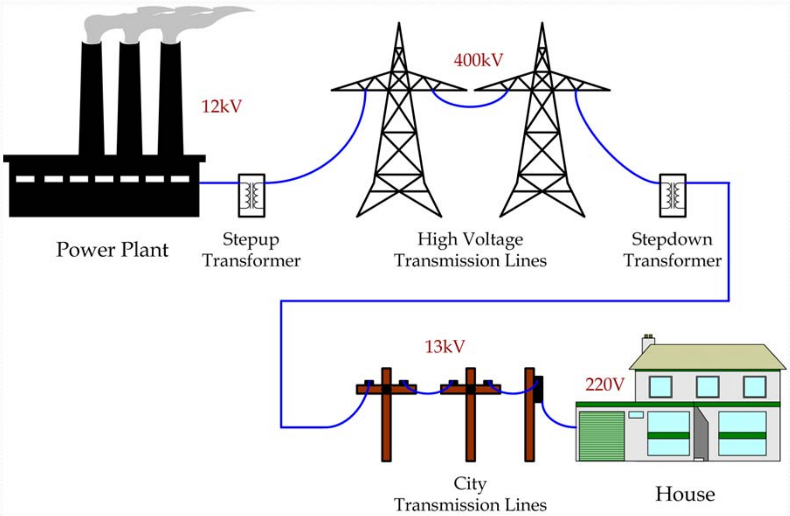
Power Generation
DC Machines

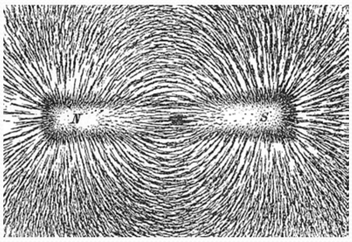
Section 07

Power Transmission



Magnet Stone

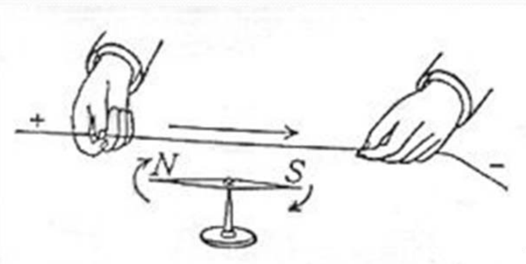
- 500 BC
  - First known in Greece, India, China
- Permanent Magnet
  - Has a force to attract
  - Other Magnets
  - Ferromagnetic Materials

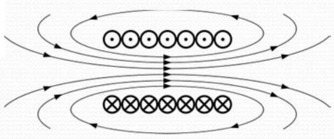


  - Ferromagnetic Materials
  - Materials that can be magnetized
  - Soft materials lose their magnetic effect after awhile

1820

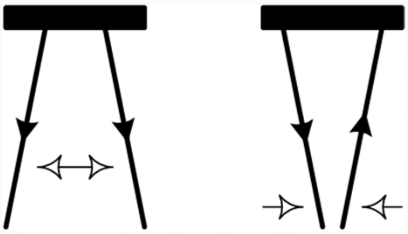
- Hans Christian Oersted:
  - *a current produces a magnetic field*





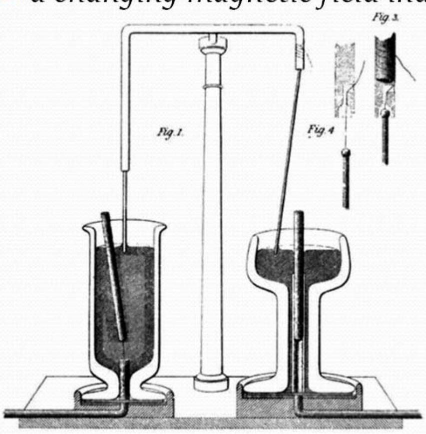
1820

- André-Marie Ampère:
  - *parallel wires carrying currents attract/repel each other*



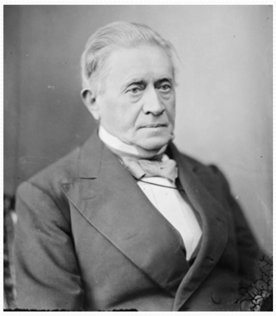
1821

- Michael Faraday:
  - *a changing magnetic field induces an electric field*



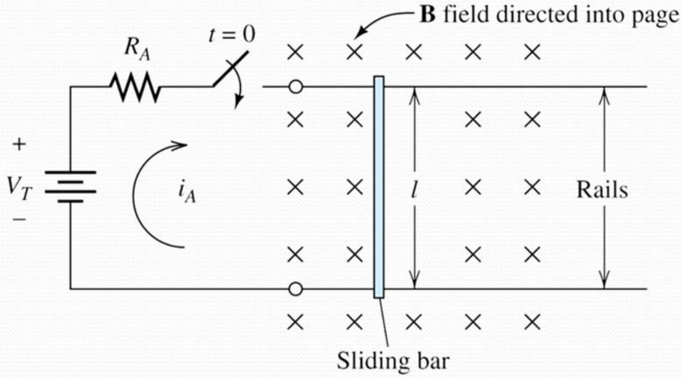
1831

- Joseph Henry
  - *discovered self-induction and built an electromagnet*

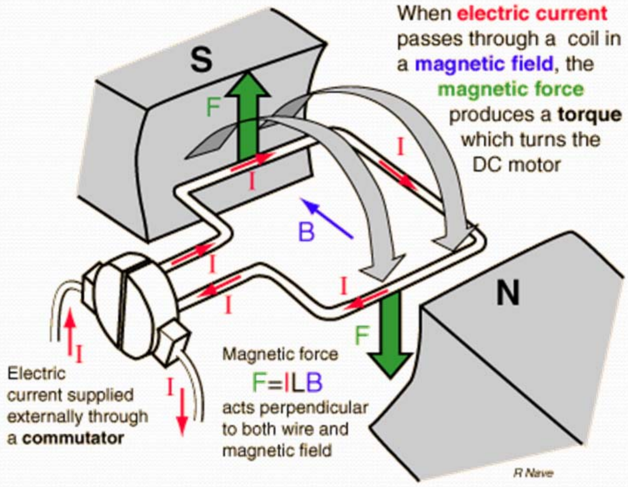


DC Machines

- Can we use the magnetic force to rotate something?



Basic Concept

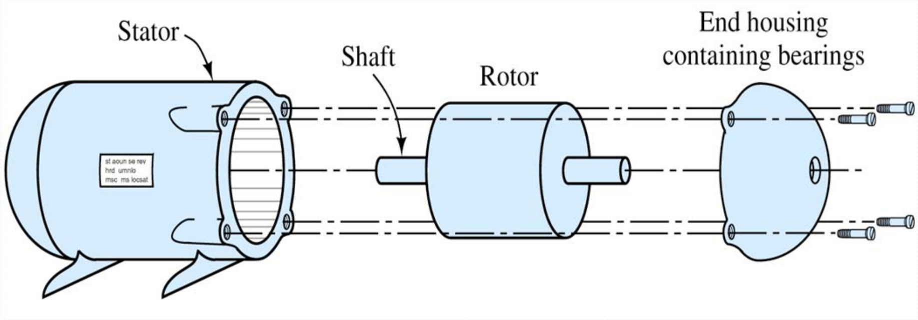


Source: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/motdc.html

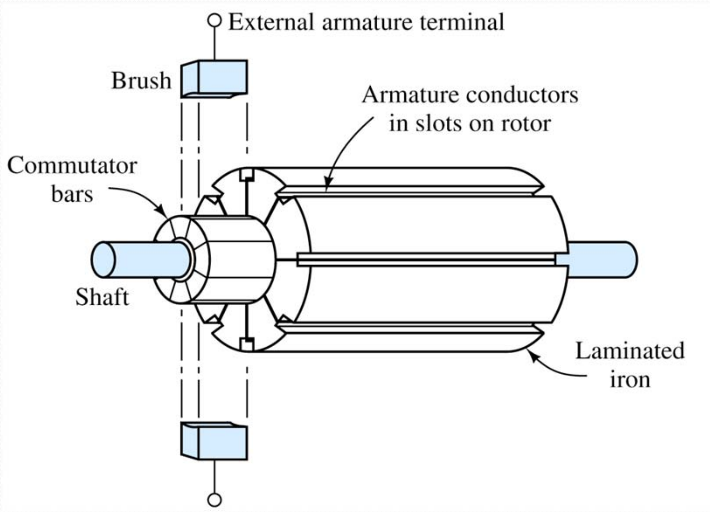
DC Machines Examples

- microwave fan
- hi-fi tape deck
- fridge
- mixer
- washing machine
- tumble dryer
- vacuum
- computers
- electric saw
- drill
- screwdriver
- leaf blower
- toothbrush
- hair dryer
- razor
- CD player
- video player
- clocks
- pond pumps
- toys

Electric Machine Parts



Electric Machine Parts



Two-Pole DC Machine

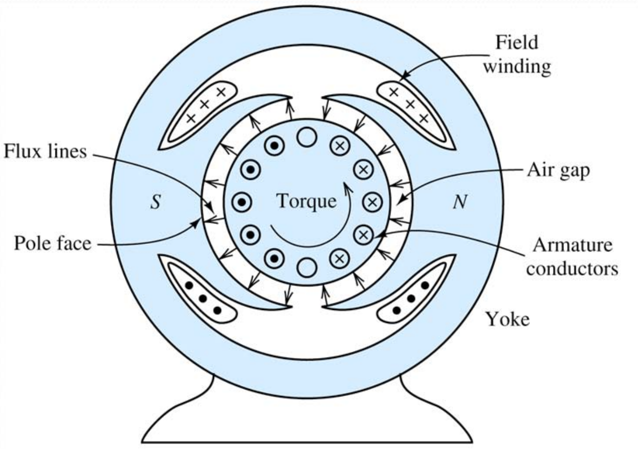


Figure 16.10 Cross section of a two-pole dc machine.

Four-Pole DC Machine

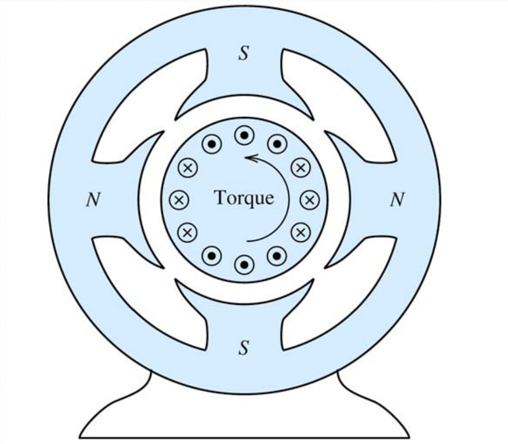
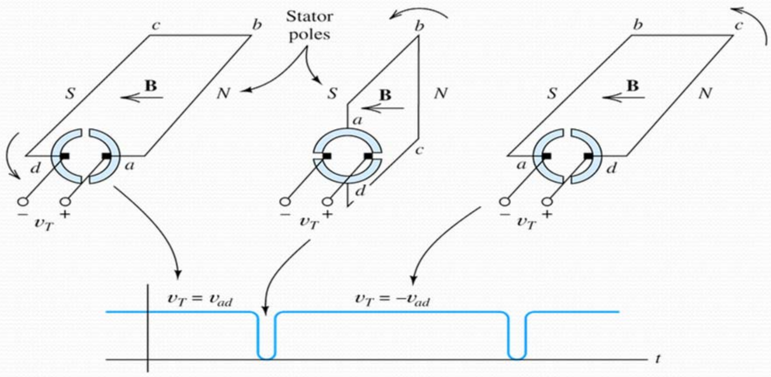


Figure 16.11 Cross section of a four-pole dc machine.

Commutator



Generated Voltage

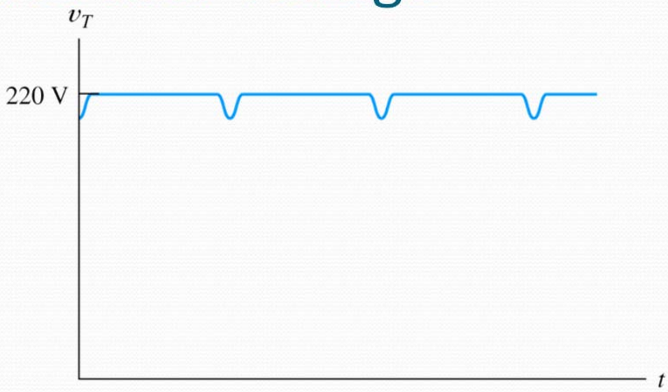
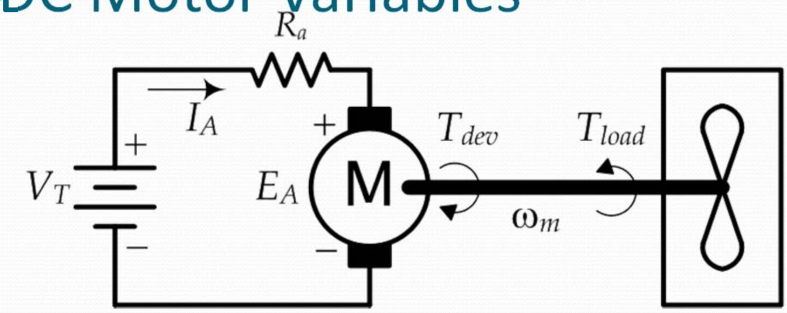


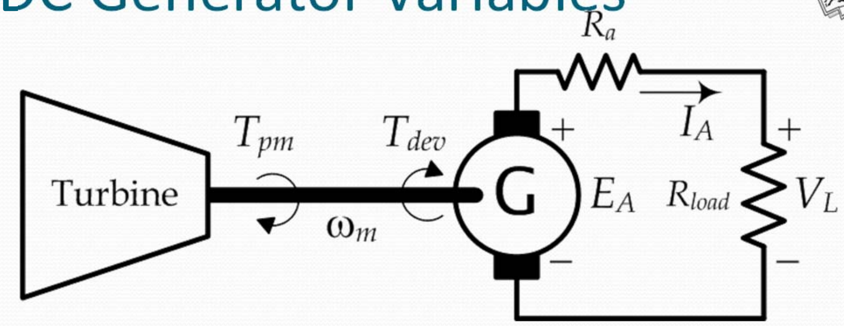
Figure 16.13 Voltage produced by a practical dc machine. Because only a few (out of many) conductors are commutated (switched) at a time, the voltage fluctuations are less pronounced than in the single-loop case illustrated in Figure 16.12.

DC Motor Variables



E_A	(volt)	is the back EMF
V_T	(volt)	is the applied voltage
T_{dev}	(N.m)	is the torque developed by DC Motor
T_{load}	(N.m)	is the opposing load torque
ω_m	(rad/s)	is the armature shaft speed = $2\pi\ rpm/60$
R_a	(Ω)	is the motor internal resistance
I_A	(A)	is the motor current

DC Generator Variables



E_A	(volt)	is the generated voltage
V_T	(volt)	is the load voltage
T_{pm}	(N.m)	is the prime-mover generated torque
T_{dev}	(N.m)	is the opposing motor torque
ω_m	(rad/s)	is the armature shaft speed = $2\pi\ rpm/60$
R_a	(Ω)	is the motor internal resistance
I_A	(A)	is the motor current

DC Machine Equations

$$E_A = K \cdot \Phi \cdot \omega_m$$

$$T_{dev} = K \cdot \Phi \cdot I_A$$

E_A	(volt)	is the generated voltage
T_{dev}	(N.m)	is the motor torque
ω_m	(rad/s)	is the armature shaft speed = $2\pi \, rpm/60$
I_A	(A)	is the motor current
K		is the machine constant
Φ	(Wb)	is the magnetic flux per pole

Power

- Electric Power:

$$P = I \times V$$

- Mechanical Power:

$$P = T \times \omega$$

Ideal DC Machine

- Motor
  - IN: Electric Power
  - OUT: Mechanical Power

$$
\begin{aligned}
P_{elec} &= E_A \cdot I_A \\
&= K \cdot \Phi \cdot \omega_m \cdot I_A \\
&= T_{dev} \cdot \omega_m \\
&= P_{mech}
\end{aligned}
$$

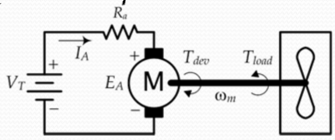
Ideal DC Machine

- Generator
  - IN: Mechanical Power
  - OUT: Electric Power

$$
\begin{aligned}
P_{mech} &= T_{dev} \cdot \omega_m \\
&= K \cdot \Phi \cdot I_A \cdot \omega_m \\
&= E_A \cdot I_A \\
&= P_{elec}
\end{aligned}
$$

Motor Example

- A DC motor having
  - $R_a = 0.2\Omega$, I_A=5A, V_T=220V, $\omega_m = 1200\ rpm$
- What is:



  - back EMF voltage?

$$V_T = E_A + I_A \cdot R_a$$

$$E_A = 220 - 5 \times 0.2 = 219$$

  - developed torque?

$$T_{dev} \cdot \omega_m = E_A \cdot I_A$$

$$T_{dev} = \frac{219 \times 5}{1200 \times \frac{2\pi}{60}} = 8.7 N.m$$

  - developed power?

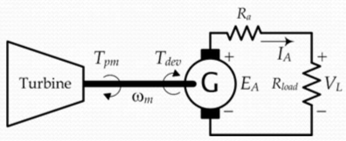
$$P = T_{dev} \cdot \omega_m = E_A \cdot I_A$$

$$P = T_{dev} \cdot \omega_m = 8.7 \times 1200 \times \frac{2\pi}{60} = 1095W$$

$$= E_A \cdot I_A = 219 \times 5 = 1095W$$

Generator Example

- A DC generator having
  - P_{mech}=1kW, $R_a = 0.3\Omega$, $R_L = 10\Omega$
- What is:



  - electric current drawn?

$$\left.\begin{aligned} P &= E_A \times I_A \\ E_A &= I_A \times (R_a + R_L) \end{aligned}\right\} \Rightarrow P = I_A^2 \times (R_a + R_L) \qquad I_A = \sqrt{\frac{1000}{10 + 0.3}} = 9.85A$$

  - terminal voltage?

$$V_T = I_A \cdot R_L$$

$$V_T = 9.85 \times 10 = 98.5V$$