

# Electric Motors

Systems Engineering

Second Grade Level

Wolfgang Neff

# Electric Motors (1)

- Electric Machines

- Motors

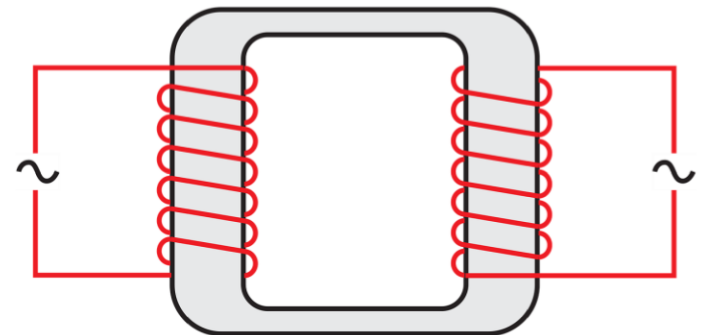
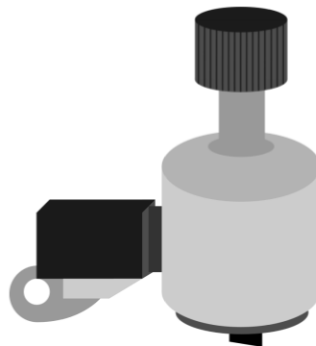
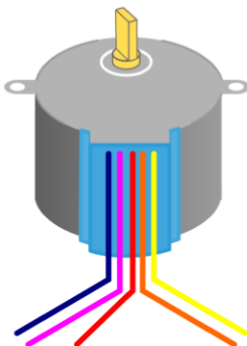
- Convert electricity to mechanical power.

- Generators

- Convert mechanical power to electricity.

- Transformers

- Transfer electric energy from one electric circuit to another.



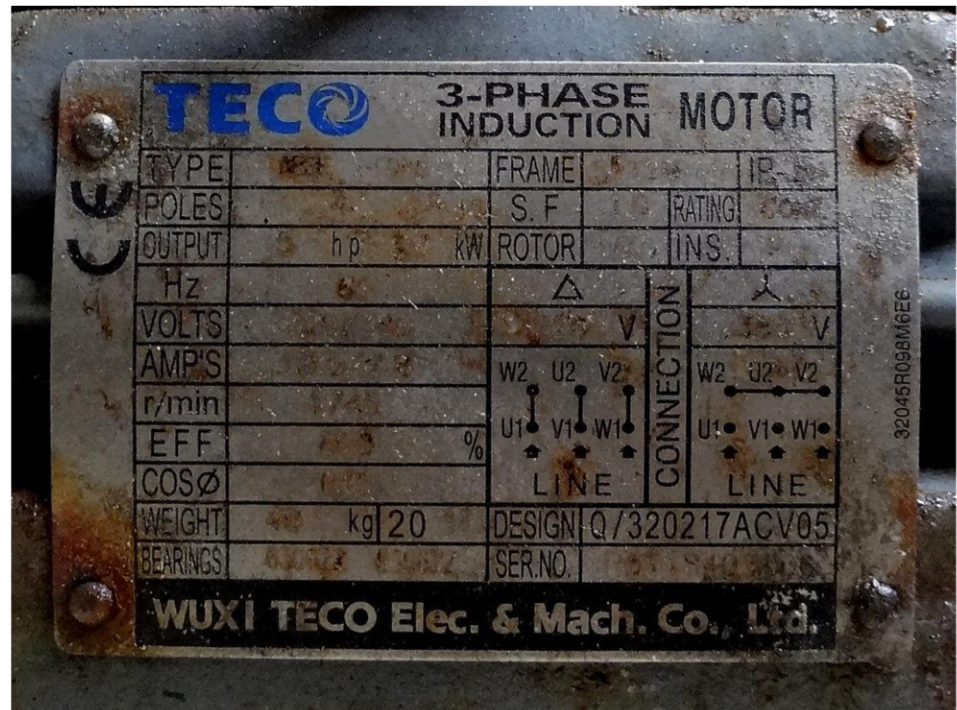
# Electric Motors (2)

- Kinds of Motors
  - DC motors
    - Are powered by a direct current source.
  - AC motors
    - Are powered by an alternating current source.
  - Stepper motor
    - Driven by a rotating magnetic field.
    - Powered by a special stepper motor driver.
    - Does not turn continuously but step-by-step.

# Electric Motors (3)

- Characteristics of Motors

- Voltage
- Nominal current
- Nominal power
- Power factor
- RPM (revolutions per sec.)
- Direction (of rotation)
- Torque
- Efficiency

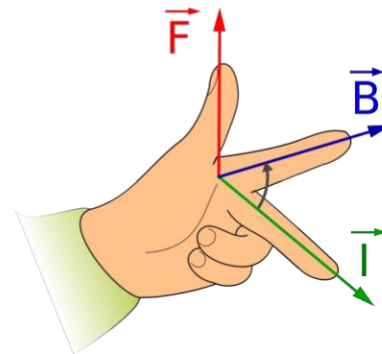


# Electric Motors (5)

- Force Produced by Motors
  - It depends on:
    - Magnetic flux density (B)
    - Electric current (I)
    - Number of wires (z)
    - Length of wire (l)
  - The Fleming's left-hand rule shows its direction.

$$F = B \cdot I \cdot l \cdot z$$

$$[B] = T, [I] = A, [l] = m$$



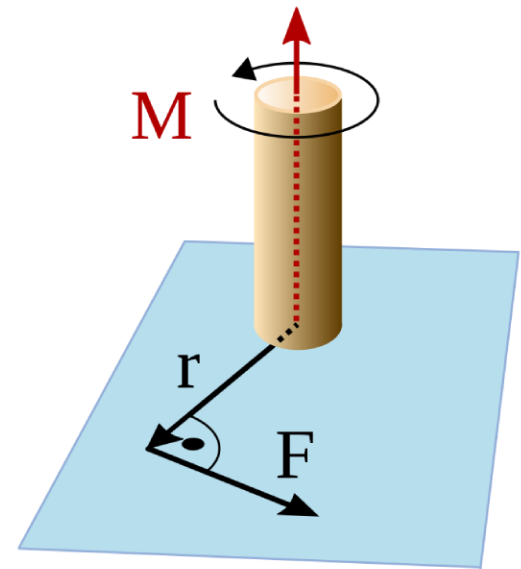
# Electric Motors (6)

- Torque Produced by Motors
  - Force of a lever arm
    - M: torque in Nm.
    - r: length of lever arm.

$$M = F \cdot r$$

- Torque on a shaft
  - P: Power in W.
  - n: Revolutions per second.

$$M = \frac{P}{2 \cdot \pi \cdot n}$$



# Electric Motors (7)

- Efficiency of a Electric Motors
  - The electric power consumed can not be used totally.
  - There are losses.

$$P_{in} = P_{out} + P_{loss}$$

- The efficiency is calculated by:

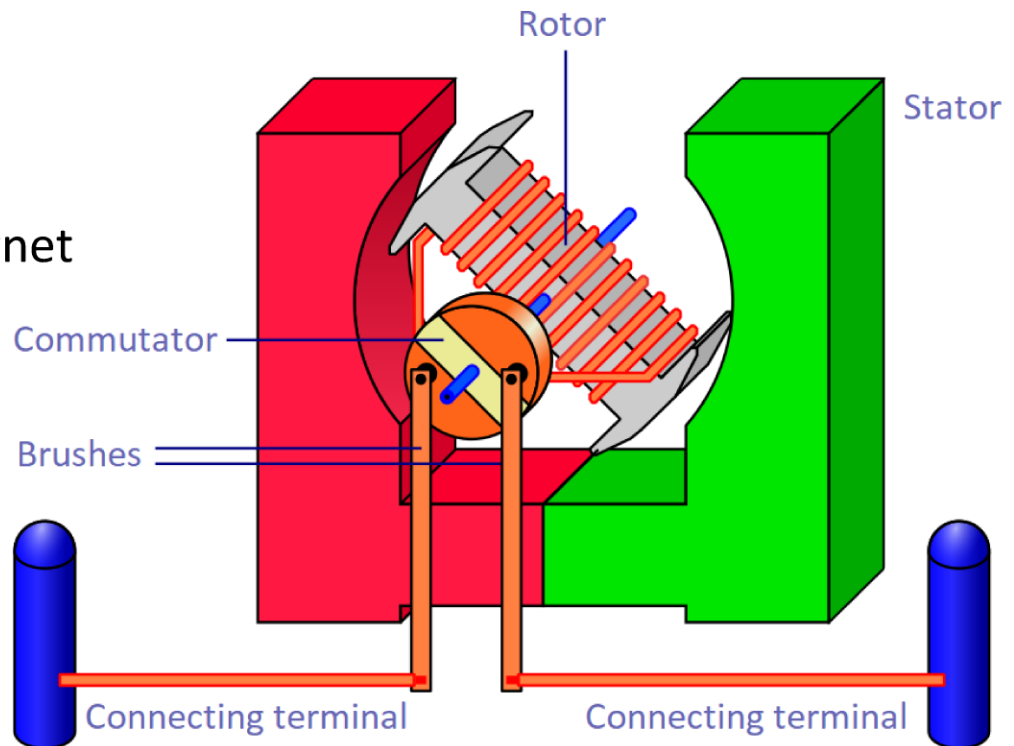
$$\eta = \frac{P_{out}}{P_{in}}$$

- Efficiency is always less than 1 (100%).

# DC Motors (1)

- Components

- Stator
  - Stationary
  - Permanent magnet
- Rotor
  - Moving
  - Electromagnet
- Commutator
  - Pole changer
  - Brushes



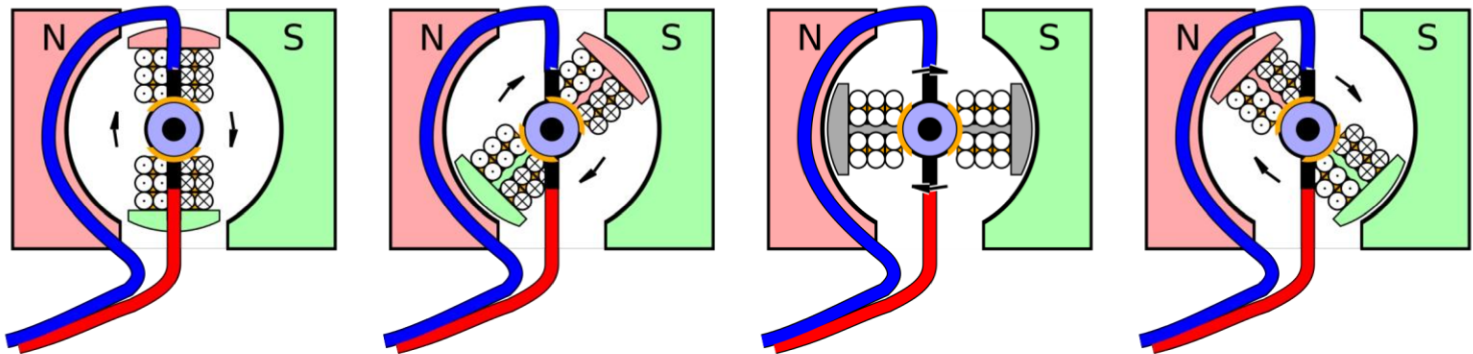
Quelle: <https://commons.wikimedia.org/wiki/File:Gleichstrommaschine.svg>



# DC Motors (2)

- Mode of Operation

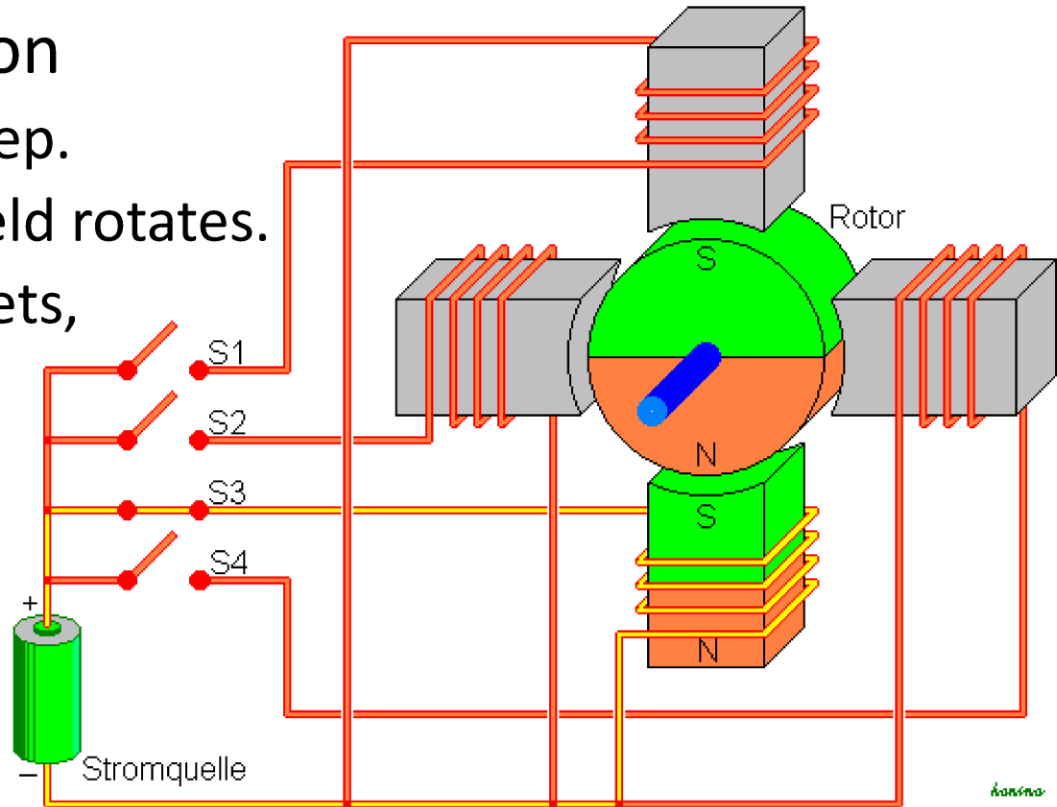
- Poles attract and repulse.
- At the dead point current is interrupted.
- After the dead point the poles are changed.



Quelle: [https://commons.wikimedia.org/wiki/File:Animation\\_einer\\_Gleichstrommaschine\\_\(Variante\).gif](https://commons.wikimedia.org/wiki/File:Animation_einer_Gleichstrommaschine_(Variante).gif)

# Stepper Motor (1)

- Mode of Operation
  - Turns step-by-step.
  - The magnetic field rotates.
  - The more magnets, the smaller the steps.



Quelle: <https://commons.wikimedia.org/wiki/File:Schrittmotor.PNG>

# Stepper Motor (2)

- Stepper Motor Drivers

- The control of stepper motors is complex.
- It is common to use a special driver.
- Commands: step, direction, enable, reset.

