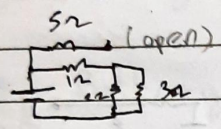
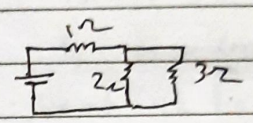
→ Ohm's Law — Acc. to Ohm's Law, the PD across any 2 pts of the conductor is ∝ to the current flowing through it. ⇒ $V \propto I$ ⇒ $V = IR$

4-1-22

ELECTRICAL

BASICS

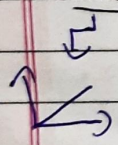
Network	Circuit
• Not necessarily closed (can be open at end(s))	• It is closed.
• Eg – Communication Lines, Distribution Systems 	• Eg – In watches 
• Current may not pass thru all comp.	• Current should pass thru all components.

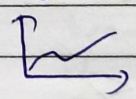
• ~~All networks are circuits, but all circuits~~

• Circuits are building blocks of a network

→ Types Of Elements

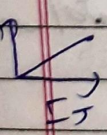
① Linear & Non Linear



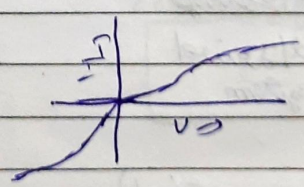


Eg – $V = IR$

$V \propto I$



Eg – Diode

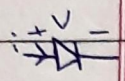


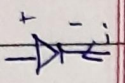
• Can be modelled mathematically

• Cannot be modelled

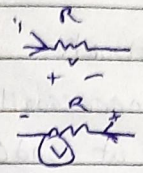
② Unilateral & Bilateral

- allows current in one direction only.
- Eg- Diode



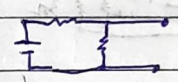


- Depends on Polarity & Direction
- Allows current in Both Direction.
- Eg- Resistor



- Eg- Resistor, Inductor & Capacitor

Open Circuit → Resistance = Infinite



OR

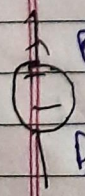
Fuse, jam bar, Short circuit.

- Inductor & Capacitor are Energy Storing Components
- Unilateral = Asymmetrical || Bilateral = Symmetrical.

③ Active & Passive

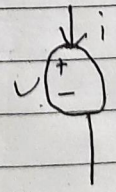
- Supplies current/voltage
- Delivers/give out/drived energy the system

- Sink
- Absorbs/Dissipate/Convert/Store.



$P_{delivered} = +VI$ (W)

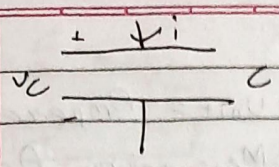
$P_{absorbed} = -VI$ (W)

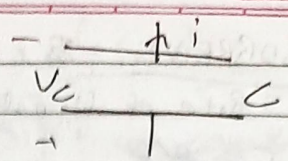


$P_{del} = -VI$ (W)

$P_{abs} = +VI$ (W)

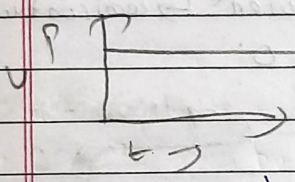
- A component can't be active & passive at the same time

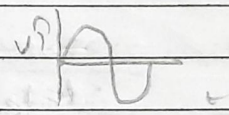




SUPPLY

DC (+ve only)	AC
• Unipolar / Unidirectional	• Bipolar / Bidirectional
• Freq = 0 Hz	• Freq = 50 Hz ± 1.5 Hz (India)
• eg - Battery	• eg - AC generator
	• Used for large, bulk & continuous power supply





• Small, independent, isolated power supply systems -

---

(1) VOLTAGE - V

• Force / EMF which can drive a system

• $V = \frac{dW}{dQ}$ $\left(\frac{\text{Work}}{\text{Charge}}\right)$

• SI Unit = Volt (V)

• eg - • Battery
  • DC generator
  • Fuel Cell

• EMF = P.D. b/w 2 terminals with no current flowing in the circuit.

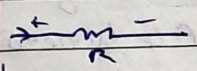
• Measured By - Voltmeter

② CURRENT – i

- Rate of flow of Charge
- $I = q/t$
- Unit = Ampere (A)
- Measured by – Ammeter

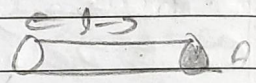
③ Resistance – R → dissipates Heat

- LTI = Linear, Time Invariant property of matter
  ↳ does not change properties with time



- Unit = Ω (Ohm)

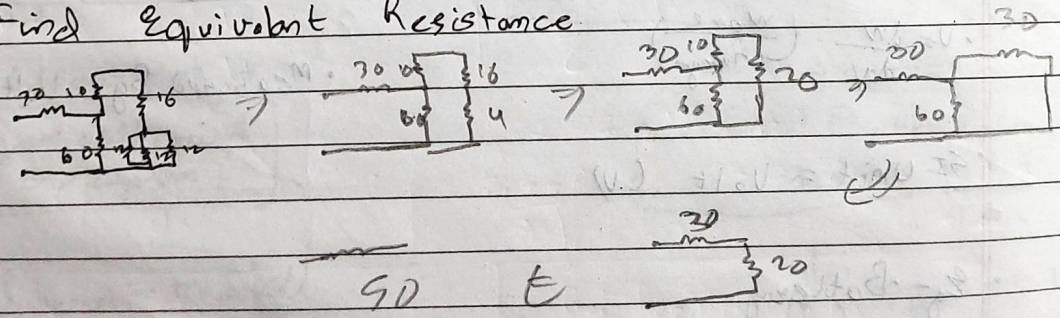
- $R_t = R_0 (1 + \alpha t)$ α = Temp. Coefficient → metals = +ve, semiconductors = -ve
  R_0 = Resistance at 0°



- $R = \frac{\rho l}{A}$
  - l = length
  - A = area of Cross Section
  - ρ = Resistivity (Unit = Ωm)

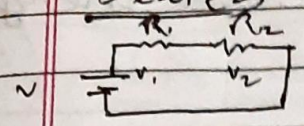
eg – • Incandescent Bulb
• Heater

Q) Find Equivalent Resistance



$R_{eq} = 50\Omega$

Series



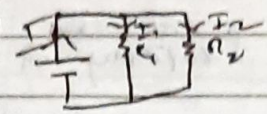
$V = IR_1 + IR_2$

$= I(R_1 + R_2)$

$\Rightarrow R_s = R_1 + R_2 + \dots$

- $V_1 = IR_1$
- $V_2 = IR_2$
- Same I, Diff. V

Parallel

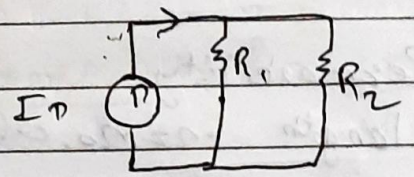


$I = I_1 + I_2$

$\Rightarrow \frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2}$

$\Rightarrow \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

- Same V; Diff I



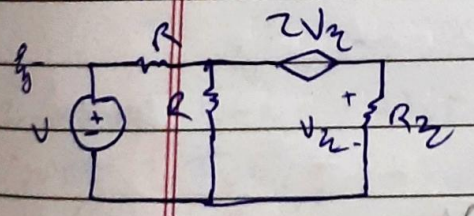
$$I_1 = \frac{IR_2}{R_1 + R_2}$$

$$I_2 = \frac{IR_1}{R_1 + R_2}$$

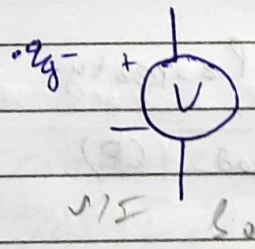
→ Dependent & Independent Sources

- ~~properties dependent~~ others

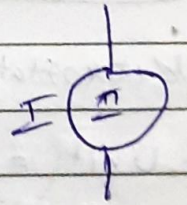
- whose properties & characteristics are independent of prop. & char. of others.



- V_2 depends on R_2



VI Source



- Will always supply constant VI

Date
DELTA Pg No.

(4) Inductance → Pure L → stores ~~Electrostatic~~ Electromagnetic Energy

↓

- Electromagnetic Property of matter
- SI Unit = Henry (H)
- Core Materials
  (1) Iron (2) Ferrite
- V-I Rel^n → $V_L = L\frac{di}{dt}$ || $i = \frac{1}{L}\int V\,dt$
- $L = \frac{\mu N^2 A}{l}$ · $\mu = \mu_0 \mu_r$ ($4\pi\times10^{-7}$) Rel. Permeability · A = Area · l = length · n = no. of turns

Eg- Choke Coil, Filter Circuit.

Flux = Presence of Force field in a specified medium · Unit = Weber (Wb)

(5) CAPACITOR - Pure C → Stores Electrostatic Energy

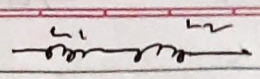
- Electrostatic Property
- SI Unit = Farad (F)
- V-I → $I = C\frac{dV}{dt}$ | $V = \frac{1}{C}\int i\,dt$
- $C = \frac{Q}{V}$
- $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$ → $\varepsilon_0 = 8.85\times10^{-12}\ Fm^{-1}$, ε_r → Rel. Permittivity. A = Area · d = distance b/w plates

→ $q = CV \Rightarrow \frac{dq}{dt} = \frac{d}{dt}(CV) = C\frac{dV}{dt}$ (as C = constant)

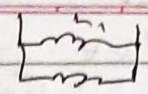
→ $i = C\frac{dV}{dt}$ ($\because \frac{dq}{dt} = i$)

Date
DELTA Pg No.

L → (same as R)

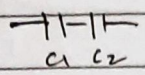


$L_{eq} = L_1 + L_2$ (same as R)

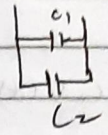


$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$

C → (opposite of R)



$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

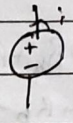


$C_{eq} = C_1 + C_2$

· opposite of (R)

(6) **Power** · $P = \frac{dW}{dt}$ $\left(\frac{\text{Work}}{\text{Time}}\right) = \frac{dE}{dt}$ $\left(\frac{\Delta \text{ in Electrical Energy}}{\Delta \text{ in Time}}\right)$

· Unit = Watt (W) = Joule/sec (Js^{-1})



$P_{del.} = +V_i$ (W)

$$\boxed{P_R = VI = \frac{V^2}{R} = I^2R}$$ → RESISTOR.

→ **FOR LRC**

· $P_{avg} = 0$ (in complete cycle)

Instantaneous Power
For L; $P = V_L I_L = i \times L\frac{di}{dt} = iL\,di/dt$ $[\because V_L = L\,di/dt]$
For C; $P = V_C I_C = V_C C\,dV/dt = VC\,dV/dt$ $[\because I_C = C\,dV/dt]$

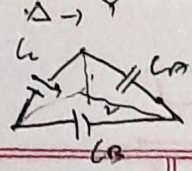
(7) **ENERGY** · Capacity to do work.

$$\boxed{E = \int P\,dt}$$

· Unit = Joules (J) // Watt-sec ie $1J = 1Ws$

· 1kWh = 1 unit of electrical power $= 3.6 \times 10^6$ J

$\Delta \to Y$

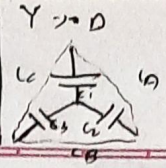


$C_1 = C_A + C_L + C_A C_L / C_B$

$C_2 = C_A + C_B + C_A C_B / C_L$

$C_3 = C_B + C_L + C_B C_L / C_A$

$Y \to \Delta$



$C_A = C_1 C_2 / C_1 + C_2 + C_3$

$C_B = C_1 C_3 / C_1 + C_2 + C_3$

$C_L = C_2 C_3 / C_1 + C_2 + C_3$

$E_R = VIt = I^2 R T = \frac{V^2}{R} t$

$E_L = \int L i(t) \frac{di(t)}{dt} dt$

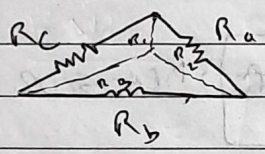
$E_C = \int C V(t) \frac{dV(t)}{dt} dt$

$-\frac{1}{2} C V^2 = \frac{Q^2}{2C} = \frac{1}{2} Q V$

$\boxed{\cdot E_C = \frac{1}{2} C V^2}$ $\boxed{\cdot E_L = \frac{1}{2} L i^2}$

→ Delta - Star Transformation (For Resistor)

① $\Delta \to Y$ $(\Delta \to \lambda)$



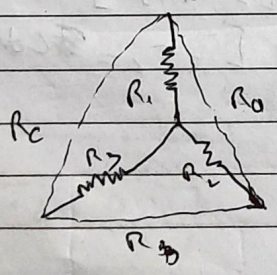
$R_1 = (R_a . R_c) / R_a + R_b + R_c$

$R_2 = (R_a . R_b) / R_a + R_b + R_c$

$R_3 = (R_b . R_c) / R_a + R_b + R_c$

→ Star Delta Transformation

① $Y \to \Delta$ $(\lambda \to \Delta)$



$\cdot R_a = R_1 + R_2 + \frac{R_1 R_2}{R_3}$

$\cdot R_b = R_2 + R_3 + \frac{R_2 R_3}{R_1}$

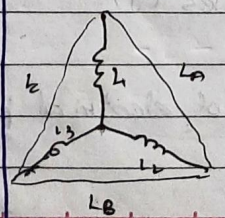
$\cdot R_c = R_1 + R_3 + \frac{R_1 R_3}{R_2}$

$\Delta \to Y$

$L_1 = \frac{L_A L_B}{L_A + L_B + L_C}$

$L_2 = \frac{L_A L_B}{L_A + L_B + L_C}$

$L_3 = \frac{L_B L_C}{L_A + L_B + L_C}$

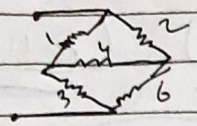


$L_A = L_1 + L_2 + \frac{L_1 L_2}{L_3}$

$L_B = L_2 + L_3 + \frac{L_2 L_3}{L_1}$

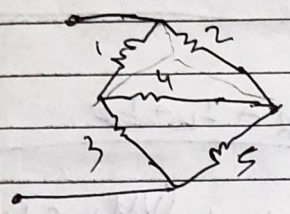
$L_C = L_1 + L_3 + \frac{L_1 L_3}{L_2}$

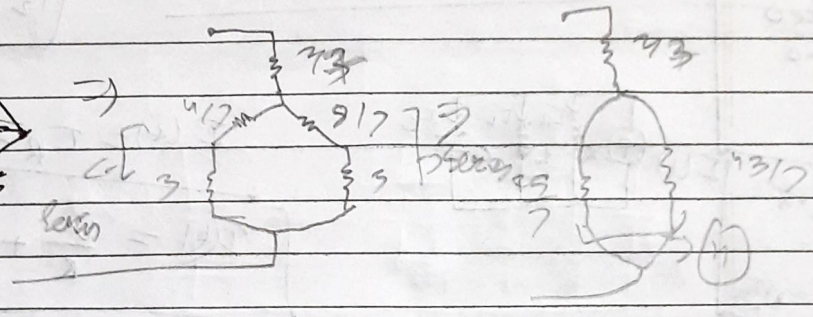
Q)

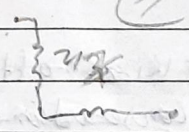


$R_{eq} = 8/3\ \Omega$ (wheatstone)

Q)

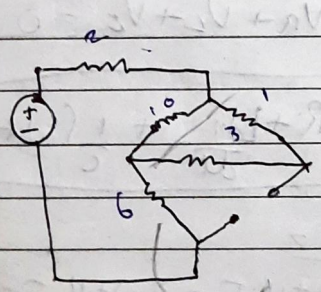


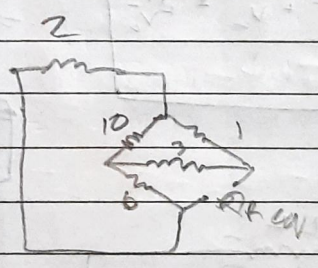


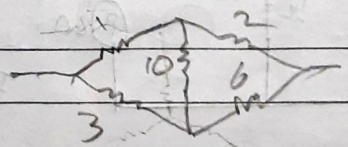


$\Rightarrow R_{eq} = 2.58\Omega$

Q.)







$= 9.14\Omega$

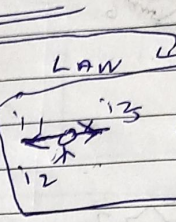
(a) Potential Rise (+ve)

(b) Drop in Potential (-ve)

→ KIRCHOFF'S LAW (= NODAL) (in 11)

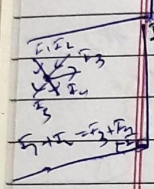
(1) KCL = Kirchoff's Current LAW
(law of conservation of charges)

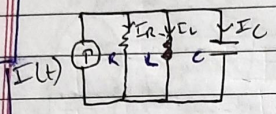
$\sum i$ at node $= 0$



$i_1 + i_3 = 0$

algebraic sum of currents meeting at a pt/point will be 0
$\Rightarrow \sum i = 0$





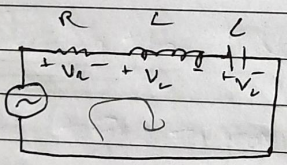
$I(t) = I_R + I_L + I_C$

$$\boxed{I(t) = \frac{V}{R} + \frac{1}{L}\int V\,dt + C\frac{dV}{dt}}$$

(2) KVL = Kirchoff's Voltage LAW (= Mesh) (in series)
(Law of Conservation of energy)

$\boxed{\sum V \text{ at mesh} = 0}$

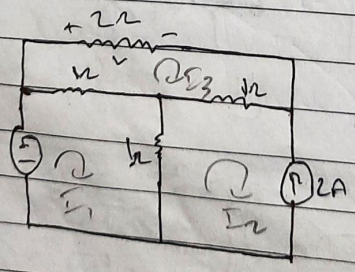
- In any closed circuit / mesh, algebraic sum of all EMFs & potential drops is 0.
  i.e. $\sum EMF + \sum IR = 0$



$\Rightarrow -V + V_R + V_L + V_C = 0$

$$\boxed{\Rightarrow V = iR + L\frac{di}{dt} + \frac{1}{C}\int i\,dt}$$

Q1)

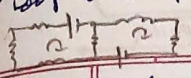


In I:
$-10 + 1(I_1 - I_3) + 1(I_1 - I_2) = 0$
$\Rightarrow 2I_1 - I_2 - I_3 = 10$

In II: $-2 + 1(I_2 - I_1) + 1(I_2 - I_3) = 0$
$\Rightarrow -I_1 + 2I_2 - I_3 = 2$

In III: $2I_3 + 1(I_3 - I_1) + 1(I_3 - I_2) = 0$
$\Rightarrow -I_1 - I_2 + 4I_3 = 0$

• Mesh – a closed path thru which current can thru ; but without any other closed path.
• Loop – a closed path thru which current can thru ; but with any other closed path.



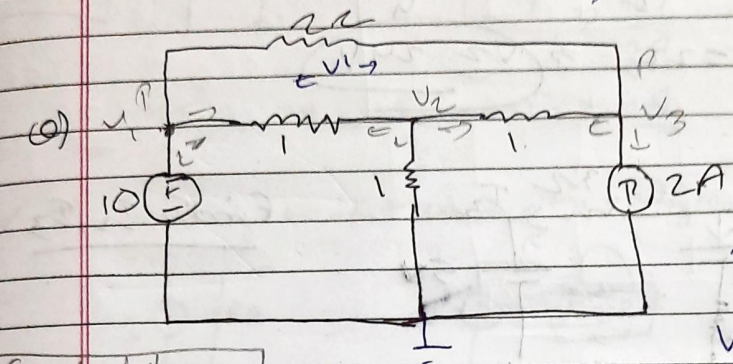
- 2 × Mesh
- 3 × Loop

Upon solving

$i_1 =$; $i_2 = -2A$; $i_3 = 4/7 A$.

$\Rightarrow V = I_3 R = \frac{8}{7} V$.

NODAL Analysis



$V_1 = 10 V$

In I

$\frac{V_2 - V_1}{1\Omega} + \frac{V_2 - 0}{1\Omega} + \frac{V_2 - V_3}{1\Omega} = 0$

$\Rightarrow \boxed{3V_2 - V_3 = 10}$

Overloaded at V_2

$\frac{V_2 - V_1}{1\Omega} + \frac{V_2 - 0}{1\Omega} + \frac{V_2 - V_3}{1\Omega} = 0$

resistance on the path

In II

$\frac{V_3 - V_2}{1\Omega} + \frac{V_3 - V_1}{2\Omega} - 2 = 0$

outgoing = +ve

$\Rightarrow \frac{2V_3 - 2V_2 + V_3 - V_1}{2} = 2$

$\cancel{\Rightarrow -V_1 + 2}$ $\boxed{\Rightarrow -V_1 - 2V_2 + 3V_3 = 4}$

$\boxed{\Rightarrow V_1 = 10V \;\Big|\; V_2 = \frac{37}{7} V \;\Big|\; V_3 = \frac{62}{7} V}$

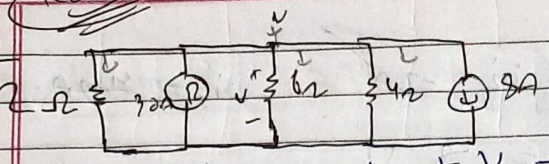
$\Rightarrow V' = V_1 - V_3 = 10 - \frac{62}{7} = \boxed{\frac{8}{7} V}$

• Parallel = KCL
• Series = KVL

Date
DELTA Pg No.

KCL

Q)

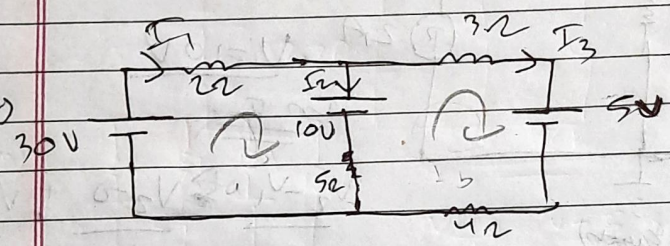


By KCL

$$\frac{V}{2} + \frac{V}{6} + \frac{V}{4} + 8 - 30 = 0$$

$$\Rightarrow \frac{11V}{12} = 22 \Rightarrow V = 24V$$

Q)



Find I_1, I_2, I_3

In I

$$2I_A - 5I_B = 20$$

In II

$$7I_B - 5I_A = 5$$

$$10I_A - 25I_B = 100$$
$$-10I_A + 14I_B = 10$$

$$I_B = -\frac{90}{11}$$

$$I_A = \frac{230}{22}$$

$$I_1 = I_2 + I_3 \rightarrow \text{I}$$

In I $\quad 2I_1 + 5I_2 = 20 \rightarrow \text{II}$

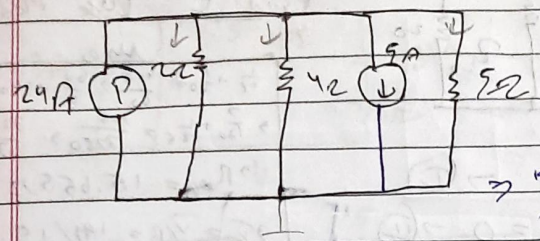
In II $\quad 7I_3 - 5I_2 = 5 \rightarrow \text{III}$

Solve,

$$I_1 = 4.5 \; ; \; I_2 = -2.2 \; ; \; I_3 = 2.3$$

- NODAL = KCL
- MESH = KVL

Q)



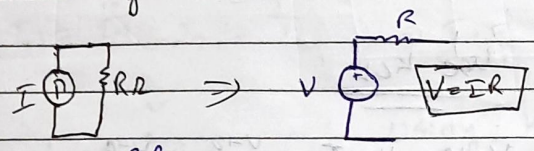
By KCL

$5 - 24 + \frac{V}{2} + \frac{V}{4} + \frac{V}{5} = 0$

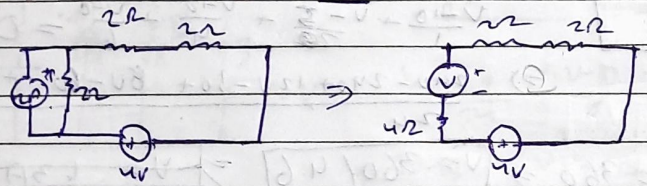
$\Rightarrow \frac{19V}{20} = 19 \Rightarrow V = 20V$

$\Rightarrow I_1 = 10A$; $I_2 = 5A$, $I_3 = 4A$.

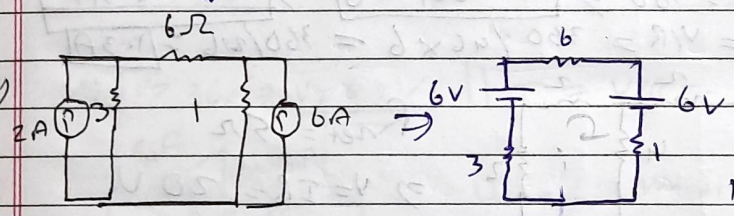
→ Converting current source to voltage.



Eg



Q)

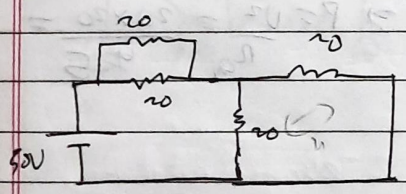


Find $I_{6\Omega}$

Cancel each other

$10i = 0 \Rightarrow i = 0A$

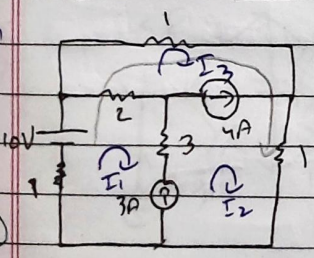
Q)



$R_{eq} = 20\Omega \Rightarrow I = \frac{50}{20} = 2.5A$

Superposition

Q)



Use KVL

From Ammeters,

$-I_2 - I_1 = 3 \Rightarrow \boxed{-I_1 + I_2 = 3}$ — (I)

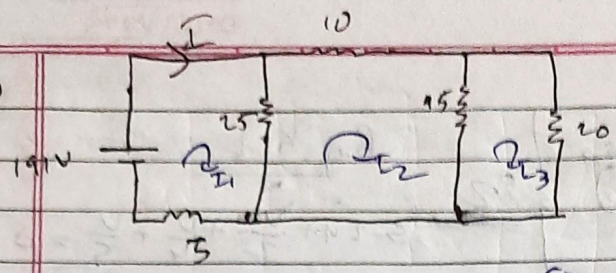
$-\boxed{I_2 - I_3 = 4}$ — (II)

From Big Loop $\Rightarrow \boxed{I_1 + I_3 + I_2 = 10}$ — (III)

$\Rightarrow \boxed{i_1 = \frac{8}{3} ; i_2 = \frac{17}{3} ; i_3 = \frac{5}{3}}$

- we donot use loops in i, & i, as we do not know the P.D. across Ammeters.

Q)



Find I use Mesh/KVL

In I → $30I_1 - 25I_2 = 191$ → (I)

In II → $50I_2 - 25I_1 - 15I_3 = 0$ → (II)

In III → $35I_3 - 15I_2 = 0$ → (III)

Ans Q.

$\frac{1}{5} + \frac{1}{30} = \frac{4\times3}{60} \Rightarrow \frac{60}{7} + 10 = \frac{130}{7}$

$\Rightarrow \frac{7}{130} + \frac{1}{25} = \frac{305}{3250} \Rightarrow \frac{3250}{305} + 5$

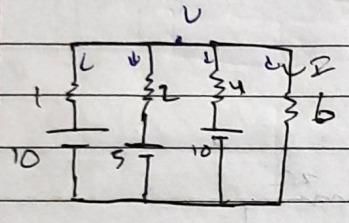
$\Rightarrow R_{eq} = 15.655\,\Omega$

$\Rightarrow I = V/R_{eq} = 191/15.655$

$\Rightarrow I = 12.2A$

$\Rightarrow I = i_1 = 12.2A.$

Q)



Use KCL

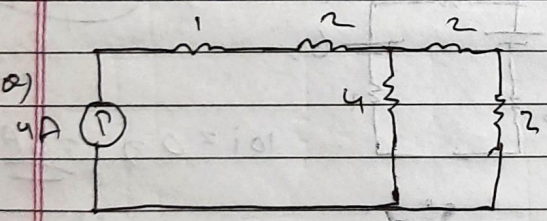
$\frac{V-10}{1} + \frac{V-5}{2} + \frac{V-10}{4} + \frac{V-0}{6} = 0$

$\Rightarrow \frac{24V - 240 + 12V - 60 + 6V - 60 + 4V = 0}{24}$

$\Rightarrow 46V = 360 \Rightarrow \boxed{V = 360/46} \Rightarrow \boxed{V = 1.3A}$

$\Rightarrow I = V/R = 360/46\times6 = 360/276 = \boxed{1.3A}$

Q)



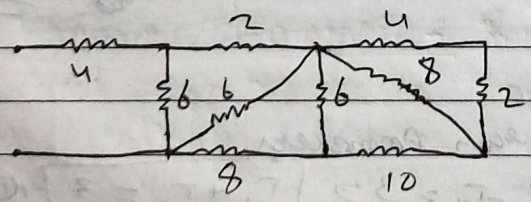
Find power across 4Ω

$R_{net} = 5\Omega$

$\Rightarrow V = IR = 20V$

$\Rightarrow P = \frac{V^2}{R_{eq}} = \frac{20\times20}{5} = 80W$

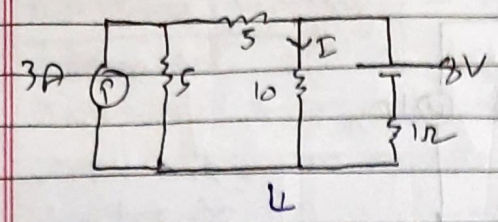
Q)



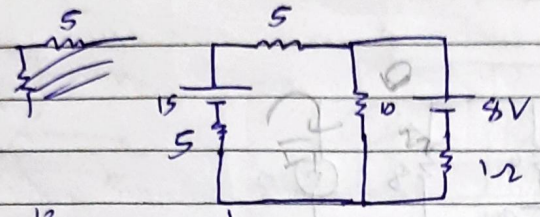
$R_{eq} = 7.2\Omega$

Date
DELTA Pg No.

Q)



Find I

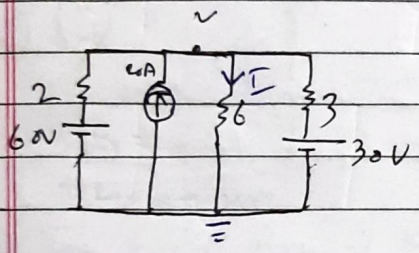


$20I_1 + 10I_2 = 15 \rightarrow (I)$

$11I_2 + 10I_1 = 8 \rightarrow (II)$

$I_1 = \frac{19}{24}$; $I_2 = \frac{1}{12}$; $\Rightarrow I_1 = I_1 + I_2 = 19/24 = 0.79A$.

Q)



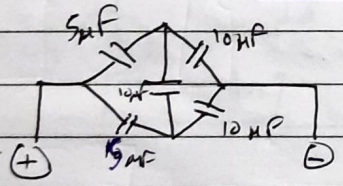
Using KCL find I

$\frac{V-60}{2} + \frac{V-0}{6} + \frac{V-30}{3} = 20$

$\Rightarrow \frac{3V-180+V+2V-60}{6} = 20$

$\Rightarrow 6V = 360 \Rightarrow V = 60V$ || $I = V/R = 60/6 = 10A$

Q)

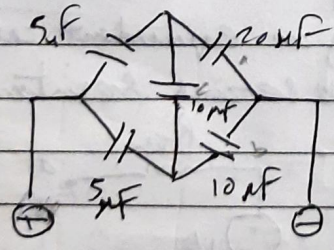


Using Wheatstone Bridge,

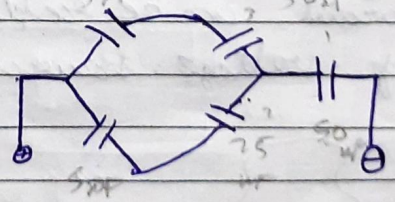
$\frac{1}{5} + \frac{1}{10} = \frac{3}{10} \Rightarrow \frac{10}{3} + \frac{10}{3}$

$\Rightarrow \boxed{C_{eq} = 20/3 \mu F}$

Q)

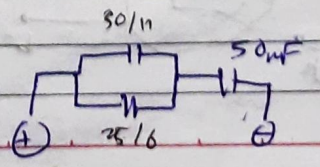


$\Rightarrow$



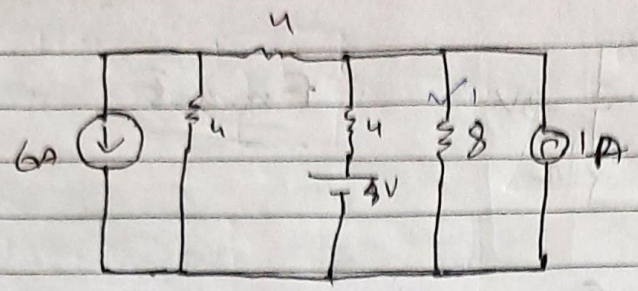
Now,

$\frac{30}{11} + \frac{25}{6} = \frac{300+275}{66} = \frac{575}{66}$

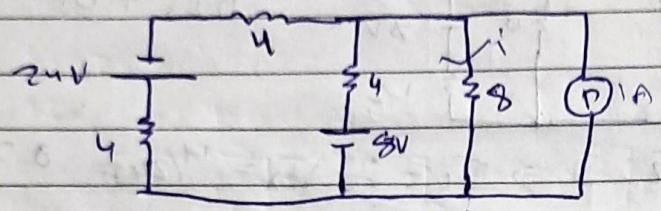


$\Rightarrow \frac{1}{C_{eq}} = \frac{66}{575} + \frac{1}{50} \Rightarrow \boxed{C_{eq} = 7.41 \mu F}$

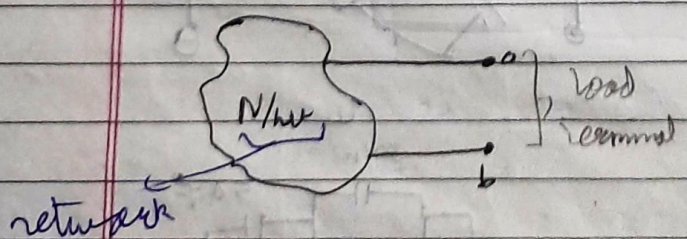
Q) Exam Ques)

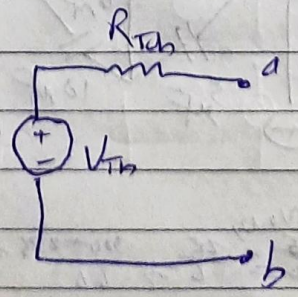


⇓

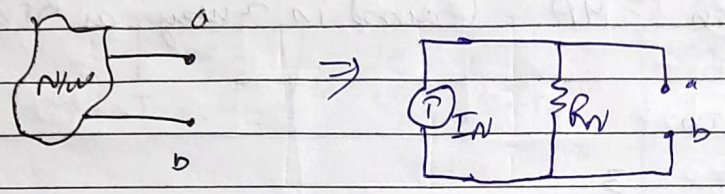


→ <u>Thevenin's Theorem</u> - any 2 terminal bilateral, linear in circuit can be replaced by an equivalent circuit consisting of voltage source with series resistance

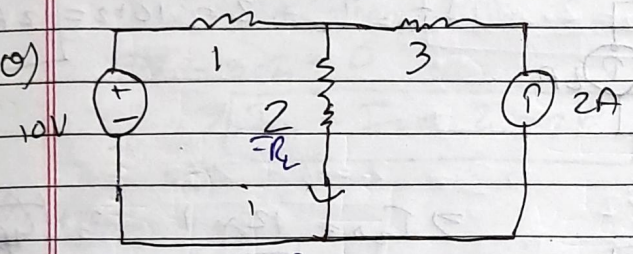




→ Norton's Theorem – A linear, active network consisting of independent and/or dependent voltage and current sources & linear, bilateral network elements can be replaced by an equivalent circuit consisting of a current source in parallel with equivalent resistance.



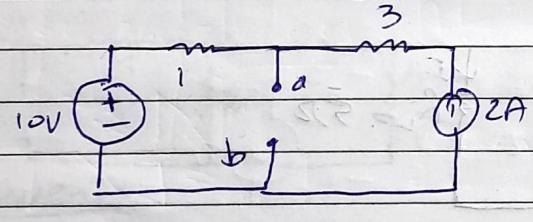
$R_{NORTON} = R_{THEVENIN}$

Q) 

• Find i by both Thevenin & Norton

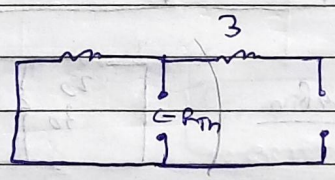
Thevenin

(a) To find R_{Th} → Short ckt the Voltage Src & Open ckt the Current Src

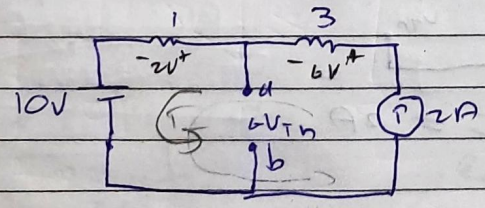


(a) For R_{Th} – as it is open ckt.

$R_{Th} = 1\Omega$.



(b) For V_{Th}



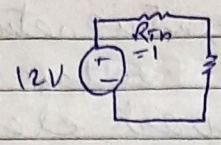
$-10 + 2 + V = 0$

$\Rightarrow -10 - 2 + V_{Th} = 0$

$\Rightarrow \boxed{V_{Th} = 12\,V}$

Date
DELTA Pg No.

(a) Find i



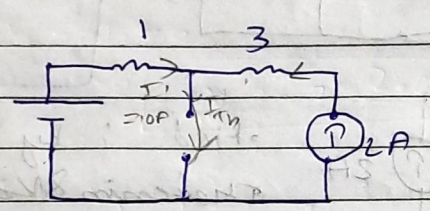
$\Rightarrow R_{eq} = 3\Omega \Rightarrow I = 12/3 = 4A$

$\boxed{\Rightarrow I_{Th} = 4A}$

→ NORTON'S

(a) $R_N = R_{Th} = 4A$ (found in same way as R_{Th})

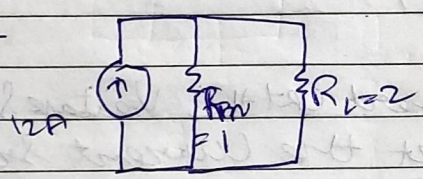
(b) For I_{Th}



$I_{Th} = I_n' + 2 = 10 + 2 = \boxed{12A}$

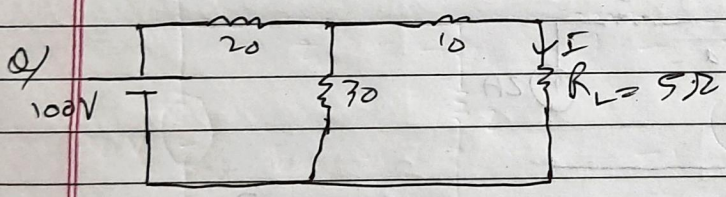
(Jain theory 2 pts)

(c) Find i

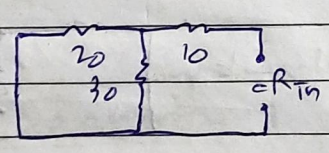


$\Rightarrow I_{eq} = \frac{12 \times 1}{1+2} = \boxed{4A}$

Q/



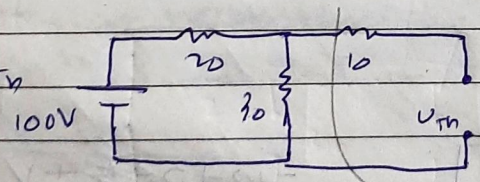
(a) For R_{Th}



$\frac{1}{20} + \frac{1}{30} = \frac{60}{5} = 12 + 10 = 22$

$\Rightarrow \boxed{R_{Th} = 22\Omega}$

(b) For V_{Th}



As it is open ckt, $V_{Th} = V_{30}$

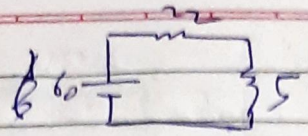
$R = 20 + 30 = 50 \Rightarrow I = 2A$

$\Rightarrow V_{30} = 60V$

$\Rightarrow V_{Th} = 60V$

Date
DELTA Pg No.

(a) Find i

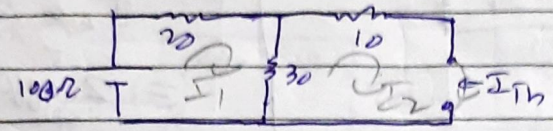


$\Rightarrow I = \frac{60}{27} = 2.2A$

→ NORTON

(a) $R_N = R_{Th} = 22\Omega$

(b) For I_{Th}



$50I_1 - 30I_2 = 100$

$40I_2 - 30I_1 = 0$

$\Rightarrow \boxed{I_{Th} = I_2 = 2.72A}$

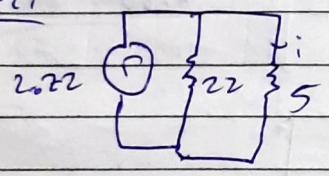
$150I_1 - 90I_2 = 300$

$-150I_1 + 200I_2 = 0$

$I_2 = 30/11$

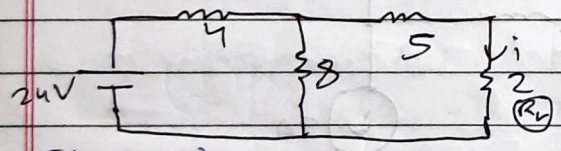
$= 2.72A$

(c) For i



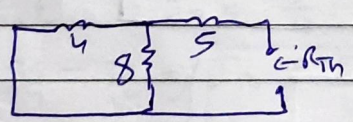
$\Rightarrow i = \frac{2.72 \times 22}{27} = 2.2A$

Q



Thevenin

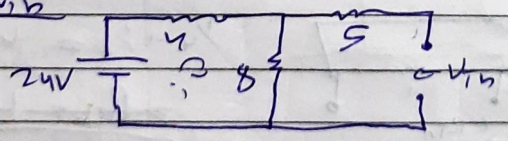
(a) For R_{Th}



$\frac{1}{4} + \frac{1}{8} = 3/8$

$\Rightarrow \boxed{R_{Th} = 23/3 = 7.67\Omega}$

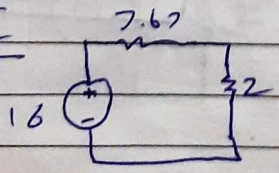
(b) For V_{Th}



$12i = 24 \Rightarrow i = 2A$

$\Rightarrow \boxed{V_{Th} = V_{ab} = 16V}$

(c) For I



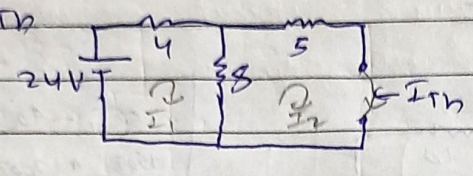
$\Rightarrow R_N = 9.67$

$\Rightarrow I = \frac{16}{9.67} = 1.65A$

Norton

(a) $R_N = R_{Th} = 7.67\Omega$

(b) For I_{Th}



$12I_1 - 8I_2 = 24$

$13I_2 - 8I_1 = 0$

$\Rightarrow \boxed{I_N = I_2 = 2.086A}$

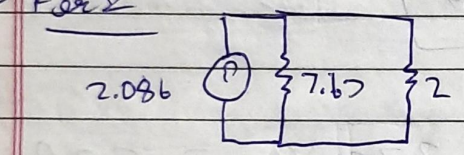
$24I_1 - 16I_2 = 48$

$-24I_1 + 39I_2 = 0$

$I_2 = 48/23$

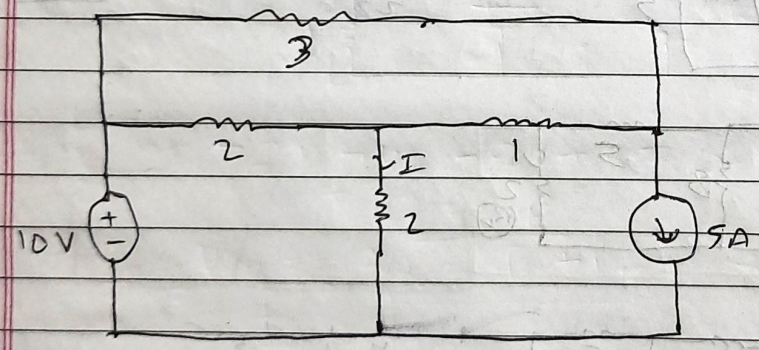
$= 2.086A$

(c) For I



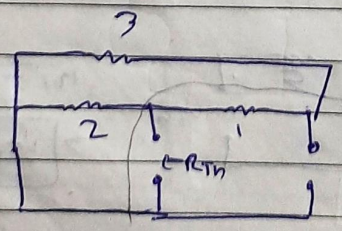
$\Rightarrow I = \frac{2.086 \times 7.67}{9.67} \Rightarrow \boxed{I = 1.65A}$

(a)



Thevenin

(a) For R_{Th}



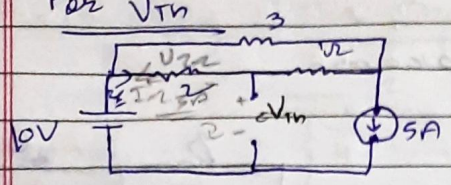
$1/4 + 1/2 = 4/3$

$\Rightarrow R_{Th} = 1.33A$

$\boxed{R_{Th} = 1.33\Omega}$

Date
DELTA Pg No.

(b) For V_{Th}

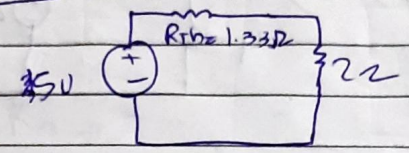


$V_{22} = 2 \times 2.5A = 5A$

$10 - 5 - V_{Th} = 0$

$\Rightarrow \boxed{V_{Th} = 5V}$

(c) For I



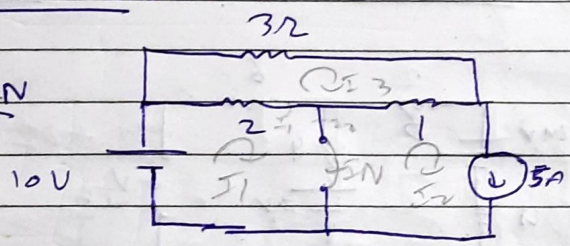
$\Rightarrow R_{eq} = 3.33\,\Omega \Rightarrow I = \frac{5}{3.33}$

$\Rightarrow \boxed{I = 1.5A} \rightarrow I_{Th} = 1.5A$

→ Norton

(a) $R_N = R_{Th} = 1.33\,\Omega$

(b) For I_N



$I_1 = I_2 + I_3 \rightarrow (I)$

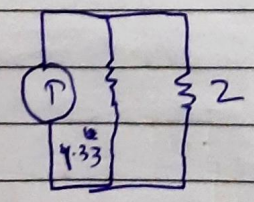
$2I_1 - 2I_3 = 10 \rightarrow (II)$

$-2I_1 - I_2 + 6I_3 = 0 \rightarrow (III)$

$I_1 = \frac{35}{4}A$; $I_2 = \frac{20}{4}A$; $I_3 = \frac{15}{4}A$ $\quad \| I_N = I_1 - I_2$

$\Rightarrow I = \frac{35}{4} - \frac{20}{4} \Rightarrow \boxed{I_N = \frac{15}{4}} = 3.75A$

(c) For I

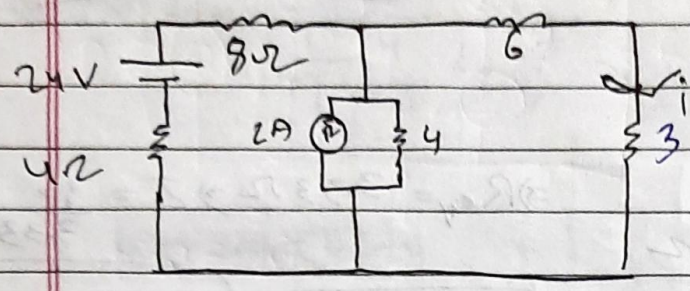


$\cancel{\Rightarrow I = \frac{3.75 \times 4.33}{6.33} = 2.56A}$

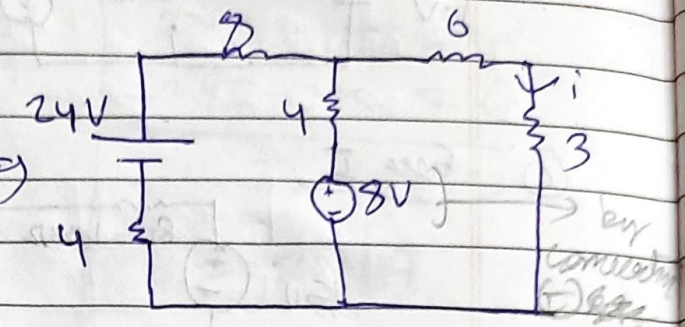
$I = \frac{3.75 \times 1.33}{3.33} = \boxed{1.5A}$

Date
DELTA Pg No.

Q Solve by Thevenin's Theorem -

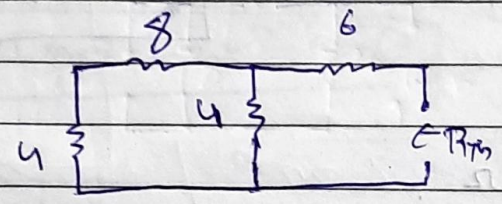


⇒



Now,

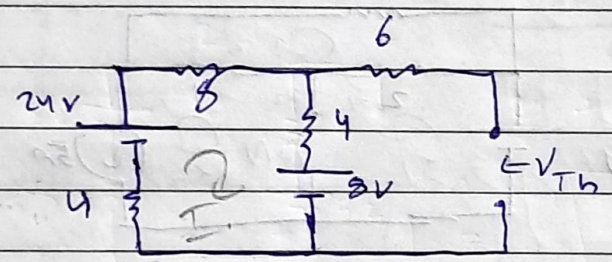
(a) For R_{Th}



$\frac{1}{12} + \frac{1}{4} = \frac{4}{12} \Rightarrow 3+4$

$\Rightarrow R_{Th} = 9\Omega$

(b) For V_{Th}



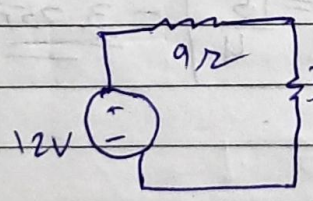
$4I - 8I - 4I - 24 + 8 = 0 \Rightarrow 16I = 16$

$\Rightarrow I = 1A$

$\Rightarrow V_{Th} = V_{8V} \Rightarrow V_{8V} = E_{8V} + I_4 = 8 + 4I = 8 + 4 = 12V$

(as E is flowing into it)

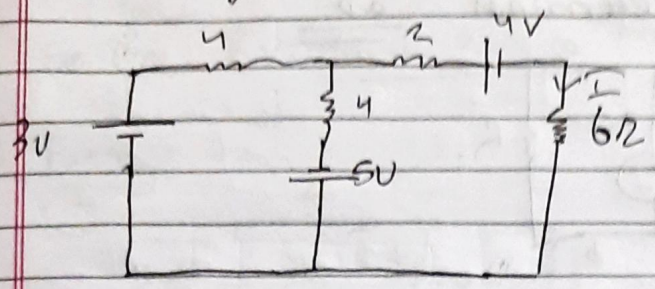
(c) For I



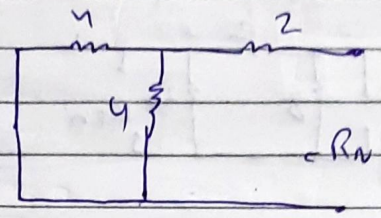
$3\Omega \Rightarrow I = \frac{12}{12} = 1A$

Date
DELTA Pg No.

Q) Solve By Norton's Theorem



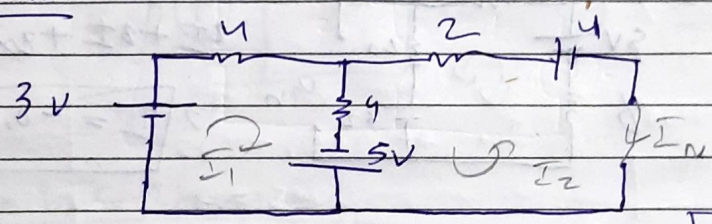
(a) For R_n →



$\frac{1}{4}+\frac{1}{4} = 2+2 = 4$

$\Rightarrow R_N = 4\Omega$

(b) For I_n



$8I_1 + 4I_2 = 8$ — (I)

$6I_2 - 4I_1 = 4$ — (II)

$\Rightarrow I_N = -I_2 = -1.25A$

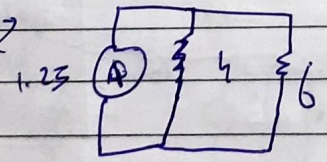
$8I_1 + 4I_2 = 8$

$8I_1 + 12I_2 = 12$

$8I_2 = 10$

$\Rightarrow I_2 = 1.25A$

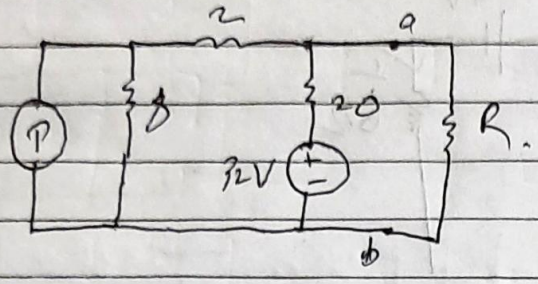
(c) For I →



$\Rightarrow I_{6\Omega} = \frac{-1.25 \times 4}{10} = -1/2\ A$

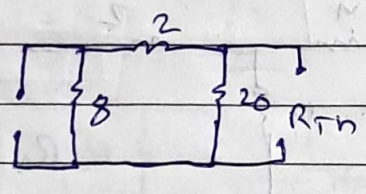
Date
DELTA Pg No.

Q Find the Thevenin & Norton eq. of the ckt. shown in fig as seen at terminal ab



Thevenin

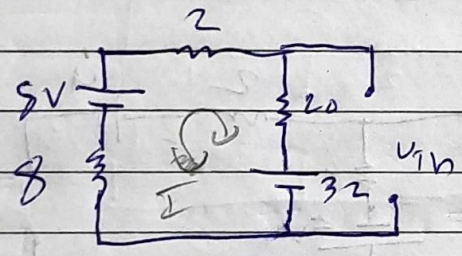
(a) For R_{Th}



$\Rightarrow \frac{1}{10} + 1/20 = 20/3\ \Omega$

$\Rightarrow \boxed{R_{Th} = \frac{20}{3}\ \Omega}$

(b) For V_{Th}

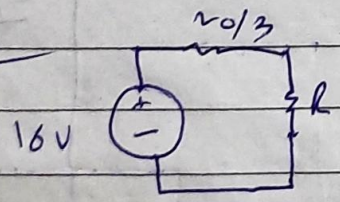


$2I + 8I + 20I = -24$

$\Rightarrow \boxed{I = -0.8A}$

$\Rightarrow V_{Th} = V_{20} \Rightarrow 20I + 32 = 20 \times (-0.8) + 32 = \underline{16V}$

(c) For I



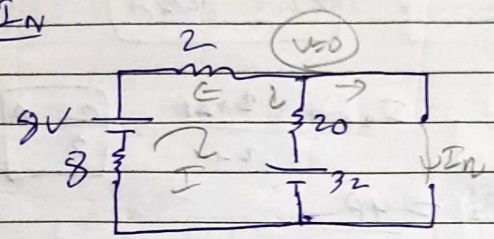
$\Rightarrow$ This is thevenin eq

Date
DELTA Pg No.

Norton

(a) For R_N; $R_N = R_{Th} = 20/3\,\Omega$

(b) For I_N



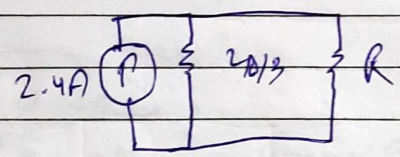
By KCL

$\Rightarrow \frac{0-8}{10} + \frac{0-32}{20} + I_N = 0$

$\Rightarrow I_N = \frac{8}{10} + \frac{32}{20} = \frac{48}{20}$

$\Rightarrow \boxed{I_N = 2.4A}$

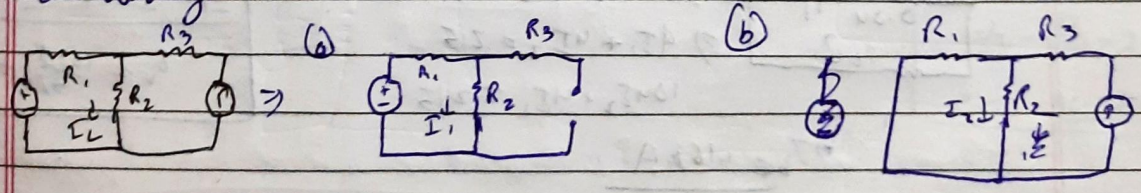
(c) For E



Norton eq

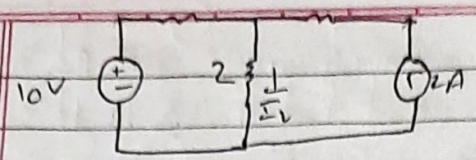
→ Super Position Theorem

- In any linear, active, bilateral network consisting of ~~not~~ numberg resistances, energy sources etc, the effect produced in any element when all sources are act at a time is equal to sum of effects produced in same element when each source is considered individually.

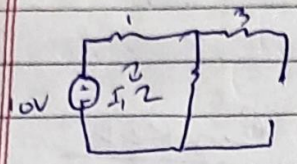


$\Rightarrow \boxed{I_L = I_1 + I_2}$

a)



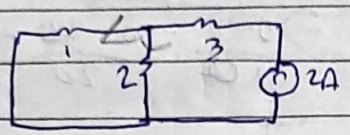
(a)



$\Rightarrow 3I_1 = 10$

$\boxed{\Rightarrow I_1 = 10/3\,A}$

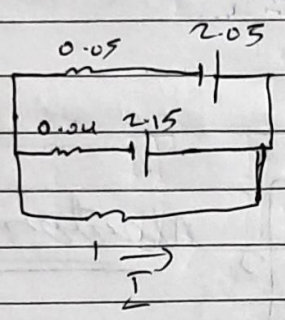
(b)



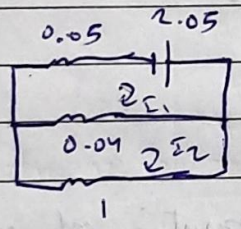
$I_2 = \frac{2 \times 1}{2+1} = \boxed{\frac{2}{3}\,A}$

$\Rightarrow I_2 = I_1 + I_2 = \underline{4A}$

c)



(a)



$0.04I_1 - 0.04I_2 = 2.05$

& $1.04I_2 - 0.04I_1 = 0$

$\Rightarrow 9I_1 - 4I_2 = 205$

& $104I_2 - 4I_1 = 0$

$\Rightarrow I_a = I_2 = \underline{0.88A}$

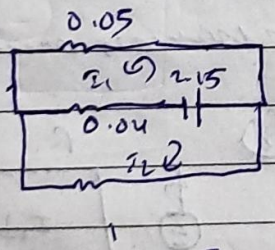
$36I_1 - 16I_2 = 820$

$\Rightarrow 36I_1 + 936I_2 = 0$

$I_2 = \frac{820}{936}$

$= 0.88$

(b)



$0.04I_1 + 0.04I_2 = 2.15$

& $1.04I_2 + 0.04I_1 = 2.15$

$\Rightarrow 9I_1 + 4I_2 = 215$

$104I_2 + 4I_1 = 215$

$\Rightarrow I_b = \underline{1.168A}$

$36I_1 + 16I_2 = 860$

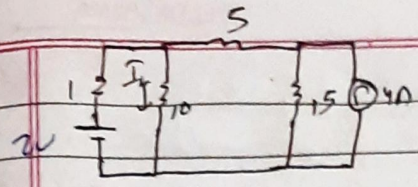
$36I_1 + 936I_2 = 1935$

$I_2 = \frac{1075}{820} = 1.168$

$\Rightarrow I' = I_a + I_b = 2.048A \approx \underline{2.05A}$

Date
DELTA Pg No.

a)



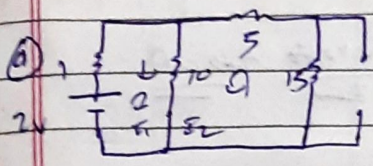
$93I_1 + 30I_2 = 6$

$15I_1 + 30I_2 = 0$

$I_1 = 6/23 = 0.26$

$I_2 = \cancel{-15/23} = 0.086$

a)

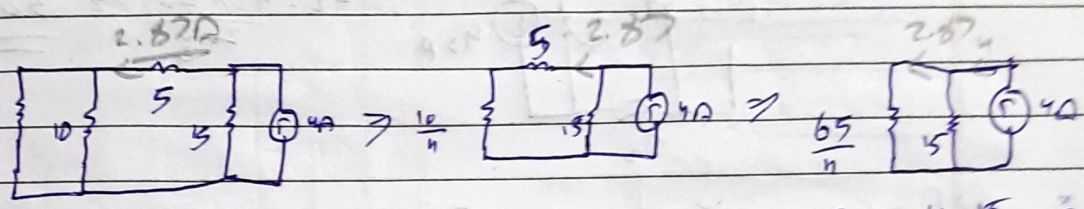


$11I_1 + 10I_2 = 2$

$30I_2 + 10I_1 = 0$

$\Rightarrow I_a = I_1 + I_2 = 0.174A$

b)



$I_{10} = \frac{2.87 \times 1}{11} = 0.26A$

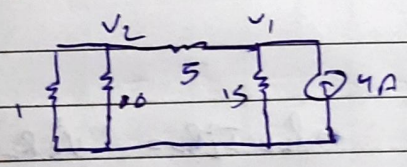
$I_{\frac{65}{11}} = \frac{4 \times 15}{\frac{15}{11} + 50} = 0.570$

$\Rightarrow I_b = 0.26A$

$\Rightarrow I_L = 0.26 + 0.174 = 0.434A$

or

b)



(I) $\frac{V_1 - V_2}{5} + \frac{V_1}{15} = 4 \Rightarrow 4V_1 - 3V_2 = 60$

(II) $\frac{V_2}{1} + \frac{V_2 - V_1}{5} + \frac{V_2}{10} = 0 \Rightarrow 13V_2 - 2V_1 = 0$

$\Rightarrow I_{10} = \frac{2.6}{10} = 0.26A$

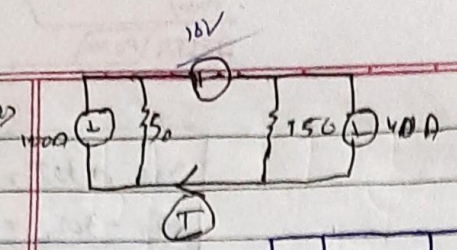
$-4V_1 + 26V_2 = 0$

$4V_1 - 3V_2 = 60$

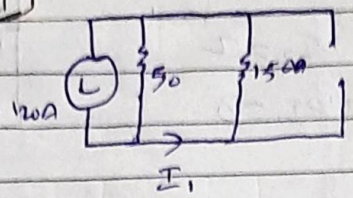
$V_2 = \frac{60}{23} = 2.6V$

$V_1 = 16.48V$

(c)

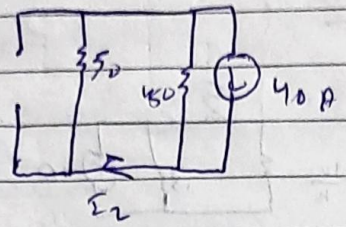


(a) For 120A



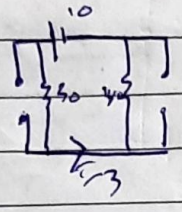
$\Rightarrow I_1 = \frac{120 \times 50}{200} = 30A$

(b) For 40A



$I_2 = \frac{40 \times 150}{200} = 30A$

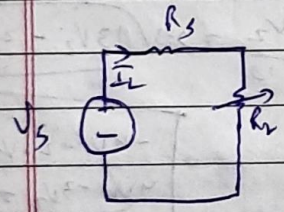
(c) For 10V



$\Rightarrow I_3 = \frac{10}{200} = -0.05A$

$\Rightarrow I = I_1 + I_2 - I_3 = -30 + 30 - 0.05 = -0.05A$

→ Maximum Power Transfer Theorem



$I_L = \frac{V_s}{R_s + R_L}$ $\Rightarrow P_L = I_L^2 R_L = \frac{V_s^2 R_L}{(R_s + R_L)^2}$

Taking derivative,

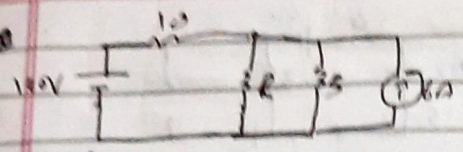
$\frac{d}{dR_L} P_L = \frac{d}{dR_L}\left(\frac{V_s^2 R_L}{(R_s + R_L)^2}\right) \Rightarrow \boxed{P_{max} = \frac{V_s^2}{4R_s}}$

• For max power, R_L should be equal to $R_s = R_{thevenin}$

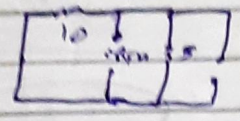
& $V_s = V_{thevenin}$

• Efficiency $= \frac{P_L}{P_T} =$ max 50%

a)



(a) For R_{Th}



$\frac{1}{10}+\frac{1}{5} \Rightarrow R_{Th} = 10/3\,\Omega$

(b) For V_{Th}

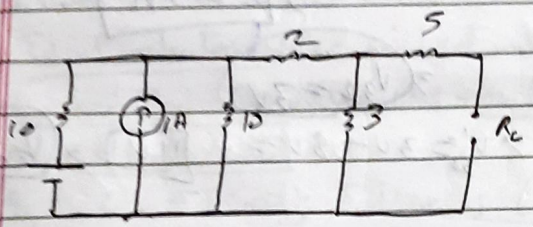
KCL $= 40 \Rightarrow I = 6A$

From II

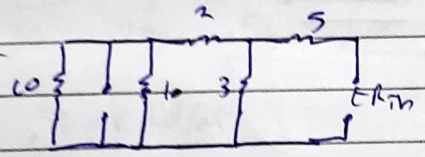
$-120 + 60 + V_{Th} = 0 \Rightarrow V_{Th} = 60V$

$\Rightarrow P_{max} = \frac{60 \times 60}{4 \times 10} \times 3 = 270\,W$

b)



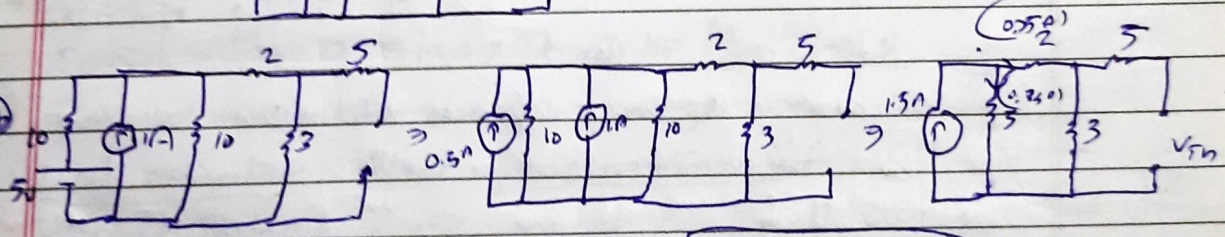
(a) For R_{Th}



$\frac{1}{7}+\frac{1}{3} \Rightarrow \frac{21}{10}+5$

$R_{Th} = 21/10\,\Omega$

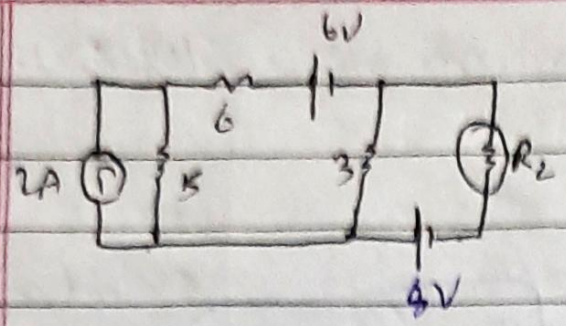
(b)

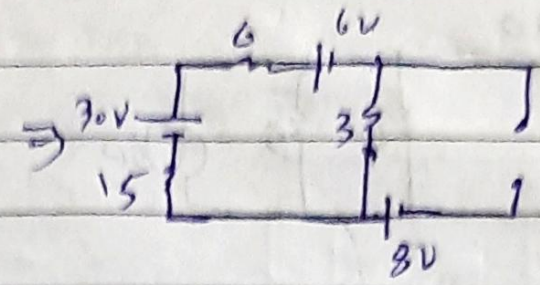


$I_{3\Omega} = 0.75A \Rightarrow V_{3\Omega} = 0.75 \times 3 = 2.25V \Rightarrow V_{Th} = V_{3\Omega} = 2.25V$

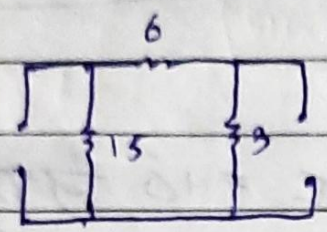
$\Rightarrow P = \frac{2.25 \times 2.25 \times 10}{4 \times 21} = 0.173\,W$

9



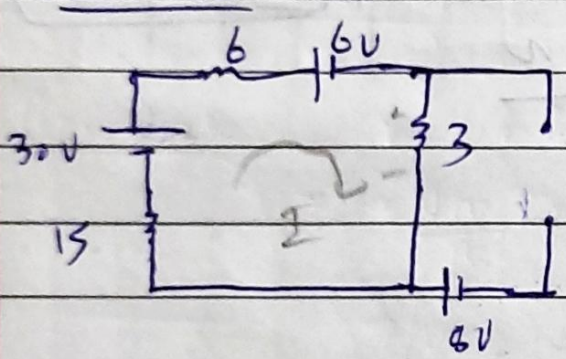


(a) For R_{Th}



$\frac{1}{3} + \frac{1}{21} \Rightarrow R_{Th} = 21/8\ \Omega$

(b) For V_{Th}



$24I = 24 \Rightarrow I = 1A$

$\Rightarrow V_{3\Omega} = 3V$

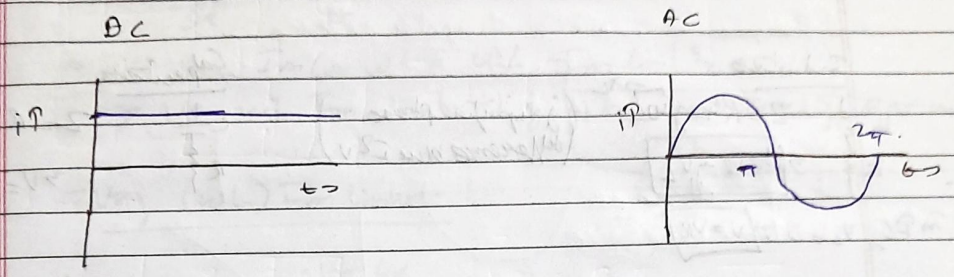
$\Rightarrow V'_{3\Omega} = 3V + 8V = 11V \Rightarrow V_{Th} = 11V$

$\Rightarrow P_{max} = \frac{11 \times 11 \times 8}{4 \times 21} = 11.52W$

• π radians = 180°

Date
DELTA Pg No.

UNIT - II → Steady State Analysis



→ **Inductor** • $V = L\,di/dt$

For DC Supply ; $\frac{di}{dt} = 0 \Rightarrow V = 0 \Rightarrow$ Inductor acts as Short Ckt For DC

- L will never allow sudden change in Current
- Ideal inductors are called wire with 0 internal resistance
- Practical Inductor will have small internal resistance in series to winding / coil.
- eg - Choke coil ; Filter ; Current limiting Reactor ; Transformer

$X_L = L\omega$ (Inductive Reactance)

(in Ω) ; L → Henry ; ω → Hz

$\boxed{\omega = 2\pi f}$ $\boxed{= 2\pi/T}$

→ **Capacitor** • $i = C\,dV/dt$

For DC → $\frac{dV}{dt} = 0 \Rightarrow i = 0 \Rightarrow$ It acts as Open Circuit

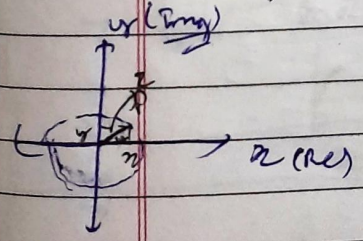
- Does not allow sudden change in voltage across it.
- Ideal capacitor will have infinite resistance in parallel
- In practical capacitor, Resistance, very high & in parallel with C.
- Uses - Filters, Power Factor Current

→ Rectangular Form & Euler Form

Rectangular form = $x + iy$

Euler Form = $r\angle\theta$

$r = \sqrt{x^2+y^2}$; $\theta = \tan^{-1}(y/x)$



• $V_{rms} = \frac{V_m}{\sqrt{2}}$ (rms) (root mean square)

Date
DELTA Pg No.

eg ⇒ $3+4j$; $r = \sqrt{3^2+4^2} = 5$; $\theta = \tan^{-1}(4/3) = 53.13°$

⇒ Euler Form ⇒ $5 \times 53.13° =$ ~~ab~~

Inductor

L, R: $Z = R + j\overset{\to X_L}{\omega L}$ (j signifies phase difference b/w I & V)

⇒ $\boxed{V = V_R + jV_L}$

Capacitor

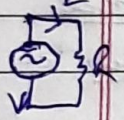
C, R: $Z = R - \underbrace{\frac{j}{\omega C}}_{\to X_C}$

⇒ $V = V_R - jV_C$

In DC, $V_L = 0$ ⇒ $\boxed{V = V_R}$

→ Relation Between V & I in Passive Elements

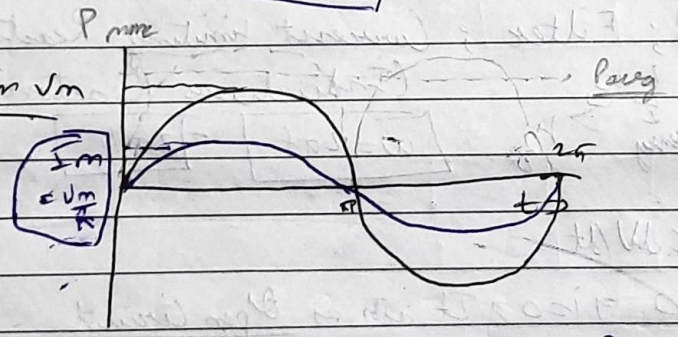
(I) Resistor $V = V_m \sin\omega t$



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

⇒ $\boxed{V = IR}$; no phase difference

Phasor Diagram V_m



$P = VI\cos\phi$ (ϕ = phase diff. b/w V & I = 0 in Resistor) ⇒ $P = VI$

⇒ $P_{avg} = \frac{1}{T}\int_0^T V_m I_m \sin^2\omega t \, dt$.

⇒ $P_{avg} = \frac{V_m I_m}{2\pi}\int_0^{\pi}(1-\cos 2\omega t)\, d\omega t = \frac{V_m I_m}{2\pi}\int_0^{\pi}[1 d\omega t - \int \cos 2\omega t \, d\omega t]$

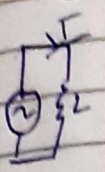
$= \frac{V_m I_m}{2\pi}[\pi - 0] \Rightarrow \boxed{P_{avg} = \frac{V_m I_m}{2}}$

⇒ $P_{avg} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$ ⇒ $\boxed{P_{avg} = V_{rms} \times I_{rms}}$

$\theta_e = \frac{P}{2}\theta_m$ (mech. degrees) ; P = number of poles
(electrical degrees)

Date
DELTA Pg No.

(2) Inductor Let $I = I_m \sin \omega t$



$\Rightarrow V = L\frac{dI}{dt} = L\frac{d}{dt} I_m \sin \omega t = L I_m \omega \cos \omega t$

$\Rightarrow V = \omega L I_m \cos \omega t = \omega L I_m \sin(\frac{\pi}{2} + \omega t)$.

$\Rightarrow V = j\omega L I_m \sin(\omega t)$ j represents phase diff. of 90° b/w V & I

$\Rightarrow V = j(\omega L) I_m \sin \omega t$

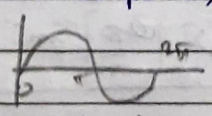
NOTES

→ Alternating Quantity – quantity which changes its magnitude continuously & direc^n periodically

→ Alternating Voltage – may be generated by:
① Rotating coil in stationary magnetic field
② Rotating magnetic field within a coil.
The value of voltage generated depends on:
① number of turns in coil
② Strength of field
③ speed with which coil / field rotates.
(a) Flux = max = plane of coil ⊥ to direc^n of flux b/w poles
(b) Flux = 0 = when plane of coil is horizontal.

→ Advantages of sine wave – ① can be expressed in simple mathematical form
② Rate of change of sinusoidal wave is also sinusoidal

→ Cycle – one complete set of +ve & -ve values at regular intervals.



← 1 cycle

• $a \pm jb$ for lagging/leading | +ve = leading curr^n
-ve = lagging curr^n

Constant term

• b is leading/lagging a by 90° || $\phi = \tan^{-1}(b/a)$

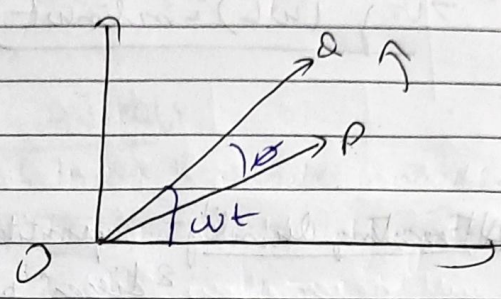
$V_1 = V_m \angle 0$
$V_2 = V_m \angle \alpha$ (V_2 leads V_1 by α)

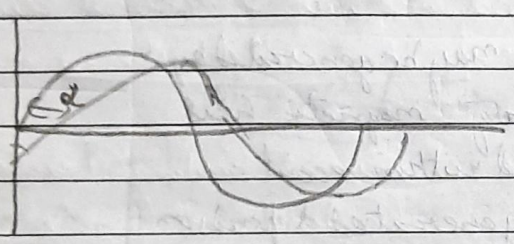
→ **Periodic Time** – Time taken to complete 1 cycle
· Unit is s · Denoted by T

→ **Frequency** – number of cycle per sec.
$f = 1/T$ ⇒ $T = 1/f$ · Unit is Hz
· $\omega = \frac{2\pi}{T} = 2\pi f$ (radian).

→ **Phase Difference**
· Anti Clockwise = +ve

· OP is lagging OQ by ϕ
· OQ leads OP by ϕ



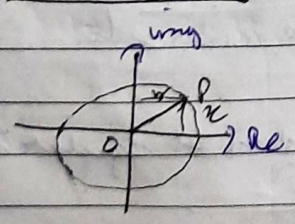


· A leads B
· B lags A
· Phase diff. = α.

To convert · to sec

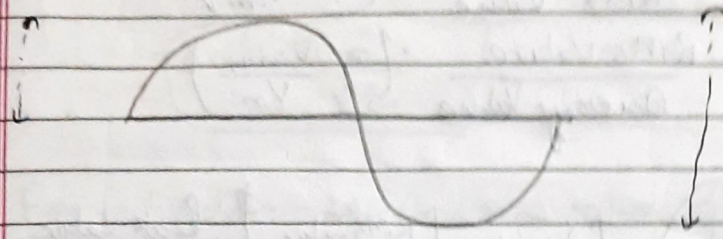
$\alpha = \omega t$ ⇒ $t = \alpha/\omega$ ⇒ $\boxed{t = \frac{\alpha T}{2\pi}}$; α = Phase Diff in °

→ **Phasor Notation**



Rectangular Form
$P = x + iy$
Euler Form $= re^{i\theta}$
$r = \sqrt{x^2+y^2}$; $\theta = \tan^{-1}(y/x)$

→ Measurements of AC Magnitude

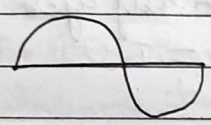


V_0 = Peak Voltage

$V_{rms} = V_0/\sqrt{2} = 0.707\ V_0$

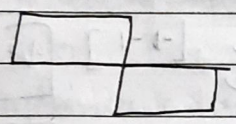
V_{avg} (or V_{mean}) $= V_0 \cdot 2/\pi = 0.637\ V_0$

(1)



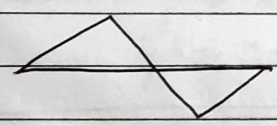
RMS = 0.707 (Peak)
AVG = 0.637 (Peak)
P-P = 2 (Peak)
} Sinusoidal Wave

(2)



RMS = 1 × (Peak)
AVG = 1 × (Peak)
P-P = 2 (Peak)
} Square Wave

(3)



RMS = 0.577 (Peak)
AVG = 0.5 (Peak)
PP = 2 (Peak)
} Triangle Wave

→ Sinusoidal Wave

$i = I_m \sin \omega t$

- Mean ~~Average Value~~

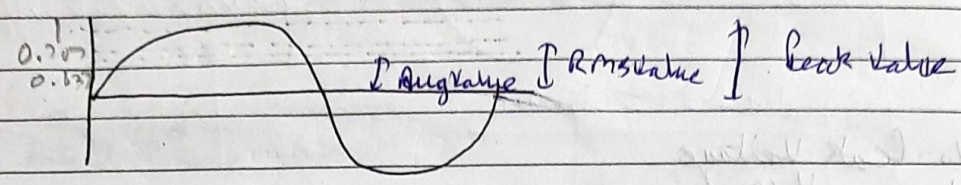
$$\Rightarrow I_{rms} = \left[\frac{1}{T}\int_0^T (i)^2\,dt\right]^{1/2}$$

$$= \left[\frac{1}{T}\int_0^T I_m^2 \sin^2 \omega t\,dt\right]^{1/2} = \left[\frac{1}{T}\int_0^T \frac{I_m^2}{2}(1-\cos 2\omega t)\,dt\right]^{1/2}$$

$$= \left[\frac{I_m^2}{2T}\left[1 - \frac{\sin 2\omega t}{2\omega}\right]_0^T\right]^{1/2} = \left[\frac{I_m^2}{2T}\left[\frac{T}{2} - 0\right]\right]^{1/2}$$

$$\Rightarrow \boxed{I_{rms} = \frac{I_m}{\sqrt{2}}}$$

- Peak Factor = $\frac{\text{Maximum Value}}{\text{RMS Value}}$ $\left(= \frac{V_0}{V_{rms}}\right)$
- Form Factor = $\frac{\text{RMS Value}}{\text{Average Value}}$ $\left(= \frac{V_{rms}}{V_m}\right)$



→ Mean/Average Value – it is that DC which flows same amount of charge in same time as flown by AC in half cycle

$\because I = dq/dt \Rightarrow dq = I\,dt$

$\Rightarrow q = \int_0^{T/2} I_0 \sin\omega t\, dt$

$\Rightarrow q = -\frac{I_0}{\omega} \left[\cos\omega t\right]_0^{T/2} = \frac{-I_0}{\omega}\left[-0-1\right] \Rightarrow \boxed{q = \frac{2I_0}{\omega}}$

Acc. to Defin^n $\Rightarrow I_m \cdot \frac{T}{2} = \frac{2I_0}{\omega} \Rightarrow I_m \frac{T}{2} = \frac{2I_0}{2\pi} \cdot T$

$\Rightarrow \boxed{I_m = \frac{2I_0}{\pi} = 0.637 I_0}$

→ Rms Value – it is that DC which will produce same amount of heat (across a resistor or network) as produced by ~~an~~ AC in 1 cycle.

$dH = I^2 R\,dt \Rightarrow dH = (I_0 \sin\omega t)^2 R\,dt = I_0^2 R \sin^2\omega t\, dt$

Integrating,

$H = \int_0^T I_0^2 R \sin^2\omega t\, dt = I_0^2 R \int_0^T \sin^2\omega t\, dt$

$\Rightarrow H = \frac{I_0^2 R}{2}\left[\int_0^T (1 - \cos 2\omega t)\, dt\right] \Rightarrow H = \frac{I_0^2 R}{2}\left[T - \frac{1}{2\omega}\left[\sin 2\omega t\right]_0^T\right]$

$\Rightarrow \boxed{H = \frac{I_0^2 R\, T}{2}}$

- $V(t) = V_0 + V_1 \sin\omega t + V_2 \sin 2\omega t$
- $V_{avg} = V_0$ (∵ in AC, avg = 0)
- $V_{rms} = \sqrt{V_0^2 + \left(\frac{V_1}{\sqrt{2}}\right)^2 + \left(\frac{V_2}{\sqrt{2}}\right)^2}$

Date
DELTA Pg No.

Acc. to Def^n ⇒ $I_0^2 R T = I_{eff}^2 R T$

$$\Rightarrow \boxed{I_{eff} = \frac{I_{max}}{\sqrt{2}}} = 0.707 I_0$$

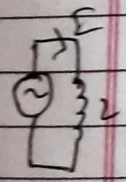
→ Form Factor - defined as ratio of Effective Value to average value of an alternating quantity. (rms/avg)

→ Operator j

- An Alternating I or V is a phasor quantity, but since the instantaneous values are changing continuously, it must be represented by a rotating vector phasor
- A phasor is a vector rotating with constant ω.

$j = 1$ angle of $90°$
$j^2 = 2$ angles of $90° = 180°$
$j^4 = 4$ angles of $90° \times 3 = 360°$

→ circuit with pure L



$V = V_m \sin\omega t$ → applied voltage

Let induced voltage be V'

$$\Rightarrow V' = -L\frac{di}{dt} = -V \Rightarrow di = \frac{1}{L}\int V\,dt$$

Now, Integrating,

$$I = \frac{1}{L}\int V_m \sin\omega t\,dt \Rightarrow I = \frac{V_m}{L\omega}\left[-\cos\omega t\right]$$

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

$\Rightarrow X_L = L\omega$

→ V leads I by 90°

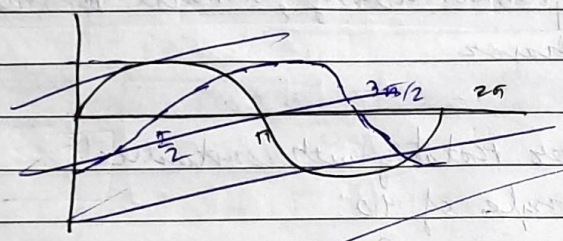
Impedance $= Z = \frac{E}{I} = \frac{V}{E} = \frac{(V_m/\sqrt{2})\angle 0}{(I_m/\sqrt{2})\angle -\frac{\pi}{2}} = \frac{E_m}{I_m}\angle \frac{\pi}{2}$

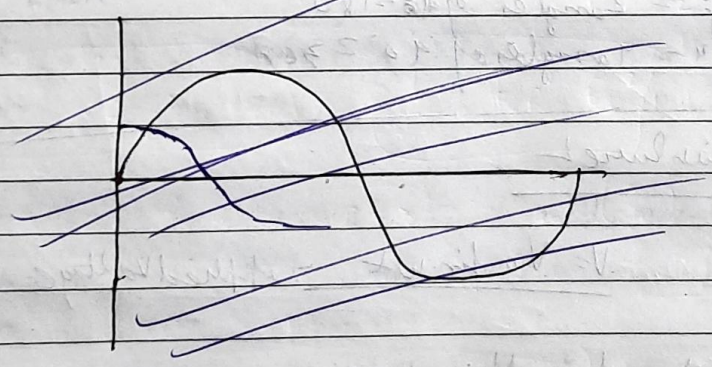
$\Rightarrow Z = \omega L \angle \frac{\pi}{2} \Rightarrow \boxed{Z = X_L = j\omega L}$

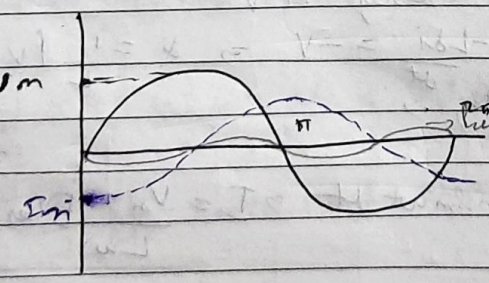
$X_L = \omega L$ → Henry (Ω)

$\frac{\pi}{2}$ rad/sec

→ Phasor Diagram







Average Power

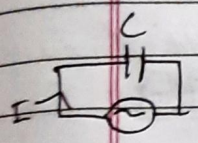
$$P = \frac{1}{2\pi}\int_0^{2\pi} V_i \, d(\omega t) = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \, I_m \sin(\omega t - \pi/2) \, d(\omega t)$$

$$\Rightarrow P = \frac{V_m I_m}{4\pi}\int_0^{2\pi} \sin(2\omega t) \, d(\omega t) = 0$$

→ Power consumed in a purely inductive ckt = 0

- Power is periodic with twice the supply frequency.
  ie energy is stored in one quarter, released in next.

→ Circuit with pure capacitor



$$V = V_0 \sin\omega t$$

$$I = C\frac{dV}{dt} = \omega C \frac{d}{dt} V_0 \sin\omega t$$

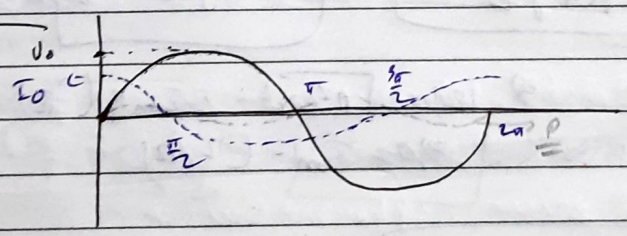
$$\Rightarrow I = \omega C V_0 \cos\omega t$$

$$\Rightarrow \boxed{I = \frac{V_0}{1/C\omega} \sin(\omega t + \pi/2)}$$

$$\boxed{X_C = \frac{1}{C\omega}}$$ • Capacitive Reactance

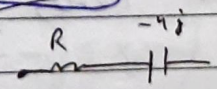
$$\Rightarrow \boxed{I = I_0 \sin(\omega t + \pi/2)}$$

Phasor



$$Z = \frac{V}{I} = \frac{(V_0 \angle 0)\Omega}{(I_0 \angle 90)\Omega} \Rightarrow \boxed{Z = \frac{V_0}{I_0} \angle -90^\circ}$$

$$\Rightarrow Z = X_C \angle -90^\circ$$
$$= -jX_C \, \Omega$$



$Z = R - j4$

Average Power

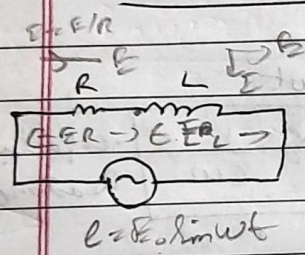
$$P = \frac{1}{2\pi}\int_0^{2\pi} V_i \, d(\omega t) = \frac{1}{2\pi}\int_0^{2\pi} V_0 \sin\omega t \cdot I_0 \sin(\omega t + \pi/2)$$

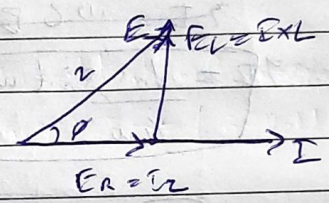
$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{V_0 I_0}{2} \cdot 2\sin\omega t \cos\omega t \, d\omega t = \frac{1}{2\pi} \cdot \frac{V_0 I_0}{2} \int_0^{2\pi} \sin 2\omega t \, d\omega t$$

$$= 0$$

- Power consumed in a purely capacitive ckt = 0
- Capacitor recieves energy during first quarter (charging), release it in second (discharging) & so on....

→ Circuit with R & L in series → RL circuit





$$\boxed{Z = R + jX_L} \qquad \boxed{E = \sqrt{E_R^2 + E_L^2}}$$

$$\Rightarrow |Z| = \sqrt{R^2 + X_L^2} \angle \tan^{-1}\left(\frac{X_L}{R}\right) = |Z| \angle \phi$$

$$\Rightarrow \phi = \tan^{-1}(X_L/R)$$

$$\boxed{I = \frac{E}{Z} \angle -\phi} \qquad (I \text{ lags } V)$$

Here, $Z = \sqrt{R^2 + X_L^2}$ = Impedance

• Power Loss is only due to Resistive component (power stored in L & C is 0)

Since power is consumed by R only,

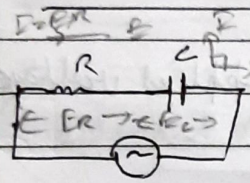
$$P = I^2R = I \cdot IR = \frac{E}{\sqrt{R^2 + (X_L)^2}} \cdot IR$$

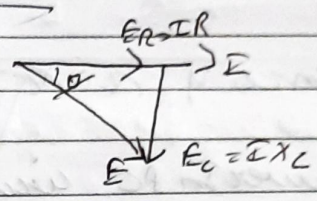
$$\Rightarrow \boxed{P = EI \cdot \frac{R}{Z}} \quad \& \quad \frac{R}{Z} = \cos\phi$$

$$\Rightarrow \boxed{P = EI\cos\phi} \quad \text{(watts)}$$

• $\cos\phi$ is called <u>Power Factor</u> (Lagging Power Factor)

→ <u>Circuit With R & C in Series</u> → RC circuit





$$\Rightarrow \boxed{Z = R - jX_C} \qquad E = \sqrt{E_R^2 + E_C^2}$$

$$\phi = Z = \sqrt{R^2 + X_C^2}\ \tan^{-1}\left(\frac{-X_C}{R}\right)$$

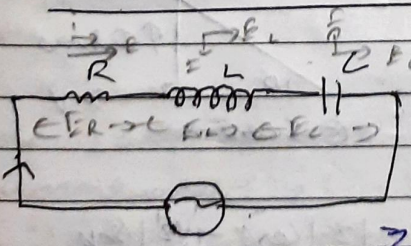
$$\Rightarrow Z = |Z| \angle -\phi \quad ; \phi = \tan^{-1}\left(\frac{-X_C}{R}\right)$$

$$I = \frac{E}{Z} \angle \phi$$

here also,

$$P = I^2R = \frac{EI \cdot R}{Z} = \boxed{EI\cos\phi} \Rightarrow \cos\phi = \frac{R}{\sqrt{R^2 + X_C^2}}$$

→ <u>Series R-L-C Circuit</u>



$$\boxed{E_L = +jIX_L}$$

$$\boxed{E_C = -jIX_C}$$

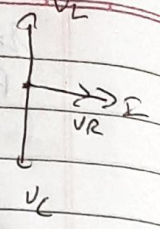
⇒ Voltage Drop in the Circuit

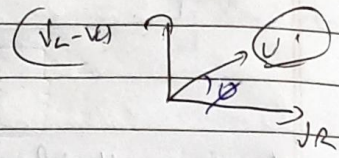
$$= +jI(X_L - X_C)$$

& Resistance Drop = IR

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

$\Rightarrow Z = \sqrt{R^2 + (X_L - X_C)^2} \angle \phi \quad \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$





① If $X_L > X_C$ – ϕ is +ve

② If $X_L < X_C$ – ϕ is -ve.

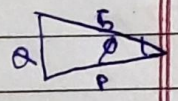
Hence if $X_L > X_C$, current lags applied voltage & viceversa

→ Power In AC circuits

① When, current is out of phase with voltage – Power = Apparent power

$(S = VI)$ $(S = V \times I^*)$ (I^* = conjugate) = S = (in Volt Ampere)

$(S = P \pm jQ)$ (LSC)

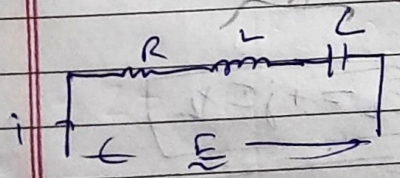


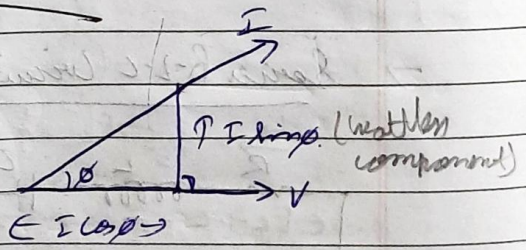
② Power that is returned to source by Reactive components (~~Reactance~~)
↳ Reactive Power = Q (in VAR - Volt ampere Reactance)

③ Power that is actually used in the ckt is True/Active Power
= P (in W or kW)

→ Active, Reactive & Apparent Power

$X = X_L - X_C$





$Z = R \pm jX = |Z|\angle\phi = |Z|\cos\phi - j|Z|\sin\phi$

$|Z| = \sqrt{R^2 + X^2}$ | $\cos\phi = R/Z$; $I = E/Z$

- This current has 2 components –

(a) $I\cos\phi$ – Wattful component

(b) $I\sin\phi$ – Wattless Component

$$\boxed{\text{Active Power} = V \times I \times \cos\phi}$$ Watts (Wattful)

$$\boxed{\text{Reactive Power} = EI\sin\phi}$$ VAR (Wattless)

$$\boxed{\text{Apparent Power} = VI}$$

- Hence, Active & Reactive powers would be given by real & j parts of voltage.
- Active Power = sum of product of real parts & j parts (ie $A_1 \cdot A_2$)

→ Power Factor = ratio of true/active power to apparent power

$$\boxed{P.F. = \cos\phi = \frac{P}{S} = \frac{R}{Z}}$$

- PF is lagging if I lags behind V & leading if I leads V.
- Significance – Companies supply us with Volt Ampere, but charge for ~~watts~~ Watts

Parallel Circuits

- As voltage across each element is same, for a ∥ network, voltage phasors taken to draw phasor diagrams
- Current in every branch is ratio of V to Z

(a) If only R → I in phase with V

(b) If only L → I lags V by 90°

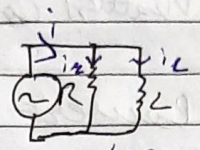
(c) If only C → I leads V by 90°

(d) If RL are present - I lags V with $0 \le \phi \le 90$

(e) If RC component ⇒ I leads V by $0 \le \phi \le 90$

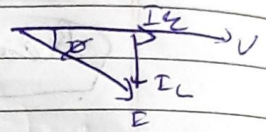
- Total current is phasor sum of all branches.

→ Parallel RL ckt



By KCL, $i(t) = i_R(t) + i_L(t) = \frac{v(t)}{R} + \frac{1}{L}\int v(t)\,dt$

⇒ $I = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L}\right)^2} \cdot V_m \sin(\omega t - \phi)$

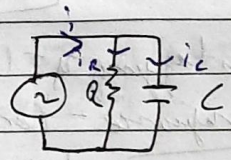


$Z = \sqrt{\frac{1}{R^2} + \frac{1}{X_L^2}}$ || $\boxed{\phi = \tan^{-1}\left(\frac{R}{X_L}\right)}$

(i) If $R >> \omega L$, then $\phi \to 90°$
Then, I in resistive branch is negligibly low & total current is equal to inductor current.

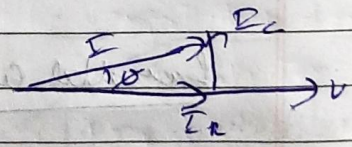
(ii) If $R << \omega L$, then $\phi \to 0°$
Then, I in inductive branch is negligibly low & total current is = to resistance current.

→ Parallel RC current



By KCL, & $i = 0$

⇒ $I = \sqrt{\frac{1}{R^2} + \frac{1}{X_C^2}}\, V_m \sin(\omega t + \phi)$

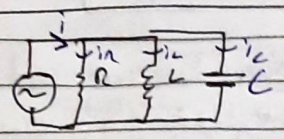


⇒ $Z = \sqrt{\frac{1}{R^2} + \frac{1}{X_C^2}}$ || $\phi = \tan^{-1}\left(\frac{-R}{X_C}\right)$

(i) If $R >> X_C$ ⇒ $\theta \to 90°$ & $I_R \approx 0$ & $I \approx I_C$

(ii) If $R << X_C$ ⇒ $\theta \to 0°$ & $I_C \approx 0$ & $I \approx I_R$

→ Parallel RLC circuit



By KCL, $Z i = 0$

$\Rightarrow \cancel{I = \sqrt{\frac{1}{R^2} + \frac{1}{(X_L - X_C)^2}}}$

$$\Rightarrow I = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2} \; V_m \sin(\omega t + \phi)$$

$$Z = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2} \quad \| \quad \phi = \tan^{-1}\left[R\left(\frac{1}{X_L} - \frac{1}{X_C}\right)\right]$$

① $\frac{1}{X_C} >> \frac{1}{X_L}$; Ckt is ≈ capacitive ckt. current phase ∠ = +ve i.e I leads V

② $\frac{1}{X_L} >> \frac{1}{X_C}$; Ckt is ≈ inductive ckt; Current Phase ∠ = -ve; i.e I lags V

③ $\frac{1}{X_L} = \frac{1}{X_C}$; Ckt is ≈ Resistive ckt (with L & C cancelling each other)
Ckt under this cond^n is parallel Resonance)

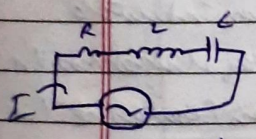
→ Resonance - Frequency response of a circuit / network when it is operating at its natural frequency

- I & V are in phase (Resistive Circuit)
- Under resonance, max power is transferred.

- Quality Factor

$$Q = 2\pi \times \frac{(\text{Max Energy stored per cycle of supply})}{(\text{Energy Dissipated per cycle})}$$

→ Series Resonance



- At resonance; V & I are in phase

$\Rightarrow \phi = 0^\circ$; $\cos\phi = 1$; $Z = R$

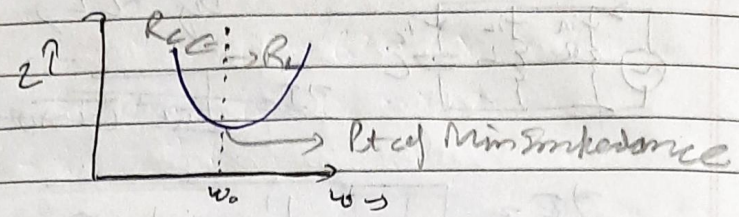
Usually, $Z = R + j(X_L - X_C)$

At Resonance; j component = 0 $\Rightarrow \boxed{X_L = X_C}$

$\Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \boxed{\omega_0 = \frac{1}{\sqrt{LC}}} \Rightarrow \boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$

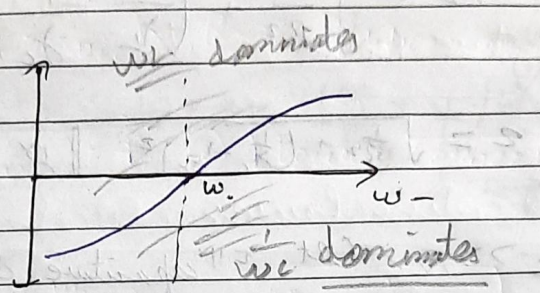
① Z Vs ω

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

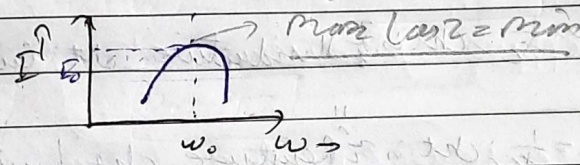


② X_{net} Vs ω

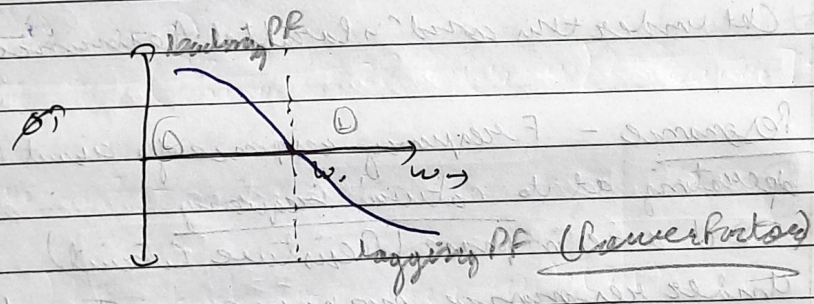
$$\boxed{X_{net} = \omega L - \frac{1}{\omega C}}$$



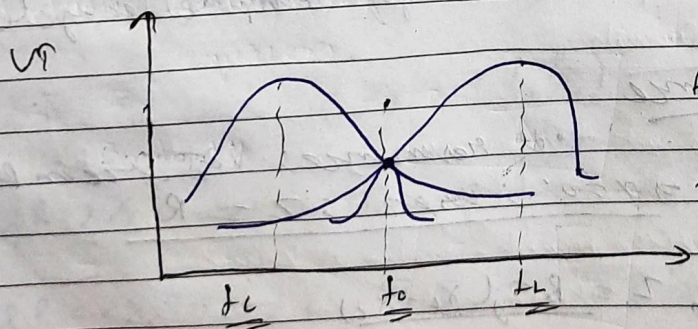
③ I Vs ω



④ φ Vs ω



→ Variation of Voltage Across Frequency



f_C = Freq at which max V in across capacitor

f_L = Freq at which max V in across Inductor

f_0 = Freq at which max V in across Resistance (i.e. at Resonance)

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(1) f_c = freq at ~~which~~ which max V_c occurs C.

$$f_c = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{2L^2}} \Rightarrow f_c = \frac{1}{2\pi\sqrt{LC}} \cdot \sqrt{1 - \frac{R^2C}{2L}} \Rightarrow \boxed{f_c = f_0\sqrt{1 - \frac{R^2C}{2L}}}$$

(2) f_L = freq at which max V occurs L

$$f_L = \frac{1}{2\pi}\sqrt{\frac{1}{LC - R^2C^2/2}} \Rightarrow f_L = \frac{1}{2\pi\sqrt{LC}} \cdot \frac{1}{\sqrt{1 - \frac{R^2C}{2L}}} \Rightarrow \boxed{f_L = \frac{f_0}{\sqrt{1 - R^2C/2L}}}$$

At Resonance $\Rightarrow I = I_0 (max) = V/R$

$P = (P_{max}) = I_0^2 R$

→ ie At $w = w_0$, $V_R = IR = I_0 R = \frac{V}{R} \cdot R = V \Rightarrow V_R = V$

· Voltage across Resistance is same as supply voltage.

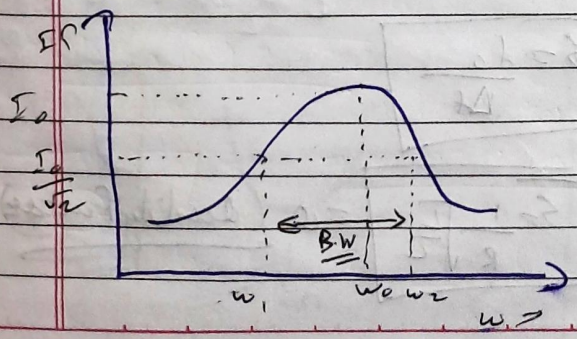
→ $V_L = jX_L I_0 = j\omega L I_0 = j\omega L \frac{V_0}{R} = \left(\frac{j\omega L}{R}\right) \cdot V \Rightarrow V_L = j\theta \cdot V$

Quality ~~power~~ Factor in RL ckt = $\boxed{\frac{\omega L}{R}}$

→ $V_C = -jX_C I_0 = \frac{-j}{\omega C} I_0 = \frac{-j}{\omega C} \cdot \frac{V}{R} = \left(\frac{-j}{\omega C R}\right) V \Rightarrow \boxed{V_C = -j\theta \cdot V}$

Quality Factor in RC ckt = $\boxed{\frac{1}{\omega C R}}$

→ Bandwidth – Range of frequency for which Power levels half of (Real/Active) Power. ie $P' = P_0/2$



$\because P = P_0/2$

$\Rightarrow I_R^2 R = I_0^2 R/2$

$\Rightarrow \boxed{I = I_0/\sqrt{2}}$

$\boxed{\Delta w = w_2 - w_1}$ rad/s

· Frequency at which $I' = \frac{I_0}{\sqrt{2}}$ is cutoff / corner frequency. (lowered the power)

At cutoff Frequency

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

$$\Rightarrow R^2 = (X_L - X_C)^2$$

$$\Rightarrow \left(\omega L - \frac{1}{\omega C}\right) = \pm R$$

At $\omega = \omega_2 \Rightarrow \left(\omega_2 L - \frac{1}{\omega_2 C}\right) = R \rightarrow (1)$ [Higher Corner Frequency]

At $\omega = \omega_1 \Rightarrow \left(\omega_1 L - \frac{1}{\omega_1 C}\right) = -R \rightarrow (2)$ [Lower Corner Frequency]

Adding (1) & (2)

$$(\omega_1 + \omega_2) L - \frac{1}{C}\left(\frac{\omega_1 \omega_2}{\omega_1 + \omega_2}\right) = 0 \Rightarrow \boxed{L = \frac{1}{C\omega_1\omega_2}} \Rightarrow L = \frac{1}{\omega_1 \omega_2}$$

If $\omega_1 = \omega_2 = \omega_0$ (At resonance),

$$\boxed{\omega_0 = \sqrt{\omega_1 \omega_2}} \Rightarrow \boxed{\omega_0 = 1/\sqrt{LC}}$$

Now, (1) − (2)

$$(\omega_2 - \omega_1) L + \frac{1}{C}\left(\frac{\omega_2 - \omega_1}{\omega_1 \omega_2}\right) = 2R \Rightarrow (\omega_2 - \omega_1)\left[L + \frac{1}{C\omega_1\omega_2}\right] = 2R$$

$$\because \omega_1 \omega_2 = \omega_0^2 = 1/LC$$

$$\Rightarrow (\omega_2 - \omega_1)\left[L + \frac{1}{C \cdot \frac{1}{LC}}\right] = 2R \Rightarrow (\omega_2 - \omega_1) \cdot (X_L) = 2R$$

$$\Rightarrow \boxed{\omega_2 - \omega_1 = \frac{R}{L}} \Rightarrow \boxed{f_2 - f_1 = \frac{R}{2\pi L}}$$ (for series RLC circuit)

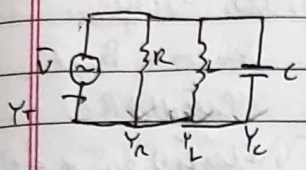
→ **Selectivity** – Ability of a system to distinguish b/w desired & undesired frequencies.

$$S = \frac{f_0}{\text{Bandwidth}} \Rightarrow \boxed{S = \frac{f_0}{\Delta f}}$$

$$\Rightarrow S = \frac{1/2\pi\sqrt{LC}}{R/2\pi L} \Rightarrow \boxed{S = \frac{1}{R}\sqrt{\frac{L}{C}}} = Q \text{ (Quality Factor)}$$

→ Parallel Resonance

(a) General Circuit –



At resonance,
$\vec{V}$ & $\vec{I}$ are in phase.
$\Rightarrow \phi = 0 \Rightarrow \cos\phi = 1$
$\Rightarrow \boxed{Y = G}$

- $Y = (G = 1/R)$
- B = Susceptance $\Rightarrow \frac{1}{X}$ $= \frac{1}{X_C}$ or $\frac{1}{X_L}$
- $G = 1/R$
- $Y = 1/Z$

$\frac{1}{j} = \frac{1}{j} \times \frac{j}{j} = \frac{j}{j^2}$
$= j/-1 = -j$

$Y_T = Y_R + Y_L + Y_C$

$\Rightarrow Y_T = \frac{1}{R} + \frac{1}{jX_L} + \frac{1}{-jX_C} = \frac{1}{R} - \frac{j}{X_L} + \frac{j}{X_C}$

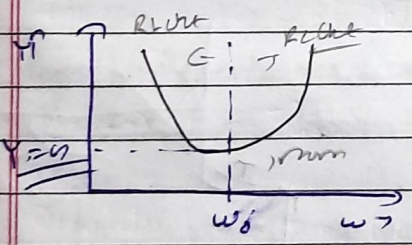
$\boxed{\Rightarrow Y_T = \frac{1}{R} + j\left(\frac{1}{X_C} - \frac{1}{X_L}\right)}$

At Resonance, $B_{net} = 0$
ie $X_L = X_C$ or $\frac{1}{X_C} - \frac{1}{X_L} = 0$

$\Rightarrow \frac{1}{X_C} = \frac{1}{X_L} \Rightarrow \omega_0 C = \frac{1}{\omega_0 L} \Rightarrow \boxed{\omega_0 = 1/\sqrt{LC}} \Rightarrow \boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$

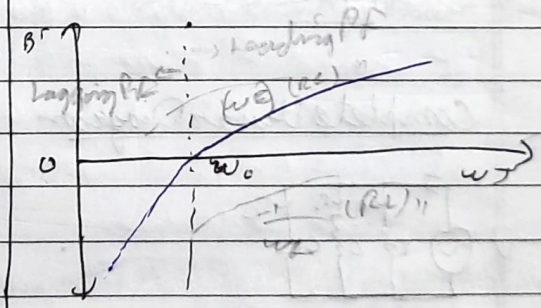
(1) Y vs ω_0

$Y = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$

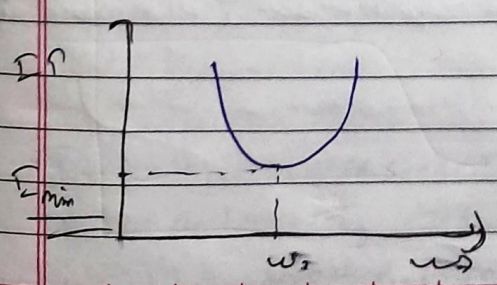


(2) B vs ω

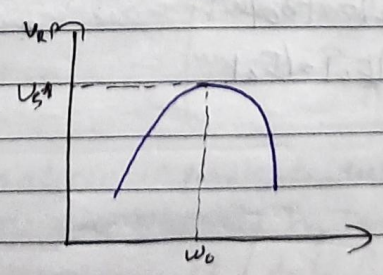
$Y = \frac{1}{R} + j\underbrace{\left(\omega C - \frac{1}{\omega L}\right)}_{B_{net}}$



(3) I vs ω



(4) V_R vs ω



→ Phasor Diagrams

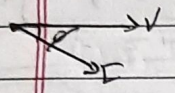
(a) $\omega < \omega_0$

$Y = G - jB_{net}$

Parallel RL

I lags V by $\phi < 90°$

(lagging PF)



$\phi = -ve$

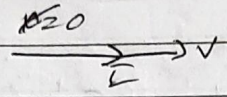
(b) $\omega = \omega_0$

$Y = G$

Purely Resistive

I in phase with V

$\phi = 0°$



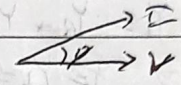
(c) $\omega > \omega_0$

$Y = G + jB_{net}$

Parallel RL

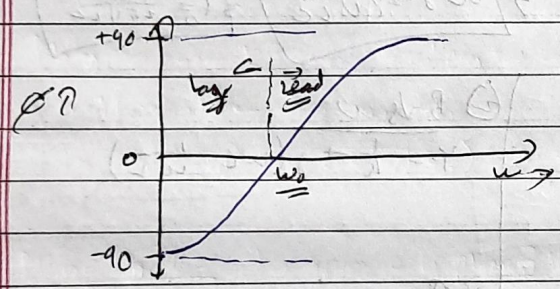
I leads V by $\phi < 90°$

(Leading PF)

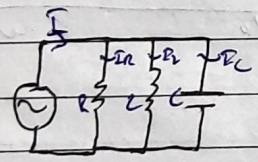


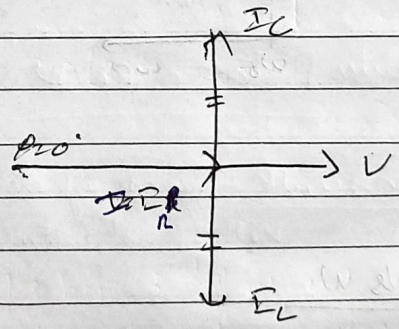
$\phi = +ve$

→ ϕ vs ω graph



Complete Phasor Diagram





$I = I_R$
$\phi = 0$
PF = Unity
PF (UPF)

at Resonance,

$|I_L| = |I_C|$

& $|E_L| = |E_C|$

From circuit,

$V = \frac{I}{|Y|} \Rightarrow \boxed{V = \frac{I}{\sqrt{\frac{1}{R^2} + \left(\omega L - \frac{1}{\omega C}\right)^2}}}$

At $\omega = \omega_1 \Rightarrow B_{net} = 0$

$\Rightarrow V = I / \sqrt{\frac{1}{R^2} + 0} \Rightarrow \boxed{V = IR}$

Max

At $\omega = \omega_0$

R $\quad I_R = \frac{V_R}{R} = \frac{V}{R} = IR/R \Rightarrow \boxed{I_R = I}$

L $\quad I_L = \frac{V_L}{j\omega L} = \frac{V}{j\omega_0 L} = -j\left(\frac{R}{\omega_0 L}\right) I \Rightarrow \boxed{I_L = -j Q_0 I}$

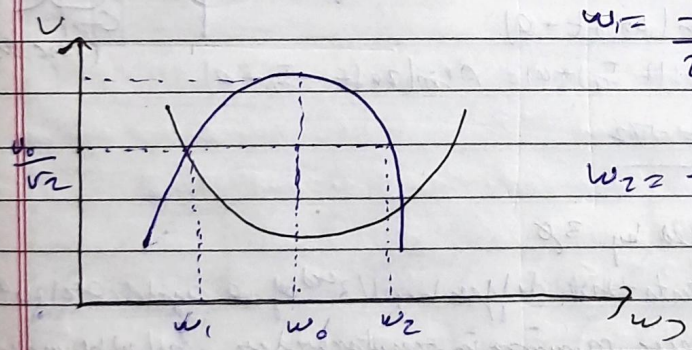
Q-Factor in $\| RL = \boxed{R/\omega_0 L j}$

C $\quad I_C = \frac{V_C}{-j/\omega_0 C} = \frac{(\omega_0 C R) I}{-j} \Rightarrow \boxed{I_C = j Q_0 I}$

Q-Factor in $\| RC = \boxed{-\omega_0 C R}$

Q_0 = Current Amplification Factor

- Parallel Resonance Phenomenon is used in Design of Passive Band Stop Filters



$\omega_1 = \frac{-1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}$

$\omega_2 = \frac{+1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}$

Stop Band

$\omega_2 - \omega_1 = \frac{1}{RC}$ rad/sec

- Practically, we never connect resistance in parallel to supply voltage. So, better frequency characteristics are obtained by tank circuit, which is practical, parallel resonance ckt (Anti Resonance ckt)

- By defaults given quantity is line quantity (unless mentioned)
- 2in che is in phase only (no line) - Find Ep from Up / 2 = then find E_L
- Default freq is 50 Hz (if not mentioned)

→ Three Phase Circuits (Skip Derivation (Theory - Only Mentioned))

- 3 phase ckts belong to a class of polyphase systems (a system consisting of numerous windings/windings).

$$\text{Electrical Angle} = \frac{2\pi \text{ Electrical Degree}}{\text{No. of Phases}} = \boxed{\frac{360^\circ}{n}} \; ; n > 2$$

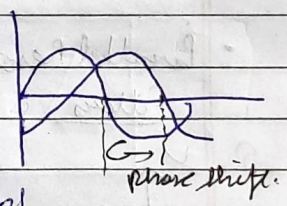
- For $n = 2 \rightarrow \angle = 90^\circ$

- Advantages
  1. Smaller In Size
  2. Constant Output Power
  3. Ease In Parallel Operation
  4. Reliability

- Phase - Greek term - refers to regular change.
  - used for alternating quantity.

  In $x(t) = A\sin(2\pi f t + \theta)$; θ = Phase

- Phase Shift - Change in θ is phase shift.
  Or Change θ from 0° is phase shift.



  If $x(t) = A\sin(2\pi f t + \theta)$

  $\Rightarrow x(t - T_4) = A\sin(2\pi f(t - T_4) + \theta) = A\sin(2\pi f t - \frac{\pi}{2} + \theta)$

  $\Rightarrow$ Phase Shift $= -\pi/2$

- Three Phase denoted by 3ϕ
  - 3 voltages or currents that differ by 1/3rd of a cycle or 120° (electrical)
  - They go through their maxima in regular order, called phase sequence

. Quantity which reaches its peak first in 3 phase ckt is leading (i.e. first) & one which reaches last is third (last) & the two one in left is second

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→ **Balanced 3 phase system** — A 3φ system is balanced if —

1. each load has same Z
2. each load Z has same angle
3. each phase voltage (& current) is equal
4. each phase voltage is displaced by 120° from each other

- **Phase sequence** — Order in which components of a polyphase system attain their maxima. (RYB → Red - Yellow - Blue)

  Significance

  1. Direc^n of rot^n of induction motor depends on it
  2. It is req^d to make connec^n in alternators & transformers in parallel

→ **Interconnection of 3 Phase System**

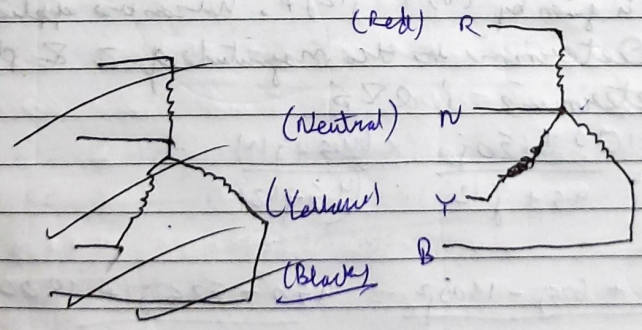
- Each coil of a 3φ system has 2 components — starting & finishing terminal

(1) **Star or Wye (Y) or T connected 3φ system**

Neutral point — common point which similar ends of each coil are joined.

(V_p)/(I_p) **Phase Voltage & Phase Current** — i.e. V or I between any 1 line & neutral line

(V_L)/(I_L) **Line Voltage & Line Current** — i.e. V or I between any 2 outgoing terminals



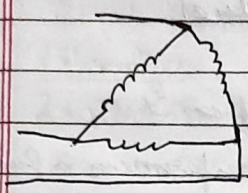
$$\boxed{\begin{aligned} V_L &= \sqrt{3}\, V_p \\ I_L &= I_p \end{aligned}}$$

- Angles are → 0°, -120° & -240° → Voltage
- Angles are → 30°, -90° & -210° → Current

~~Thor~~ Three ϕ Power

$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$ $\Rightarrow$ $\boxed{P = 3 V_p I_p \cos\phi}$ $\cos\phi = \frac{R}{Z}$

(2) Delta or Mesh or π Connected 3ϕ systems



$$\boxed{\begin{aligned} V_L &= V_P \\ I_L &= \sqrt{3}\, I_P \end{aligned}}$$

- Angles are → 0°, -120° & -240° (voltage)
- Angles are → 30°, -90° & -210° (current)

Three ϕ Power

~~$P = \sqrt{3} V_L I_L = 3 V_P I_P$~~

$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$ $\Rightarrow$ $\boxed{P = 3 V_P I_P \cos\phi}$ $\boxed{\cos\phi = \frac{R}{Z}}$

---

(1) The I in a det is given by $(4.5 + j12)$ A. When applied V is $(100 + j150)$ V. Determine ~~to~~ the magnitude of Z & phase angle. Also determine P, Q & S

Ans) $Z = \frac{V}{I} = \frac{100 + 150j}{4.5 + j12} \times \frac{(4.5 - j12)}{(4.5 - j12)}$

$= \frac{450 - j1200 + 675j - 1800j^2}{164.25} = \frac{450 - 525j + 1800}{164.25}$

$\Rightarrow Z = \frac{2250 - j525}{164.25} \Rightarrow Z = 13.7 - j3.196\ \Omega$

$\Rightarrow |Z| = \sqrt{(13.7)^2 + (3.196)^2} = 14.058\ \Omega$

$\Rightarrow \theta = \tan^{-1}\left(\frac{-3.196}{13.7}\right) = -13.138^\circ$

$\rightarrow S = V I^* \text{ (conjugate)} = (100 + 150j)(7.5 - 12j)$

$= 750 - 1200j + 675j - 1800j^2$

$\Rightarrow S = 2250 - 525j$ VA $\Rightarrow |S| = 2310.438$ VA; $\theta = -13.138$

$\rightarrow$ ~~P~~ $\Rightarrow P = 2250$ W & $Q = -525$ VAR (capacitive)

(3) In an RL series ckt; $R = 10\Omega$ & $X_L = 8.66\Omega$ & $I = (5-10j)$ A. Find (a) Applied Voltage V (b) Power Factor (c) P & Q

Ans) $Z = \sqrt{R^2 + X_L^2} = \sqrt{(10)^2 + (8.66)^2} = 13.23\ \Omega$

$\theta = \tan^{-1}\left(\frac{X_L}{R}\right) = 40.89^\circ$ | $Z = 13.23 + 40.89j$

(a) $\Rightarrow V = IZ = (5-10j)(13.23 + 40.89j)$

$= 66.15 + 204.45j - 132.3j - 540.98j^2$

$= (607.13 + 72.15)$ V

$\Rightarrow V = 611.40 \angle 6.775^\circ$

Ans) (a) $I = 5 - 10j$; $Z = 10 + 8.66j \Rightarrow V = IZ = (5-10j)(10+8.66j)$

$\Rightarrow |V| = 148$ & $\theta = -22.53$ V $(136.6 - 56.7j)$

$I = 5 - 10j = \cancel{11.68}\ 11.18 \angle -63.43$ (ie $|I| = 11.18$ & $\theta = -63.43$)

(b) ~~$PF = \frac{R}{Z} = \frac{10}{10+8.66j} \times \frac{10-8.66j}{10-8.66j}$~~

(b) $|Z| = \sqrt{10^2 + 8.66^2} = 13.23\ \Omega \Rightarrow PF = R/Z \Rightarrow \cos\theta = \frac{10}{13.23} = 0.756$ (Lag)

(c) $S = VI^* = (136.6 - 56.7j)(5 + 10j)$

$= 683 + 1366j - 283.5j - 567j^2$

$\Rightarrow S = (1250 + 1082.5j)$ VA ie

P Q

Q) A coil of resistance 12Ω & $X_L = 25\Omega$ is connected in series with a capacitive reactance of $X_C = 41\Omega$. The combⁿ is connected to 230V; 50Hz. Find -

(a) Circuit Impedance (b) Current (c) Power consumed

Ans) (a) $R = 12\Omega$; $X_L = 25\Omega$; $X_C = 41\Omega$.

$\Rightarrow Z = 12 - 16j \Rightarrow |Z| = 20\Omega$ & $\phi = -53.06°$

(b) $I = \frac{V}{|Z|} = \frac{230}{20} = 11.5A$

(c) $P = VI\cos\phi = 230 \times 11.5 \times \frac{12}{20} = 1587W$

• PF is leading

Q) A resistance of 20Ω & coil of L = 31.8 mH are connected in parallel across 230V, 50Hz supply. Find - Line currents, Power factor & Power consumed.

($I_L = \sqrt{I_R^2 + I_C^2}$)

Ans) $L = 31.8$ mH; $X_L = L\omega = 100\pi \times 31.8 \times 10^{-3} = 9.99\Omega$

$\Rightarrow Z = 20 + 10j \Rightarrow |Z| = \sqrt{500} = 22.36\Omega$

$\Rightarrow I = \frac{V}{Z} = \frac{230}{22.36} = 10.29A$

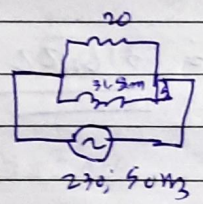
Date
DELTA Pg No.

$PF = \frac{R}{Z} = \frac{20}{22.36} = 0.89$

$P_{source} = VI\cos\phi = 230 \times 10.24 \times 0.89 = 2106.363$

$L = 31.8\,mH \Rightarrow X_L = 31.8 \times 10^{-3} \times 100 \times \pi = 10\,\Omega$

$\Rightarrow Z = \sqrt{\frac{1}{R^2} + \frac{1}{X_C^2}} = \sqrt{\quad}$



$I_t = \sqrt{I_R^2 + I_L^2}$

$I_R = \frac{230}{20} = 11.5A \angle 0$

$I_L = \frac{230}{X_L} = \frac{230}{10} = 23\angle -90^\circ$

$\Rightarrow I_t = \sqrt{(11.5)^2 + (23)^2} = 25.71\,A$

$I_t = I_R + I_L = 11.5 + 23\angle -90$ $\quad (\theta = \tan^{-1}(\frac{-23}{11.5}))$

$= 25.71 \angle -63.43$

$\Rightarrow \theta$ b/w V & I $= 0 - (-63.43) = 63.43^\circ$

$\Rightarrow PF = \cos(63.43) = 0.447$ (lag)

$\Rightarrow P = VI\cos\phi = 230 \times 25.71 \times 0.447 = 2643.25\,W$

Q) A coil $R = 10\,\Omega$ & $L = 100\,\mu H$ is connected in series with $C = 100\,pF$. Ckt is connected to 10 V variable freq source.

(a) Calculate Resonant frequency

(b) Find I at resonance

(c) Voltage across L & C at resonance

(d) Q Factor

Ans (v) $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-4} \times 10^{-10}}} = \frac{\sqrt{10^{11}}}{2\pi} = 50.33 \times 10^3 \, Hz$

(ii) At Resonance, $Z = R = 100\,\Omega \Rightarrow I = \frac{10}{100} = 0.1A$

(iii) $V_L = jI_0 X_L = j I_0 \omega L = \frac{jV\omega L}{R} \Rightarrow V_L = 3.141V\,j$

$V_C = -jI_0 X_C = \frac{-jI_0}{\omega C} = \frac{-jV}{\omega CR} = 3.183 \times 10^6 \, V$

(d) $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{100}\sqrt{\frac{10^{-4}}{10^{-10}}} = \frac{10^2}{10^2} \times \sqrt{10} = 316.22$

(i) $f_0 = 5.9 \, MHz$

(ii) $I = 0.1A$

(iii) $V_L = IX_L = 100V$ $\quad V_C = 100V$

(iv) $Q = 10$

(a) $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-4} \times 10^{-10}}} = 5.9 \, MHz$

(b) At Resonance $Z = R = 100\,\Omega \Rightarrow I = 10/100 = 0.1A$

$X_L = 1000\,\Omega$ $\quad X_C = 1000\,\Omega$

(iii) $V_L = IX_L = 100V$ & $V_C = IX_C = 100V$

(d) $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{100}\sqrt{\frac{10^{-4}}{10^{-10}}} = 10$

Date
DELTA Pg No.

(8) A choking coil is connected in series with a 20μF capacitor, with a constant supply voltage of 200V. It is found that the circuit takes an current of 50A when supply freq. is 100Hz. Calculate (Series)

(a) R & L (b) V_C (c) Q.-Factor

Ans) $\omega_0 = \frac{1}{\sqrt{LC}} \Rightarrow R = \frac{V}{I} = \frac{200}{50} = 4\Omega$

$\omega_0 = \frac{1}{\sqrt{LC}} \Rightarrow 2\pi \times 100 = \frac{1}{\sqrt{L \times 2\times10^{-5}}}$

$\Rightarrow 4\pi^2 \times 10^4 = \frac{1}{L \times 2\times10^{-5}} \Rightarrow L = \frac{1}{2\times10^{-5} \times 4\pi^2 \times 10^4} = \frac{10}{8\pi^2}$

$\Rightarrow L = 0.1266H$

(b) $V_C = IX_C = 50 \times \frac{1}{10^{-3} \times 2 \times 200\pi} = 3980V$

(c) $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{4}\sqrt{\frac{0.1266 \times 10^5}{2\times10^{-5}}} = \frac{1}{4}\sqrt{6330} = 19.89$

(9) A series RLC circuit has $R = 100\Omega$, $L = 100mH$ & $C = 10\mu F$. Applied $V = 100V$; calculate —

(a) f_0 (b) Q at resonance (c) ~~Angular F req.~~

(d) At what ~~freq.~~, angular freq, half power point occur

(e) Bandwidth

$R = 1000\,\Omega$; $L = 10^{-1}\,H$; $C = 10^{-5}\,F$; $V = 100\,V$

① $\cancel{\omega_0 = \frac{1}{}}$ $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-6}}} = \frac{10^3}{2\pi} = \underline{159.23\,Hz}$

② $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{1000}\sqrt{\frac{10^{-1}}{10^{-5}}} = \underline{\underline{0.1}}$

③ Bandwidth $= \frac{R}{L} = \frac{10^3}{10^{-1}} = \underline{\underline{10^4}}$ rad/s

⑥ $BW = \omega_2 - \omega_1$ && $\omega_0 = \sqrt{\omega_1\omega_2}$

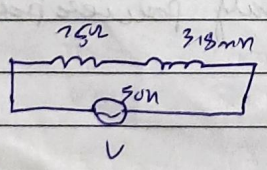
$\Rightarrow \underline{\omega_2 - \omega_1 = 10^4}$ || $\underline{\omega_1\omega_2 = 25,354.19}$

$\Rightarrow \omega_1 = \frac{-R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}$ || $\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}$

$\Rightarrow \omega_1 = \underline{99.0195}$ rad/s ; $\omega_2 = \underline{10099.0195}$ rad/s

9 A pure inductance of $L = 318\,mH$ is connected in series with a pure resistance of $75\,\Omega$. The ckt is supplied from 50 Hz source & $V_{across\ 75\Omega\ resistor}$ is $\underline{150\,V}$.
Find supply voltage & phase angle series

Ans $L = 318\,mH$ || $R = 75\,\Omega$ || $V_R = 150\,V$.



$I = \frac{V_R}{R} = \underline{\underline{2\,A}}$

$X_L = 318 \times 10^{-3} \times 100 \times \pi = \underline{100\,\Omega}$

Y = Star
Δ = Delta

• we do $I_{ph} = \frac{V_{ph}}{Z_{ph}}$ (not ~~Line value~~)

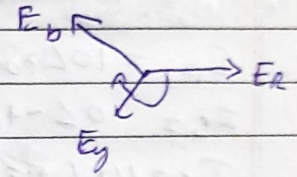
DELTA Pg No.

$\Rightarrow Z = \sqrt{100^2 + 75^2} = \sqrt{15625} = 125\,\Omega$

$\Rightarrow V = ZI = 125 \times 2 = 250\,V$

Now, $\phi = \tan^{-1}\left(\frac{X_L}{R}\right) \Rightarrow \phi = 53.123$ (lagging)

(c) Phase voltages of a star connected alternator are $E_R = 231\angle 0$; $E_Y = 231\angle -120$ & $E_B = 231\angle +120$. What is the phase sequence of system. compute E_{RY} & E_{YB}



Ans) Sequence = RYB

E_{RY} & E_{YB} are line voltages

$\Rightarrow E_L = \sqrt{3} E_P = 231 \times \sqrt{3} = 400\,V$

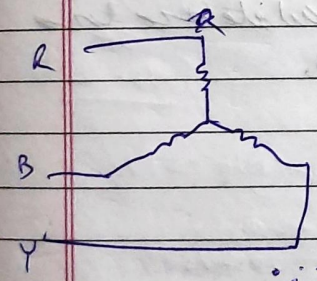
ie $E_{RY} = 400\angle 30^\circ$

$E_{YB} = 400\angle -90^\circ$

$E_{BR} = 400\angle 150^\circ$

$(E_R - E_Y)$ $[231\angle 0 - 231\angle -120]$
$= 400\angle 30^\circ$

(d) 3 with each having $R = 20\,\Omega$ & $X_L = 15\,\Omega$ are connected in star to a 400V ; 3φ ; 50Hz supply. Calculate (i) line current (ii) power factor (iii) power supplied.



$V_L = 400\,V$

$\Rightarrow V_P = \frac{V_L}{\sqrt{3}} = 231\,V$

$Z = \sqrt{20^2 + 15^2} = 25\,\Omega$

$\therefore I_L = I_{ph} = \frac{V_{ph}}{Z} = \frac{231}{25} = 9.24\,A$

(ii) $\cos\phi = \frac{R}{Z} = \frac{20}{25} = 0.8$ (lagging)

(iii) $P = \sqrt{3} V_L I_L = \sqrt{3} \times 400 \times 9.24$

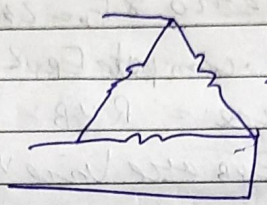
(iv) $P = \sqrt{3} V_L I_L \cos\phi = 3 V_P I_P \cos\phi = 5122.656\,W$

Q ~~3 50D~~.

Q A 3φ, Delta connected alternator device a balanced 3φ load, whose each phase current is 10A in magnitude. At the terminals when $I_A = 10\angle 30°$, determine the following for a phase sequence of abc

(a) Polar expr" for I_b & I_c (b) ~~for~~ Polar expr" for 3 line currents

In Δ → $V_L = V_P$ & $I_L = \sqrt{3} I_P$



$I_{ph1} = I_L\angle 30$

$I_{ph2} = I_L\angle -90$

$I_{ph3} = I_L\angle -210$

$I_A = 10\angle 30°$

$I_B = 10\angle -90°$

$I_C = 10\angle +150°$

Line current

$I_{ab} = I_a - I_b = 10\sqrt{3}\angle 60° = 17.32\angle 60°$

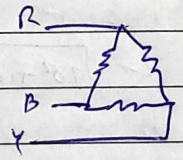
$I_{bc} = I_b - I_c = 10\sqrt{3}\angle \; = 17.32\angle -60°$

$I_{ac} = I_c - I_a = 10\sqrt{3}\angle \; = 17.32\angle +180°$

Q 3 ~ loads each having R = 5Ω & L = 0.02H are connected in Delta to a 440V; 3φ; 50Hz supply. Calculate the line current & total power absorbed.

$X_L = 2\pi \times 50 \times 2\times10^{-2} = 6.28\Omega$

$Z_{(ph)} = \sqrt{R^2 + X_L^2} = 8.03\Omega$



$V_L = 440V \Rightarrow V_P = V_L$ (Delta) $= 440V$

$\Rightarrow I_P = \frac{V_P}{Z} = \frac{440}{8.03} = 54.86A$

Now, $I_L = \sqrt{3} I_P = \sqrt{3} \times 54.86 = 94.91A$

$P = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 440 \times 94.91 \times \frac{5}{8.03} = 45kW$

Date
DELTA Pg No.

Q. 3; 50Ω resistors are connected in star across 400 V, 3φ supply. Find I_P; I_L & power

$V_L = 400V$; $\Rightarrow V_P = 400/\sqrt{3} = 231V$

$\Rightarrow I_P = \frac{231}{50} = 4.62A$

~~$I_L = \sqrt{3} I_P = 8A$~~ $I_L = I_P = 4.62A$

$P = \sqrt{3} V_L I_L \cos\phi = 3200.736W$

Q. A 3φ; 50Hz; 400V ac supply is feeding a 3φ delta connected load with each phase having R = 25Ω L = 0.15H & C = 120μF resp. Find line current, P, Q & S

$P = \sqrt{3} V_L I_L \cos\phi$

$Q = \sqrt{3} V_L I_L \sin\phi$

$S = \sqrt{3} V_L I_L$

Ans) $X_L = L\omega = 100 \times \pi \times 0.15 = 47.12\Omega$

$X_C = 1/C\omega = \frac{1}{100 \times \pi \times 120 \times 10^{-6}} = \frac{10^3}{12\pi} = 26.53\Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(25)^2 + (20.59)^2} = 32.39\Omega$

$\Rightarrow V_L = 400V = V_P$

$\Rightarrow I_P = \frac{V_P}{Z} = \frac{400}{32.39} = 12.35A$

$\Rightarrow I_L = \sqrt{3} I_P = 21.39A$

$P = \sqrt{3} V_L I_L \cos\phi = 11437.94W$

$Q = \sqrt{3} V_L I_L \sin\phi = 9420.285 VAR$

$S = \sqrt{3} V_L I_L = 14818.992 VA$

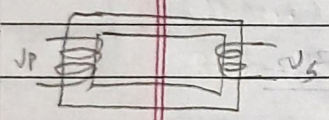
Unit - II

Transformer

- Transformer is a static device that transforms electrical energy from one electrical ckt. to another electrical circuit through medium of magnetic fields without a change in frequency.

- Transformer is an electromagnetic energy conversion device

electrical energy (primary coil) → Magnetic energy → electrical energy (secondary coil)



- Not connected electrically
- coupled magnetically

(Decide Direc")

- high V to low V
- low V to high V
- Isolation $V_1 = V_2$ or $(V_P = V_S)$

* If $N_S > N_P$ then $V_S > V_P$
  - Step Up Transformer

* If $N_P > N_S$ then $V_P > V_S$
  - Step Down Transformer

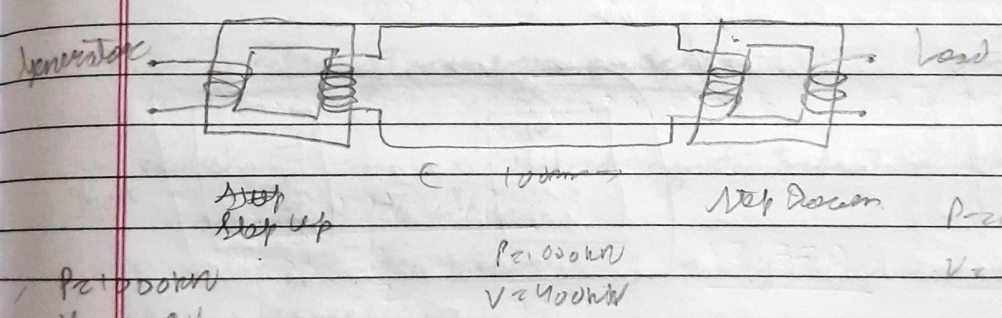
NOTES

- Efficiency (η) is high → 96-98%.
  coz, there are no moving parts.
- Requires negligible amount of maintainence & supervision

Why We Need Transformer?

- Insulation considerations limit the generation of alternator (eg → 11 to 22kV)
- By using ~~tr~~ transformer, we can step up the voltage
  however, Input Power = Output Power
- Higher voltage in line reduces the losses in transmission (I^2R)

Eg:-



- Decreasing or increasing voltage & current levels from one ckt to another.
- For matching impedance of source & its load for max power transfer in electronic & control ckts.
- For isolating DC while permitting flow of AC between 2 circuits for isolating one ckt from another.

→ **Transformer Construction**

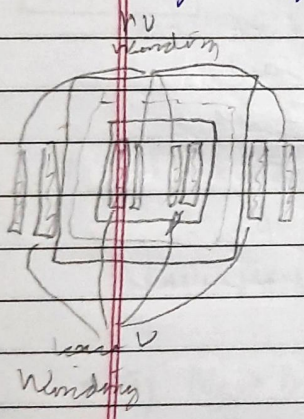
Core Type — Shell Type

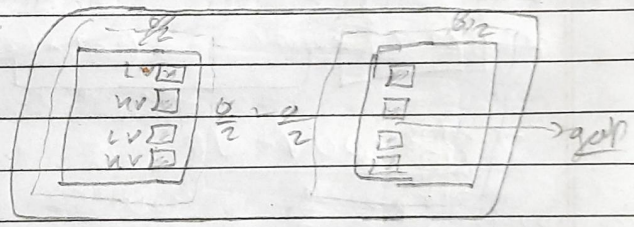
- They differ from each other by the manner in which the windings are wound around the core

Core Materials :- silicon - steel
- Aluminium
- Al-Ni-Co (alloy)

Why laminated? :- To reduce Eddy current losses.

How to Reduce Core loss?
- By making core from cold rolled, grain oriented sheet (steel)





Core Type
→ Concentric coils

Shell Type
→ Interleaved / Sandwiched coil.

- High voltage coil / plate is placed ~~away~~ away from core

Date
DELTA Pg No.

Leakage Flux → Flux that leaks through the core legs & non magnetic material surrounding.

Useful Flux → Flux that is not leaked is useful flux.

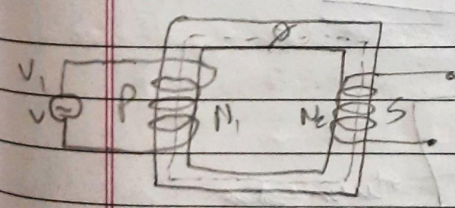
→ Why windings are divided in core type transformer?
→ to reduce leakage flux.
↳ this will ↑ performance (η↑)

- Low Voltage coil is placed adjacent to steel core & H.V coil outside, in order to minimizing the amount of insulation required (for core)

- **Shell Type T/F** is preferred for **Low V, Low power levels**
- **Core Type T/F** are preferred for **High V, High power levels**

→ **Principle of Transformer Action**

- Works on prin. of '**Electromagnetic Induction**' b/w two (or more) coupled circuits or coil
- According to this principle, an emf, is induced in a coil if it links a changing flux.



- MMF = magneto motive force
- Due to this flux flows
- MMF = NI (ampere turns)

- $V_1 \rightarrow I_p$ in N_1 → alternating mmf $N_1 I_p$ (set up) → ϕ (flux)
- Now ϕ is confined to the high permeability iron path
- Alternating flux (ϕ) $\xrightarrow{\text{induce}}$ E_1 (induced voltage) in primary
  $\xrightarrow{\text{induce}}$ E_2 (induced voltage) in secondary

- If Load is connected across secondary, a load current starts flowing

- Dire. emf E_1 (in Volts), induced in primary coil of N_1 turns by alternating flux ϕ is given by –

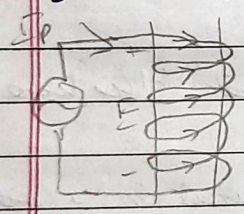
$$\boxed{e_1 = \pm N \frac{d\phi}{dt}}$$

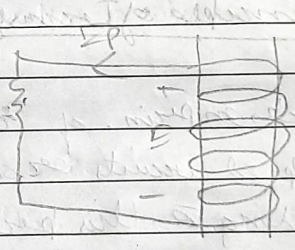
→ Lenz Law – the direc^n of induced emf is ~~fact~~ such that it is allowed to cause a current (by short circuiting the coil), then the current so produced would have an effect that opposes the cause.

$$e_1 = \pm N \frac{d\phi}{dt} = -N \frac{d\phi \sin\omega t}{dt} = -N\phi_m \omega \cos\omega t$$

$$\Rightarrow e = -N\phi_m \omega \sin(\omega t + \pi/2) \Rightarrow e = \frac{N\phi_m \omega}{\sqrt{2}} \Rightarrow \boxed{E = 4.44\, \phi_m N f}$$

- Sign depends on Lenz's law & which terminal is taken as +ve.





$$E = +N\frac{d\phi}{dt}$$

Transformation Ratio ← $\boxed{\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}}$ → turns ratio

→ **Construction of transformer**

Properties of core

① Rel. permeability (μ_r) should be high.

② Reductance should be low

S = Hinderance to flow of flux.

$$S = \frac{l}{\mu_0 \mu_r A}$$

③ Less or negligible Eddy's Current

④ Well Insulated

EMF eqn of Transformer

$$\phi_m = \phi_{max} \sin \omega t$$

→ **Rating Transformer**

- Rating is load carrying capacity of the machine
- Shows max value of voltage at which machine is designed & current consumption occur at that voltage
- Transformer & alternator are rated in Volt Ampere (VA)

↳ 2 reason

① Difference b/w (KW) & (KVA)

- KVA = KV × A
- KW = KV × A × P.F

Power factor – P/Z = Thous total power consumed by load

② Loss occur in transformer

DC Motors

- Converts Electrical Energy to Mechanical Energy

Essential Parts

- Yoke / Frame
- Pole, Pole Core & Pole Shoe
- Interpoles
- Field Windings
- Brush & Brush Holders
- Armature Core
- Armature Winding
- Commutator
- Bearings
- Shaft

- **Principle** - On Lorentz Law, which states -
  "when a current carrying conductor is placed in a magnetic field, it experiences a force".
- Fleming's Left Hand Rule gives direc^n of force.

Parts

- **Yoke / Frames** Outer cover of machine protecting internal parts.

- **Pole, Pole Core & Pole Shoe**
  - Poles are small structures riveted to yoke.
    Terminologies - Pole core - to hold shoe above yoke
    - Pole shoe

- **Field Windings** - made with field coils wound over shoes of pole shoes such that 2 adjacent ones have opposite polarity.
  - Made of Cu or Al.
  - It ~~connect~~ can be connected in 2 ways
    Series - ~~wires less~~ less turns with larger cross section sections
    Shunt (sh) - large ~~turns~~ turns, cross section is less.

→ Brushes & Brush Holder
- Rest on commutator & maintains contact when it is running.
- Made of carbon / graphite

→ Armature Core – Rotating part of machine
- Thin, laminated, circular sheets

→ Armature Winding – made from copper
- consists of large no. of insulated coils of one / more turns
- of two types –

① Lap – • no of parallel paths (A) = no of poles (P)

② Wave – • A = 2; (fixed).
- No of poles is always multiple of 2

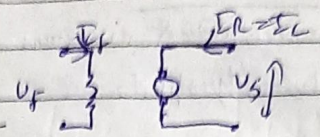
→ Commutator –
It periodically reverses the current direc" b/w the rotor & external ckt.
- It is a cylindrical structure made up of copper segments

→ Bearings – • Ball / roller bearings are fitted in end housings
- High carbon steel is used for const" of bearings

→ Shaft – • made of mild steel with max breaking strength
- used to transfer mechanical power from or to the machine.

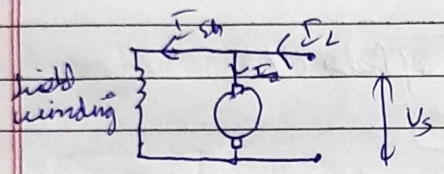
→ Types of Motor

① Seperately excited Motor

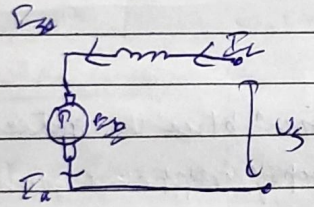


- used in servo motor
- excellent speed
- Low & medium starting torque
- eg – Paper Mill, Steel Rolling etc

② Shunt Motor

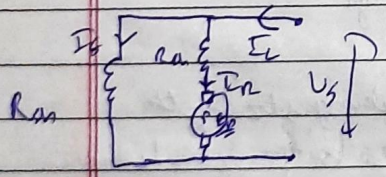


③ Series Motor

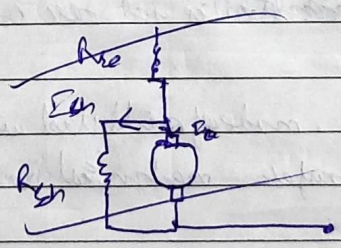


- Highest starting Torque
- eg – ~~etc~~ Cranes

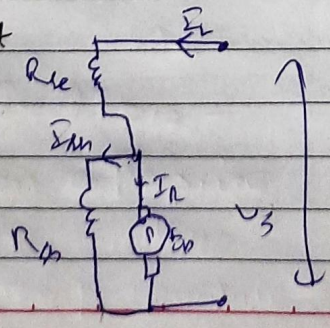
④ Long Shunt



⑤ ~~Short Shunt~~

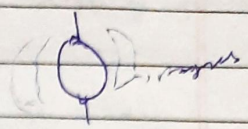


⑤ Short Shunt



6 **Permanent Magnet DC Motor** –

- Uses magnet to create flux.
  - Radially magnetized magnets.
- Has great starting torque, good speed regulation.



→ **Back EMF In DC Motor**

- It is the internal emf produced in the coil (in opposite direc")

No. of conductors — No. of Poles.

$$\boxed{E_b = \frac{Z\phi PN}{60A}}$$

speed rotor

No. of paths

flux

Why is it important?

- It opposes supply voltage

or

- Energy conversion in DC Motor is only possible due to back emf

- $\boxed{E_b = \frac{N\phi Z P}{60A}}$
- $\boxed{V = E_b + I_a r_a}$
- $\boxed{I_a = \frac{V - E_b}{R_a}}$
- $F = B \times I_a \times l$

Lorentz force

$R_T = R_0(1+\alpha\Delta T)$

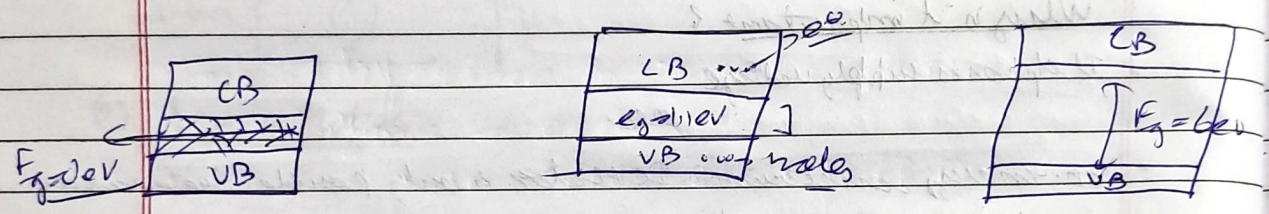
Date
DELTA Pg No.

Electronics

Electronics	Electrical
• current due to e^- & hole	• current due to e^-
• ~~Heavy machine~~	• ~~works on semiconductor~~
• works on heavy machinery etc	• Works on low voltage system - diode, BJT, IC etc.

→ **Materials**

Conductor | Semiconductor | Insulator



• At 0K → semiconductor behaves as Insulator → CB = empty

• As Temp. ↑, e^-'s cross → conductivity ↑ & Resistivity ↓
↳ -ve temp coefficient for semiconductors
(↓R ↑T with ↑ in temp)

→ **Semiconductor Materials**

Silicon & Ge
preferred bcz –
① Si is less expensive
② abundant in nature
③ Less temp. sensitive.

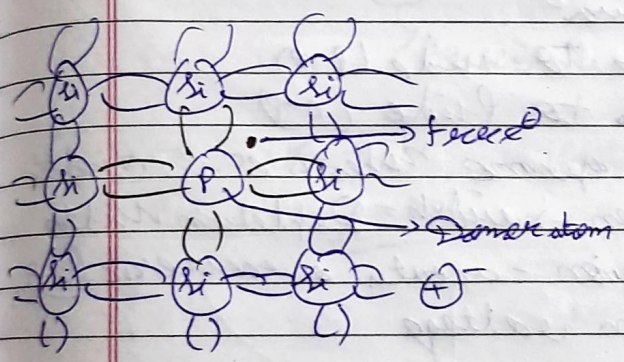
Si: 4 valence $e^{\ominus}$ – Intrinsic S/C → without doping purest
↳ don't have sufficient no. of charge carriers

~~Intrinsic S/C → n type – typ +5~~
~~→ p type – typ −13~~

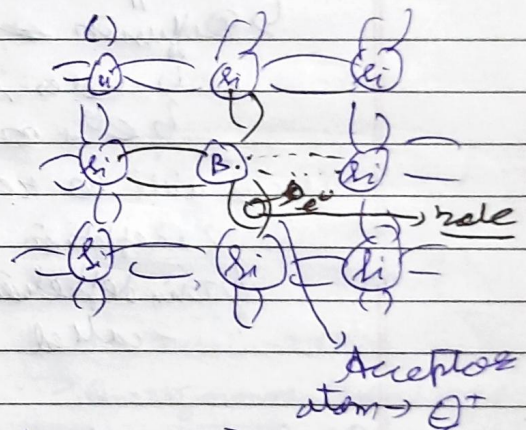
→ • Purely insulator at 0K.

• To ↑ conductivity, we use extrinsic S/C – adding of impurities / called doping atom.

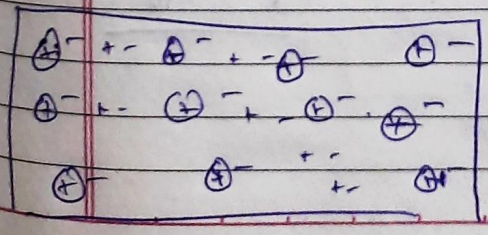
n type
↓
typ −15 (Pentavalent)
↓
5 valence $e^{\ominus}$s



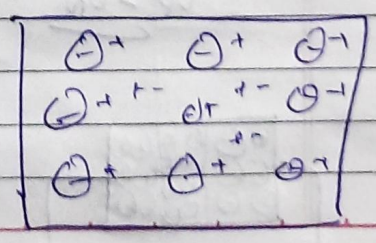
p type
↓
typ −13 (Trivalent)
↓
3 valence $e^{\ominus}$s



• free $e^{\ominus}$ due to addition of atom
• free $e^{\ominus}$–(+) pair due to recombination
∴ $e^{\ominus}$s are majority carriers

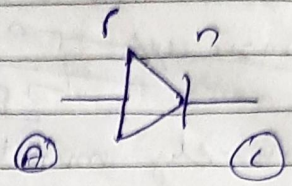


• holes are majority carriers

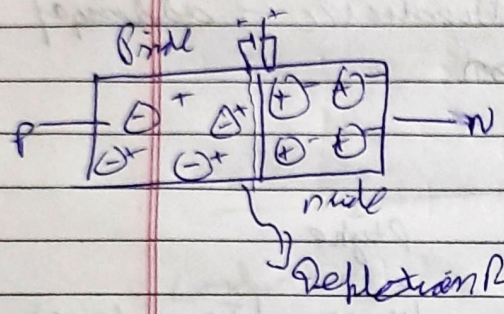


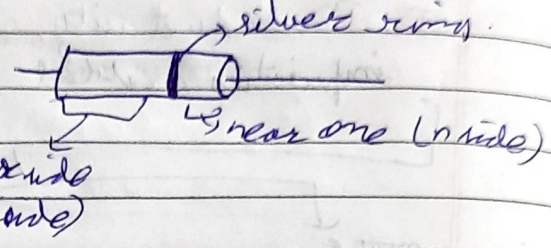
Diodes

- non linear
- unidirectional



- Current flows from (p→n) only

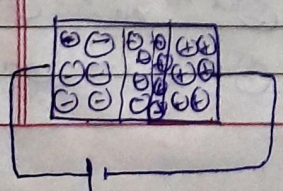




- There is difference in conc. on P side.
  - ↳ Diffusion occurs.
    - ↳ holes move to n side (p→n)
    - ↳ e^-s moves to P side (n→p)
- There will be recomb^n of some holes & e^-s in middle
  - ↳ Depletion Region → width = Depletion width
  - ↳ This depletion region - creates a barrier (V) - called cut-in voltage

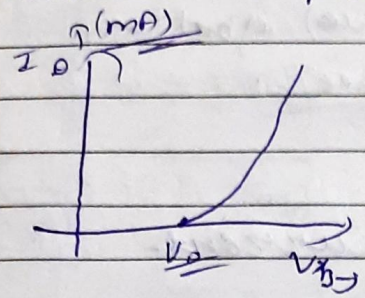
→ Biasing — applying ext. voltage

- Forward
  - ↳ +ve of battery at p
  - ↳ $V_P > V_N$
- Reverse
  - ↳ +ve of battery at n
  - ↳ $V_P < V_N$



• FB → holes move from n → p
& e^{-} " " p → n

• Due to this depletion width decreases



• V_D will force h^+ & e^- to cross the junc. → they recombine reduce width (drift I)

0.3 = Ge
0.7 = Si
1.24 = GaAs

• Net current flows from p → n

Ideal constant (η)

$$I_D = I_0 \left(e^{\frac{V_D}{\eta V_T}} - 1\right)$$

I_0 → Reverse saturation current

V_T = Thermal Voltage
• T = ~~ok~~ in K always

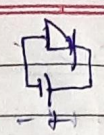
• I_D = Diode I
• V_D = Applied V

$q = 1.6e^{-19}$; $K = 1.23e^{-23}$ J/K.
↳ Boltzmann Constant

• At room temp → V_T = 26 mV

• η → if not mentioned :- take as 1.

- Reverse Bias $V_N > V_P$



$I \approx I_0 \approx 0$

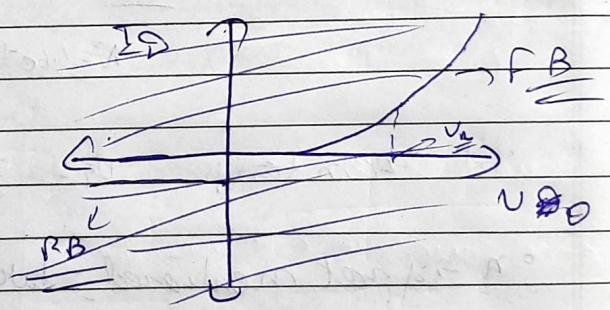
- Holes are attracted by (-ve) of battery
  & e^-s " " " (+ve) " "
- Depletion width ↑
- $I \approx I_{co}$ → Reverse sat^n current
  ↓ ~~temp. dependent only~~
  ↓ ~~not dependent on V~~
- I_{co} doubles for every 10°C rise in temp

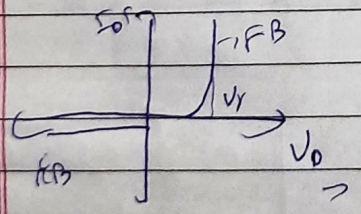
$$\cancel{I = I_{co1} \frac{(T_2 - T_1)}{10}}$$

$$I_{co2} = I_{co1} \cdot 2^{\left(\frac{T_2 - T_1}{10}\right)}$$

$I_{co1} \rightarrow T_1$ (at)

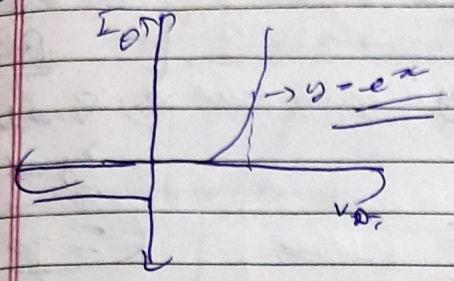
$I_{co2} = ??$ (at T_2)

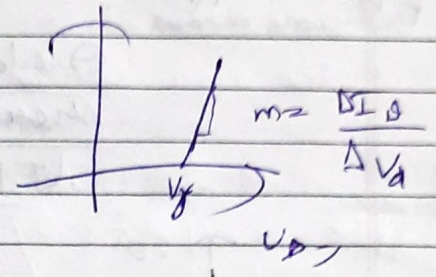




Diode model

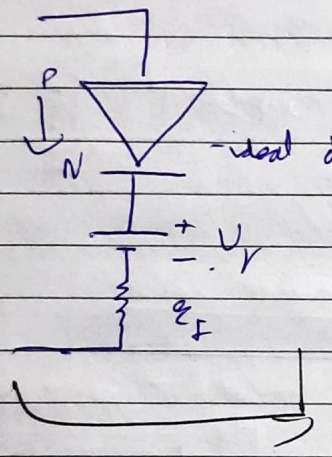
① Piecewise Model



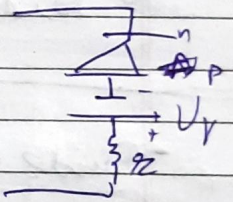


$$r_D = \frac{\Delta V_D}{\Delta I_D} = r_f$$

forward resistance



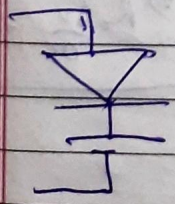
Practical Diode
↳ Piecewise model

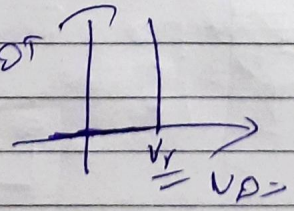


r_f = very small ≈ 5 – 10Ω (in ideal case).

② Constant Voltage Drop Model

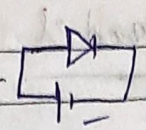
$r_f \to 0$



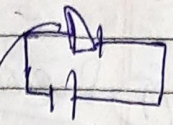


(c) Ideal Diode

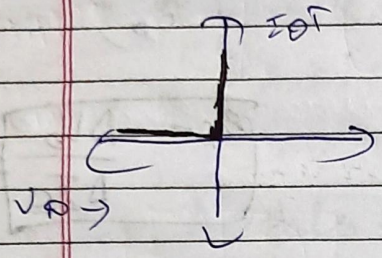
FB RB



Diode replaced by short ckt
(I Max)



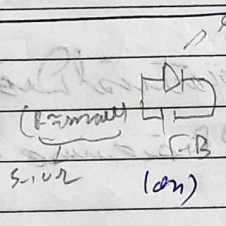
Diode replaced by open ckt
$I = 0$

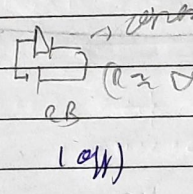


FB

ie Diode acts as a switch

→ Diode Modelling

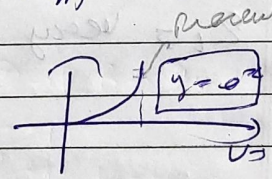




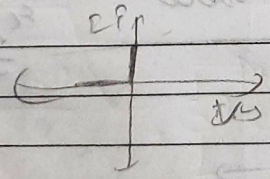
Ideal
FB → R = 0.6V
RB → R = ∞

• For Ideal Diode

→ Diode as linear element



1) Ideal Diode ($V_\gamma = 0$)

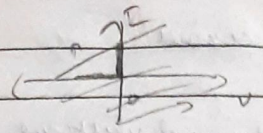


$$\text{Slope} = \frac{\Delta I}{\Delta V}$$

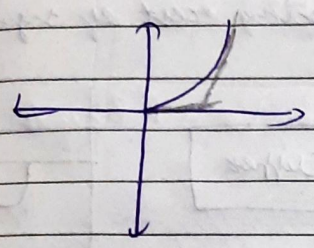
$$\Rightarrow R = \frac{\Delta V}{\Delta I} = \frac{1}{\text{Slope}}$$

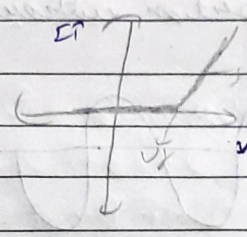
Date
DELTA Pg No.

① Ideal Diode

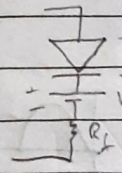


V_1 & Diode Forward Resistance are ~~[illegible]~~ present





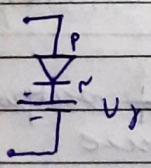
slope $= \frac{\Delta I}{\Delta V} = \frac{1}{R_f}$ (resistance F.B.)

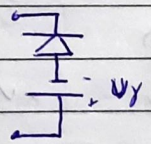


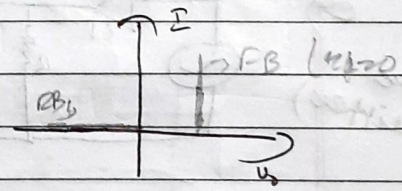
→ Ideal Diode - to establish flow of current

→ Constant Voltage Drop - resistance (R_f) becomes 0.

R_f is neglected ($R_f \to 0$)





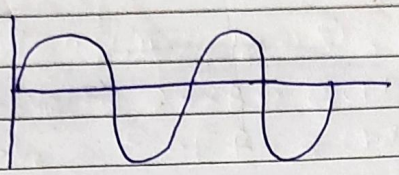


→ Clipper circuit – limiter circuit

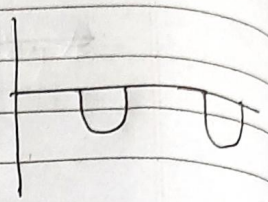
- used to change appearance of signal without affecting remaining part of ckt
- Clip away portion without affecting rest of signal

+ve Clipper

+ve part is clipped off

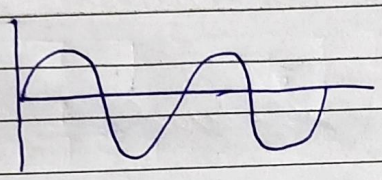


Clipper

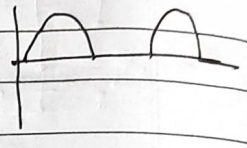


-ve Clipper

-ve part is clipped off

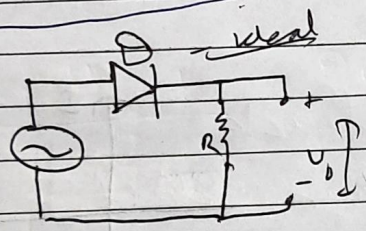


Clipper



Universal Diode

(a) (+ve Clipper)

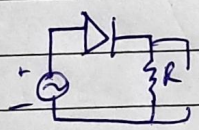


– ideal

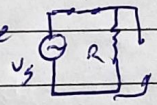
Ideal V_0 & Transfer Curve

- V_0 waves output as input wave

Sol – +ve Half cycle

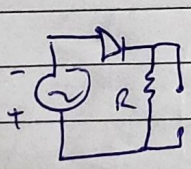


D → F.B → Short ckt

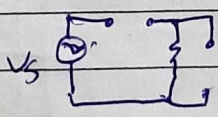


$V_0 = V_s$

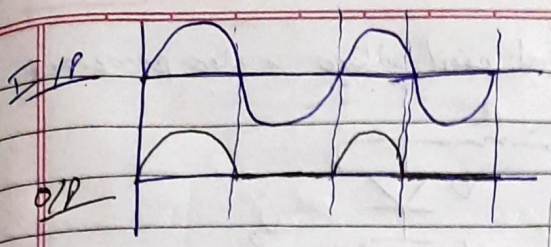
-ve Half cycle

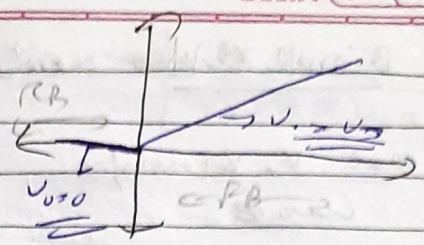


D → RB → Open ckt



$V_0 = 0$

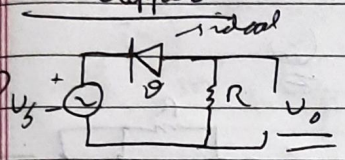




b. wave

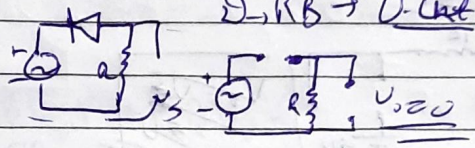
Transfer curve

(b) -ve clipper (Diode is reversed)



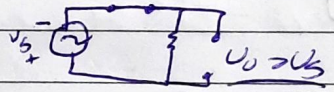
+ve half cycle

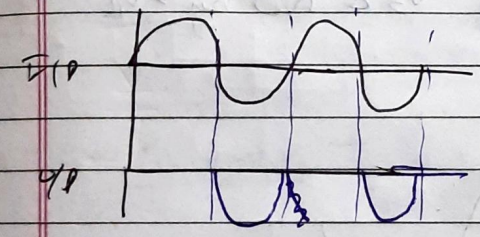
D → RB → O.Ckt

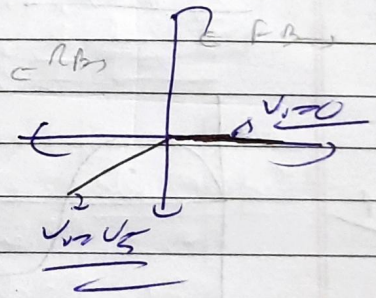


-ve half cycle

D → FB → S. Ckt

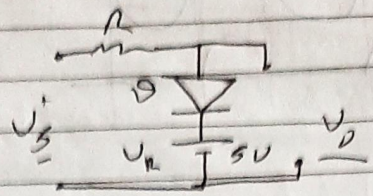






→ Biased Clipper – external bias voltage is also present

Q) Plot V_o & Transfer curve

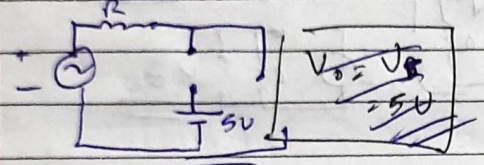


Sol: → +ve ~~Half~~ Half cycle → D is FB by V_s & RB by V_R

(i) $V_s < V_R$ → D → RB → O. Ckt

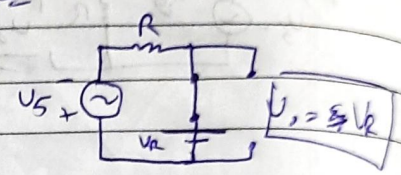
(ii) $V_s > V_R$ → D → FB → S. Ckt.

(i)

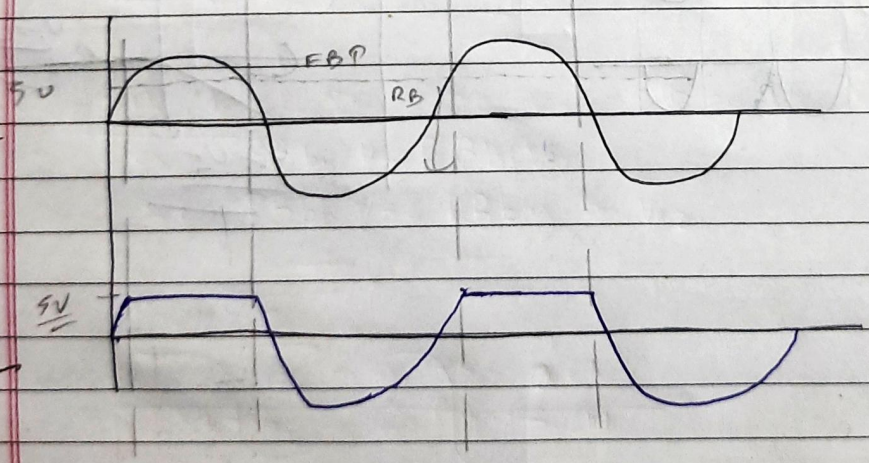


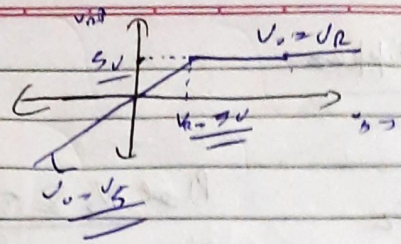
$\boxed{V_o = V_s}$

(ii)



→ -ve Half Cycle. → D is RB by V_s & RB by $-V_R$

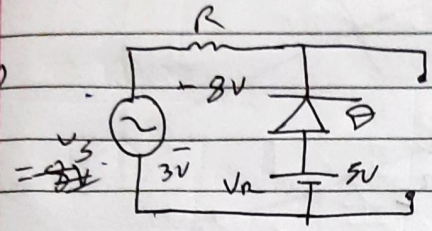




vs here | $V_S < V_R \Rightarrow V_o = V_S$ → o/p
$V_S > V_R \Rightarrow V_o = V_R$ → o/p

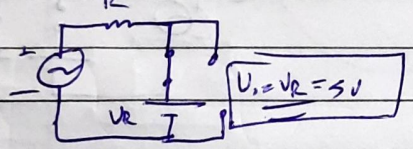
- Reference voltage transistor – when input V = externally applied V (i.e $V_S = V_R$) → ~~only~~

(a)

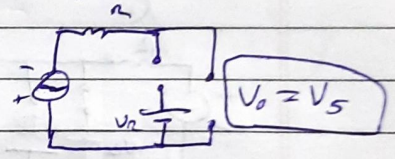


→ +ve Half cycle → D is RB by V_S & FB by V_R.
(i) $V_S < V_R \Rightarrow$ D → FB → S. Ckt
(ii) $V_S > V_R \Rightarrow$ D → RB → O. Ckt

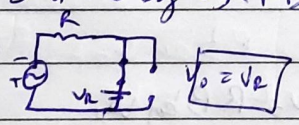
(i)

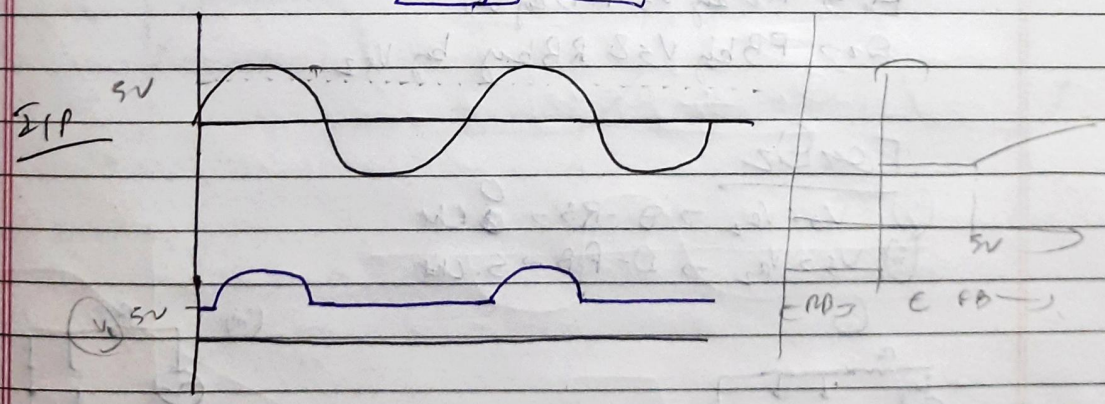


(ii)

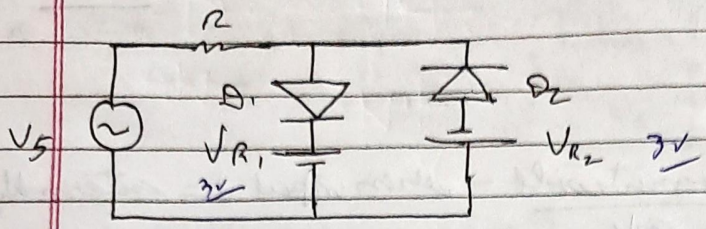


→ −ve Half cycle → D is FB by V_S & FB by V_R





→ Double Biased / Parallel Clipper



Plot V_o & Transfer Curve

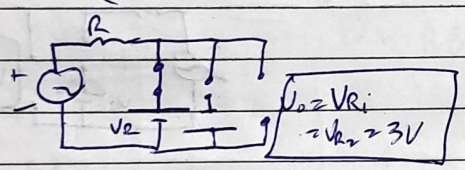
Ans → +ve Half Cycle

D_1 → FB by V_S & RB by V_{R_1}
D_2 → RB by V_S & RB by V_{R_2}

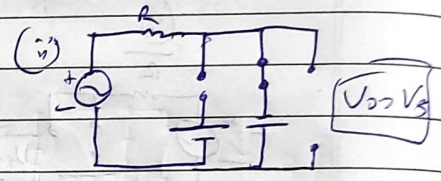
For D_1

(i) $V_S > V_{R_1}$ → D → FB → S. Ckt
(ii) $V_S < V_{R_1}$ → D → RB → O. Ckt

(i)



(ii)



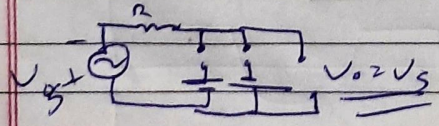
→ -ve Half Cycle

D_1 → RB by V_S & RB by V_{R_1}
D_2 → FB by V_S & RB by by V_{R_2}

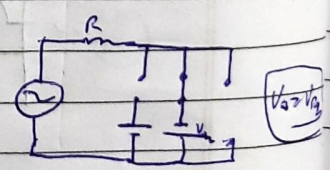
For D_2

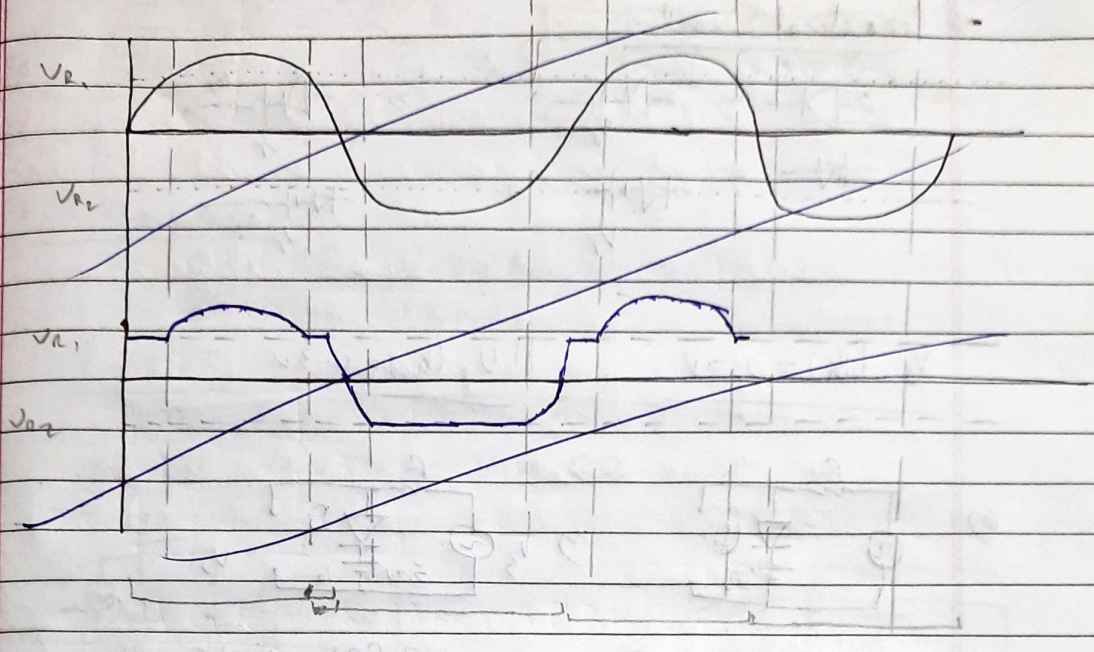
(i) $V_S < V_{R_2}$ → D - RB → O. Ckt
(ii) $V_S > V_{R_2}$ → D - FB → S. Ckt

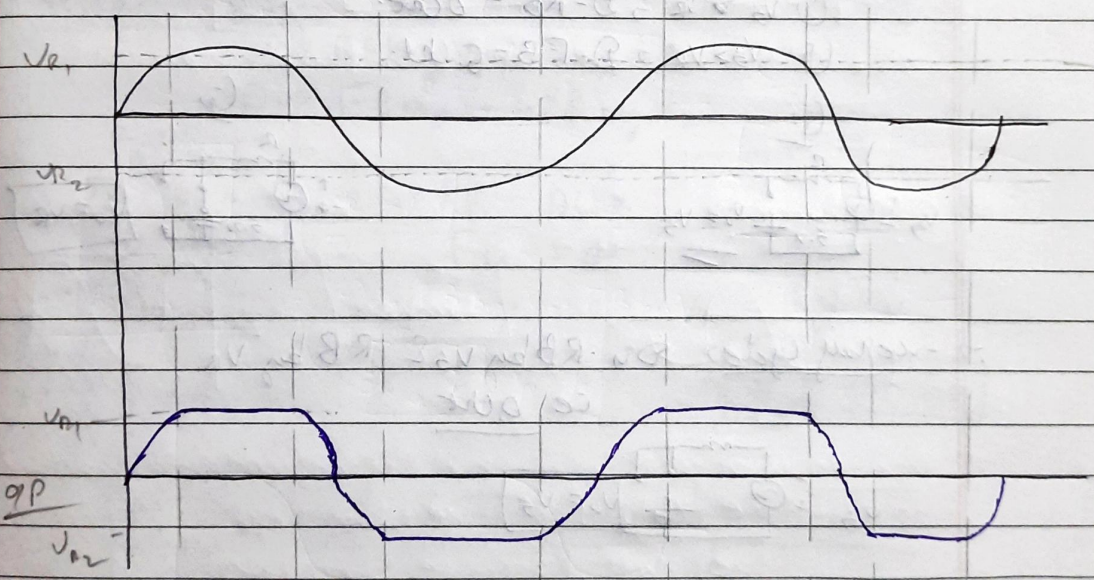
(i)

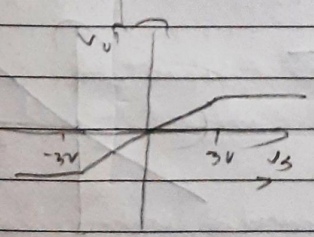


(ii)

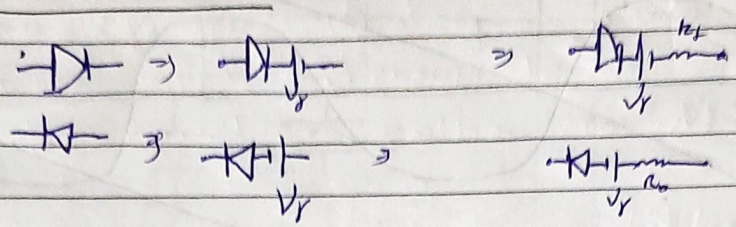



V_{R_1}
V_{R_2}
V_{R_1}
V_{R_2}


V_{R_1}
I/P
V_{R_2}
V_{R_1}
O/P
V_{R_2}

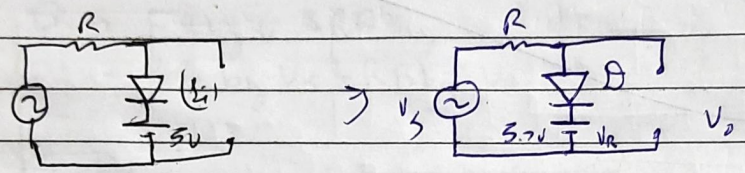

V_0
-3V
3V
V_s

→ Practical Diode



V_γ (Si) = 0.7V || V_γ (Ge) = 0.3V

Q)

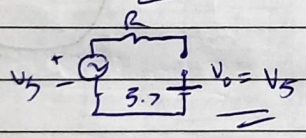


→ +ve Half cycle → D is FB by V_s & RB by V_R (5.7V)

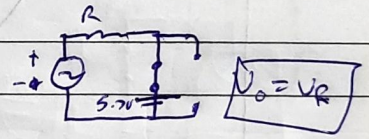
(i) $V_s < V_R$ → D - RB - O Ckt.

(ii) $V_s > V_R$ → D - FB - S. Ckt.

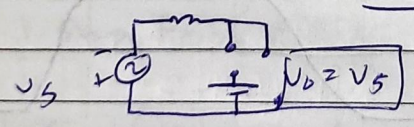
(i)

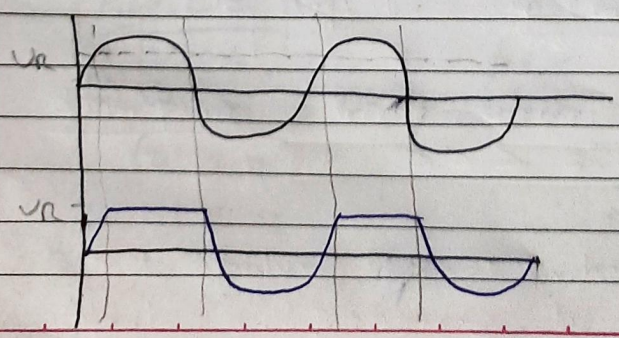


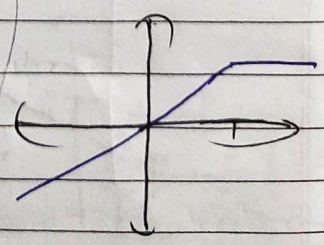
(ii)

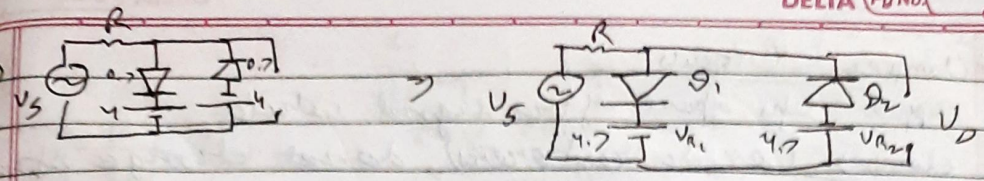


→ -ve Half cycles → D is RB by V_s & RB by V_R.
ie O.Ckt









→ +ve Half cycle

$D_1 \rightarrow$ FB by V_S & RB by V_{R_1}

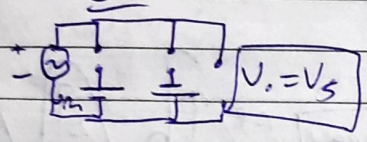
$D_2 \rightarrow$ RB by V_S & RB by V_{R_2}

For D_1

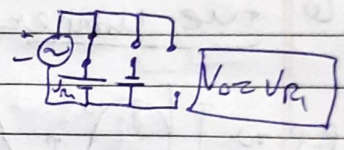
(i) $V_S < V_{R_1} \rightarrow D_1$ - RB - O. ckt

(ii) $V_S > V_{R_2} \rightarrow D_1$ - FB - S. ckt

(i)



(ii)



→ -ve Half cycle

$D_1 \rightarrow$ RB by V_S & RB by V_{R_1}

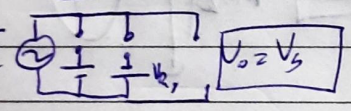
$D_2 \rightarrow$ FB by V_S & RB by V_{R_2}

For D_2

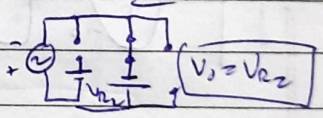
(i) $V_S < V_{R_2} \rightarrow D$ - RB - O. ckt

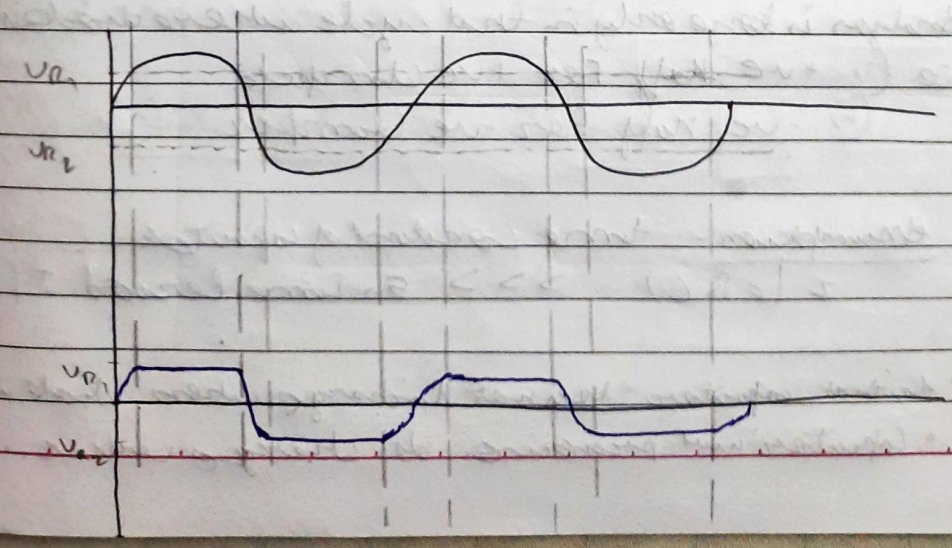
(ii) $V_S > V_{R_2} \rightarrow D$ - FB - S. ckt

(i)



(ii)





→ Clamper Circuits

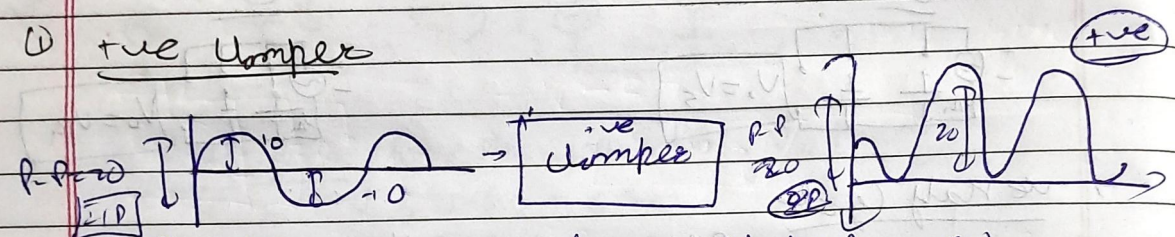
- clipper clips a part of the signal while clamper (or dc restorer), does not change shape of input waveform, rather they add a dc level to it.

- there are +ve, -ve & biased clippers.

- consists of only diode & RC element.

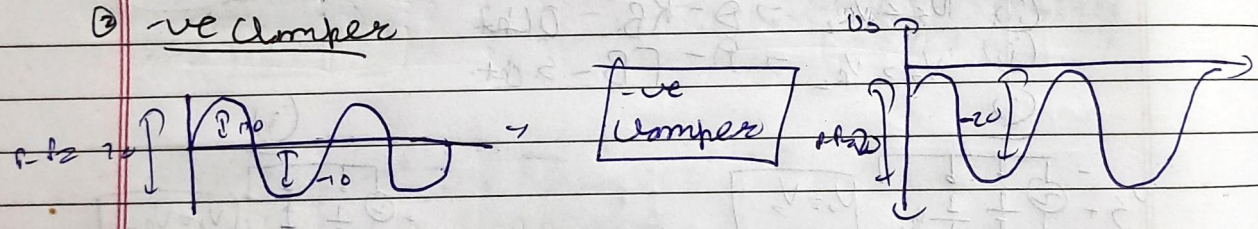
Input Peak to Peak = Output Peak to Peak

① +ve Clamper



- Shifts all +ve peaks up (ie amplitude changes)

② -ve Clamper



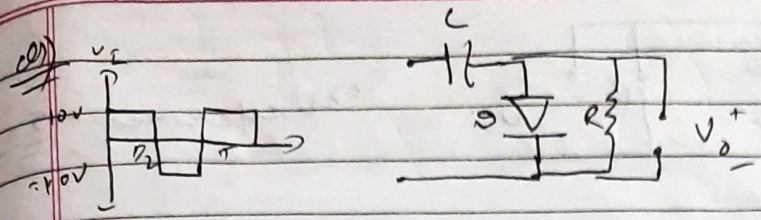
- Analysis is done only in that cycle where diode is on.
  ie (i) +ve Half for +ve clamper
  (ii) -ve Half for -ve clamper.

Assumption - time constant of capacitor
τ (= RC) >>> 5 × time period T (Pinput)

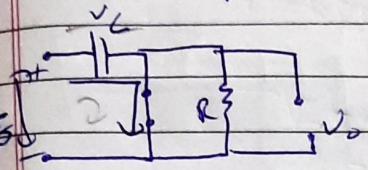
- So, that capacitor does not discharge when diode is in RB.
- Capacitor will preserve its charge value.

Date
DELTA Pg No.

-ve Clamper, as diode is pointing down



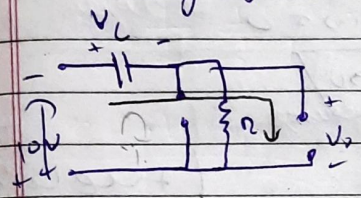
+ve half cycle → D → FB → short ckt. → ON



$V_o = 0V$ (limiting voltage across diode)

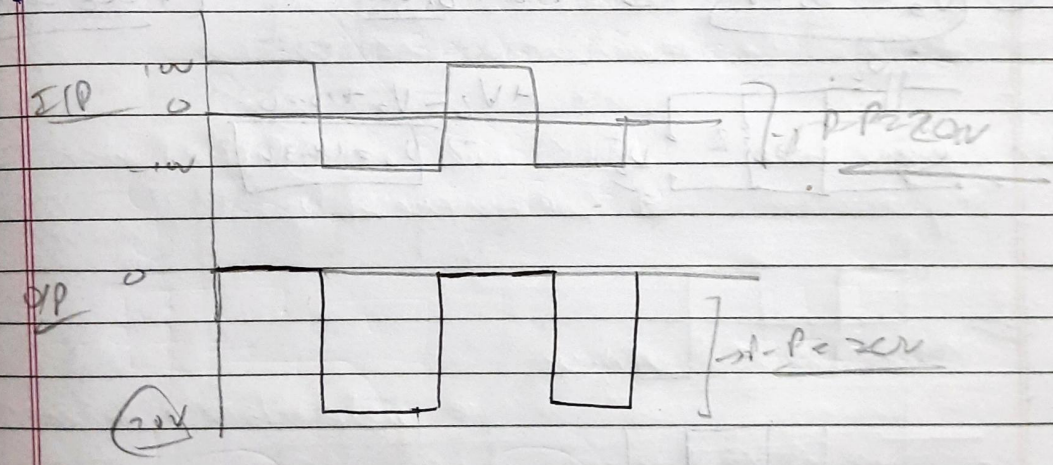
$V_C - 10 = 0 \Rightarrow \boxed{V_C = 10V}$ (By KVL)

-ve half cycle → D → RB → open ckt. → off

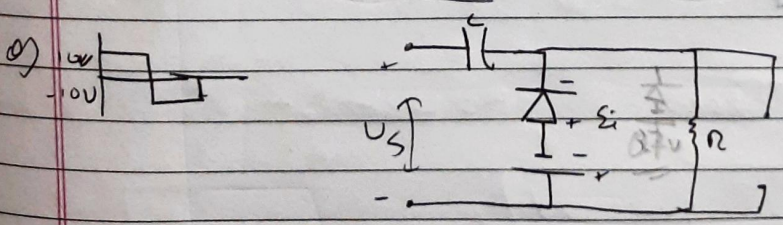


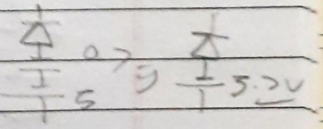
~~$10 - V_o + 10 = 0 \Rightarrow V_o = 20$~~

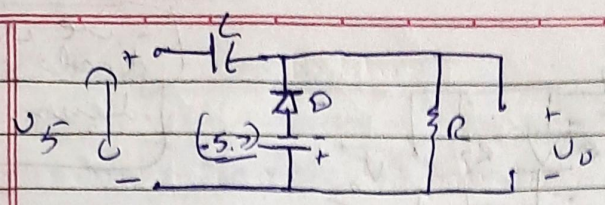
$-10 - 10 + V_o = 0 \Rightarrow \boxed{V_o = 20V}$



→ Silicon Diode Biased Clamper

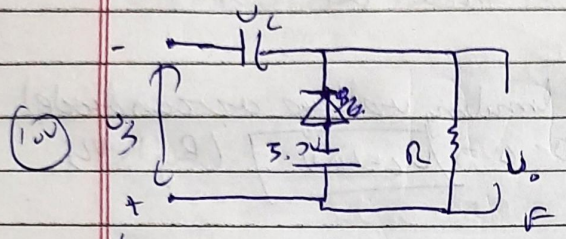




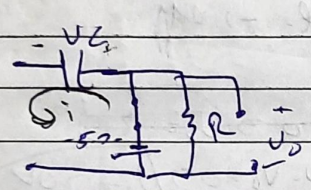


⇒ $V_{reference} = -5.7V$

→ -ve Cycle → D → FB by ~~5.7V~~ V_s & RB by 5.7V



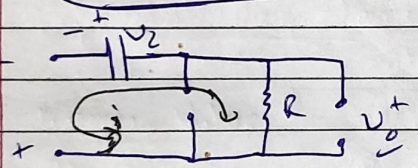
(i) $V_s < -5.7 \Rightarrow D = RB \rightarrow$ ~~0.6V~~ 5V



$-V_L - 5.7 + 10 = 0$

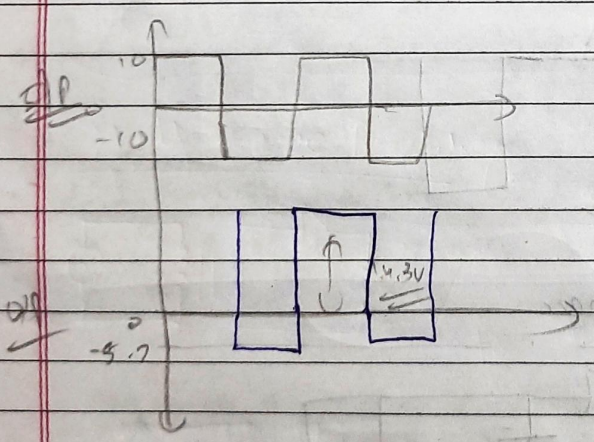
$\Rightarrow \boxed{V_L = 4.3V}$

(ii) $V_s > -5.7V \rightarrow D = RB \rightarrow 0.6V$ (+ve cycles)

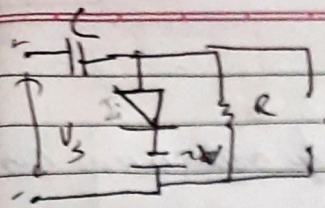


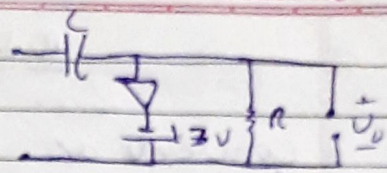
$+V_L - V_o + 10 = 0$

$\Rightarrow \boxed{V_o = 14.3V}$



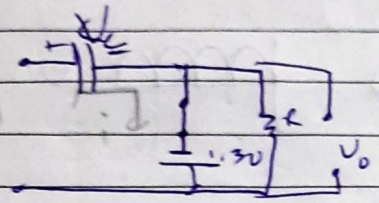
9





$\boxed{V_{avg} = -1.3V}$

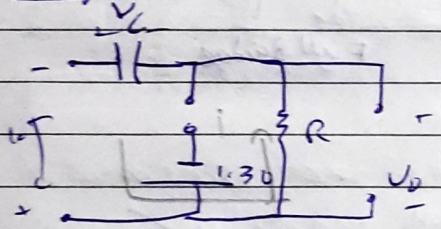
① +ve cycle → D = FB → S. cht. $(V_s > 1.3V)$



$-V_c + 1.3 + 10 = 0$

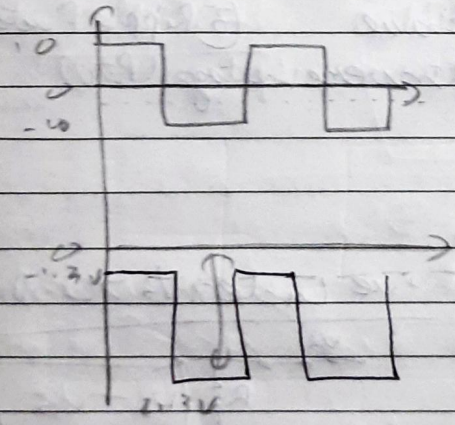
$\Rightarrow \boxed{V_c = 11.3V}$

② -ve cycle → D = RB → O. cht



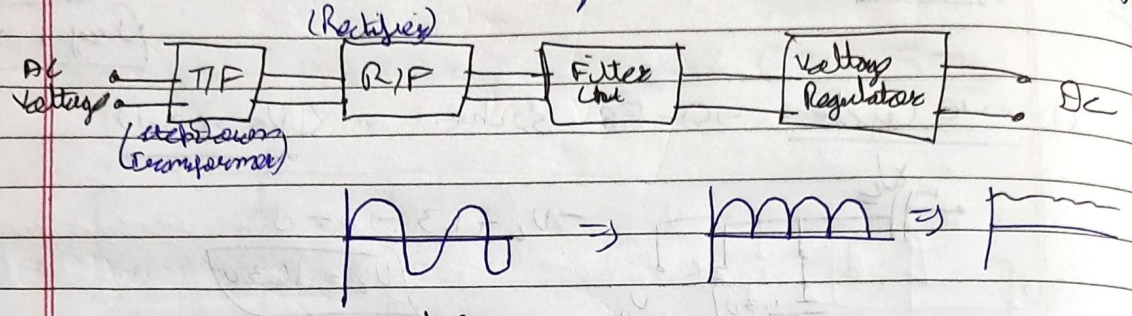
$10 - V_o + V_c = 0$

$\Rightarrow \boxed{V_o = 21.3V}$



Rectifier

- Converts ac to pulsating dc (not pure, has harmonics)



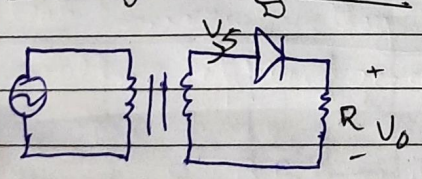
Half Wave Rectifier (HWR)

Full Wave Rectifier (FWR)
- Full Bridge
- Centre Tapped Transformer (FWR)

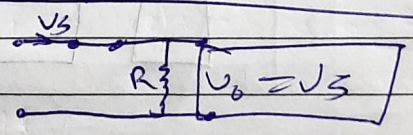
→ Important Properties

1. Average Value
2. RMS Value
3. Ripple Factor
4. Efficiency
5. Peak Inverse Voltage (PIV)

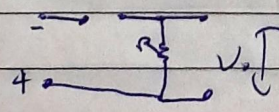
(I) Half Wave Rectifier



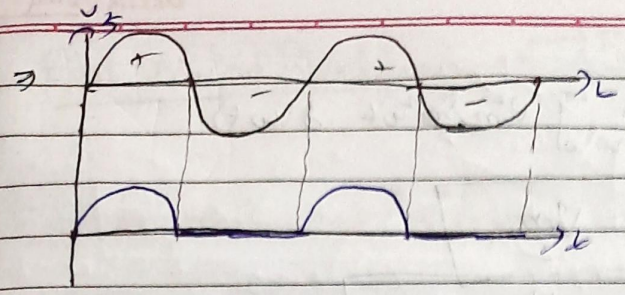
→ +ve Cycle → Vs > 0 → D → FB → S.Ckt



→ -ve Cycle → Vs < 0 → D → RB = O.ckt



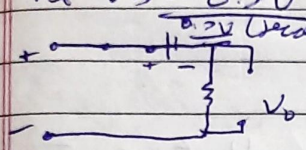
$V_o = 0V$



If $V_\gamma \neq 0$ ie if $V_\gamma = 0.7V$ (Si) conty

• We check at $V_s > 0.7$ & $V_s < 0.7$ & reference $V = 0.7V$

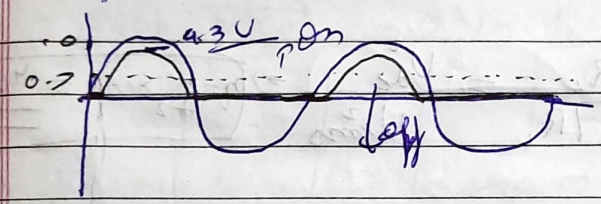
At $V_s > 0.7V$



$V_o = V_s - V_\gamma = V_s - 0.7V$

ie $\boxed{V_o = V_s - V_\gamma}$

eg → if $V_s = 10V$ ⇒ $V_o = 10 - 0.7 = 9.3V$

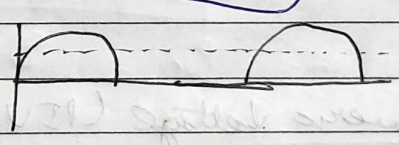


eg- Convert 12V rms in 5:1 ratio of V_s

$\Rightarrow \frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{12}{V} = \frac{5}{1} \Rightarrow V = 2.4V$

if it is $V_{rms} \Rightarrow \boxed{V_{o(rms)} = \frac{\sqrt{2} \times V_{rms(1)}}{n \text{ (ratio)}}}$

⇒ Analysis



(1) V_{dc} (avg) ⇒

$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \, d(\omega t) = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t) + 0$

$\Rightarrow \boxed{V_{dc} = \frac{V_m}{\pi} = 0.318 V_m}$ $\boxed{\Rightarrow I_{dc} = \frac{I_m}{\pi}}$

If $V_\gamma \neq 0 \Rightarrow \boxed{V_{dc} = \frac{V_m - V_\gamma}{\pi}}$ $= \frac{1}{2\pi}\int_0^{\pi} (V_m - V_\gamma) \sin\omega t \, d\omega t$

(2) V_{rms}

$$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2\omega t \, d(\omega t)$$

$$\Rightarrow \boxed{V_{rms} = \frac{V_m}{2}}$$

If $V_\gamma \neq 0 \Rightarrow$ $\boxed{V_{rms} = \frac{V_m - V_\gamma}{2}}$

(3) Efficiency (η)

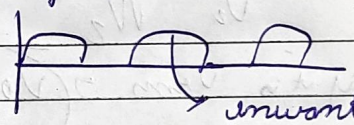
$$\boxed{\eta = \frac{P_{dc}}{P_{ac}}}$$

• $P_{dc} = V_{dc} I_{dc} = \frac{V_{dc}^2}{R_L}$ or $I_{dc}^2 R_L$

$$\Rightarrow \eta = \frac{V_{dc}^2 / R_L}{V_{rms}^2 / R_L} = \frac{V_{dc}^2}{V_{rms}^2} \Rightarrow \boxed{\eta = \frac{4}{\pi^2} \times 100 = 40.5\%}$$

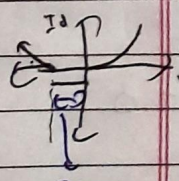
(4) Ripple Factor - unwanted ac component left in output of rectifier

$$\boxed{\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = 1.21}$$

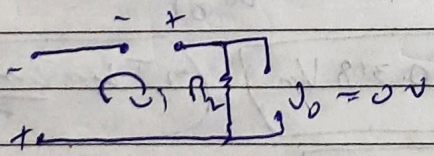


unwanted ac + dc

(5) Peak Inverse Voltage (PIV) - It is the maximum voltage applied across diode when D is in RB.



$\therefore$ D = RB $\Rightarrow$ open ckt.



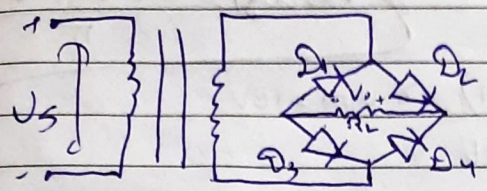
$\Rightarrow -V_s + V_{PIV} = 0$

$\Rightarrow V_{PIV} = V_{s\,max}$

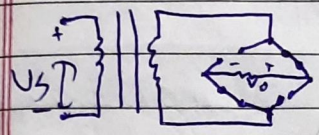
$\Rightarrow \boxed{V_{PIV} = V_m}$

② Full Wave Rectifier → Full wave Bridge (R/F) / Centre tapped FF (R/F)

ⓐ Full Wave Bridge Rectifier

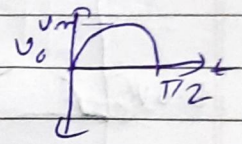


→ +ve half cycle → D_1 & D_4 in FB ⇒ S cht.
D_2 & D_3 in RB ⇒ O cht.

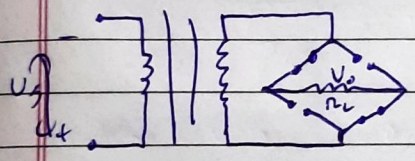


⇒ $V_m - V_o = 0$

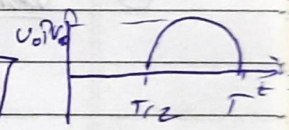
→ $\boxed{V_o = V_m}$



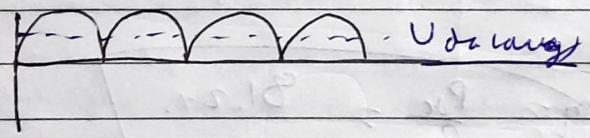
→ -ve half cycle → D_2 & D_3 are in FB ⇒ S cht.
D_1 & D_4 are in RB ⇒ O cht.



$-V_m + V_o = 0$ ⇒ $\boxed{V_o = V_m}$



O/P

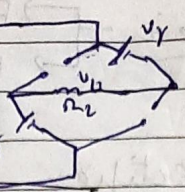


① $V_{dc\,(avg)}$

$$V_{dc\,(avg)} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\omega t \, d(\omega t)$$

$$\Rightarrow \boxed{V_{dc\,(avg)} = \frac{2V_m}{\pi}} = 0.637 V_m$$

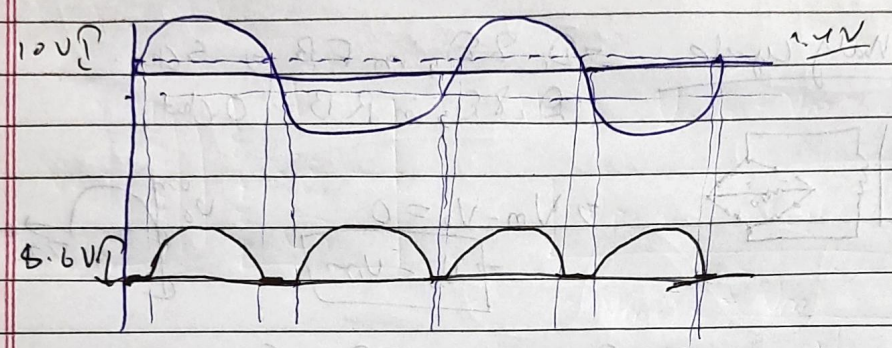
If $V_\gamma \neq 0 \Rightarrow$



$\Rightarrow \boxed{V_0 = V_m - 2V_\gamma}$ $\Rightarrow \boxed{V_{dc(avg)} = \frac{2(V_m - 2V_\gamma)}{\pi}}$

eg $\rightarrow$ If $V_\gamma = 0.7V$ (Si) & $V_m = 10V$

$\rightarrow V_0 = 10 - 1.4 = 8.6V$



(2) Vrms

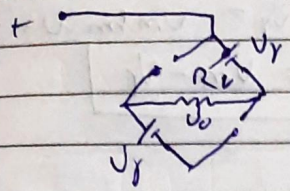
(3) η $\boxed{\eta = \frac{P_{dc}}{P_{ac}} = 81.2\%}$

(4) Ripple Factor

$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$ $\boxed{= 0.48}$ (less than HWR)

Date
DELTA Pg No.

(a) PIV — if $V_\gamma \neq 0$



$\Rightarrow -V_\gamma - V_o + V_{PIV} = 0$

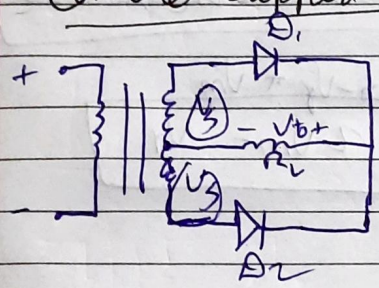
$\Rightarrow \boxed{V_{PIV} = V_o + V_\gamma}$

$= V_m - 2V_\gamma + V_\gamma$

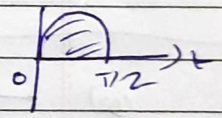
$\Rightarrow \boxed{V_{PIV} = V_m - V_\gamma}$

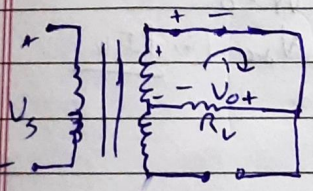
If $V_\gamma = 0$ $\Rightarrow \boxed{V_{PIV} = V_m}$

(b) Centre Tapped ~~B~~ T/F R/F



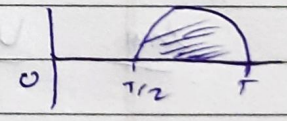
→ +ve half cycle → D_1 is in FB → S.Ckt
& D_2 is in RB → O.Ckt.

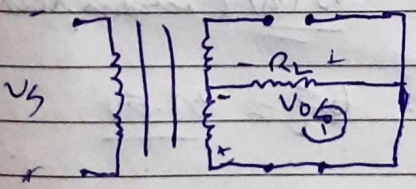




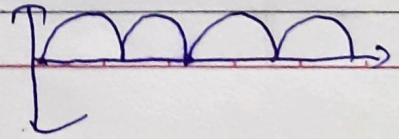
$\boxed{V_o = V_s = V_m \sin \omega t}$

→ -ve half cycle → D_2 is in FB → S.Ckt
& D_1 is in RB → O.Ckt.

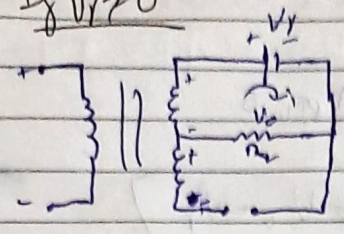




$\boxed{V_o = V_s = V_m \sin \omega t}$



If $V_\gamma \neq 0$

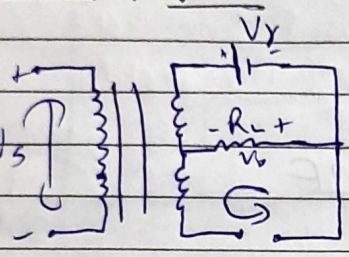


$V_s - V_\gamma - V_o = 0$

$\Rightarrow V_o = V_s - V_\gamma = V_m \sin \omega t - V_\gamma$

$\Rightarrow \boxed{V_{o(m)} = V_m - V_\gamma}$

- PIV - If $V_\gamma \neq 0$



$V_{PIV} - V_{o,m} - V_m = 0$

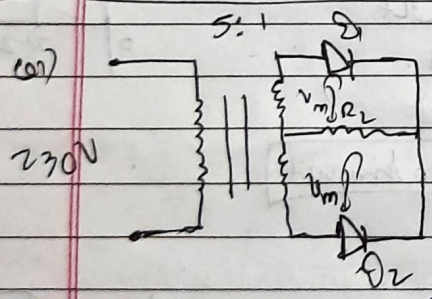
$\Rightarrow \boxed{V_{PIV} = V_{o(m)} + V_m}$

$= V_m - V_\gamma + V_m$

$\Rightarrow \boxed{V_{PIV} = 2V_m - V_\gamma}$

If $V_\gamma = 0 \Rightarrow \boxed{V_{PIV} = 2V_m}$

(or)



If $V_\gamma = 0$ & $V_\gamma \neq 0$

Find (i) V_{dc} (ii) PIV

Ans $\frac{V_1}{V_2} = \frac{n_1}{n_2} \Rightarrow \frac{230}{V} = \frac{5}{1}$ & $V_2 = 46V$

$\Rightarrow V_{2(max)} = 46 \times \sqrt{2} = 65V$ ($V_{o(2)}$) (across secondary coil)

Across half secondary coil $= V_m = \frac{65}{2} = 32.5V$