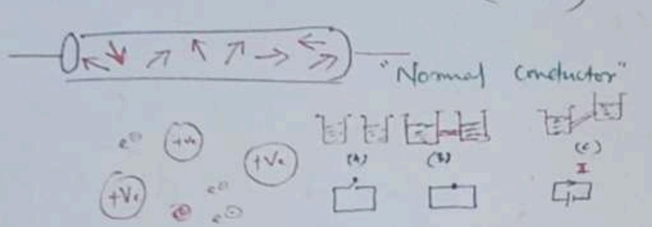
Basic Electrical Engg

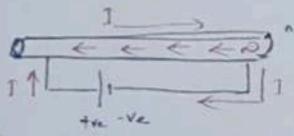
* Current (start with Atomic structure)

The rate at which e⊖ flows through ~~a conductor~~ crossection of a conductor/wire. is called current.

Symbol :- I, i

Unit :- Andre "Ampere". (French)





Conventional 'I' is opposite to e⊖ flow direction because :- it was assumed prior to "Electron theory" Franklin Assumed

EIE

* Source

An electric source is that which can supply electric power to any load.

ex- Voltage Source, Current Source.

* Load

Anything in electric circuit which consume power is Know as Load.

ex- Resistor, inductance, Cap..

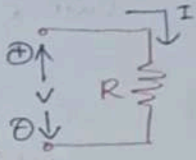
* Ohm's Law [George Simon Ohm]

The current flowing through a conductor is directly proportional to the potential difference maintained across its both ends, provided ~~the~~ temperature & other physical condition constant.

$$I \propto V$$

$$\Rightarrow IR = V$$

$$\Rightarrow \boxed{I = \frac{V}{R}}$$



← Easy to remember.

* Electric potential (After Current)

Work (Energy) done to carry a unit charge from one point to other point ~~the~~ against an electric field.

$$V = \frac{\text{Work Done}}{Q \rightarrow \text{charge}}$$

* Potential difference

The difference in potential between two point of a circuit.

~~Imp~~ Unit - Volt (Allesandro Volta) (Italian) ← Battery inventor

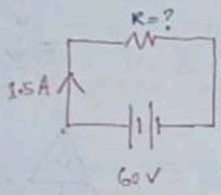
* Resistance

It is the property of ~~a~~ substance which opposes the flow of electric current through it.

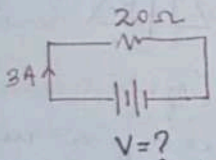
Symbol :- —⩘⩘—

Unit :- Ω (Ohm)
(George Simon Ohm) → German

Ⓠ



②



V=?

*** Resistance depends upon –**

① $R \alpha l$

② $R \alpha \frac{1}{a}$

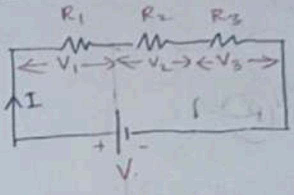
③ R α nature of materials

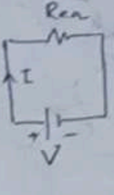
④ R depends upon temperature.

$$R \alpha \frac{l}{a} \Rightarrow R = \rho \frac{l}{a}$$

Resistivity <

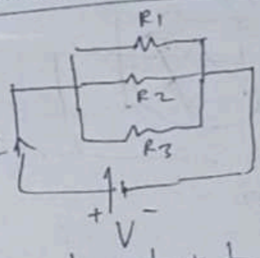
"R" connected in series

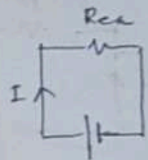




$$R_{eq} = R_1 + R_2 + R_3 + \dots$$

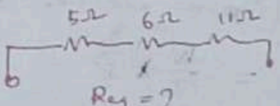
"R" connected in ||el



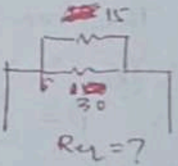


$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

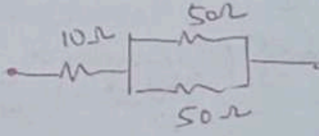
Ex



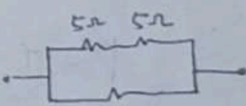
$R_{eq} = ?$



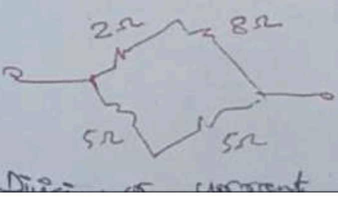
$R_{eq} = ?$



$R_{eq} = ?$

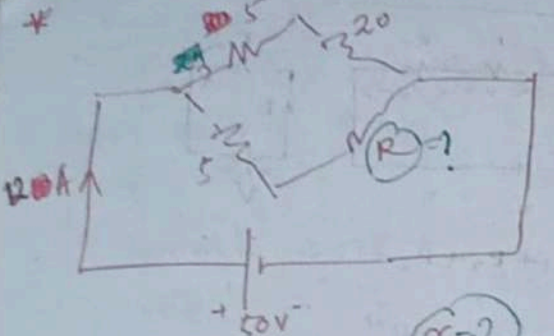


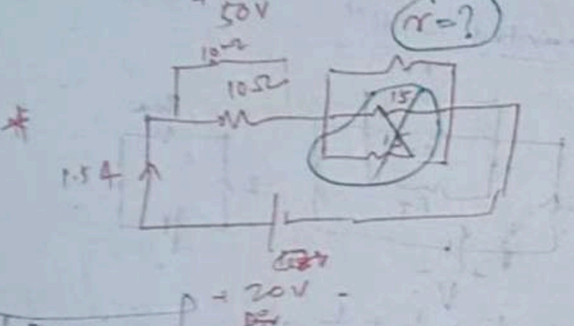
$R_{eq} = ?$



$R_{eq} = ?$

* Division of current & voltage in parallel





* POWER

The rate of at which energy is consumed in a electric ckt

$$P = \frac{Energy}{Time} = \frac{W}{Q} * \frac{Q}{t}$$

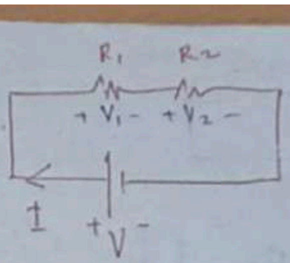
$\frac{W}{Q} \to V$

$$P = VI$$

unit : Watt (James watt - Steam engine) Improve (Mechanical engineer) to make Industrial sector

$$P = I \cdot IR = I^2R$$

$$P = V^2/R$$

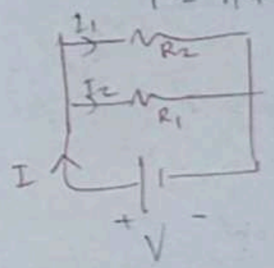


P = Power delivered/Supply by cell = VI ✓

P_1 = Power consumed by $R_1 = IV_1 = I^2R_1$ ✓

P_2 = —"— $R_2 = IV_2 = I^2R_2$

$$P = P_1 + P_2$$



$$P = VI$$

$$P_1 = I_1V = V^2/R_1$$

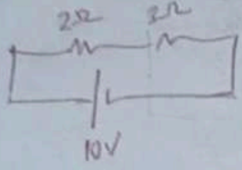
$$P_2 = I_2V = V^2/R_2$$

$$P = P_1 + P_2$$

$$\boxed{\sum P_{supply} = \sum P_{consumed}}$$

Kirchoff's current law & KVL

Eg



Find $P_{2\Omega}$ ~~&~~ $P_{3\Omega}$ & P_{10V}

$I = \frac{10}{2+3} = 2A$

$P_{2\Omega} = I^2 R_{2\Omega}$

$\Rightarrow P_{2\Omega} = 2^2 \cdot 2$

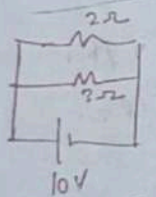
$\Rightarrow P_{2\Omega} = 8W$

$P_{3\Omega} = I^2 R_{3\Omega} = 2^2 \cdot 3$

$\Rightarrow P_{3\Omega} = 12W$

$P_{10V} = 12 + 8 = 20W$

Eg



$P_{2\Omega} = I_{2\Omega}^2 R_{2\Omega} = \frac{V^2}{R_{2\Omega}} = \frac{10^2}{2} = 50W$

$P_{3\Omega} = \frac{V^2}{R_{3\Omega}} = \frac{10^2}{3} = 33.33W$

$P_{10V} = 50 + 33.33 = 83.33W$

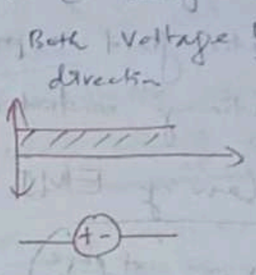
That's why load are connected in Parallel.

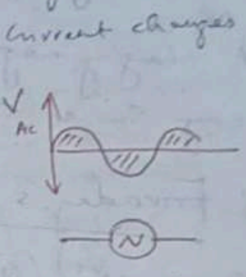
AC Theory

DC → Current flow in one directⁿ

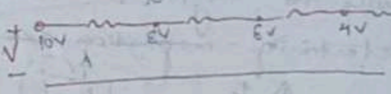
AC → $e^{\ominus}$ ~~electron~~ flow changes periodically

Both Voltage & current changes direction





→ For transmitting over long distance DC was loosing power. So, voltage drop along the length.



("Thomas" Edison)

→ AC could easily "step up" or step down ~~So, with less~~ using Transformers (Nicola Tesla)

Farraday's law of electromagnetic induction

"War of Currents".

→ Compass (1200)
→ Earth magnetism - 1600 (William Gilbert)
→ Volta (1800) Cu-Zn & NaCl
→ Oersted (1820) $\vec{I}$-$\vec{B}$
→ Electro-magnet (1824)
→ Ohm's law (1827)
→ Farraday's law of EMI (1831)
→ Lenz's law (1934)

E8

Generation of Alternating EMF

When a conductor is rotated in magnetic field; emf is generated.
OR
A changing magnetic field ~~we~~ ~~prod~~ ~~induc~~ generates emf in a stationary conductor.

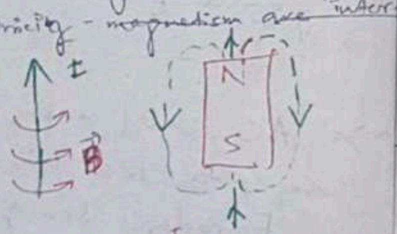
Faraday's Law of EMI

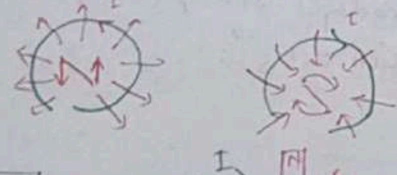
HC Oersted (A) (Start from next page) $\vec{I} \rightarrow \vec{B}$

In 1820; electric current in a wire from a battery caused a nearby compass needle to deflect.

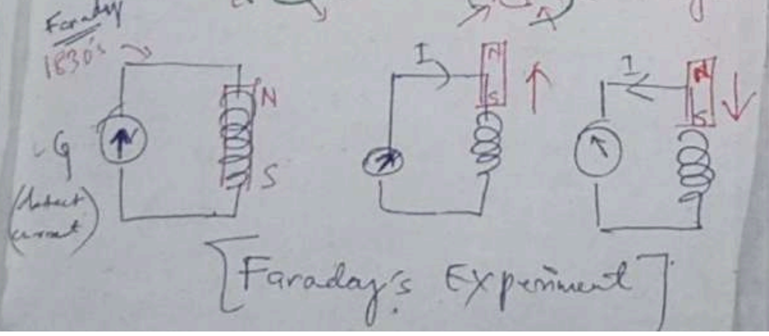
∴ ~~So, electricity - magnetism are~~ inter~~related~~.

So; electric current create magnetic field.





→ Electro magnet



[Faraday's Experiment]

→ Changing magnetic field ~~produced~~ induces emf in a circuit $\left(B = \frac{\Phi}{A}\right)$ wb, Amer

$$\text{emf} \propto \frac{d\Phi}{dt}$$ (rate of change of flux magnetic)

Application
→ Generator, transformer, motor

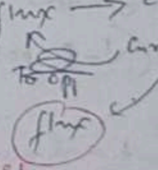
Two way ~~of~~ $\frac{d\Phi}{dt}$ can be done

① Motion of conductor & constant flux. (dynamically induced emf)

② Change in current → leads to change In ft magnetic flux linked with stationary coil (statically induced emf ∵ we can't see magnetic flux.

→ The direction of induced emf is found by LENZ's LAW.

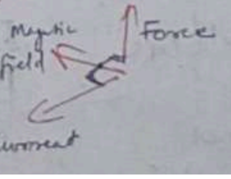
Voltage → current → flux → EMF induced e)



Current Induced = $\frac{d\Phi}{dt}$

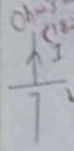
opposes

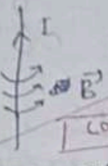
Fleming's right hand rule



Oersted → link betn $\vec{B}$ & $\vec{I}$

Right hand Thumb Rule



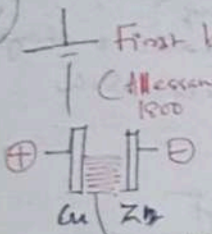


Closed paired. field line
↳ More power / attraction

COMPASS

200 BC – China (Magnetic material discovered) MgN Fe
1200 AD – Europe made compass used for navigation
1300 AD – World map designed using compass
→ Trade & slavery started later on.

② First battery (Allessandro Volta) 1800

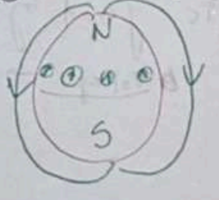


③

Galvanometer (1820)
Andre Marrie Ampere

Father of Magnetism – William Gilbert (English)

① 1600 – De Magnete
Earth Magnetism
(N-S pole)

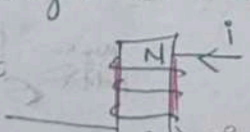


* Electromagnet (1824)

William Sturrgen (British)

Iron, steel, nickel, cobalt. } CORE

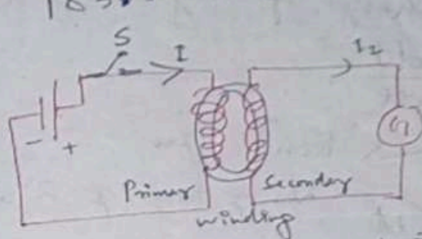
→ Large size magnet



Wire is wound around a magnetic material.

Faraday law of Electromagnetic induction

1831's Michael Faraday



To see, ~~the effect~~ if we can generate ~~magnetic~~ electric ~~field~~ current/emf from magnetic field. $\vec{B} \to \vec{I}$
(Opposite of Oersted)

→ He saw transient current in (G) when he switch ON & OFF the supply.

→ But during the supply; no deflection in (G) was observed.

∴ Change in magnetic flux (field line) $\phi = \frac{B}{A}$ induces an emf in 2° coil. Next page → $e = \frac{d\phi}{dt}$

→ Emil Lenz (1934) gave Lenz's law which ~~descr~~ gives the direction of induced emf & current resulting from electromagnetic induction.

→ induced emf → induced current → flux (2°) opposes the change in ~~1 ... field~~ magnetic flux (1° flux)

Law of EMI

The emf induced ~~is~~ in a loop of wire is given by the "rate of change of magnetic flux".

$$E = \ominus \frac{d\phi}{dt}$$

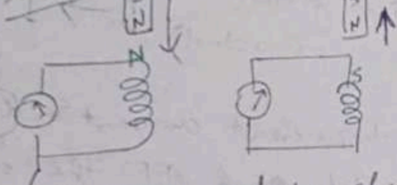
→ Lenz's law.

$$E_1 = \ominus N \frac{d\phi}{dt}$$

→ Nos of turns of 2° coil.

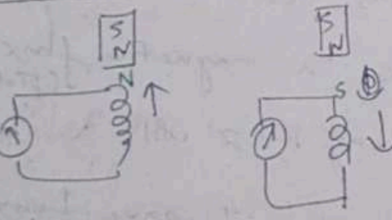
Ⅱ Statically induced emf

"Teach after Lenz's law"



(Stationary conductor - change in $\vec{B}$)

① Dynamically Induced emf

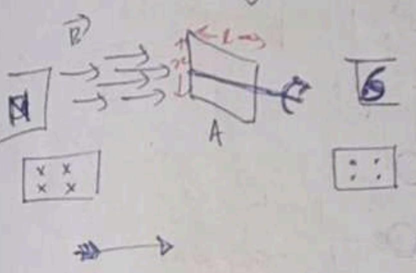


Magnetic flux (Φ)

Unit - Weber

Nos of magnetic field line ~~[illegible]~~ ~~per~~ passing through a unit Area.

→ strength of magnetic field



~~$\Phi = \frac{\vec{B}}{A}$~~

→ Area of loop

$$\phi = \vec{B}\cdot\vec{A}$$

$$\Rightarrow \phi = \vec{B}\cdot L x$$

→ length → breadth

But, $\mathcal{E} = -\frac{d\phi}{dt} = -BL\frac{dx}{dt} = \underline{\vec{B}\,l\,\vec{v}}$

l → length of conductor/loop

v → velocity of conductor

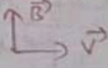
$\vec{B}$ → magnetic field intensity.

When a conductor is moved in a magnetic field it induces an emf.

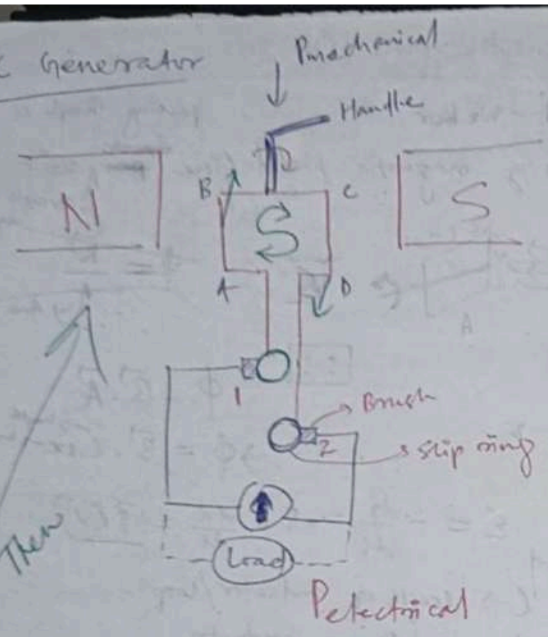
$$\mathcal{E} = \vec{B}\,l\cdot\vec{v}$$

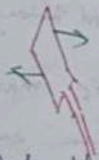
(dynamically induced emf)

if $\vec{B}\cdot\vec{v}$ has $\underline{90^\circ}$



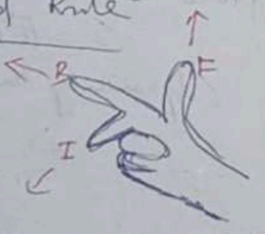
AC Generator





Start with

Flemings Right Hand Rule (Lenz's + EMI)

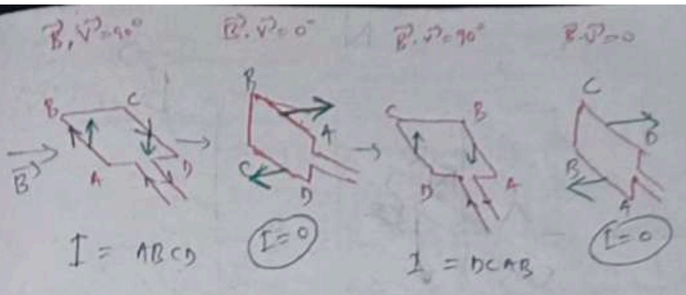


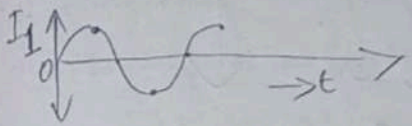
Thumb:
point to the direction of Force

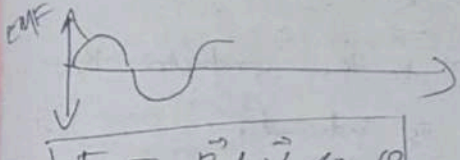
Index finger:
point ~~a~~ in the direction of magnetic ~~[illegible]~~ field.

Middle finger:
point the direction of flow of current

They are $\perp^{r}$ to each other

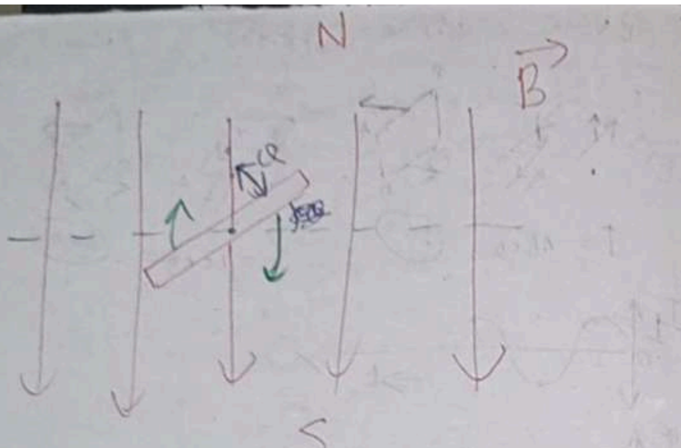






$$\boxed{E = \vec{B} l \vec{V} \sin \theta}$$

$$\boxed{E = E_{max} \sin \theta}$$

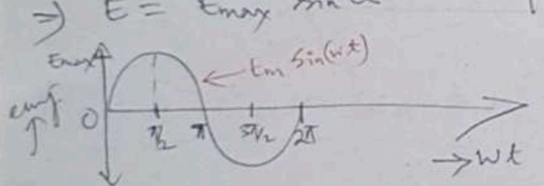


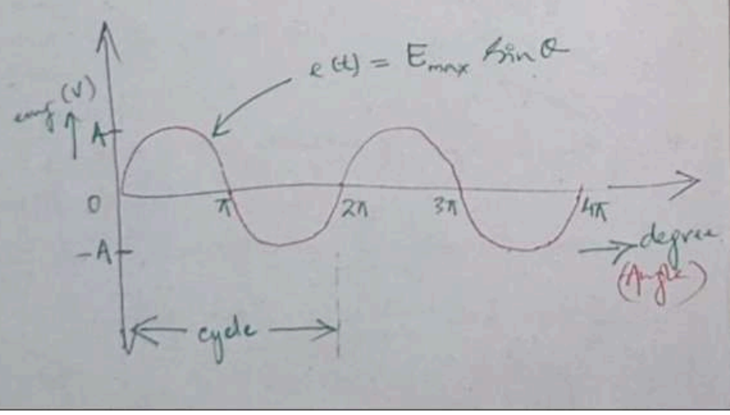
if $\vec{B}$ is ⊥r to the conductor then maximum emf is induced.

$$E = \underbrace{BLV}\sin\theta .$$

$$\Rightarrow E = E_{max}\sin\theta$$

$\theta = \omega t$
↓
Angular speed.

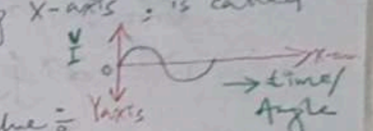




Terminology

① **Waveform:-**

The shape of curve of the voltage or current along Y-axis when plotted against time/angle along X-axis : is called waveform.



② **Instantaneous value :**

The voltage/current at any instant

e (t), i(t) ← representation.

③ **Amplitude**

The 'maximum' value of the positive or negative half of ac wave.

④ **cycle**

A sine wave represent one cycle.

A combination of positive half & negative half cycle.

A cycle spread over 360° or 2π radian

⑤ **Time period (T)**

Time taken by an AC voltage/current to complete one cycle is ...

Unit : Second

$$\boxed{T = \frac{1}{f}}$$

⑥ **Frequency**

The nos of cycles passed through in one second.

Unit - Hz (Hertz)

$$\boxed{f = \frac{1}{T}}$$

⑦ Angular velocity :-

It is the angular distance covered per second.

represented by :- ω (Omega)

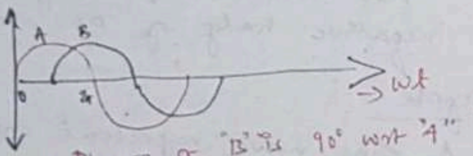
Unit :- rad/sec

$\omega = 2\pi f \xrightarrow{} \text{frequency}$

$\cdot\ \omega = \frac{\theta}{\text{time}}$

⑧ Phasor Angle ~~diagram~~ ~~difference~~

It is the angular displacement of the phasor from a reference value.

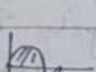


Phase of "B" is 90° wrt "A"

⑨ Phase difference

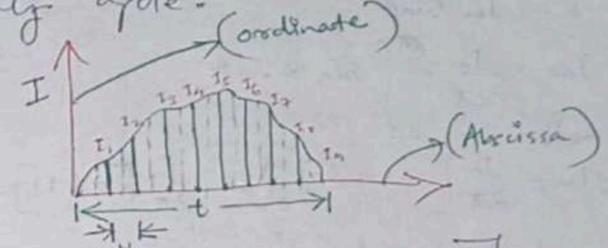
The difference betⁿ the phases of two alternating quantity.

90° phase difference betⁿ "A" - "B".

AC	DC
① "I" change its magnitude & directⁿ 	① "I" does't change magnitude & direction 
② e⁻ flow is bidirectional	② e⁻ flow in one directⁿ
③ $f = 50 Hz$, India	③ $f = 0 Hz$
④ $Pf = 0-1$	④ $Pf = 1$
⑤ $Z = jX + R$	⑤ $Z = R$
⑥ AC generated by AC gen	⑥ DC generator
⑦ Represented by sine, triangle, square	⑦ Represented by stright li
	⑧.

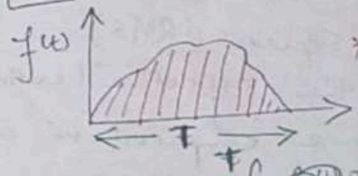
* Average Value

It is the arithmatic mean of the ordinates at equal interval over a half cycle.



$$\boxed{I_{av} = \frac{i_1 + i_2 + \cdots + i_m}{m}}$$

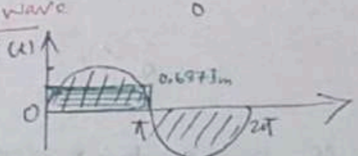
m → Nos of interval.

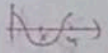


* Area under the curve

$$I_{av} = \frac{1}{T}\int_{0}^{T} i_{\theta} \cdot d\theta \qquad I_{av} =$$

Half wave



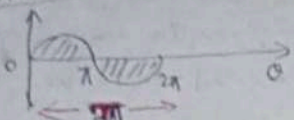


$$I_{av} = \frac{I_{max}}{\pi}\int_{0}^{\pi} \sin\theta \cdot d\theta$$

$$\Rightarrow I_{av} = \frac{I_{max}}{\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{I_{max}}{\pi}\left[-\cos\pi - -\cos 0\right]$$

$$\Rightarrow I_{av} = \frac{I_{max}}{\pi}\left[1+1\right] = \frac{2}{\pi} I_{max} = 0.637\ I_{max}$$

* Full Sine wave



$I = I_m \sin\theta$

$$I_{av} = \frac{I_m}{2\pi}\int_0^{2\pi} \sin\theta \cdot d\theta$$

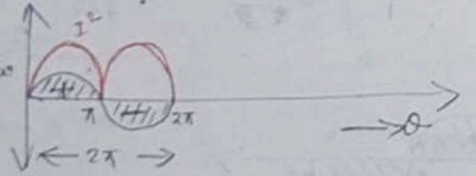
$$\rightarrow I_{av} = \frac{I_m}{2\pi}\Big[-\cos\theta\Big]_0^{2\pi} = \frac{I_m}{2\pi}\Big[-1+1\Big] = 0$$

∴ Area under curve over a one cycle is zero.

* RMS Value

→ Root mean Square (RMS)

→ It indicate the effective heating value of wave compared to a steady DC value.



$E_w = I^2 R.t$

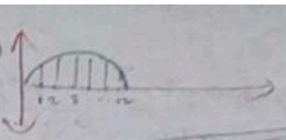
→ "Amount of AC power that produces the same heating effect as an equivalent DC power".

Definition

→ Square root of the mean of the square of instantaneous value

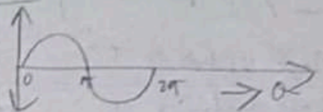
$$i_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \cdots + i_n^2}{n}} = \sqrt{\frac{1}{T}\int_0^T i^2 . dt}$$

n → nos of interval.



~~$i_{rms} = \sqrt{\text{Sum of}}$~~

Sine Wave



$i(t) = I_{max} \sin\theta$

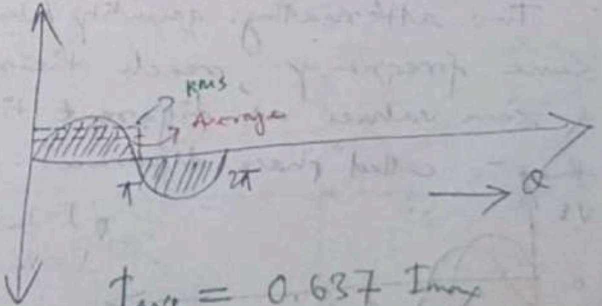
$$I_{rms} = \sqrt{\frac{I_{max}^2}{2\pi}\int_0^{2\pi} \sin^2\theta \cdot d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi}\left[\frac{1-\cos 2\theta}{2}\right] d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right]_0^{2\pi}}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\frac{2\pi}{2} - \left(\frac{\sin 2\cdot 2\pi}{4} - \frac{\sin 0}{4}\right)\right]}$$

$$I_m = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}} = 0.707\ I_{max}$$



$I_{avg} = 0.637\ I_{max}$

$I_{RMS} = 0.707\ I_{max}$

Form factor

$$FF = \frac{\text{Rms value of } I}{\text{Average value of } I} = \frac{0.707\, I_m}{0.637\, I_m} = 1.11$$

Sine wave

Peak factor / Amplitude factor

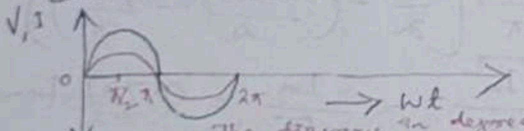
$$PF = \frac{\text{Max value of } I}{\text{RMS value of } I} = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2}$$

$$= 1.414$$ Sine wave

---

* Phase & Phase ~~Sequence~~ Difference

Two alternating quantity are said to be in "phase" when they reach their maximum & zero values at the same time.

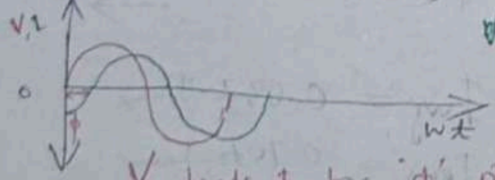


The difference in degree fraction when two ~~ck~~ AC quantity reach their maximum & zero values.

Two alternating quantity / Wave with same frequency, reach their maximum & zero values at different time / instant that is called "phase difference".

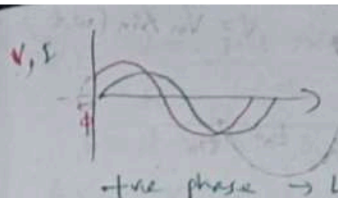
$I = I_m \sin(\omega t - \phi)$

$V = V_m \sin(\omega t)$



V leads I by 'φ' phase angle.

OR I lags V by φ phase angle



$I = \sin(\omega t)$

$V = \sin(\omega t + \phi)$ lead

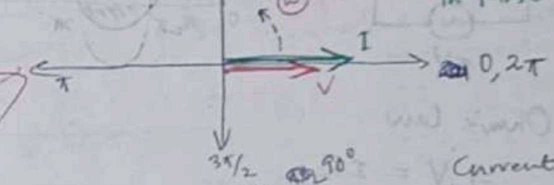
+ve phase → LEAD

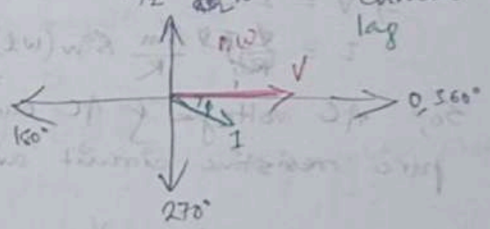
-ve phase → LAG

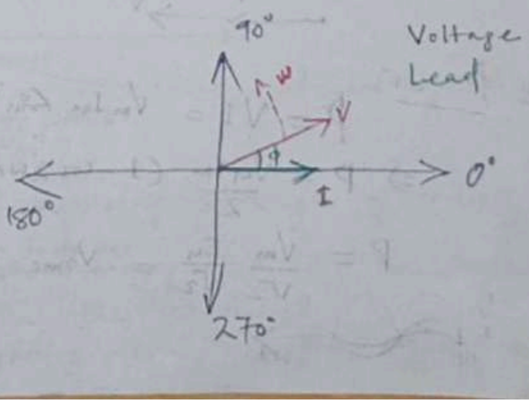
---

* PHASOR

It is a rotating vector which has uniform angular speed (ω) & in the anti-clockwise direction

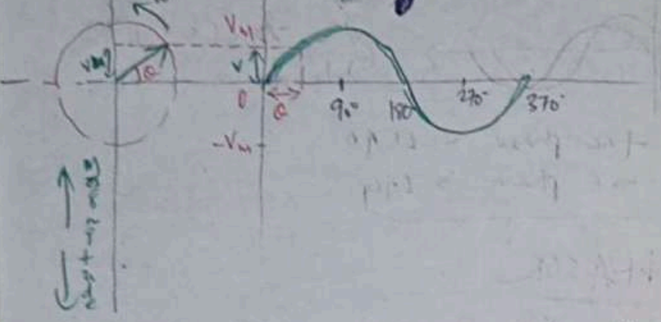




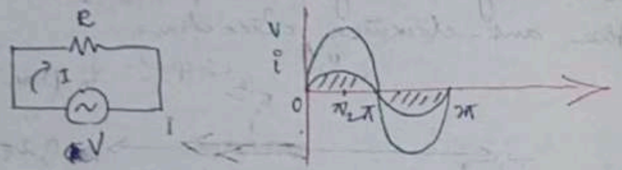


$V = V_m \sin(\omega t)$

II



* AC through purely Resistive circuit

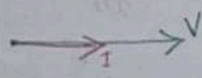


Ohm's law

$$\Rightarrow V = IR$$

$$I = \frac{V_m}{R} \sin(\omega t) = I_m \sin(\omega t)$$

So; AC voltage & AC current in a pure resistive circuit are in-phase,

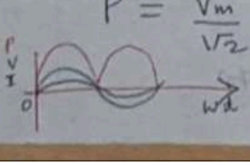


Power

$$P = VI = V_m I_m \sin^2(\omega t)$$

$$\Rightarrow P = \frac{V_m I_m}{2} (1 - \cos 2\omega t)$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} = V_{rms} I_{rms}$$



Q. $V = \underline{141} \sin(314t + \pi/3)$

$R = 10\Omega$

Find RMS & maximum value of current

Ans

$$i = \frac{V_m}{R} \sin(314t + \pi/3)$$

$$\Rightarrow i = 14.1 \sin(314t + \pi/3)$$

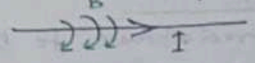
$$i_m = 14.1 \text{ Amp}$$

$$I_{Rms} = \frac{14.1}{\sqrt{2}} = 10 \text{ Amp}$$

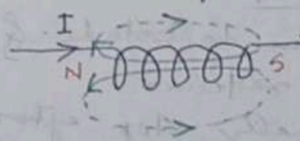
* AC through purely inductive ckt

- **Inductor** { It is a electrical device which store magnetic energy.

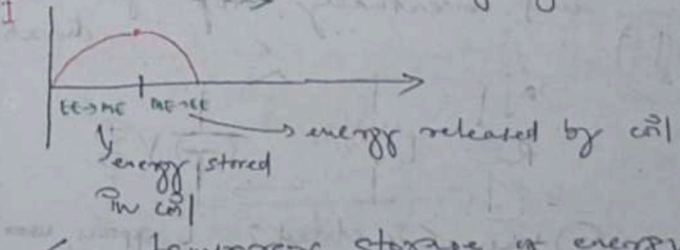
III



Small magnetic field



Strong magnetic field

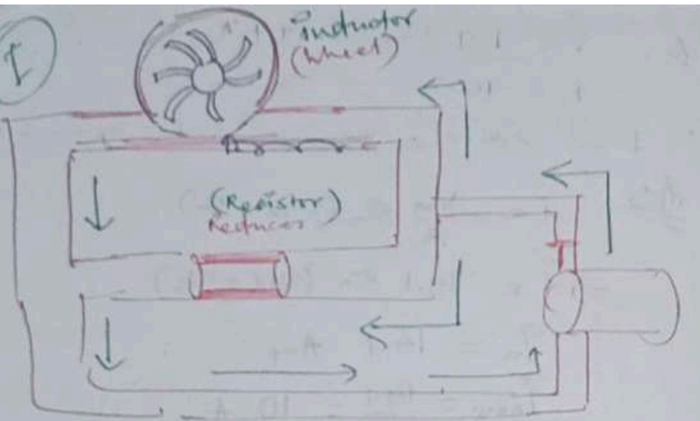


So; temporary storage of energy.

→ The ~~stored energy~~ inductor opposes the sudden change in the current.

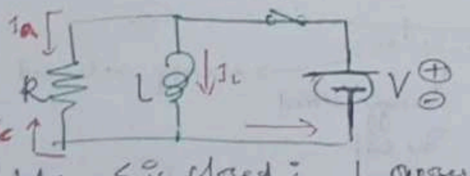
→, This opposing force is called back EMF

I



- @ initial time (Resting wheel)
  Wheel offer high resistance to water flow
- ~~On~~ At max speed of wheel
  It offer no resistance to water
- Once pump stop
  Wheel continue to rotate & flow water through reducer. and eventually stop after short duration.

II

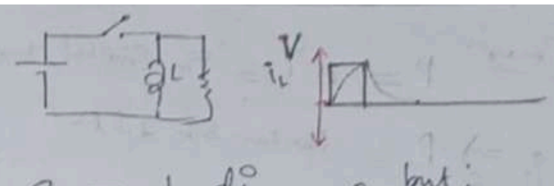


ⓐ When S is closed; L opposes I to flow.

ⓑ After some time; L allow I without resistance.

ⓒ When S is opened; L deliver current to R for some time b4 it collapse.

IV



$$e_{in} = -L\frac{di}{dt}$$

back emf (induced emf)

but; $e = V_m \sin(\omega t)$

(e in) opposing

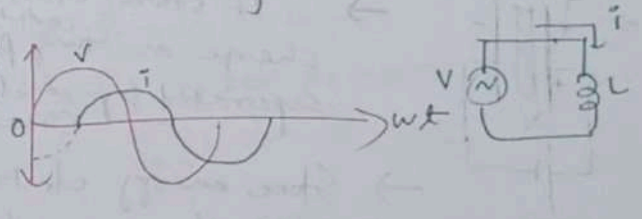
$$\Rightarrow \frac{di}{dt} = +\frac{e}{L} \Rightarrow i = \frac{+1}{L}\int e\,dt$$

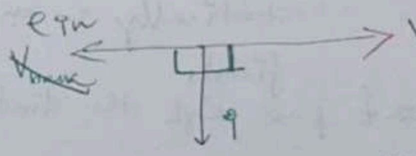
$$\Rightarrow i = +\frac{1}{L}\int V_m \sin(\omega t)\,dt$$

$$\Rightarrow i = \frac{V_m}{L}\left[-\cos \omega t\right]$$

$$\Rightarrow i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$\omega L = 2\pi f L$ ⇝ inductive reactance

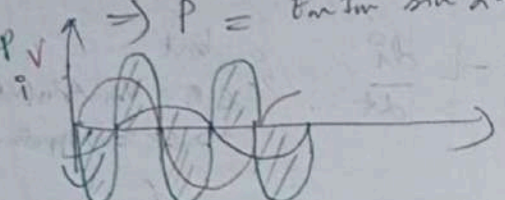




Current lag behind Voltage by angle 90° (π/2)

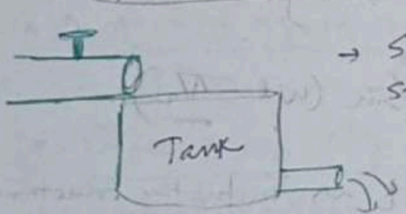
Power $P = e\,i = E_m \sin wt . I_m \overset{\sin(wt-90)}{\cancel{\cos}}$

$\Rightarrow P = E_m I_m \sin 2wt$.

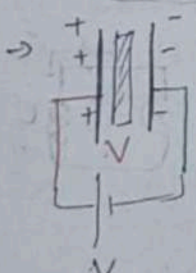


→ Average power consumed in pure inductive ckt is ZERO.

* AC through pure capacitor



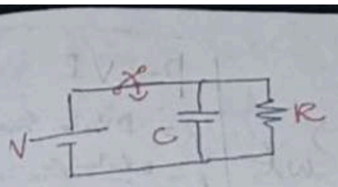
→ Smooth interruption in supply

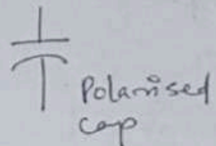


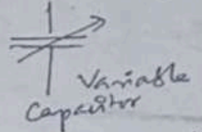
→ It store electric charge on two conducting plate separated by dielectric (insulator)

→ Store energy electro-statically in an electric field.

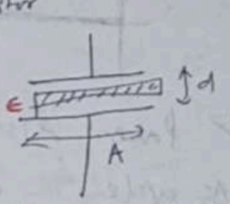
→ $e^{\ominus}$ can't pass thgh the dielectric medium.







$$C = \frac{\epsilon_0 A}{d}$$



Capacitance in "Farad"

Voltage ⇒ Max voltage that cap can handle.

$$C = \frac{Q}{V}$$ → charge stored / → voltage developed

$\Rightarrow Q = CV$

$\Rightarrow \frac{dQ}{dt} = C\frac{dV_m \sin(wt)}{dt}$

$\Rightarrow i = wCV_m \cos wt)$

$\Rightarrow i = i_m \cancel{\cos} \sin(wt + \pi/2)$

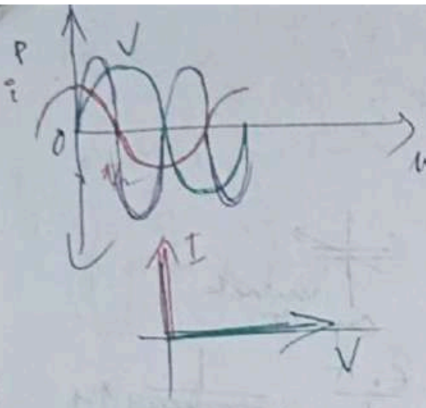
why $i_m = V_m . wC = \frac{V_m}{X_c}$

Capacitive reactance

$$\boxed{X_C = \frac{1}{wC}}$$

$$\boxed{X_L = wL}$$

So, current lead 90° wrt supply voltage.



$p = VI$

$p = V_m I_m \sin\omega t \cos$

$p = \frac{V_m I_m}{2} \sin 2\omega t$

⇒ Power dissipation over a complete AC cycle in a capacitive ckt is zero.

Ⓠ A $V = 141 \sin(\cancel{\omega t}\ 314t\ [illegible])$ is applied to a 10 μF capacitor, Find X_c, I, I_{rms}, I_{max}

$X_c = \frac{1}{\omega C} = \frac{1}{(314)(10)\mu}\ \Omega = 318.47\,\Omega$

$i = I_m \sin(\omega t + \pi/2)$

$i = \frac{141}{318.47} \sin\left(314t + \frac{\pi}{3} + \frac{\pi}{2}\right)$

$I_{max} = 0.443$

$I_{rms} = \frac{0.443}{\sqrt{2}} = 0.313$ Amp.

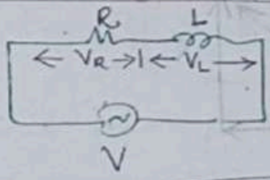
* **Reactance**

In AC circuit the opposition to the current offered by inductive & capacitive load,

$X_L = \omega L$ ⇒ inductive reactance

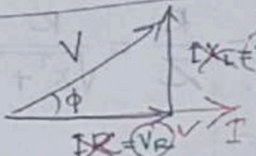
$X_C = \frac{1}{\omega C}$ → capacitive reactance

* AC through R-L ckt



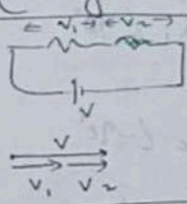
[L-R Series AC ckt]

(I)



[Voltage Δ]

But; in DC



$V_R = IR$

$V_L = IX_L$

$V = \sqrt{V_R^2 + V_L^2}$

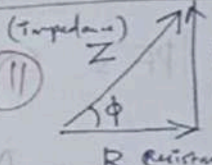
$\Rightarrow V = \sqrt{(IR)^2 + (IX_L)^2}$

$\Rightarrow V = I\sqrt{R^2 + X_L^2}$

$\Rightarrow I = V/Z$

Z → impedance

(II)

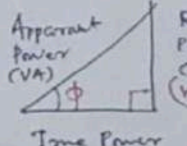


[Impedance Δ]

$Z = \sqrt{R^2 + (X_L - X_c)^2}$

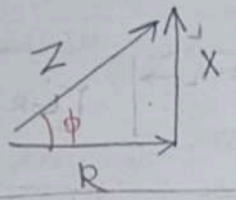
$Z = R + j(X_L - X_c)$

Power Δ (later)



Power Factor (PF) $e^{ix} = \cos(x) + i\sin(x)$

③ It is the cosine of the angle of lead/lag between applied voltage & current in a AC circuit.

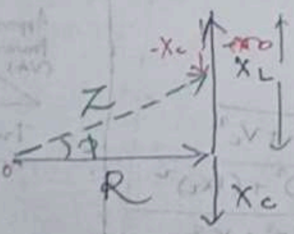


$$\boxed{PF = \cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{X^2+R^2}}}$$

* Impedance Δ ⑤

Inductance: $X_{L} = \frac{V}{I_L\angle -90°} = X_L\angle 90°$

Capacitor: $X = \frac{V}{I_L\angle 90°} = X_c\angle -90°$



* Impedance

The effective Resistance of an electric circuit to AC, arising from the combined effects of ohmic resistance & reactance.

④ Active power = $VI\cos\phi = Z\frac{I}{\cancel{Z}}I\left(\frac{R}{Z}\right)$

$$\Rightarrow \boxed{P_a = I^2R}$$

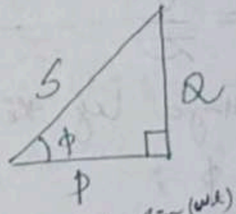
⑤ Reactive power (Q) $= VI\sin\phi = ZII\left(\frac{X}{Z}\right)$

$$\Rightarrow \boxed{Q = I^2X_c}$$ Unit - VAR

Apparent power (S) = $VI = IZI$

$$\boxed{S = I^2Z}$$

Combination of P & Q ; VA ← Unit Transformer



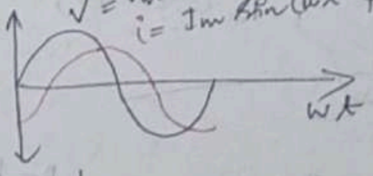
$S = \sqrt{P^2+Q^2}$

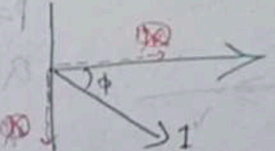
$Z = \sqrt{R^2+X^2}$

⟶

$v = V_m\sin(\omega t)$

$i = I_m\sin(\omega t - \phi)$



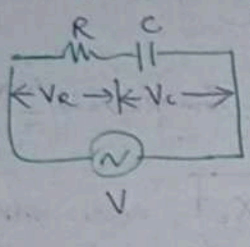


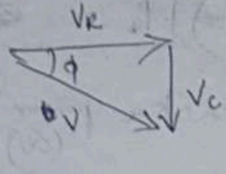
(lagging PF)

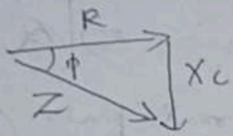
* Reactance

The non-resistive component of impedance in AC ckt, arising from the effect of L or C or both ; causing the current to be out phase with supply v

* AC through R-C circuit







$V_R = IR$

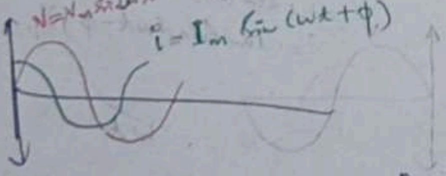
$V_C = IX_C$

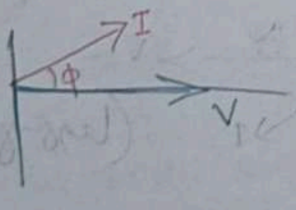
$V = \sqrt{V_R^2 + V_C^2}$

$\Rightarrow V = I\sqrt{R^2 + X_C^2}$

$\Rightarrow I = \frac{V}{\sqrt{R^2 + X_C^2}} = \frac{V}{Z}$

⇝ Applied voltage lag the current by an angle ϕ ;



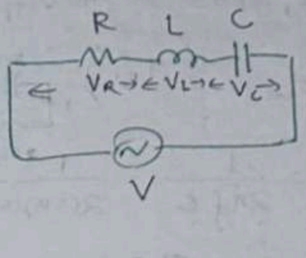


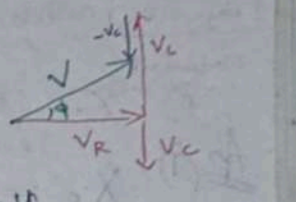
$P = I^2R$

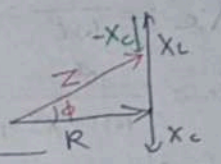
$Q = I^2X_C$

$S = I^2Z$

* AC through R-L-C







$V = \sqrt{(V_R)^2 + (V_L - V_C)^2}$

$\Rightarrow V = I\sqrt{(R^2 + (X_L - X_C)^2)}$

$\Rightarrow I = \frac{V}{Z}$; $Z = \sqrt{R^2 + (X_L - X_C)^2}$

∴ In series R-L-C ckt;

if $X_L > X_C$ then I lag V by ϕ angle

if $X_C > X_L$ then I lead V by ϕ angle

$P = I^2R$

$Q = I^2(X_L - X_C)$

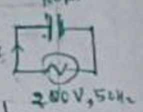
$Z = I^2Z$

* Problems

Ex - 6.14
Page - 155

A capacitor of 100 μF is connected across 200V, 50Hz 1φ supply.

Calculate
(i) X_C (ii) I_{Rms} (iii) I_{Max}



Ans (i) $X_C = \frac{1}{WC} = \frac{1}{2\pi f C} = \frac{1}{2(3.14)(50)100\mu F}$

$\Rightarrow X_C = \frac{10^6}{10000 \times 3.14} = 31.8\ \Omega$

(ii) $I_{Rms} = \frac{V_{Rms}}{X_C} = \frac{200}{31.8} = 6.29$ Amp.

(iii) $I_{max} = I_{rms}\sqrt{2}$
$= 6.29 \times 1.41$
$= 8.87$ Amp.

If $V = 100 \sin(314t)$

* $V_{rms} = \frac{100}{\sqrt{2}}$

* $V_{max} = 100$

* $\cdot$ $W = 314$
$\Rightarrow 2\pi f = 314$
$\Rightarrow f = \frac{314}{2 \times 3.14} = 50Hz$

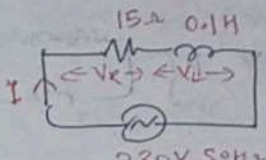
$W = \frac{2\pi \rightarrow \text{one cycle}}{T \rightarrow \text{one period}} = 2\pi f$

Ex 7.1 (202 page)

Q. $L = 0.1H$
$R = 15\ \Omega$

230V, 50Hz

Find out
(i) $I = ?$
(ii) $PF = \cos\phi$
(iii) V_L
(iv) V_R



(i) $I_{Rms} = \frac{V_{rms}}{Z} = \frac{230}{\sqrt{R^2 + X_L^2}}$;

$X_L = WL = 2 \times 50 \times 3.14 \times 0.1 = 31.4\ \Omega$

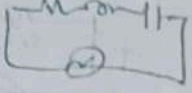
$I_{Rms} = \frac{230}{\sqrt{15^2 + 31.4^2}} = \frac{230}{34.85} = 6.6A$

(ii) $PF = \cos\phi = \frac{R}{Z} = \frac{15}{34.83} = 0.43$ (lag)

(iii) $V_R = I(R) = 6.6 \times 15 = 99V$

(iv) $V_L = I(X_L) = 6.6 \times 31.4 = 207.4\ V$

Ⓠ A $R = 20\Omega$; $L = 0.2H$, & $C = 150\mu F$ are connected in series. fed from 230V, 50Hz supply.
Find:- X_L, X_C, Z, Y, Pf



Ans

$V_{rms} = 230V$

① $X_L = \omega L = 2 \times 3.14 \times 50 \times 0.2$
$\Rightarrow X_L = 62.8\Omega$

② $X_C = \frac{1}{\omega C} = \frac{10^6}{314 \times 150} = 21.23\Omega$

③ $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{20^2 + 41.57^2}$
$= 46.13\Omega$

④ $Y = \frac{1}{Z} = 0.0217$
(admittance)

⑤ $PF = \frac{R}{Z} = \frac{20}{46.13} = \underline{\underline{0.433}}$

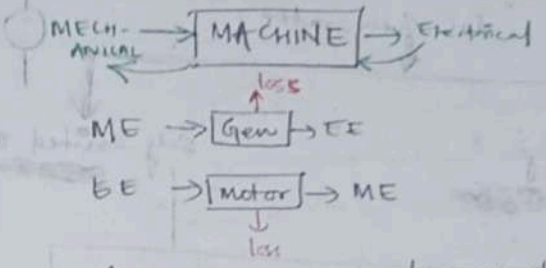
---

③ Armature - Armature winding are placed on it. it complete low reluctance path for magnetic flux. Made up of Silicon steel.
~~laminated to ca~~

④ Commutator - It is a rotating switch. AC to DC in DC Generator & DC to AC in DC motor.
Made up of hard drawn copper.

⑤ Brush - Brush carry current from ~~commutator~~ Armature ~~conductor~~ winding through commutator.
Made up of carbon material.

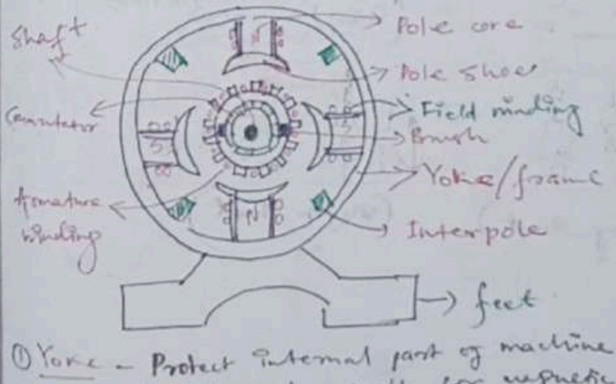
CONVERSION OF ELECTRICAL POWER



A part of energy lost as heat during the process.

* Main part of DC machine

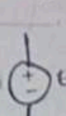
① Pole shoes & pole core
② Yoke / magnetic frame (Steel/iron)
③ Armature core
④ Field coil.
⑤ Armature winding
⑥ Commutator
⑦ Brush & bearing
⑧ Shaft



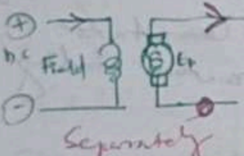
① Yoke - Protect internal part of machine. Provide return path for magnetic flux.

② Pole & pole shoes - It is use to provide housing to the field winding. When excited it behave like a magnet. Pole shoes provide mechanical support to the field winding.

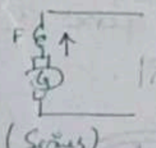
* Classification of DC generator :-



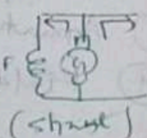
DC Generator
- Separately Excited
- Self excited
  - Shunt
  - Series
  - Compound
    - long shunt
    - Short shunt



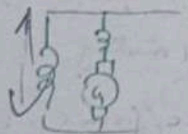
Separately



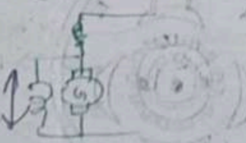
(Series)



(shunt)



(long shunt)



(short shunt)

Classification of DC motor :-

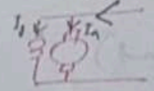
DC motor
- Shunt
- Series
- Compound
  - Cumulative compound
  - Differential compound

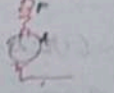
* Uses of DC Generator

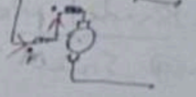
(i) Lighting of Power supply
(ii) Charging batteries
(iii) Booster

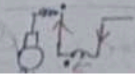
* Uses of DC motor

(i) Constant speed drive → system employed for motion control.
(ii) Drilling machine, (ix) Fan
(iii) Water pump (viii) Cutting machine
(iv) Elevator (vii) Crane
(v) Train (vi) Printing machine







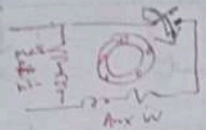


* 1 phase Induction motor

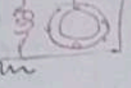
Type 1-φ winding, mounted on the stator

Types

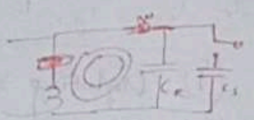
① Split-phase



② Capacitor start



③ Cap-start & Capacitor run



④ Shaded pole

× ⑤ Repulsion

⑥ Capacitor run

Uses

1) Split phase

(a) Small pump (b) Grinder

② Capacitor start

(a) Pump (b) Compressor

③ Cap-Start-Run

(a) AC compressor (b) Water cooler

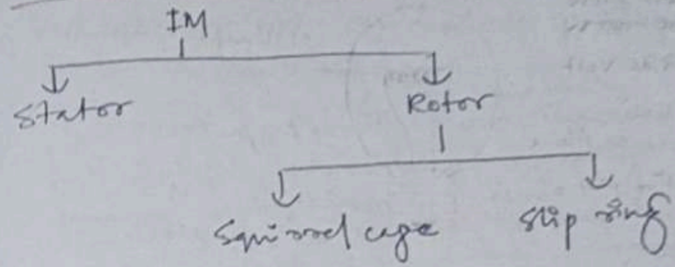
④ Shaded pole

(a) Small fan (Unidirectional)

⑤ & Repulsion motor

(a) mixer (b) Blower

Parts of Induction motor



LUMEN (Teach after LED bulb)

Total amount of visible light emitted by a source per unit time.

lumen	450	(lumen/watt)
Filament →	40W	10
CFL →	9W	49
LED →	6W	67.

* Types of lamp

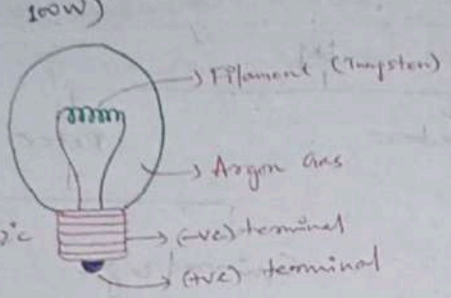
(I) Filament Bulb -

→ Thin filament wire with high melting point. When exposed to O_2, it get oxidised and burn. (Bcz for burning O_2 is required)

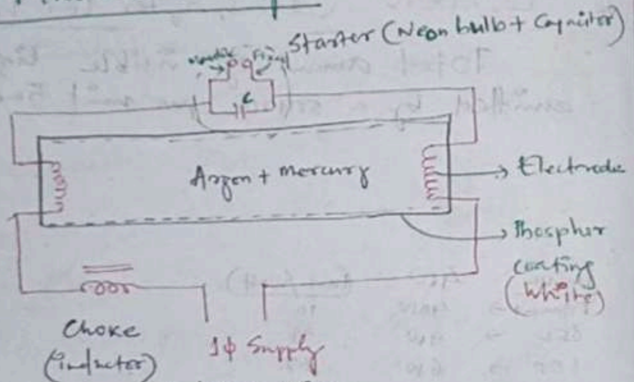
→ So, inert gas (Noble gas) is put inside the glass casing and it provide suitable environment for the glow of filament.

→ But, 10% of energy ~~that~~ is light energy & 90% is lossed as heat energy.

(But generally 100W)
25-250W
→ ~~60-100 W~~
→ 220 Volt
→ 2500°c heat @ filament
→ melting point = 3422°c



② Fluorescent Lamp



→ When ~~switch is ON~~ supplied from main; ~~Starter~~ sparre electrical contact in ~~[illegible]~~ Starter open & close rapidly. bcz of bimetallic contact.

① ~~When~~ 220V ~~supplied with~~ produces a ~~p~~ spark & filament get heated & movable contact ~~to~~ bent & touch the fixed contact (i.e. closed)

② As a result spark reduces and ~~the~~ temperature of filament comes down & movable contact get open.

③ ~~And~~ ~~con~~ Process followed by step ①

→ $e = L\frac{di}{dt}$ becomes large;

Voltage across choke increases ~~to~~ several folds.

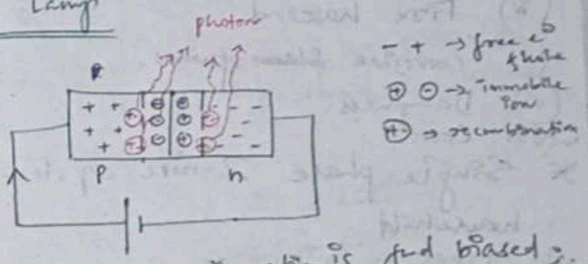
→ It heat the tungsten filament (~~i~~electrode)

→ Due to high voltage Argon gets ionised and mercury gets vaporised. and they form a conducting path.

→ UV rays are emitted from mercury, but they are not visible, so, phosphor coating ~~produce visible light~~. excited by UV ~~light~~ produce a visible radiation.

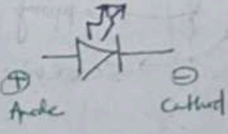
→ starter gets inactive during Fluorescent lamp glowing. About 80% efficient But harmful (bcz of mercury)

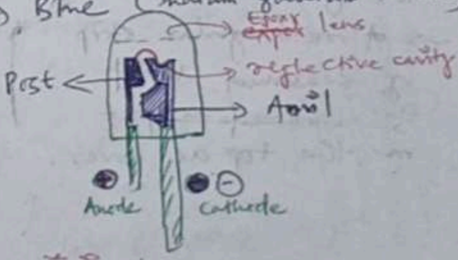
③ LED Lamp



→ When a p-n junction is fwd biased;. e⊖ & holes recombines at depletion layer and light/photon are emitted in all direction.

Ex - AlGaAs → red (Al Ga Arsenic)
AlGaP → Green (Al Ga Phosphide)
InGaN → Blue (Indium gallium nitride)





→ About 90% efficient

* WIRING & POWER BILLING

→ The process by which electric supply is made available to various load point through a network of conductor

factors affecting the choice of wiring.

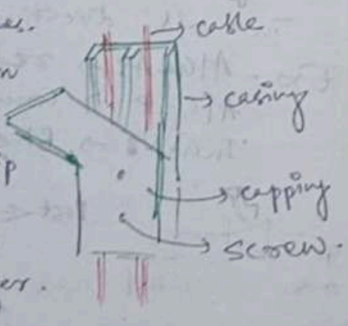
(i) life of Installation
(ii) Future extention
(iii) Construction of building.
(iv) Fire hazard
(v) Corrosive ~~flame~~ fumes.
(vi) Dampness.
(vii) Cost

* Single phase 2-wire system used in household.

Types of wiring –

① 1 Wooden casing & capping

→ casing is fixed on wall with the help of screw ~~& gutties~~.
→ wires are placed on the grooves.
→ A rectangular strip of seasoned wood is ~~covered on~~ put on the top as cover.

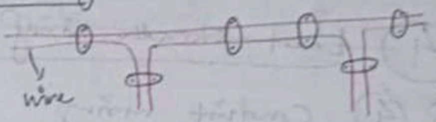


- **Advantages**
→ Environmental protection
→ Easy inspection
→ Easy to renew.

- **Disadvnt.**
→ Fire risk
→ Not suitable for damp situation

② 1. Cleat wiring


(Cleat with two groove)



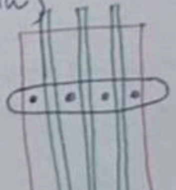
→ cable run in groove of porcelain cleat which are fastened in wooden plug on the wall.

* **Advnt**
→ Cheapest
→ Little skill required
→ Can be dismateled easily with little waste

* **Disadv**
→ No protectn against mechanical injury (fire, fume, water)
→ Not good looking.
→ Temporary ~~(age)~~ (Short life)

③ 3 ~~CCT~~ CTS (Cable tyre sheath)

→ TRS (Tough rubber sheath)
→ conductor run on the wooden batten ~~on the wall~~.
→ width of batten is depend upon the nos of wires :-
→ Hybrid of Cleat & casing capping.



Adv	Disadvn
→ Easy installation and repair	→ Prone to mechanical injury
→ Nice appearence	→ Take more ~~[illegible]~~ time for Installation.

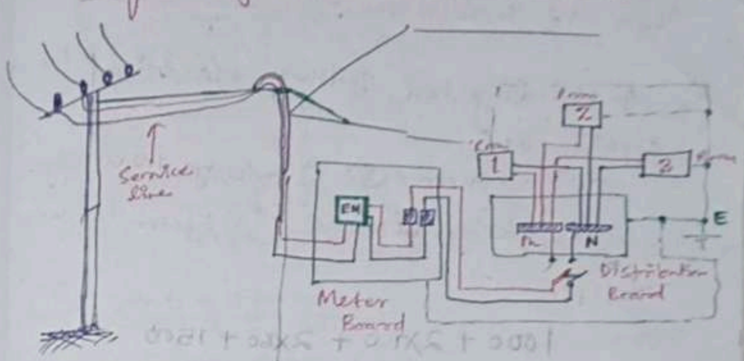
④ ~~Lead sheath wiring~~

⑤ ④ Conduit wiring

⇒ ⓐ Surface conduit wiring
ⓑ Concealed conduit wiring

Adv	Disadv
① Neat & Attractive appearence	① Costly
② Good protection against fire, mechanical dmg, moisture	② Skilled technician required.
③ High durability	③ More time taking

Layout of household EE wiring



* Protective Devices used in wiring

① **Fuse** – It is a electrical safety device which operate to provide overcurrent protection
$I > I_{fusing}$
→ One time use

② **MCB (Miniature circuit Breaker)** –
It operate when overload condition occur
When brought back to normal condition;
Reusable

③ **Lightning Arrestor** –
It protect house from the damaging effect of lightning. It is projected on the top place of house & connected to the earth.

④ **Earthing** –
The ~~body~~ /Chassis/covering of ~~machine~~ electrical devices are connected to the earth by the help of low resistance wire for transferring immediate electrical discharge.

Calculation of energy in small household Installation

Q A building has following electrical appliances:

① 1kW motor ② 2 bulb of 100W each.
③ 2 fan of 60W each ④ heater 1.5kW

Total power ?

$$1000 + 2\times100 + 2\times60 + 1500$$
$$= 2820\ W$$
$$= 2.82\ kW$$

Q. Energy = Power * Time

1 hp motor for 5 hr/day,
3 → 80 W fan for 10 hr/day
4 tube of 40W for 15 hr/day
Calculate the bill ~~of~~ for November if unit cost of bill is 2.5 Rs.

1 unit = 1 kWh
1HP = 746 W.

Energy (per day) = 746×5 + 80×3×10 + 4×40×15
= 3730 + 2400 + 2400
= 8530 Wh
⇒ (E/day) = 8.53 kWh

Total energy consumed for month = 8.53×30~~2~~=255.9 unit

Monthly bill = Rs. 639.75

Generation of Electrical Power

HYDRO -

① • Choice of site

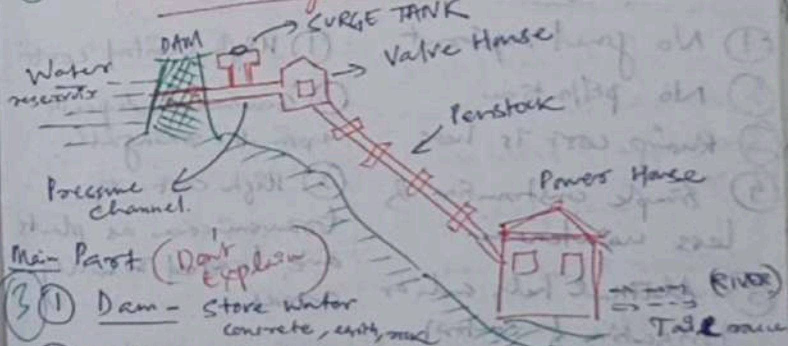
① Availability of water -
Huge quantity of water at good height

② Water Storage.
Dam constructed to store water.

③ Cost of type of ~~land~~ land
To withstand of ~~load~~ weight of equipments to be installed.

④ Transportation facility

② • Block diagram



Main Part (Don't Explain)

③ ① Dam - Store water
concrete, earth, rock

② ~~Sp~~ Surge Tank -
In ~~~~ abnormal condition; water in penstock may damage the conduit/pipe. Surge tank act as protection.

③ Penstock - This is conduit which carry water to turbine. Reinforced concrete/St

④ **Valve House** -
It control the amt of water to be flow thgh the penstock.

⑤ **Power House**

(A) **Turbine** -
It conv energy of falling water into mechanical energy.

(B) **Alternator / Generator** (AC)
ME → EE

⑥ **Spillway** - When water storage limit exceed; surplus water is removed from the storage reservoir into river on the down-stream side.

* Advantage	* Disadvantage
① No fuel requirement ② No pollution ③ Running cost is less ④ Simple construction & less maintenance ⑤ Additional help such as irrigation & control of flood.	① High capital cost ② Generation depends upon the rainfall. ③ High cost of transmission as plants are located in hilly areas.

Working (Before ; Adv)

(i) When water from reservoir is allowed to pass through pressure channel; it reaches valve house

(ii) Surge tank is provided in order to safeguard the extra-back thrust of water causing heavy damage to penstock.

(iii) Valve house control the amt of water will flow to the turbine thgh penstock.

(iv) Inside Power house; turbine conv & conv fall of water into mechanical energy and Alternator conv ME into EE.

STEAM / THERMAL POWER PLANT

Choice of site

① Supply of coal. (fuel)
② Availibility of water - used in condenser.
③ Transport facility - material of machinery
④ Cost of type of land - cheap land
⑤ Nearness to load centre - low transmission loss.
⑥ Distance from populated area - pollution

Main unit

Air, Coal → Steam (water)

③ Ⓐ Coal storage plant
Ⓑ Coal Handling plant (pulverization)
Ⓒ Ash storage plant
Ⓓ Ash Handling plant
Ⓔ Boiler - wet steam is produced
Ⓕ Superheater - wet steam to dry steam
Ⓖ Economiser - feed water heater & ~~[illegible]~~ derive heat from flue gases.
Ⓗ Air pre-heater - increase temperature of air supplied for coal burning.
Ⓝ FD fan - forced draught fan (draw air from atmosphere)
Ⓘ ID fan - draw flue gases & send to chimney (Induced draught)
Ⓙ Steam turbine - Steam ~~to~~ into ME
Ⓚ Alternator - ME into EE
Ⓛ condenser (- exhausted steam ~~from~~ is condensed & feed back to boiler thgh cooling ~~[illegible]~~ tower.
Ⓜ Cooling tower - → Provide cooling arrangement for feed water to be reused in boiler

Working -

④ (i) When water from condenser is fed to the boiler thgh economiser it remain little hot.

(ii) Boiler is extremely heated chamber bcz of continues burning of coal in the presence of air injected by FD fan thgh air preheater

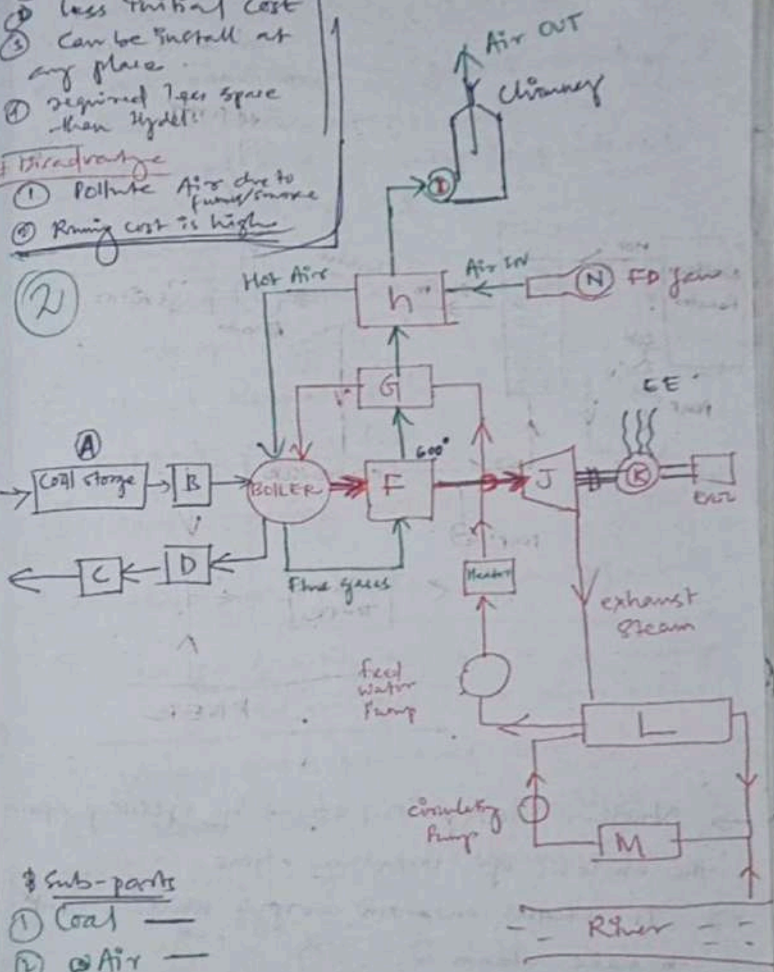
Advantage ⑤

① Coal is cheap
② less initial cost
③ Can be install at any place.
④ required less space than Hydel.

Disadvantage

① Pollute Air due to fumes/smoke
② Running cost is high

②

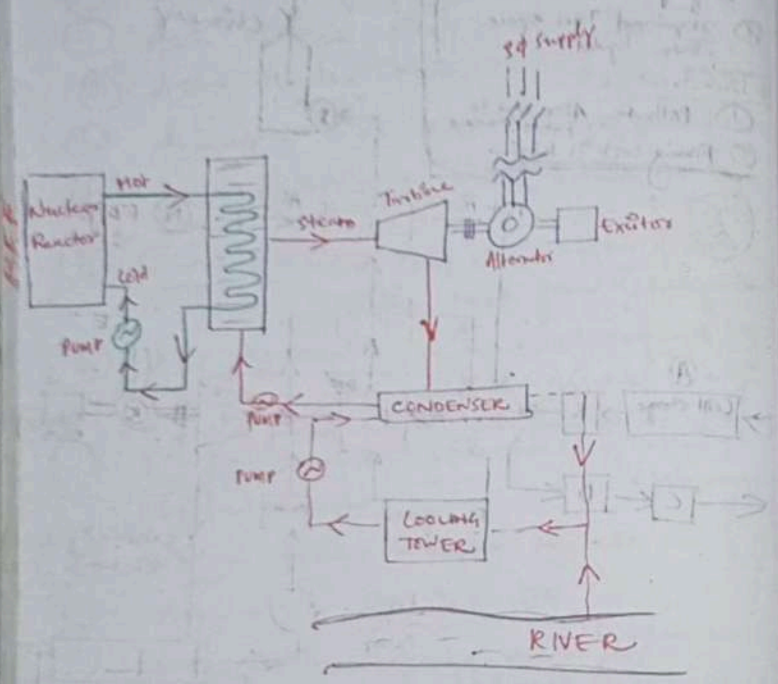


$ Sub-parts
① Coal —
② Air —
③ Water —

(iii) So, water get converted into steam (High Pressure & high temp), and reaches to turbine thgh superheater (which dries the wet steam).

(iv) Internal energy of steam → ME by turbine & ~~the~~ Alternator convert ME → EE.

③ Nuclear Power Plant



→ Nuclear energy is produced by splitting apart the nucleus of uranium atoms.

→ It releases enormous energy which is used to make steam.

→ Steam runs the turbine & ME is converted into EE.

Advantages

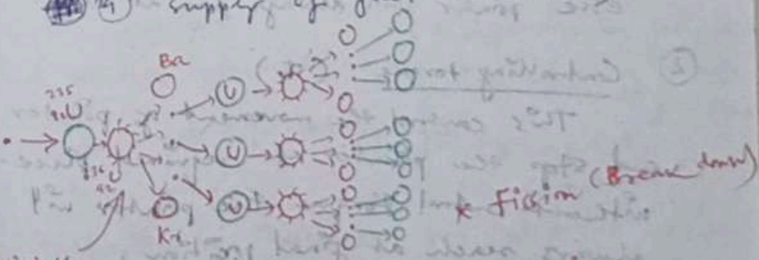
① No pollution
② Don't contribute to global warming.
③ Most reliable energy source
~~④~~ ④ Large amt of energy is produced.
⑤ Low starting cost.

Disadvantages

① Waste is radioactive and its disposal is very difficult.
② Local thermal pollution from wastewater affect marine life
③ Large running cost.

• Location for Nuclear power plant

① Large quantity of water for cooling is required. Coastal or river side.
② Away from populated place.
③ Transportation facility.
④ Supply of fuel (uranium).



[Chain Reaction]

MEASURING INSTRUMENTS

The instruments which are used to measure electrical quantities like current, voltage, power, energy etc ~~are k~~ AKA electrical measuring instruments.

Measuring Instruments
- Absolute (Primary)
  - Ex- Tangent Galvanometer (Standard)
  - (Value from deflection)
  - → For testing & calibration
- Secondary
  - Scale caliberated in the term of unit of quantity.
  - Indicating
    - Magnitude of quantity
    - Ex- Ammeter, Voltmeter, Wattmeter
  - Recording
    - continuous record of variation of quantity over a time period.
    - Ex- ECG machine (Heart beat rate)
    - → Annual load curve by (Wattmeter)
  - Integrating
    - Integrate (Add) total quantity over a period of time.
    - Ex- Energy meter. (Bill) (Watt-hour meter)

Torque in instruments

② ① Deflecting torque (τ_d)

it deflect / move the pointers. else pointer will always free at zero.

② Controlling torque (T_c)

This control the movement of pointer and stop the pointer at required place. without control torque the pointer will always reach at final position.

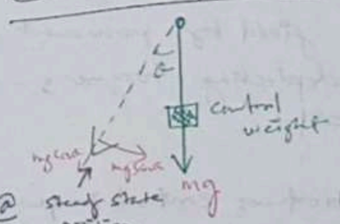
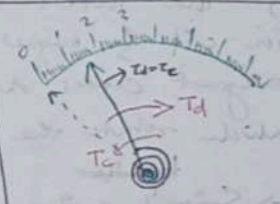
③ Damping Torque

Without damping torque the pointer make oscillation about the steady state position (equilibrium).

This oscillation are damped out by means of damping torque.

Damping torque is present when the pointer move and it becomes zero when the pointer is at steady state position.

Types of controlling torque

Ⓐ Gravity control	Ⓑ Spring control
	
@ steady state position $T_d = T_c$ ~~deflect~~	→ Spring made up of phosphorus-bronze.
→ cheap	→ costly.
→ No fatigue	→ affected by fatigue (stress)
→ Reading affected by height	→ Not affected by latitud
→ It is not affected by temperature.	→ Affected by temperature
→ Position of instrument affect reading (Panel mounting)	→ Pos^n do not affect reading (Portable)
→ Scale non-uniform	→ Scale uniform.

① **Torque**

- Deflecting
- Controlling
  - Spring control
  - Gravity control
- Damping
  - Air friction (Hot wire instruments)
  - Fluid friction
  - Eddy current (moving iron)
  - ~~Electromagnetic~~

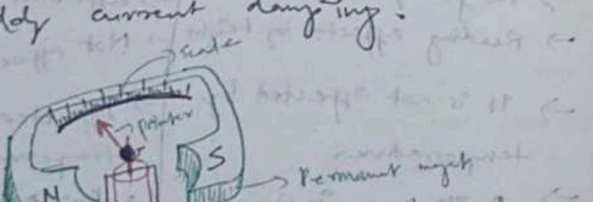
PMMC (Permanent magnet moving coil)

→ The interaction between current in coil & magnetic field by permanent magnet causes a deflecting torque; which rotate the coil.

→ Spiral ~~[illegible]~~ spring produces control torque

→ Eddy current ~~induced~~ setting on the metal ~~frame~~ core due to movement of coil which opposes the movement.

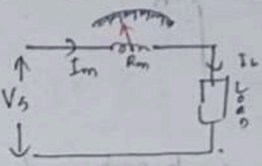
→ Eddy current damping.



Use of PMMC

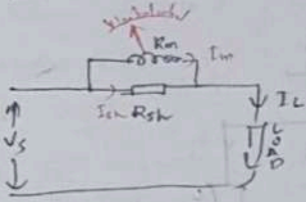
① PMMC as an Ammeter (meter connected in series with load)

ⓐ For low range



Im → measuring current
IL → load current
Rm → meter resistance

ⓑ For high range



Rsh → Shunt resistance

$R_m >> R_{sh}$

$I_m << I_{sh}$; $I_{sh} = I_L - I_m$

$I_m(R_m) = (I_L - I_m) R_{sh}$

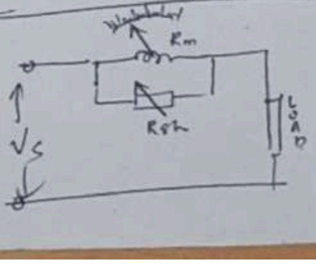
$\Rightarrow R_{sh} = \frac{I_m}{I_L - I_m} R_m$

$\Rightarrow \boxed{R_{sh} = \left(\frac{1}{m-1}\right) R_m}$

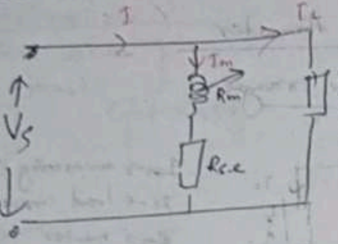
$m = \frac{I}{I_m}$

multiplication factor

ⓒ Multiple range



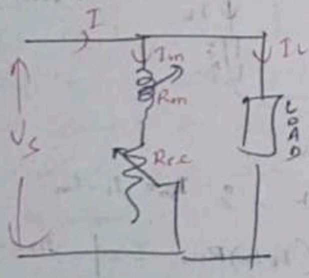
② PMMC as Voltmeter (meter connected across load in parallel)



$$\boxed{I_m = \frac{V}{R_m + R_{se}}}$$

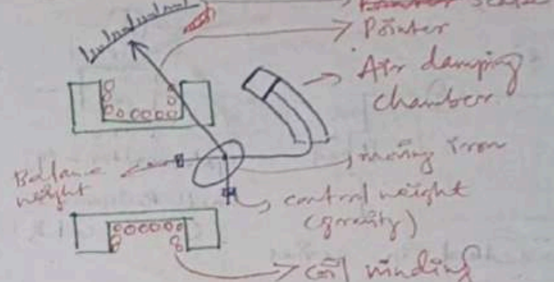
We want to reduce I_m so that I_L is large.

Multiple range



$$R_{se} = (m-1) R_m$$

④ MOVING IRON (MI) type instruments



Control torque → gravity (weight)

Damping torque → Air damping (pneumatic)

→ When current flows through the coil it produces a magnetic field. ~~along the~~

→ The soft iron piece inside the coil attracted due to magnetic field & produces a deflecting torque.

$$T_d \propto I^2$$

$$T_c \propto \sin\theta \quad (\text{due to gravity control})$$

$$\boxed{\sin\theta \propto I^2}$$

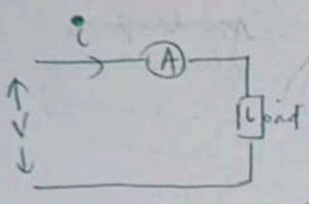
@ equilibrium.

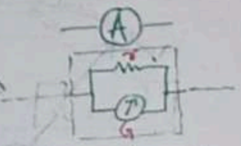
Remarks

① Non-uniform scale
② Use for both AC & DC
③ $T_d \propto$ [illegible] I^2. So, RMS quantity is measured.
④ As both Ammeter & voltmeter

* Connection diagram

① Ammeter



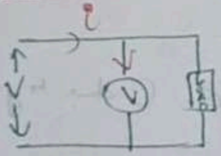


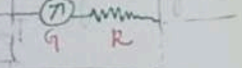
Galvanometer - G

Small Resistance - r
(Thick coil & less turn)

→ connected in series

② Voltmeter





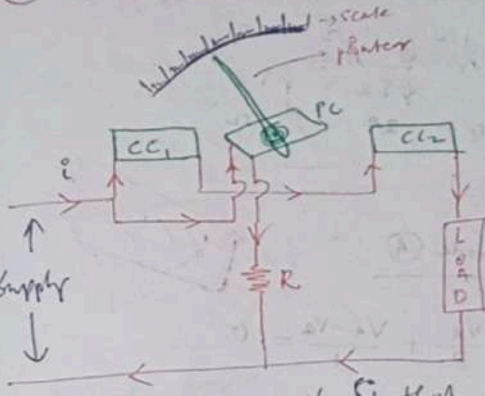
R → large resistance
(Thin coil & large turns)

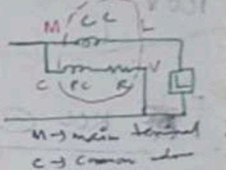
→ PMMC with ~~a~~ allow small current thgh it.

→ connected in parallel.

③ Wattmeter

(fixed coil)
CC → current coil
PC → pressure coil
(moving coil)





M → main terminal
C → common do
L → load do
V → potential do

Deflecting torque $\propto$ (i thgh CC) * (i thgh PC)

$\Rightarrow \tau_d \propto (i_{cc}) * (V_{pc})$

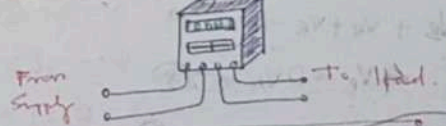
$\Rightarrow \tau_d \propto$ Power

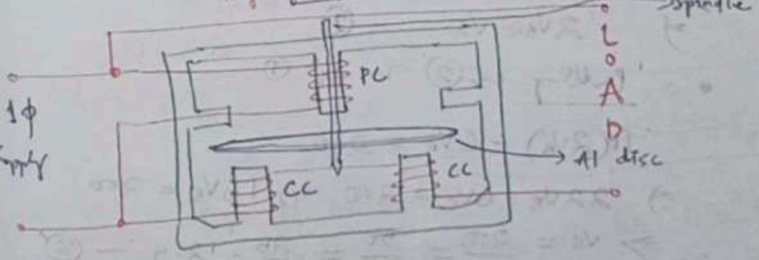
Both DC & AC measured

CC → few turns of thick wire (R↓↓)
PC → more turns of thin wire (R↑↑↑)

→ controlling torque is provided by spring.

④ Energy meter





* KIRCHHOFF'S LAW

1) Kirchhoff's current law {Nodal Analysis}

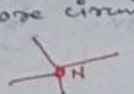
It states that the algebraic sum of currents leaving (or entering) a node is equal to ZERO.

$$\sum_{m=1}^{B} I_m = 0$$

Ignore

Node -

Where two or more circuit elements are connected.



Circuit -

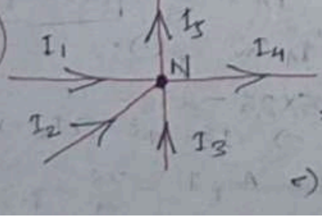
An electric circuit contain a closed path for providing a flow of electrons from a voltage/current source to loads which may be connected in series, parallel. or series-parallel.

Network -

It is consist of active and passive (load) elements. It need not contain a closed path for providing a flow of e⊖ from active to passive elements.

- I_m is the mth branch current leaving the node.
- B is the number of branches connected to that node.

Problem next page



$$\sum_{m=1}^{5} I_m = 0$$

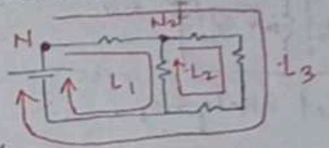
$$\Rightarrow \boxed{I_1 + I_2 + I_3 - I_4 - I_5 = 0}$$

$$\Rightarrow \boxed{I_1 + I_2 + I_3 = I_4 + I_5}$$

(II) Kirchhoff's voltage law {Mesh Analysis}

Algebraic sum of voltage around a loop or mesh is equal to ZERO.

Loop - It is a path that terminate at the same node where it started from.

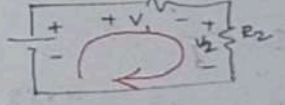


Mesh -

Mesh is a loop that doesn't contain any loop inside a loop.

L_1, L_2 are mesh

But L_3 is not a mesh

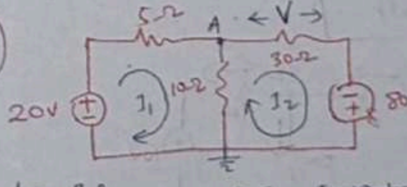


~~$V = V_1 + V_2$~~

$$\Rightarrow \boxed{V_s - V_1 - V_2 = 0}$$

$$\Rightarrow \boxed{V_s = V_1 + V_2}$$

Ex



$V_A = ?$

In loop I: $20 - I_1 5 - \cancel{I_1 10 +} (I_1 - I_2) 10 = 0$

$\Rightarrow 15 I_1 - 10 I_2 = 20$ — ①

In loop II:

$80 - 10(I_2 - I_1) - 30 I_2 = 0$

$\Rightarrow 40 I_2 - 10 I_1 = 80$ — ②

Solving eqn ① & ②, we get

$I_1 = 16/5$ A, $I_2 = 14/5$ A

Sol:

$V_{30} = I_2 * 30$

$\Rightarrow V_{30} = \frac{14}{5} * 30 = 84$ Volt

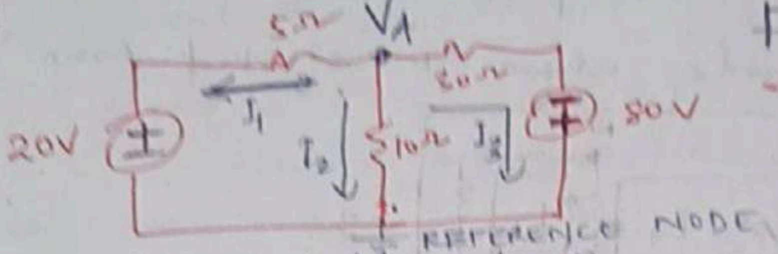
$\Rightarrow \boxed{V_{30} = 84 \text{ Volt}}$

$20V - I_1 * 5 = V_A$

$\Rightarrow V_A = 20 - \frac{16}{5} * 5$

$\Rightarrow \boxed{V_A = 4 \text{ Volt}}$

(Ex)



Find node voltge V_A

Using nodal analysis

At node "A"

$$\frac{V_A - 20}{5} + \frac{V_A - 0}{10} + \frac{V_A + 80}{30} = 0$$

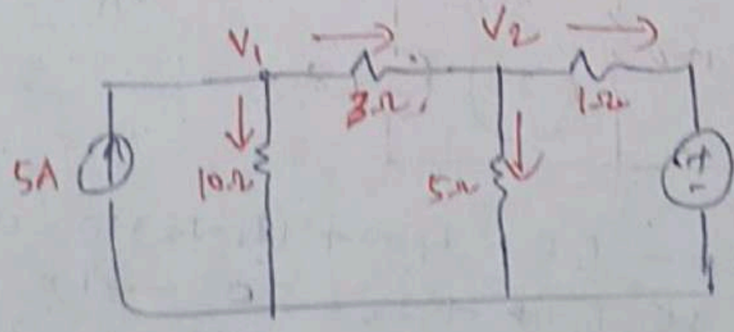
$$\Rightarrow \frac{V_A}{5} + \frac{V_A}{10} + \frac{V_A}{30} - 4 + \frac{8}{3} = 0$$

$$\Rightarrow \frac{6V_A + 3V_A + 1V_A}{30} - \frac{4}{3} = 0$$

$$\Rightarrow \frac{10 V_A}{30} = \frac{4}{3} \Rightarrow V_A = \frac{4 \times 30}{3 \times 10} = 4 \text{ volt}$$

$$\boxed{V_A = 4 \text{ Volt}}$$

(EX)



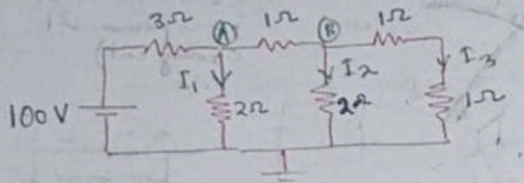
At node 1:

$$5 = \frac{V_1}{10} + \frac{V_1 - V_2}{3} \quad — ①$$

At node 2:

$$\frac{V_1 - V_2}{3} = \frac{V_2}{5} + \frac{V_2 - 10}{1} \quad — ②$$

* KVL & KCL problem solving



KCL

(I) KCL @ Node (A)

$$\frac{V_A-100}{3}+\frac{V_A}{2}+\frac{V_A-V_B}{1}=0$$

$$\Rightarrow \frac{V_A}{3}+\frac{V_A}{2}+V_A-\frac{100}{3}-V_B=0$$

$$\Rightarrow 2V_A+3V_A+6V_A-200-6V_B=0$$

$$\Rightarrow 11V_A-6V_B=200 \quad \text{— ①}$$

- KCL @ Node (B)

$$\frac{V_B-V_A}{1}+\frac{V_B}{2}+\frac{V_B}{2}=0$$

$$\Rightarrow 2V_B+V_B+V_B-2V_A=0$$

$$\Rightarrow 4V_B=2V_A$$

$$\Rightarrow 2V_B=V_A \quad \text{— ②}$$

- Putting eq ② in eq ①

$$11(2V_B)-6V_B=200$$

$$\Rightarrow 22V_B-6V_B=200 \Rightarrow 16V_B=200$$

$$\Rightarrow V_B=\frac{200}{16}=\frac{50}{4}=\frac{25}{2}=12.5 \quad \text{— ③}$$

- Put ③ in ②

$$V_A=2(12.5)=25 \quad \text{— ④}$$

So;

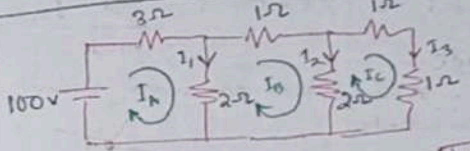
$$I_1=\frac{V_A}{2}=\frac{25}{2}=12.5\text{ Amp}$$

$$I_2=\frac{V_B}{2}=\frac{12.5}{2}=6.25\text{ Amp}$$

$$I_3=\frac{V_B}{2}=\frac{12.5}{2}=6.25\text{ Amp}$$

?

(II)



KVL

KVL @ loop A ;

$$100-3(I_A)-2(I_A-I_B)=0$$

$$\Rightarrow 100-\cancel{8}5I_A+2I_B=0 \quad \text{— ①}$$

$$\Rightarrow 5I_A-2I_B=100$$

$$1I_B+2(I_B-I_C)+2(I_B-I_A)=0$$

$$\Rightarrow 5I_B-2I_C-2I_A=0 \quad \text{— ②}$$

$$I_C+I_C+2(I_C-I_B)=0$$

$$\Rightarrow 4I_C-2I_B=0 \Rightarrow I_B=2I_C \quad \text{— ③}$$

Put ③ in eq ① & ②

$$\Rightarrow 5I_B-I_B-2I_A=0$$

$$\Rightarrow 2I_A-4I_B=0 \quad \text{— ④}$$

$$2\times(5I_A-2I_B)=(100)\times 2 \quad \text{— ⑤}$$

$$\underset{-}{} \quad \underset{+}{} \quad \underset{-}{}$$

$$8I_A=200$$

$$\Rightarrow I_A=\frac{200}{8}=\boxed{25\text{ Amp}}$$

Put "I_A" in eq ①;

$$5\times 25-2I_B=100$$

$$\Rightarrow 125-100=2I_B \Rightarrow \boxed{I_B=\frac{25}{2}\text{ Amp}}$$

$$I_2=I_B-I_C$$
$$\Rightarrow I_2=12.5-6.25$$
$$\Rightarrow I_2=6.25\text{ Amp}$$
$$I_1=I_A-I_B$$
$$\Rightarrow I_1=25-12.5$$
$$\Rightarrow I_1=12.5A$$

Put "I_B" in eq ③

$$I_B=2I_C \Rightarrow ~~25\text{ Amp}~~\; I_C=\frac{25}{4}\text{ Amp} \Rightarrow \boxed{I_C=I_3=6.2}$$