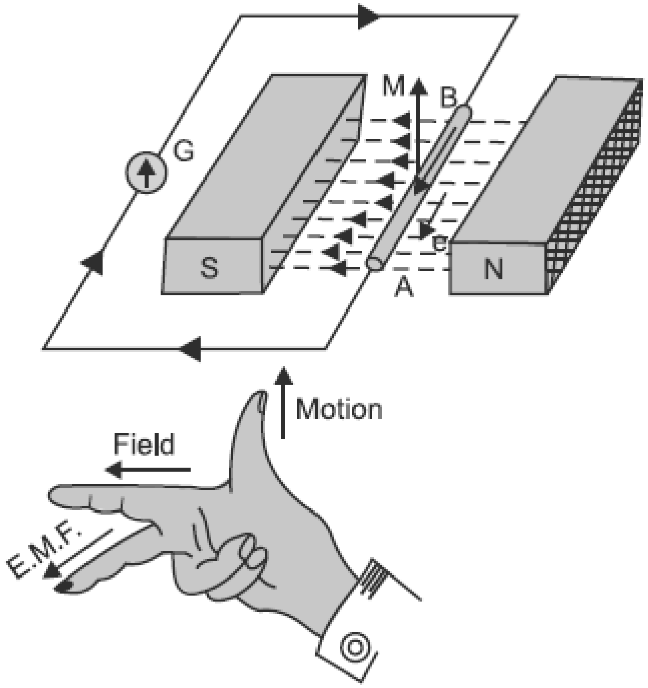
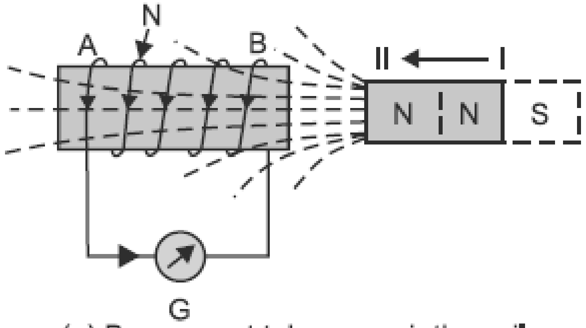
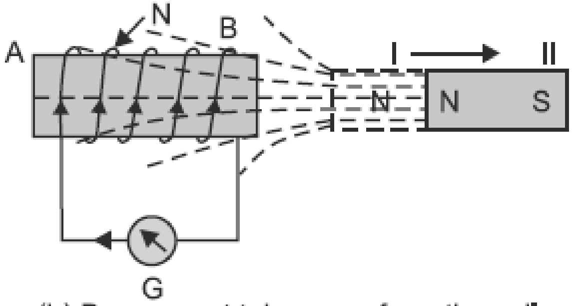
Circuitos electro- magnéticos





(a) Bar magnet taken mearir the coil



(b) Bar magnet take away from the coil

$$e = N \frac{d\phi}{dt}$$

Portanto poderemos ter uma tensão induzida num condutor de duas formas:

Mantendo o campo magnético constante e movendo o condutor ou mantendo o condutor imóvel e movendo o campo magnético - tensão induzida dinâmica. Acontece nos motores

Variando o fluxo sem mover o condutor ou mover o campo magnético- tensão induzida estática – acontece nos transformadores

Imaginemos uma bobina com 500 voltas imersa num fluxo magnético de 2 mWb

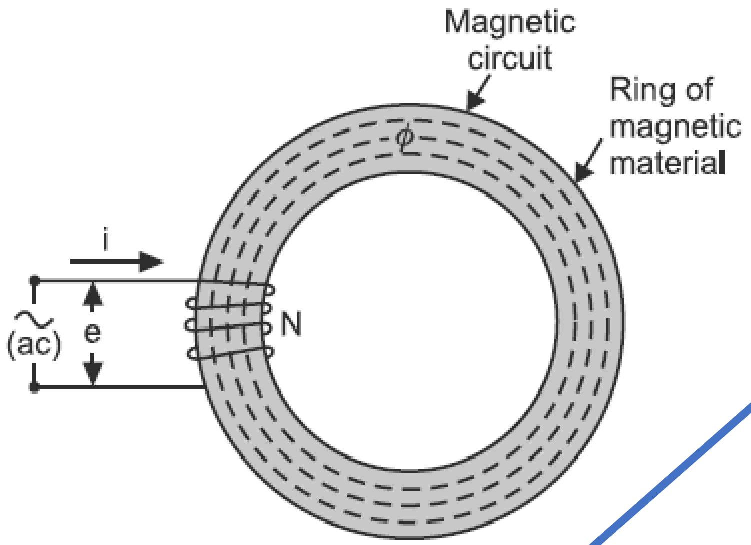
Se o fluxo for invertido em 4 ms qual será a tensão induzida na bobina?

$$e = N\frac{d\phi}{dt}$$

$N = 500$ turns; $d\,\phi = 2 - (-2) = 4\ m\ Wb$; $dt = 4 \times 10^3\ s$;

$$e = 500 \times \frac{4 \times 10^{-3}}{4 \times 10^{-3}} = \mathbf{500\ V}$$

Excitação AC de circuitos magnéticos



$$e = N\frac{d\phi}{dt}$$

$$\phi = \phi_m \sin \omega t = \phi_m \sin 2\pi ft$$

$$e = N\frac{d\phi}{dt} = N\frac{d}{dt}(\phi_m \sin 2\pi ft)$$

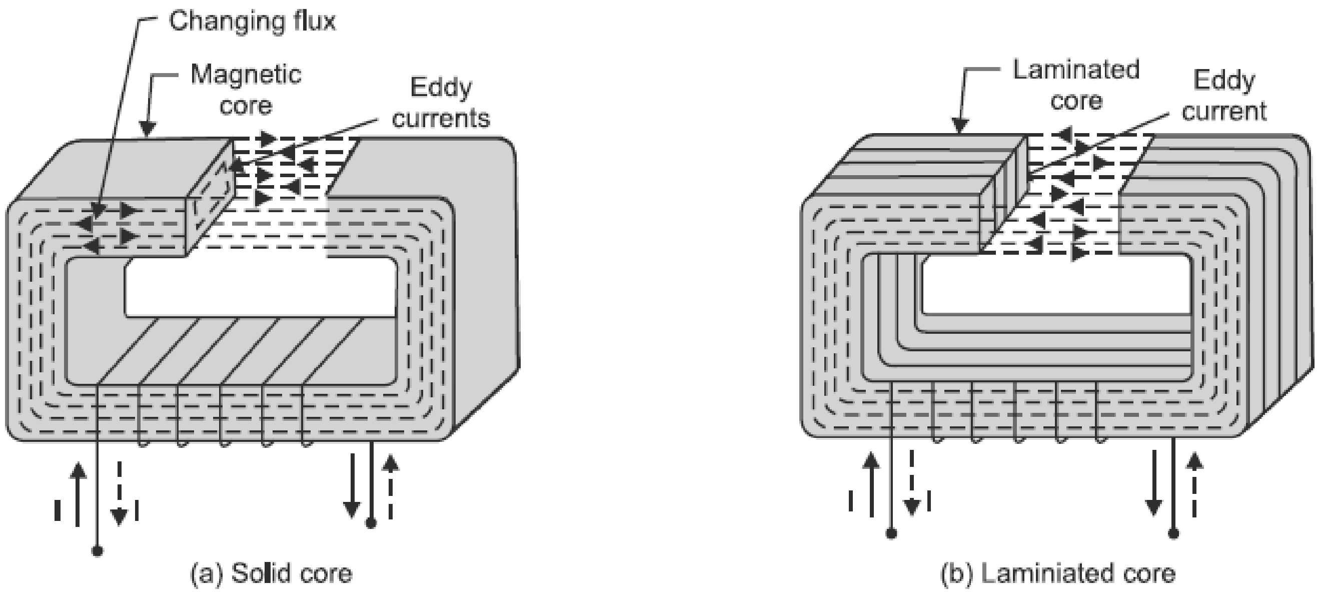
$$= 2\pi fN\phi_m \cos 2\pi ft = 2\pi fN\phi_m \sin\left(2\pi ft + \frac{\pi}{2}\right)$$

$$E_{rms} = \frac{E_m}{\sqrt{2}} = \frac{2\pi fN\phi_m}{\sqrt{2}} = 4{\cdot}44\, f N \phi_m$$

A tensão está adiantada de 90º
em relação à corrente

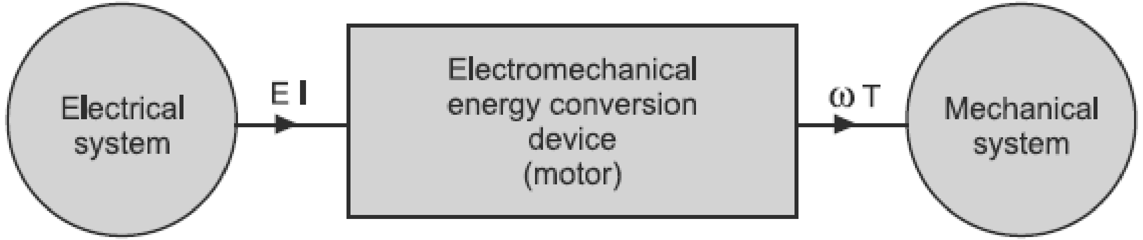
Num material magnético sujeito a um campo magnético variável haverão também tensões induzidas no próprio material magnético

Estas tensões dão origem a correntes induzidas no material magnético e devido à resistência eléctrica deste irãi provocar aumento de temperatura por efeito de Joule

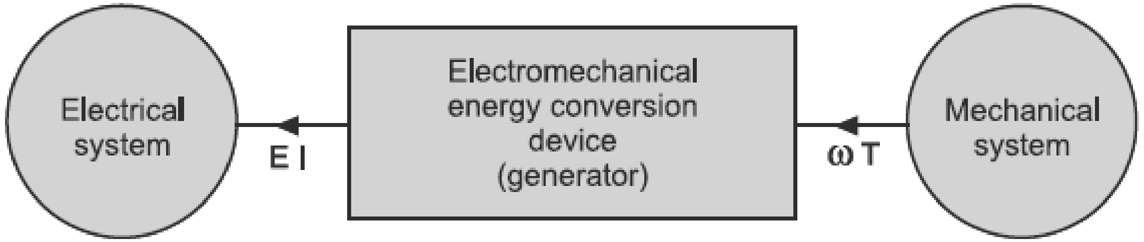


Material laminado em vez de sólido

Dispositivos electro-mecânicos de conversão de energia

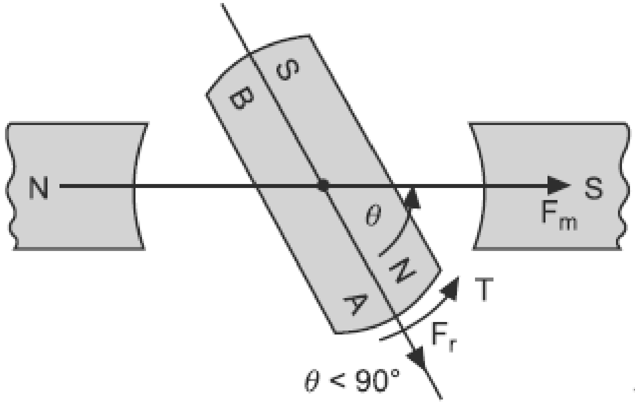


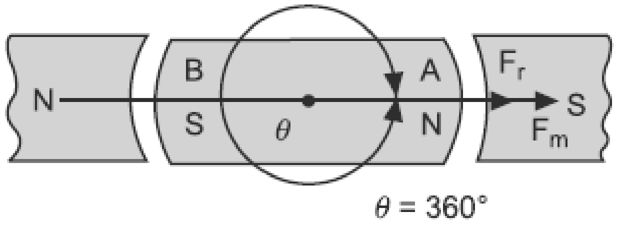
motor

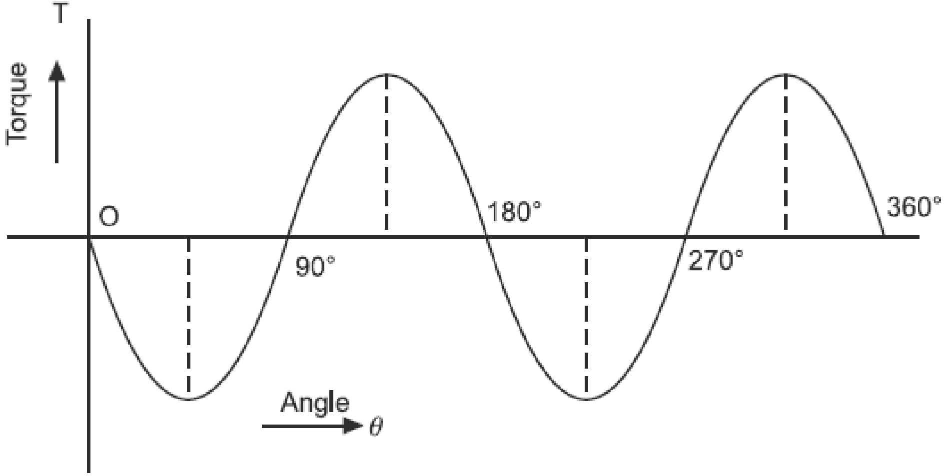


gerador

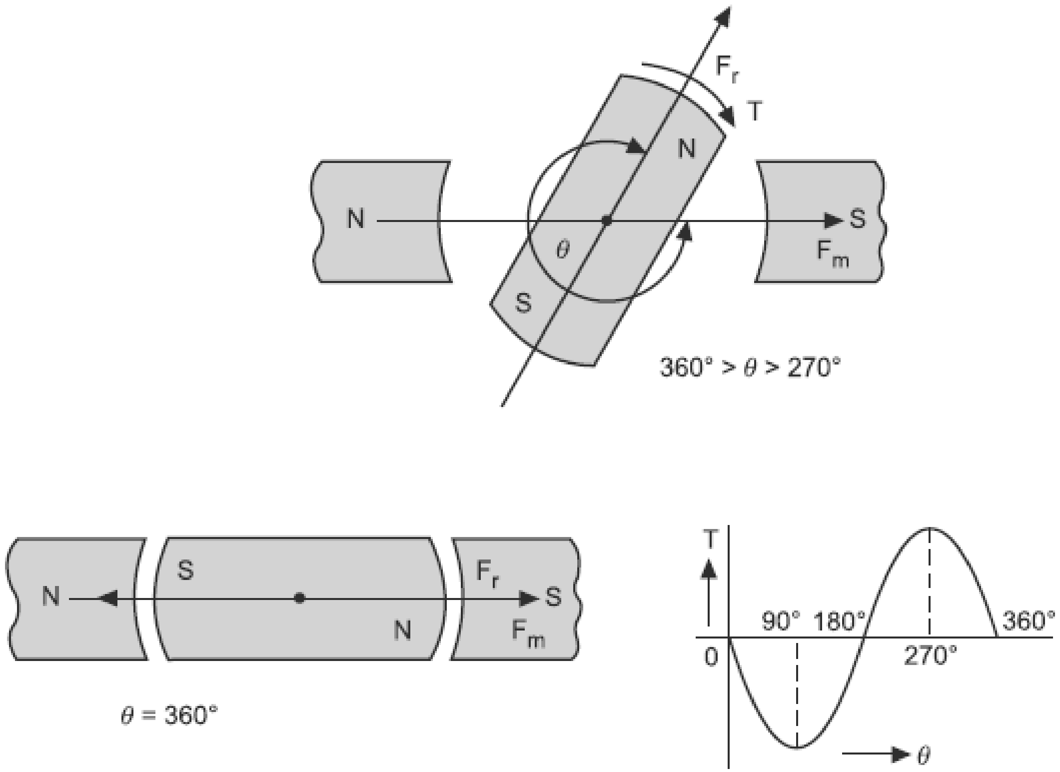
Aparecimento de uma força mecância associada aos polos magnéticos que aparecem num núcleo de ferro imerso num campo magnético



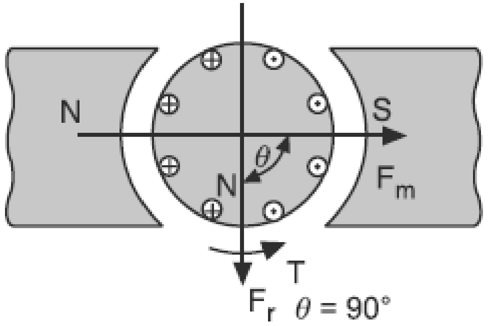


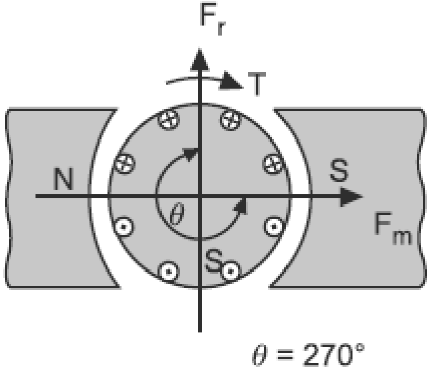


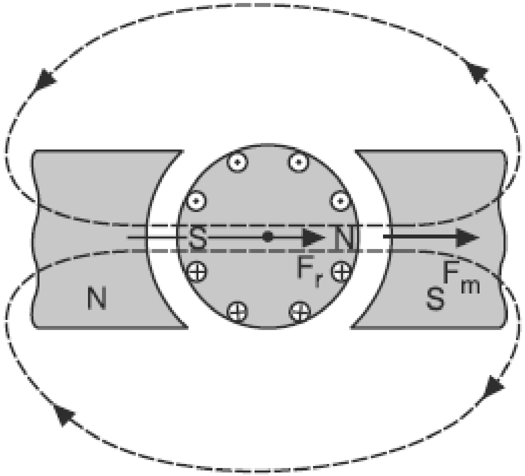
O mesmo se passa se tivermos um magnete permanente imerso num campo magnético.



Se tivermos um electro-magnete imerso num campo magnético.



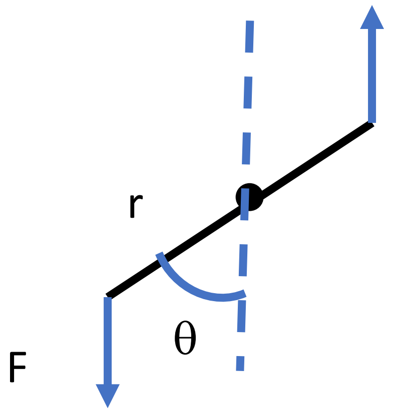




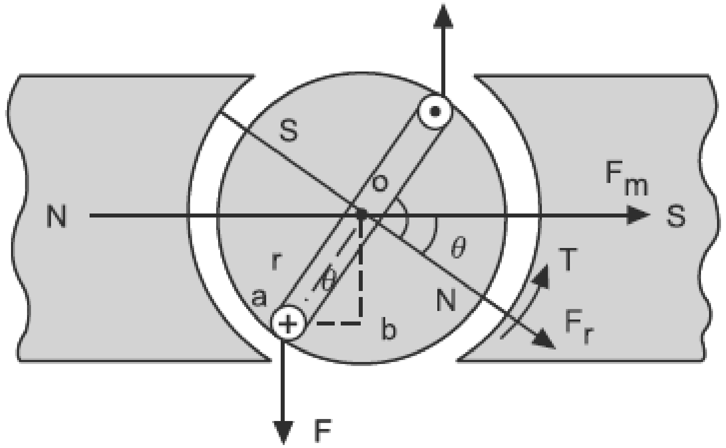
Posição de equilíbrio
Binário nulo

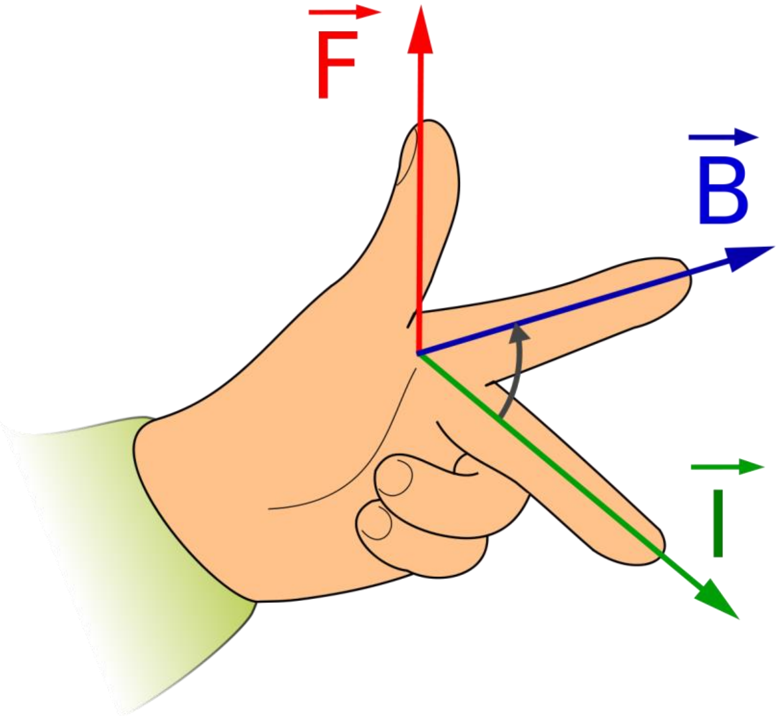
$$\vec{F} = q\vec{v} \times \vec{B}$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

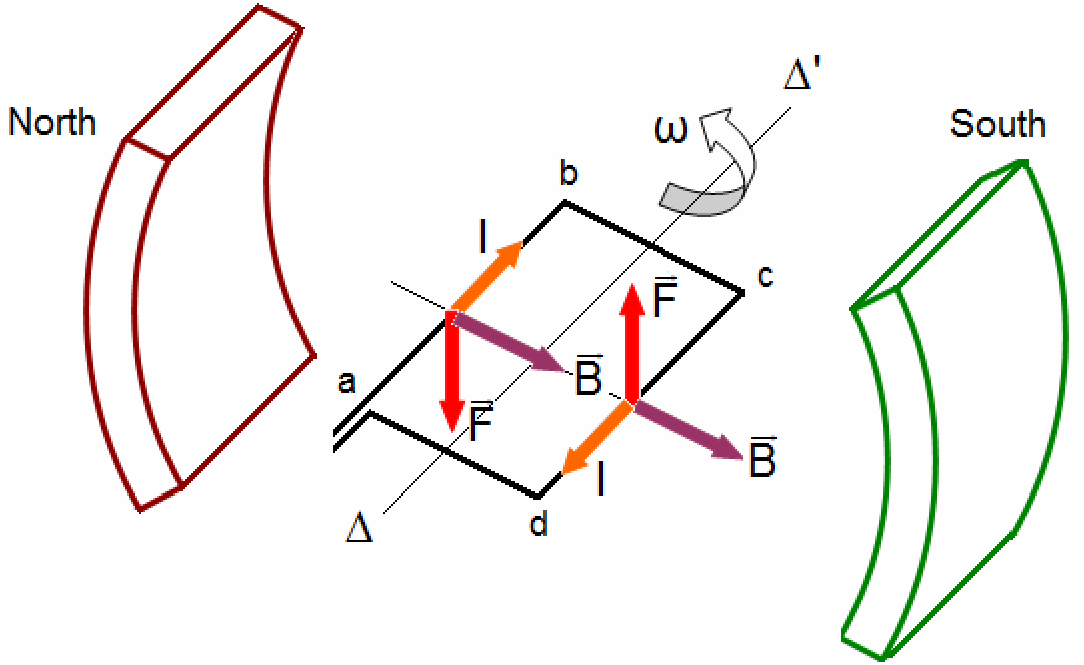


T= F r sen θ

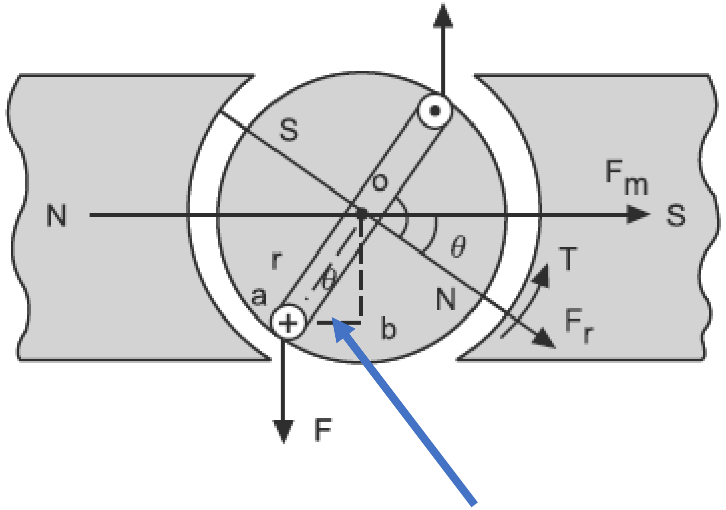




Lei da mão esquerda de Fleming



North
South
ω
Δ'
Δ
a
b
c
d
I
I
F̄
F̄
B̄
B̄



$r \sin \theta$

F = Force acting on the two conductors.

r = radius of circle in which conductor rotates.

θ = angle between the field F_m and F_r.

Torque = Force × Perpendicular distance.

$$T = 2F_r \sin \theta$$

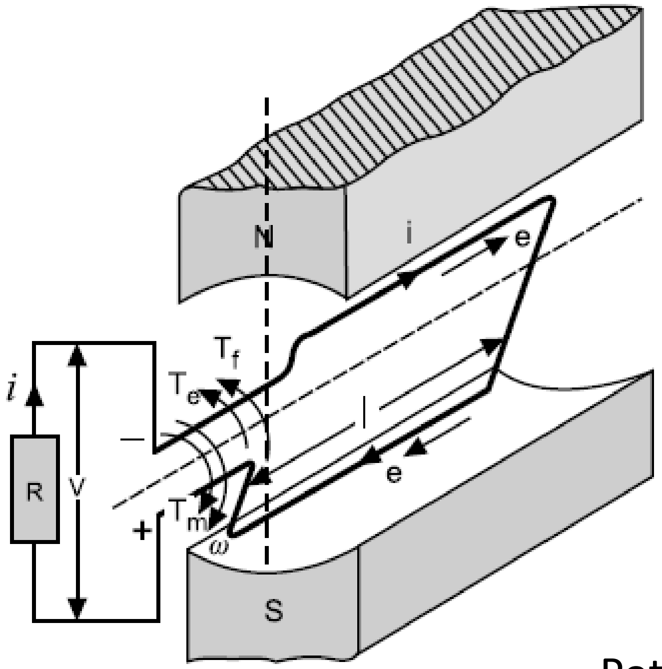
B = Flux density of the main field.

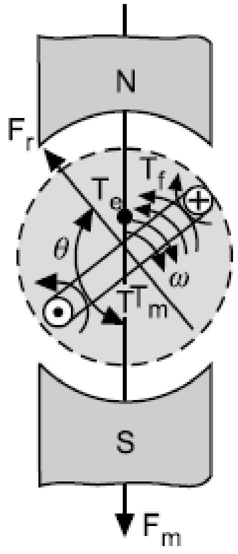
I = Current flowing through the conductor.

l = Effective length of conductor.

$$T = 2BIlr \sin \theta$$

Operação da máquina eléctrica como gerador





$T_m = T_f$ (at no-load)

Se passar corrente no rotor

$$T_m = T_e + T_f$$

$$\omega T_m = \omega T_e + \omega T_f$$

$$\omega T_e = \omega T_m - \omega T_f$$

Potência mecânica

Potência convertida electricamente

Perdas associadas a atrito na máquina

Quando o condutor se move perpendicularmente ao campo magnético

$$e = 2\,B\,l\,v$$

$$e\,i = 2\,B\,i\,l\,v = 2\,F\,v \qquad [\because F = B\,i\,l]$$

$$= 2\,\mathrm{F} \times \text{radius of coil} \times \frac{v}{\text{radius of coil}}$$

$$= T_e \times \omega \qquad [\because T = 2F \times \text{radius and } \omega = \frac{v}{\text{radius}}].$$

$$ei = \omega T_e \qquad \text{...}(iii)$$

Sendo r a resistência interna do rotor

$$i = \frac{e}{r + R} \text{ or } e = ir + iR$$

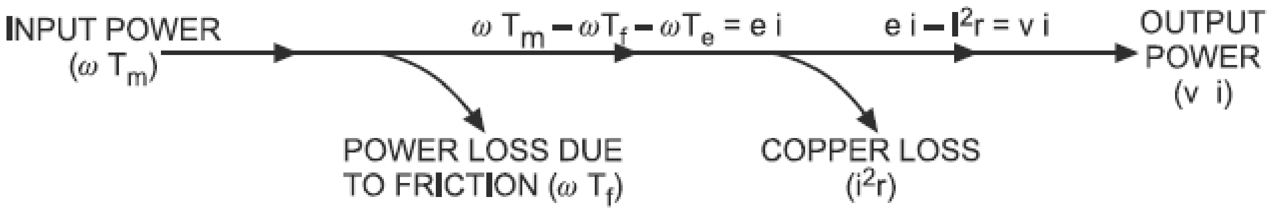
$$ei = i^2 r + i^2 R$$

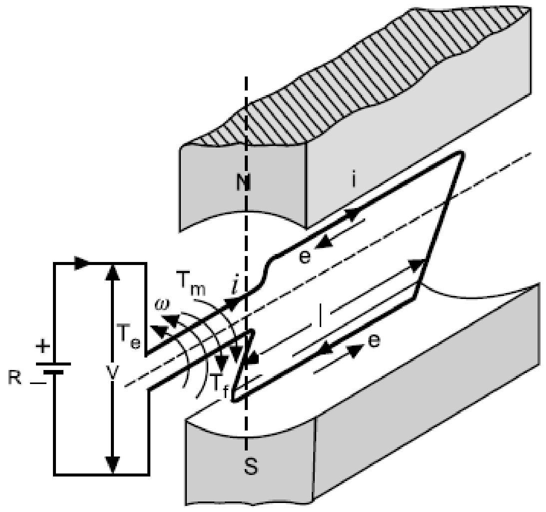
$$ei - i^2 r = vi$$

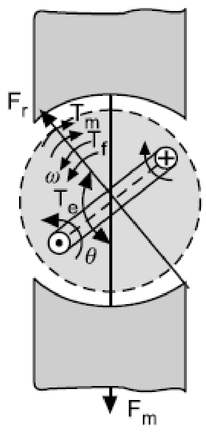
ei = electrical power generated,

$i^2 r$ = power lost in the resistance of coil, called copper losses,

vi or $i^2 R$ = electrical power output to the load.







Sendo r a resistência interna do rotor

$$V = e + ir$$

$$V\,i - i^2\,r = ei$$

Vi = electrical power input,

i^2r = power lost in the resistance of the coil called copper losses,

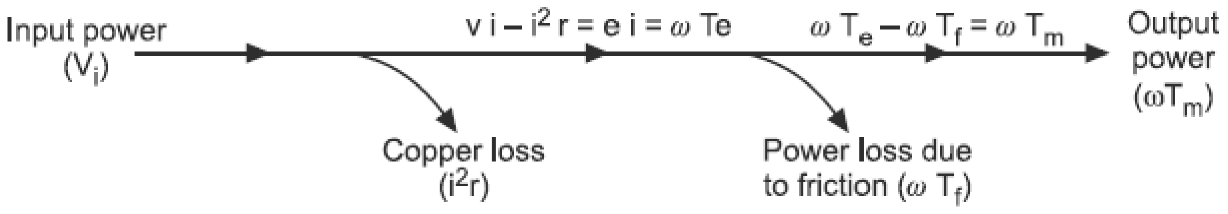
ei = electrical power developed in the rotor which is converted into mechanical power.

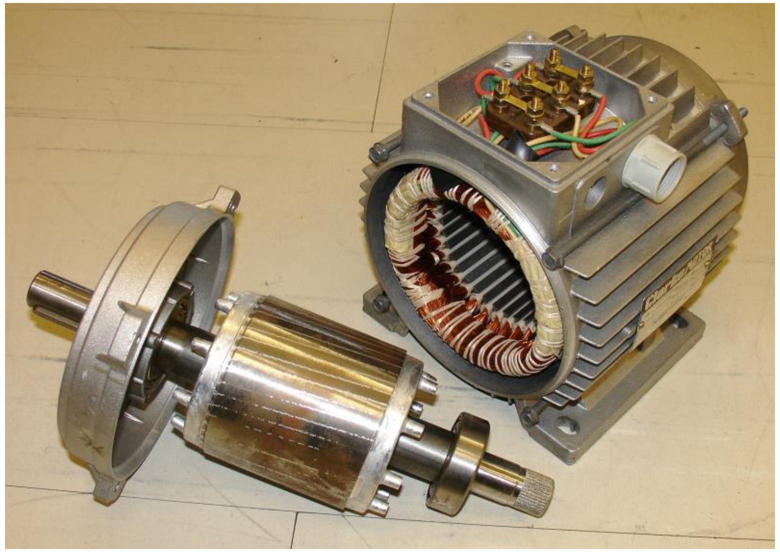
$ei = \omega\,T_e$ [from equation (*iii*)]

$$T_e = T_m + T_f$$

$$\omega T_e = \omega T_m + \omega T_f$$

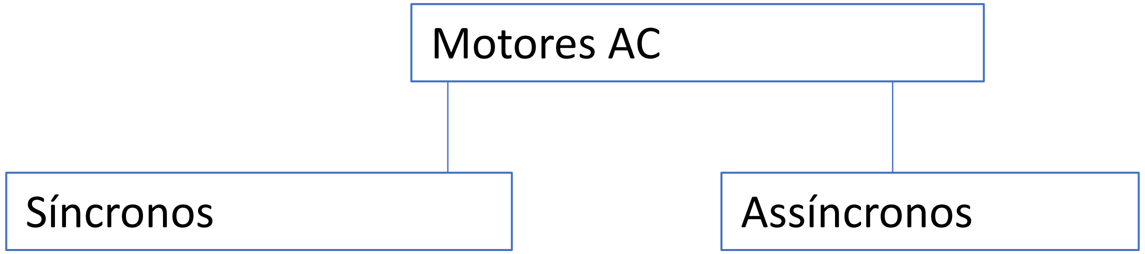
$$\omega T_e - \omega T_f = \omega T_m.$$



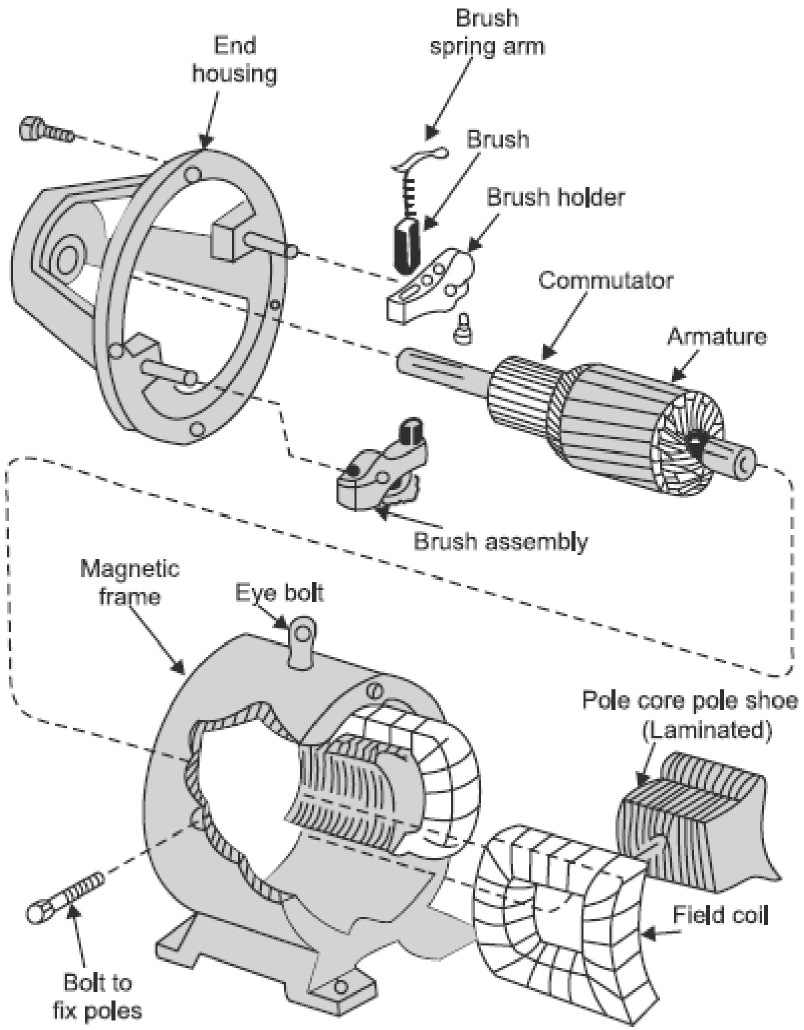


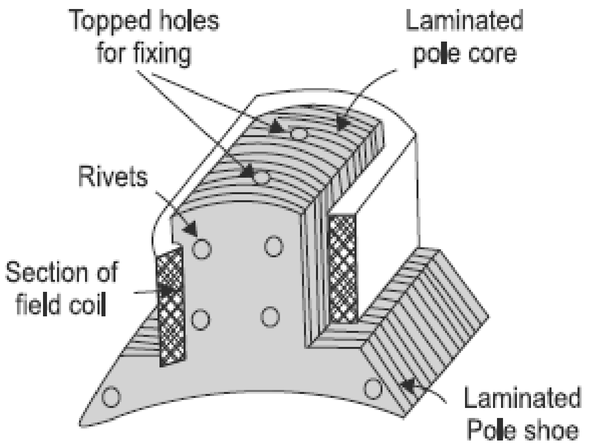
Motores eléctricos

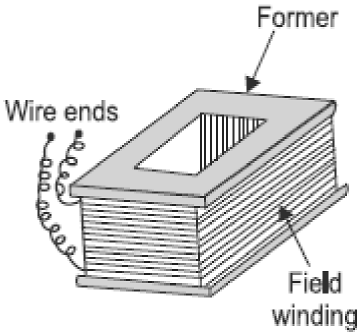
- De corrente contínua (DC)
- De corrente alternada

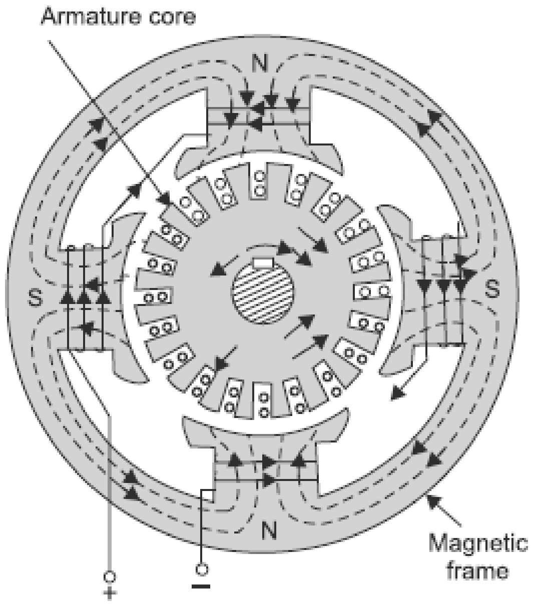

Motores AC
Síncronos
Assíncronos

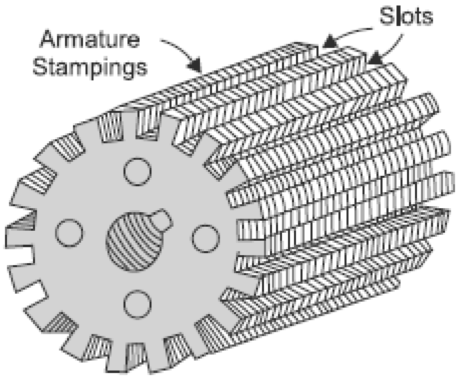
Máquinas eléctricas DC

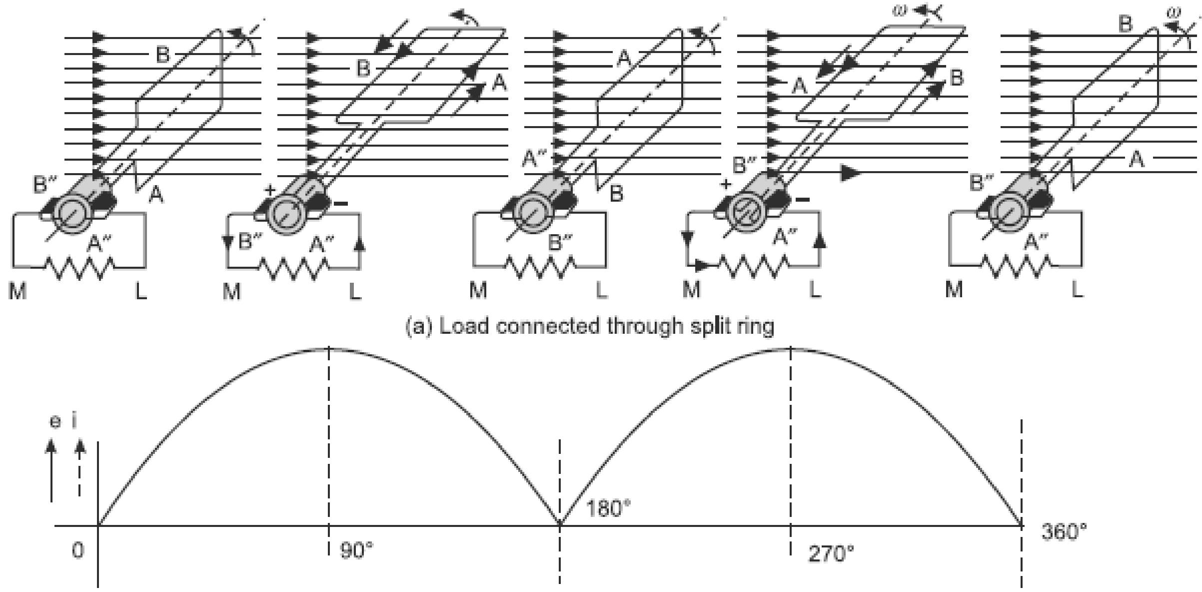






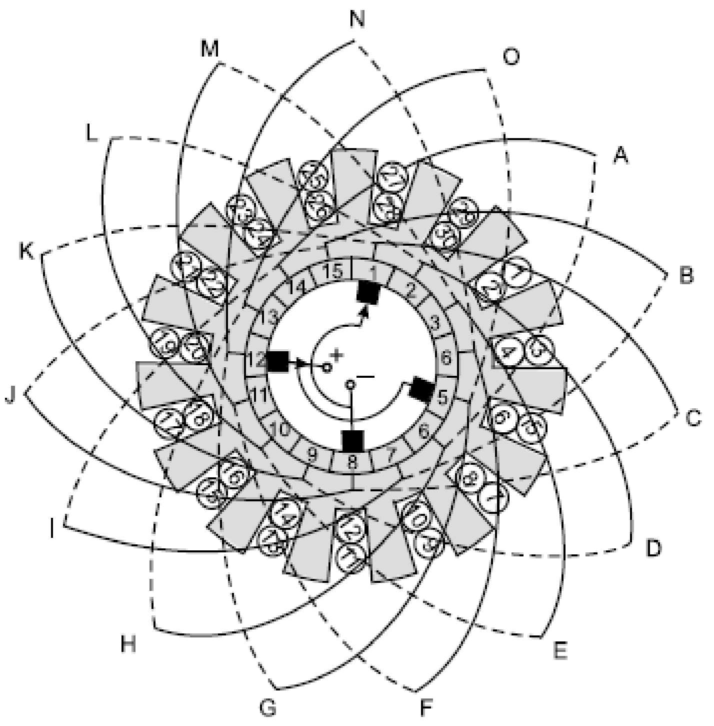

Armature core
N
S
S
N
Magnetic frame
+
−


Armature Stampings
Slots

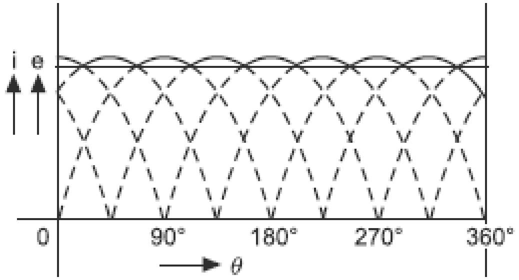


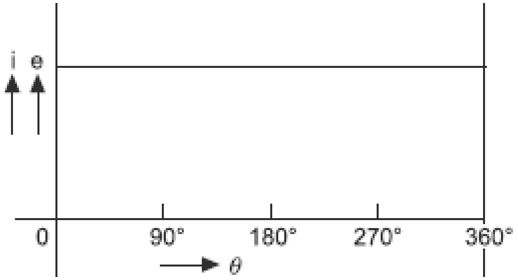
(a) Load connected through split ring

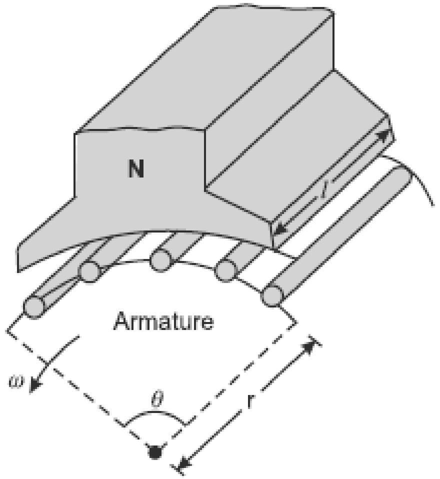
O comutador faz com que a força eçletromotriz gerada seja unidirecional, isto é contínua



Existindo muitos enrolamentos no rotor obtém-se







P = Number of poles of the machine.
ϕ = Flux per pole in Wb
Z = Total number of armature conductors.
N = Speed of armature in *rpm*
A = Number of parallel paths in the armature winding.

Numa revolução o fluxo apanhado por um condutor é

$$= P\phi \text{ Wb}$$

$$e = \frac{P\phi}{t} = \frac{P\phi}{60 / N} = \frac{P\phi N}{60} \text{ volt}$$

$$E = \frac{p\phi N}{60} \times \frac{Z}{A} = \frac{PZ\phi N}{60A} \text{ volt}$$

$$E = \frac{PZ\phi n}{A} \text{ where } n \text{ in speed in } r.p.s.$$

Tempo de uma revolução →

$$n = \frac{N}{60}$$

Para uma dada máquina o nº de polos e nº de condutores por caminho paralelo é constante

$E = K\,\phi\,n$ where $K = \dfrac{PZ}{A}$ is a constant or $E \propto \phi\,n$

$E = K_1\,\phi\,N$ where $K_1 = \dfrac{PZ}{60A}$ is another constant or $E \propto \phi\,N$

$E \propto \phi\,\omega$ where $\omega = \dfrac{2\pi N}{60}$ is the angular velocity in radian/second

Conclui-se que a força electromotriz induzida é proporcional ao fluxo por polo e à velocidade de rotação

Se a máquina trabalha como gerador

$$E_g = \frac{PZ\phi N}{60A} \text{ volt.}$$

Se a máquina trabalha como motor

$$E_b = \frac{PZ\phi N}{60A} \text{ volt.}$$