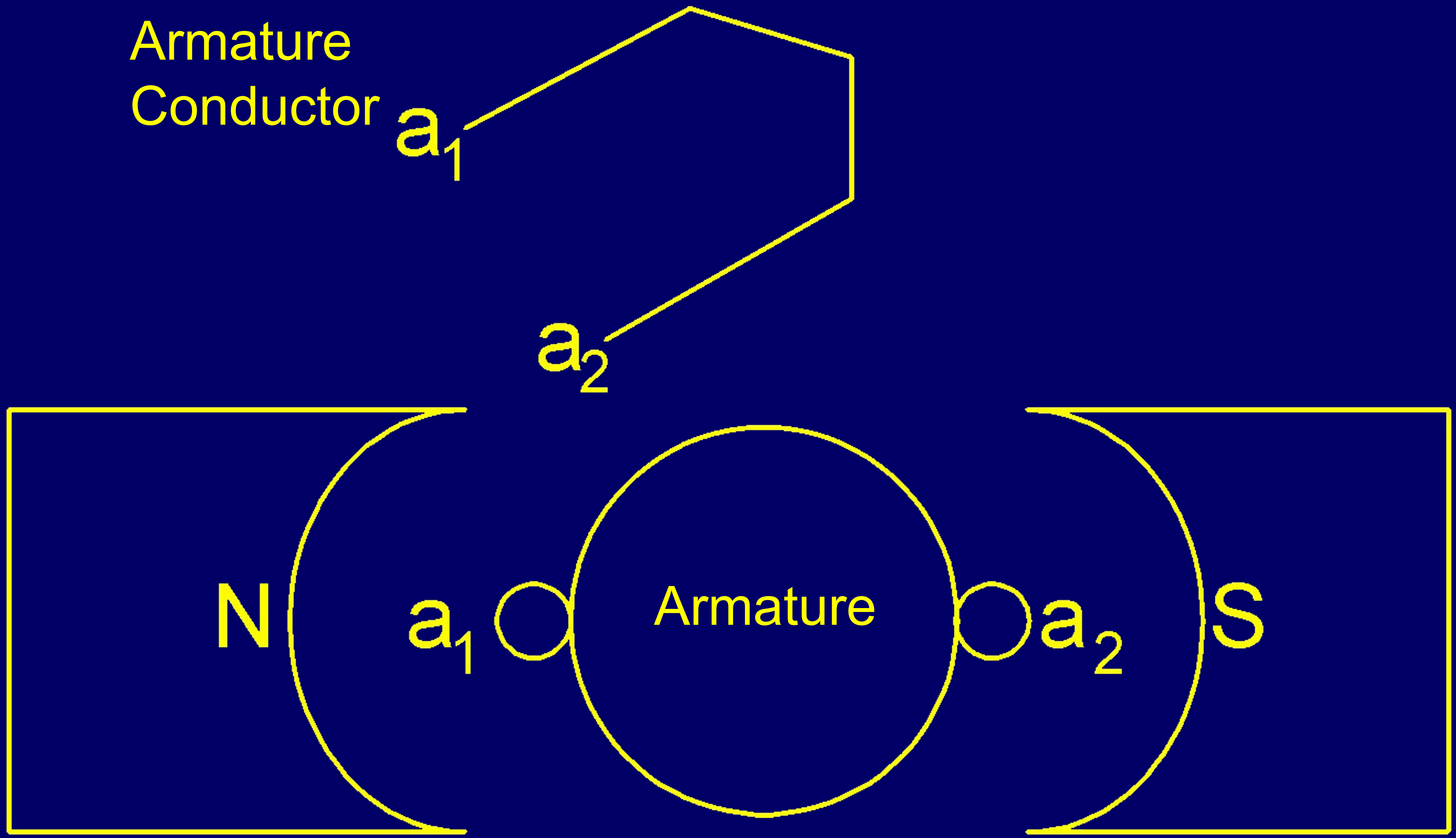
MS 101

DC Motors

K. Chatterjee, D. Chakraborty, B. G. Fernandes
J. John, P. C. Pandey, N. S Shiradkar, K. R. Tuckley

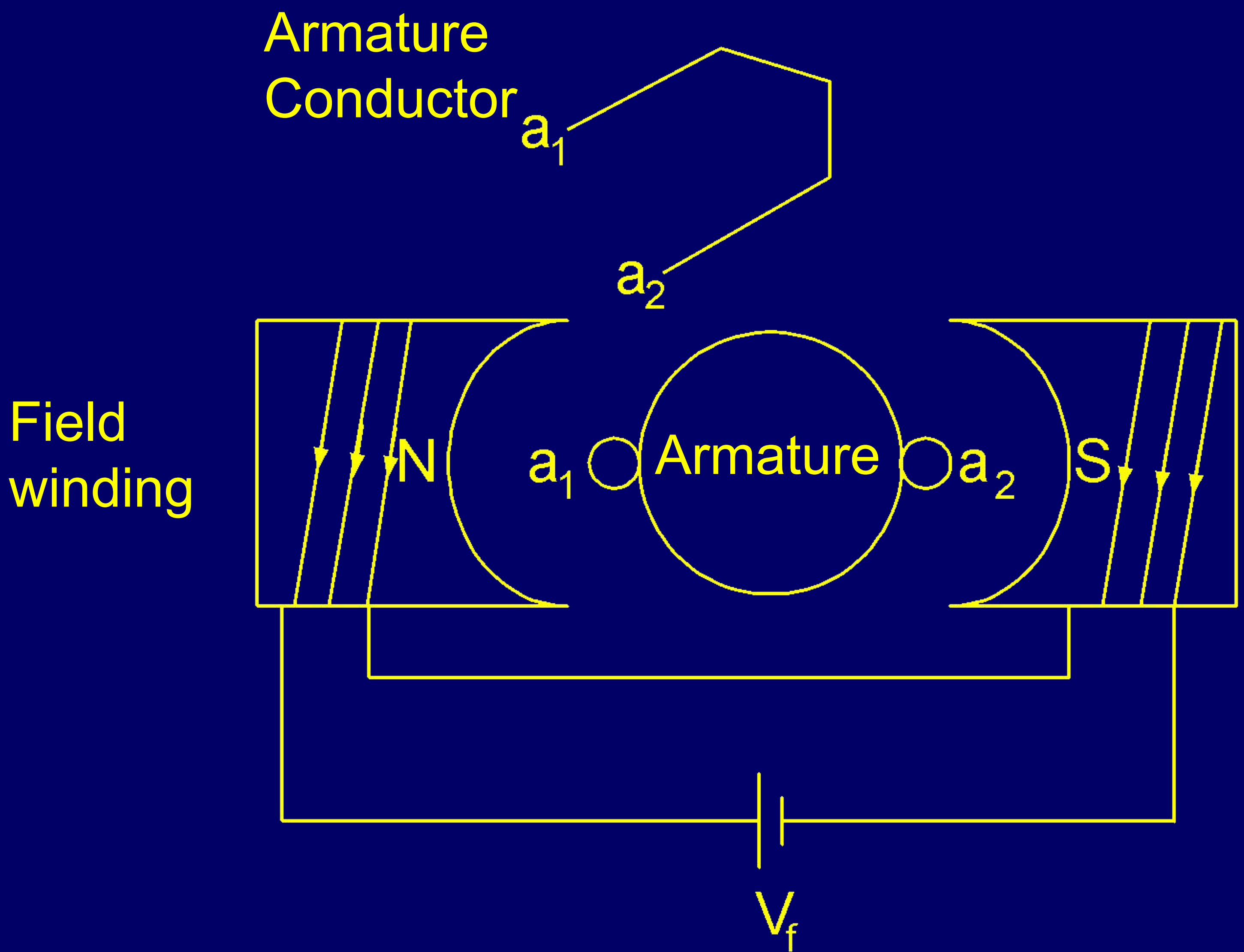
EE Department
IIT Bombay, Mumbai

DC Motor : Principle of Operation



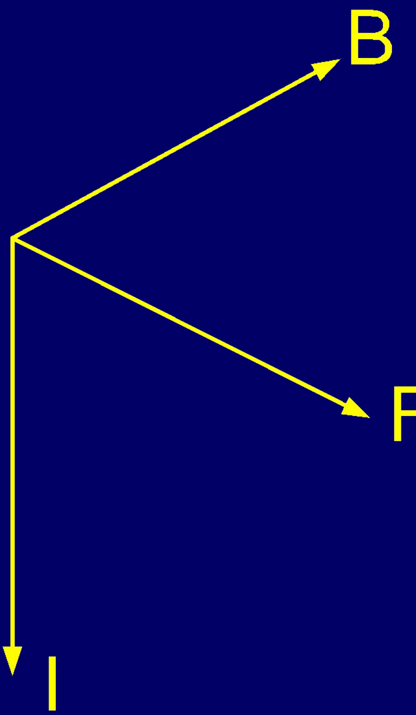
Field of the stator (by virtue of permanent magnets) : BO Motor also known as 'permanent magnet dc motor'

DC Motor : Principle of Operation

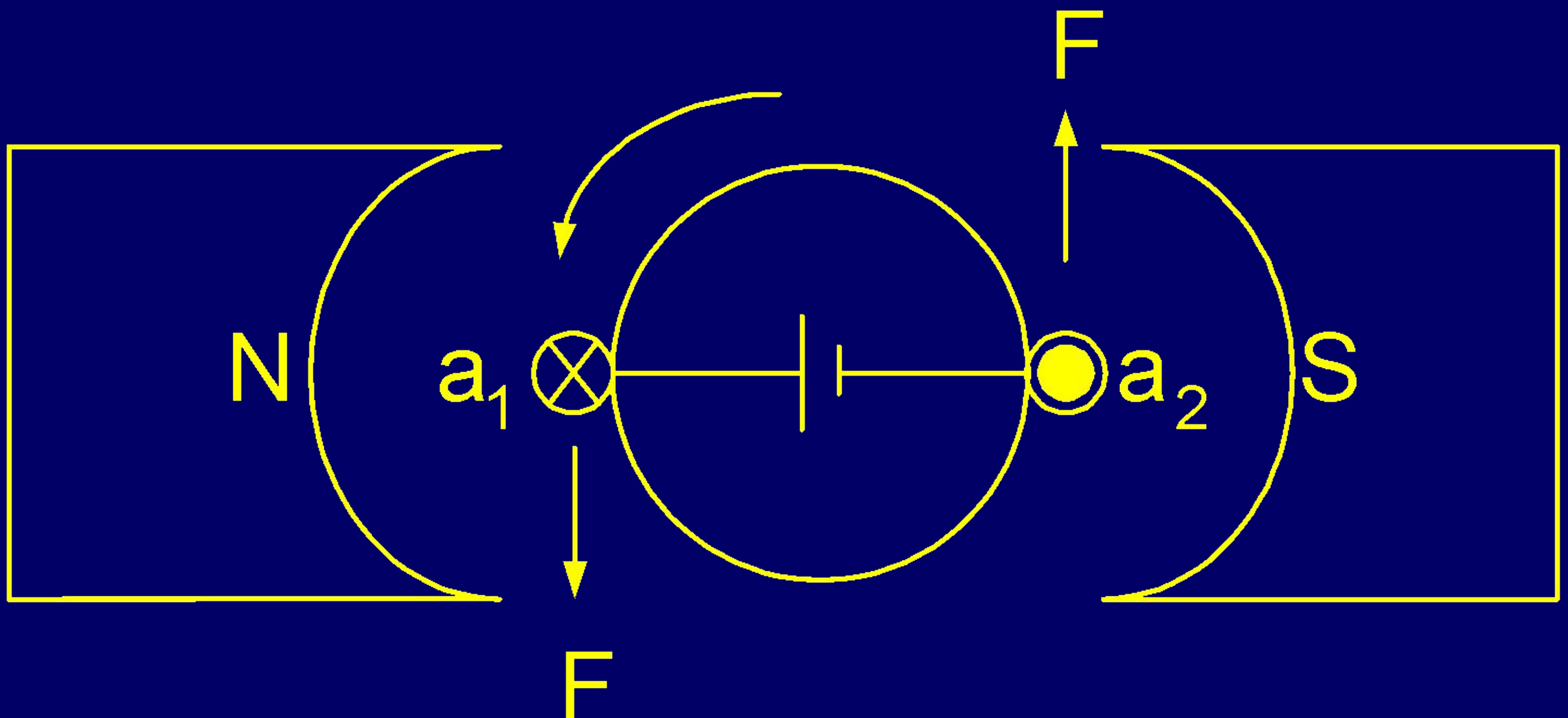


Conductor carrying current when placed in a magnetic field experience Mechanical force.

Fleming’s Left Hand Rule



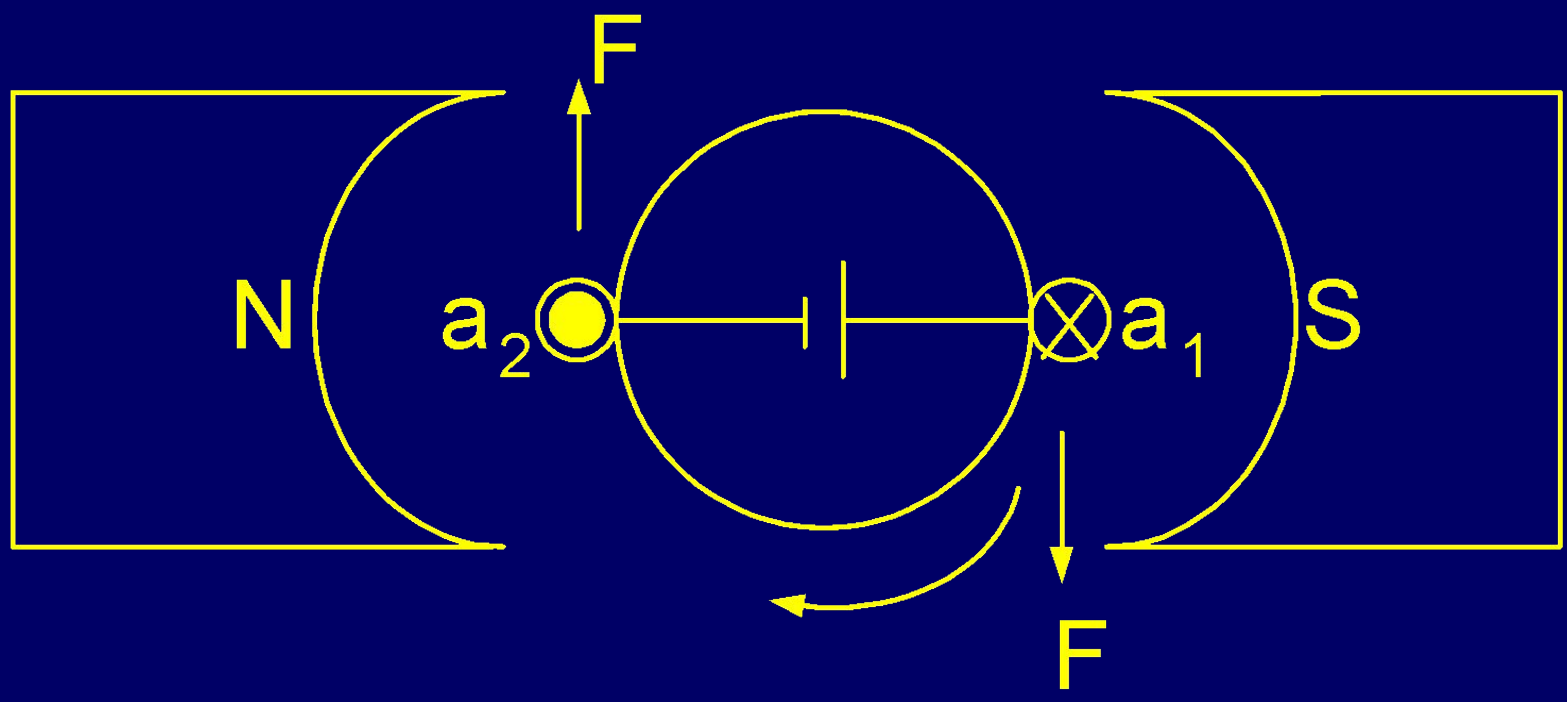
DC M/C : Principle of Operation



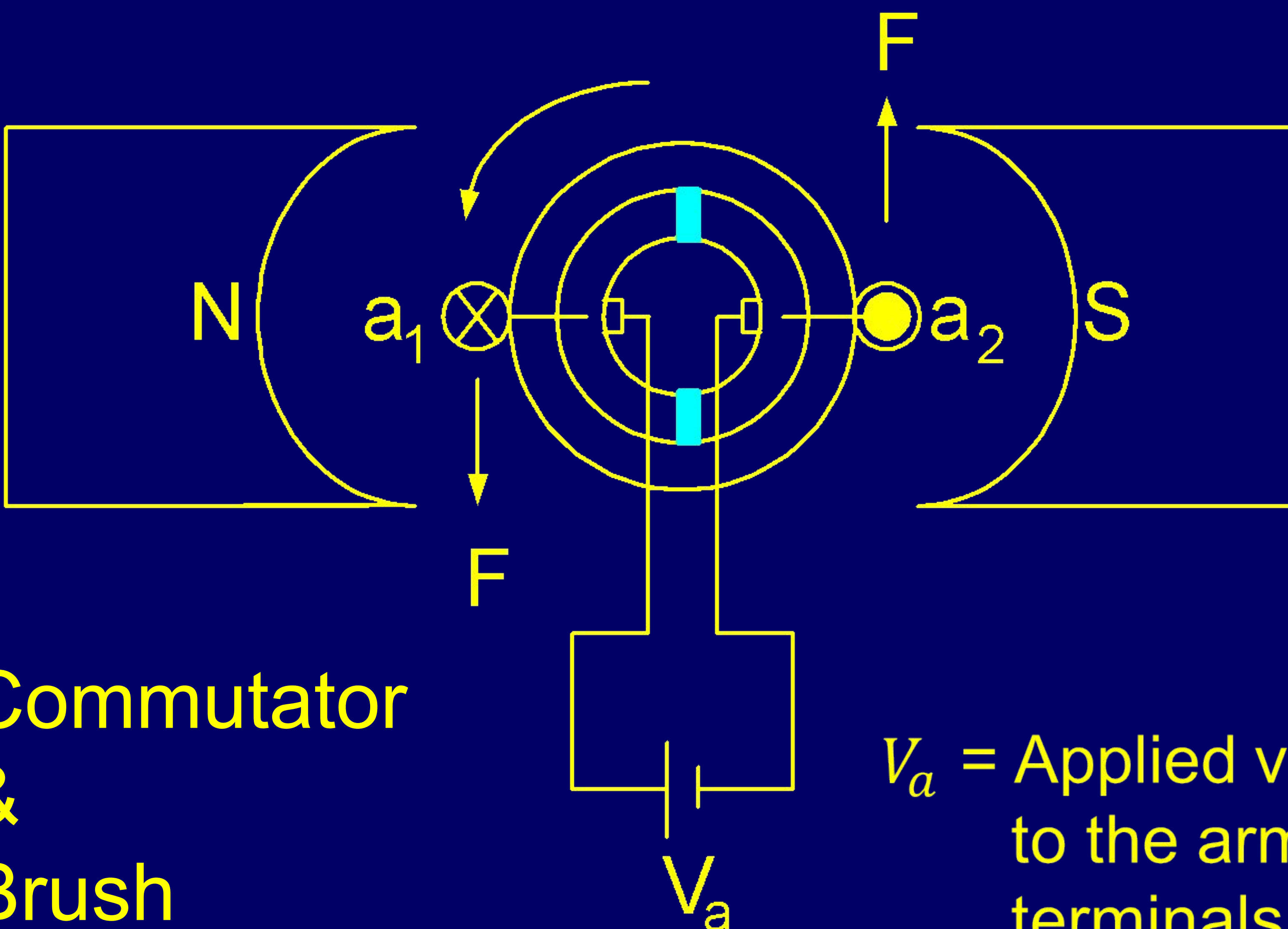
$\otimes$ represents current going into the plane of the slide

● represents current coming out of the plane of the slide

DC M/C : Principle of Operation



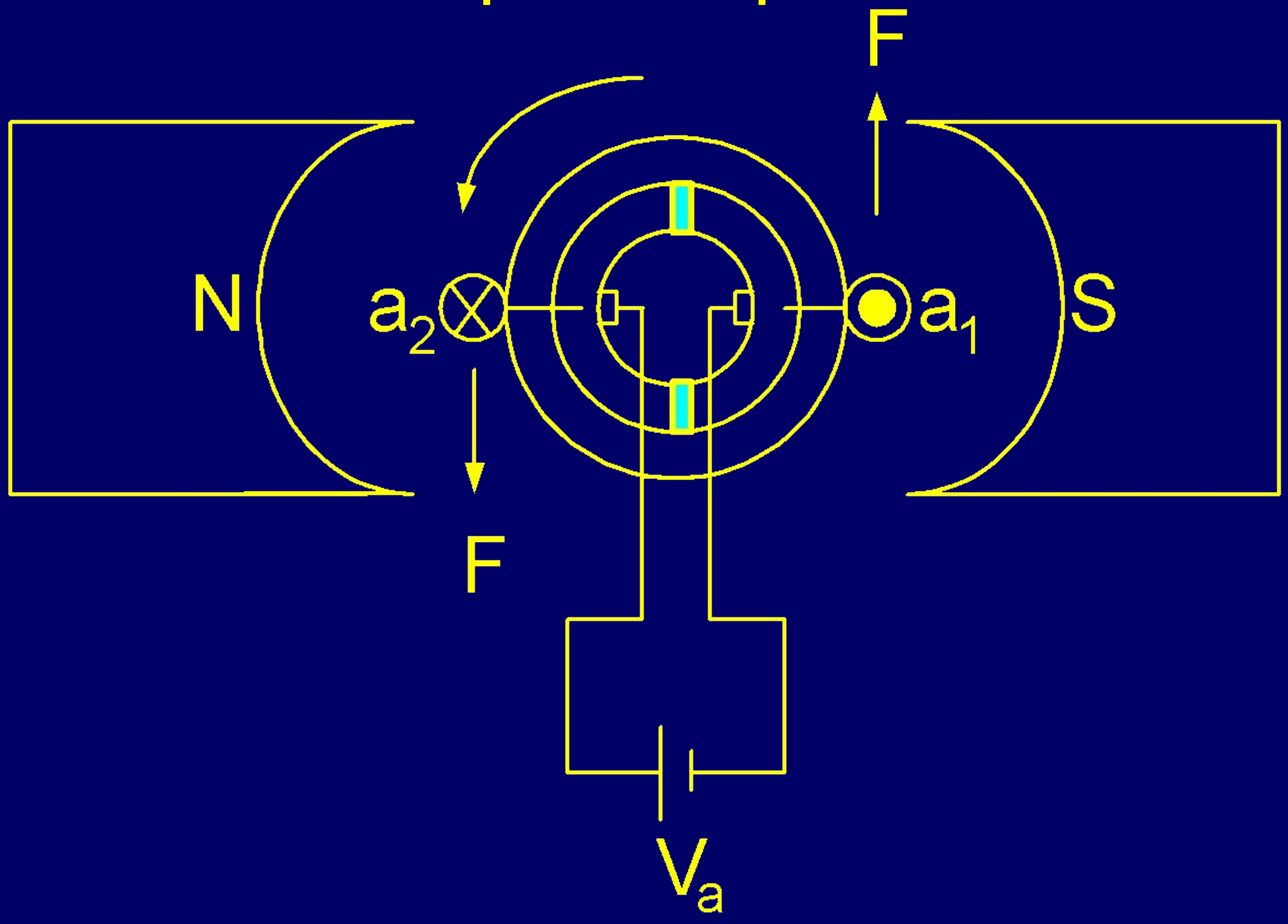
DC M/C : Principle of Operation



Commutator
&
Brush

V_a = Applied voltage to the armature terminals

DC M/C : Principle of Operation



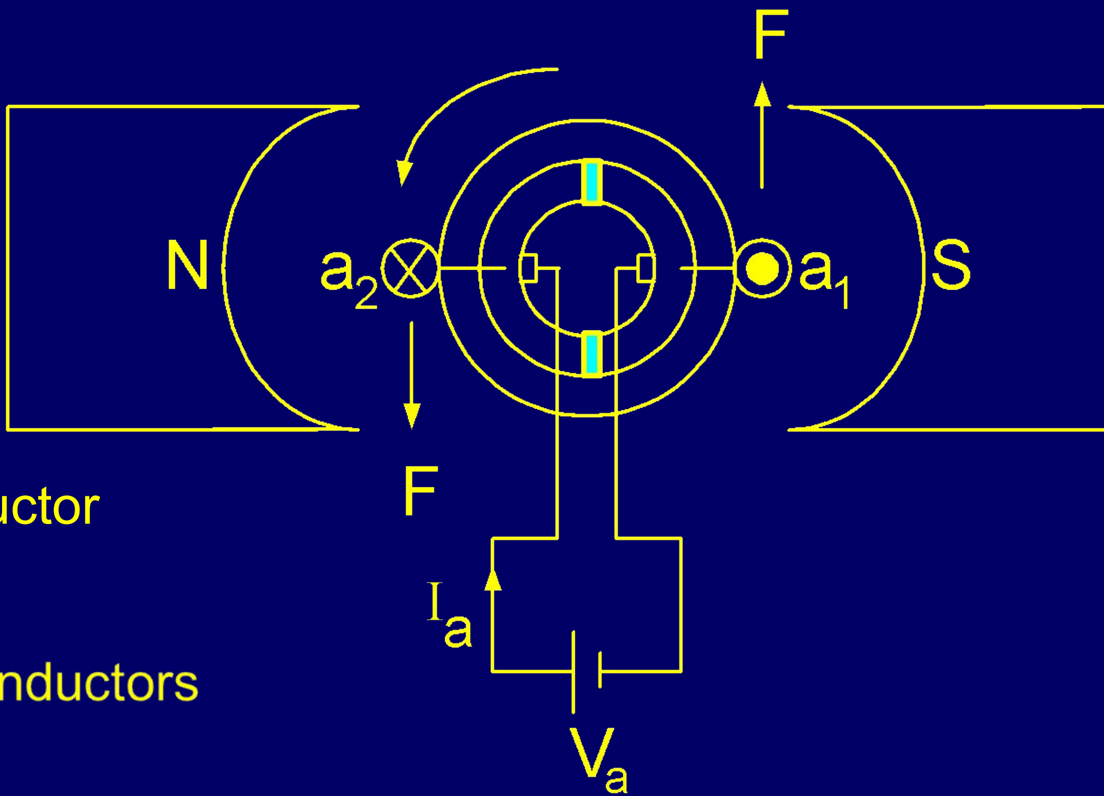
DC M/C : Principle of Operation

$$F = BI_aL\sin\theta$$

$$\theta = 90^0$$

$$T \propto \phi I_a$$

$$T = K_e\phi I_a$$



F = force experienced by a conductor

B = Flux density

I_a = Current through armature conductors

L = length of a conductor

$\theta =$ angle between the length of the conductor and the magnetic field

ϕ = Flux per pole

$T =$ torque developed by the motor

$K_e =$ Proportionality constant = Machine Constant

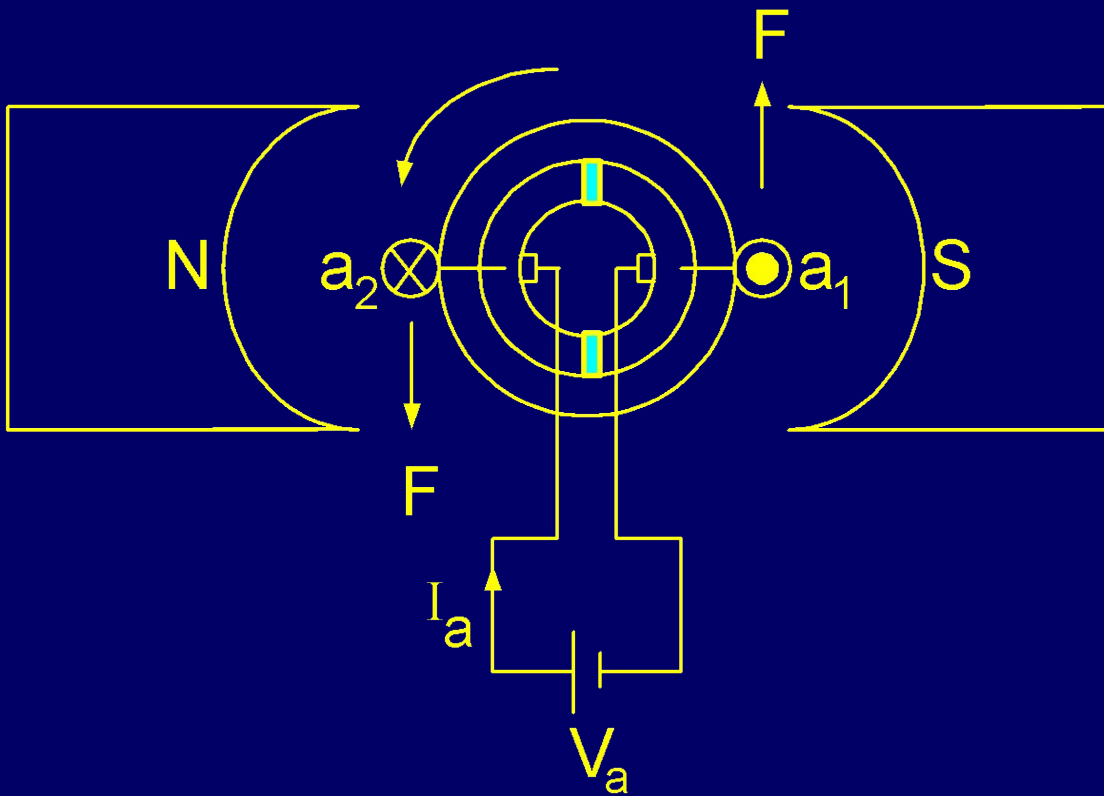
DC M/C : Principle of Operation

$F = BIL\sin\theta$

$\theta = 90^0$

$T \propto \emptyset I_a$

$T = K_e \emptyset I_a$



If the polarity of V_a is reversed, the direction of torque developed will get reversed, and hence the direction of speed of rotation will also get reversed

Contradiction from Faraday's Law

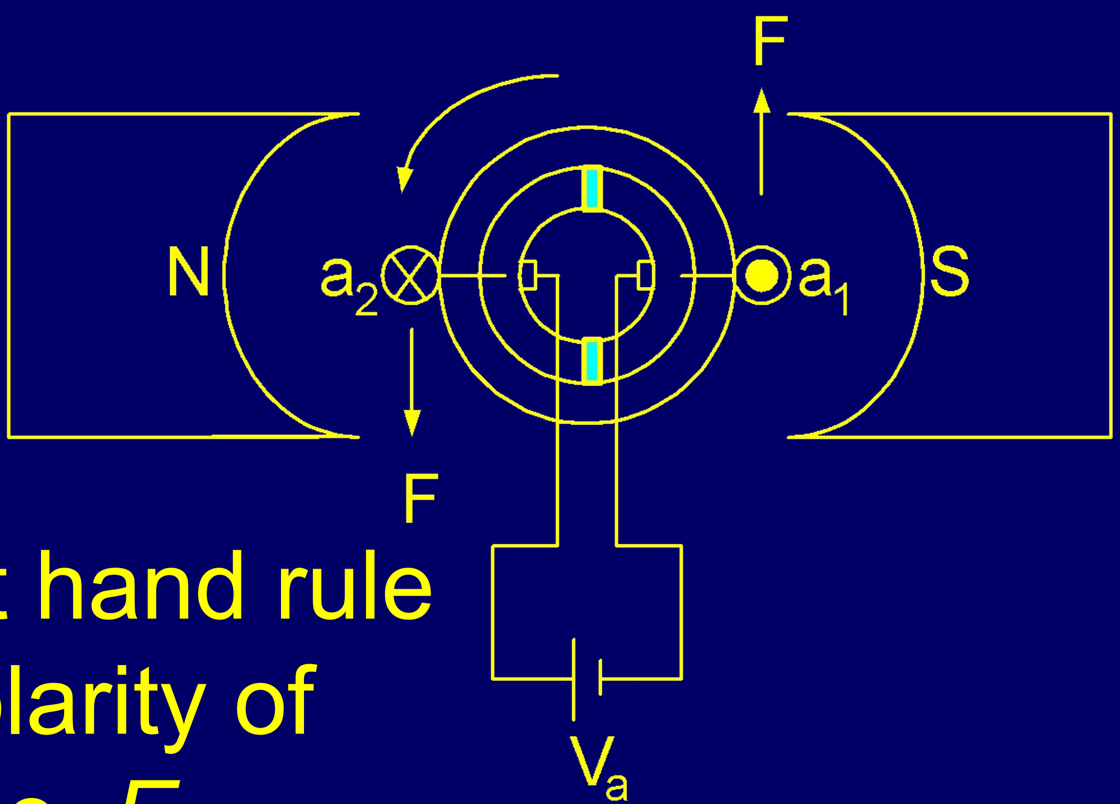
$$E_b = 2BLv\sin\theta$$

$$E_b \propto \phi\omega$$

v = linear velocity of a conductor

ω = angular speed in rad/s

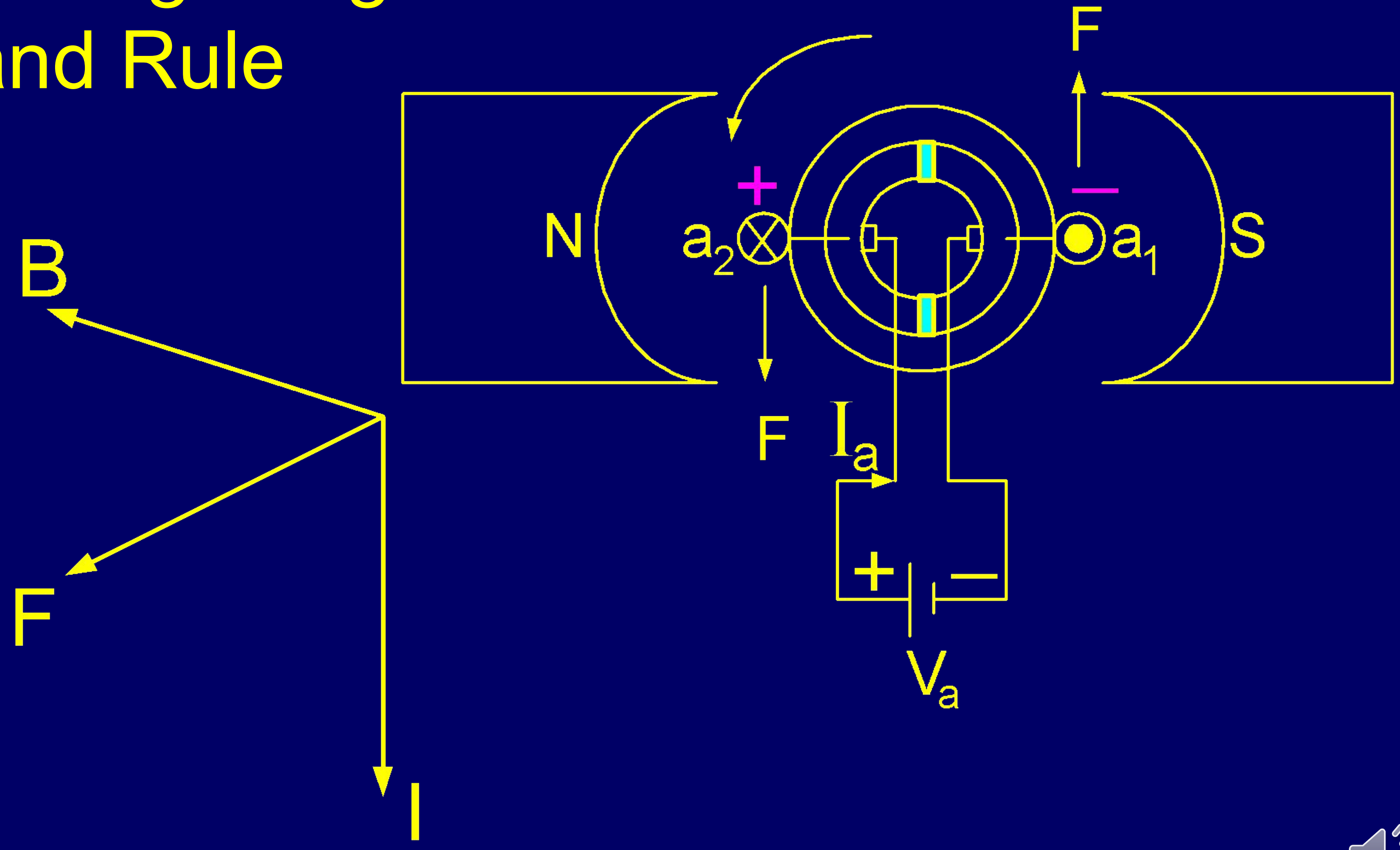
E_b is known as the back emf



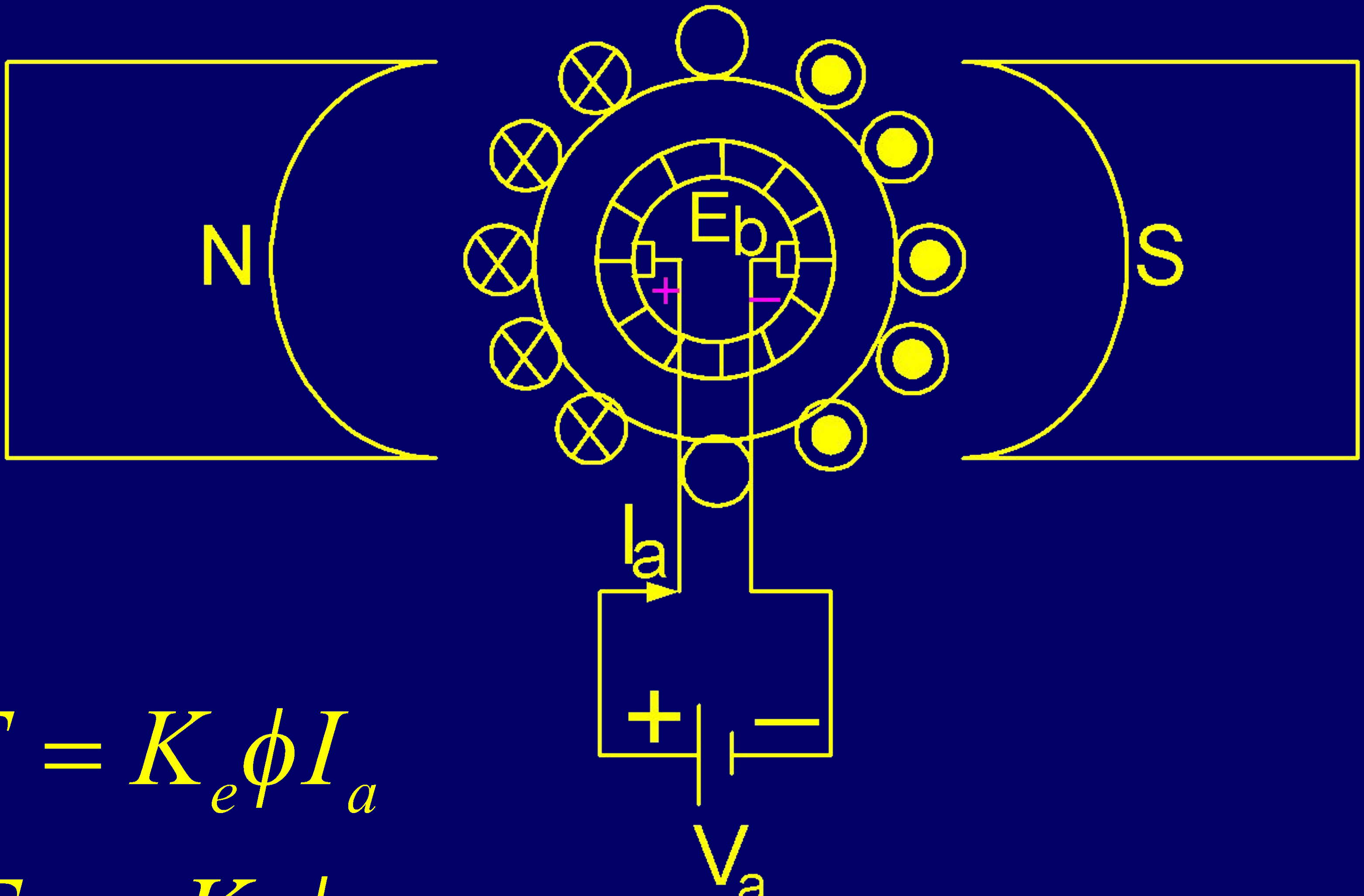
Fleming's right hand rule assigns the polarity of induced voltage, E_b

DC M/C : Principle of Operation

Fleming's Right Hand Rule



A Realistic DC Machine



$$T = K_e \phi I_a$$

$$E_b = K_e \phi \omega$$

DC Motor: Steady state model and behaviour

For Sep. Excited Motor or BO Motor

$$V_a = E_b + I_a R_a$$

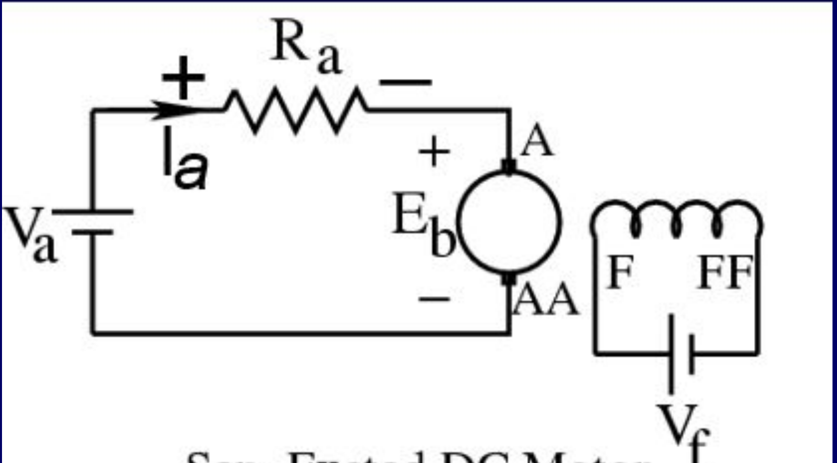
$$E_b = K_e \emptyset \omega$$

$$T = K_e \emptyset I_a$$

$$\omega = \frac{V_a}{K_e \emptyset} - \frac{R_a}{K_e \emptyset} I_a$$

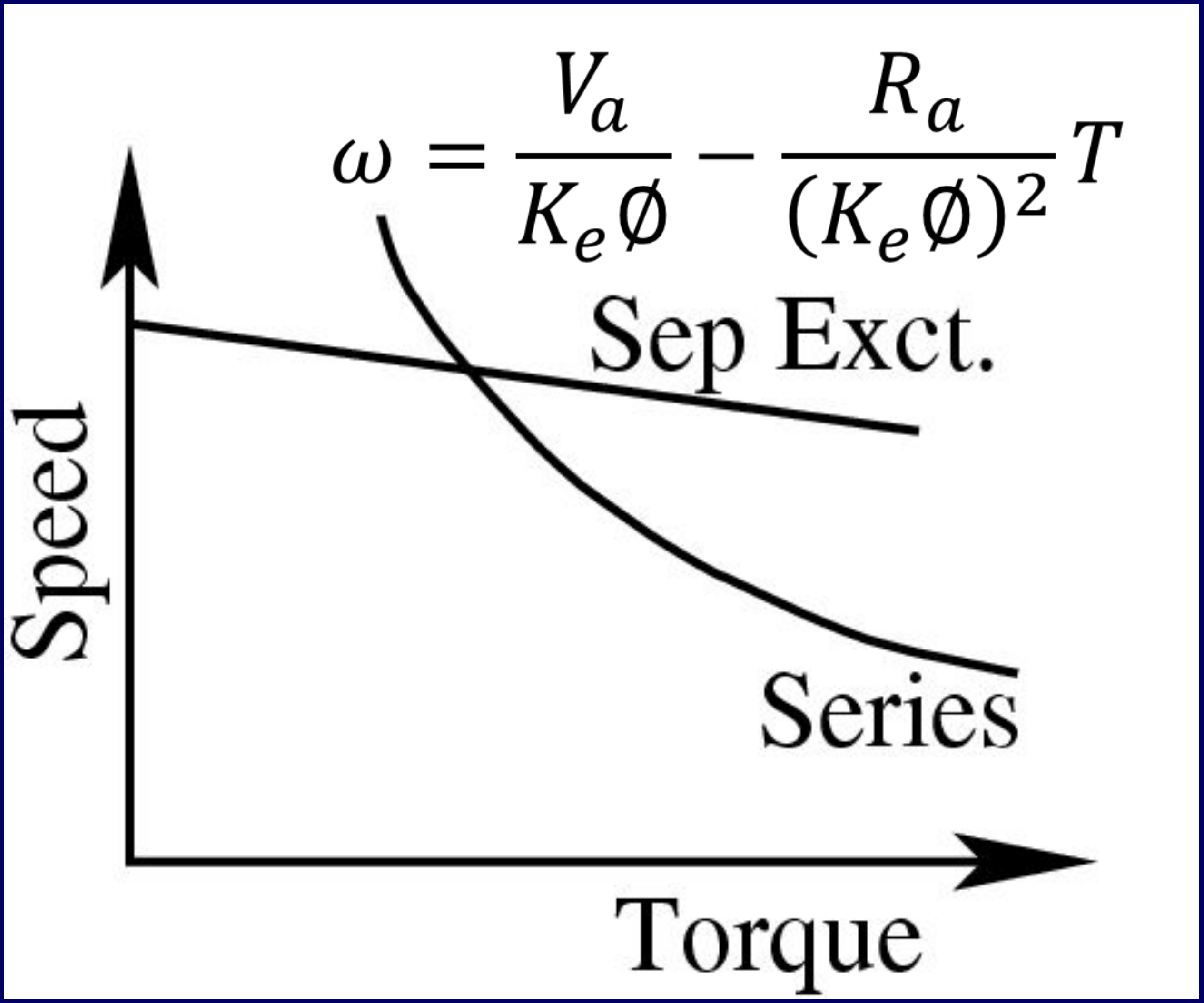
or

$$\omega = \frac{V_a}{K_e \emptyset} - \frac{R_a}{(K_e \emptyset)^2} T$$

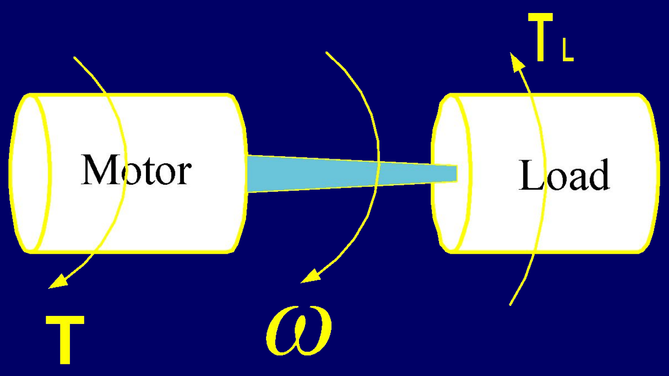


Sep. Excted DC Motor

Speed – Torque Characteristic



Motor-Load Interaction



$$T(\omega) = T_L(\omega) + J\frac{d\omega}{dt} \text{ --- (A)}$$

J = Polar moment of inertia

$T_L(\omega)$ = Load torque

We have already derived:

$$\omega = \frac{V_a}{K_e\emptyset} - \frac{R_a}{(K_e\emptyset)^2}T \quad \text{---- (B)}$$

The equations (A) and (B) represent the model of a dc motor while driving a certain load having torque, $T_L(\omega)$

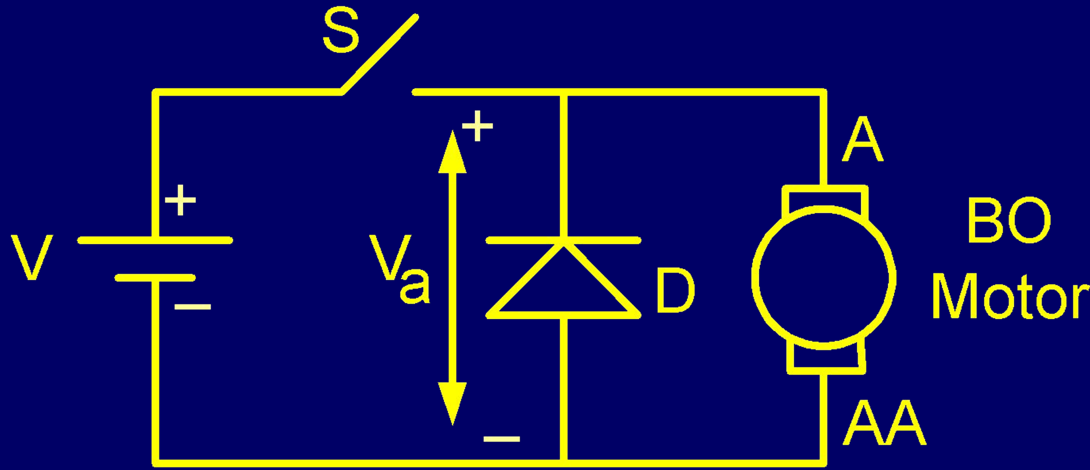
Implementation of Speed/Position control

$$\omega = \frac{V_a}{K_e \emptyset} - \frac{R_a}{(K_e \emptyset)^2} T$$

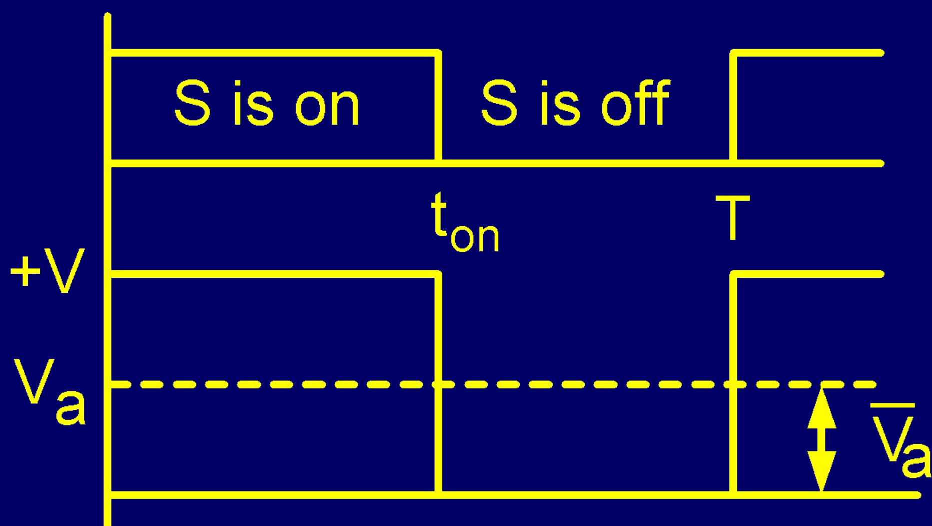
Applied voltage, V_a needs to be varied

- This is accomplished by applying PWM (Pulse Width Modulated) pulses instead of applying a constant dc voltage

Control of Speed by PWM



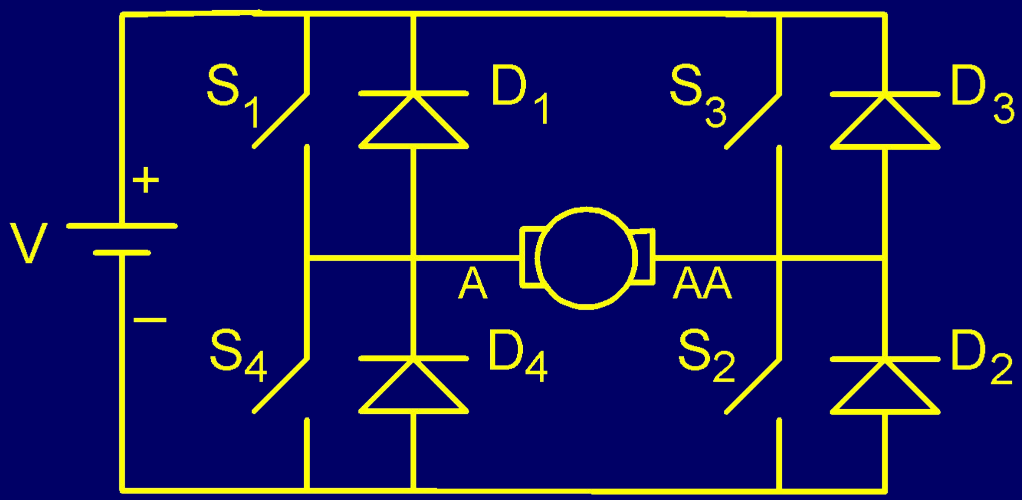
Diode, D provides a path for the inductive current to flow when S is turned off.



$$\overline{V_a} = V\frac{t_{on}}{T}$$

By varying t_{on} magnitude of V_a is varied

Speed Reversal



To operate in a particular direction:

S_2 is kept on while S_3 and S_4 are kept off. S_1 is operated in PWM to control speed in this direction

To operate in the reverse direction:

S_4 is kept on while S_1 and S_2 are kept off. S_3 is operated in PWM to control speed in the reverse direction

Reference Book:

Fundamentals of Electrical Engineering by Leonard S. Bobrow, Oxford Unversity Press.