Motional EMF :-

Considering a rod of length l moving with velocity v and placed in a magnetic field B such that $\vec{v}$, $\vec{l}$ and $\vec{B}$ are mutually ⊥ as shown.

Since, free electron experiences a magnetic force downward, it accumulates at the bottom of the rod which results an electric field in the downward direction as shown.

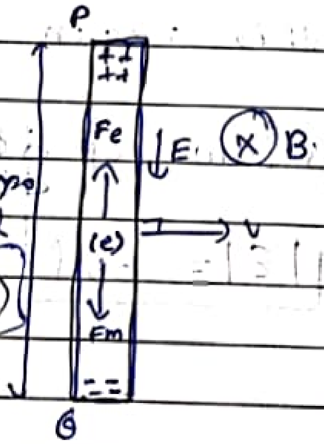
Due to this electric field, free electron again experiences a force upward and hence this redistribution will take place until electric force becomes equal to magnetic force as calculated.

$\Sigma \vec{F} = 0$

$\vec{F}_e + \vec{F}_v = 0$

$-e\vec{E} + (-e)(\vec{v} \times \vec{B}) = 0$

$\vec{E} = -(\vec{v} \times \vec{B})$



$$\vec{F_m} = -e(\vec{v} \times \vec{B})$$
$$\vec{F_e} = -e\vec{E}$$

When, $|\vec{F_e}| = |\vec{F}_m|$

$$e(|\vec{E}|) = e(|\vec{v} \times \vec{B}|)$$
$$|\vec{E}| = |\vec{v} \times \vec{B}|$$

or $\vec{E} = -(\vec{v} \times \vec{B})$

Potential difference b/w P and Q

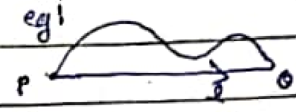
$$\int_{V_P}^{V_Q} dV = -\int \vec{E} \cdot \vec{dl}$$

$$V_P - V_Q = \int -(\vec{v} \times \vec{B}) \cdot d\vec{l}$$

↳ in the direction of E

$$\boxed{V_P - V_Q = Blv}$$

eg:



This potential difference is developed due to magnetic force which is non-electrostatic in nature. Hence, this potential difference can be called as Emf.

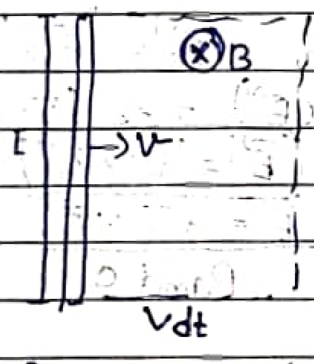
$$\boxed{Emf = \mathcal{E} = \Delta V = Blv}$$

Faradays Law applies in explaination of motional emf :-

Due to motion of the conductor magnetic field lines is being cut by the metallic rod. Hence in time dt it sweeps an area i.e. $dA = vdt \times l$

Hence flux through this area in time dt is $d\phi = B\,dA$

∴ from faraday's Law $|\mathcal{E}| = \frac{d\phi}{dt}$



$$\boxed{|\mathcal{E}| = Bvl}$$

Derivatio

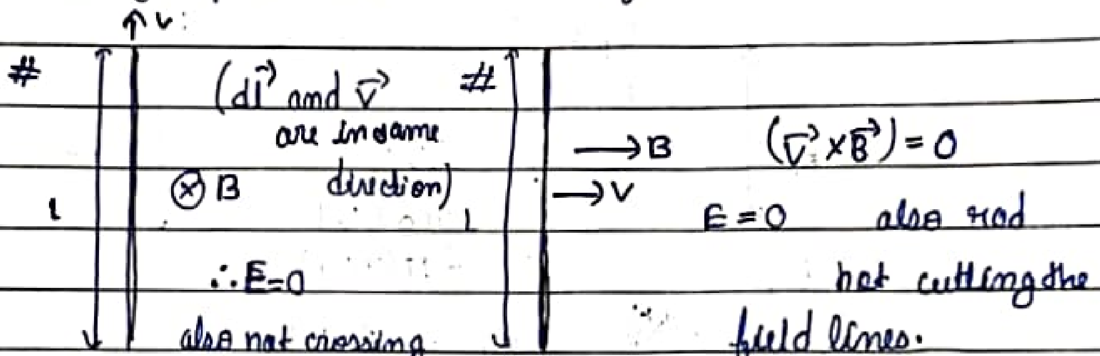
Direction of Induced Emf :-

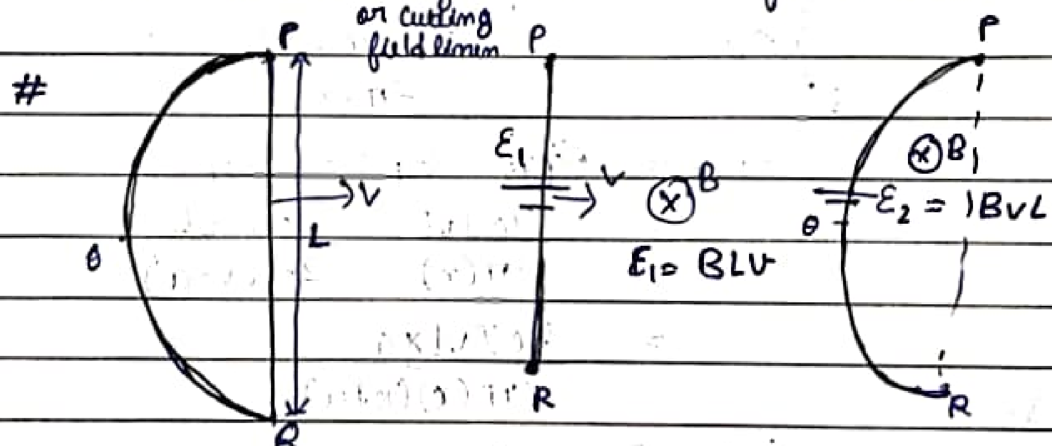
1) **Right Hand Thumb Rule:**

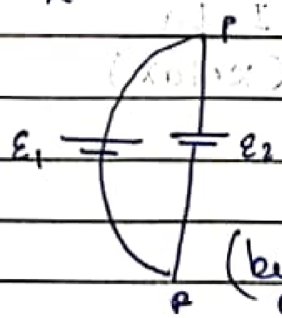
When we follow the cross product rule in ($\vec{v} \times \vec{B}$) then the direction of thumb is towards an end of the conductor which is / at the higher potential.

2) **Flemings Right Hand Rule:**

Place the fore finger, middle finger and thumb of right hand mutually ⊥ . Fore finger points in the direction of magnetic field, thumb points in the direction of velocity then the middle will point towards the high potential end of the conductor.







$E = \varepsilon_1 - \varepsilon_2 = 0$

↳ net emf in the loop

(by faraday's law → flux is not changing)

$\therefore E = 0$

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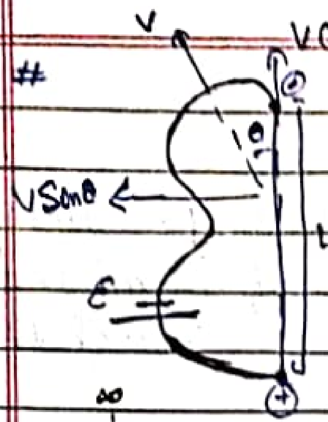
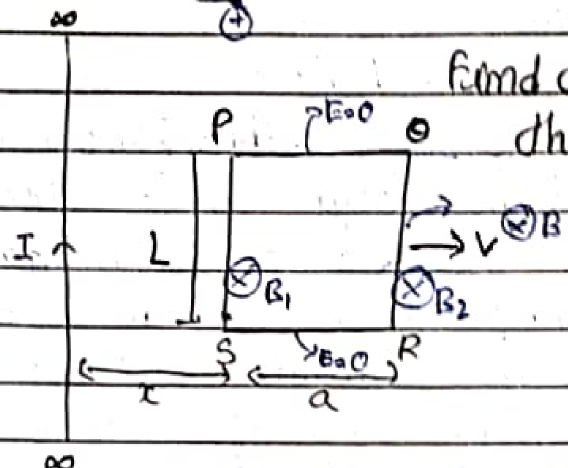
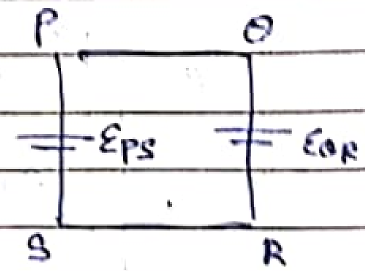


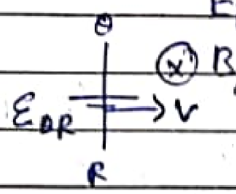
$\mathcal{E} = Blv \sin\theta$

Q. Find the emf induced in the loop.



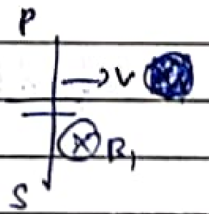
$E_{PQ} = 0 \qquad E_{SR} = 0$





$\mathcal{E}_{QR} = B_2 vL$

$= \frac{\mu_0 I vL}{2\pi(x+a)}$



$\mathcal{E}_{PS} = B_1 vL$

$= \frac{\mu_0 I vL}{2\pi(x)}$

$\mathcal{E}_{net} = \mathcal{E}_{PS} - \mathcal{E}_{QR}$

$= \frac{\mu_0 I vL}{2\pi(x)} - \frac{\mu_0 I vL}{2\pi(x+a)}$

$= \frac{\mu_0 I vL \times a}{2\pi(x)(x+a)}$

$\mathcal{E}_{net} = \frac{\mu_0 I vLa}{2\pi(x^2+ax)}$ //