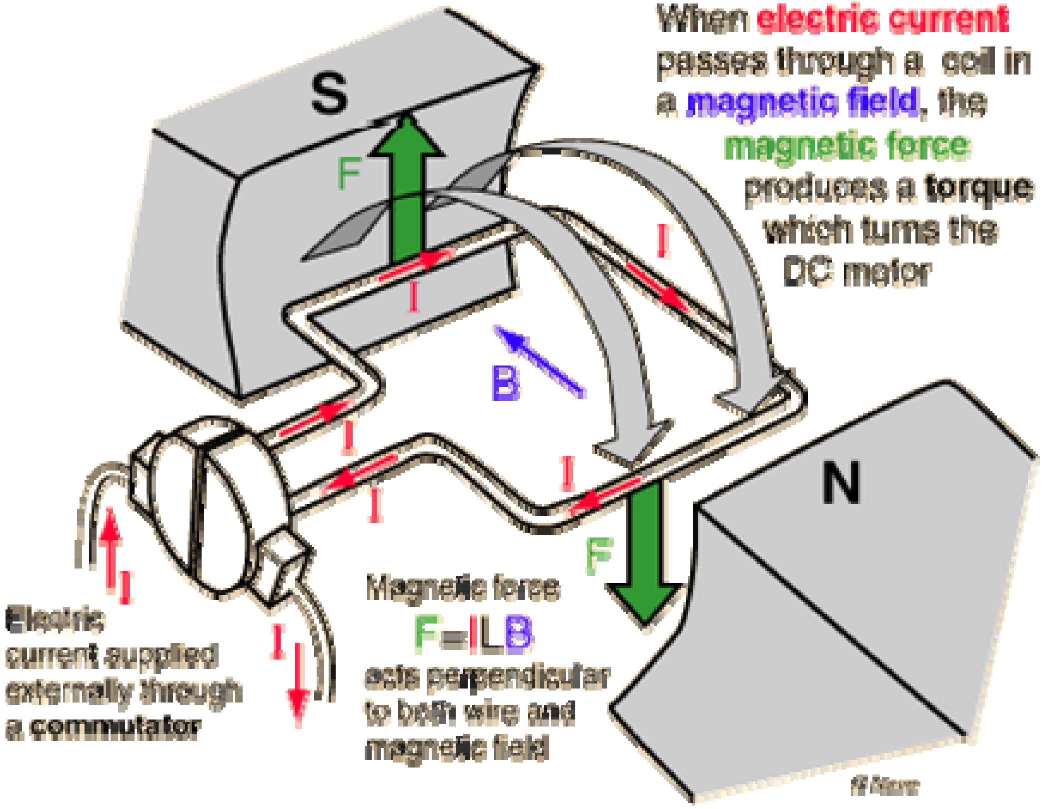
DC MOTORS

EE 340

Spring 2008

Basic DC Motor Operation



When electric current passes through a coil in a magnetic field, the magnetic force produces a torque which turns the DC motor

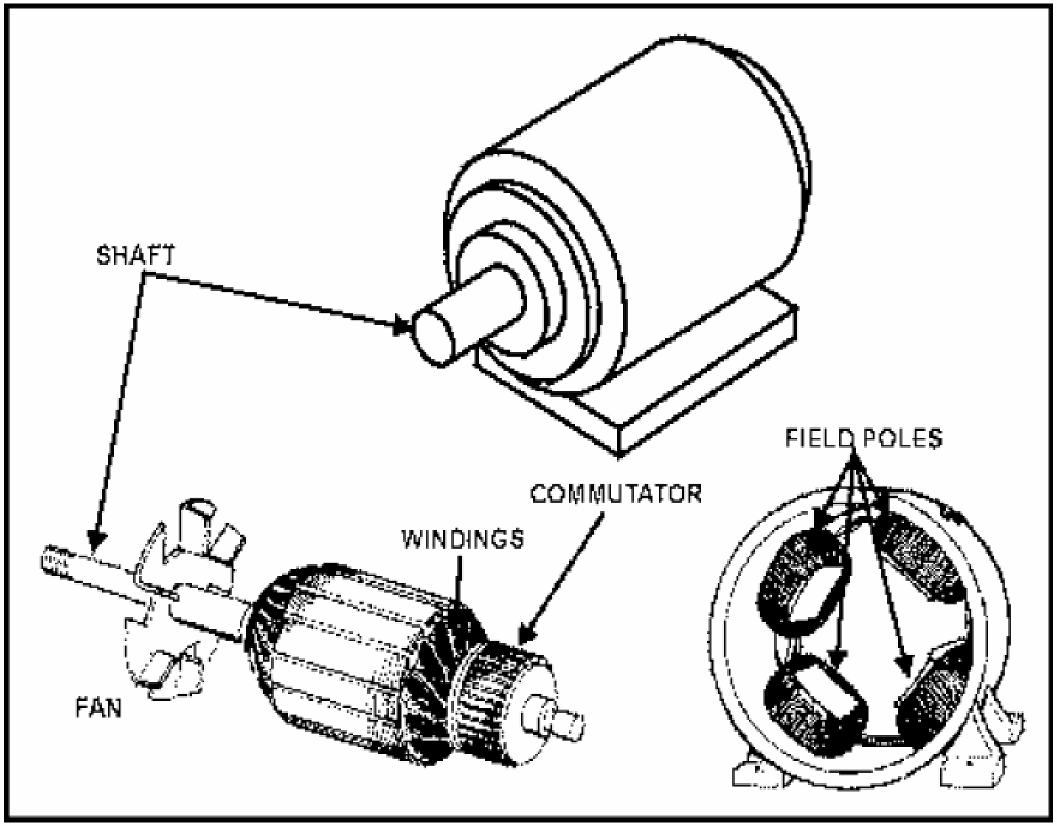
Electric current supplied externally through a commutator

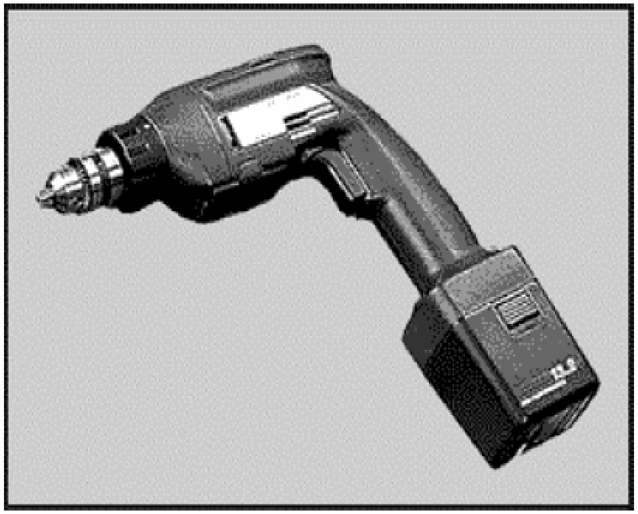
Magnetic force
$F = ILB$
acts perpendicular to both wire and magnetic field

Induced Torque: $\tau_{ind} = 2rI_A lB \;= k\Phi I_A$

Motor Components

- A common application of a DC motor is a battery powered hand drill
- The commutator has many segments and delivers relatively smooth output torque

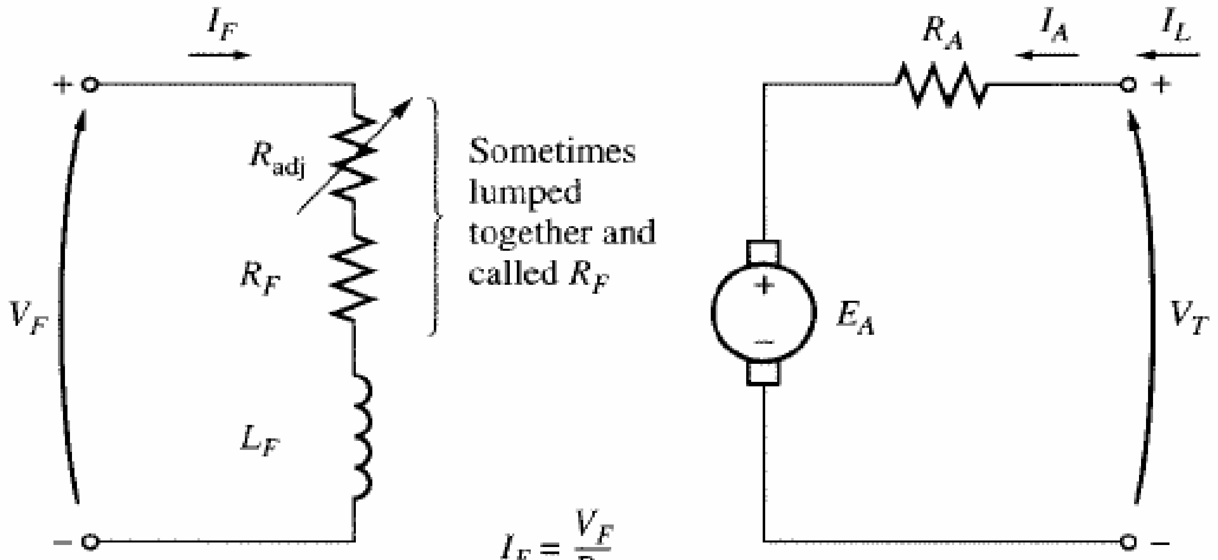




Types of DC Motors

- Separately Excited Motor
- Shunt Excited Motor
- Series Excited Motor
- Compound Excited Motor
- Permanent Magnet (PM) Motor

Equivalent Circuit of a DC Machine (separately excited)



Sometimes lumped together and called R_F

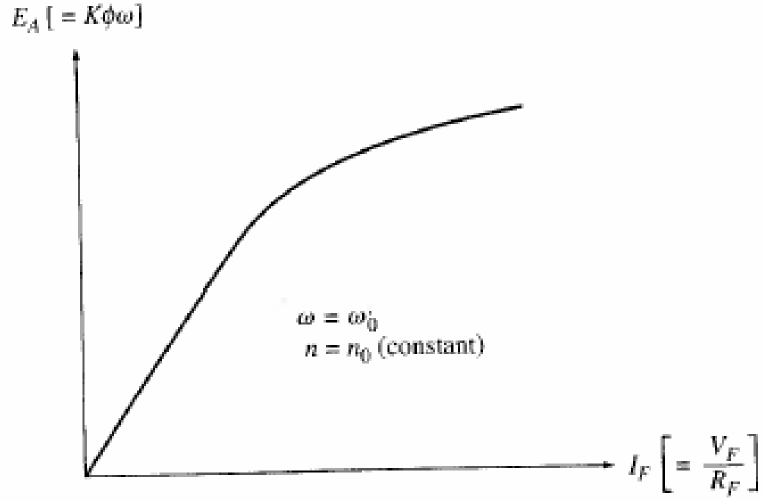
$$I_F = \frac{V_F}{R_F}$$

$$V_T = E_A + I_A R_A$$

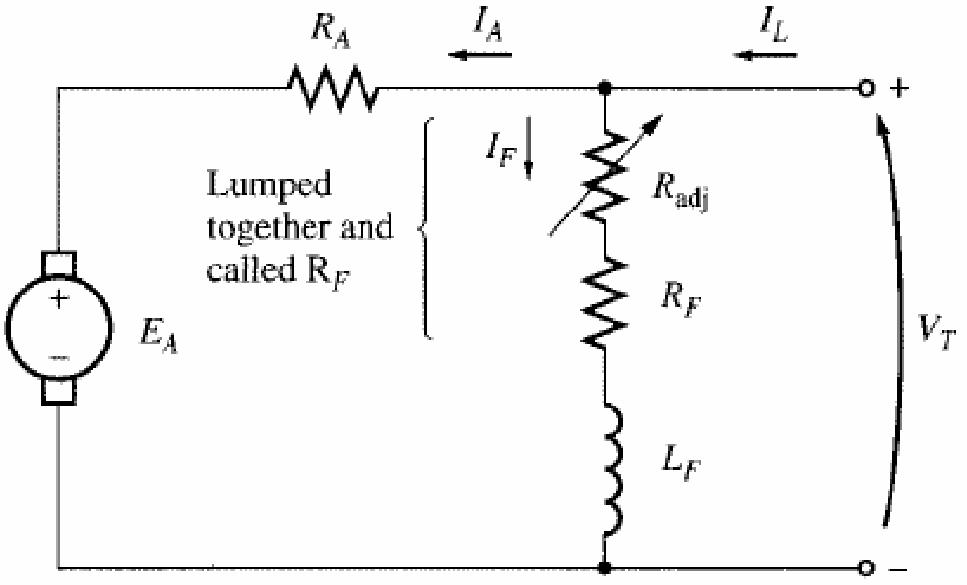
$$I_L = I_A$$

$$E_A = k\Phi\omega$$

$$\tau_{ind} = k\Phi I_A$$



Equivalent Circuit of Shunt-Excited DC machine



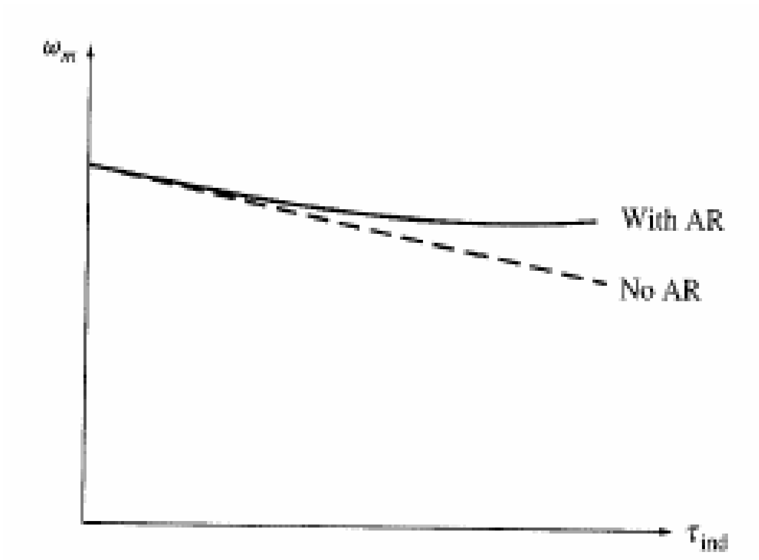
$$I_F = \frac{V_T}{R_F}$$

$$V_T = E_A + I_A R_A$$

$$I_L = I_A + I_F$$

$$E_A = k\Phi\omega$$

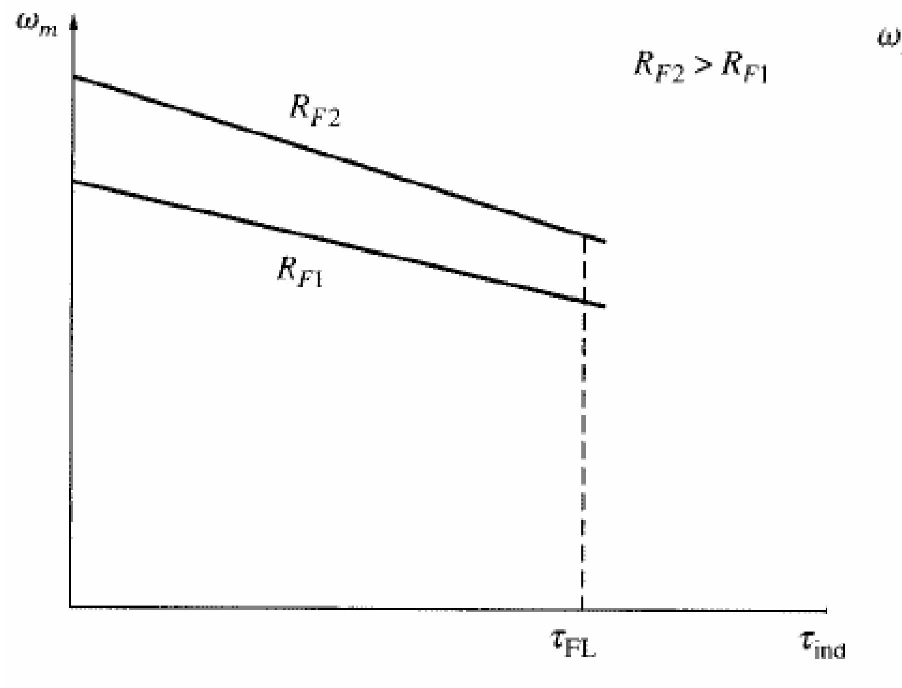
$$\tau_{ind} = k\Phi I_A$$



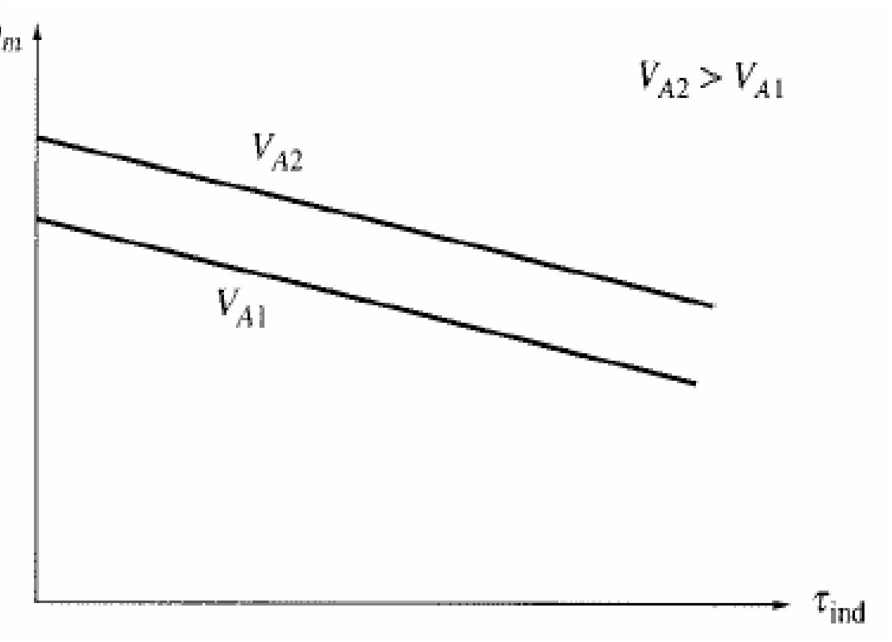
Speed-Torque Relation: $\omega = \frac{V_T}{k\Phi} - \frac{R_A}{(k\Phi)^2}\tau_{ind}$

Speed Control of Shunt-Excited Motors

A) By changing field resistance
(field control)

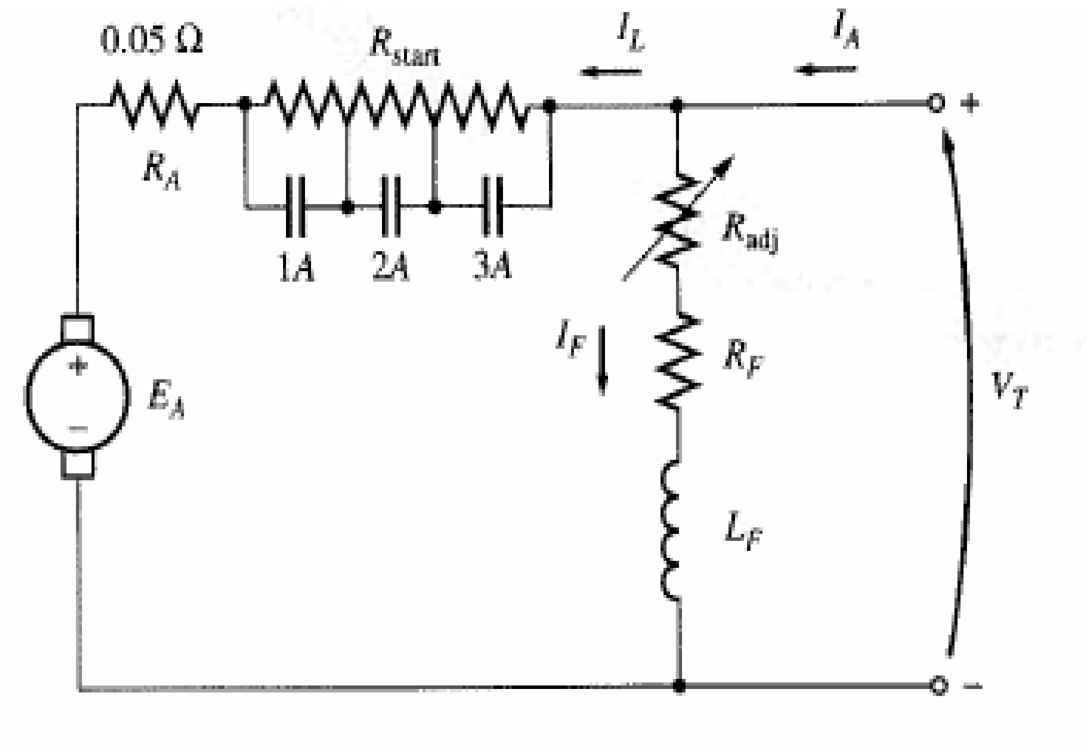


B) By changing armature voltage
(voltage control)

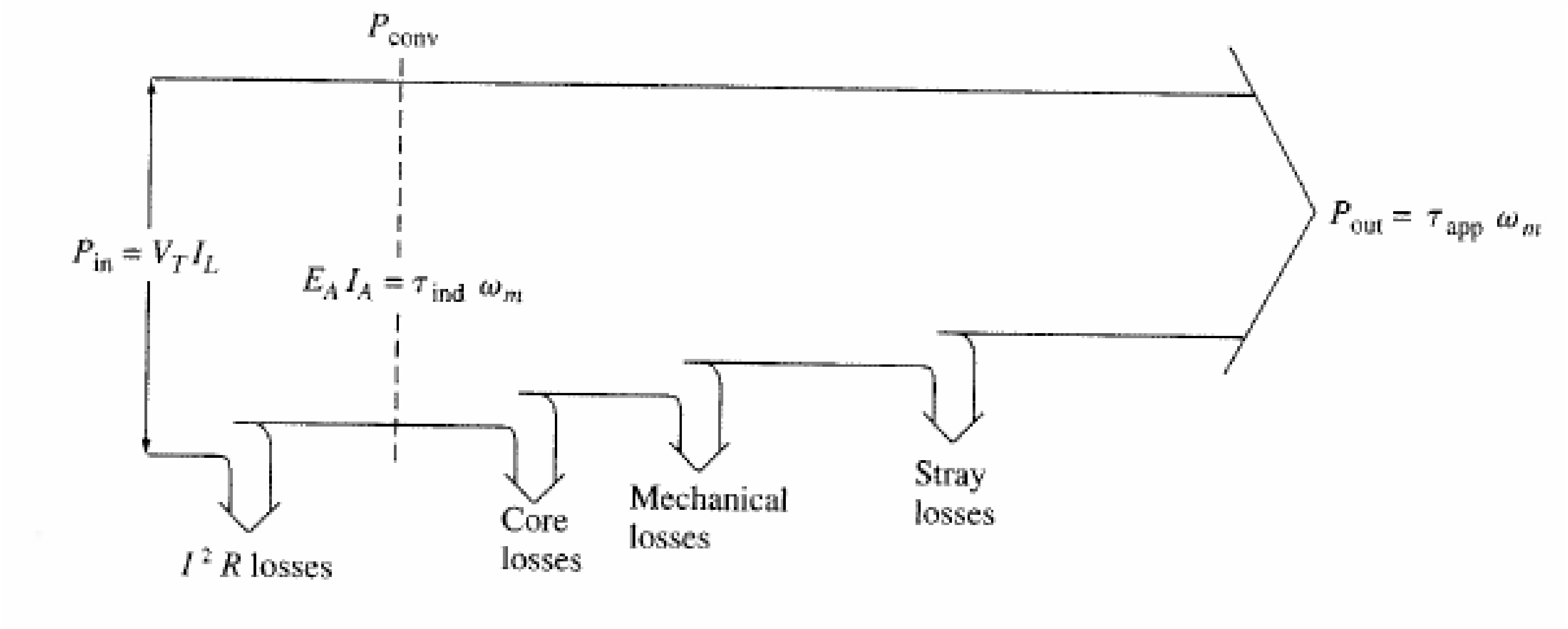


Motor Starting

- To limit the starting current, the motor must be started with
  - – a variable voltage source,
  - – or inserting start-resistors (in case the source voltage is fixed).

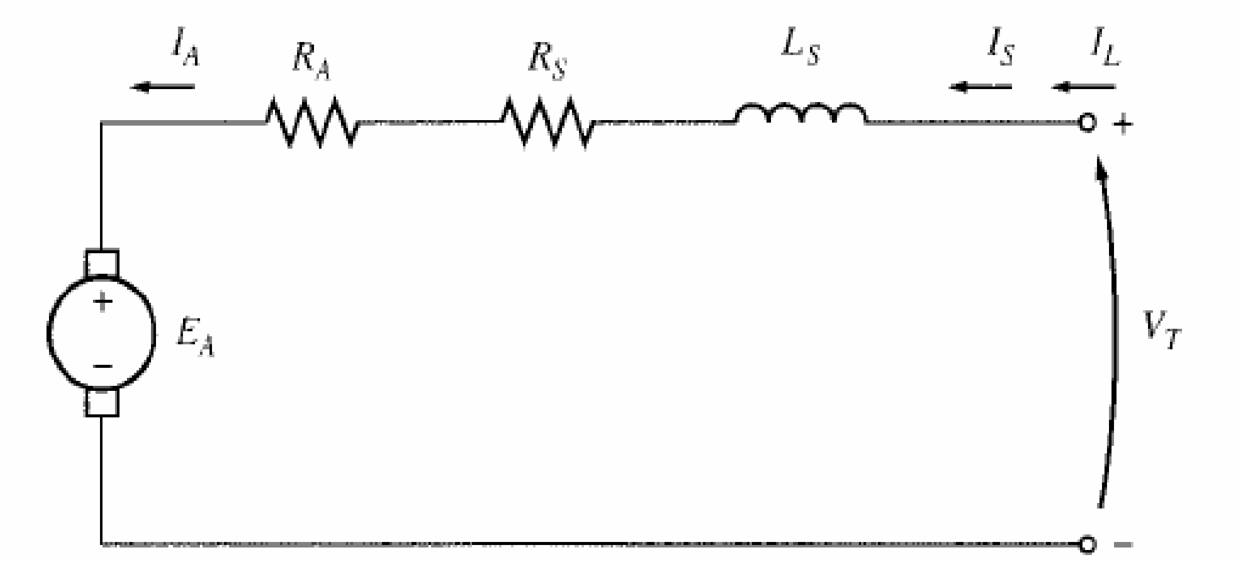


Power low in DC motor



Copper loss in armature, field and series windings
Brush loss is sometimes included ($V_{brush}*I_A$)

Equivalent Circuit of Series Motor



$$I_A = I_S = I_L$$

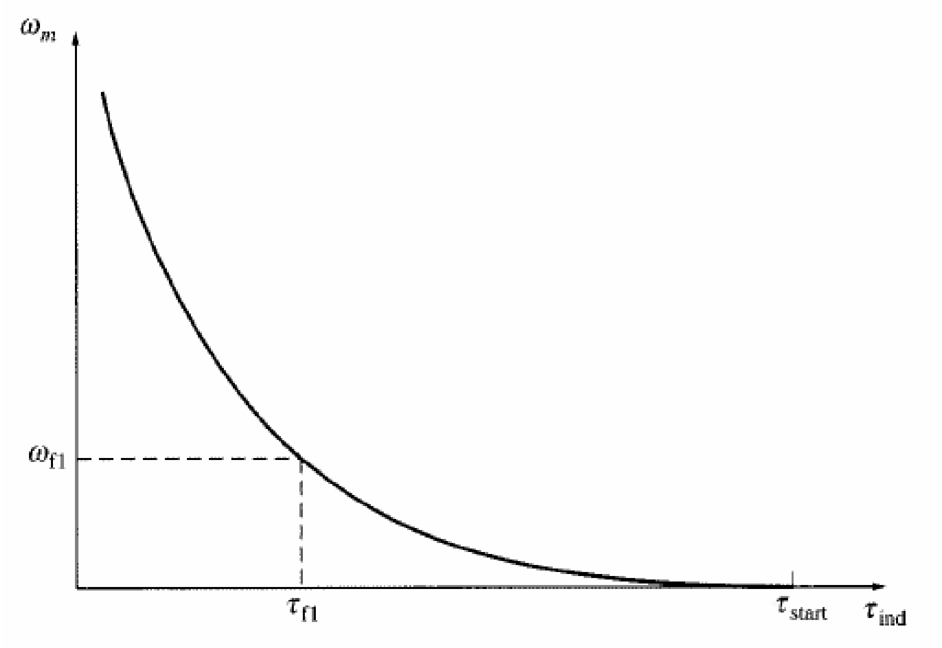
$$V_T = E_A + I_A(R_A + R_S)$$

$$E_A = k\Phi\omega$$

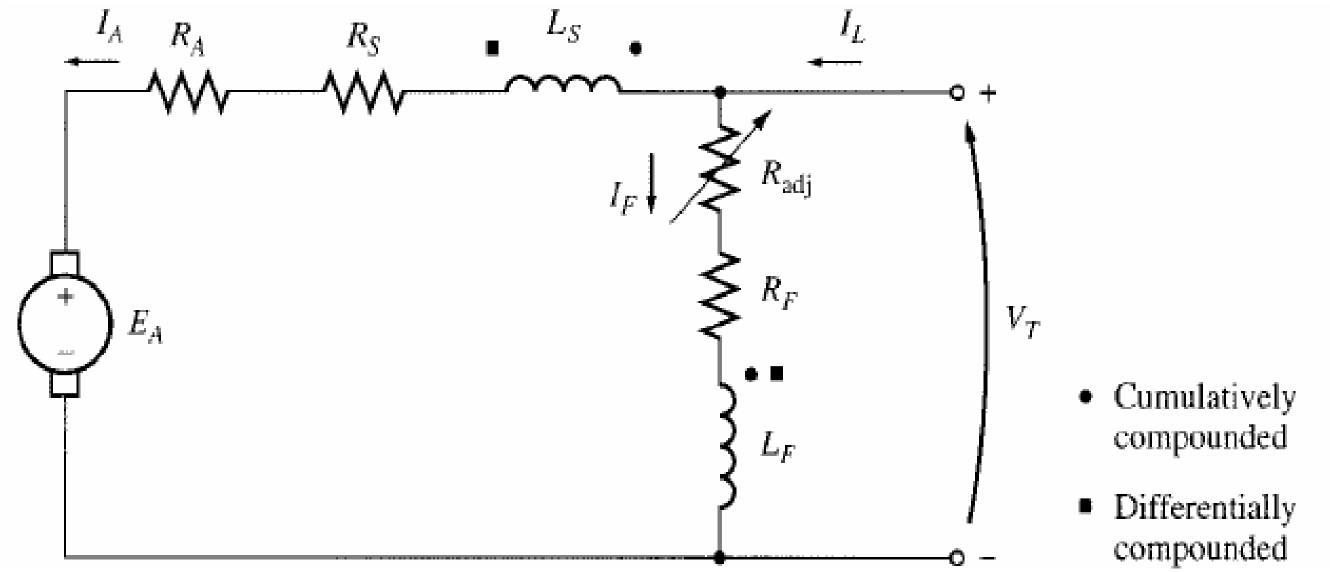
$$\tau_{ind} = k\Phi I_A = kcI_A^2$$

Speed-Torque Relation:

$$\omega = \frac{V_T}{\sqrt{kc}}\frac{1}{\sqrt{\tau_{ind}}} - \frac{R_A + R_S}{kc}$$



Equivalent Circuit of Compound Excited DC Motor



$$I_L = I_F + I_A, \quad I_S = I_A$$

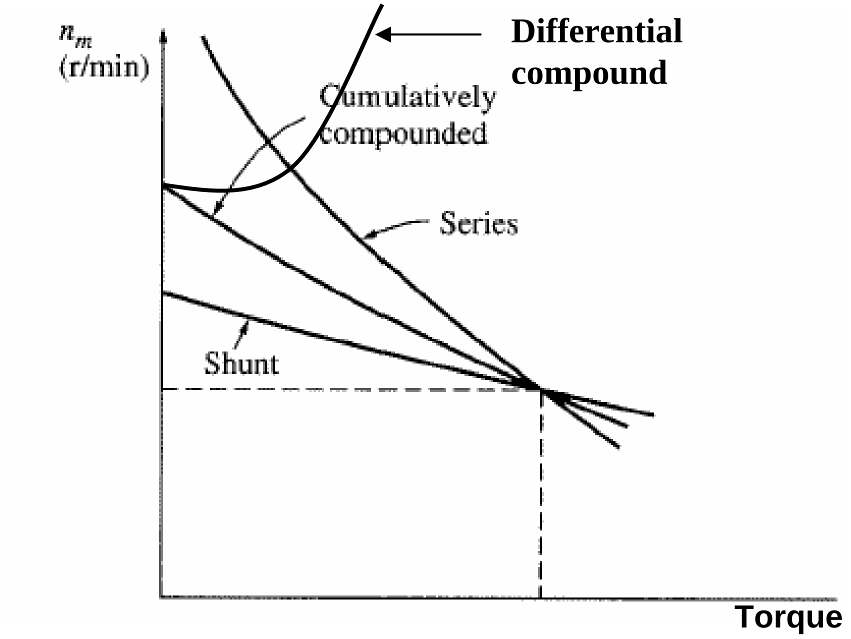
$$I_F = \frac{V_T}{R_F}$$

$$I_F^* = I_F \pm \frac{N_S}{N_F} I_A$$

$$V_T = E_A + (R_A + R_S) I_A$$

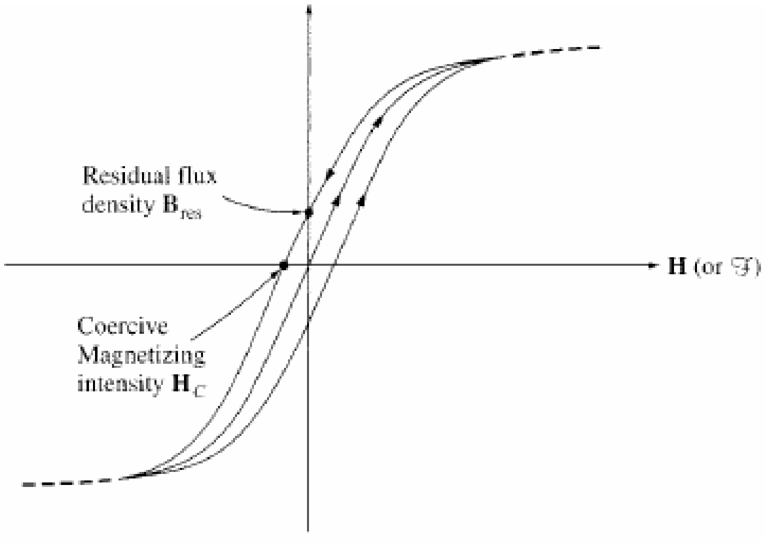
$$E_A = k\Phi^* \omega, \quad \Phi^* = \Phi_F \pm \Phi_A$$

$$\tau_{ind} = k\Phi^* I_A$$

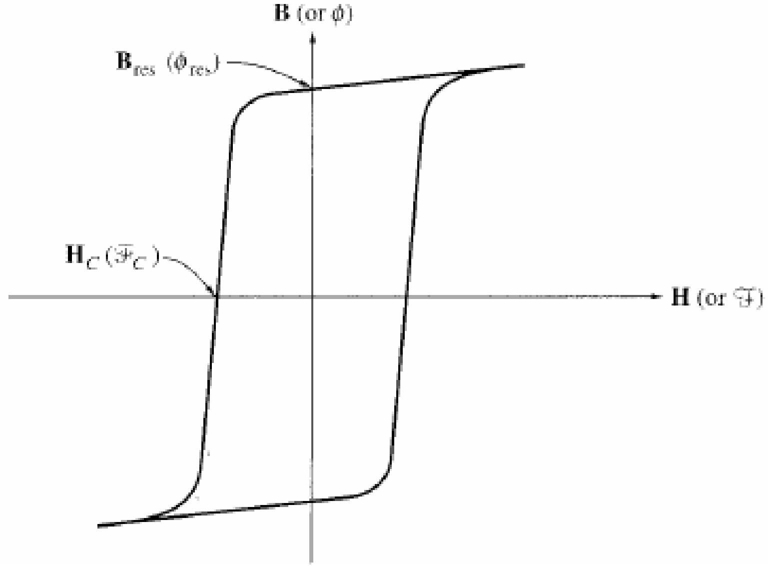


PMDC Motor

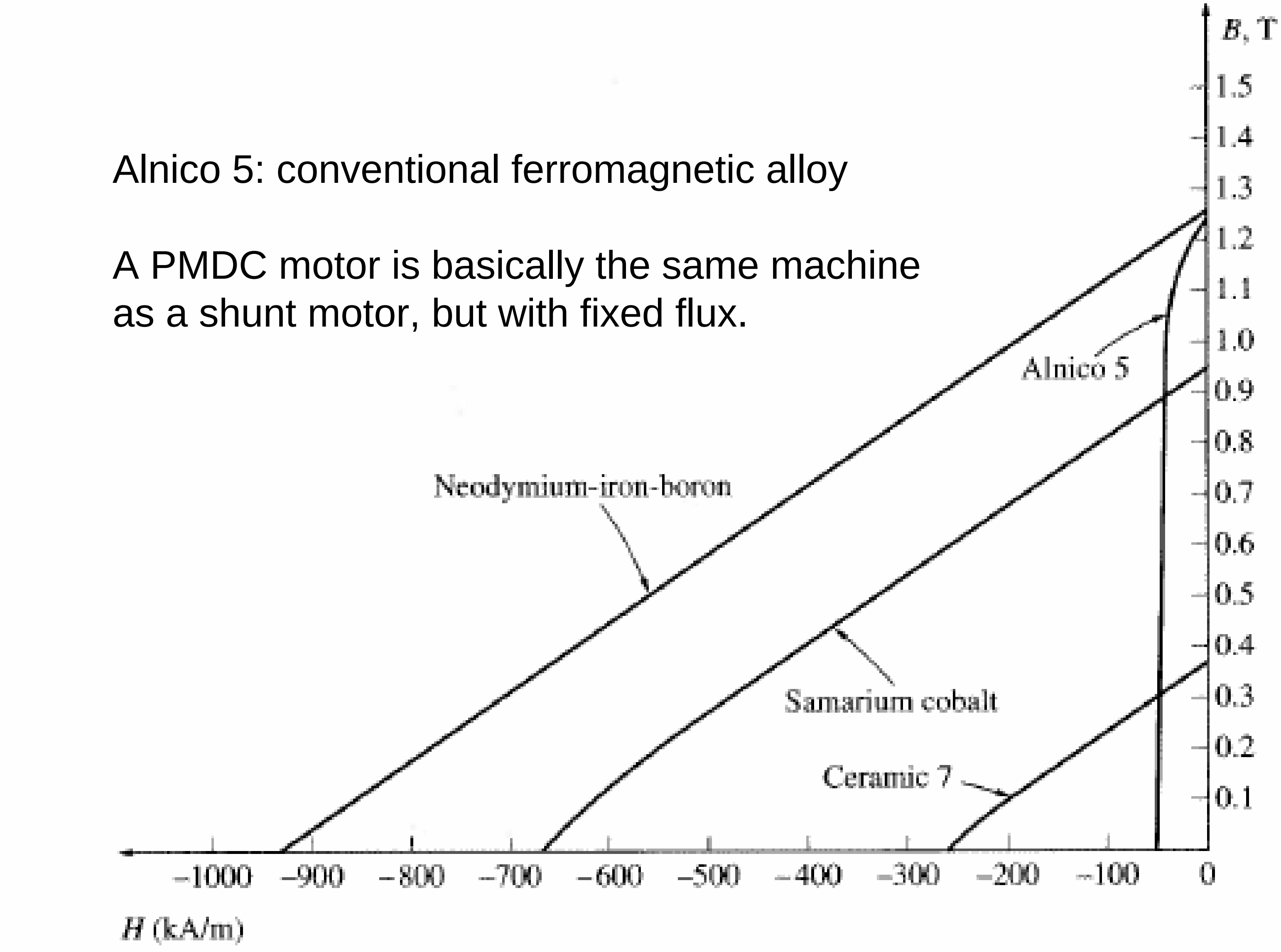
- For normal applications (e.g., transformers, rotors and stators of motors), the ferromagnetic material should have a small residual flux density and coercive magnetizing field intensity).
- A good material for the poles of a PMDC motor should have the apposite of the above.



(a)



B-H Curves (4th quadrant) of Typical Ceramic and Rare-Earth Magnets



Alnico 5: conventional ferromagnetic alloy

A PMDC motor is basically the same machine as a shunt motor, but with fixed flux.

Homework

- 8.3, 8.4, 8.5, 8.7, 8.8
- 8.10 - 8.11
- 8.12 – 8.14
- 8.15 – 8.16
- 8. 17 – 8.18