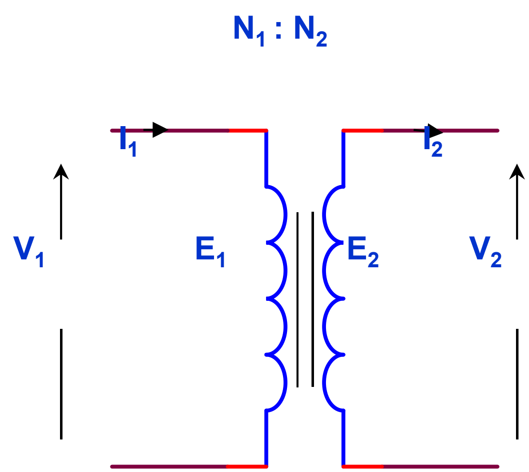
Ideal Transformer

- An ideal transformer is a transformer which has no loses, i.e. it's winding has no ohmic resistance, no magnetic leakage, and therefore no I^2R and core loses.
- However, it is impossible to realize such a transformer in practice.
- Yet, the approximate characteristic of ideal transformer will be used in characterized the practical transformer.



V1 – Primary Voltage
V2 – Secondary Voltage
E1 – Primary induced Voltage
E2 – secondary induced Voltage
N1:N2 – Transformer ratio

Transformer Equation

- Faraday's Law states that,
  - If the flux passes through a coil of wire, a voltage will be induced in the turns of wire. This voltage is directly proportional to the rate of change in the flux with respect of time.

$$V_{ind} = Emf_{ind} = -\frac{d\Phi(t)}{dt}$$

If we have N turns of wire,

$$V_{ind} = Emf_{ind} = -N\frac{d\Phi(t)}{dt}$$

Transformer Equation

- For an ac sources,
  - Let $V(t) = V_m \sin\omega t$
    $i(t) = i_m \sin\omega t$

  Since the flux is a sinusoidal function;

Then:

$$\Phi(t) = \Phi_m \sin \omega t$$

Therefore:

$$V_{ind} = Emf_{ind} = -N \frac{d\Phi_m \sin \omega t}{dt}$$

$$= -N\omega\Phi_m \cos \omega t$$

$$V_{ind} = Emf_{ind\,(\max)} = N\omega\Phi_m = 2\pi f N\Phi_m$$

Thus:

$$Emf_{ind\,(rms)} = \frac{N\omega\Phi_m}{\sqrt{2}} = \frac{2\pi f N\Phi_m}{\sqrt{2}} = 4.44\, fN\Phi_m$$

Transformer Equation

- For an ideal transformer

$$E_1 == 4.44\, fN_1\Phi_m$$
$$E_2 == 4.44\, fN_2\Phi_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

- In the equilibrium condition, both the input power will be equaled to the output power, and this condition is said to ideal condition of a transformer.
- From the ideal transformer circuit, note that,

$$Input\ \ power\ = output\ \ power$$
$$V_1 I_1 \cos\theta = V_2 I_2 \cos\theta$$
$$\therefore \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

- Hence, substitute in (i)

$$E_1 = V_1 \ and\ E_2 = V_2$$

Transformer Equation

$$\textit{Therefore,} \quad \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = a$$

Where, ‘a’ is the Voltage Transformation Ratio; which will determine whether the transformer is going to be step-up or step-down

For a >1 $\longrightarrow$ **$E_1 > E_2$** $\longrightarrow$

For a <1 $\longrightarrow$ **$E_1 < E_2$** $\longrightarrow$

Transformer Rating

- Transformer rating is normally written in terms of Apparent Power.
- Apparent power is actually the product of its rated current and rated voltage.

$$VA = V_1 I_1 = V_2 I_2$$

- Where,
  - I_1 and I_2 = rated current on primary and secondary winding.
  - V_1 and V_2 = rated voltage on primary and secondary winding.

    - Rated currents are the full load currents in transformer

Transformer Losses

- Generally, there are two types of losses;
  i. Iron losses :- occur in core parameters
  ii. Copper losses :- occur in winding resistance

i. <u>Iron Losses</u>

$$P_{iron} = P_c = (I_c)^2 R_c = P_{open\ circuit}$$

ii <u>Copper Losses</u>

$$P_{copper} = P_{cu} = (I_1)^2 R_1 + (I_2)^2 R_2 = P_{short\ circuit}$$

$$or\ if\ \ referred, P_{cu} = (I_1)^2 R_{01} = (I_2)^2 R_{02}$$

Transformer Efficiency

- To check the performance of the device, by comparing the output with respect to the input.
- The higher the efficiency, the better the system.

$$Efficiency, \eta = \frac{Output\ Power}{Input\ Power} \times 100\%$$

$$= \frac{P_{out}}{P_{out} + P_{losses}} \times 100\%$$

$$= \frac{V_2 I_2 \cos\theta}{V_2 I_2 \cos\theta + P_c + P_{cu}} \times 100\%$$

$$\eta_{(full\,load)} = \frac{VA\cos\theta}{VA\cos\theta + P_c + P_{cu}} \times 100\%$$

$$\eta_{(load\ n)} = \frac{nVA\cos\theta}{nVA\cos\theta + P_c + n^2 P_{cu}} \times 100\%$$

Where, if ½ load, hence n = ½ ,
¼ load, n= ¼ ,
90% of full load, n =0.9

Where Pcu = Psc
Pc = Poc

Voltage Regulation

- The purpose of voltage regulation is basically to determine the percentage of voltage drop between no load and full load.

Voltage Regulation (Basic Definition)

- In this method, all parameter are being referred to primary or secondary side.
- Can be represented in either
  - Down – voltage Regulation

$$V.R = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100\%$$

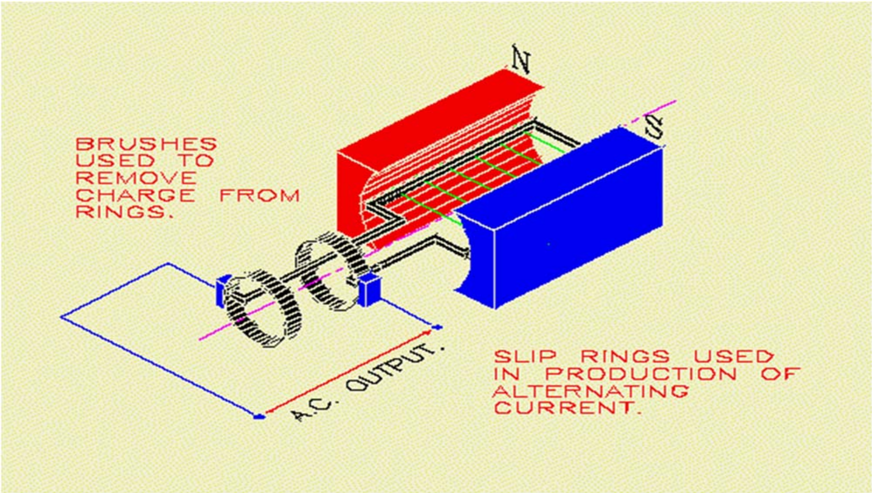
  - Up – Voltage Regulation

$$V.R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

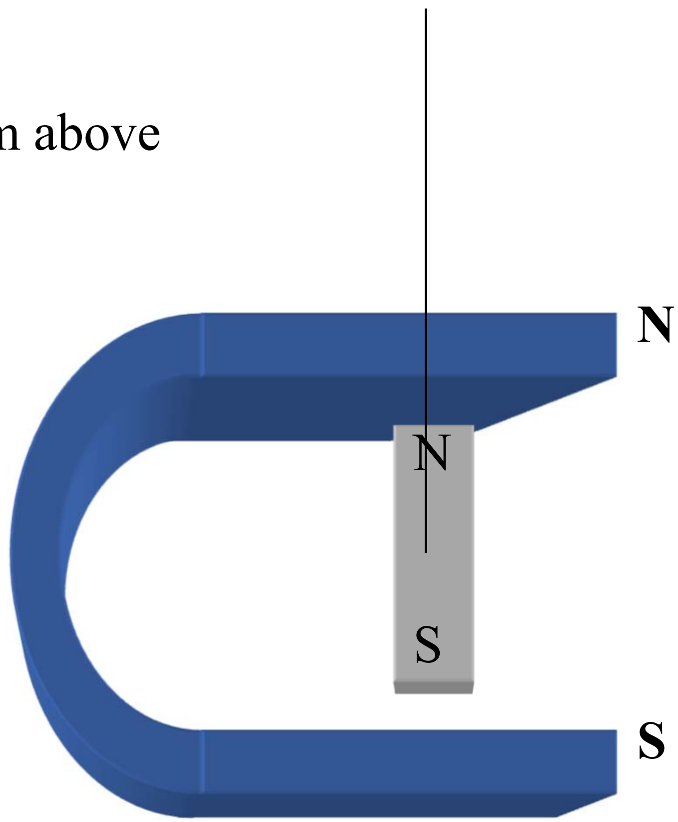
Motors

AC Motor:::

- An **AC motor** is an electric motor driven by an alternating current (AC).

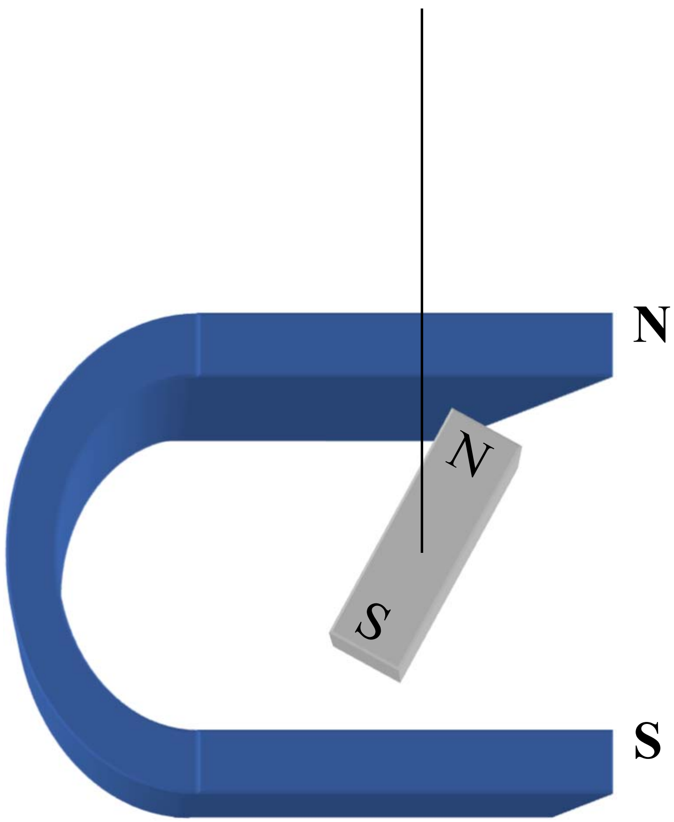


Magnet supported from above

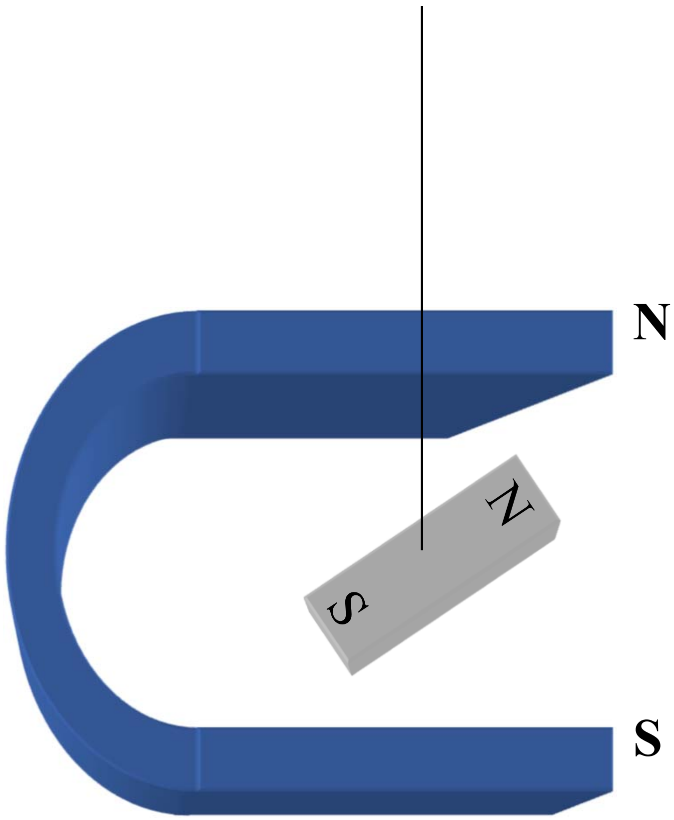


Since unlike poles repel each other, the magnet will rotate

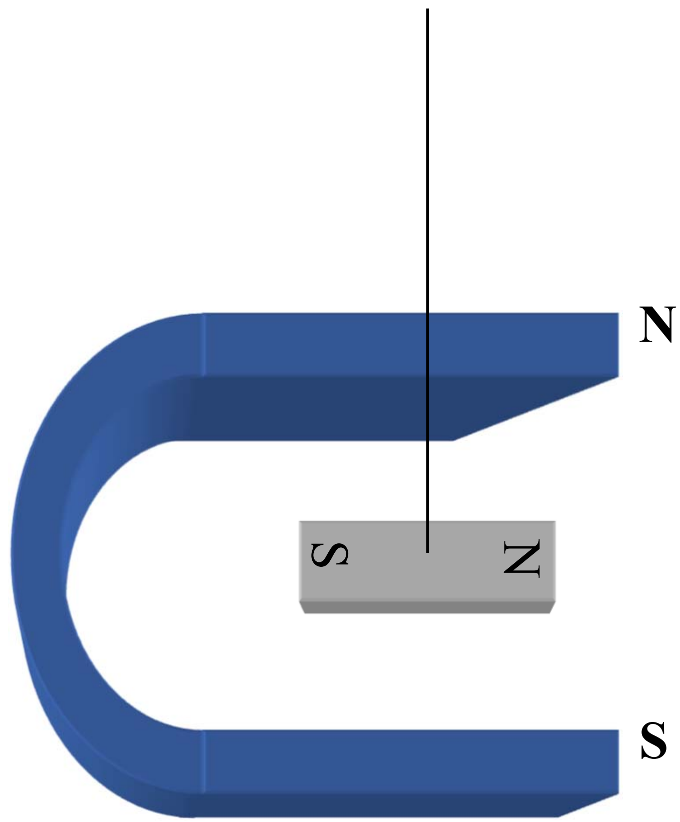
Stationary Magnet



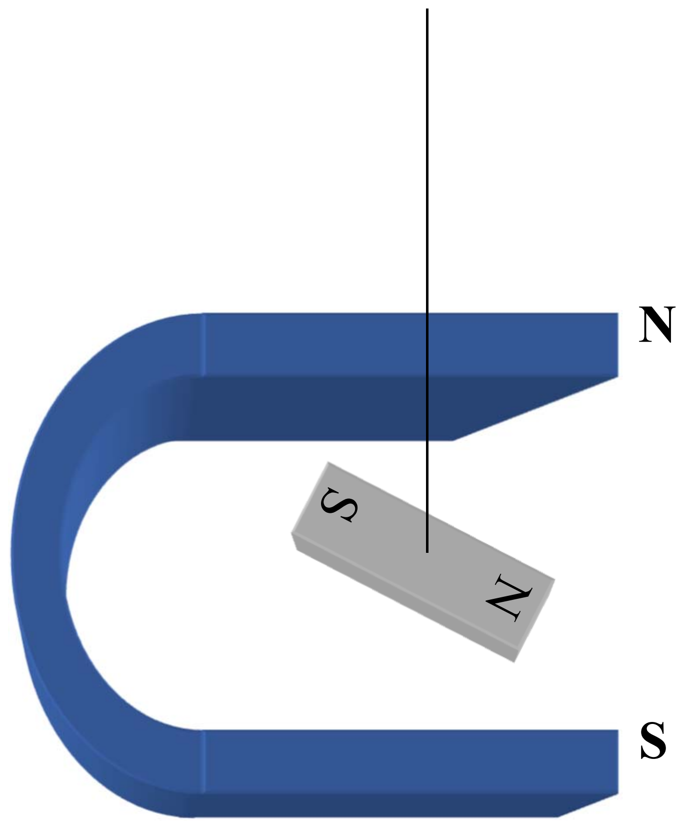
Stationary Magnet



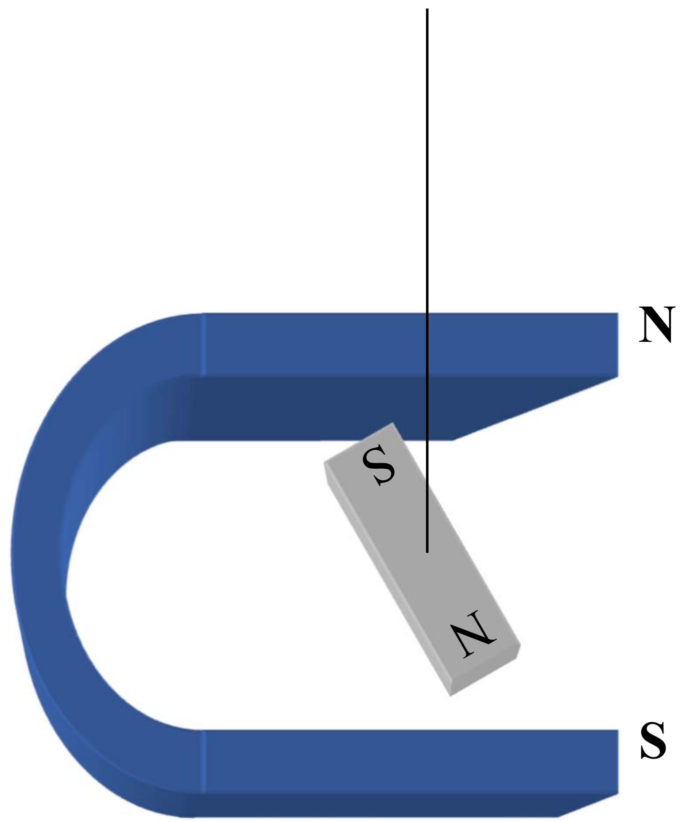
Stationary Magnet



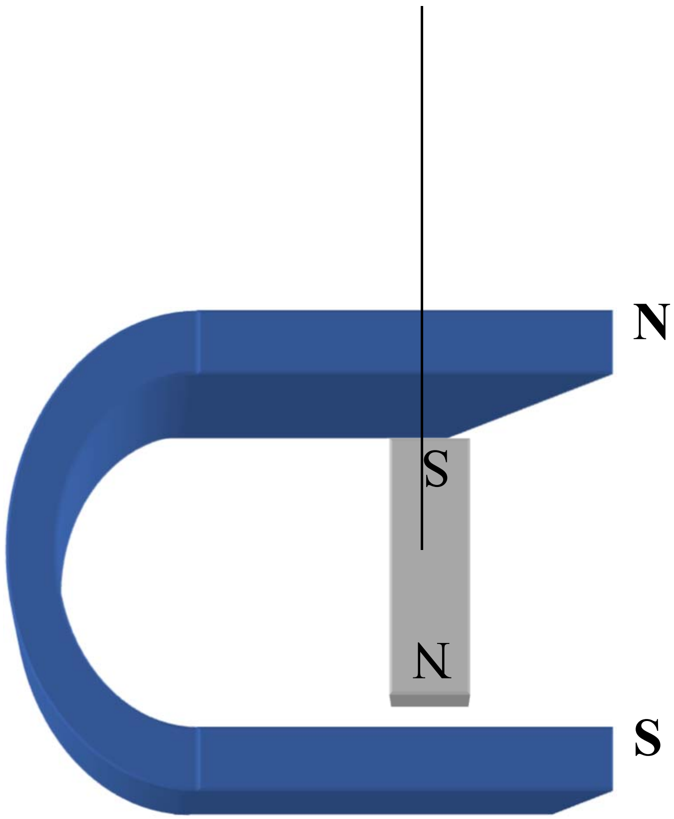
Stationary Magnet



Stationary Magnet



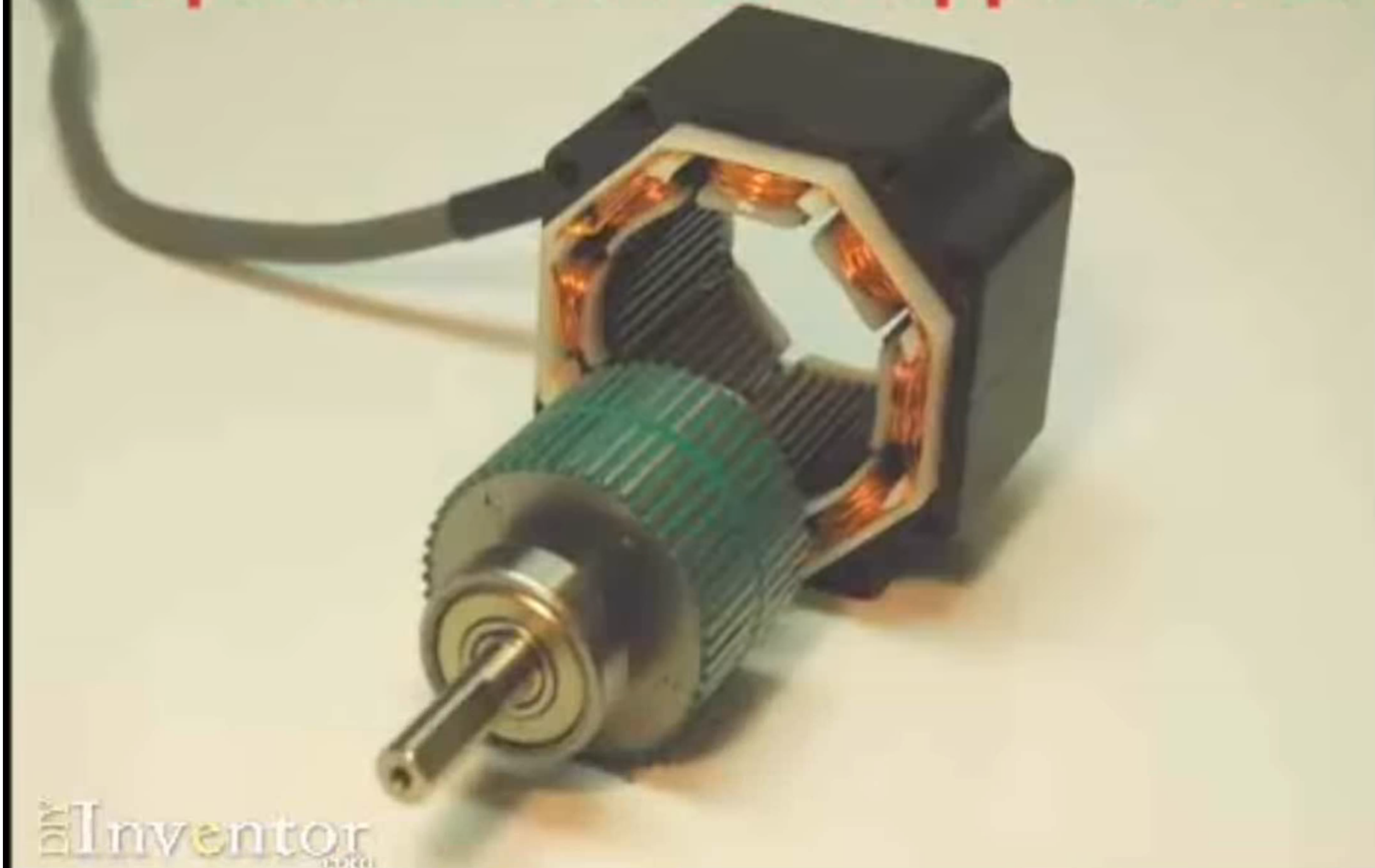
Stationary Magnet



When the unlike poles are lined up with each other, rotation will stop

Stationary Magnet

Exploded View of Stepper Motor



Stepper Motor

- SPR = NR x N
- Where: SPR = number of steps per revolution
- NR = total number of rotor teeth (total for both yokes)
  - In the previous example, NR = 50 +48 =98
- N = number of motor phases
  - In the above example, the number of phases are two
- SPR = 98 × 2 = 198
- In one revolution, there are 360°
- Angle of rotation for one revolution

$$\theta = \frac{360^\circ}{SPR}$$

$$\theta = \frac{360^\circ}{198} = 1.8^\circ$$