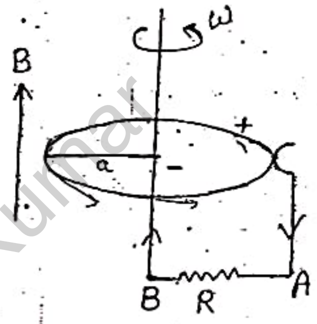
" " e^- upward.

then $A \to -ve$ & $B \to +ve$

& Now Current will flow from $C \to D$.

Que:- A metal disc of radius 'a' rotates with angular velocity ω about vertical axis through a uniform mag field $\vec{B}$ pointing in the upward dir^n. A circuit is made by connecting one end of the resistor to the axle & other two to the sliding contact which touches the outer edge of the disc. Find the current in the resistor with dir^n.

If charges are not in motion then no change in flux & there will be No emf.



Emf induces due to motion of charges.

In present case due to the motion of charges, their area is changing bcoz disc is rotating & charges are displacing from their position.

$$\vec{\omega} = \omega \hat{z}$$

$$\vec{v} = \vec{\omega} \times \vec{r}$$

$$= \omega r (\hat{z} \times \hat{r})$$

$$\boxed{\vec{v} = \omega r \hat{\phi}}$$

$\vec{r} \to$ radius vector of the disc having dir^n $\hat{r}$.

for charges of on the circumference the speed v is constant (same) but for all other charges speed is different.

force per unit charge,

$$\vec{f}_{mag} = \vec{v} \times \vec{B}$$

$$= \omega r \hat{\phi} \times B \hat{z}$$