

MS 101

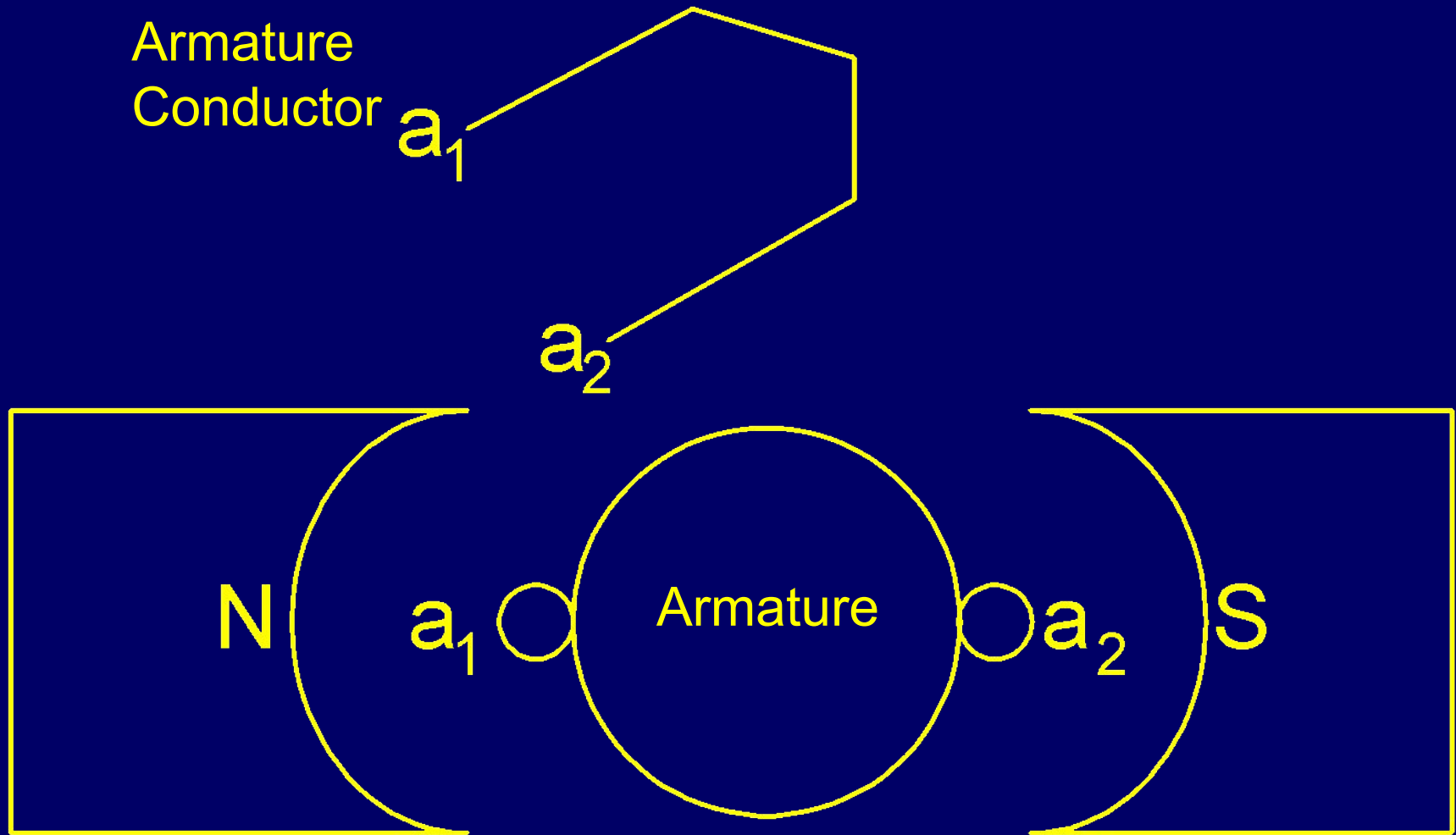
# DC Motors

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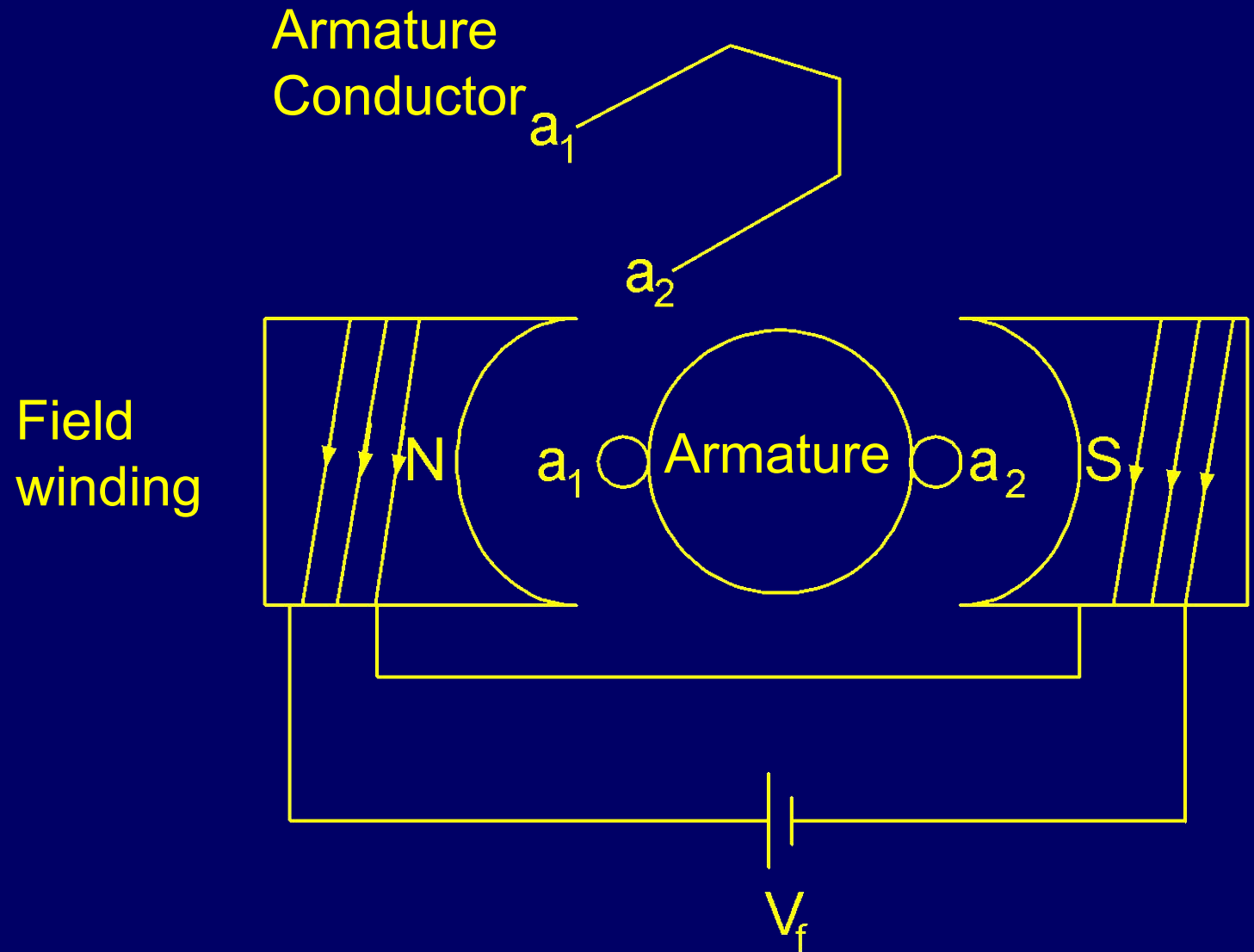


# DC Motor : Principle of Operation



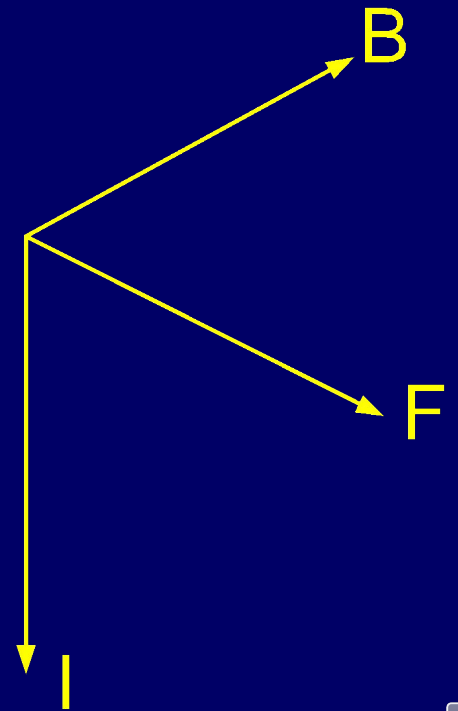
Field of the stator (by virtue of permanent magnets) : BO Motor also known as 'permanent magnet dc motor'

# DC Motor : Principle of Operation

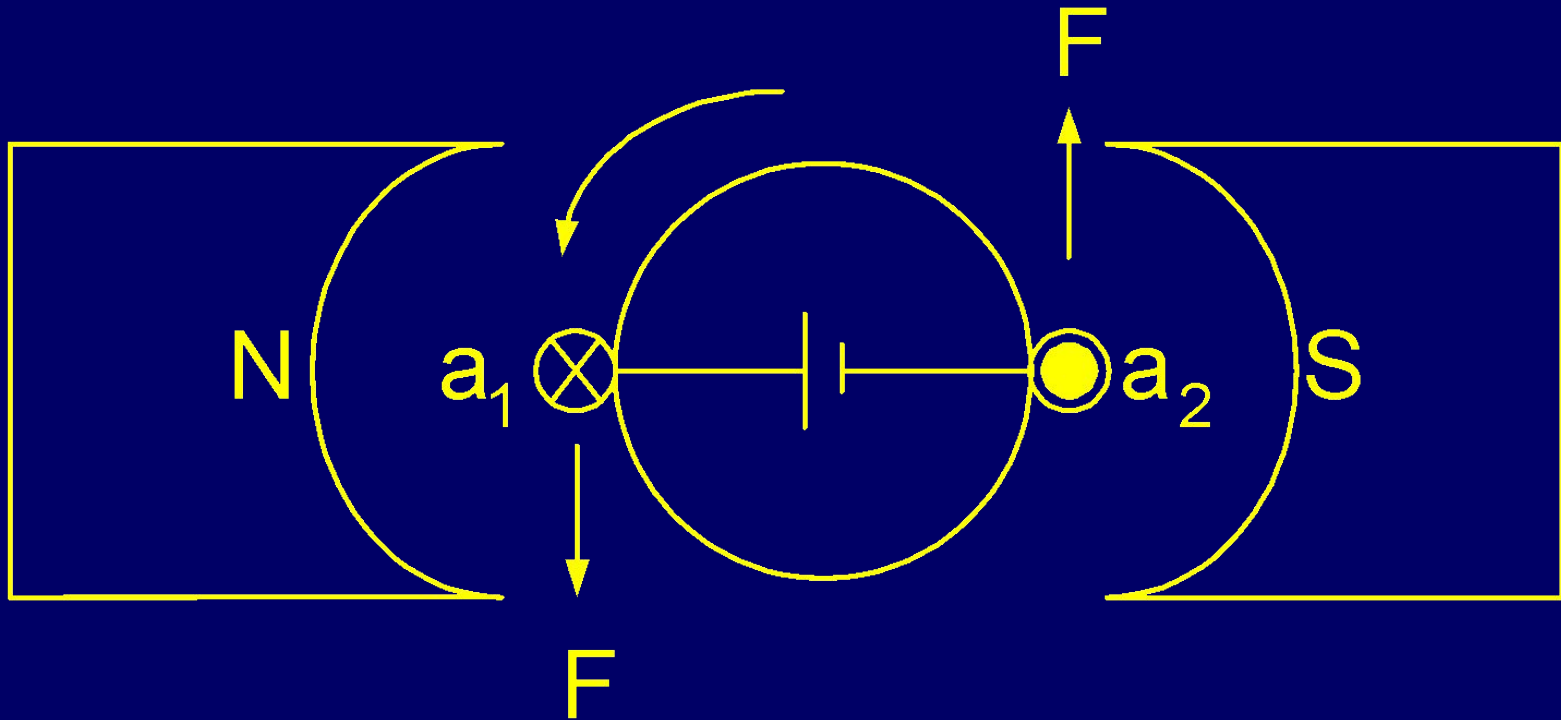


Conductor carrying current when placed  
in a magnetic field experience  
Mechanical force.

Fleming's Left Hand Rule



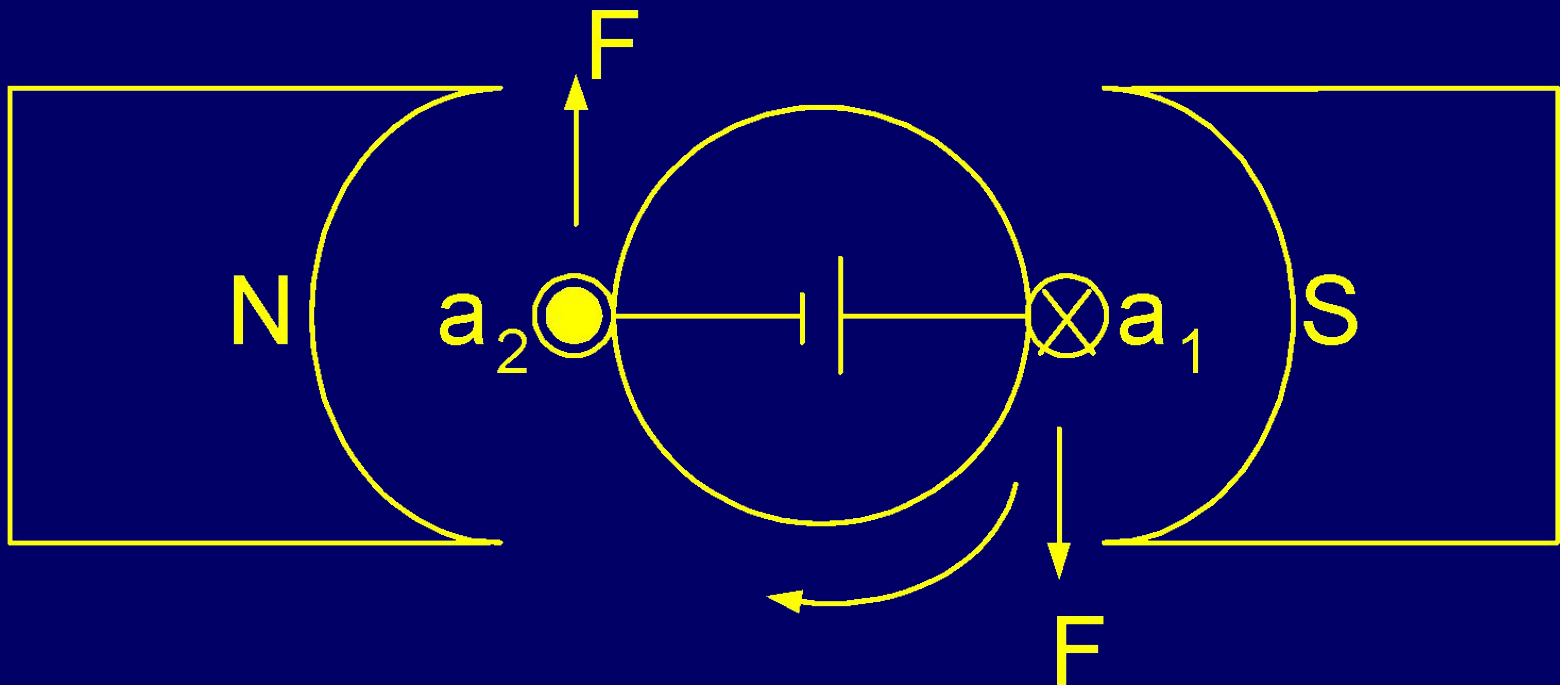
# DC M/C : Principle of Operation



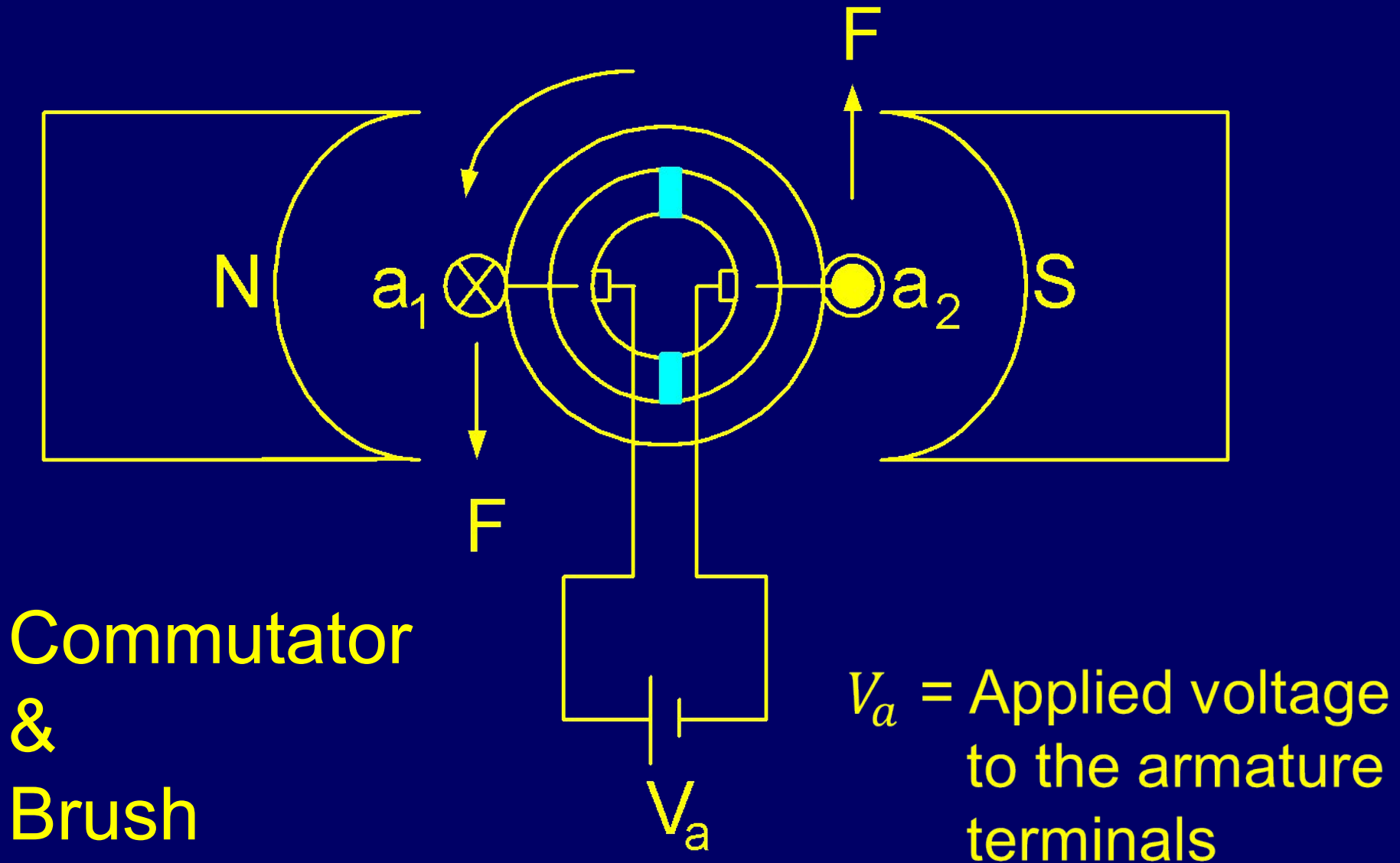
$\otimes$  represents current going into the plane of the slide

$\bullet$  represents current coming out of the plane of the slide

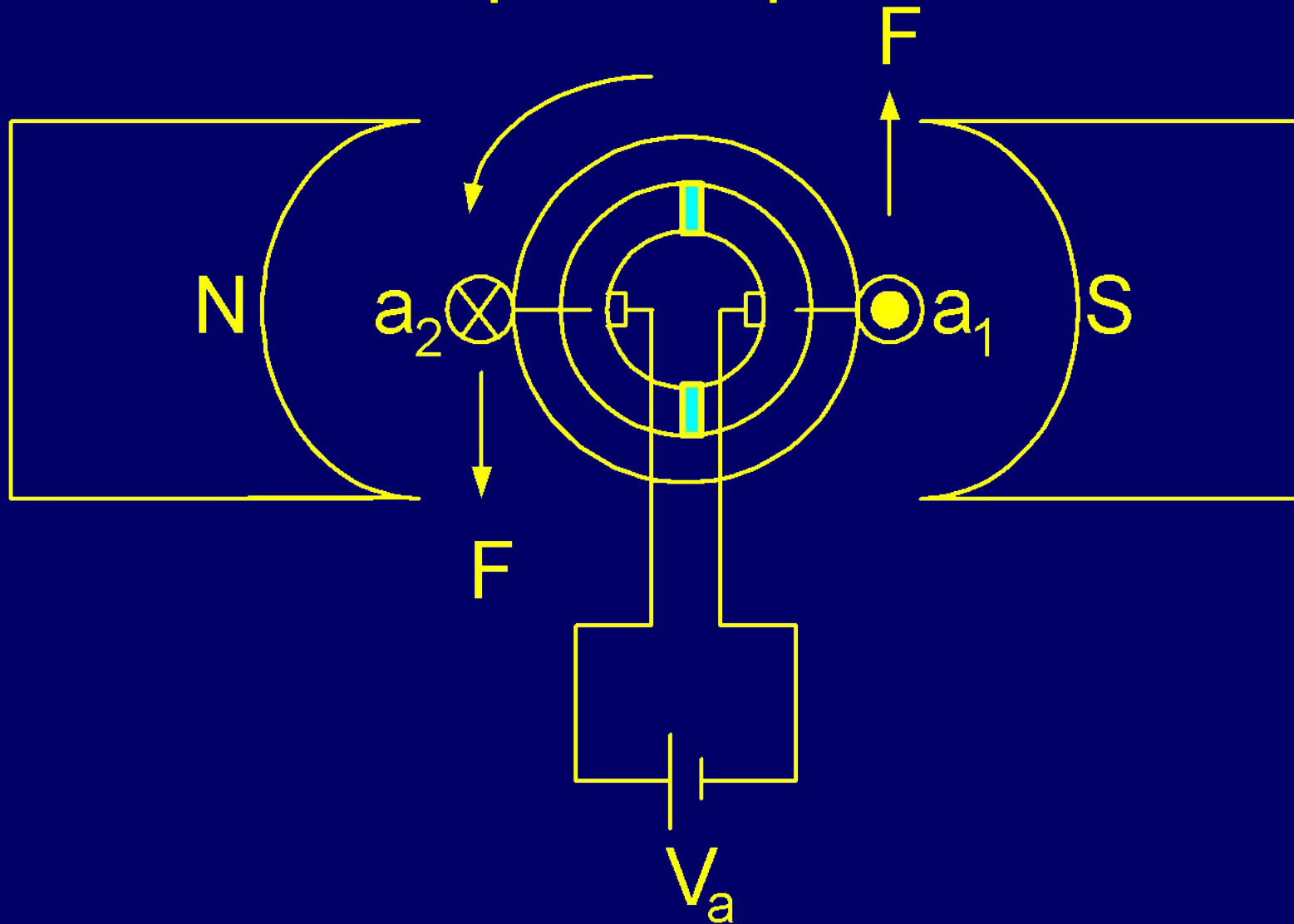
# DC M/C : Principle of Operation



# DC M/C : Principle of Operation



# DC M/C : Principle of Operation





# DC M/C : Principle of Operation

$$F = BI_a L \sin \theta$$

$$\theta = 90^\circ$$

$$T \propto \phi I_a$$

$$T = K_e \phi I_a$$

$F$  = force experienced by a conductor

$B$  = Flux density

$I_a$  = Current through armature conductors

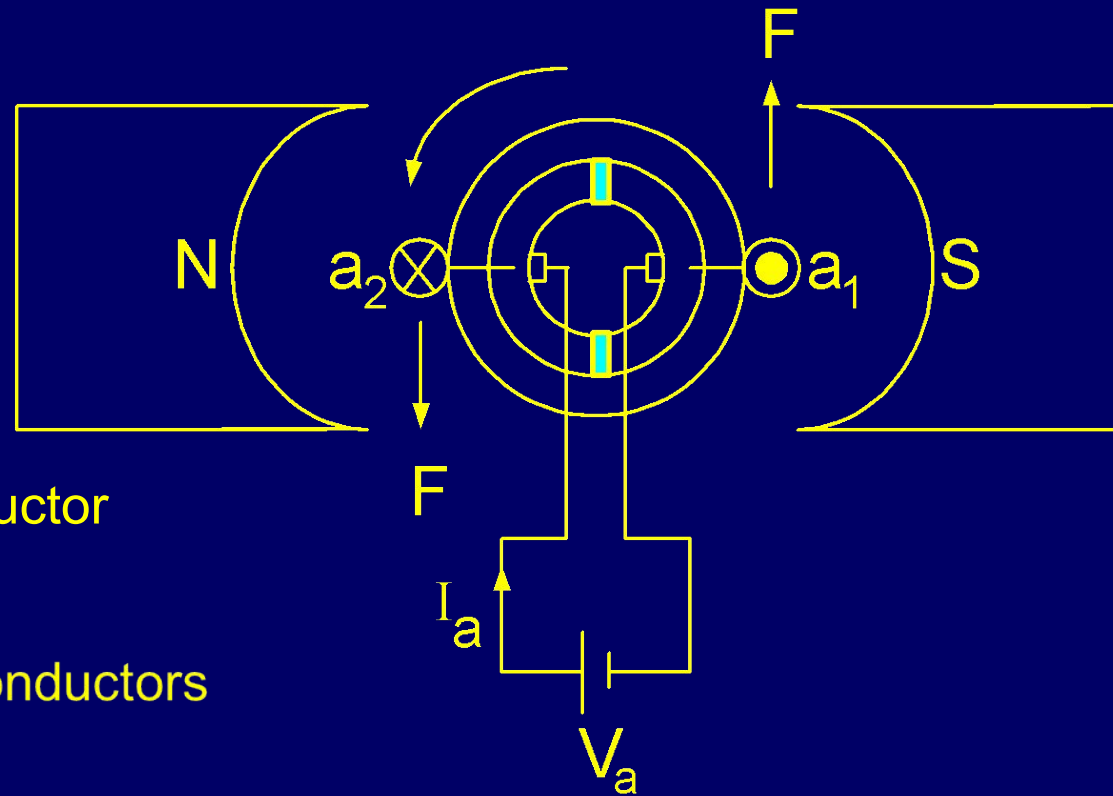
$L$  = length of a conductor

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

$\phi$  = Flux per pole

$T$  = torque developed by the motor

$K_e$  = Proportionality constant = Machine Constant



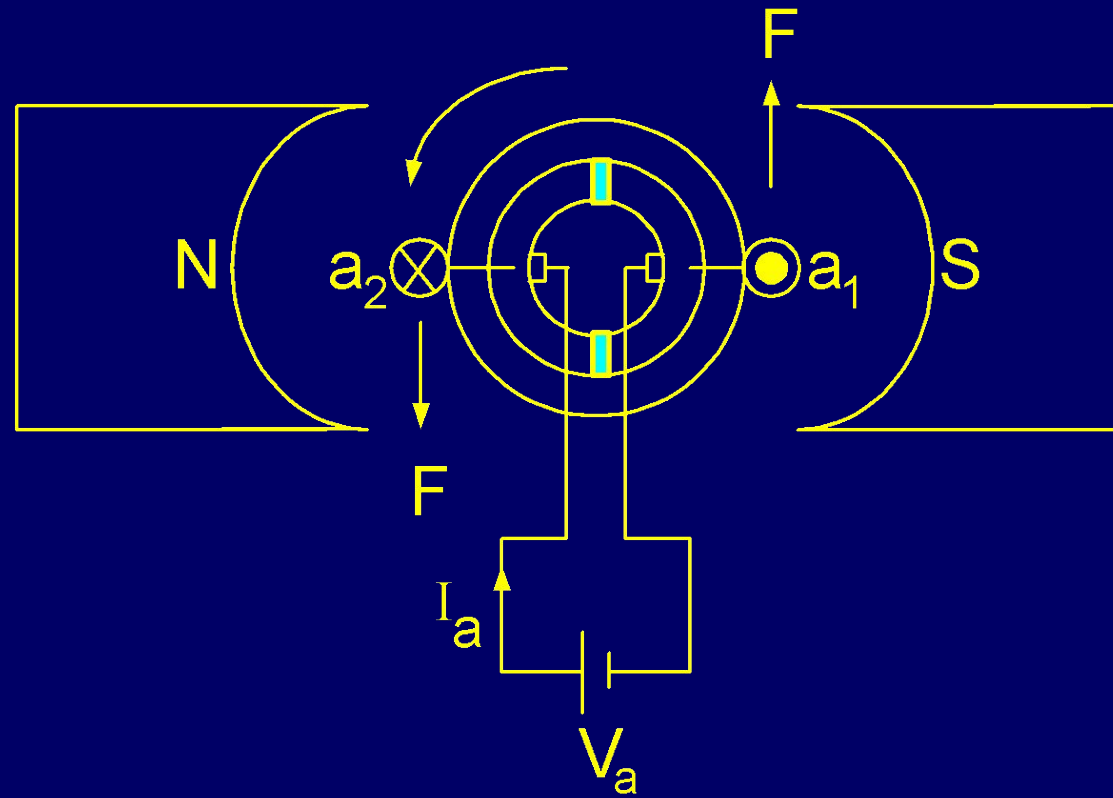
# DC M/C : Principle of Operation

$$F = BIL \sin \theta$$

$$\theta = 90^\circ$$

$$T \propto \phi I_a$$

$$T = K_e \phi I_a$$



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

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

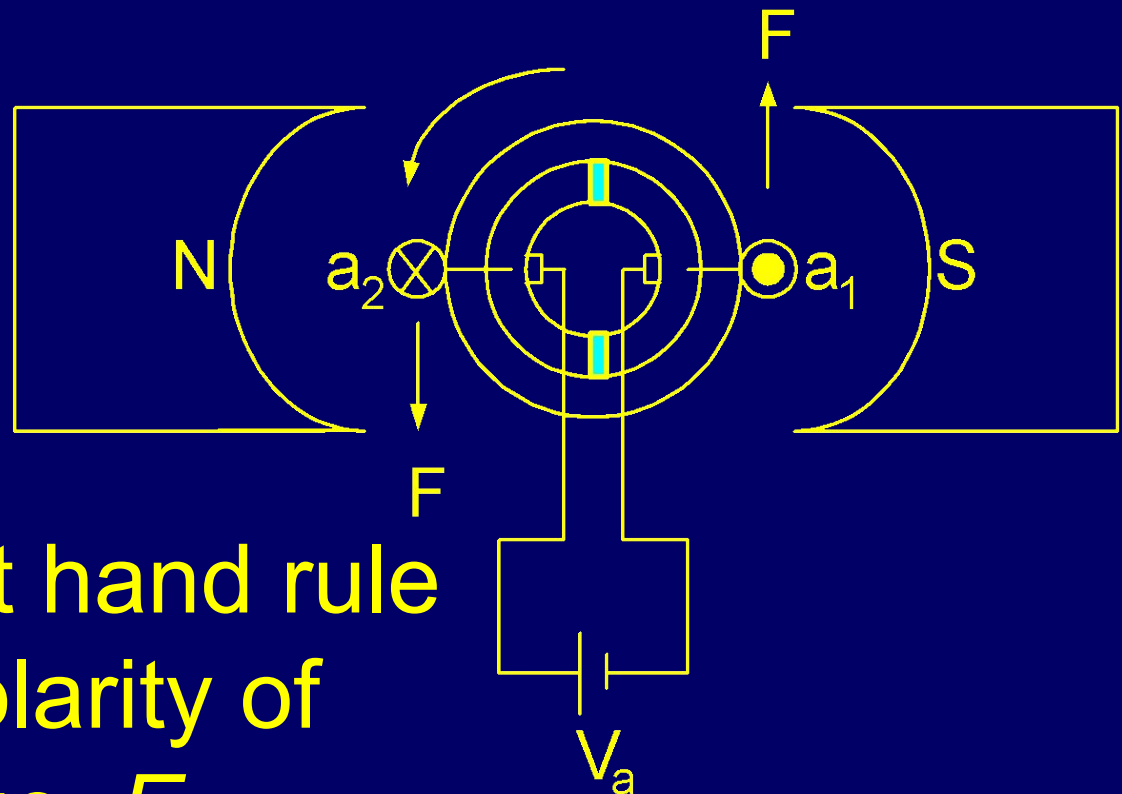
$$E_b \propto \phi \omega$$

$v$  = linear velocity of a conductor

$\omega$  = angular speed in rad/s

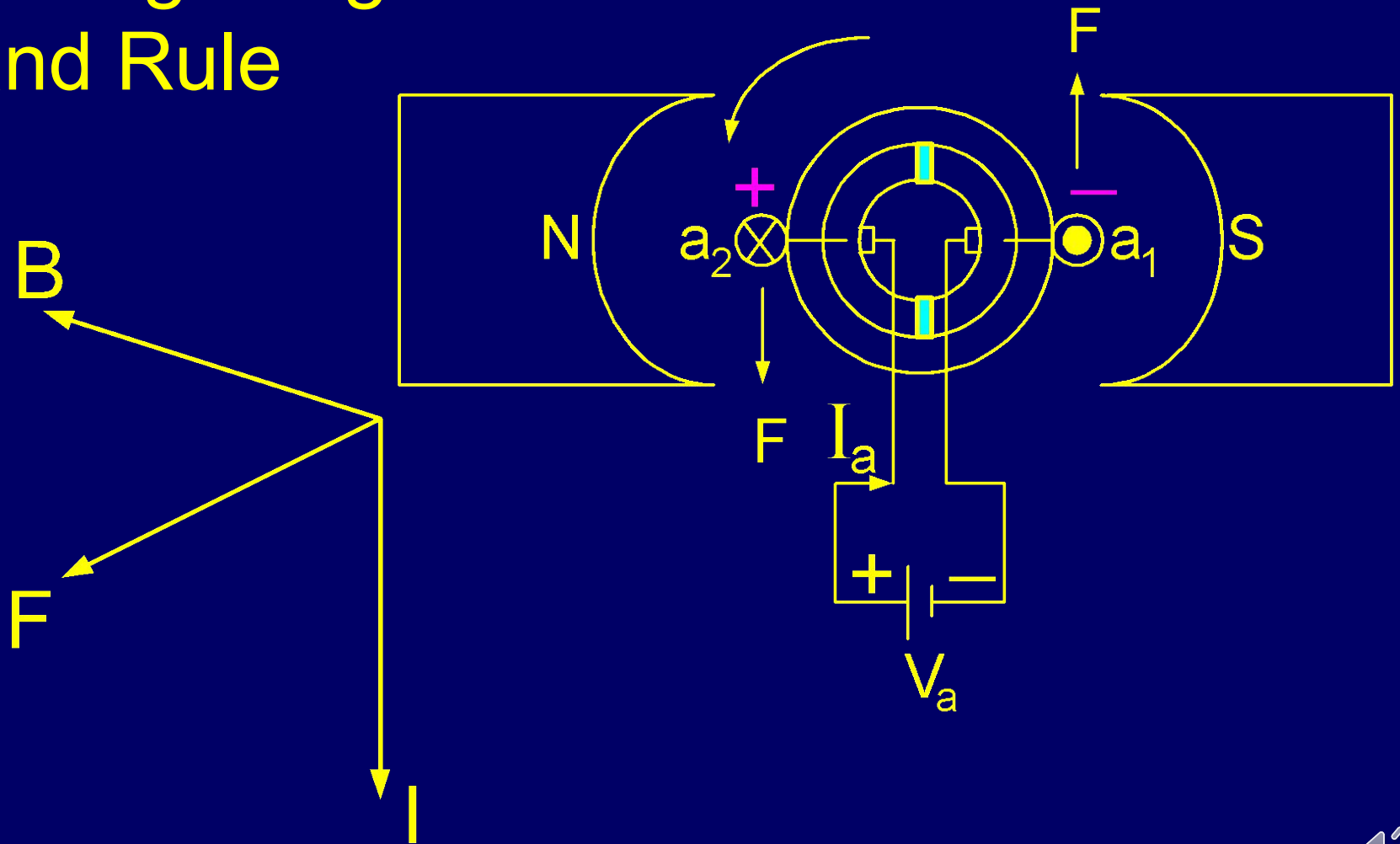
$E_b$  is known as the back emf

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

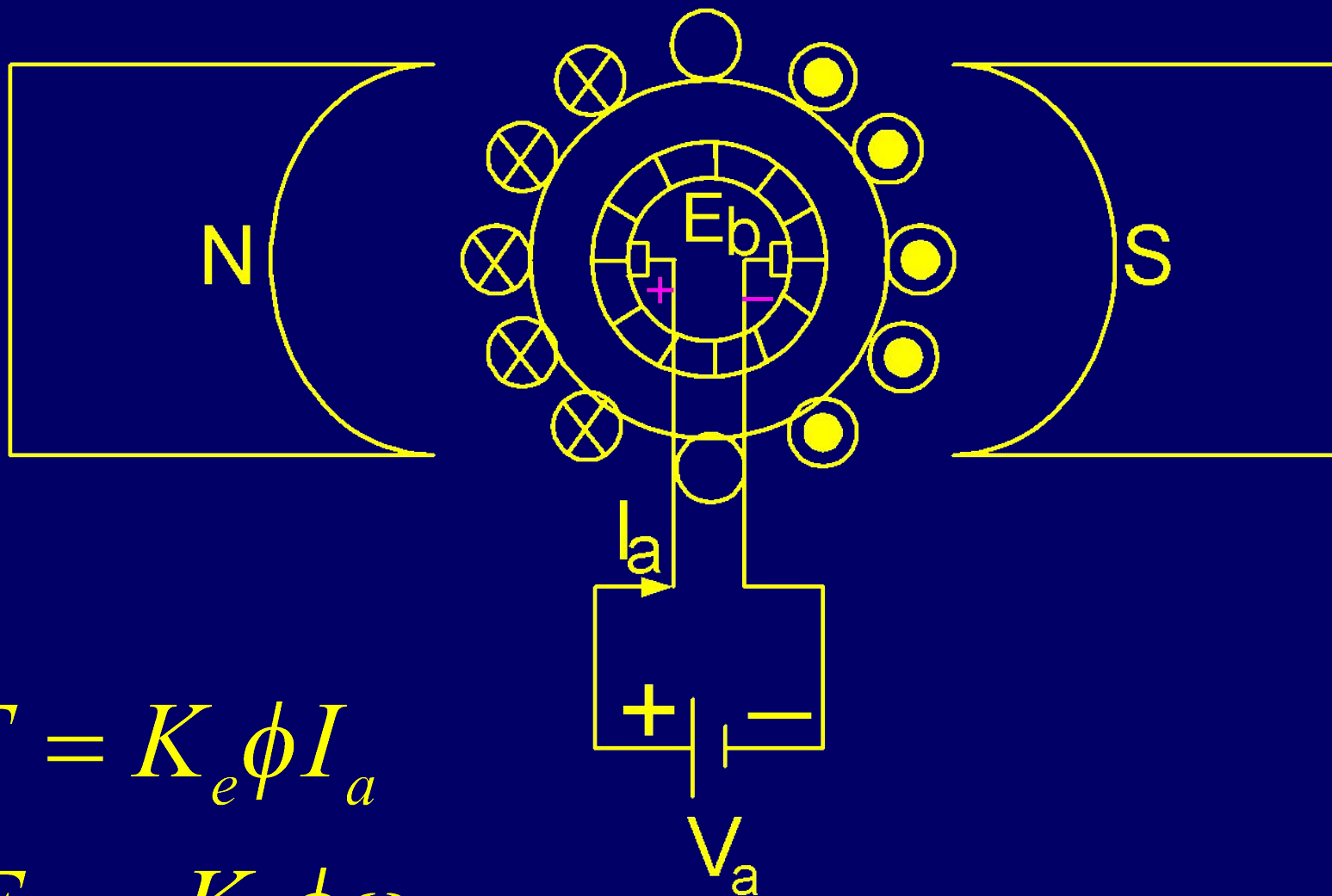


# DC M/C : Principle of Operation

## 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

$$V_a = E_b + I_a R_a$$

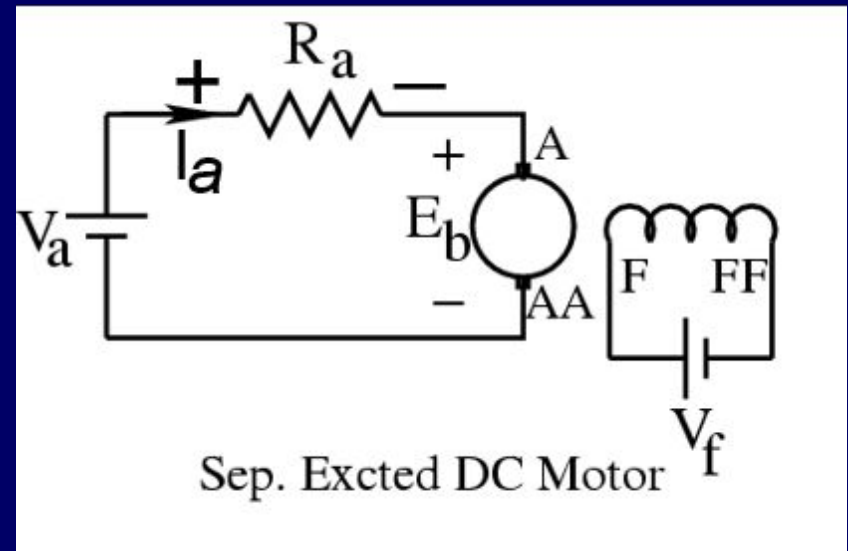
$$E_b = K_e \Phi \omega$$

$$T = K_e \Phi I_a$$

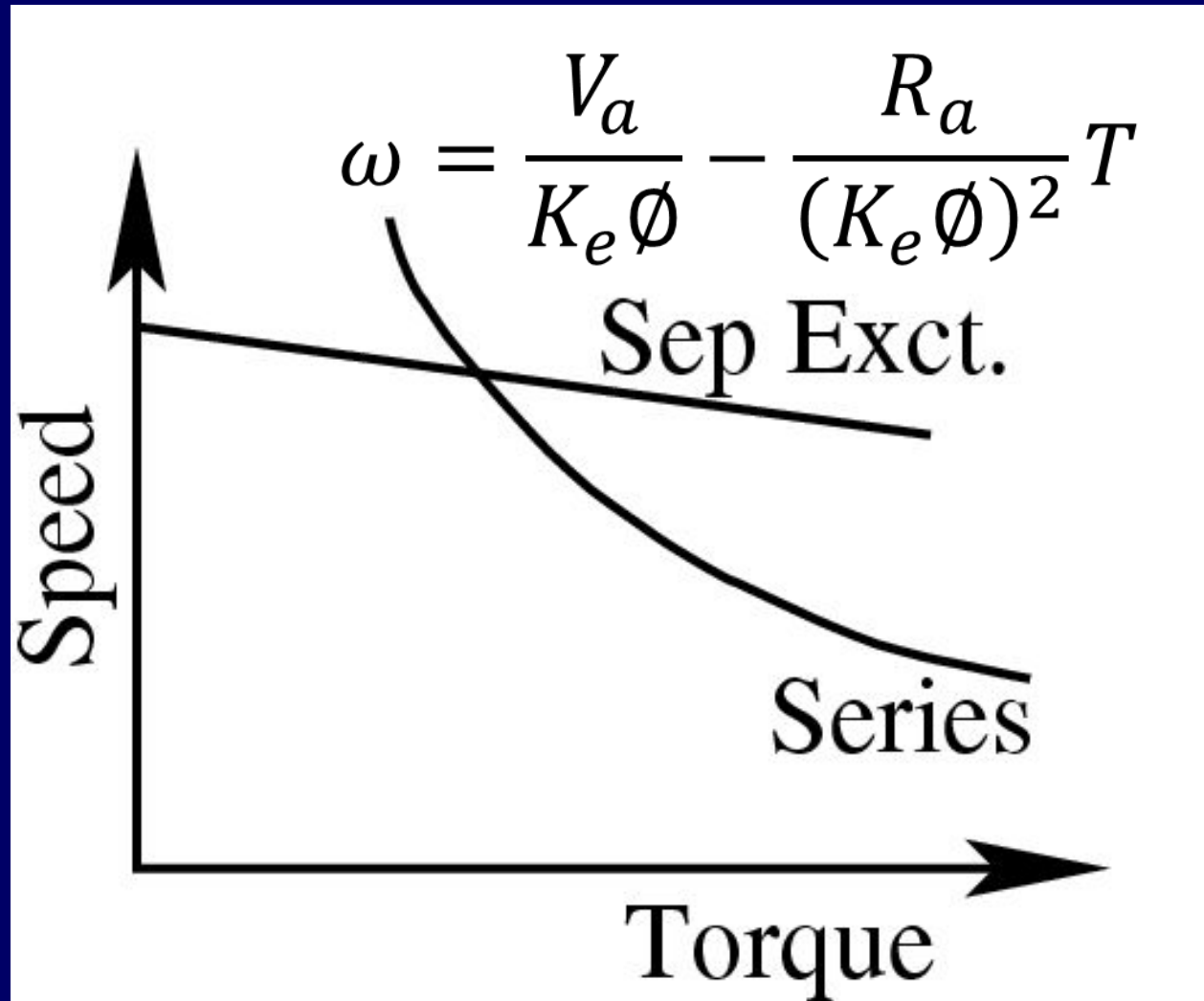
$$\omega = \frac{V_a}{K_e \Phi} - \frac{R_a}{K_e \Phi} I_a$$

or

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

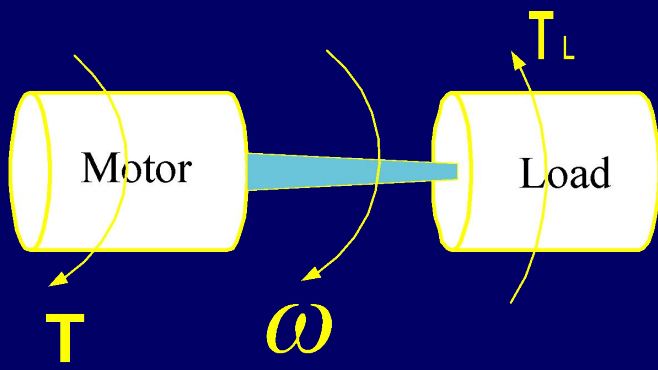


# Speed – Torque Characteristic





# Motor-Load Interaction



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

$J$  = Polar moment of inertia

$T_L(\omega)$  = Load torque

We have already derived:

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

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

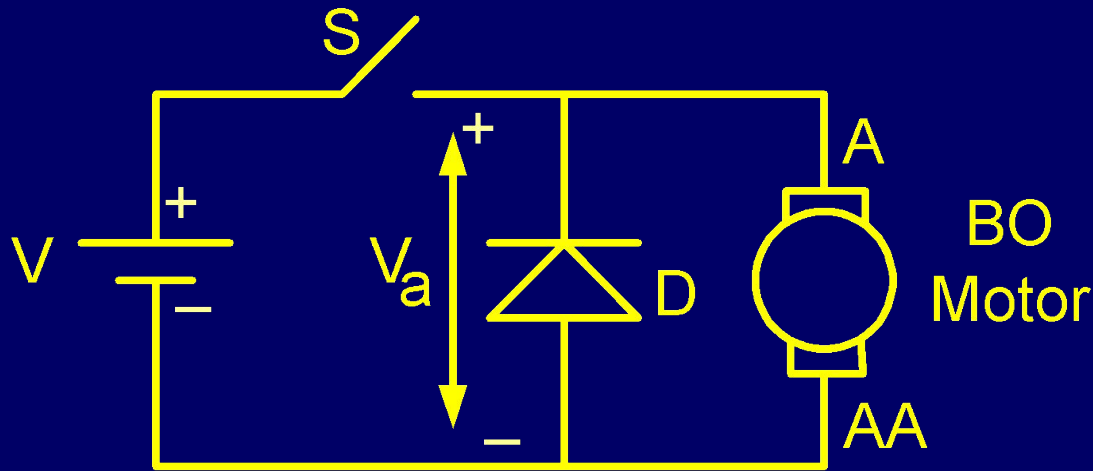
# Implementation of Speed/Position control

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

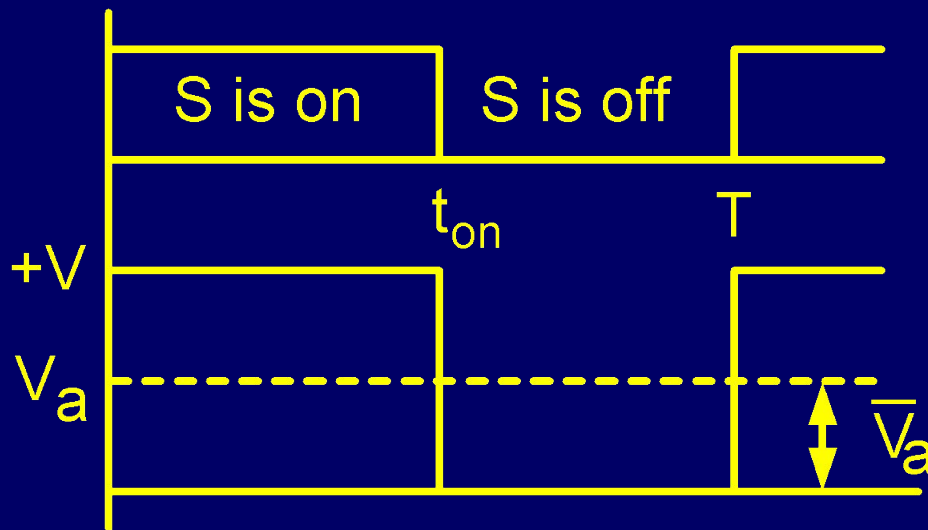
Applied voltage,  $V_a$  needs to be varied

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

# Control of Speed by PWM



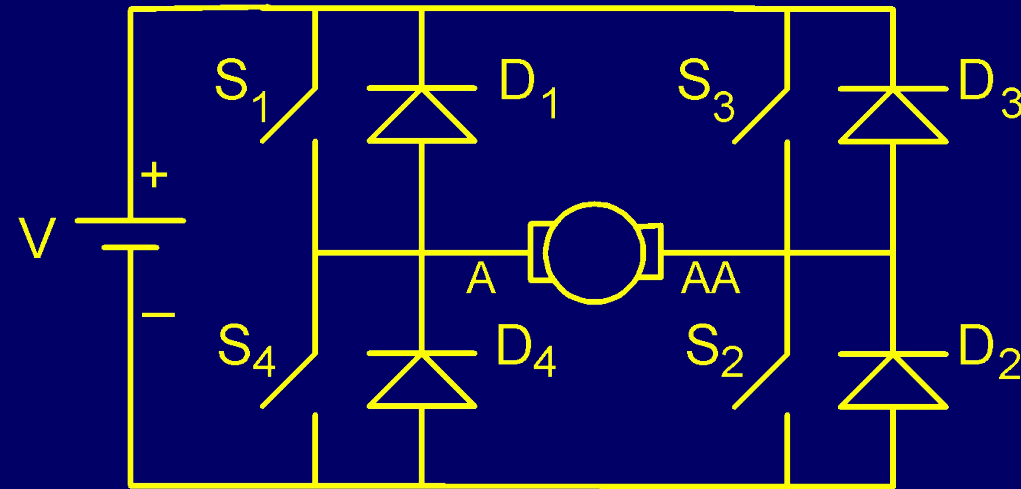
Diode,  $D$  provides a path for the inductive current to flow when  $S$  is turned off.



$$\bar{V}_a = V \frac{t_{on}}{T}$$

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 University  
Press.