Electrical Machines Fundamentals

* Motors ⇒ electrical → Mechanical
* Generator ⇒ Mechanical → electrical

Review: CH4, CH9 & CH10 & Complex Numbers

AC & Power calculations

1 → By Ampere's

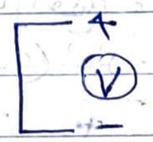
إذا مر تيار في سلك يتولد مجال مغناطيسي.

2

إذا يوجد مجال مغ متغير مع الزمن وقربته عموصل يتولد فرق جهد على أطراف الموصل

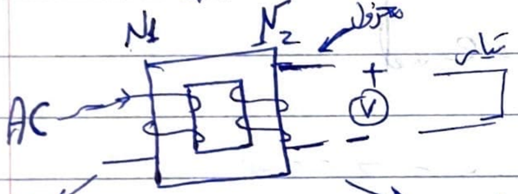
Faraday's law

$$\frac{d\varnothing}{dt}$$



Transformer ⇒ changing of voltage level.

تيار when closed circuit

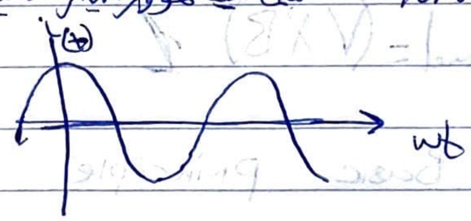


معزول

core

سماحية لمرور التيار عالية — Ferromagnetic

$i(t) = I \cos \omega t$



الهواء سماحيته قليلة

فال Ø بتنتقل عبر الـ core للطرف الثاني ولا يتولد تيار وإنما

يصبح هناك فرق جهد

secondary

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

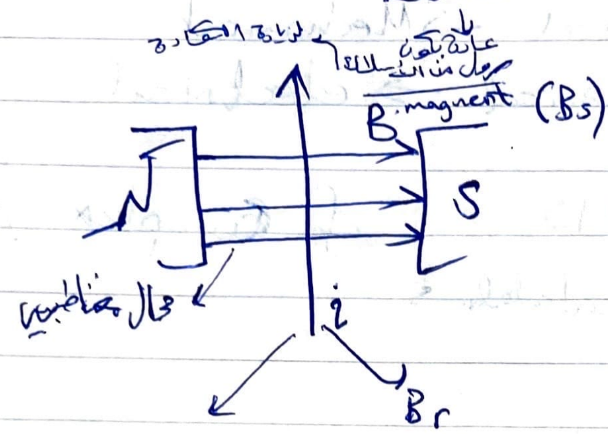
e induced

Naturally ← مغناطيسي

تيار في السلك ← (electrical)

[3] إذا كان في مجال مغناطيسي موجود naturally ووضعت سلك موصل يمر به تيار

ستنشأ Force تحاول السلك تحرك.



الجزء المعرّض للمجال المغناطيسي

$$\vec{F} = i\,(\hat{L} \times B_s)$$

شدة المجال الخ

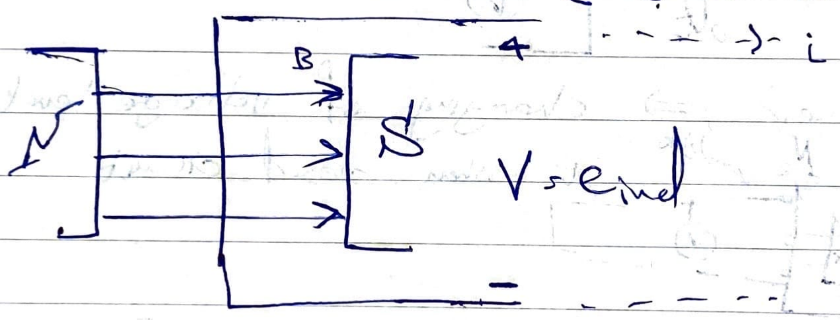
↳ Basic principel of motors

B_r المتولد من مرور التيار الساري في الموصل

هو disturbans

mechanical

[4] بوجود مجال مغناطيسي ، وسلك ~~أقطع~~ خطوط المجال ~~بحركة~~ بواسطة موصل سينشأ فرق جهد على أطراف السلك



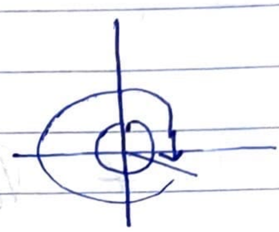
$$e_{ind} = (V \times B)\, L$$

↳ Basic principle of generator

* Induction motor $\equiv$ rotational transformer

* small size
  clean
  مخزنة لا تحتاج تحملها مثل محركات الاحتراق الداخلي
  easy to move efficiently

* linear speed / vel $= \frac{\Delta d}{\Delta t}$



* rotational ~~speed~~ angular velocity $= \frac{\Delta \theta}{\Delta t}$ --- rad/sec

  $\Delta\theta \rightarrow$ angular position

  معدل تغير الزاوية بالنسبة للزمن

  (+) counterclockwise
  (−) clockwise

* $f_m \rightarrow$ angular vel --- rev/sec
* $n_m \rightarrow$ angular vel --- rev/minute

* given rad/se $\longrightarrow$ rpm
  $157 \longrightarrow 157 \times \frac{60}{2\pi}$

  larger than ω كرقم

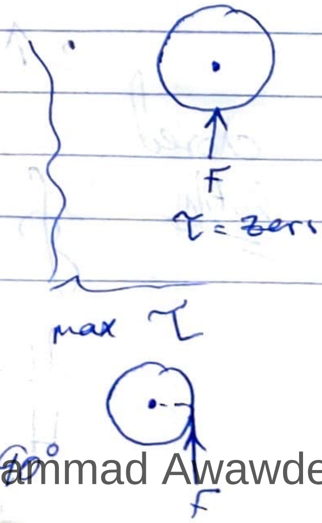
* given rpm $\longrightarrow$ rad/sec (ω)
  $1500 \text{ rpm} \longrightarrow 1500 \times \frac{2\pi}{60}$

* angular acc $= \frac{d\omega}{dt} = \frac{d\ddot{\theta}}{d^2 t}$ rad/sec^2

* $\tau =$ Force $\times$ perpendicular distance
  $\tau = F r \sin\theta$

  العزم الدوراني
  $\tau = J\alpha$ --- Nm

  J: moment of inertia
  ممانعة الجسم للدوران



* $\int \rightarrow$ when distance varies

$W = F(r)$ — Joules

إزاحة

* $P = \frac{dW}{dt} = \frac{d(\tau\theta)}{dt} = \tau \frac{d\theta}{dt}$

$\Rightarrow \boxed{P = \tau\,\omega}$ مقدار التغير في الشغل بالنسبة للزمن

mech power — watt , J/sec

electrical power

* $P_e = iV$

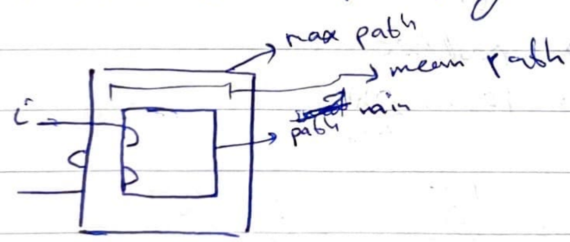
$i = \frac{dq}{dt}$

$V = \frac{dw}{dq}$

$\rightarrow P = i \cdot V = \frac{dq}{dt} \times \frac{dw}{dq}$

$\boxed{P_e = \frac{dW}{dt}} = \tau\omega$

* Production of Magnetic Field → natural magnet / electrical magnet



$i \uparrow$, اتجاه الخ . $\uparrow$

H

closed path

$\oint H\,dL = I_{net} = i \times N_{turns}$ الجهد اللازم لتوجيه مجال مغ.

magnetic field intensity

$dl \rightarrow$ الطول للمسار عبر التيار

$H\,L_c = Ni \Rightarrow \boxed{H = \frac{Ni}{L_c}}$ ---- $\frac{A \cdot turns}{m}$

mean path

الهوا

$\mu_0 = 4\pi \times 10^{-7}$

$\mu_r = 2000 - 6000$

$\mu_{total} = \mu_0 \mu_r$

magnatic field density → كثافة المجال الخ

≡ التدفق بالنسبة للمساحة

* $\boxed{B = \mu H}$

$\boxed{B = \dfrac{\mu N i}{l_c}}$ -- Tesla.

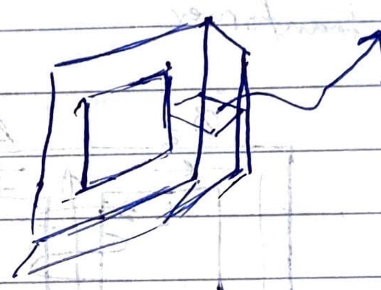
μ ⇒ معامل نفوذية المادة

is magnetic permeability

Henry / weber

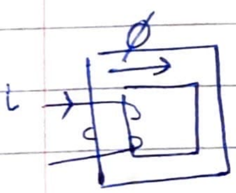
تدفق المجال الخ

* $\boxed{\begin{aligned}\phi &= BA \\ &= \dfrac{\mu N i A}{l_c}\end{aligned}}$ ---weber

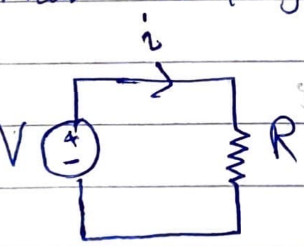


⇒ $\boxed{B = \dfrac{d\phi}{A}}$

* all can't be found so we can do some مقارنة between electrical circuit & magnetic circuit



magnatic circuit



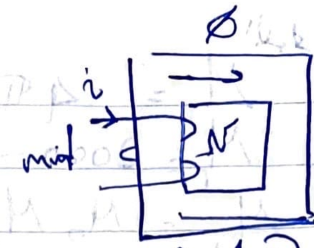
electrical circuit

$f = Ni$ (magnet motive force)

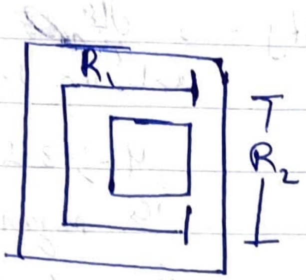
→ reluctance معاوقة المادة لمرور المجال الخ

⇒ $f = \phi \mathcal{R}$

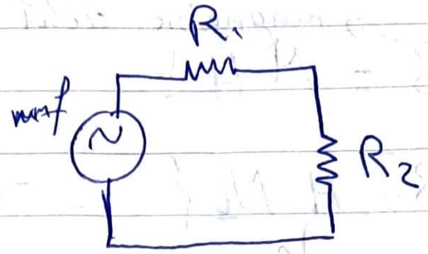
$\mathcal{R} \rightarrow$ might be changable due same system. How?



$f = \phi \mathcal{R}$

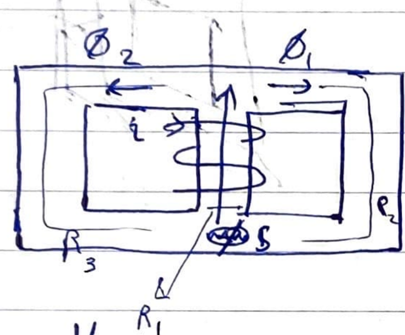


$\Rightarrow$



in series becaus same flux pass acceross them

Three leg transformer

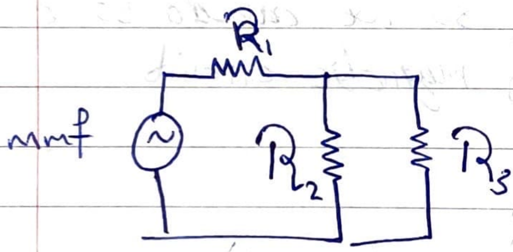


$\phi_s = \phi_1 + \phi_2$

القاطع بتختلف حسب الـ application

← وبالتالي بتكون in series or in parallel.

$\Downarrow$



*In electricity

الموصلية $G = \frac{1}{R}$ ... Siemens Ω^{-1} $\mho$

*In magnet

permance ← $\mathcal{P} = \frac{1}{\mathcal{R}}$ ← reluctance

$\Rightarrow f = \phi \mathcal{R}$

$Ni = \phi \frac{1}{\mathcal{P}}$

$\Rightarrow \mathcal{P} = \frac{\phi}{Ni}$

$$\mathcal{R} = \frac{\mathcal{F}}{\phi} = \frac{Ni}{\phi} = \frac{Ni}{\frac{\mu N i A}{l_c}}$$

$$\boxed{\mathcal{R} = \frac{l_c}{\mu A}}$$

* Possible inaccuracy → losses in flux

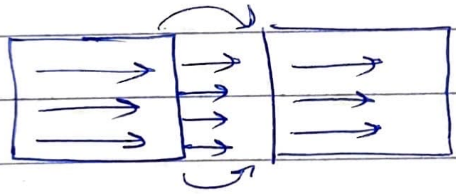
① leckage flux at edges

⇒ ~~Tr~~ Troidal Transformer (filleb edges)

② Mediums permeability → Ferromagnet → high permeability; → Air → low → leckage of flux

③ Uniform ~~Area~~ Cross sectional area

④ Fringing effect ⇒ reluctance & cross sectional area differs due to the air gab



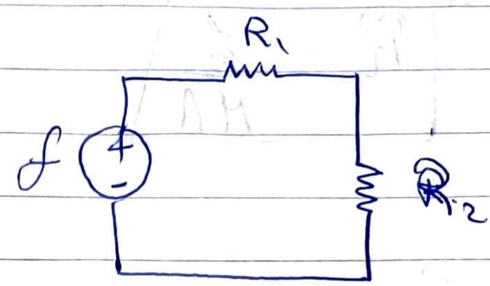
⑤ μ_r & H ⇒ non-linear relationship for permeability

* Example 1-1

in series 'cause same flux

$f = Ni$

$$\phi = \frac{f}{R_{total}} = \frac{Ni}{R_{total}}$$



* $R_{total} = R_1 + R_2$

* $R_1 = \frac{l_c}{\mu A} = \frac{1.3}{(4\pi \times 10^{-7})(2500)(0.15 \times 0.1)}$

mean path

width

depth

$\mu = \mu_0 \mu_r$

$=$

* $R_2 = \frac{l_c}{\mu A} = \frac{0.45}{(4\pi \times 10^{-7})(2500)(0.1 \times 0.1)}$

$=$

$\rightarrow R_{total} \searrow$

* $\phi = \frac{(200)(1\,A)}{R_{total}}$ ...... Weber

* Example 1-2

$$\phi = \frac{Ni}{R_{total}}$$

$R_{core} = \frac{l_c}{\mu A} = \frac{0.4}{(4\pi \times 10^{-7})(4000)(12 \times 10^{-4})} =$

$R_{airgab} = \frac{0.05 \times 10^{-2}}{(4\pi \times 10^{-7})(12 \times 10^{-4} + 1.05)} =$

5% ضايع

$\Rightarrow R_{total} = R_{core} + R_{airgab}$

μ, B changes for one material

~~[illegible]~~

* $\phi = \dfrac{Ni}{R_{total}}$

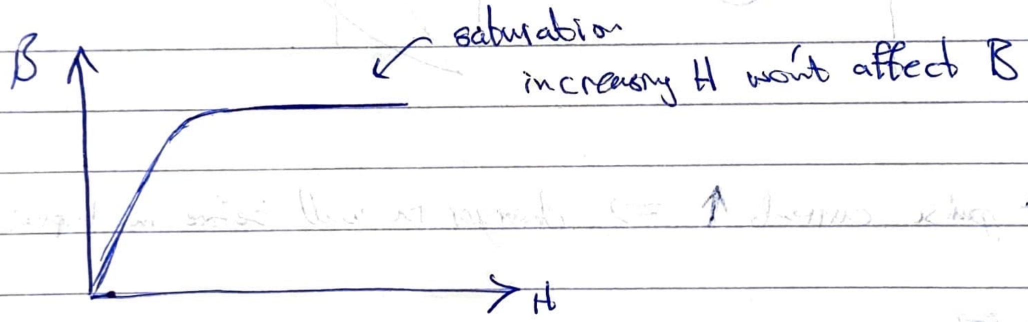
$\cancel{\phi}\ BA = \dfrac{(400)(i)}{R_{total}}$

$\underbrace{(0.5)\ (12 \times 10^{-4})(1.05)}$ $= \dfrac{(400)\ (i)}{R_{total}}$

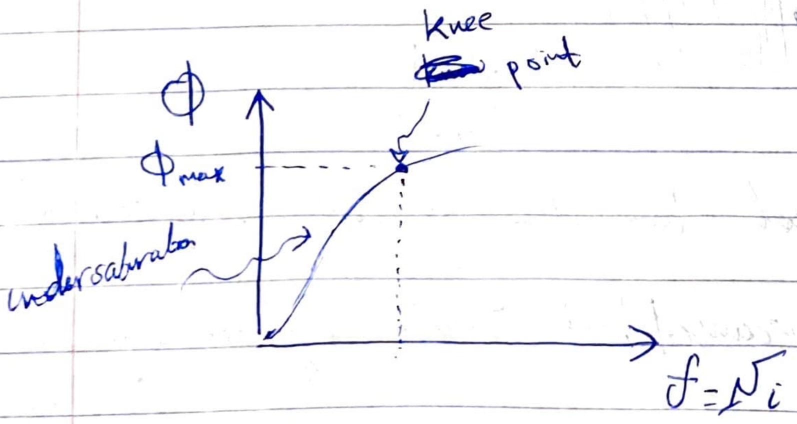
air gab area

the increase of A because of leckage.

* Magnetization curve or Saturation curve (2 plots)



* rated value for device ⇒ value for best performance
nominal value without harming the device



a knee point → best performance with least current

$I \uparrow \rightarrow \phi \uparrow$

* Losses in Core

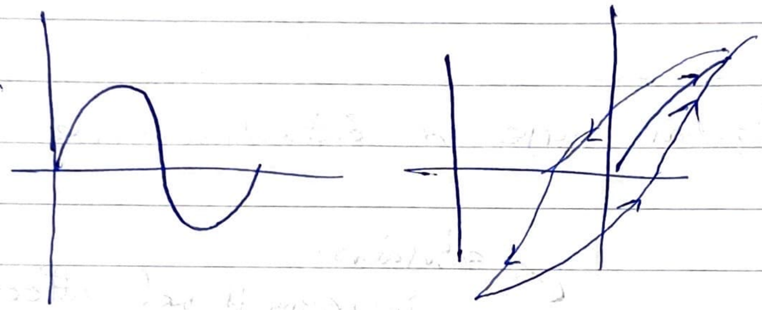
① Hysteresis losses in one cycle

* القوة اللازمة لأجل reorientation الشبكات

Ideal core ⟹ least losses when it goes & returns at same curve.

* losses appear as heat problems

فولتجا الج متغير



* pulse current ↑ ⟹ charger in wall before in Laptop

②

* to reduce eddy current & keep same performance

put slices material → steel lamination
How?

search How steel lamination reduce eddy current?

because of heat dissipation, reduction of eddy current will reduce heat

eddy current: a current induced because of time changing in magnetic field on a closed path of core
it causes heat dissipation, that can be solved using steel lamination.

$$e_{ind} = - N \frac{d\phi}{dt}$$

because of lens' law