first - field
2^{nd} - current

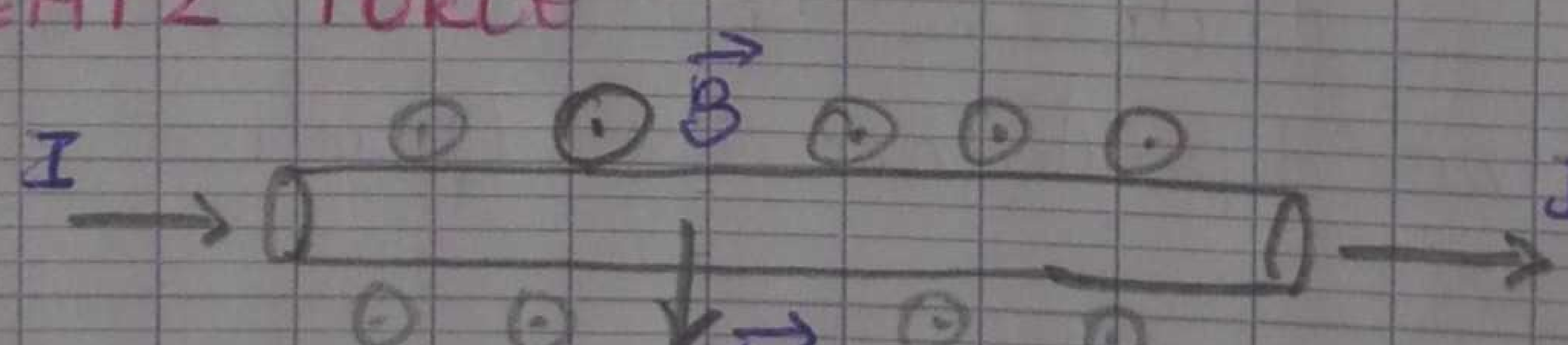
DC machine	Synchronous Machine	Asynchronous 1ϕ	Transformer
& High speeds	1) Power generation	1 Petroleum &	1 Voltage level
& high torques)	2 Power factor correct	Chemical pumps	adjustment
1 Rolling mills	3 Wind energy turbines	2 cooling fans	2) Power flow
2 Elevators (lifts)	4 Voltage regulation	3 Air handling	re-directing
3 Conveyor belts	5 Electric clock drives	equipement.	3 Power
4 Electric trains	6 Gasoline engine drive	4 compressors	measurement
5 Cranes & hoists	7 Servo drives	5 process machine	4 Isolation
6 Lathes ("tours")	8 Compressors etc	6 Blowers & fans	of part -
7 Machine tools		7 drilling machines	networks
8 fans, Blowers etc		8 Grinders	
9 Rapid transit sys		9 Lathes	
		10 Conveyors	
		11 Crushers etc	

Basic principles underlying Electromechanical Energy Conversion

1. Motor action
2. Generator action
3. Transformer action.

LORENTZ FORCE

* Motor action



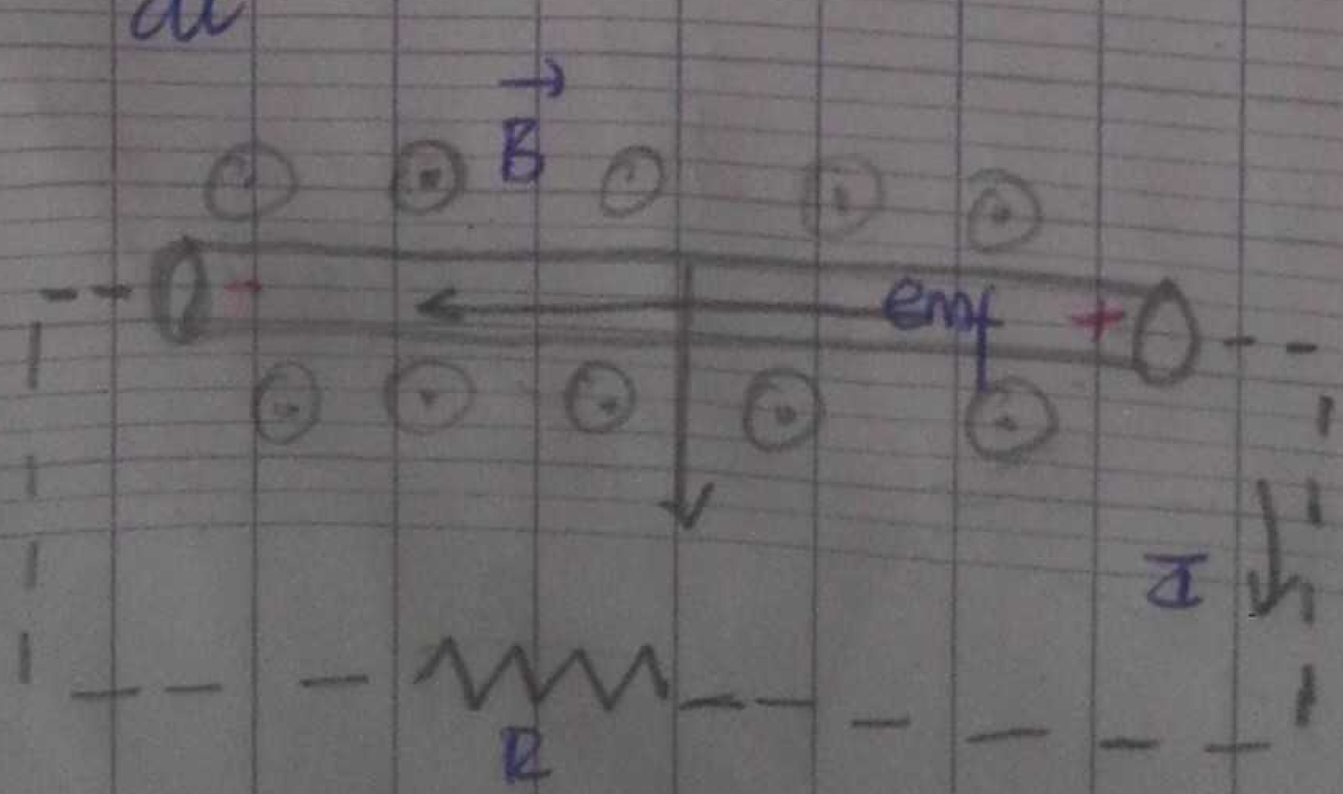
$\vec{F} = I\vec{L} \times \vec{B}$

Fundamental "Motor"

* Generator action

Faraday's law of electromagnetic induction

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



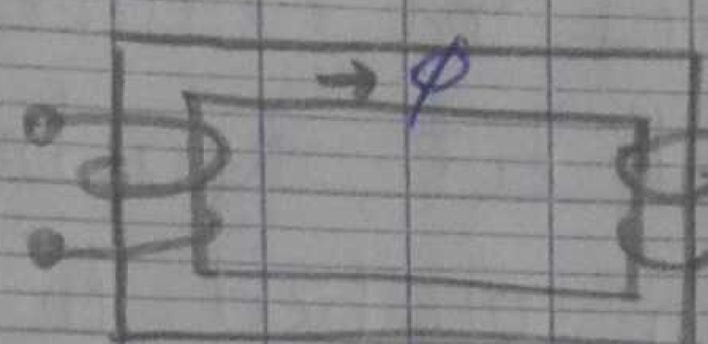
It is when an emf is induced due to FLUX CUTTING action.

Motional Emf

* interaction of the 2 circuit ;
- magnetic - electric w/c causes the change in energy.

* Transformer action

An emf is induced due to **Flux-CHANGING** action



NB dc cannot be used to produce emf because ϕ does not chang.

Transformer emf

NB All the three actions are present in a devices but one dominates

dc ⇏ emf

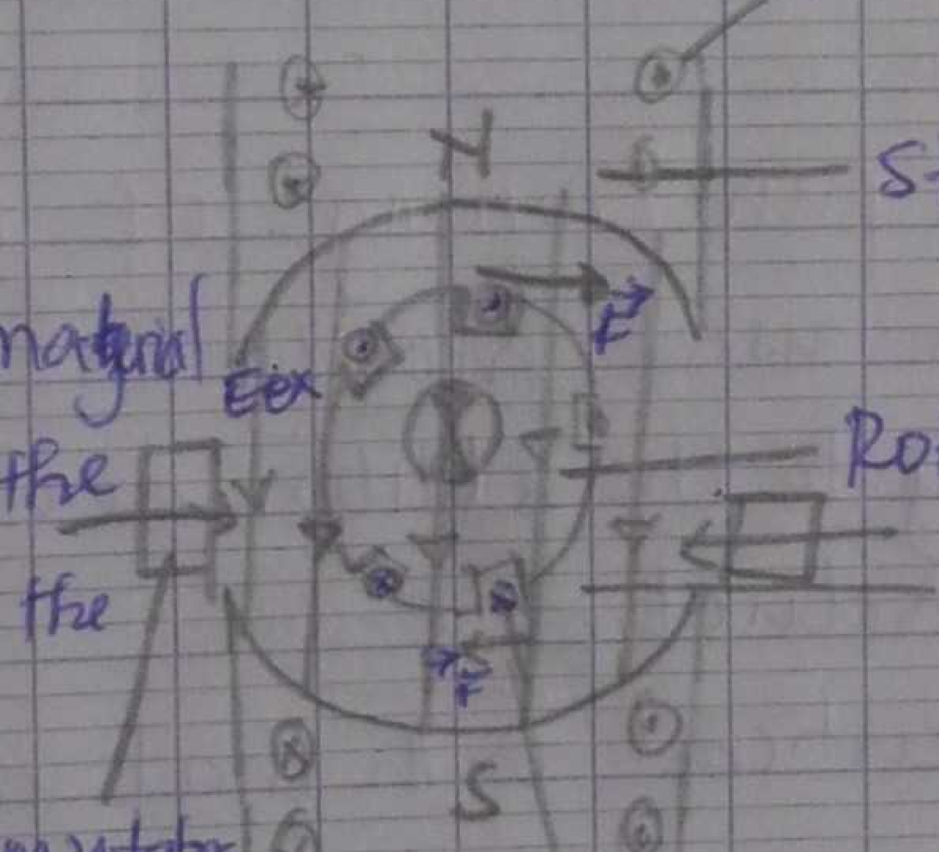
Principle of functioning of the DC machine :

A dc is a current flows in one direction. Its characters is Average value.

iron is good for conduct flux lines

copper is good for conducting current

* the rotor & stator are feromagnetic material
* by increase the stats increases the force.



to have flux lines we can use
- permanent magnets
- coil around the stator

current direct° must change in every conduction

* 2 source of excitat

* the excitat° field is the one of the stator. (Eex

Commutator (ensures that the inside current is ac and outside is dc. It is a mechanical rectifier or inverter)

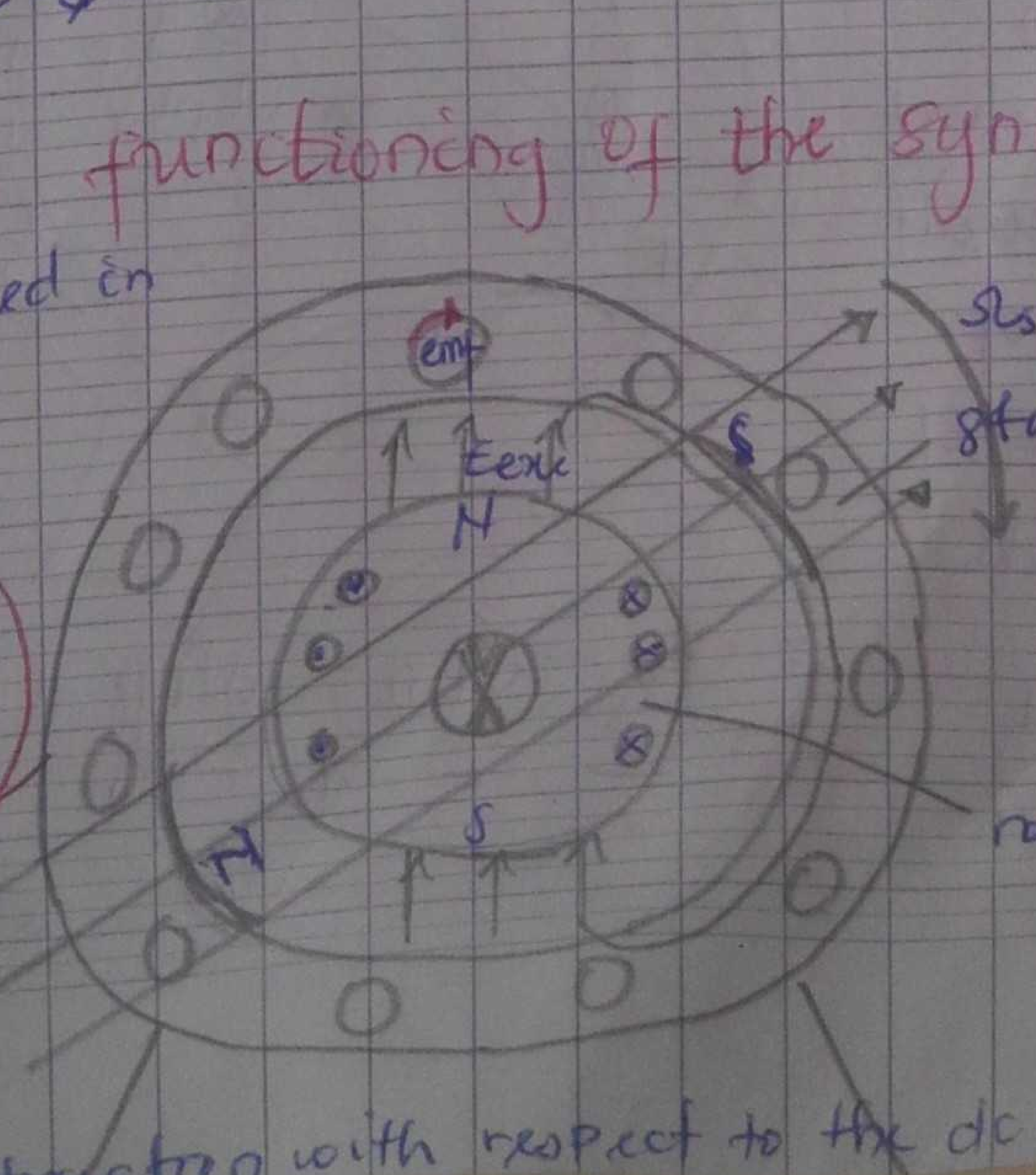
ac - dc   dc - ac

Principle of functioning of the synchronous machine

* stator & rotor are feromagnetic materia

* to get emf created in the rotor we use ;
- permanet magnet

* the 2 fields will interact



stator (to produce a revolving field on the air gap)

* the excitation field is the one of the rotor (Eex)

* 2 source of excitatio

* Generator mode $\overline{w}$ mechanical power

we turn the rotor and an emf will be induced in the rotor, The N will stick to S and it starts

...traction with respect to the dc machine.

The rotor on the synchronous mach has a winding that permits it to start called the amortisseur winding or Damper winding (- to start and stabilize during changes in load (generator m) - to start & damper the machine in motor mode)

* Motor mode: (There is vibrating of the rotor caused by the fast moving poles of the stator). The principle is the revolving field of the stator causes the rotor to follow this movement at synchronous speed, after the rotor has been pushed to move.

NB: This machine is used for power generator, the armature is the stator and it has the following reason;
- It is easier to tape the electricity (it is dangerous to have electricity and turn it.)
- There will be heating and it needs cooling (Therefore it is easier to cool the stator than rotor.

Principle of functioning of the Asynchronous Machine (induction machine)

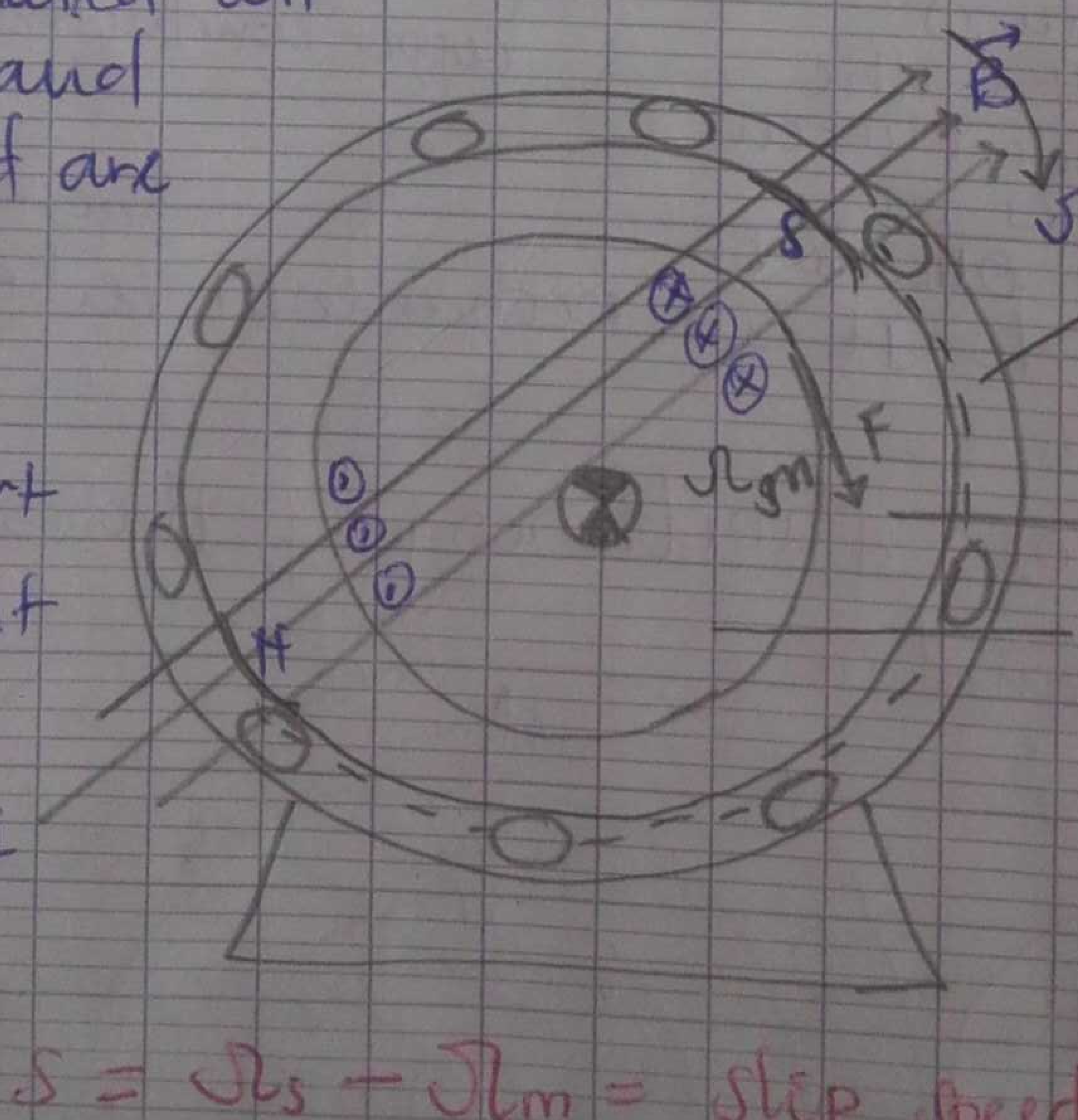
This machine is used mostly in motor mode. The current is supplied only to the stator and energy is supplied to the rotor by induction.

* stator is identical with that of the synchronous machine

* Force is created on the rotor and stator field and speed diff

* Lens law says a short circuit current at the drop will cause it to oppose its sorurse.

* Induced current causes the Force



$S = \Omega_s - \Omega_m$ = slip speed

$s = \frac{S}{\Omega_s} = \frac{\Omega_s - \Omega_m}{\Omega_s}$

Permit or "slip"
1) Start up; $s = 1$
2) At no-load: $s = 0$ (theoretically)

$\Omega m = \Omega s$ the rotor will be turn at its loaded load and delivering a little mechanical energy as used to overcome winding.

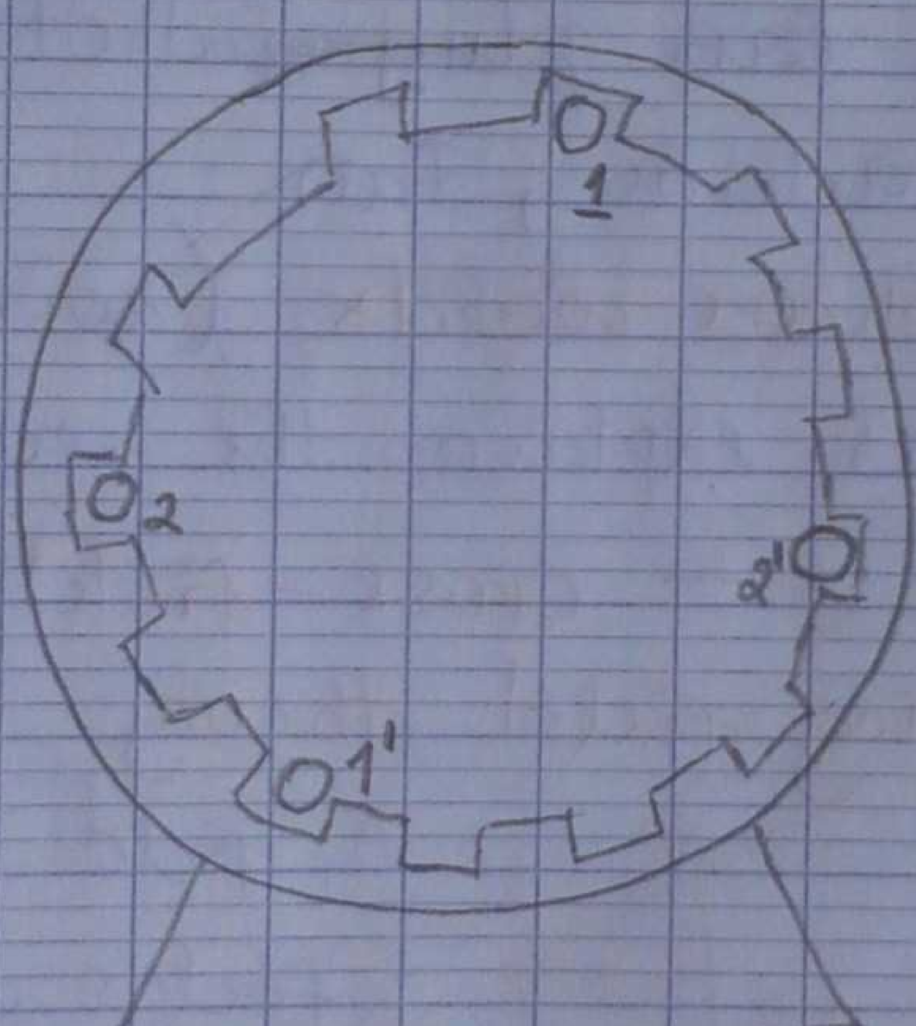
We allow current into the rotor from out only to control speed of the machine.

* Generator mode: We accelerate the rotor mechanically so that the $\Omega m > \Omega s$, causing a higher induce emf $\bar{n}$ high voltage in R causing the current to reverse direct^n and flow in the overline network.
* Motor mode: $\Omega s > \Omega m$.

The origin of the revolving field

We get the revolving field when we displace the flux

* If we cross the conductor like this and there is a dephasing of 90° a revolving field is created



* right hand current flow generate field.

* Mathematically (Revolving field of 2 orthogonal coils)

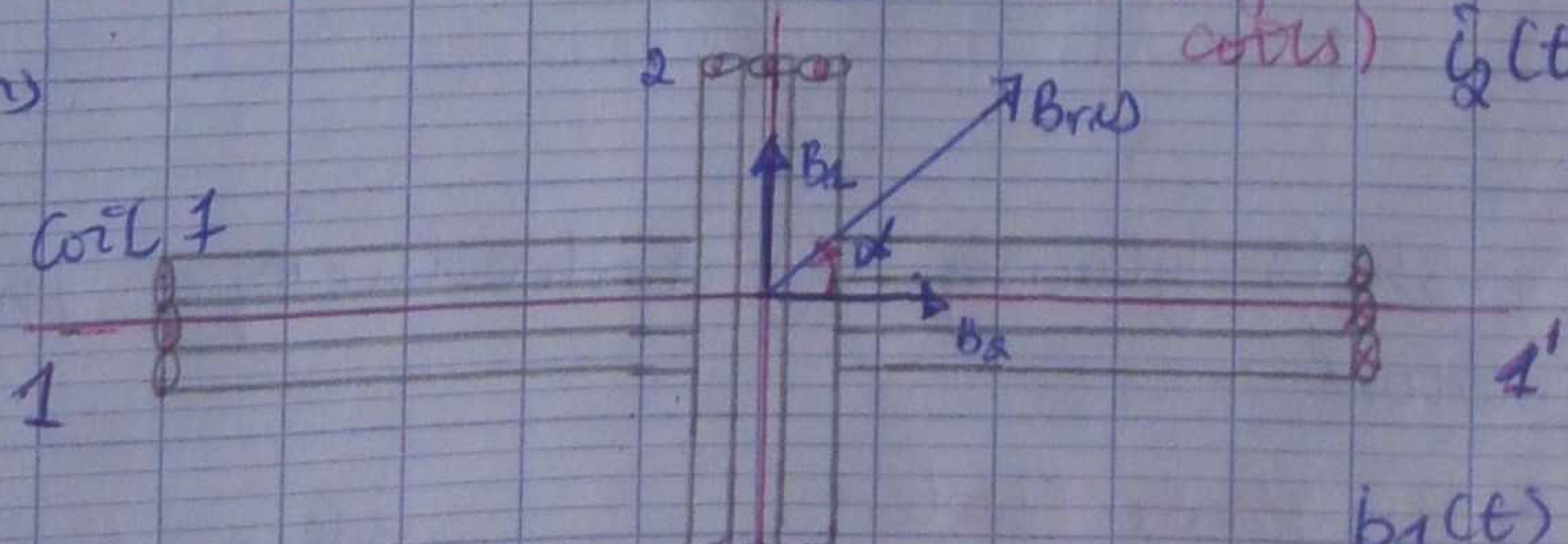
Coil II

$i_1(t) = \hat{I}_1 \sin \omega t$

$i_2(t) = \hat{I}_2 \sin(\omega t - \frac{\pi}{2})$
$= \hat{I}_2 \cos(\omega t)$

* Flux wave forms will be exactly the current wave forms

$\phi = I \times L$



$b_1(t) = \hat{B} \cdot \sin \omega t$

$b_2(t) = -\hat{B} \cdot \cos \omega t$

$b = \sqrt{b_1^2 + b_2^2}$
$= B_{res} \sqrt{\sin^2 \omega t + \cos^2 \omega t}$
$= \hat{B}$

$\tan \alpha = \frac{b_1}{b_2} = \frac{\hat{B} \sin \omega t}{-\hat{B} \cos \omega t} = -\tan \omega t = \tan(\pi - \omega t)$

Hence $\alpha = \pi - \omega t$

We will have to take out 1 phase $\bar{n}$ neutral from AEs panel

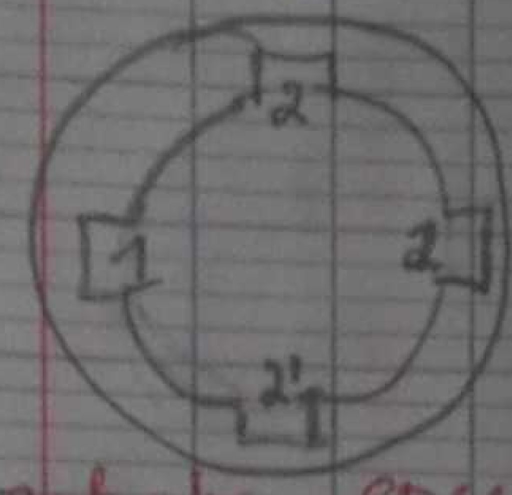
$\alpha = \pi - \frac{2\pi}{T} t$

Observat°

1) magnitude $\hat{B} = \frac{N^{o}_{coil} \hat{B}}{2}$
2) synchronous speed $\omega = 2\pi f$
3) It is a 2-pole machine

$t=0$	$\alpha = \pi$
$t = T/4$	$\alpha = \pi/2$
$t = T/2$	$\alpha = 0$
$t = 3T/4$	$\alpha = -\frac{\pi}{2}$
$t = T$	$\alpha = -\pi$

here the resulta field;
- has an ampli
- It is moving at the speed of $\omega = 2\pi f$



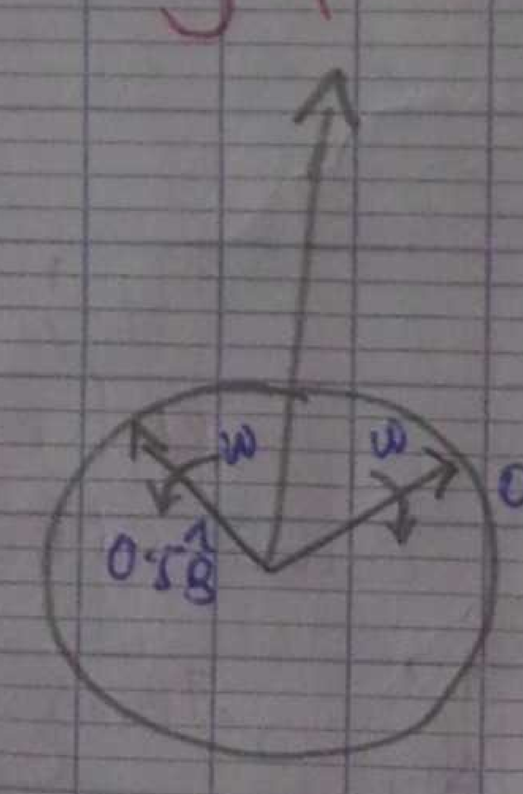
1 way of controle speed
- as N° pole pairs increase $\omega \downarrow$ (we cannot increase ω using pole pairs)
- $\uparrow$ in f will cause an $\uparrow \omega$

Single-Phase Motor

on 220V

It is one we can plug and it starts working
ex Sewing machine, Fan
It has the 2phase windx (winding placed orthogonally
This 2 theories explain the reason why this machine run like that. — Cross-field theory.
- Double revolving field theory

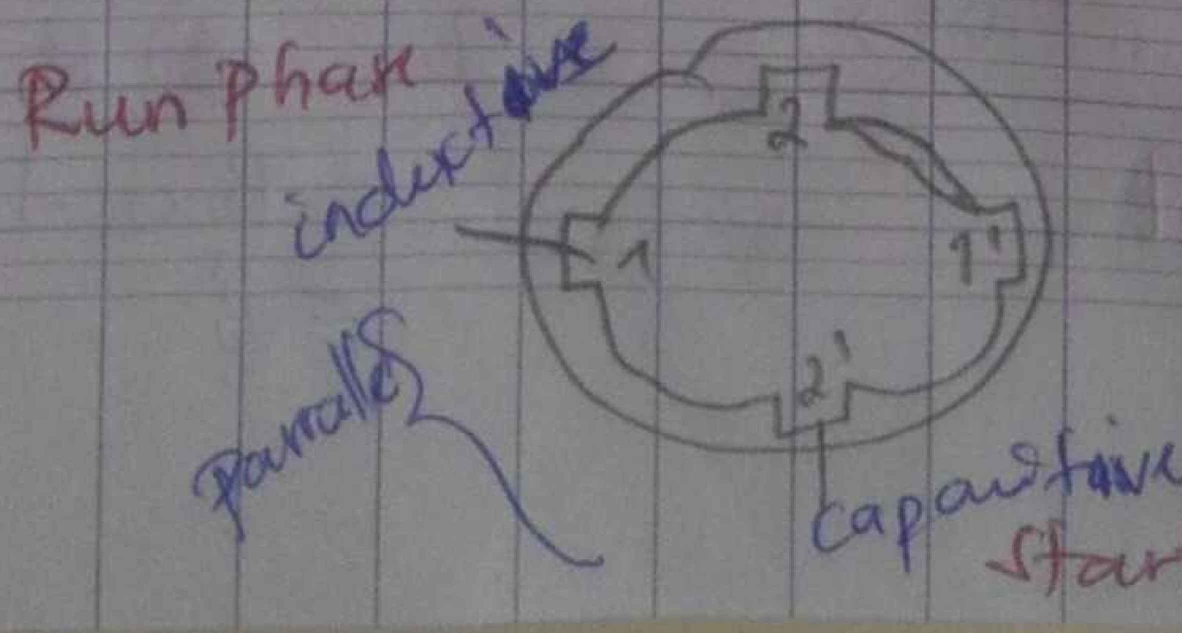
A field can be broken into 2 fields with rotating speed

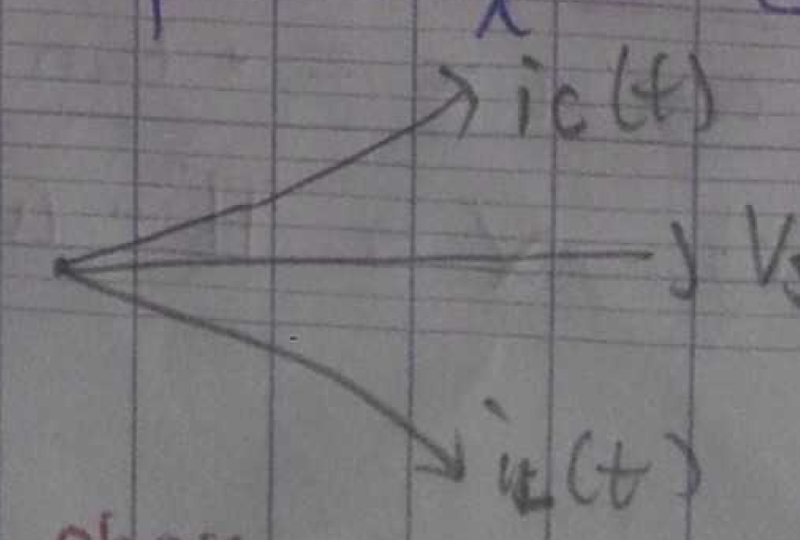


The push is giving by introducing a phase shift into the motor.

1 Split phase motor

We can use inductors n capacitors to shift the field (coils in parallel)





the windings are connected in parallel

How to make coils inductive or capacitive

- Inductive : Thick wire, few turns $\Rightarrow R\downarrow, X_L\downarrow$ (reactance)

For the simplest type of motor we can use thin wire several turns $\Rightarrow R\uparrow, X_L\uparrow (Z\uparrow)$. but to perfect we bring in capacitive coil.

2. Start phase.

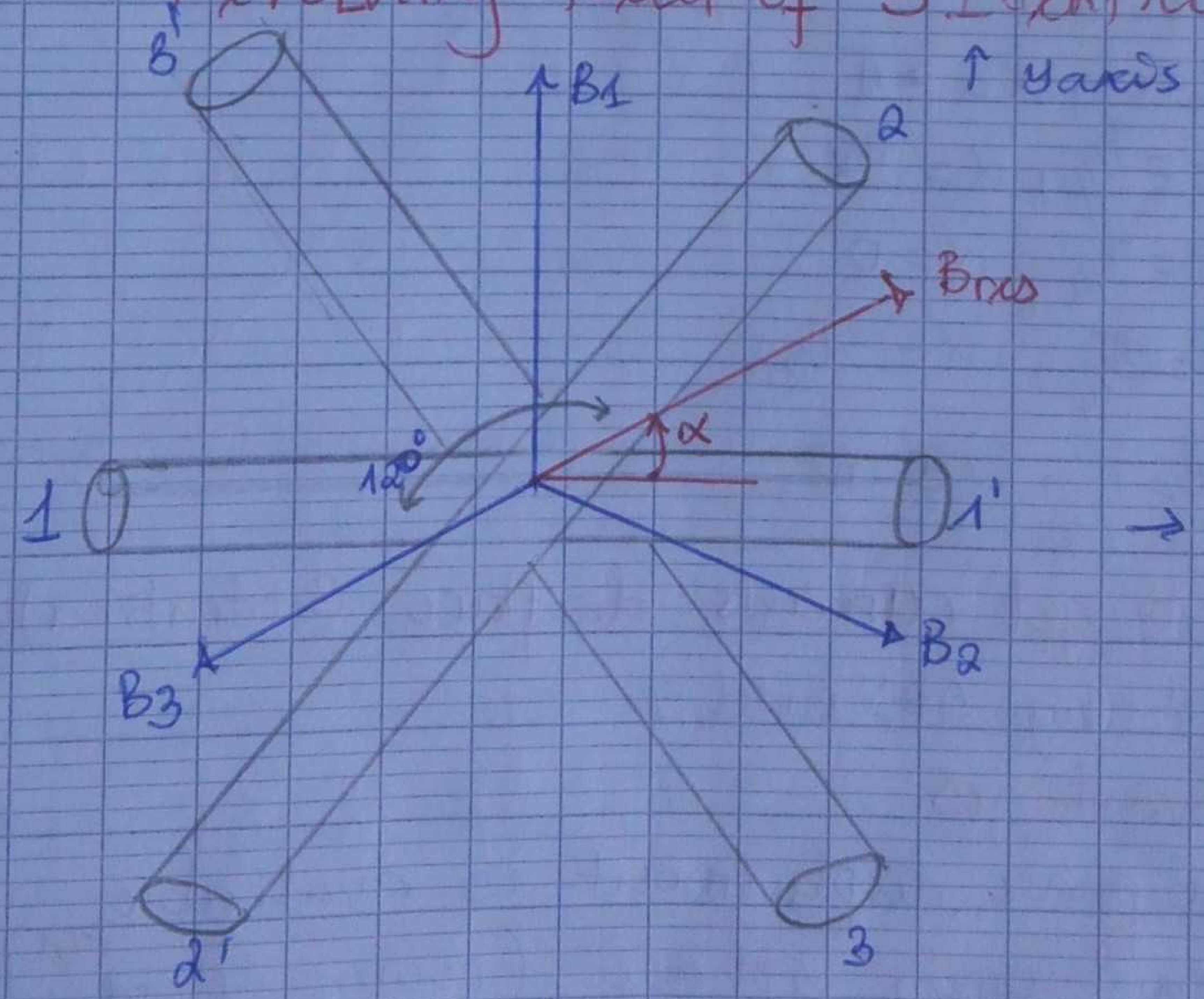
Using a switch to cause a jump effect and it gets disconnected and allows the Run phase to continue

ex Capacitor start motor

3 For capacitor run motor it is the opposite, the start phase is on the inductive coil.

4 For permanent split capacitor ~~run~~ Motor (PSC) It remains perment (no switch to desactivate it) It is use for higher torq since both inductive and capacitive coils run.

2 Revolving field of 3 Identical coils



- the coils are placed 120° to each other ~~n~~ excited with a sinusoidal

- flux is also 120° phase with each o

$b_1(t) = \hat{B}\sin\omega t$

$b_2(t) = \hat{B}\cdot\sin(\omega t - 2\pi/3)$

$b_3(t) = \hat{B}\cdot\sin(\omega t - 4\pi/3)$

fractional horse power range
$> 0 \cdots 1hp$
$> 1hp \cdots 10hp$

Resolving along the x-axes

$b_{1x}(t) = 0$

$b_{2x}(t) = \hat{B} \sin(\omega t - \frac{2\pi}{3}) \cdot \cos \pi/6$

$b_{3x}(t) = \hat{B} \cdot \sin(\omega t - \frac{4\pi}{3}) \cdot \cos \pi/6$

Resolving along the Y-axes

$b_{1y}(t) = \hat{B} \cdot \sin\omega t$

$b_{2y}(t) = -\hat{B} \sin(\omega t - \frac{2\pi}{3}) \sin \pi/6$

$b_{3y}(t) = -\hat{B} \sin(\omega t - \frac{4\pi}{3}) \sin \pi/6$

sum ~~the~~ components along x-axis & along y-axis

$b_x(t) = -\frac{3}{2} \hat{B} \cos\omega t$

$b_y(t) = 3/2 \hat{B} \sin\omega t$

Magnitude of $B_r = \sqrt{b_x^2 + b_y^2} = \underline{3/2 \hat{B}}$

$\tan\alpha = \frac{b_y(t)}{b_x(t)} = \frac{\sin\omega t}{-\cos\omega t} = -\tan\omega t$

$= \underline{\tan(\pi - \omega t)}$

At $t = 0$, $\alpha = \pi$
$t = T/4$, $\alpha = \pi/2$
$t = T/2$, $\alpha = 0$
$t = 3T/4$, $\alpha = -\pi/2$
$t = T$, $\alpha = -\pi$

Where to get currents displace 3 identical coils ? the currents supplied by AES sonel -

Advantages

- Its 3 phase displacement is available
- AES sonel offers 3 phase (power delivered is constant) $P_{tot} = 3 V_a I_a \cos\theta$
- Runs smoothly with no vibration (instead of vibrate like 1 phase machines)

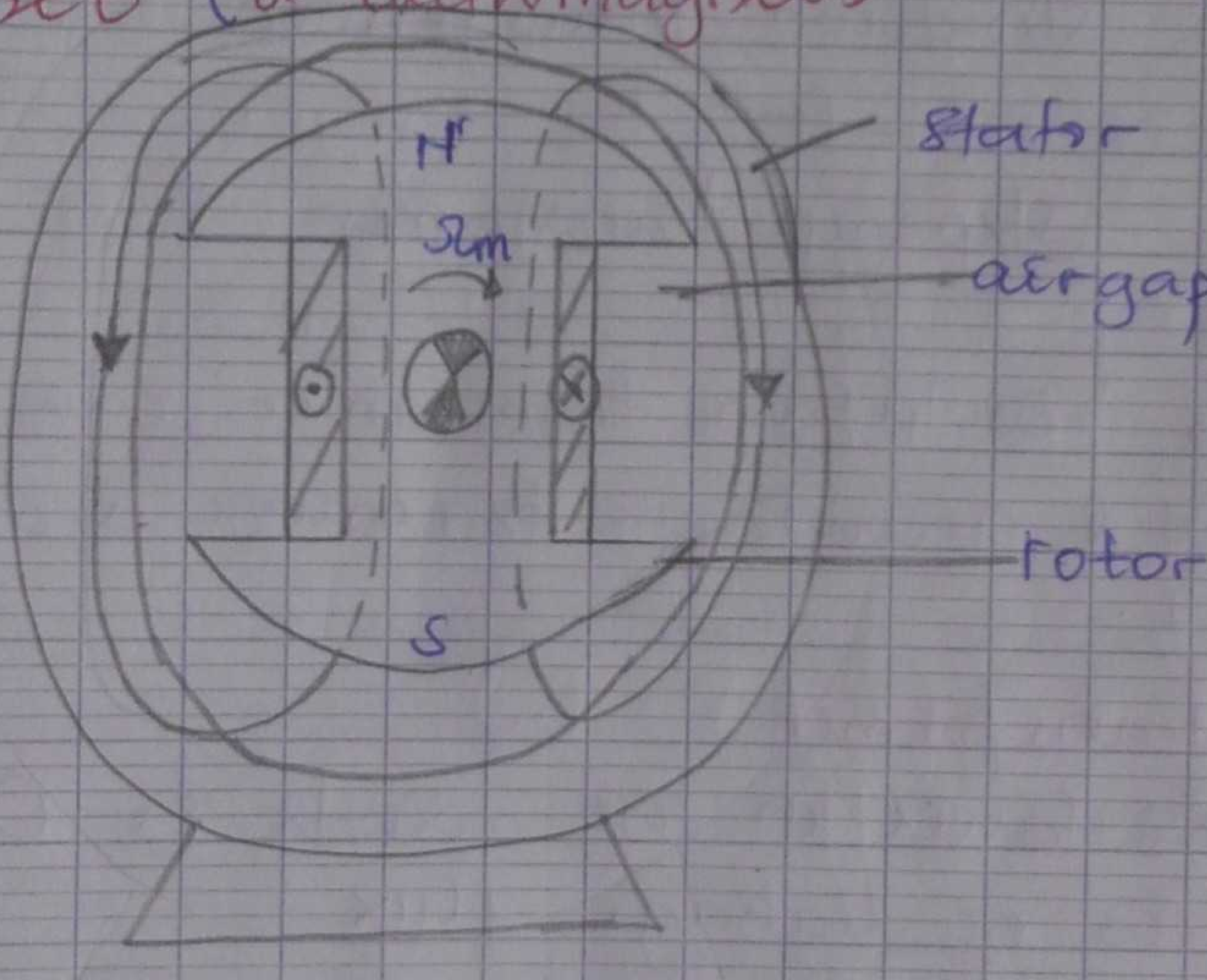
C.C thursday next week

observat^n
1) magnitude $\frac{3B}{2}$
2) speed $\omega = 2\pi f$
3) 3phase machine

Home work

How does the speed of the revolving field vary with a change in: - Supply current frequency?
- Number of machine poles?

3) Revolving field of a Rotating Permanent Magnet (or Electromagnet)

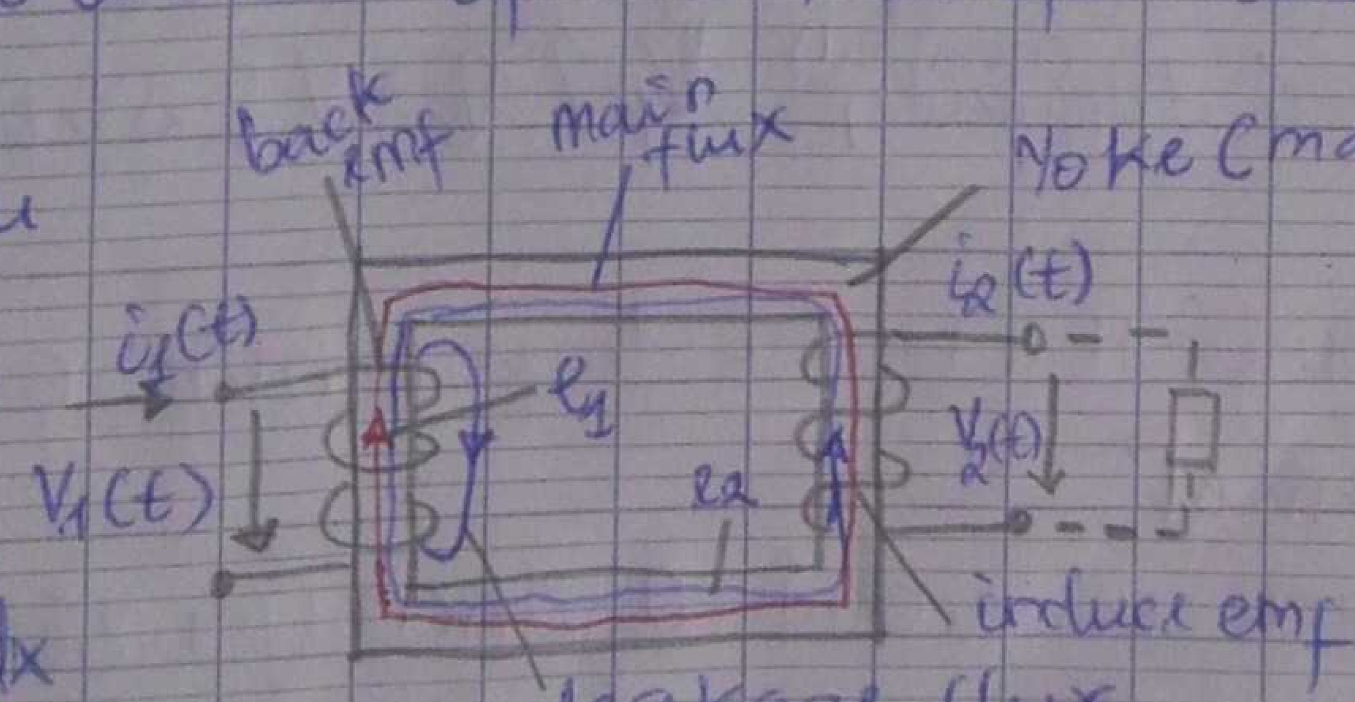


* If ω_m in both direct^n

TRANSFORMER

To adjust voltage and to step up or step down voltage. The efficiency of a transformer is high. The two winding of the transfor has to take the same Power

* Some flux line will still flow thru air and it is called Leakage flux



* When a second winding is placed on the coil and current flows thru it it causes an induced emf.

* An emf will be induced in the winding by Lens law opposes $V_1(t)$ thereby limiting $I_1(t)$ called back emf ($e(t)$)

$$\left.\begin{aligned} P_{out} &= V_2(t)\, i_2(t) \\ P_{in} &= V_1(t)\, i_1(t) \end{aligned}\right\}$$

For ideal transformer (no losses) $P_{out} = P_{in}$ ($V_1 = e_1$, $V_2 = e_2$)

As soon as a load is connected to the transformer another flux is created in opposition to $i_2(t)$ causing the e_1 to decrease and increase the i_1. The flux remains constant in the magnetic cores.

$$N_1 I_1 = N_2 I_2$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{V_1}{V_2} = a \rightarrow a \text{ transformation ratio.}$$

* $a > 1$

$V_1 > V_2$ Step-down transformer

* $a < 1$

$V_2 > V_1$ Step-up transformer

* $a = 1$

$V_1 = V_2$ isolation transformer can be used to separate 2 circuit and to remove a dc component in a circuit.

Ideal transformer

- The resistance in the windx is 0
- There is no leakage flux
- $i_1(t)$ is 0 (magnetisation current)
- No heatx of the Yoke (iron core)

Cooling a transformer

- Use a fan
- Placed in a tank of oil

Name Plate: $P_{apparent}$ (nominal), V_p / V_s - V, Step-down

$a = \frac{V_p}{V_s}$

Pnom: It is the Power that the transformer can carry continuously.

Autotransformer

The windxs of the are connected together for either + of V or - of V. There is gain of Power but increase in problems of fan.

Courses 2

field

store

The Role of the Magnetic Field in E/M energy

A field is a space with a characteristic; every pt in the space is attributed a physical quantity.

In magnetic field the 2 quantities attributed $\vec{H}$ (mag field intensity) A/m, $\vec{B}$ (mag flux density) Wb/m²

In an electric field; $\vec{E}$ (electric field intensity) V/m, $\vec{D}$ (electric flux density) C/m²

four of both fields

a stationary charge has electric field round it

* Stores energy
* We can put and take out electrical (transformer)

in a mag field put n take out mechanical (Motor)

put mechanical n take out electrical (Generator)

How to get magnetic field

- permenant magnet.
- send a current thru a conductor (movement of charge)
- change in magnetic field is brought by acceleratn of charge.

1 Stationary charge ⇒ electric field

2 moving at constant speed ⇒ magnetic field

3 movement with acceleration ⇒ electromagnetic field ⇒ wave

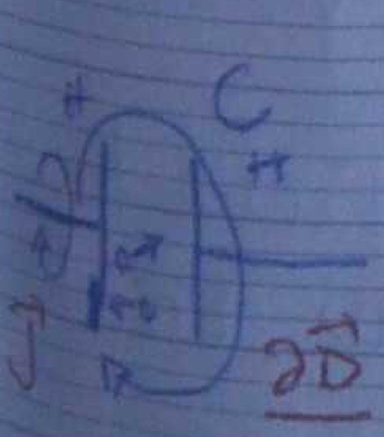
Around the inductance is the mag field, and the capasitor is elect field.

In every circuit there is oscilation of energy in mag n elec field we give phase shift.

Interaction of Electric n magnetic field.

Fundamental laws of electromagnetism (MAXWELL)

1) $\text{Curl}\,\vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$ $\quad\vec{J}$ is the volume current density (A/m²)



$$\oint_c \vec{H}\cdot d\vec{l} = \int_s \vec{J}\cdot d\vec{s} + \int_s \frac{\partial \vec{D}}{\partial t}\, d\vec{s}$$

displacement current (becuz charges r displaced)

(Generalised form of Amper circuital law)

every move or time vary electrical field is surrounded by a magnetic field.

2) $\text{Curl}\,\vec{E} = -\frac{\partial \vec{B}}{\partial t}$ surrounded by a time varying or movx mag field creats an electric field.

↓ the sum of both motional & transformer emf

3) $\text{div}\,\vec{B} = 0$ where the flux lines come from is not known (thereby flux lines are continuous)

4) $\text{div}\,\vec{E} = \rho$ electric flux density comes from the volume charge. (C/m^2) (but has no end) except...

5) Law of conservation of charge.

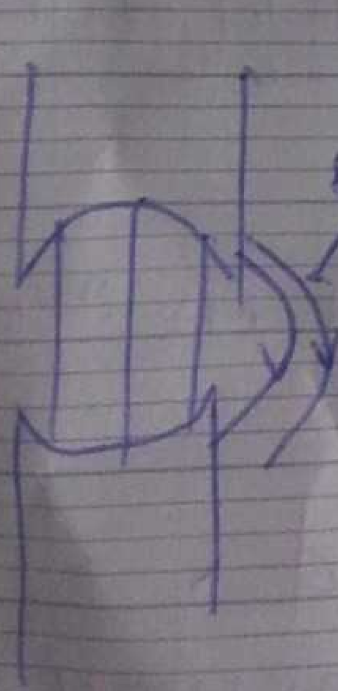
$\text{div}\,\vec{j} = \frac{\partial \rho}{\partial t}$ charge on the electrode of a condenser can only be build up gradually because it depends on the current density

6) Lorentz force equation.

$$\vec{F} = q(\vec{E} + \vec{V} \times \vec{B})$$

7) $\vec{B} = \mu_r \mu_0 \vec{H}$

8) $\vec{D} = \varepsilon_r \varepsilon_0 \vec{E}$



* FARADAY'S LAW OF ELECTROMAGNETIC INDUC...

The sum of the "motional emf" & "transformer emf" is equal to the rate of change of the total flux $-N\frac{d\phi}{dt}$

* the -ve sign is a reflection of lens law it says

* By neglecting "LEAKAGE" & "FRINGING" fluxes

Expl

A coil with 1000 turns is placed in a mag field that varies uniformly from 100 mWb to 2000 mWb in ... Determine the induced emf in the coil.

$e_t = -\int_S \frac{\partial \vec{B}}{\partial t} \vec{ds}$ Transformer

$e_m = \oint (\vec{v} \times \vec{B}) \cdot dl$ motional

$e = N \times \left(\frac{\phi_1 - \phi_2}{T}\right) = 1000 \times \frac{80 \times 10^{-3}}{5} = 16V$

Principle of funx of the Dc machine

The apmature of the dc machine is the rotor. The rotor and stator are the main parts of the dc machine. A dc machine makes use of the generator action and the motor action.

- motor action; a dc current is sent into the stator which is surounded by a coil or permanet magnet (to produce the flux of the excitation field.) a dc current is sent into the rotor to produce a turning force.
- generator action; the presence of the flux produces a field. The turning force and the field produce a current in the rotor.

The rotor and stator are feromagnetic to increase conduction of flux lines. The rotor has shafts, inbetween them are conductors of copper. There is the presence of a commutator which is a mechanical rectifier (exterior dc - rotor ac) and inverter (rotor ac - output dc).

Principle of fxn of the synchronous machine

The armature of the synchronous mach is the stator. There are conductors present on the stator, and coils on the rotor.

- Generator mode: the rotor is turned mechanically and an emf is induced in the ~~rotor~~ ~~by~~ The turning causes the H_R to stick to the S_S. Causing the rotor to turn at the speed of the rotating field of the stator ots.

- Motor mode: a current is sent onto the coils of the rotor, which cause it to turn. Causing the rotor to turn at the speed of the rotatx field of the stator due to the magnetic reaction of the H_R and the S_S.

These effects cause an emf to be formed in the conductors on the stator.

Advantages in power generation (massive current)

- Unlike the dc machine it has no danger of current being produced and rotated or moving at the same time.
- Can be easily cool in case of heating. (cause it is the stator that bears most heat)
- It is easy to tape out ~~electricity~~ current.