DC M/C :-

1. Fleming's Right Hand Rule
2. " Left Hand Rule

→ Induced Emf Dirⁿ?

$$\left(\vec{E} = l\,\vec{v} \times \vec{B}\right)$$

velocity

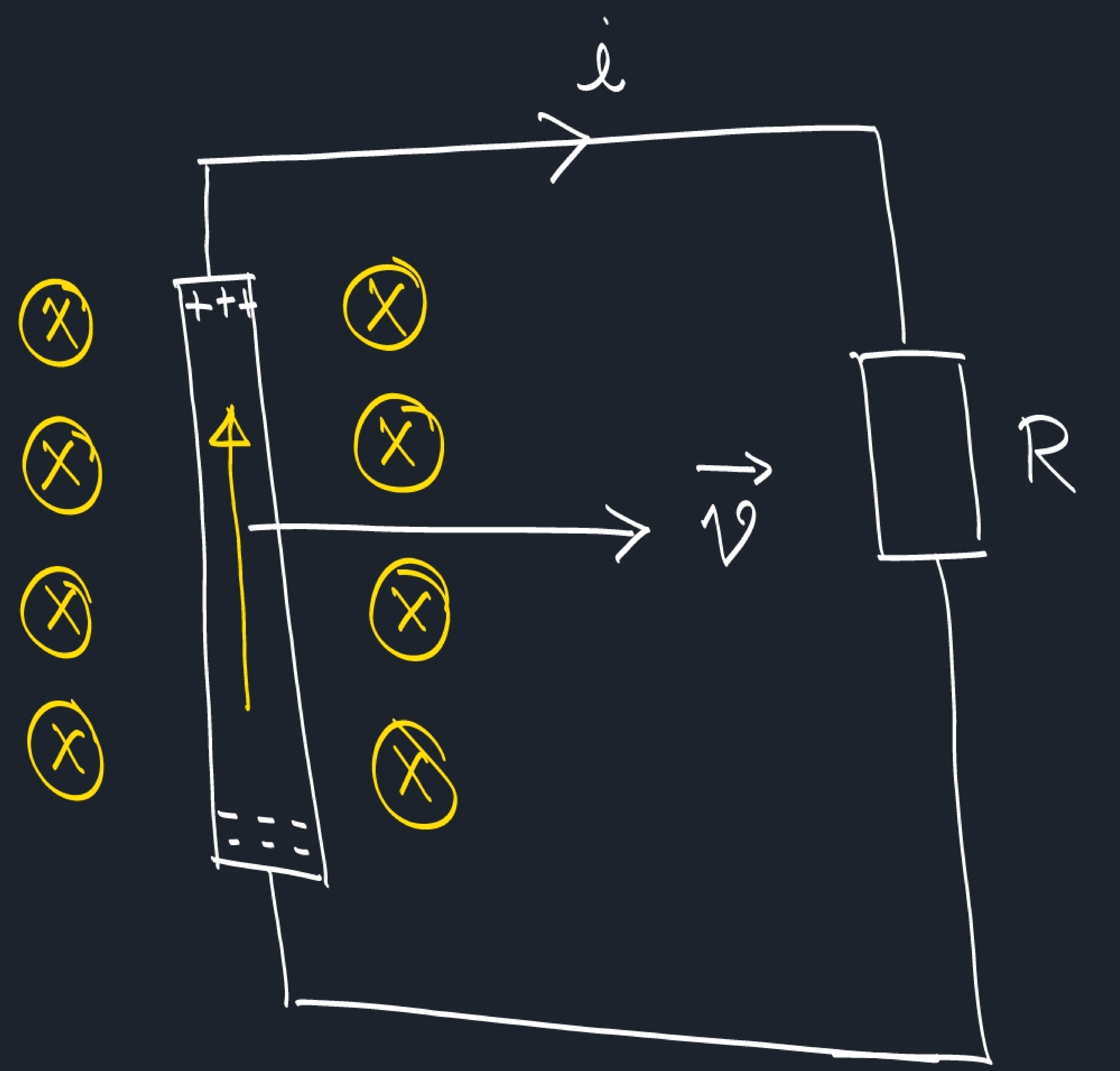
Magnetic Flux Density

Charge.

$$\left\{ q.\vec{v} \times \vec{B} \right\}$$

velocity

MFD.



$$i = \frac{Blv\sin\theta}{R}$$

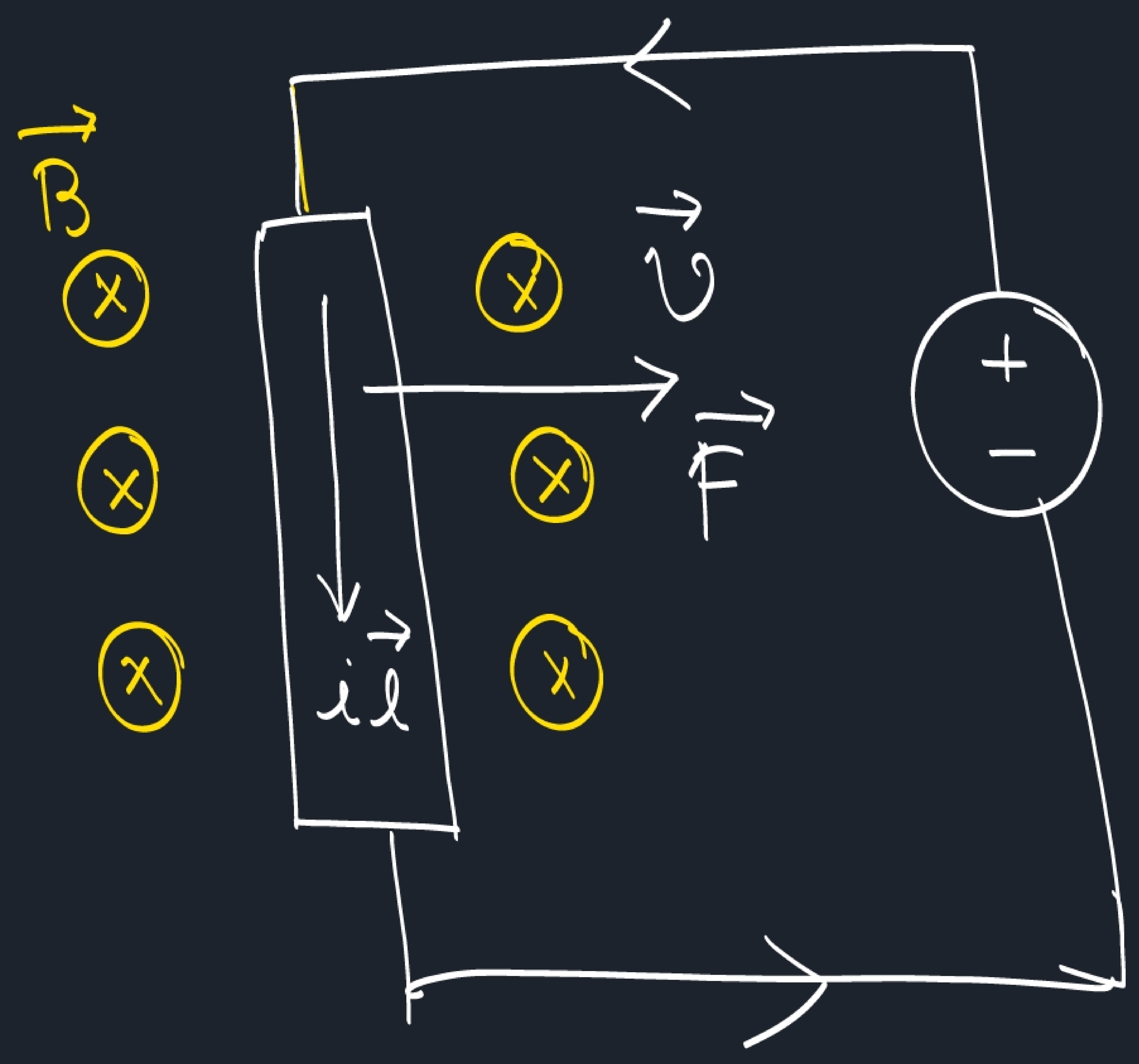
$$\boxed{i = \frac{Blv}{R}}$$

4. Flemings Left Hand Rule :-

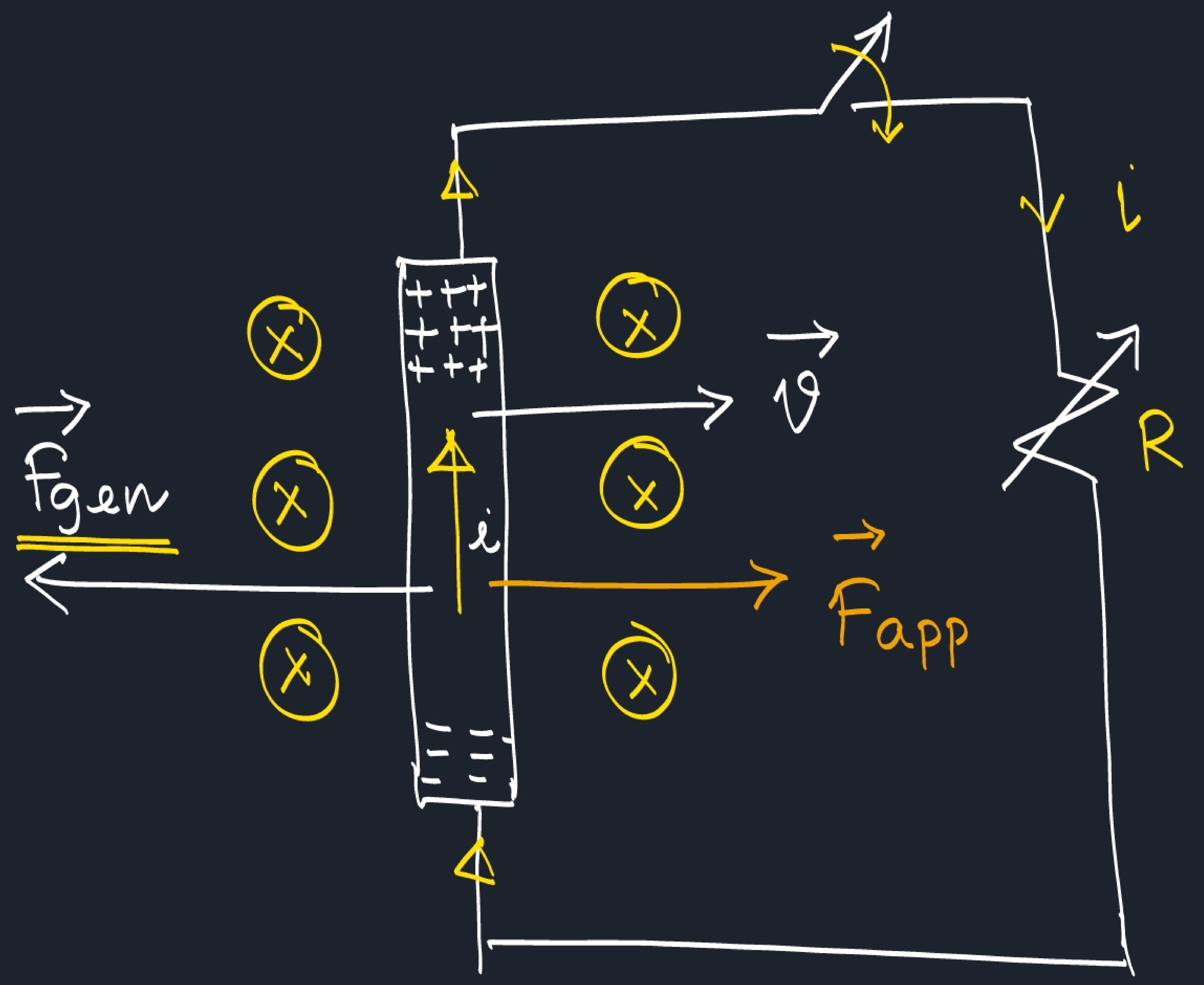
→ Dir^n of Force on Current carrying Conductor.

$$\left(d\vec{F} = i\,d\vec{l} \times \vec{B}\right)$$

$$\left(\vec{F} = i\vec{l} \times \vec{B}\right)$$



DC Generator :-



$$\vec{E} = l\vec{v} \times \vec{B}$$

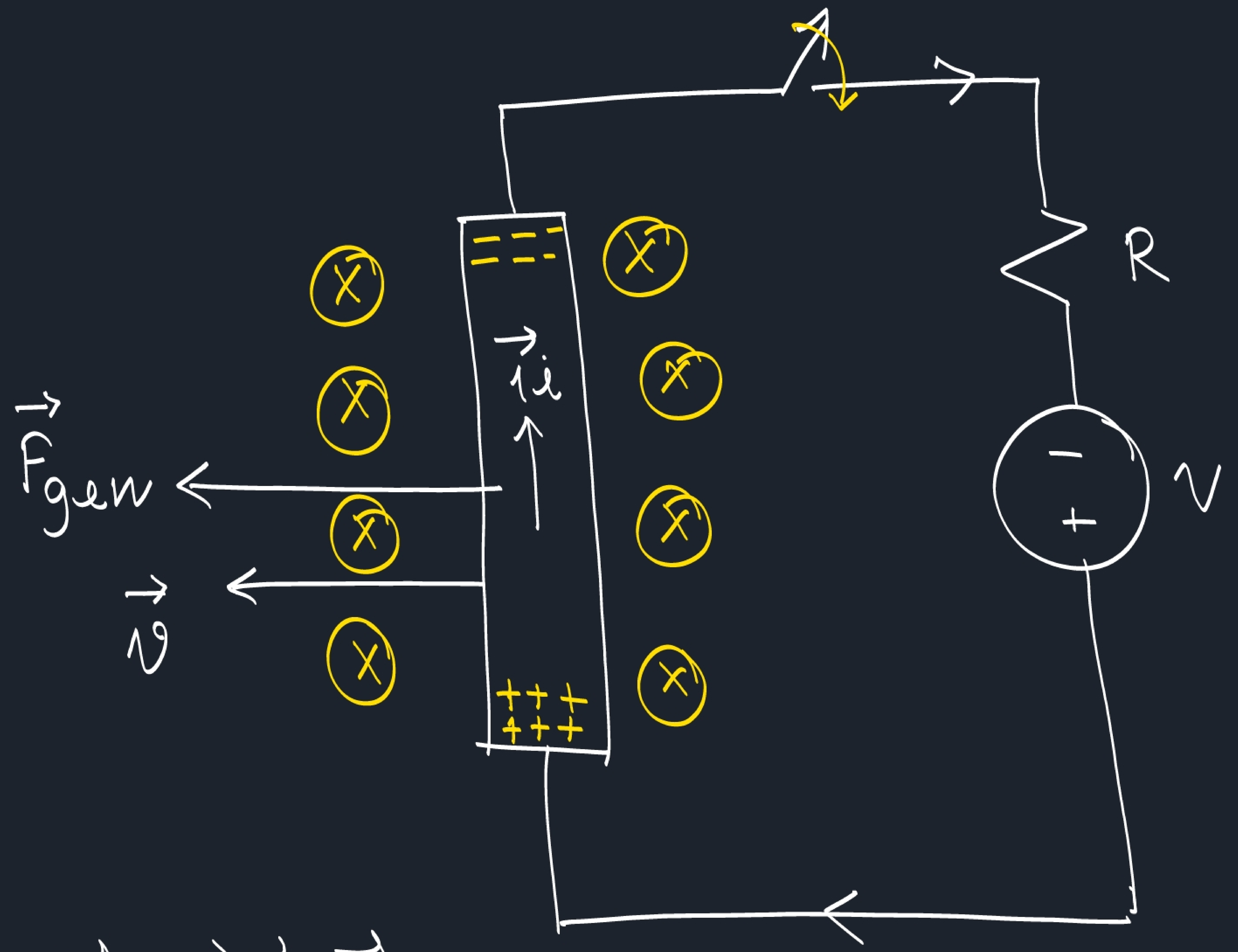
$$i = \frac{Blv}{R}.$$

$$|F_{app}| = |F_{gen}|$$

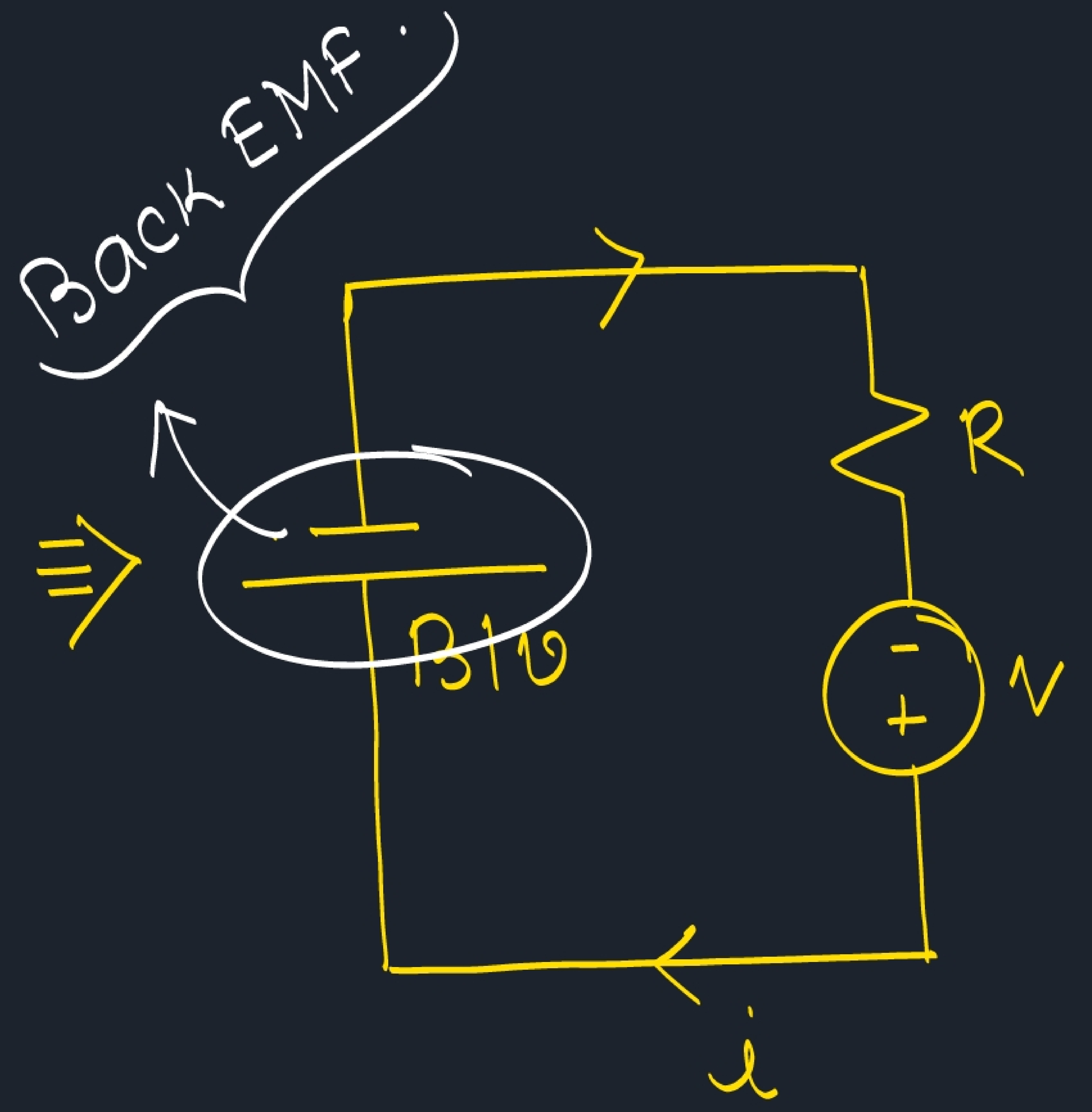
Must have to have a prime mover.

electromagnetic Torque is in the opposite dirn. of angular velocity.

DC Motor :-



$\vec{E} = \vec{l}\,\vec{v} \times \vec{B}$

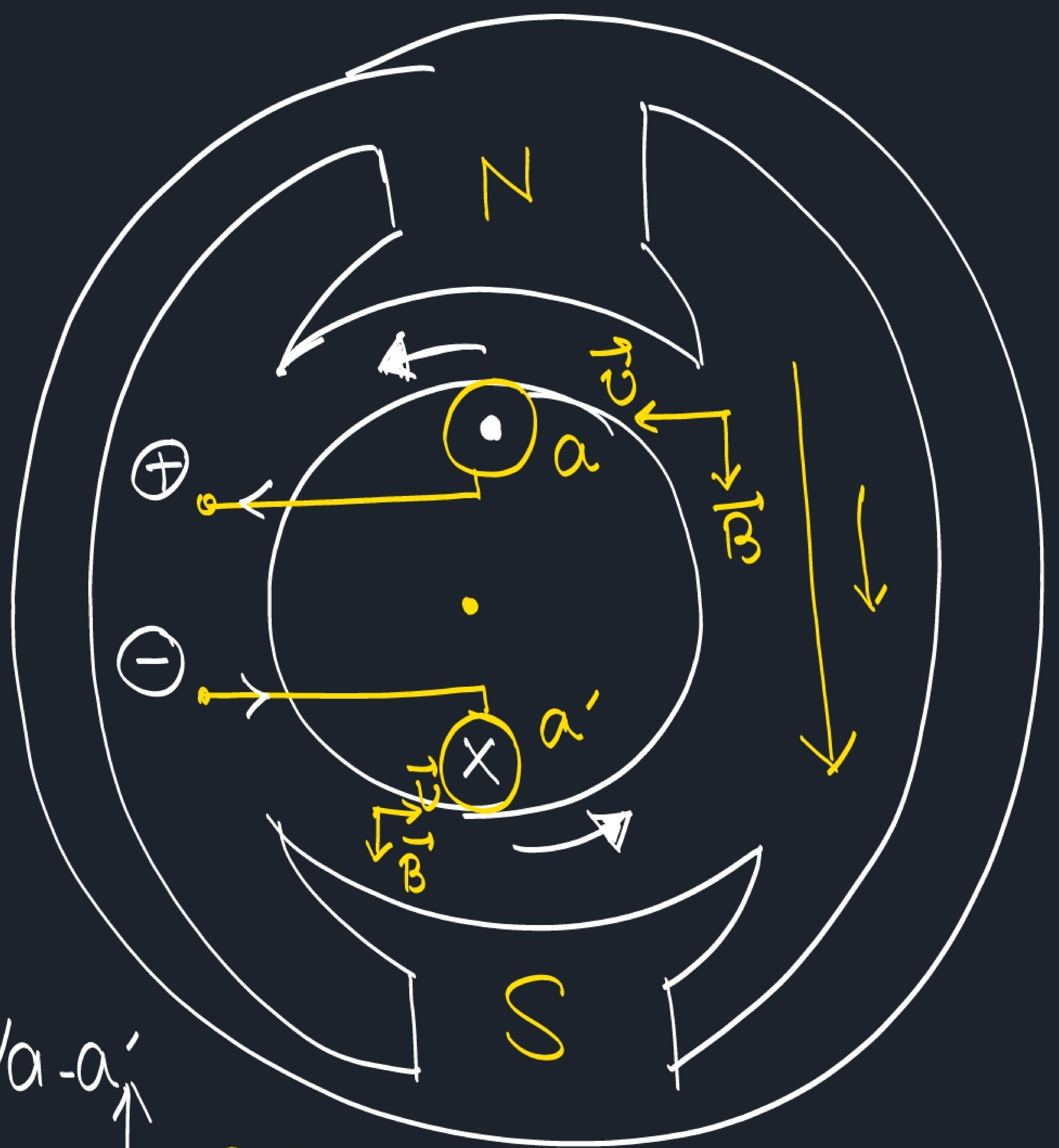


$$\boxed{i = \frac{V - Blv}{R}}$$

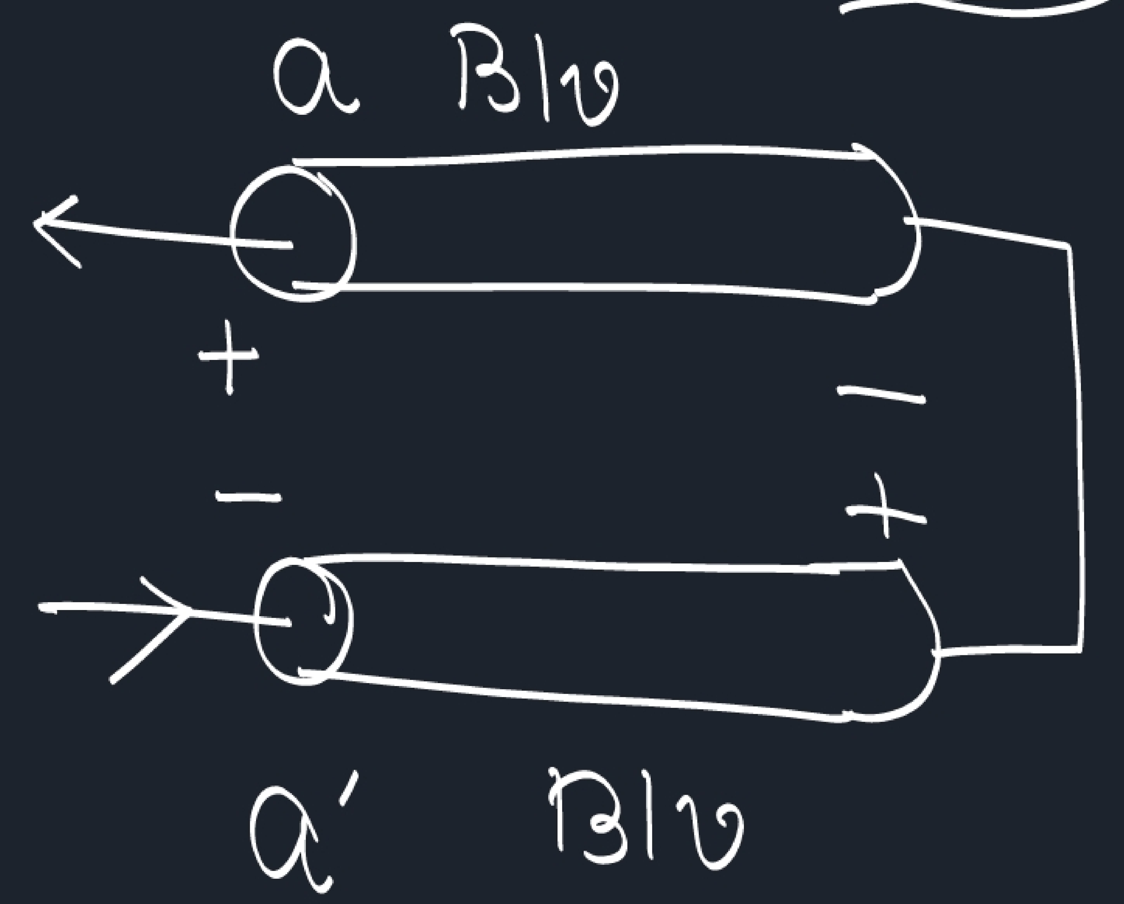
③ DC Gen:-

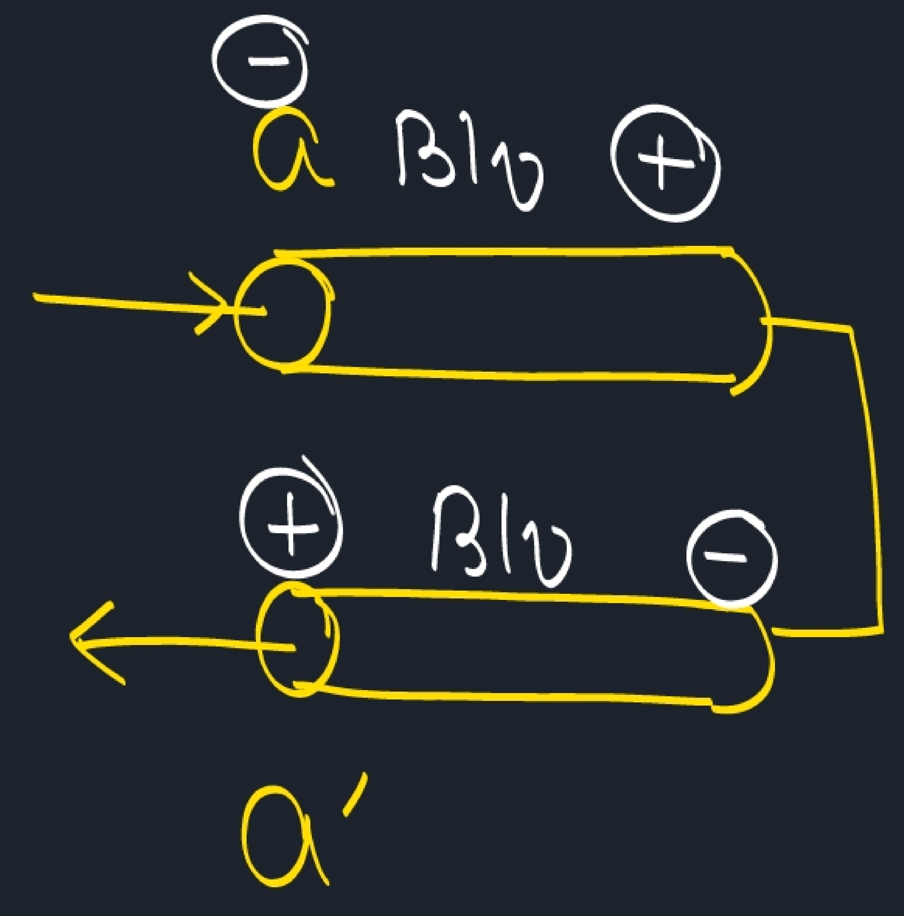
Stator → Keep The magnets.

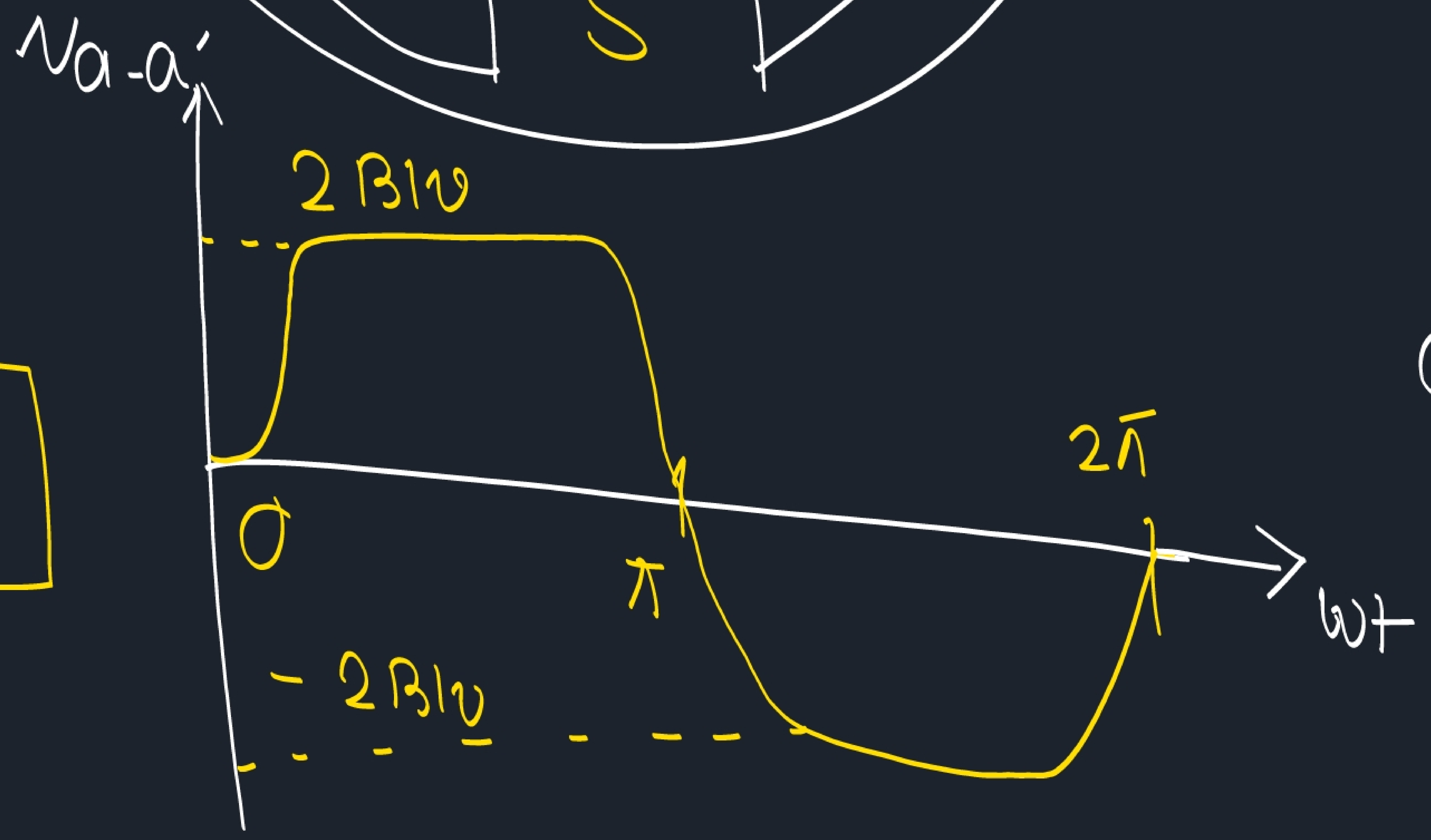
Rotor (Armature) → Place Conductors

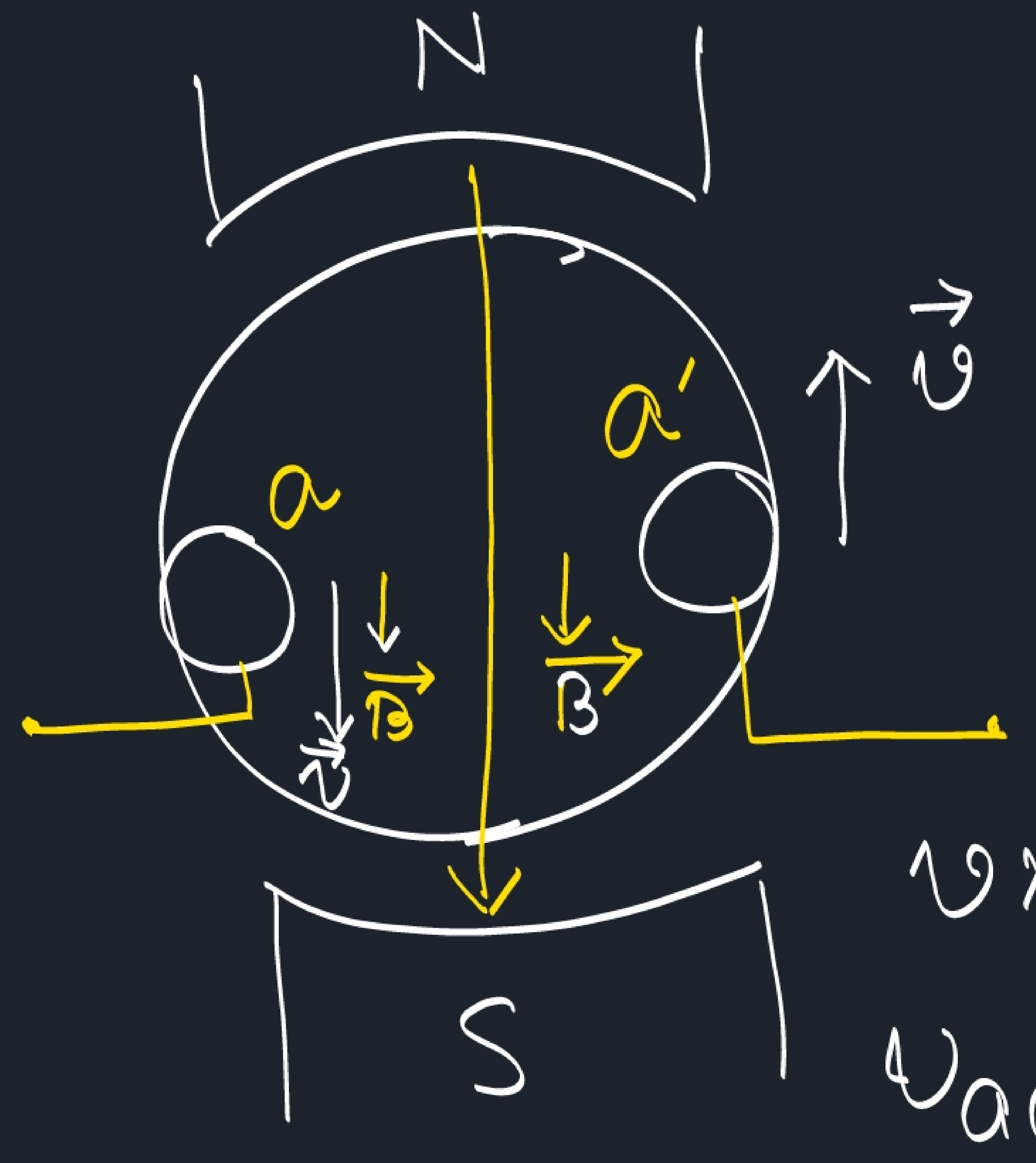


$$v_{aa'} = Blv - (-Blv)$$
$$= \boxed{2Blv}$$



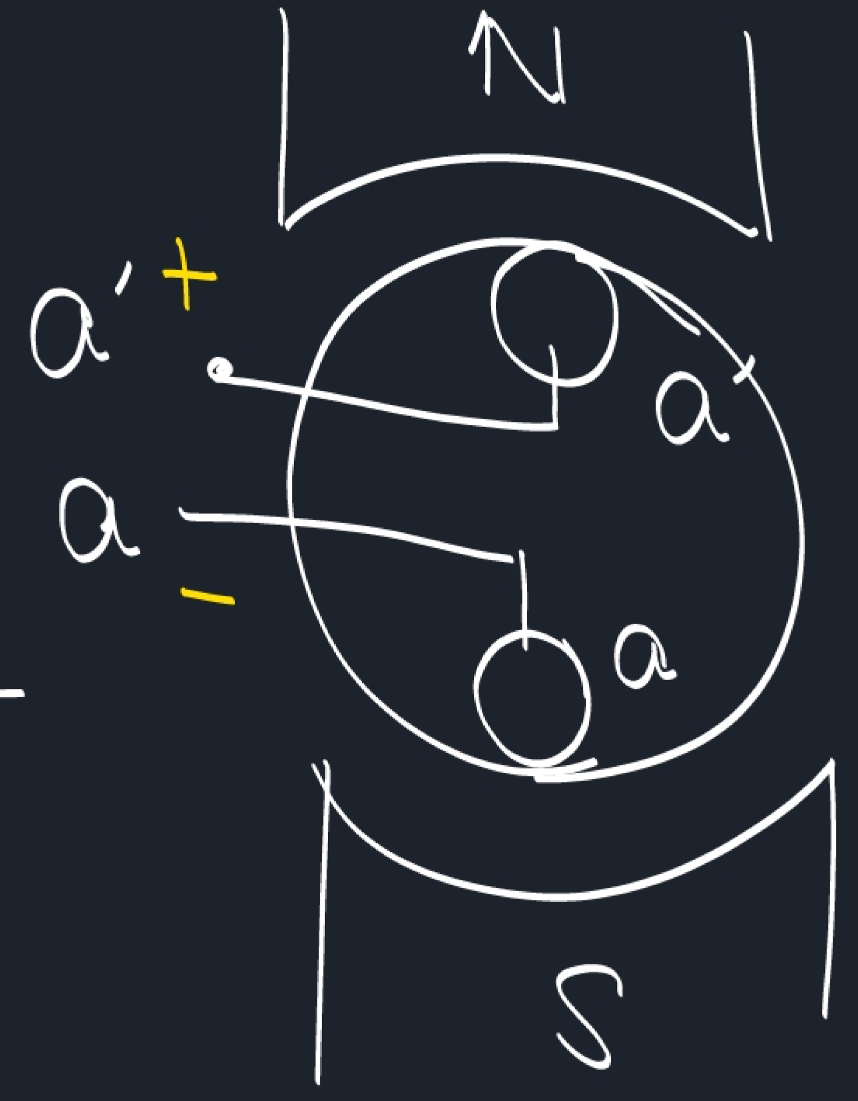






$\vec{v} \times \vec{B} = 0$

$v_{aa'} = 0$

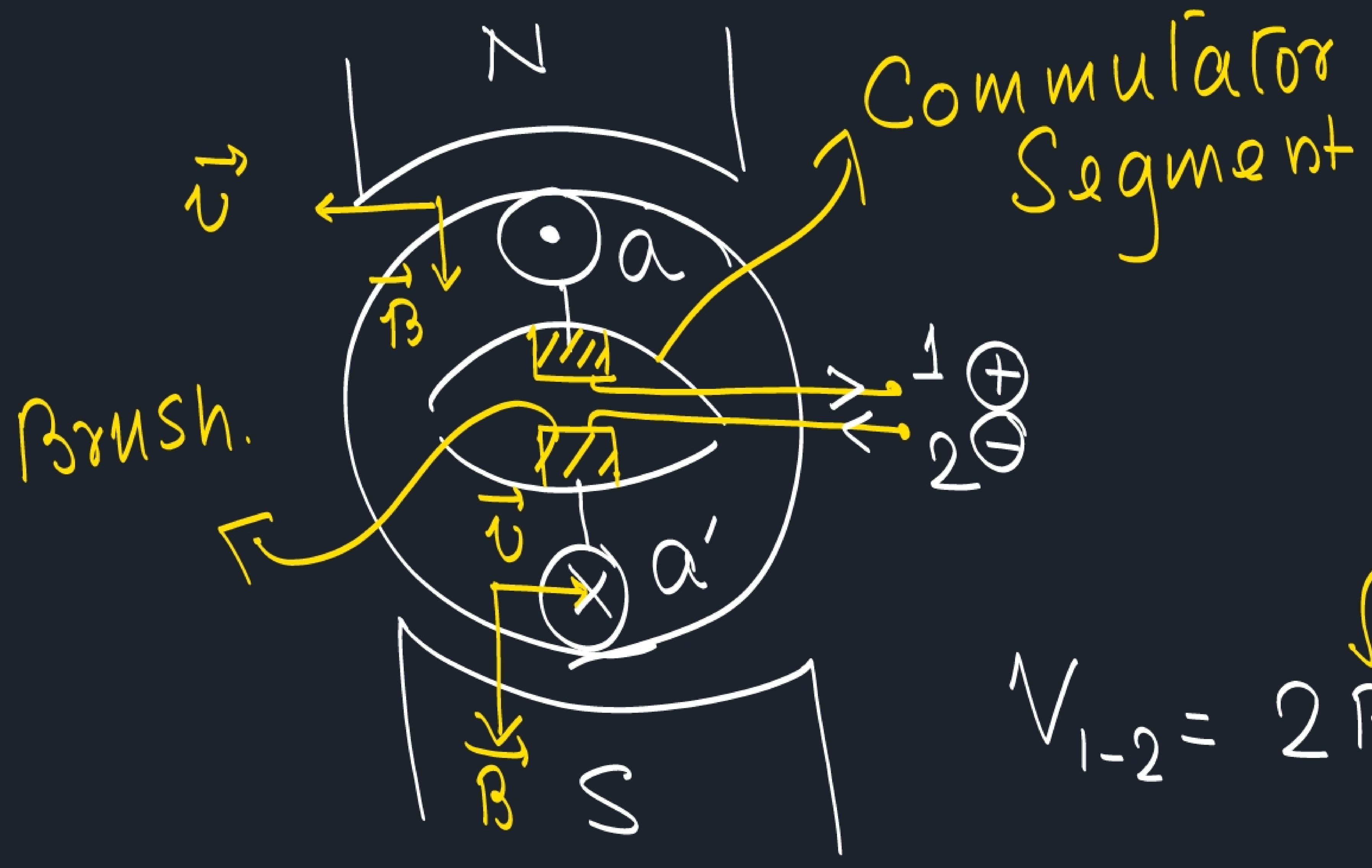


$V_{a-a'} = -2Blv$

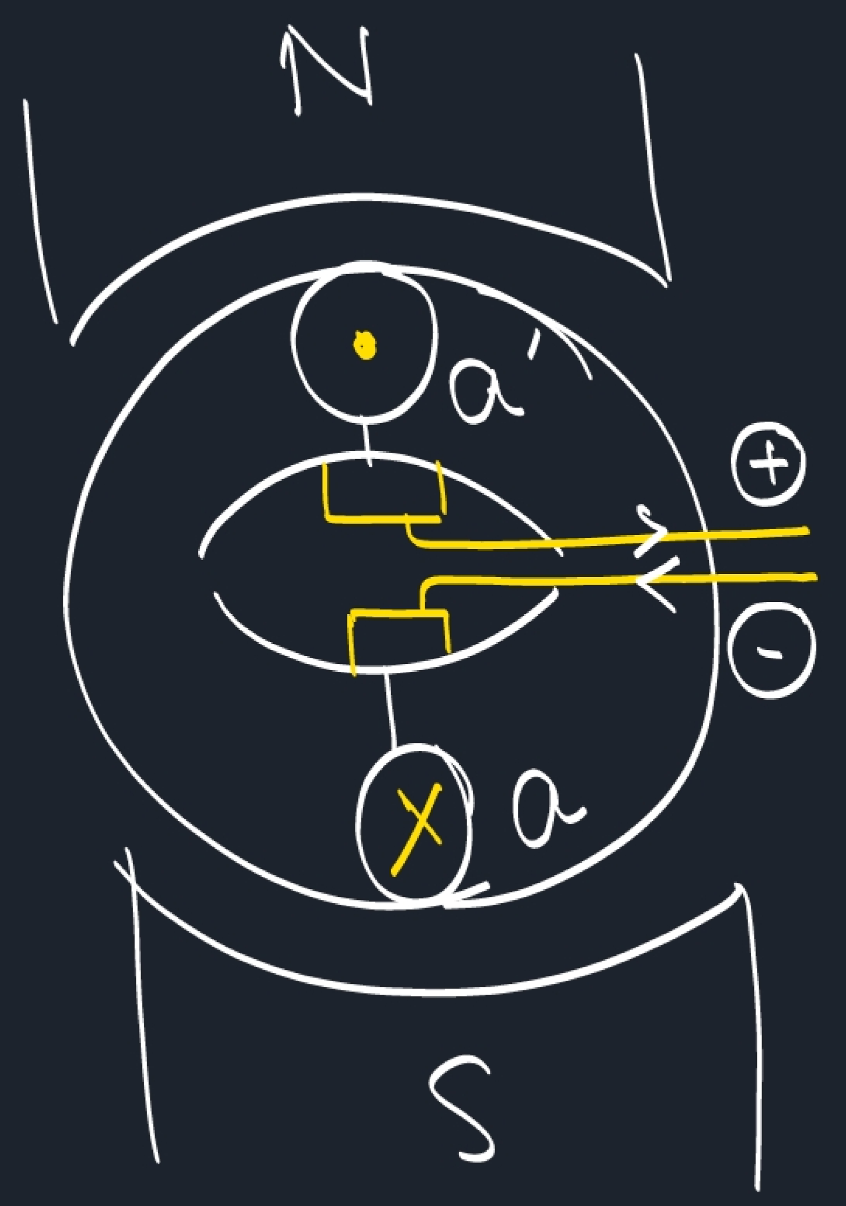
Brush + Commutator Arrangement :-

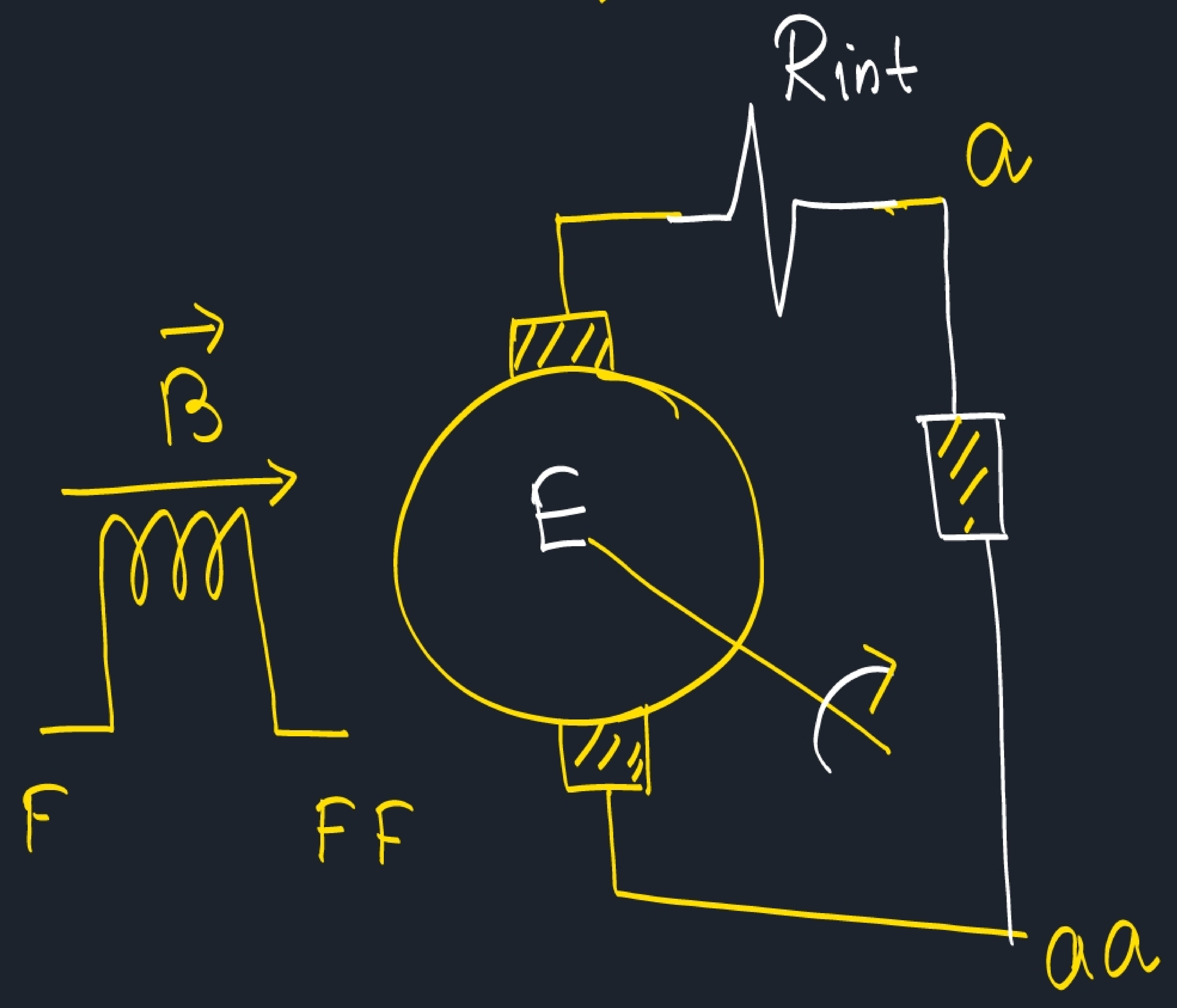
Static — AC → DC

Rotating

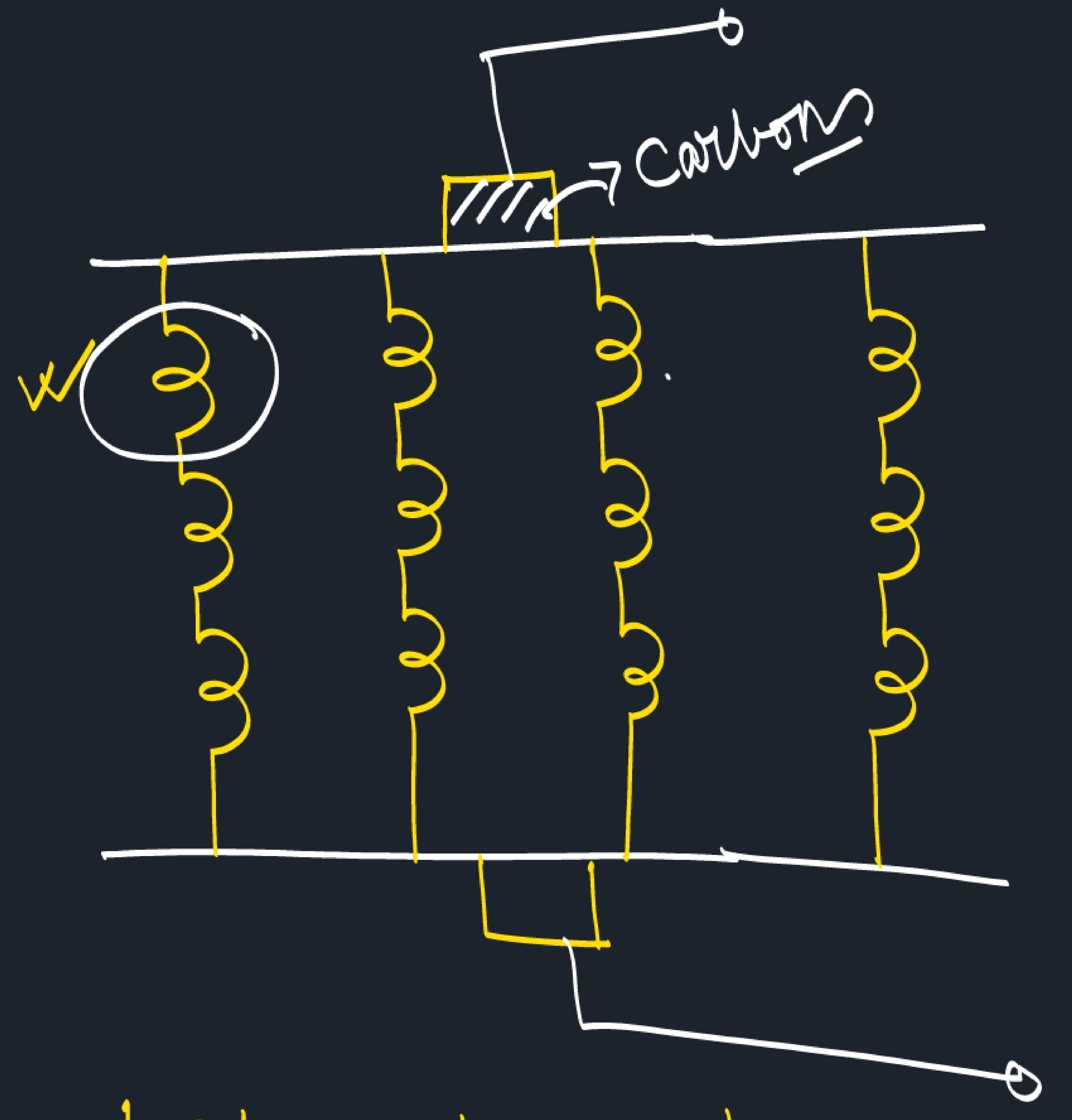


$$V_{1-2} = 2Blv.$$





$$\boxed{P = V I}$$



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

$$\boxed{E = \frac{\phi P N}{60}\left(\frac{Z}{A}\right)}$$

Z = Total no. of Armature Conductors.

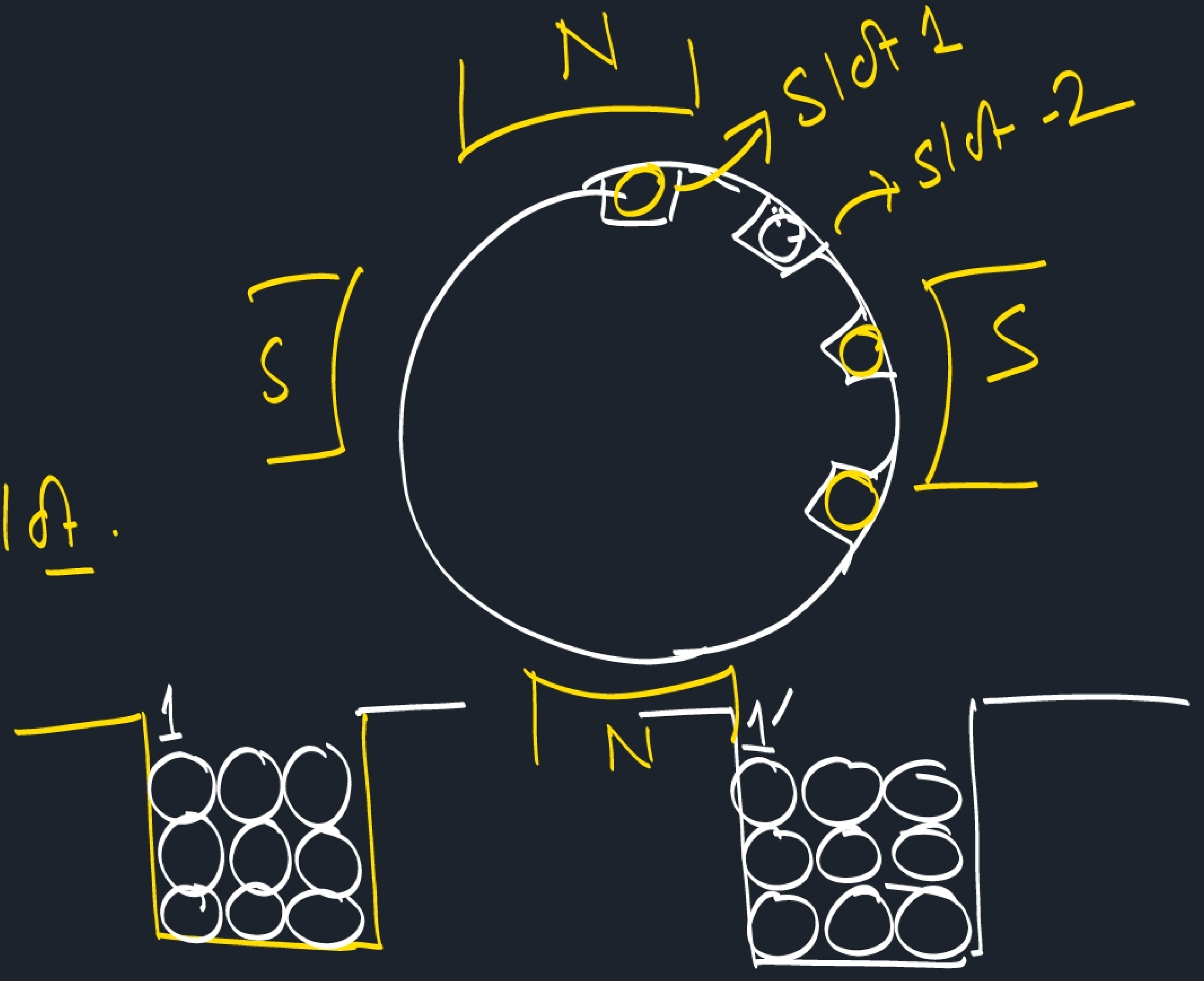
= Total no of Slots × Armature conductors per Slot.

A = no of Parallel Path

$\frac{Z}{A}$ = Conductors / Parallel Path.

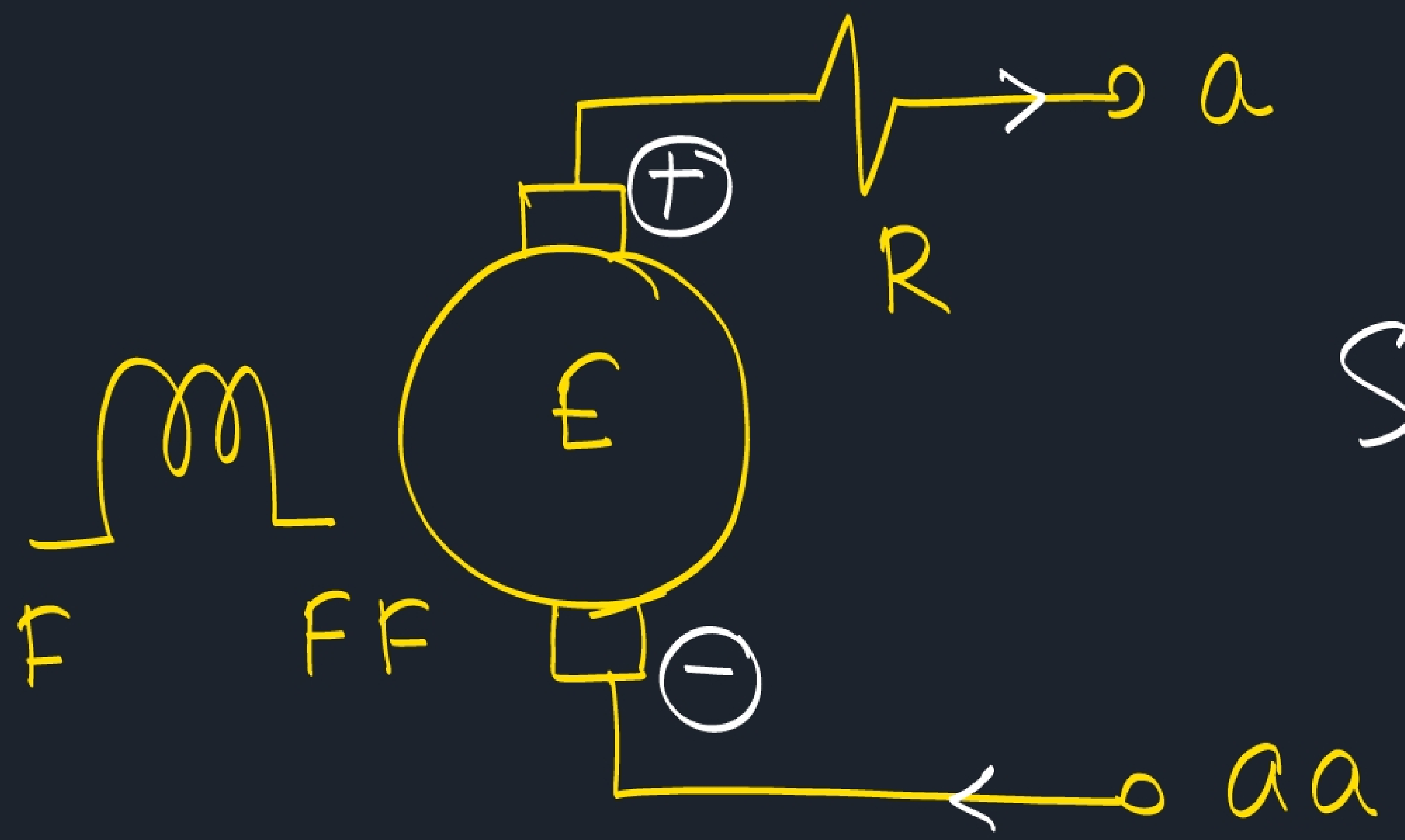
P = No of poles. ϕ = flux/Pole.

N = Rotational Speed (RPM)

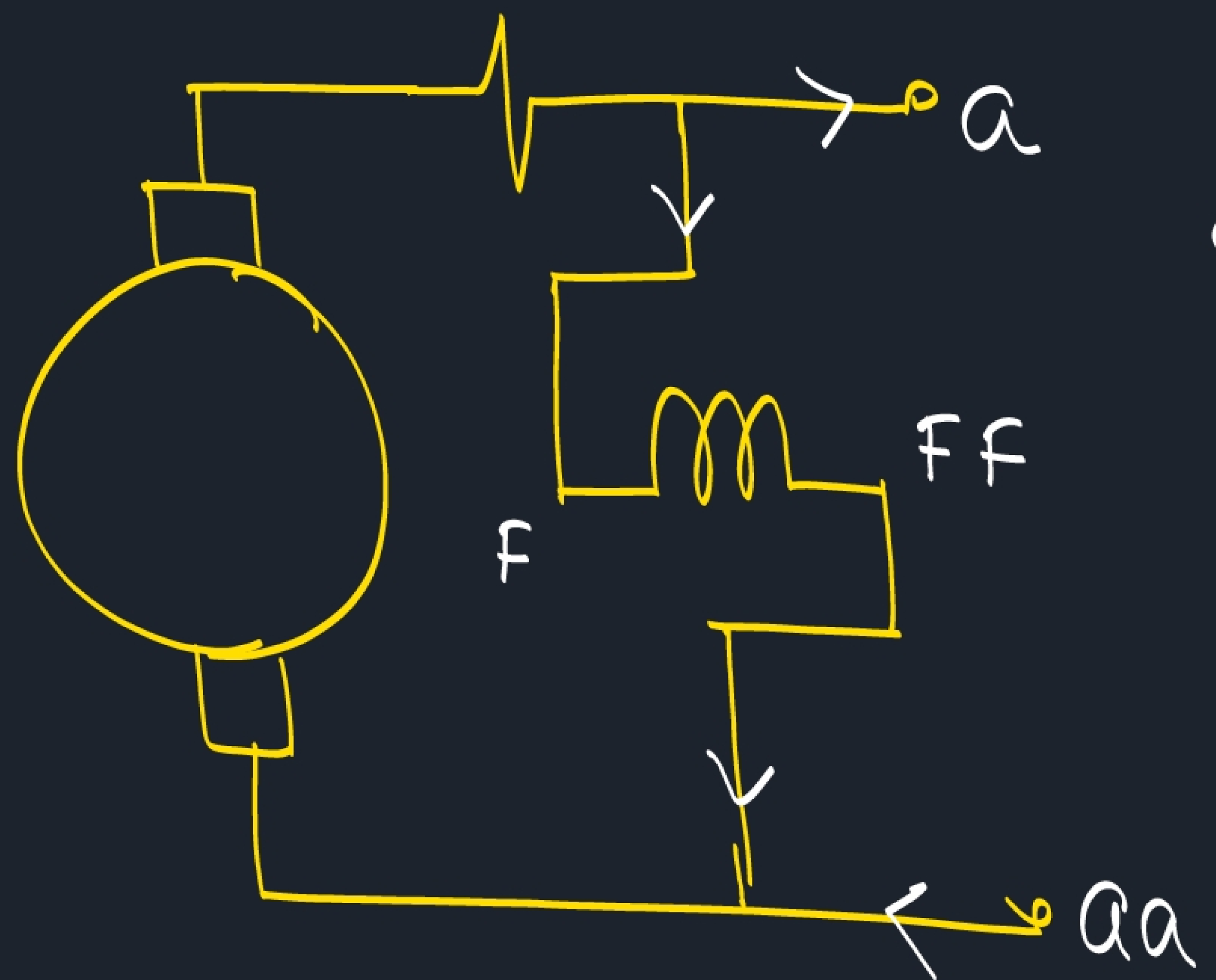


$$d\phi = P\phi.$$

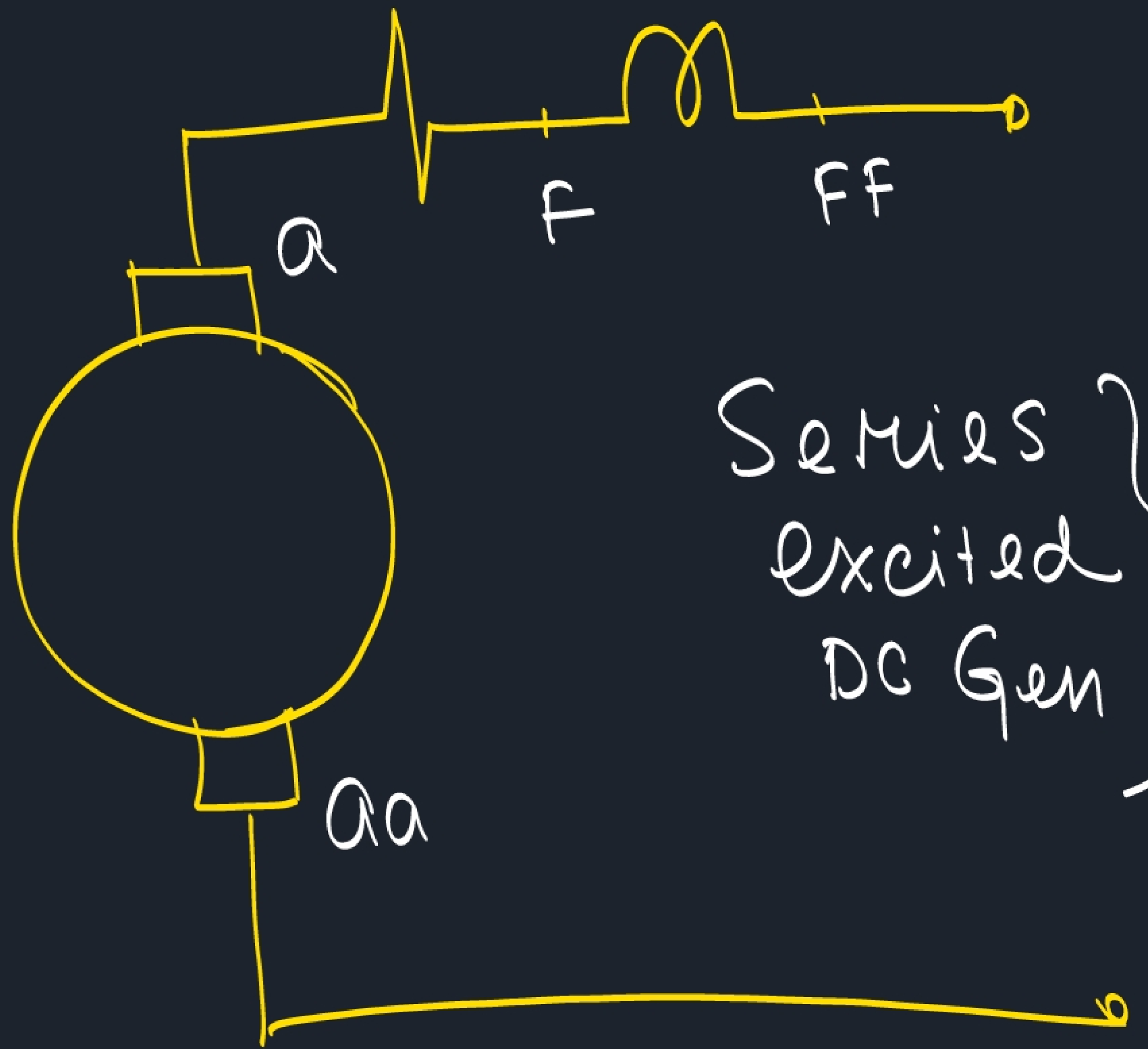
$$\frac{P\phi}{60/N} = \frac{\phi P N}{60}$$



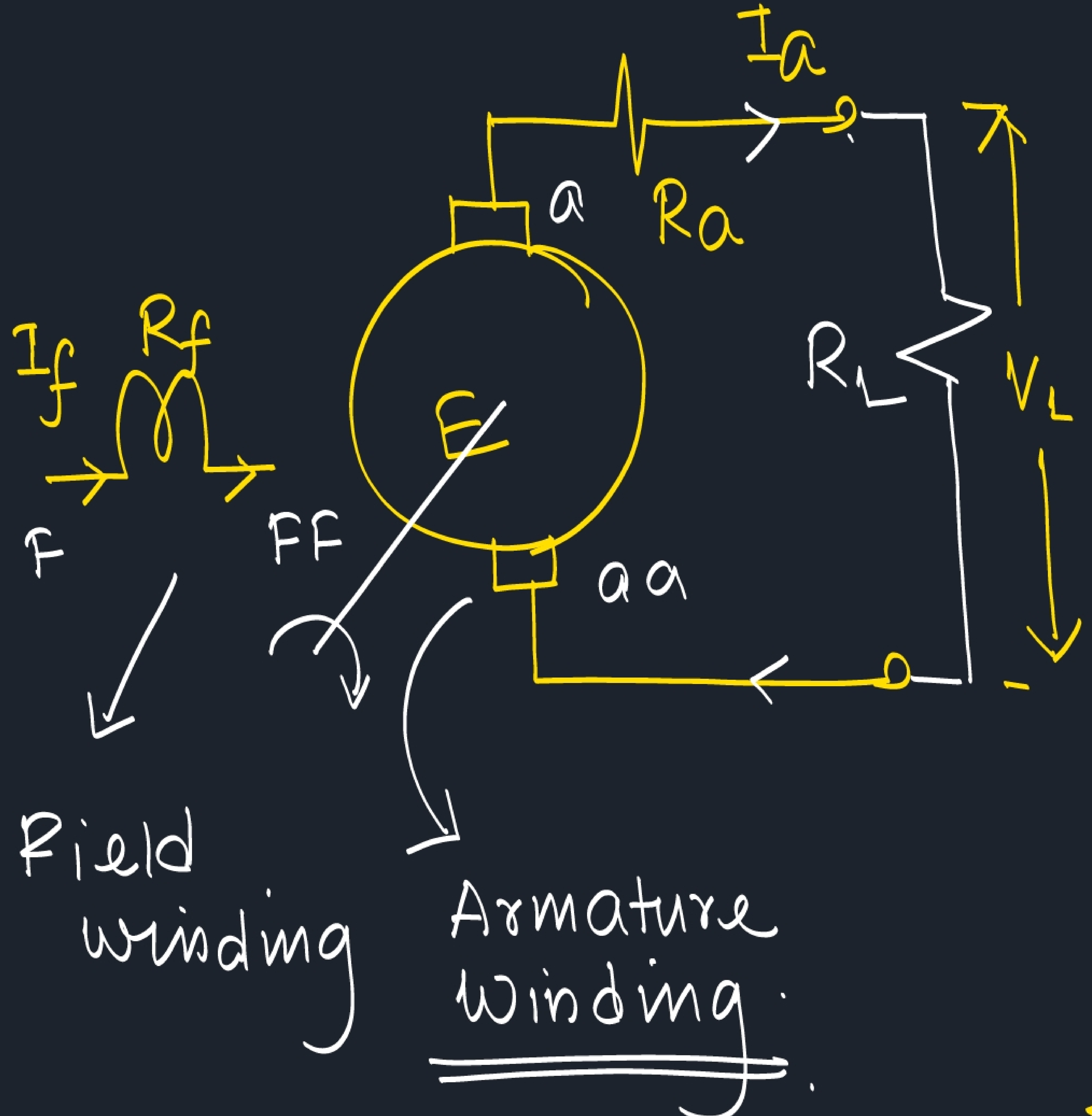
Separately excited DC Gen.



Shunt excited DC Gen.

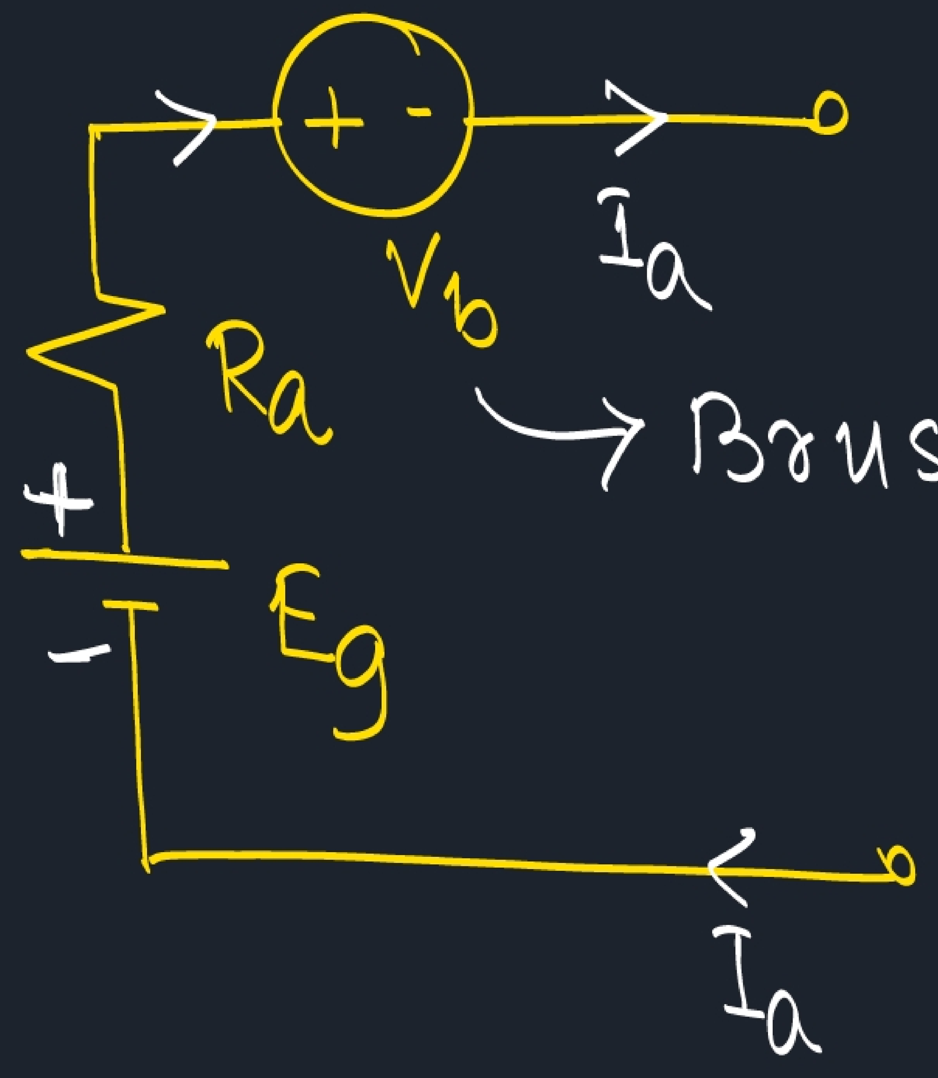


Series excited DC Gen

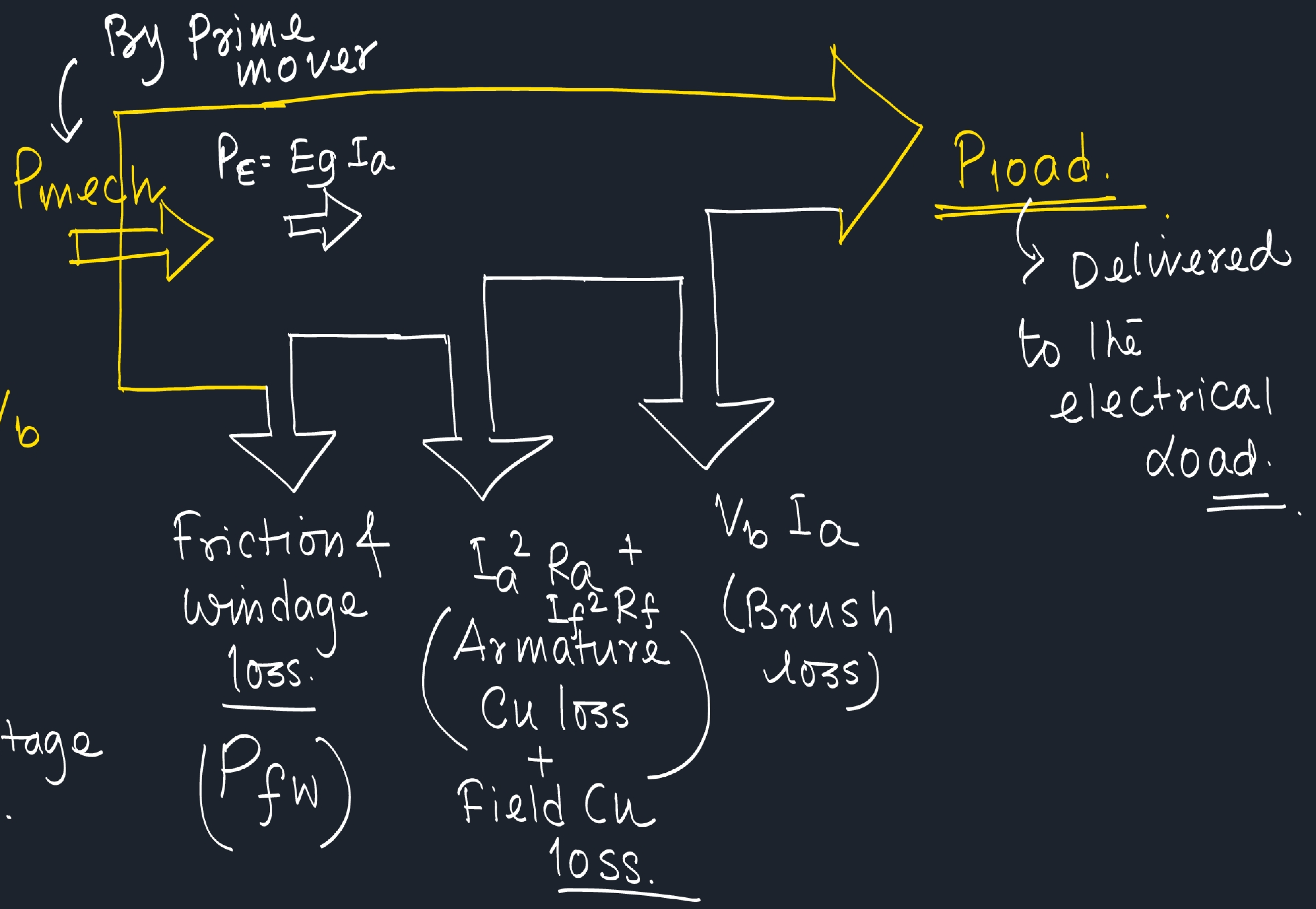


$$E = \left(\frac{\Phi Z N}{60} \cdot \frac{P}{A}\right)$$

$$V_L = E_g - I_a R_a - V_b$$



→ Brush voltage drop.

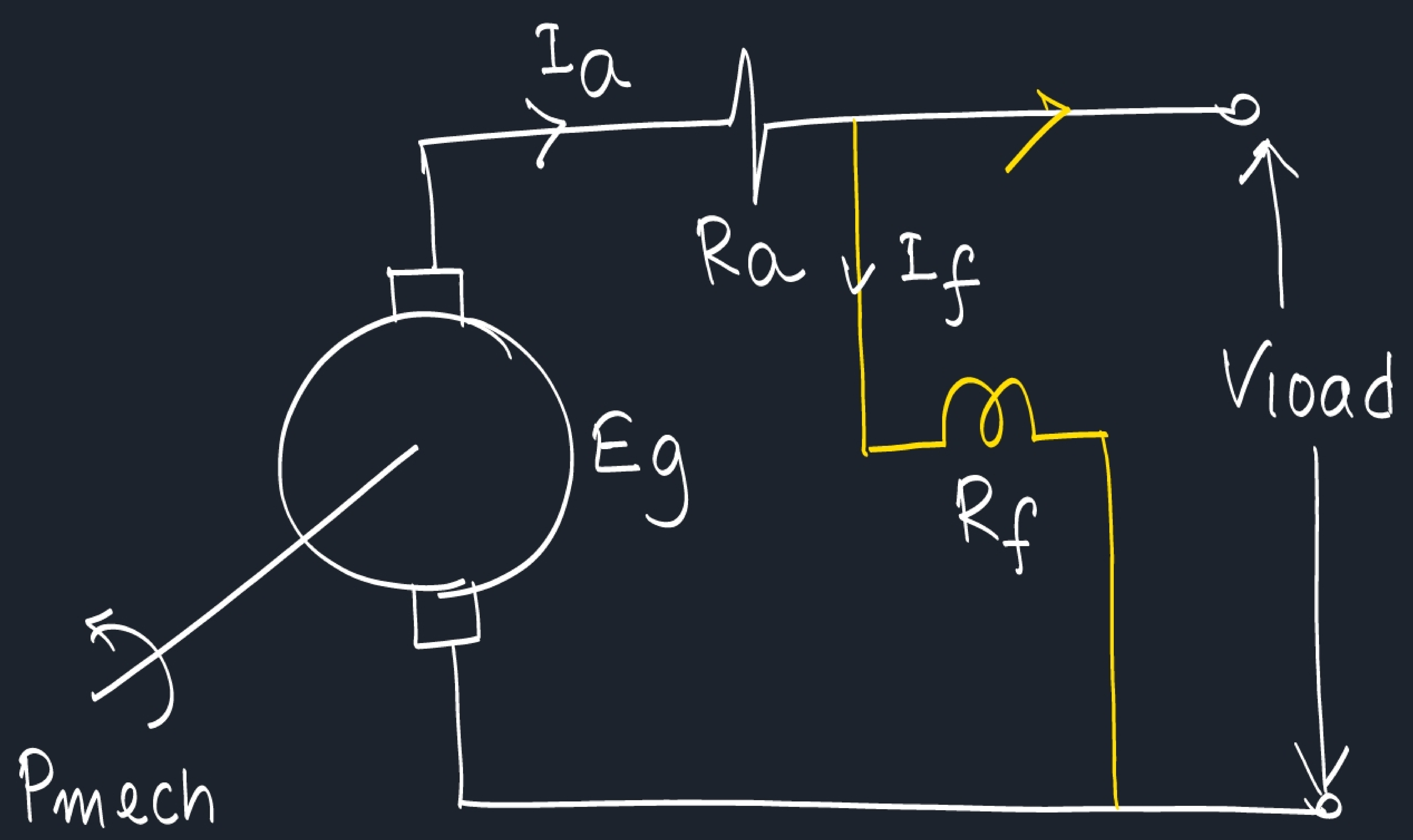


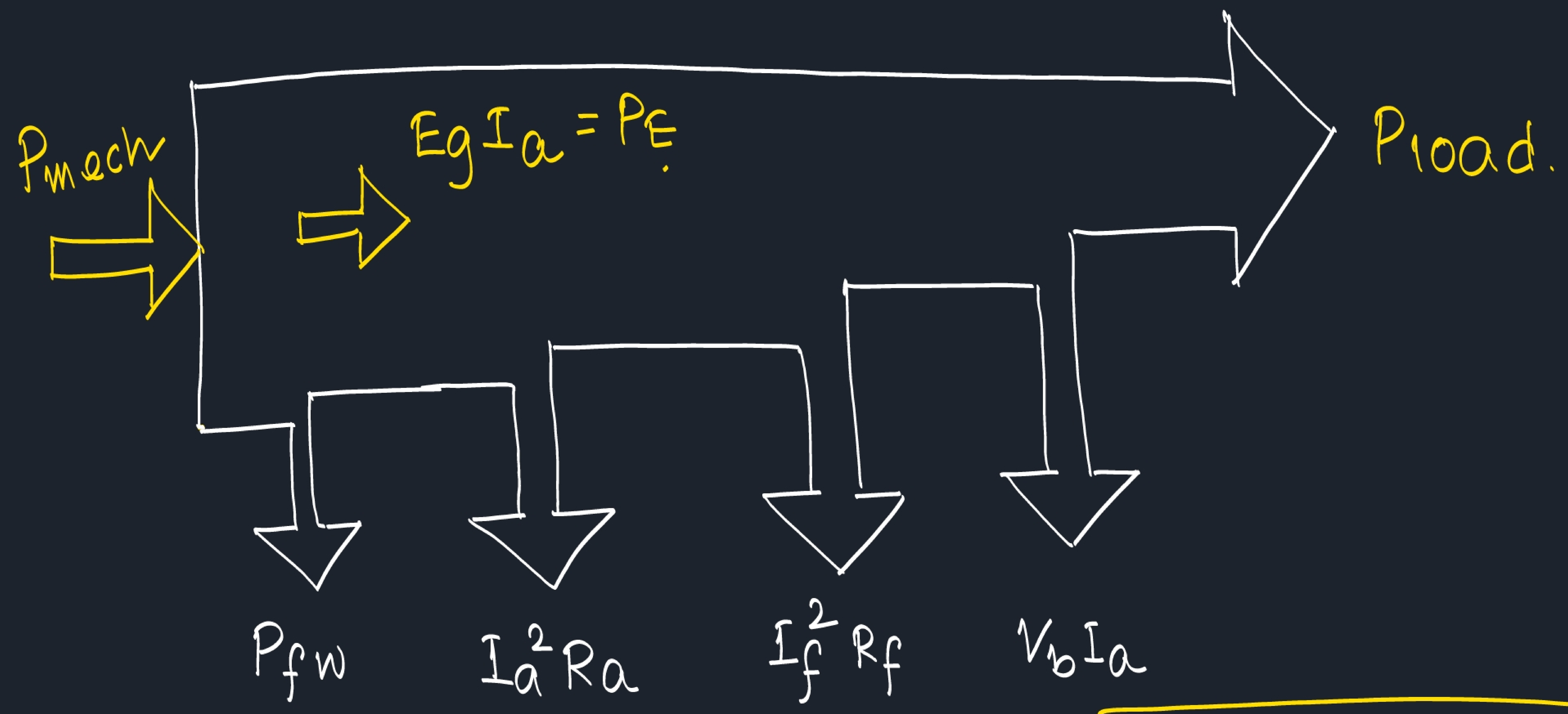
$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

$$= \frac{P_{load}}{P_{mech}} \times 100$$

$$= \frac{P_{load}}{P_{load} + V_b I_a + I_a^2 R_a + I_f^2 R_f + P_{fw}}$$

Shunt Excited Gen:-





$$V_{load} = E_g - I_a R_a$$

$$P_{load} = V_{load} \cdot (I_a - I_f)$$

$$I_f = \frac{E_g - I_a R_a}{R_f} = \frac{V_{load}}{R_f}$$

$$\boxed{P_{mech} = P_E + P_{fw}}$$

$$\boxed{E_g = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)}$$

$$eff = \frac{P_{out}}{P_{in}}$$

$$= \frac{P_{load} \times 100}{P_{fw} + I_a^2 R_a + I_f^2 R_f + V_b I_a + P_{load}}$$

$$E_g = \frac{\phi Z N}{60} \cdot \left(\frac{P}{A}\right)$$

1. Lap winding (A = No. of Poles) $A = P$

2. Wave winding ($A = 2$)

↳ For both motor & Gen.

Prob:-

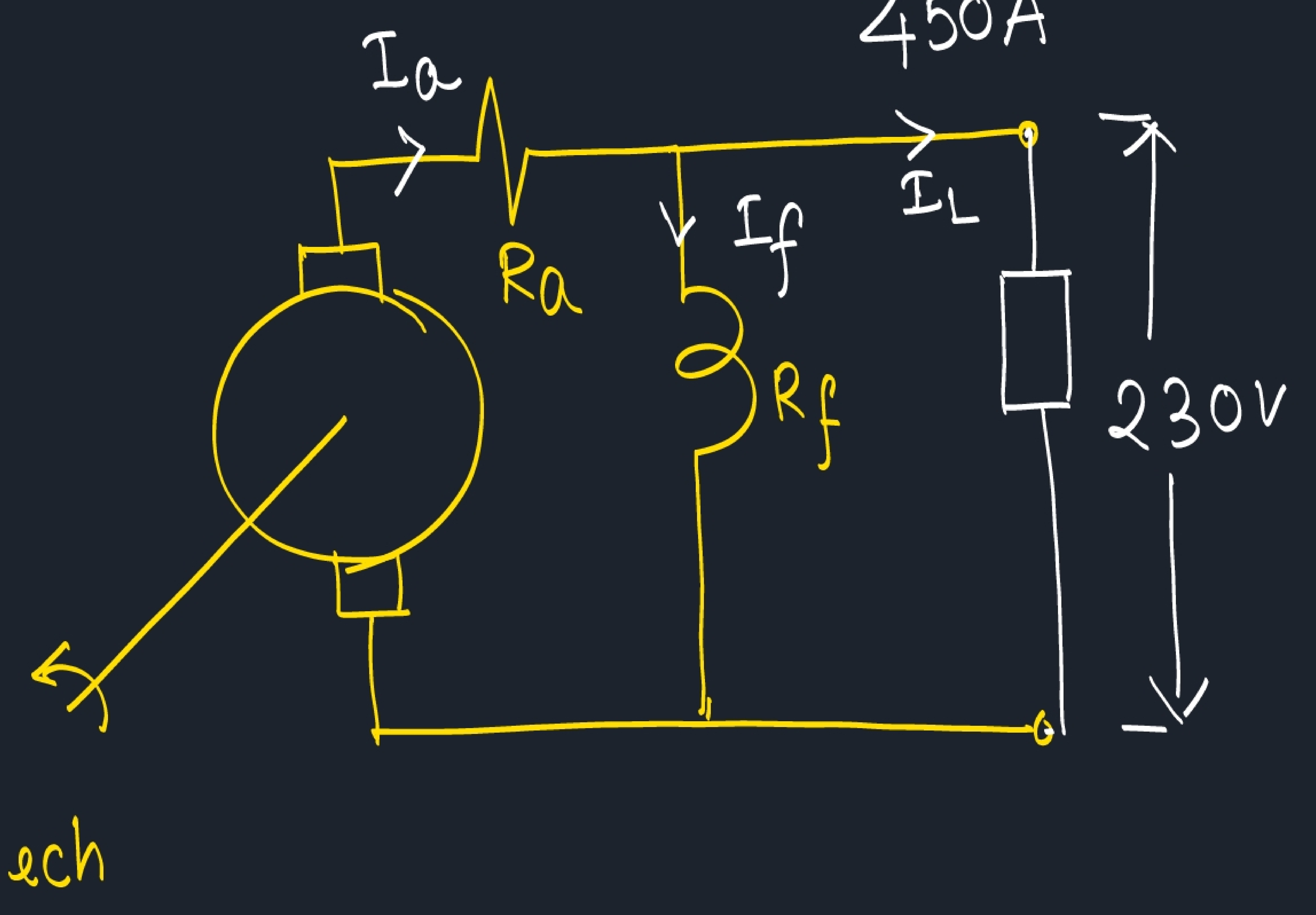
DC Shunt Gen

Delivers 450 Amp @ 230 V

$R_f = 50\Omega$, $R_a = 0.3\Omega$

$P_{fw} = 2$ kW.

find out η (in %)



$$P_{out} = (450 \times 230)\,W$$

$$P_{mech} = P_{in} = P_E + P_{fw}$$
$$= E_g I_a + P_{fw}$$

$$E_g = V_{load} + I_a R_a$$

$$I_a = I_L + I_f$$
$$= 450 + \frac{230}{50} = 454.6\,A.$$

$$E_g = 230 + (454.6) \times 0.3 =$$
$$= 366.38 \text{ Volt.}$$

$$\eta\% = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{mech}} \times 100$$

$$= \frac{450 \times 230 \times 100}{366.38 \times 454.6 + 2000}$$

$$= 61.4\%$$

(11) Prob:-

Sep. Ex. DC Gen.

Delivers 150A @ 400V and 1000 rpm.

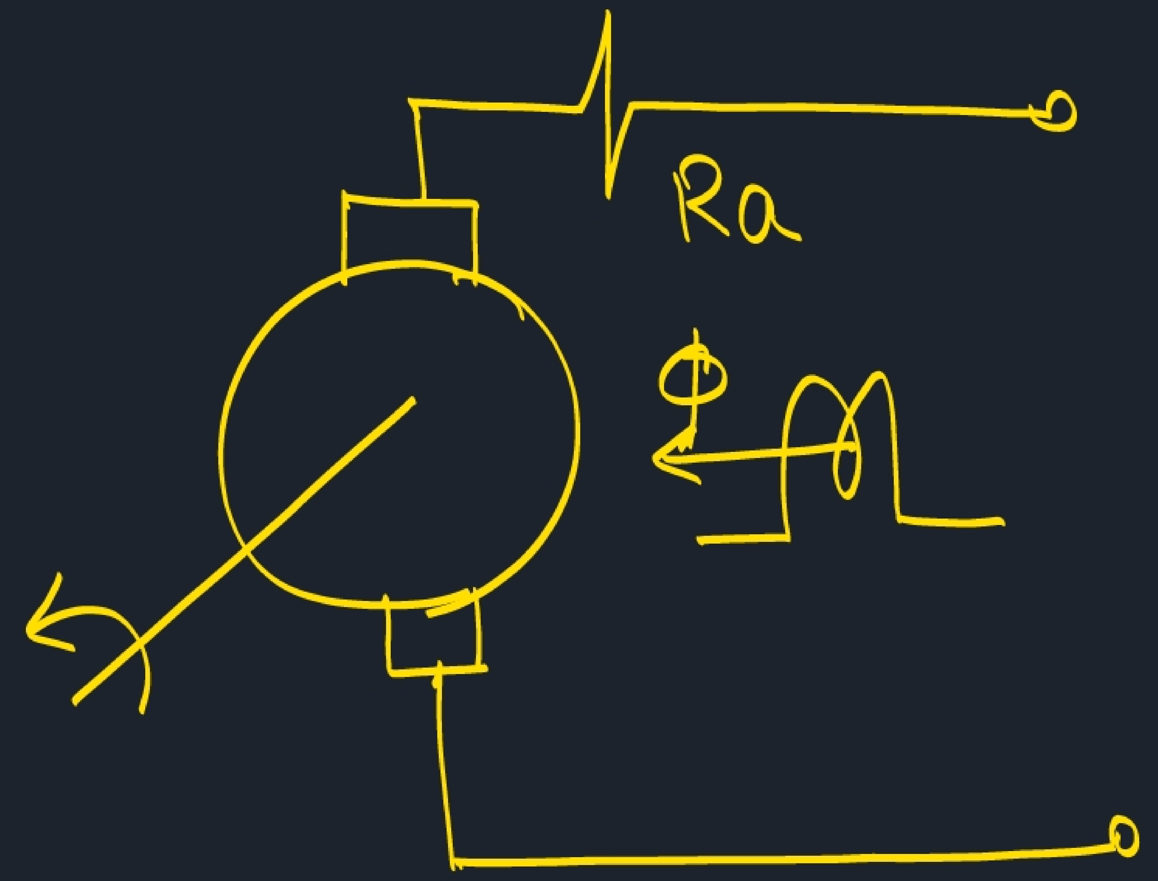
The load is a constant resistive load.

Current to the load is reduced to 100A

Determine the Speed.

$R_a = 0.12\,\Omega$

Brush voltage drop = 2 volt.



$$E_g = \frac{\phi Z N}{60} \cdot \left(\frac{P}{A}\right)$$

$$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2} = \frac{1000}{N_2}$$

$N_2 = 668.26$

≈ 669 (rpm)

* E_{g1} :-

$V_{load_1} = 400V$

$E_{g1} = 400 + 150 \times 0.12 + 2$

$= 420$ volt.

* E_{g2} :-

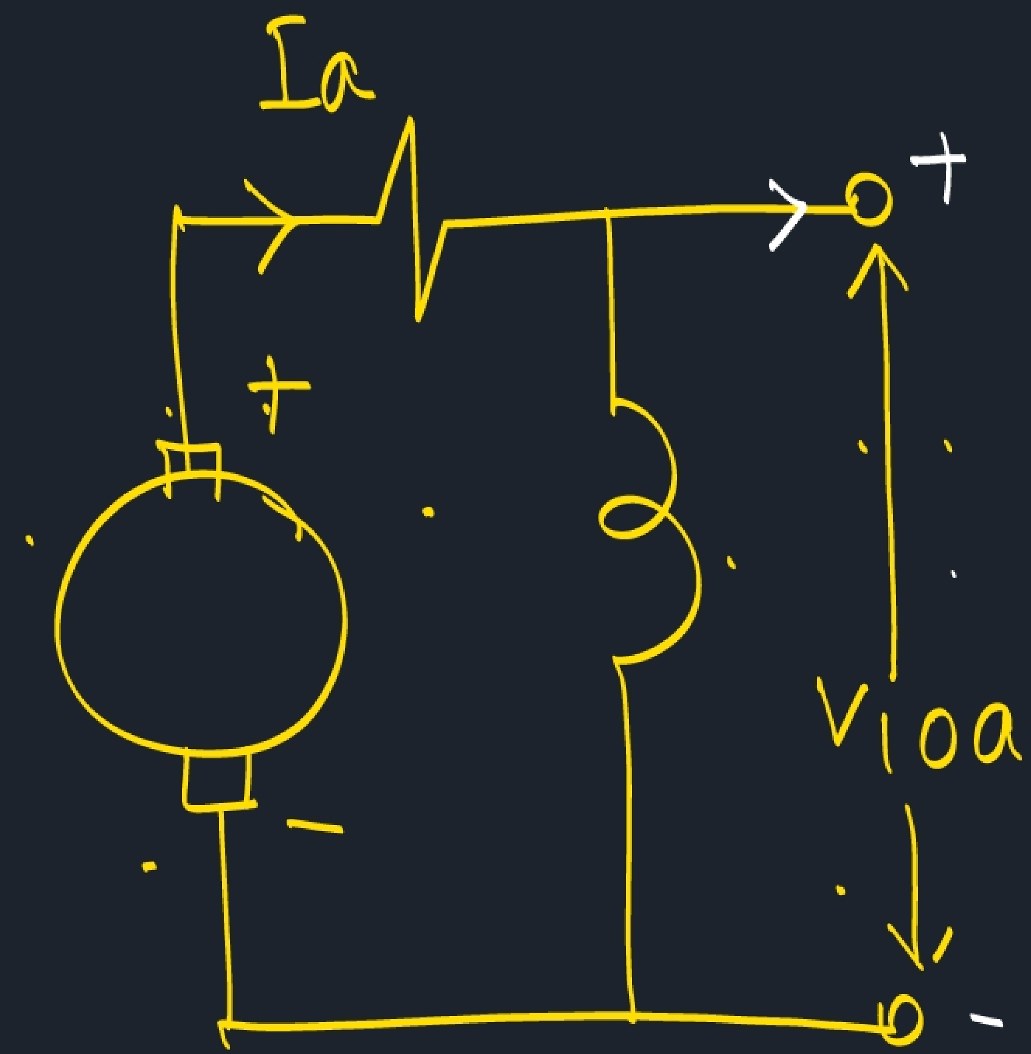
$V_{load2} = ?$

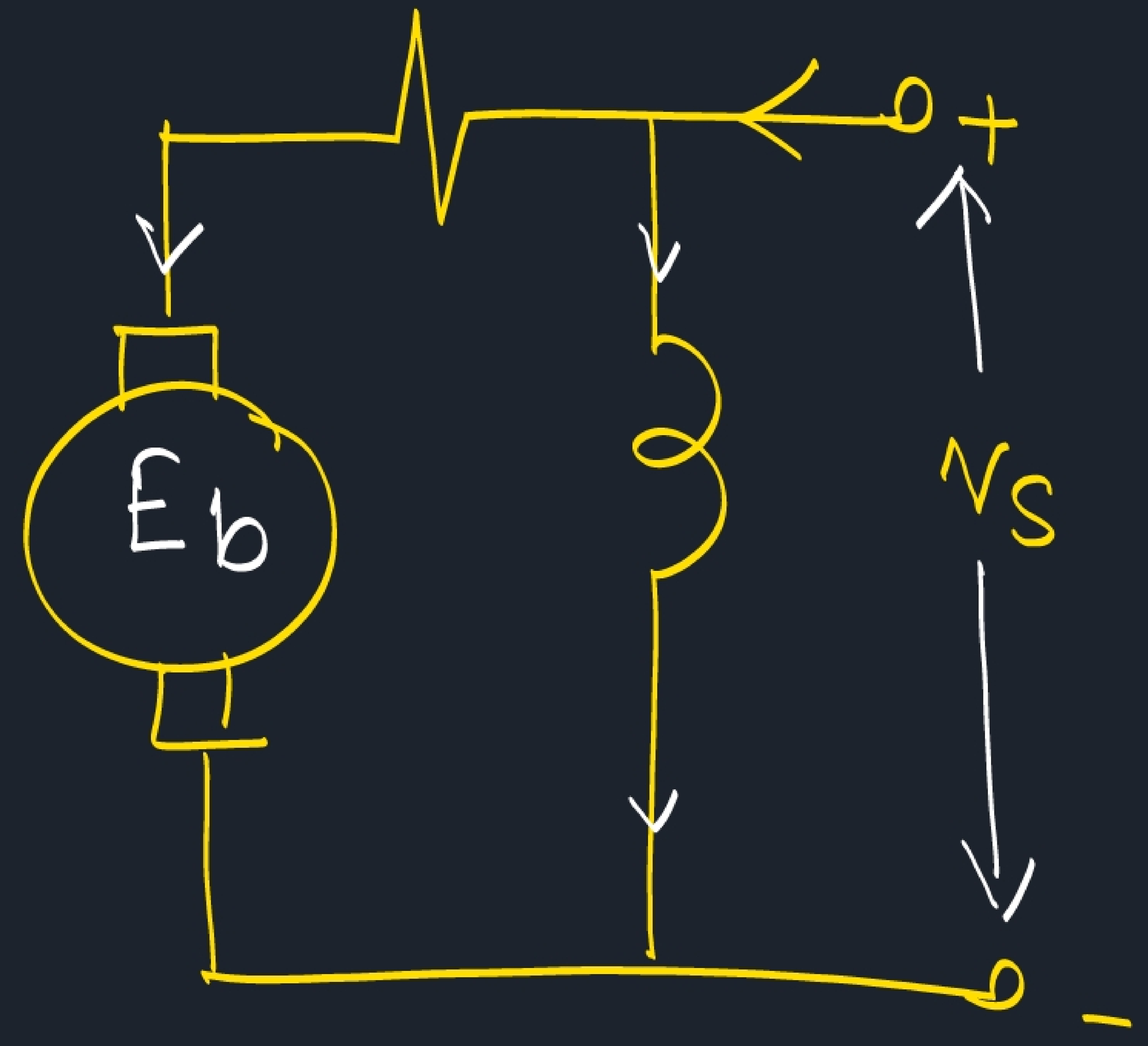
$= \left(\frac{400}{150} \times 100\right)$ Volt. $=$

$= 266.67$ volt.

$E_{g2} = 266.67 + 100 \times 0.12 + 2$

$= 280.67$ V



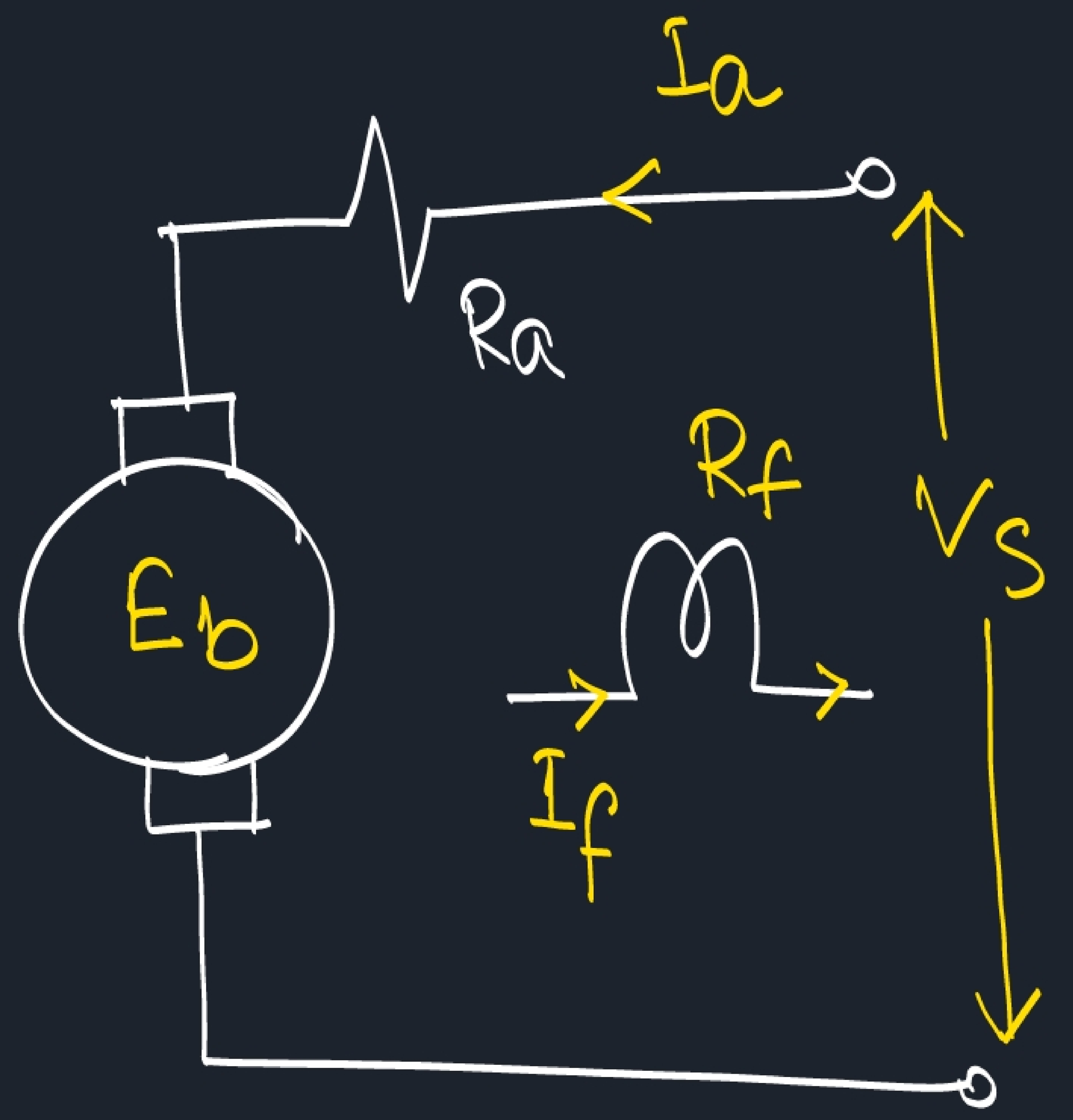


$$\vec{F} = (i\vec{l} \times \vec{B})$$

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

I/p is electrical power
O/p is mechanical power.

(II) Sep. Ex. DC Motor:-



$E_b = V_s - I_a R_a - V_b$

$P = \tau \cdot \omega$

$\Rightarrow E_b I_a = \tau_{gross}\,\omega$

$$\tau_{gross} = \frac{E_b I_a}{\omega}$$

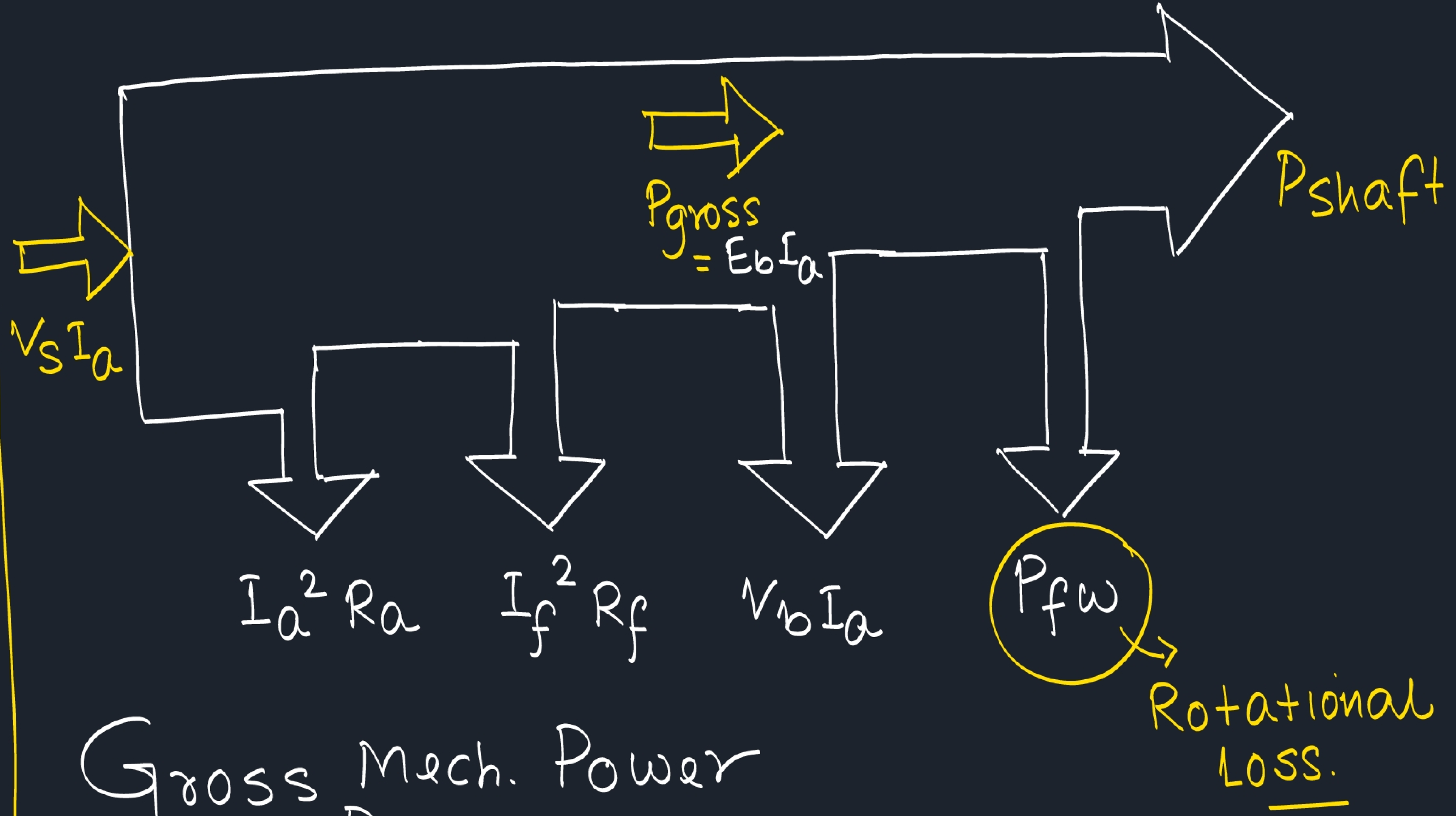
$$= \frac{E_b I_a}{\left(\frac{2\pi N}{60}\right)}$$

$P_{shaft} = E_b I_a - P_{fw}$

$$\tau_{shaft} = \frac{E_b I_a - P_{fw}}{\left(\frac{2\pi N}{60}\right)}$$

INPUT = Electrical Power

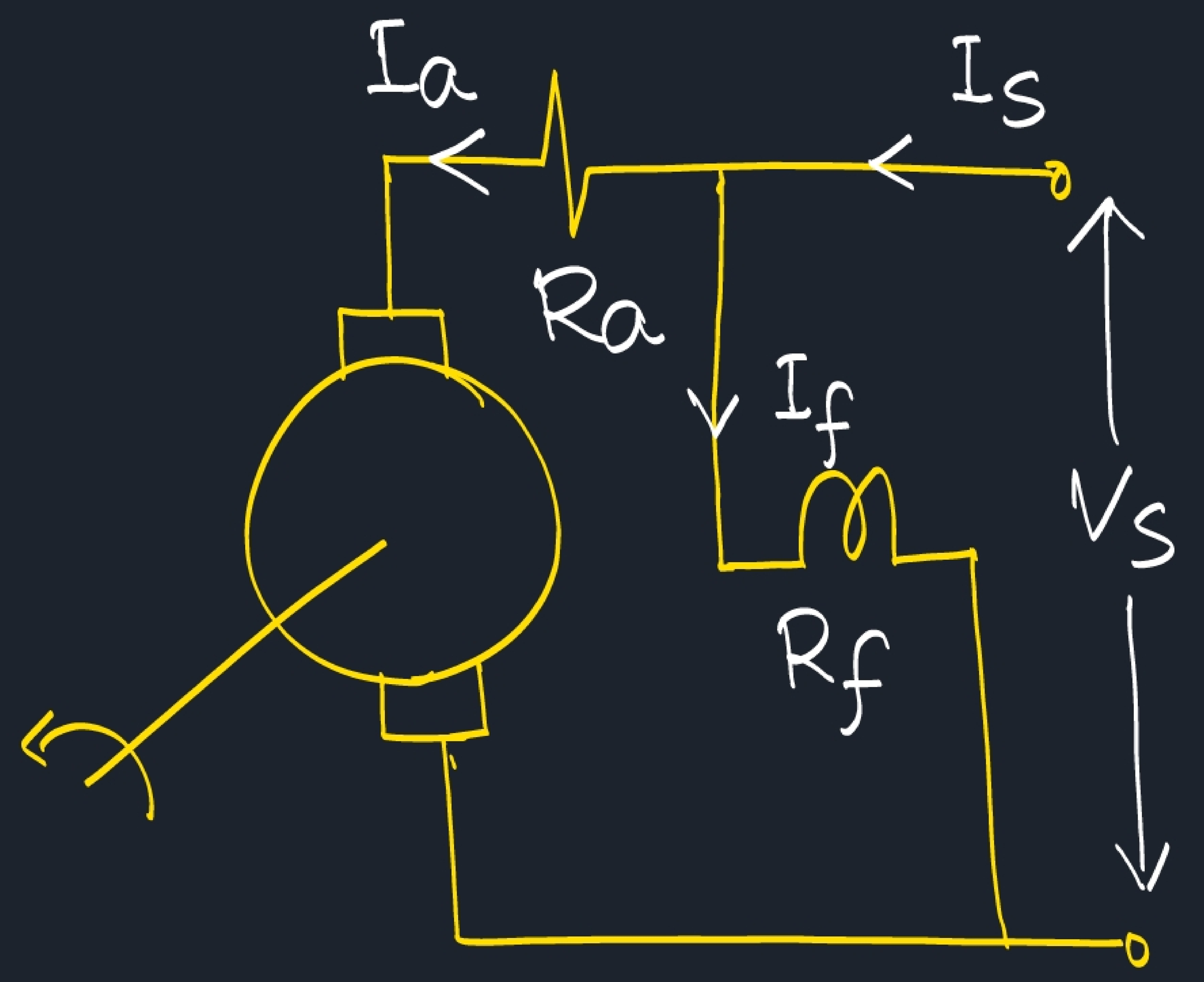
OUTPUT = Mechanical Power.



Gross Mech. Power Developed = $E_b I_a$

Shaft power developed in the motor = P_{shaft}.

Shunt DC Motor :-



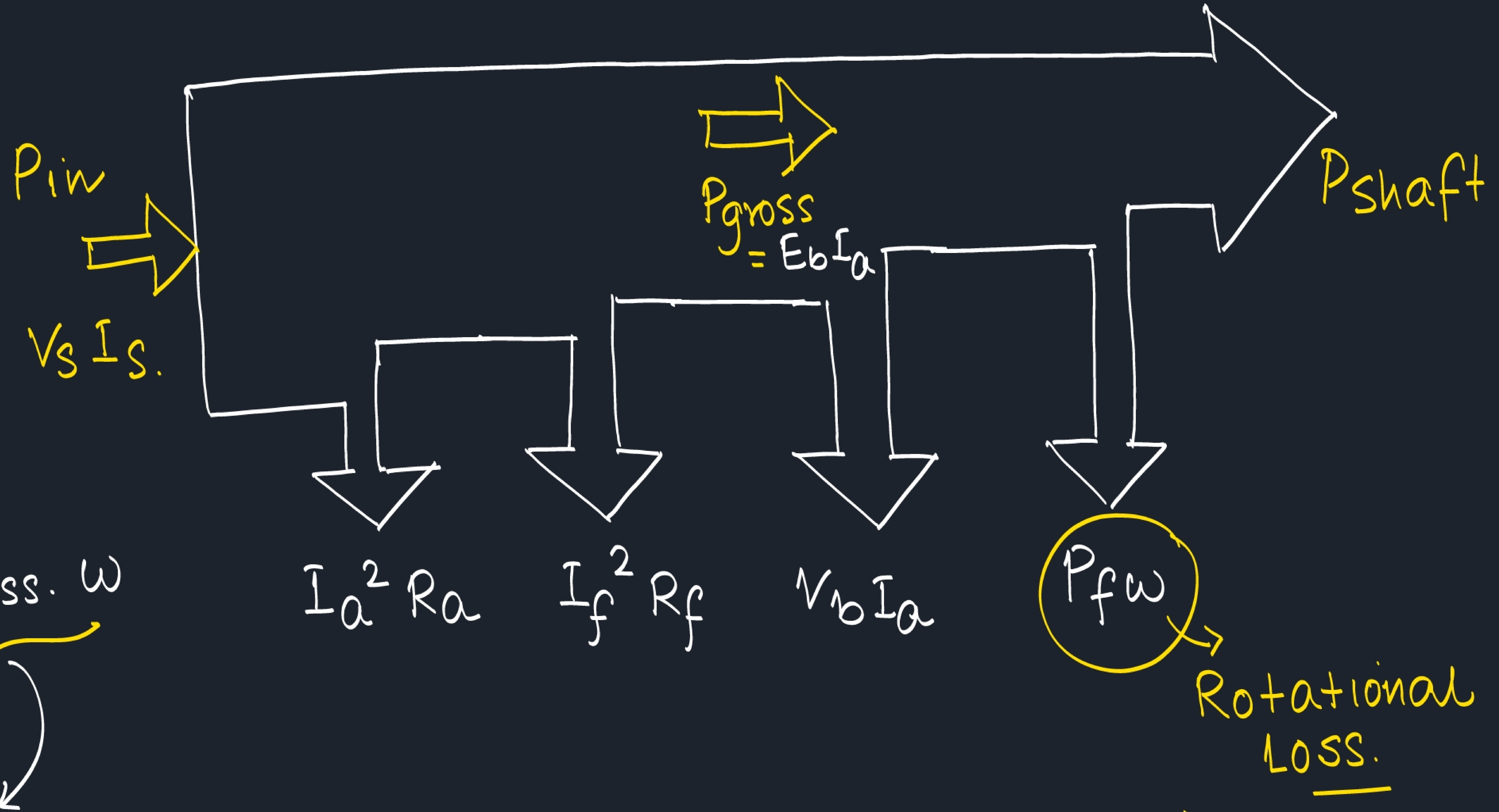
$$E_b = V_s - I_a R_a - V_b$$

$$I_f = \frac{V_s}{R_f}$$

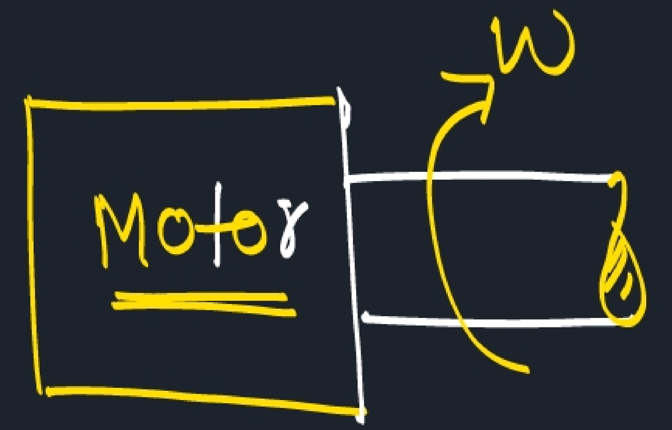
$$I_a = I_s - I_f$$

$$P_{gross} = E_b I_a = \tau_{gross} \cdot \omega$$

P_{fw} = Rotational Loss



τ_{gross} = Gross Electromagnetic Torque developed.



$$P_{shaft} = E_b I_a - P_{fw}$$

$$\tau_{shaft} = \frac{E_b I_a - P_{fw}}{\left(\frac{2\pi N}{60}\right)}$$

Mechanical Torque available in motor shaft.

$$\boxed{\tau_e \omega = E_b I_a}$$

$$E_b = \frac{\phi Z N}{60} \cdot \left(\frac{P}{A}\right) = \frac{\phi Z}{\cancel{60}} \cdot \frac{\cancel{60}}{2\pi} \omega \cdot \left(\frac{P}{A}\right)$$

$$\omega = \frac{2\pi N}{60} \qquad = (\phi \omega) \cdot \frac{ZP}{2\pi A} \rightarrow K$$

$$\boxed{N = \frac{60}{2\pi} \cdot \omega}$$

rpm   rad/sec.

$$\boxed{E_b = K\phi\omega}$$

$$\tau_e \cdot \omega = E_b I_a$$
$$= K\phi\omega I_a$$

$$\boxed{\tau_e = K\phi I_a}$$

11 Prob:-

4 Pole, 220V dc Shunt Motor

It has 540 Lap wound Conductors.

Motor Rating ⇒ 5.595 KW

$I_f = 1$ A

$I_a = 32$ A

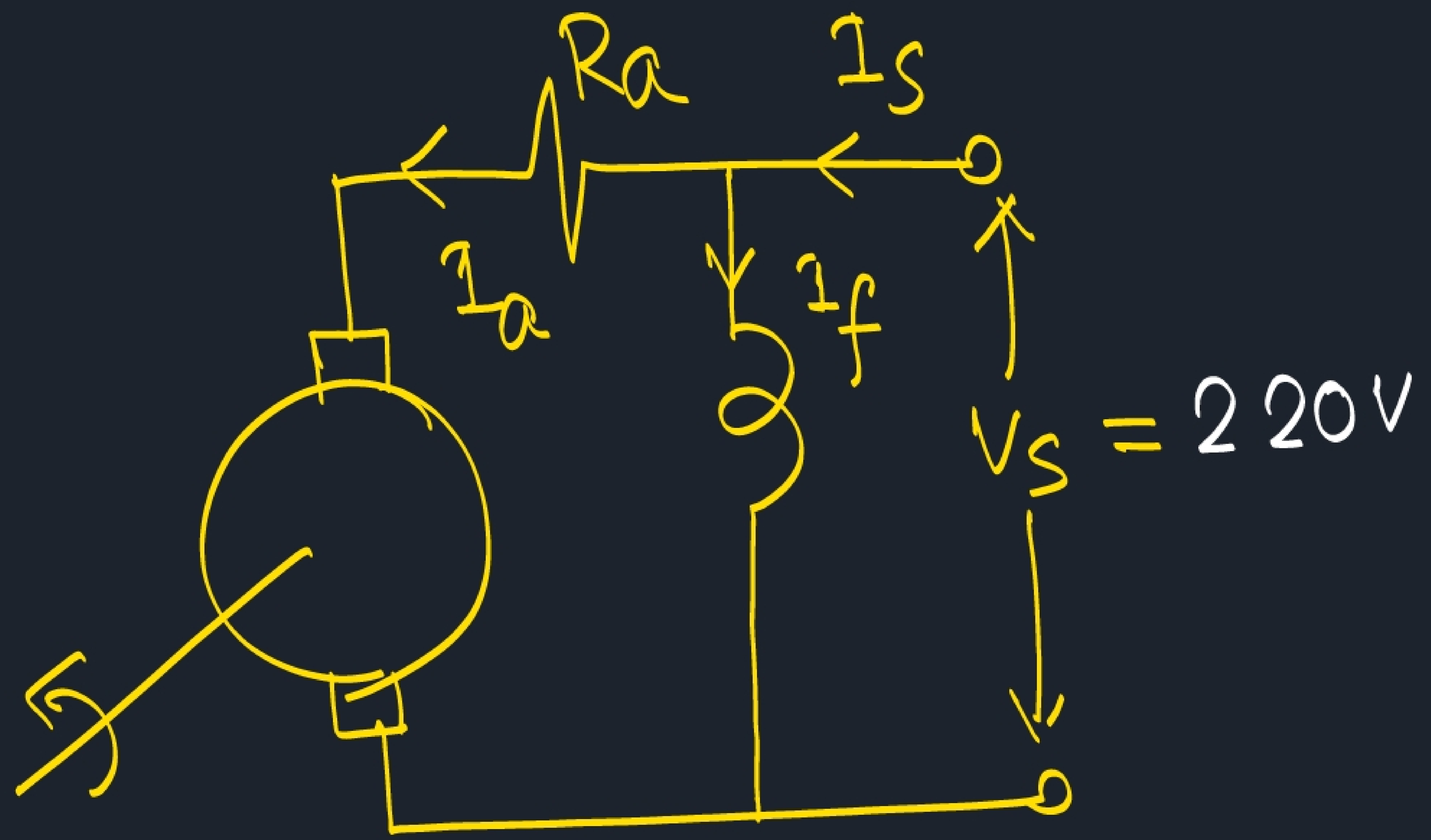
$R_a = 0.09\ \Omega$

$\phi = 30$ mwb.

i) Speed.

ii) Shaft torque developed.

iii) P_{fw}



$E_b = ?$ $\quad E_b = V_s - I_a R_a - \cancel{V_b}^{\,0}$

$E_b = 220 - (32 \times 0.09)$

$= 217.12$ Volt.

$E_b = \dfrac{\Phi Z N}{60}\left(\dfrac{P}{A}\right)$

$P_{fw} = E_b I_a - P_{shaft}$

$= \{(217.12 \times 32) - 5595\}$ W

$= 1352.84$ W

Supply voltage = 220V

$P_{shaft} = 5.595$ kW. = Rating of the motor.

Lap wound $A = P$.

$217.12 = \dfrac{30 \times 10^{-3} \times 540 \times N}{60}\left(\dfrac{4}{4}\right)$

$\boxed{N = 804.15 \text{ RPM.}}$

$P_{shaft} = \tau_{shaft}\left(\dfrac{2\pi N}{60}\right)$

$\tau_{shaft} = \dfrac{5595 \times 60}{2\pi \times 804.15}$ N-m.

$= 66.44$ N-m

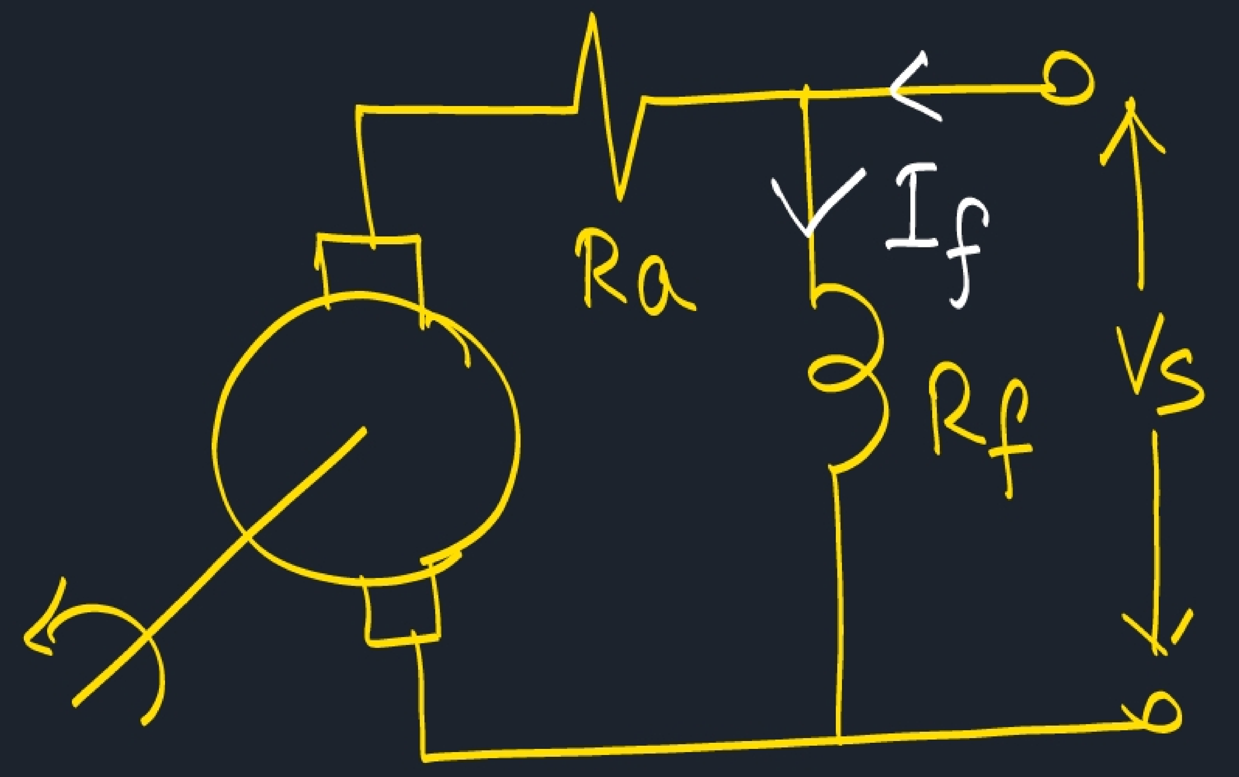
Prob:-

A 500 V DC Shunt Motor. It takes a current of 5A at no load.

$R_a = 0.22\,\Omega$

$R_f = 250\,\Omega$

Find η when the motor is taking a current of 100A.



Case-1 (No load) :-

$E_b I_a = \cancel{P_{shaft}}^{0} + P_{fW}$

$E_b = 500 - (5-2) \times 0.22$

$P_{fw} = E_b \cdot I_a$

$= 1498.02\ W$

$V_s = 500\ V$

$I_f = \frac{V_s}{R_f} = \frac{500}{250} = 2A$.

Case-2 (Load cond) :-

$E_b = 500 - (100-2) \times 0.22$

$P_{gross} = E_b I_a$

$P_{shaft} = E_b I_a - 1498.02$

$= 45389.5\ W$

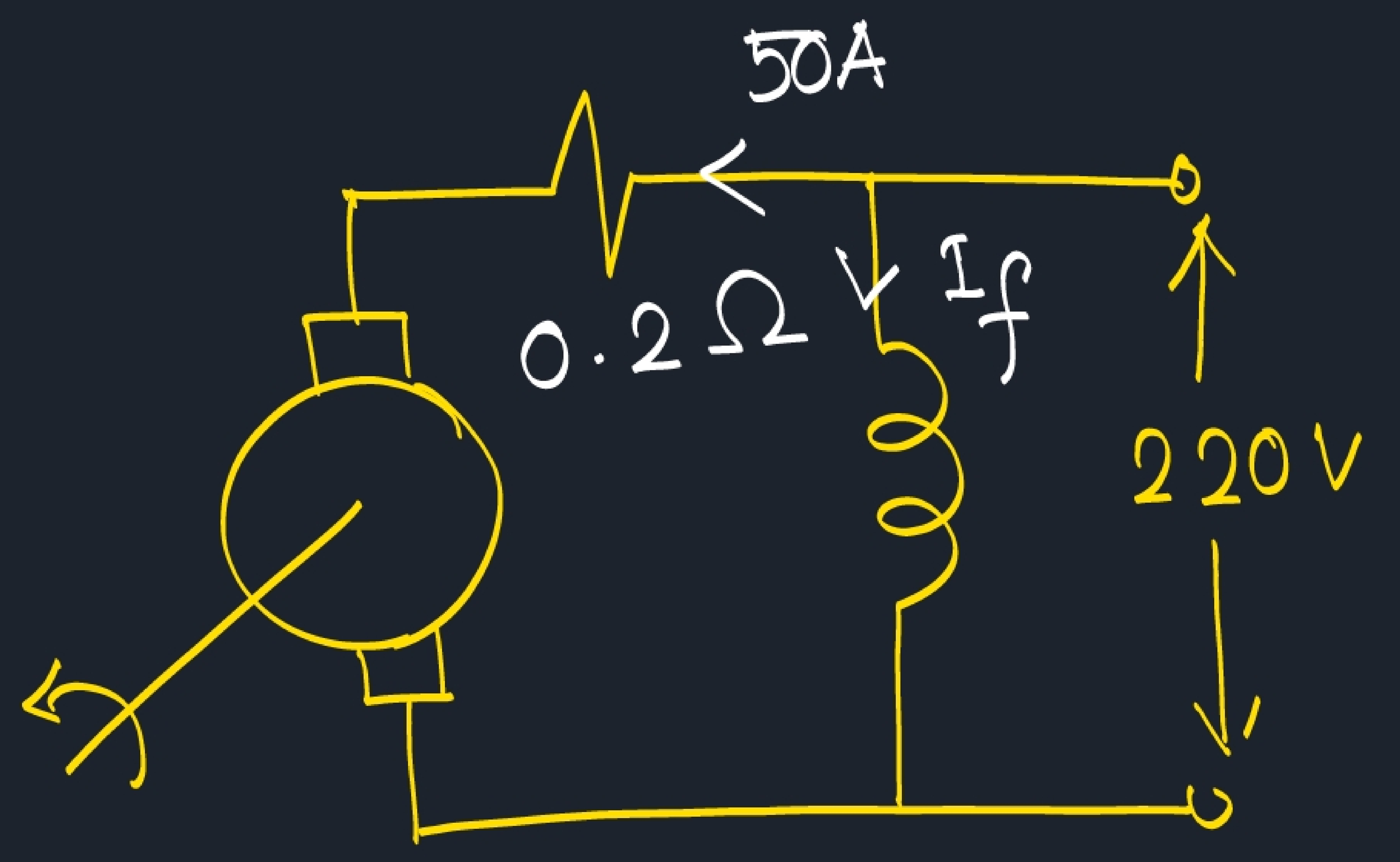
$\eta = \frac{P_{out}}{P_{in}} \times 100$

$= \left\{ \frac{45389.5 \times 100}{100 \times 500} \right\} = ?$

Prob:-

220 V DC Shunt Motor
Runs @ 500 rpm
Armature Current = 50A
$R_a = 0.2\Omega$
Calculate the Speed if torque is doubled.

$\phi \propto I_f$



flux is fixed. $\Phi_1 = \Phi_2$

$$\boxed{\begin{array}{l} \tau \propto \phi I_a \\ E_b \propto \phi \omega \\ E_b \propto \phi N \end{array}}$$

$$\boxed{\begin{array}{l} \tau_1 = \tau,\ I_{a_1} = 50A \\ \tau_2 = 2\tau,\ I_{a_2} = ? \end{array}}$$

$E_b = V_t - I_a R_a$

$$\frac{E_{b_1}}{E_{b_2}} = \frac{\Phi_1 N_1}{\Phi_2 N_2} = \frac{N_1}{N_2}$$

$$\frac{\tau_1}{\tau_2} = \frac{\Phi_1 I_{a_1}}{\Phi_2 I_{a_2}}$$

$$\frac{\tau_1}{\tau_2} = \frac{I_{a_1}}{I_{a_2}}$$

$$\frac{\tau}{2\tau} = \frac{50}{I_{a_2}}$$

$I_{a_2} = 50 \times 2 = 100$ Amps.

$$\frac{V_t - I_{a_1} R_a}{V_t - I_{a_2} R_a} = \frac{500}{N_2}$$

$$\Rightarrow \frac{220 - 50 \times 0.2}{220 - 100 \times 0.2} = \frac{500}{N_2}$$

$$\boxed{N_2 = 476 \text{ rpm}}$$

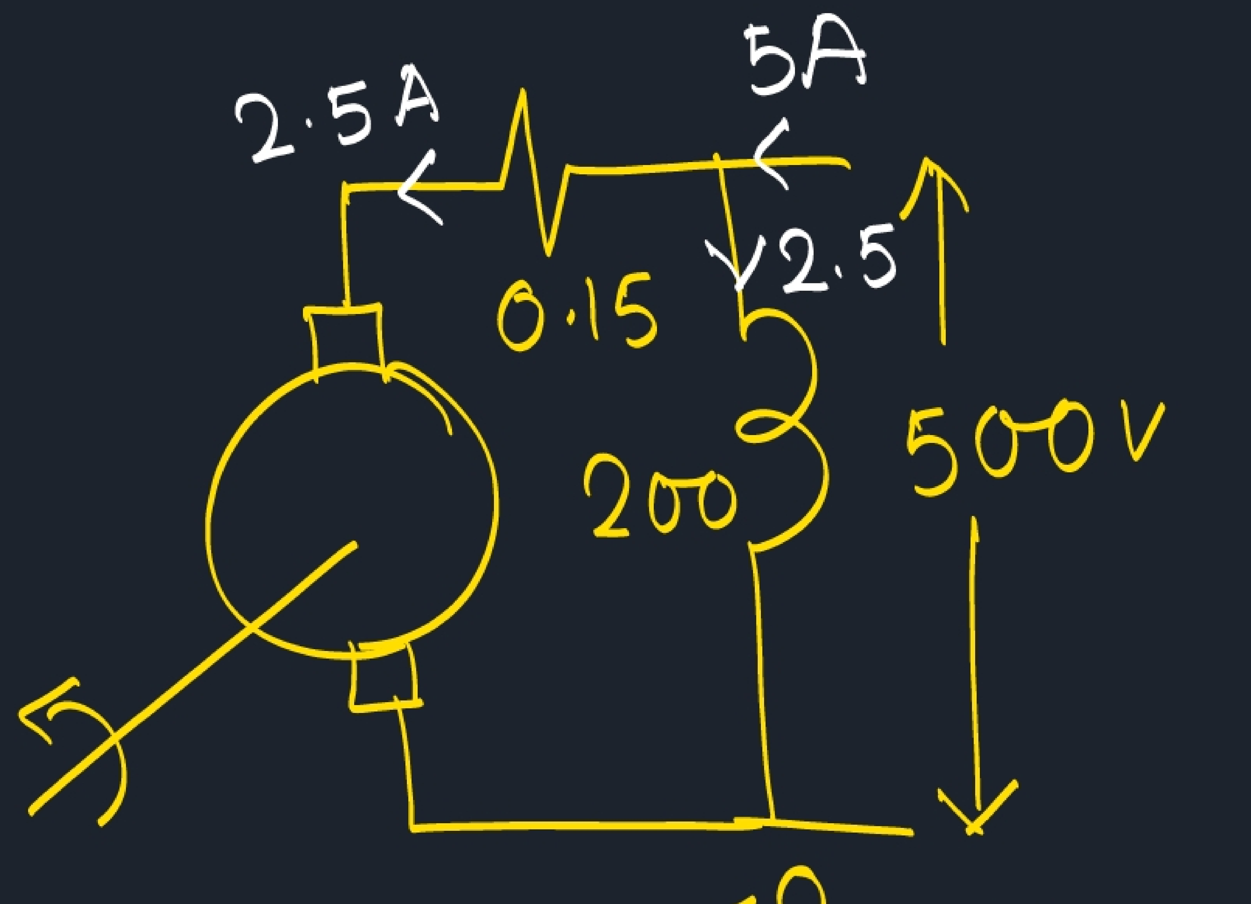
Prob :-

500 V DC Shunt motor draws a line current of 5 A @ no load.

$R_a = 0.15\,\Omega$

$R_f = 200\,\Omega$

Determine η of the m/c running as DC shunt gen delivering a load current of 40 Amps.



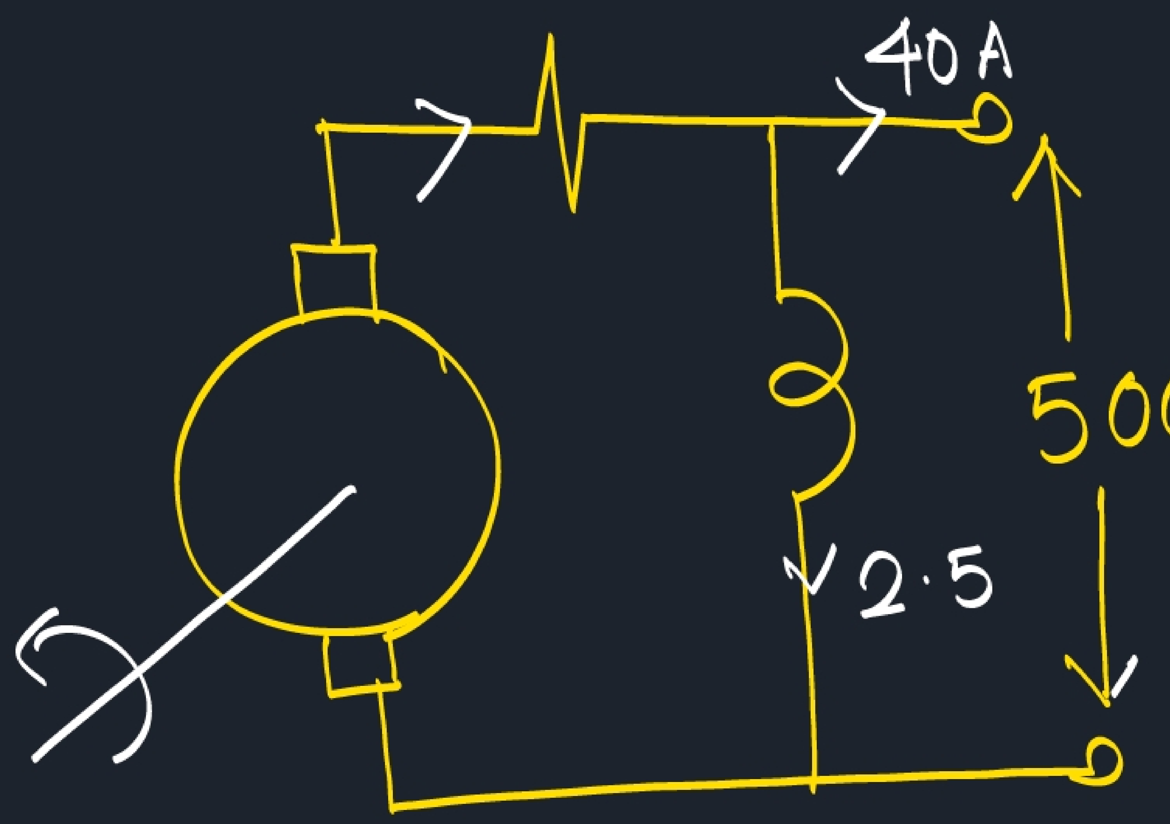
$E_b I_a = \cancel{P_{shaft}}^{\,0} + P_{fw}$

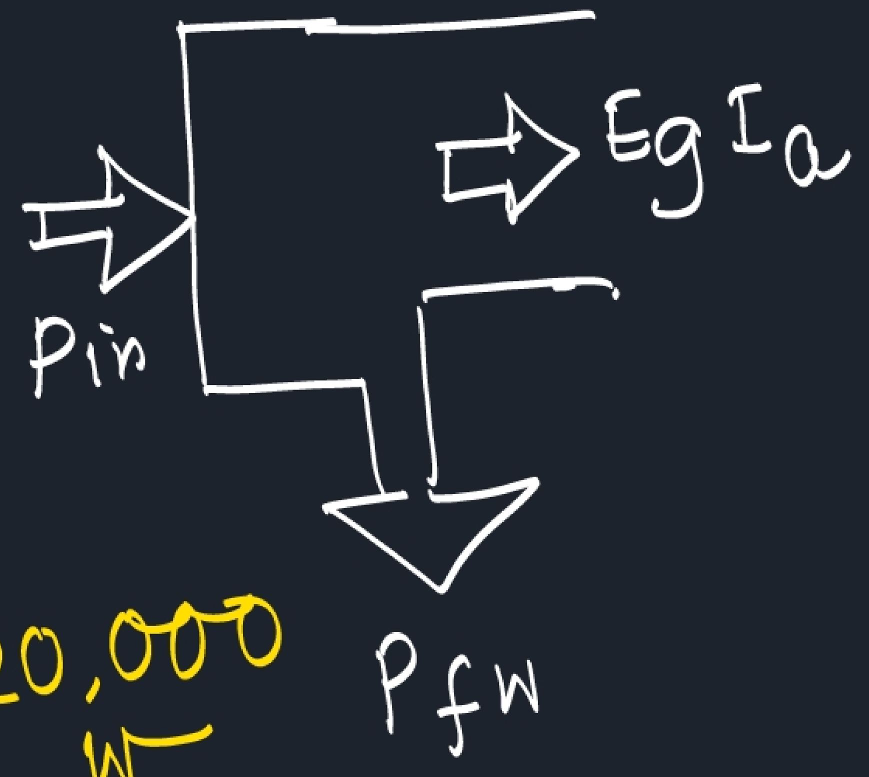
$E_b = V_t - I_a R_a$

$= (500 - 2.5 \times 0.15)$

$P_{fw} = E_b \times 2.5$

$= 1249.06\ W$





$P_{out} = (40 \times 500)\ W = 20{,}000\ W$

$E_g = V_t + I_a R_a$

$= 500 + (40 + 2.5) \times 0.15$

$E_g I_a = ?$

$P_{in} = E_g I_a + P_{fw} = 22770\ W$

$$\eta = \frac{20{,}000 \times 100}{22770} = \boxed{87.8\ \%}$$

Prob:

230 V DC Shunt motor

$R_a = 0.5\,\Omega$

$R_f = 115\,\Omega$

@ no load Speed = 1200 rpm

& armature current = 2.5 A

* when rated load applied to the motor Speed drops to 1120 rpm

Determine armature Current @ rated load.

$\tau \propto \phi I_a$

$E_b \propto \phi \omega$

$V_t - I_a R_a$

$$\frac{V_t - I_{a_1} R_a}{V_t - I_{a_2} R_a} = \frac{N_1}{N_2}$$

$$\Rightarrow \frac{230 - 2.5 \times 0.5}{230 - I_{a_2} \times 0.5} = \frac{1200}{1120}$$

$\Rightarrow I_{a_2} = 33$ Amps.