Energy conversion I

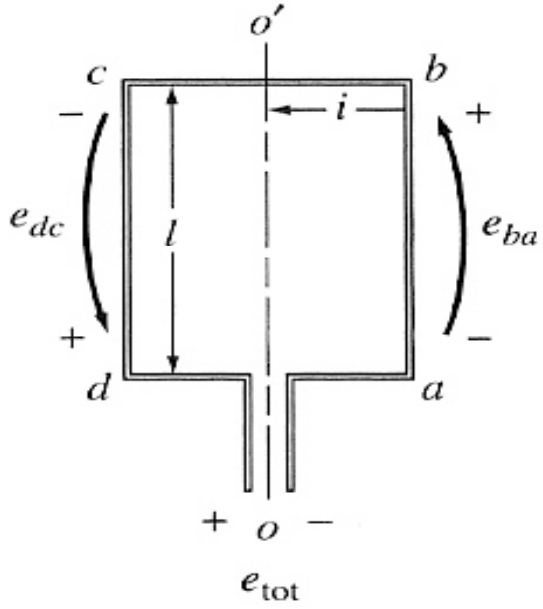
Lecture 21:

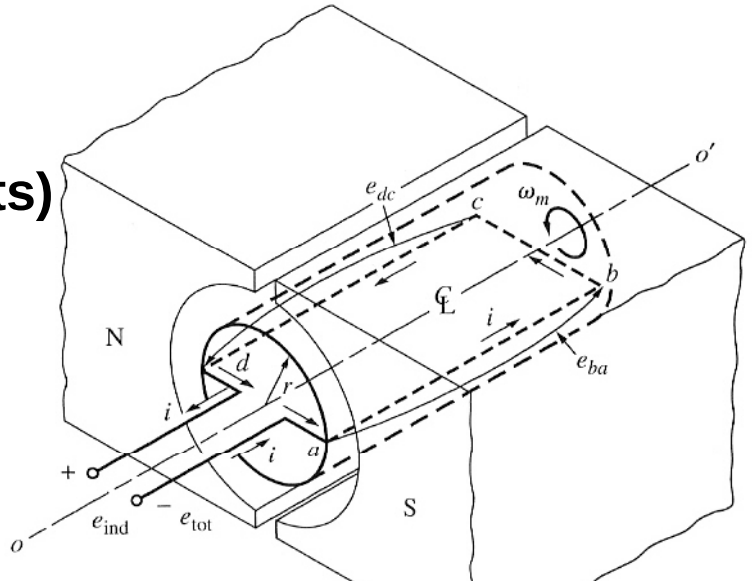
Topic 6: DC Machines (S. Chapman ch. 8 &9)

- **A Simple Rotating Loop between Curved Pole Faces.**
- **Structure of DC machines**
- Commutation Problems in Real Machine.
- The Internal Voltage and Torque Equations of Real DC Machine.
- The Equivalent Circuit of a DC Motor.
- Power Flow and Losses in DC Machines.
- Separately Excited, Shunt, Permanent-Magnet and Series DC Motors
- DC Motor Starter
- Introduction to DC Generators

Simple DC Machine

- **A uniform radial magnetic field supplied by Electromagnetic (/Permanent magnets) poles Stator.**
- **a single rotating loop of wire (rotor).**





$e_{ind} = (v \times B) \cdot l$

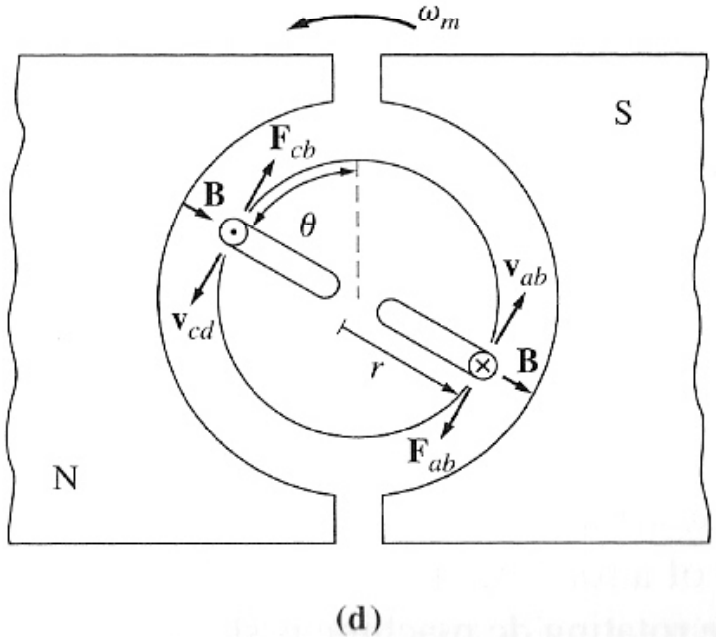
$e_{ind,loop} = 2lVB$

$V = r\omega$

$A_p = \pi r l$

$B = \phi / A_p$

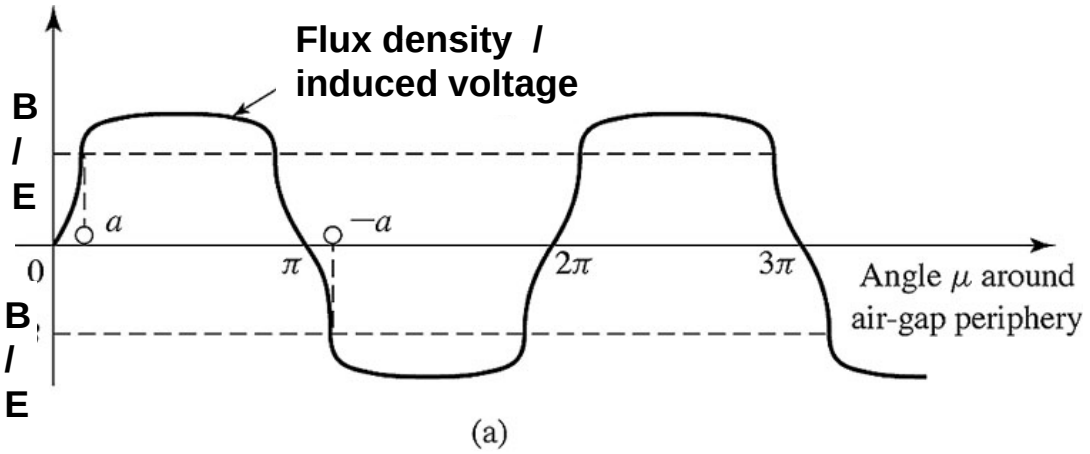
$$e_{\text{ind, loop}} = \frac{2}{\pi}\varphi\omega$$

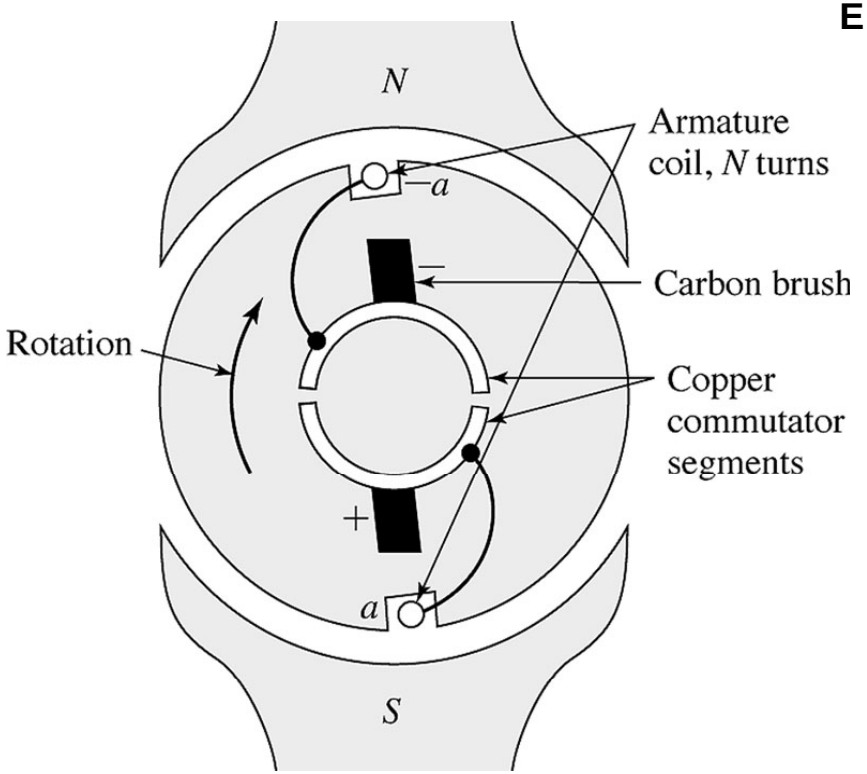


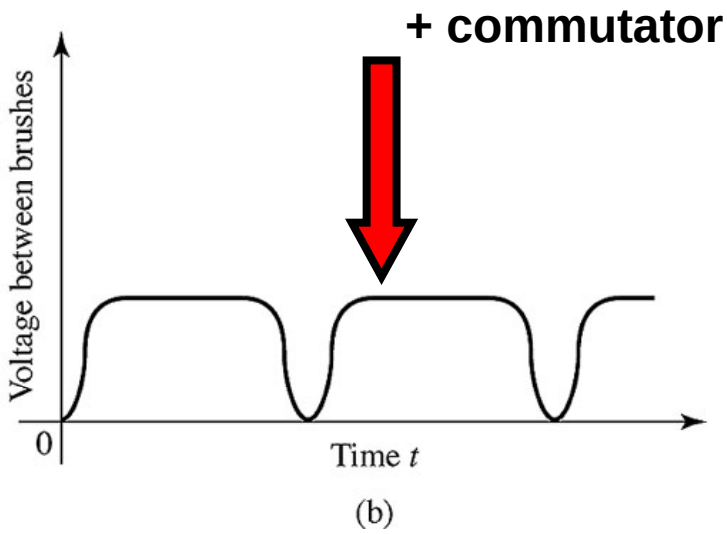
(d)

Commutator Effect in DC Machine

Commutator behaves as a mechanical rectifier for induced voltage







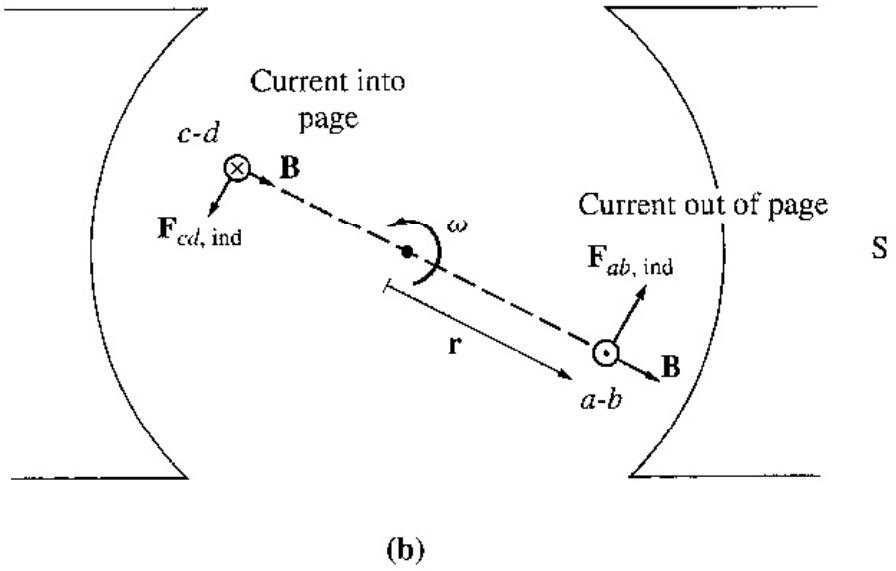
Induced Torque in Simple DC Machine

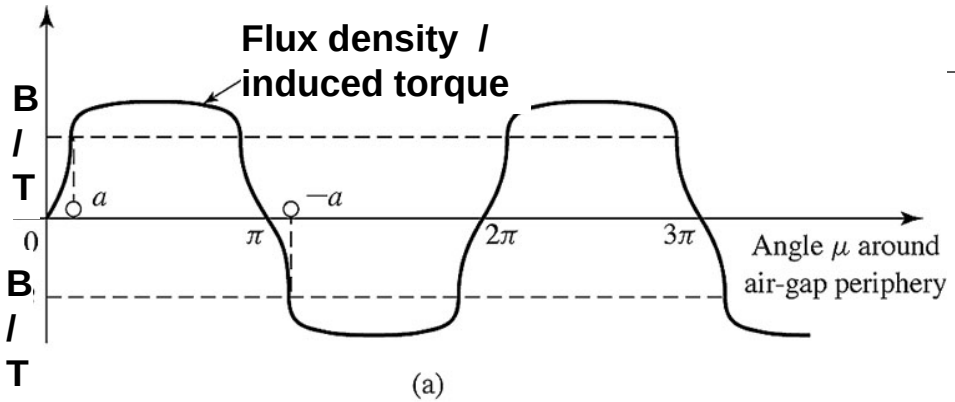
$T_{ind,loop} = 2rilB$

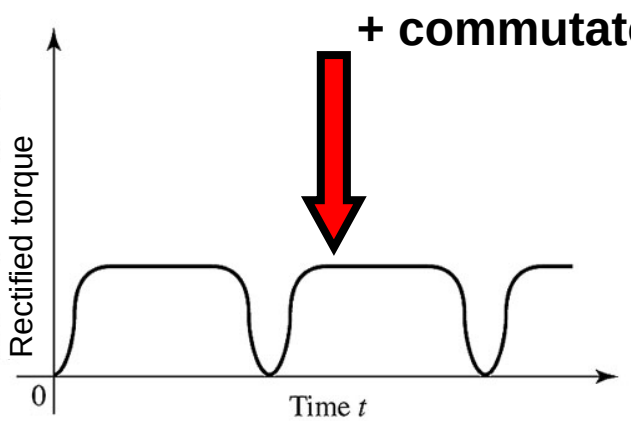
$A_p = \pi rl$

$B = \phi / Ap$

$$T_{ind,loop} = \frac{2}{\pi}\varphi i$$







Commutator behaves as a mechanical inverter (dc to ac converter) for terminal current

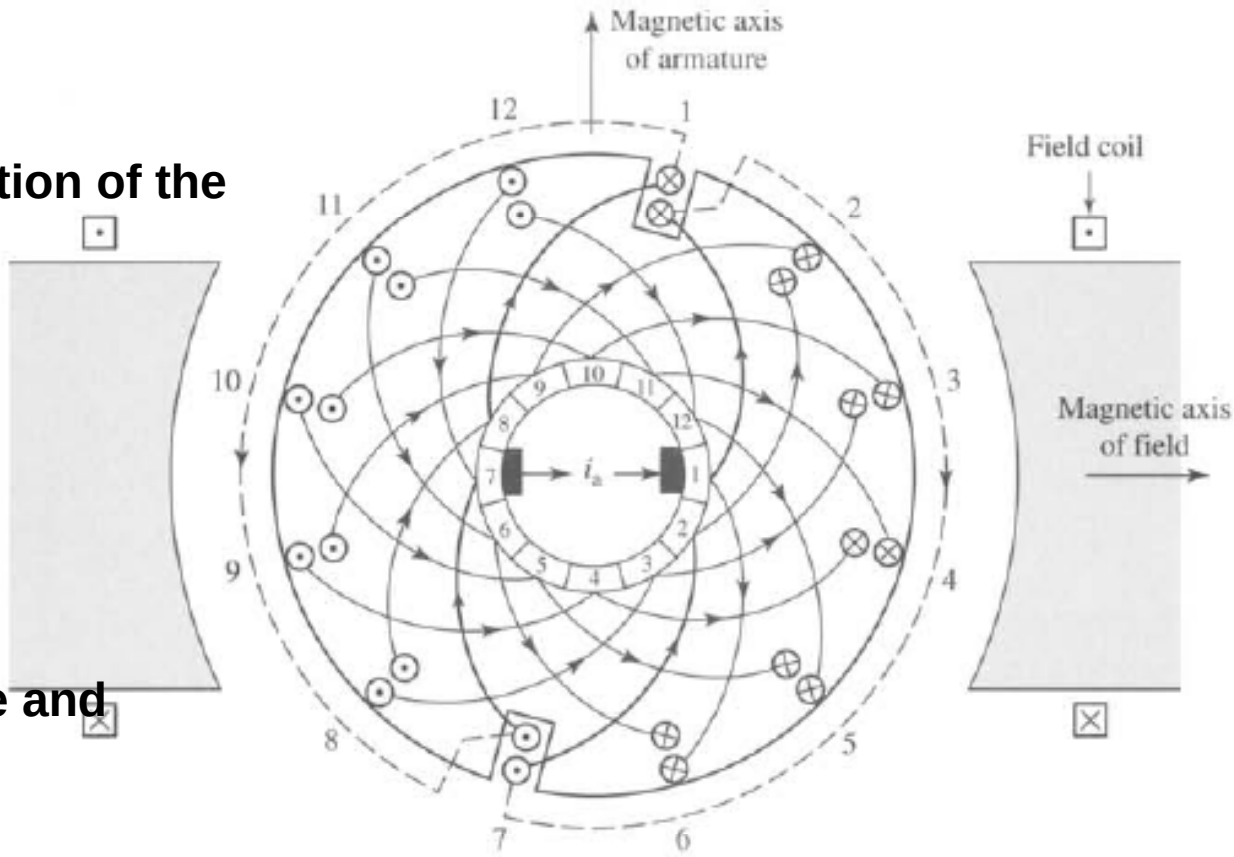
Induced Torque and voltage in DC Machine

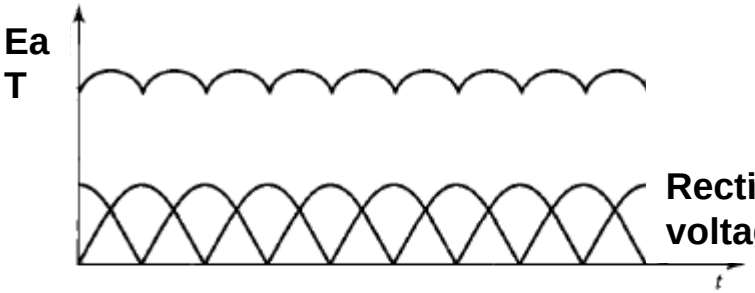
Multi slots and multi coils

Series and parallel connection of the coils

Brush + Commutator and Commutation

Low ripple induced voltage and torque





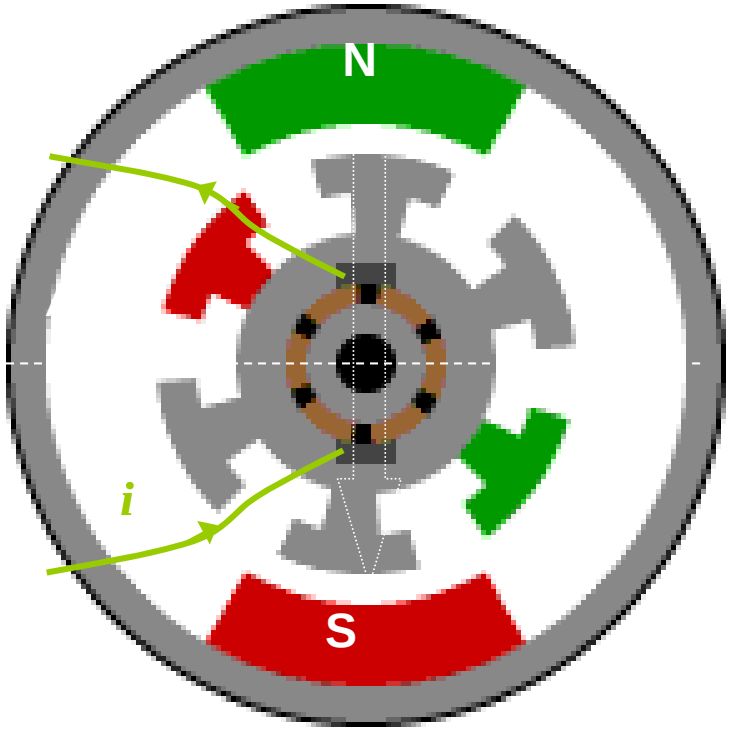
Rectified Torque and induced voltage of each coil

Commutator action

- **Feeding the DC input current to the proper winding to generate torque**

- **Changing the direction of the armature winding in proper times (armature current frequency proportional to rotor speed)**

- **Converting the AC induced voltage of the winding to DC output voltage**

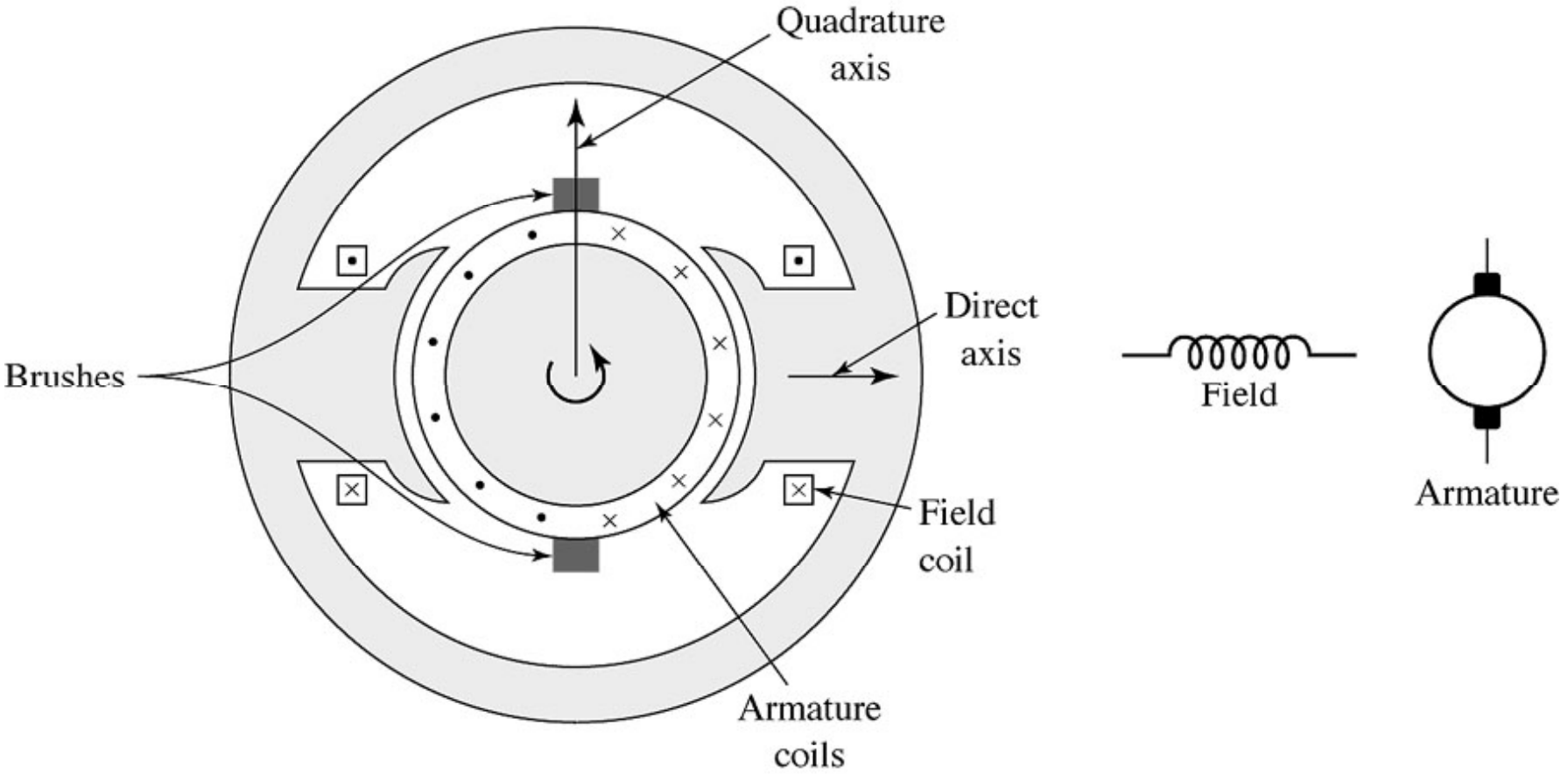


In a real machine all coils are connected in series or parallel properly

Torque ripple and voltage ripple will be negligible

Construction of DC Machine

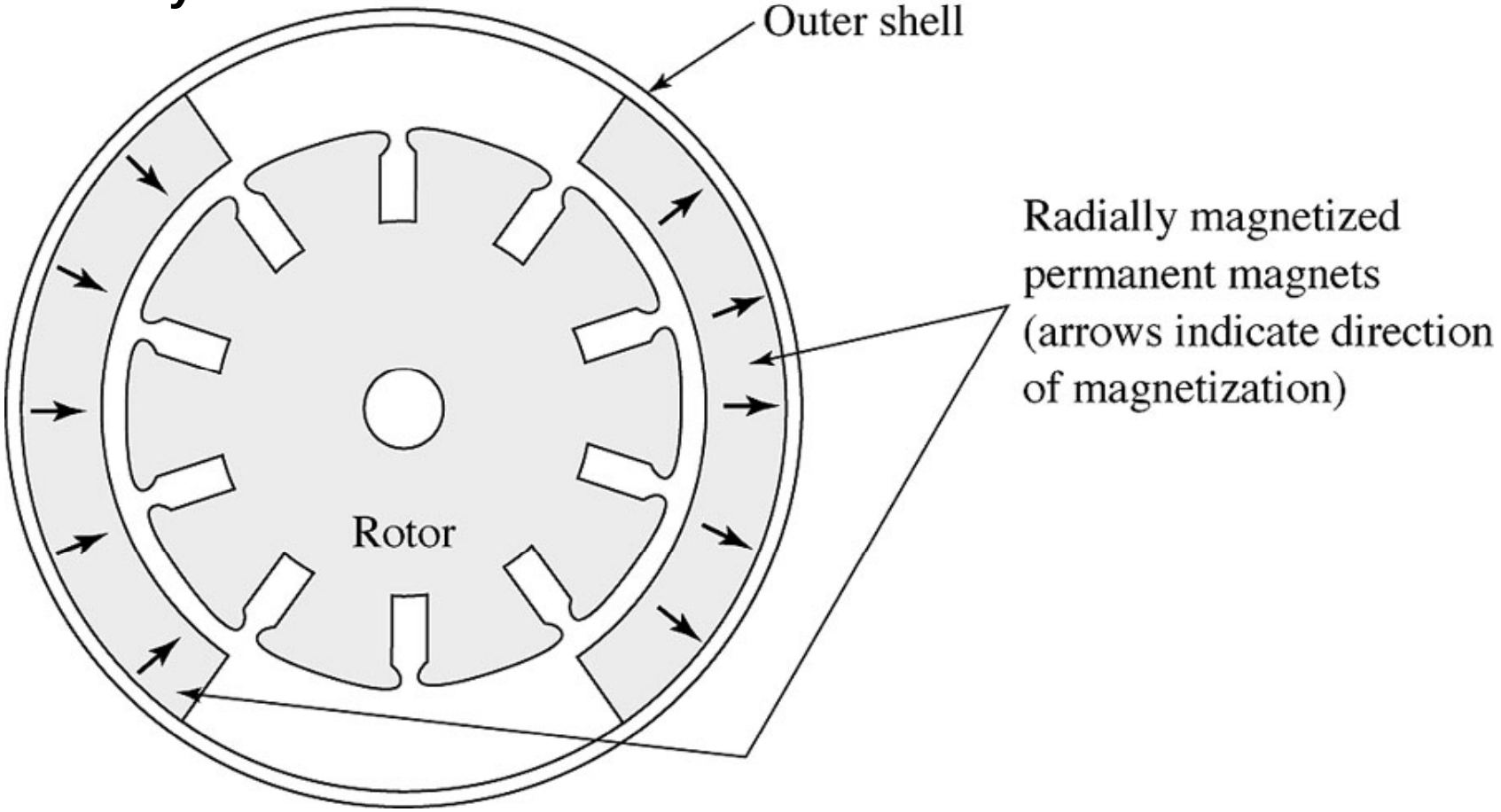
Two main parts: Stator / Field / Excitation: generates air-gap flux.
Rotor / Armature: conducts main current for energy conversion.



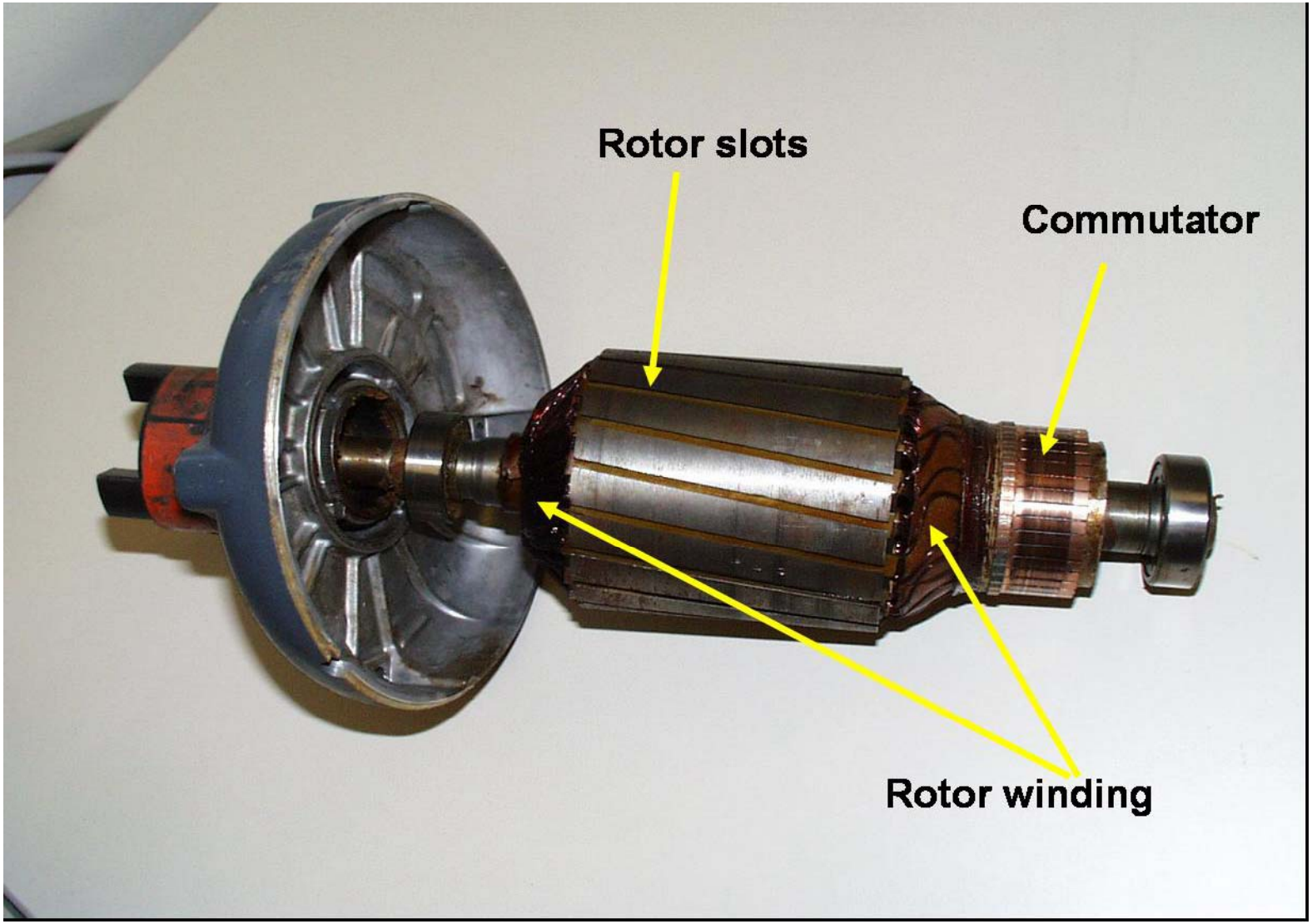
Permanent Magnet DC Machine

Magnetic field is generated by PM materials
Rotor is very similar to others

Usually for small DC motors



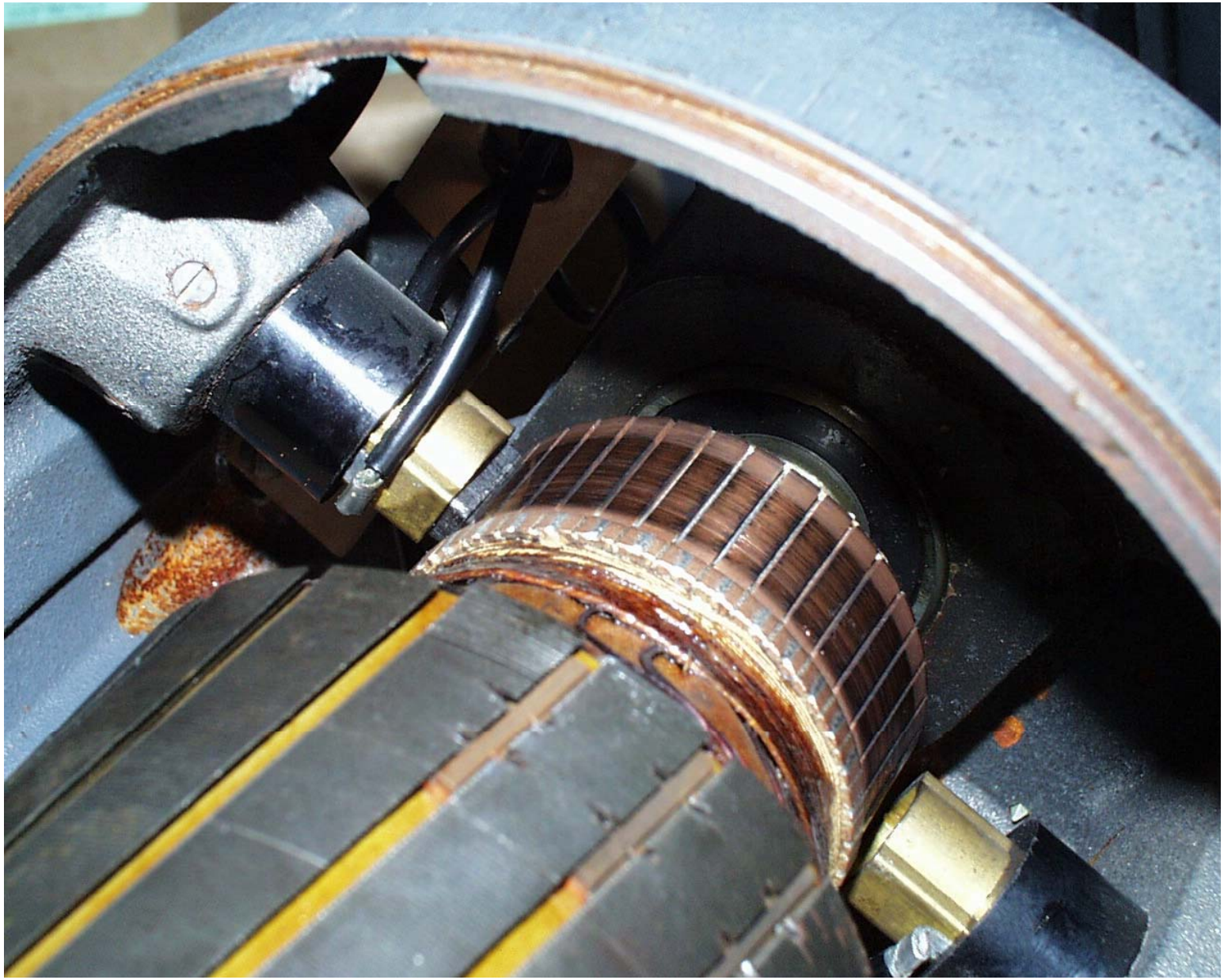
Structure of DC machines: rotor (Armature)



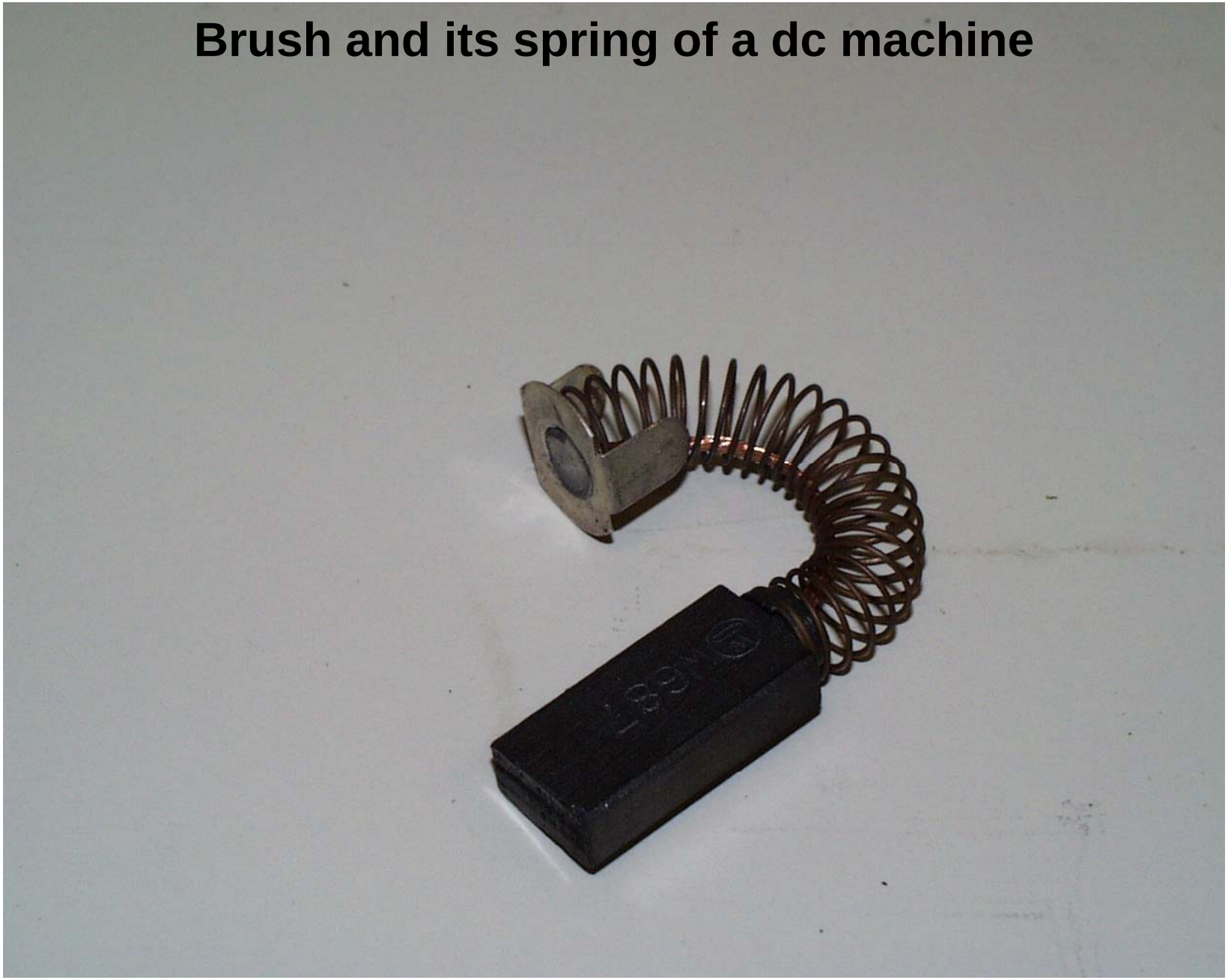
Stator of a dc machine

Stator is usually salient pole with concentrated winding

Commutator and brushes of a dc machine



Brush and its spring of a dc machine



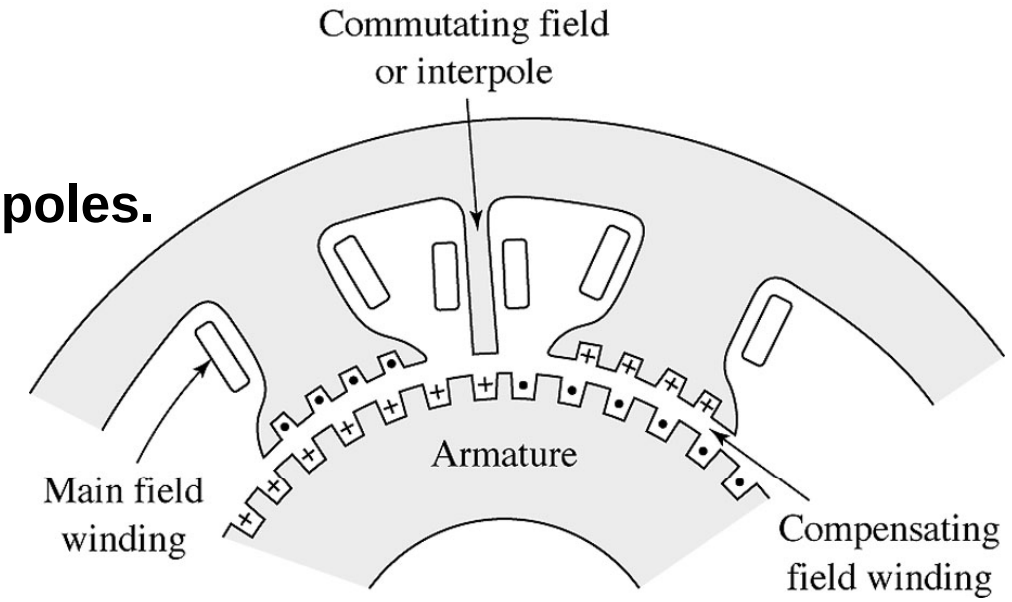
Structure of Larger dc Machines

Interpoles situated between poles.
Interpoles conducting Armature current.

Compensate effect or armature field.
Less arc due to commutation

Compensating winding in the main poles.
Conducting Armature current.

Compensate for Armature MMF.
Lower voltage drop



All to make machine to behave as an ideal dc machine!!