GATE/ESE NOTES for

ELECTRIC CIRCUITS (EEE)
NETWORK THEORY (ECE)
BASICS OF CIRCUITS (INST)

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Networks

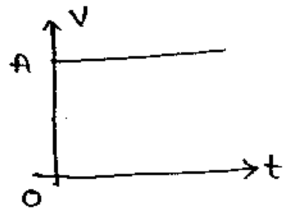
What to study to get Rank.

1. Notes of Every Teacher Volume-1 classwork Volume-2 H/W +100% Attendence.
2. collect and Study all pervious year IES objective of EEE and E&T(ECE) prelims
3. collect & study all previous year Gate solution bits of EEE & ECE Instrumentation Common Subjects.
4. Text Book bits ⟶ standard.

   Ex: CL Wadhwa, B.S. Bimbra, (M/c and power Electronics) + Genco Transco papers + UPSC civil services, ISRO, DRDO, BARC.
5. Write lot of online & offline Exams. and Take self feedback.

Syllabus:

first three chapters are of DC circuits

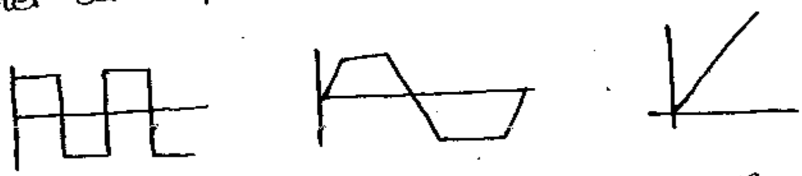


R ⟶ Homogeneous & proportional

L ⟶ S.C

C ⟶ O.C

4. chapter Basics of Time Variance.

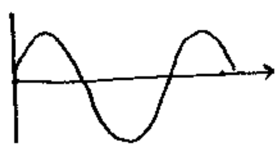


R ⟶ Homogeneous & proportional

$\left.\begin{matrix} L \\ C \end{matrix}\right\}$ will Respond.

Chaper : $\underbrace{5, 6, 7, 8, 9, 10, 11}$

AC circuits

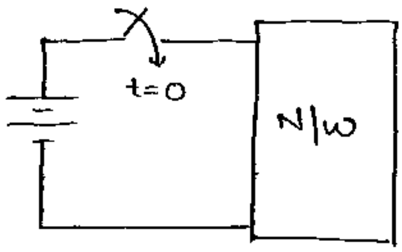


R ⟶ Homogeneous & proportional (in phase elements)

L ⟶ Lagging

C ⟶ Leading.

12. } Transient Response
13. }



Level 1 $\longrightarrow$ 1-4 chapters.

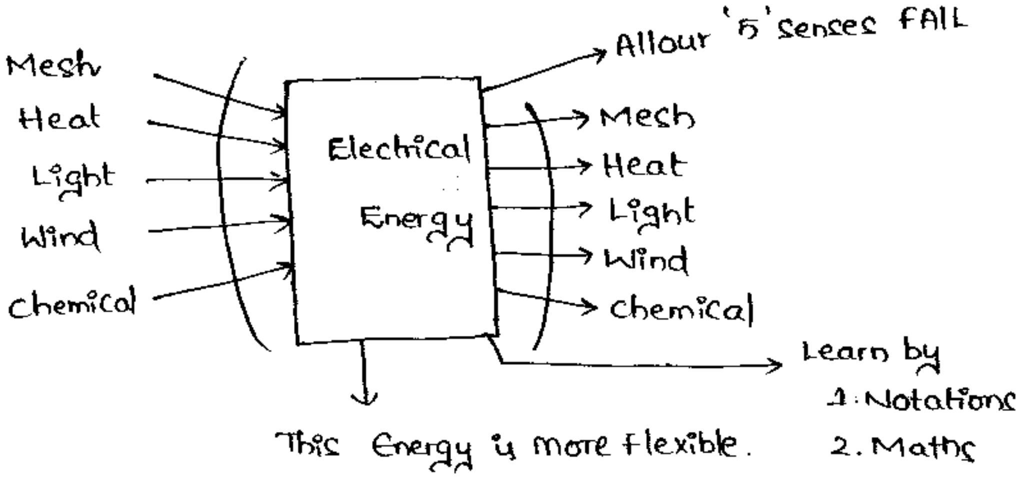
Level 2 $\longrightarrow$ 5-10 chapters.

Level 3 $\longrightarrow$ 11-15 chapters.

Electrical Energy: Dominent & Most Superior form of Energy by

1. interconvertability
2. Transportation.

2



2. Generate & Transport
   - Bulk Qualities
   - Larger distances
   - Most Economically way

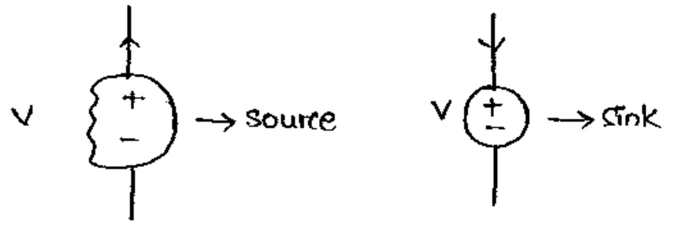
Ex: 1. unit of Electrical Energy = 1 kWh
= 1000 * 1 hr
RS 3/- per unit
C>70% population in India.

Electrical Energy

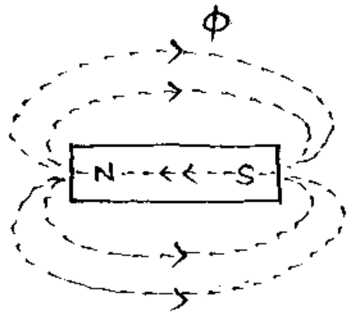
- → EEE → power level → kV, kA (MW ≃ GW), f = 50Hz
- → ECE → signal level → (mV~V), mA (mW~W) f ∈ {KHz, MHz, GHz.
    - → precision, Accuracy, Speed, Compact, portable Artificial Intelligence, Communications
    - → cost, %η, pf cosφ, % VR, losses, protection safety.

Notations :

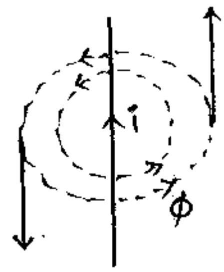
1.



2.



- Ampere Right Hand Thumb Rule :



IEEE Symbol

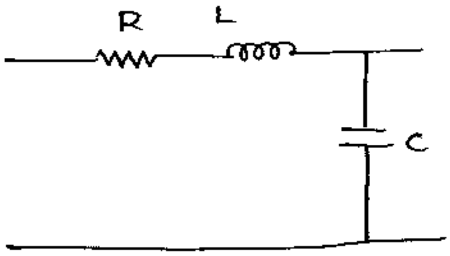
- Any material

Resistor → Represents Linear Time invariant Electrical property of Matter.

Inductor → Electro Magnetic property of Matter.

Capacitor → Electro static property of Matter.

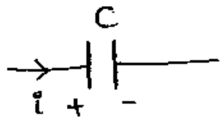
Ex: 1:



* greater than (or) Equal to 10 mA of Current flows through Human Body the Human Can die.

* 2 mA Current Can effect body of paralysis

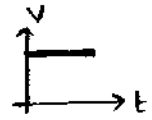
Capacitor:



From Ohm's Law

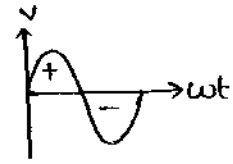
$$\boxed{i = C\frac{dv}{dt}}$$

→ DC

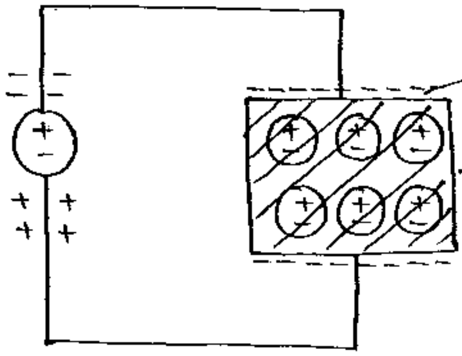


→ $i_C = 0$ ⇒ Capacitor acts as O.C

→ AC



→ $i_C = I_m \sin(\omega t + 90^\circ)$ ↓ Leading.



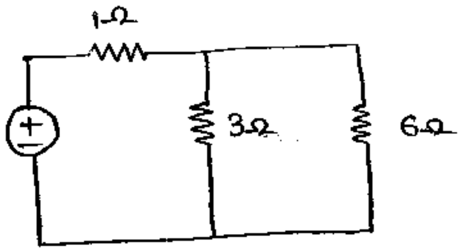
→ charge is a function (displacement Current)

→ dielectric Exhibits polarization

Note:, Engineering is Application of Science & Analysing by mathematical modelling

DC Generator is introduced by Tecla in 1902

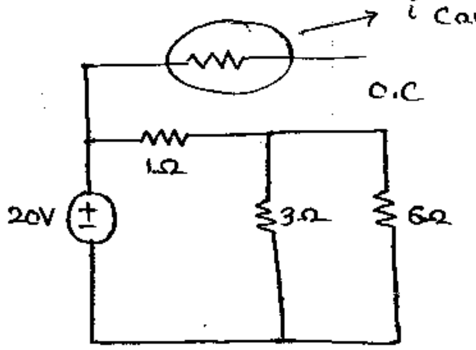
Circuit:



⇒ Current 'i' is intended to flow through all the Components.

$\boxed{i}$ → EMF / voltage
→ closed path

Network:



Here there is No Closed path for the Flow of Current.

* All our practical big interconnected Systems are Networks but we do Circuits Analysis to those parts where Current is flowing.
* circuits are Building Blocks of Networks.

Ex: Our power System is a Big Network But a motor running in it is ckt at power level.

Ex: our Communication System is a big Network But a Transmitter working in it is a ckt at Signal level.

EEE = power level = circuits

Ex: Fault Analysis, power Electronics, T&D

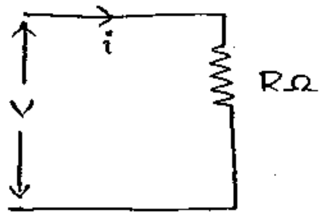
ECE / Instruments = signal level = Network.

Ex: Mobile Communication, WiFi, Bluetooth, Microwave Engineering.

Network Components (or) Elements :

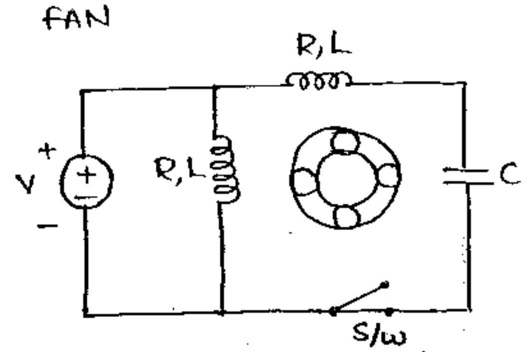
⇒ All our Application in Electrical Engineering are our Components But When this applications are mathematically modelled as ckts or N/wc we use fundamental N/w Components such as V, I, R, L, C etc to Model them

Ex: Heater

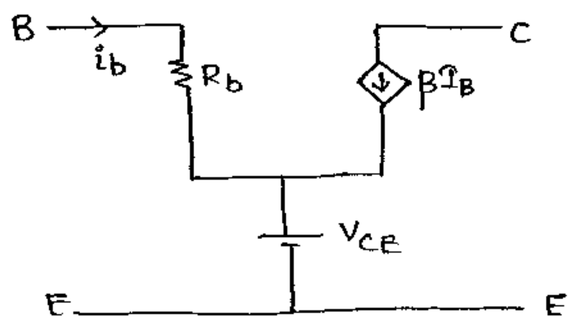


$$P_{abs} = i^2R = \frac{V^2}{R}$$

FAN



Ex: BJT



V , I , R , L , C

Mother (internal Resistance = 0)

Father (internal Resistance → ∞)

Boy (independent of freq)

Girls (dependent of freq)

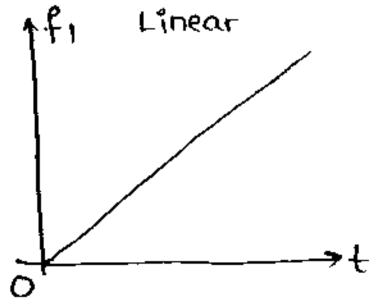
$V = L\frac{di}{dt}$

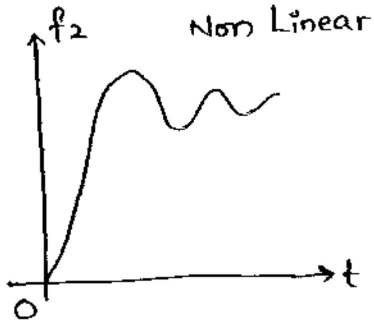
$i = C\frac{dV}{dt}$

L, C → Reactive power.

Linear Components & Linear Networks:

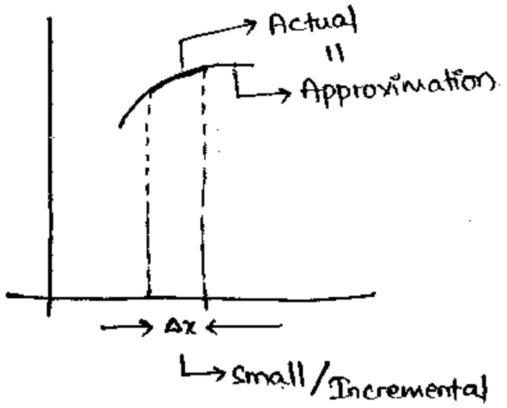
* All our practical Components are originally non Linear in Nature. But Any non Linear System Can be Linearised by Small Incremental change in time. But the Same System for the Sudden big changes undergoes non Linear Mode of operation.

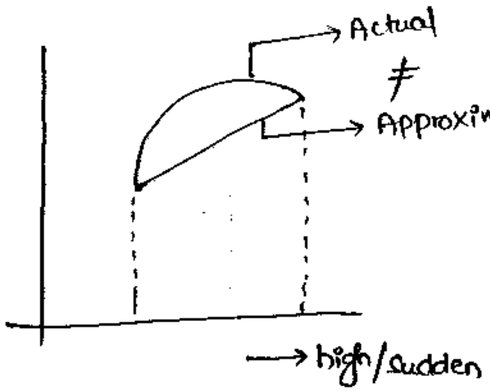




⇒ it is a function of Homogeneous
⇒ it can be Modelled in maths

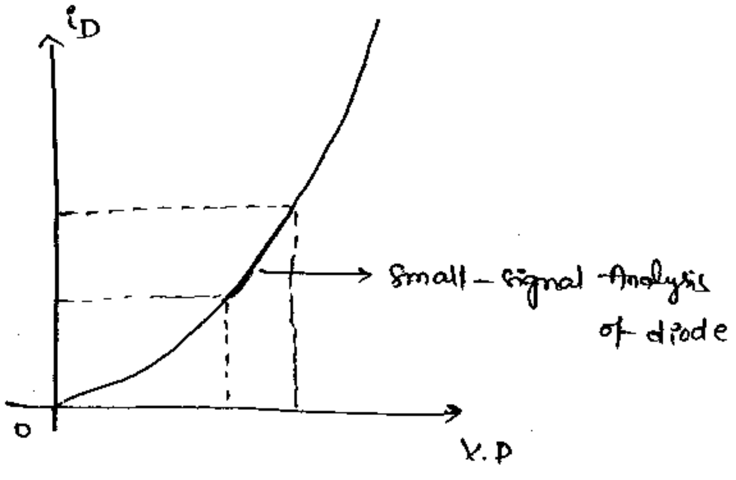
→ Non Homogeneous
⇒ Can't be modelled in maths

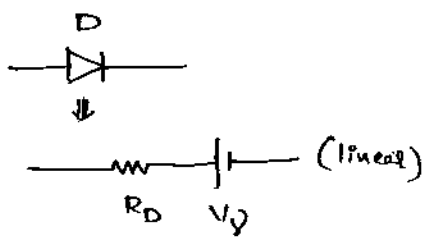




* All our Engineering Components & Design have Rating / Specifications.

Ex: Diode:

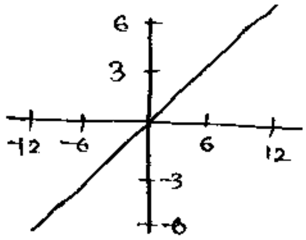




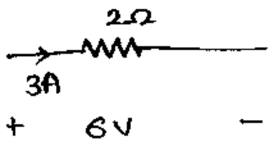
* in Electrical ckt Analysis if every Component is designed & operated within the Ratings is said to be linear. Where it obeys ohm's law kirchoff's Law, Super position Theorem etc

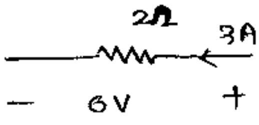
Bilateral Component :

$\boxed{I = III}$ → symmetrical.



Ex: Resistor.





(V=iR)

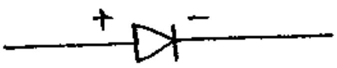
$P_{abs} = 18\,\omega = \frac{V^2}{R} = \frac{36}{2}$ $\qquad$ $P_{abs} = \frac{V^2}{R} = \frac{6^2}{2} = \frac{36}{2} = 18\,\omega$

⇒ The properties & characteristics of such elements are independent to ckt Condition

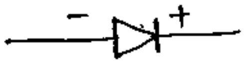
Ex: R, L, C are Bilateral.

Unilateral Components:

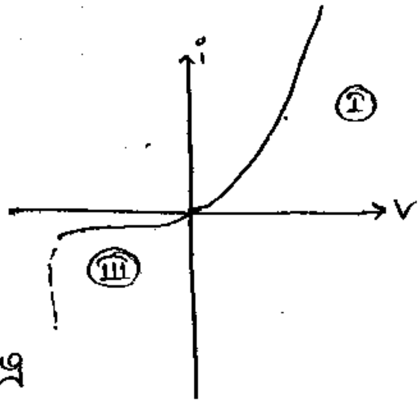
Ex: Diode



→ F.B
→ will Conduct
→ $R_{ON} = 0\,\Omega$



→ R.B
→ Not Conducting
→ $R_{OFF} = \infty\,\Omega$

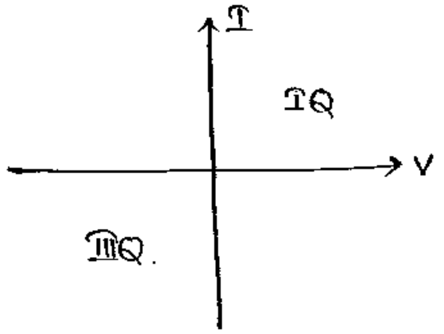


I ≠ III
↓
asymmetrical

→ The properties & characteristics of such Components depend upon ckt Condition

Ex: Diode, BJT, MOSFET etc are Unilateral.

Based on static V-I characteristics:

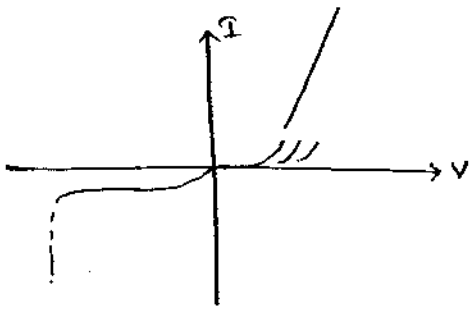


if $IQ = IIIQ \Rightarrow$ Symmetrical $\Rightarrow$ Bilateral

$IQ \neq IIIQ \Rightarrow$ asymmetrical $\Rightarrow$ Unilateral

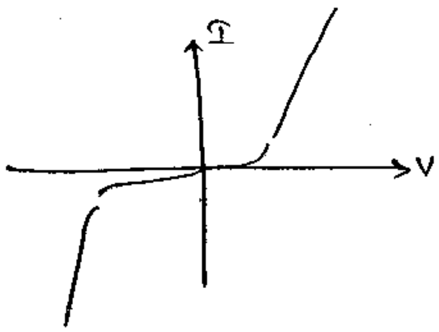
Examples:

SCR



$IQ \neq IIIQ$
unilateral switch

TRIAC

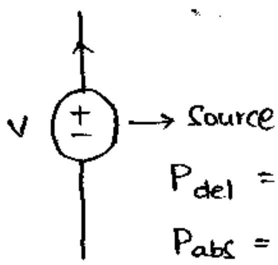


$IQ = IIIQ$
Bilateral Switch

Active elements: (source)

Any element can
- → Generate
- → give out
- → drive
- → Energise
- → deliver

} externally E.E.



$P_{del} = +V.i$ W

$P_{abs} = -V.i$ W

Ex: V, I

passive elements (components):

Any element Can

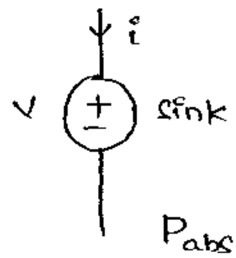
- → Absorb
- → Store
- → Convert
- → dissipate
- → Waste

} Electric Energy in Any form

Ex: R, L, C.

$\boxed{R}$ → dissipate.

E.E → Heat.



$\boxed{L}$ → Store

E.E → E.M Form (flux)

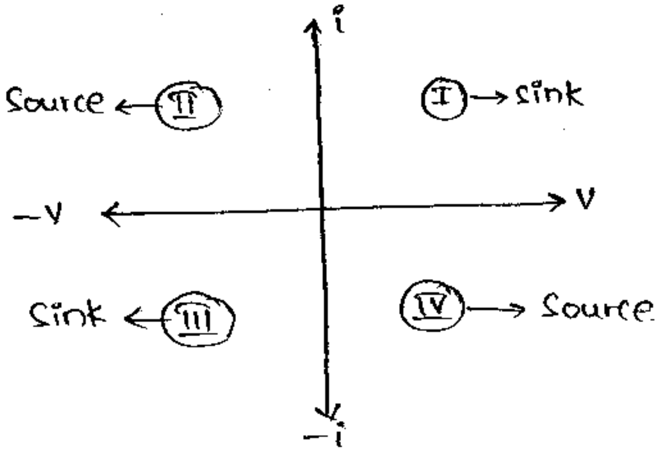
$P_{abs} = +V.i$ W

$P_{del} = -V.i$ W

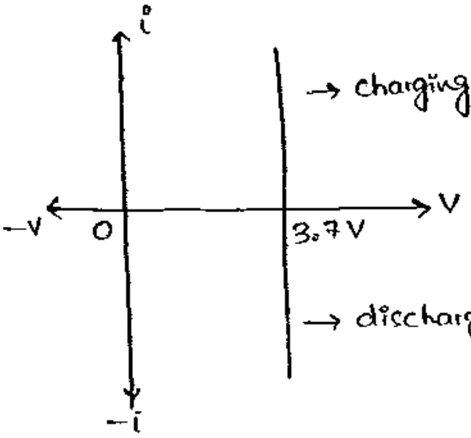
$\boxed{C}$ → Store

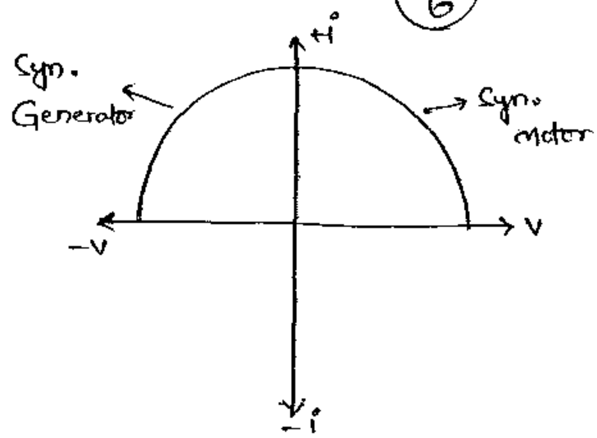
E.E → E.S form (charge)

Based on Static V-I Characteristics:

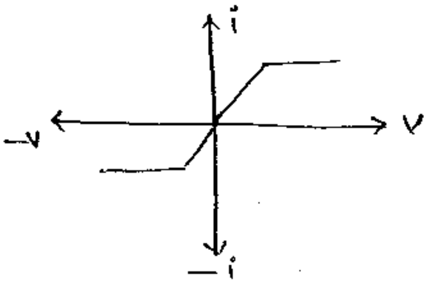


Ex: Rechargeable Battery



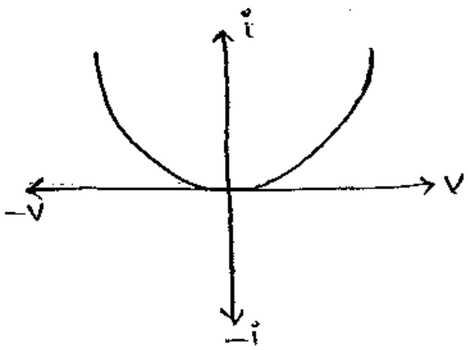


* The static V-I characteristics of a particle Components are shown below then the Component is NLPBi



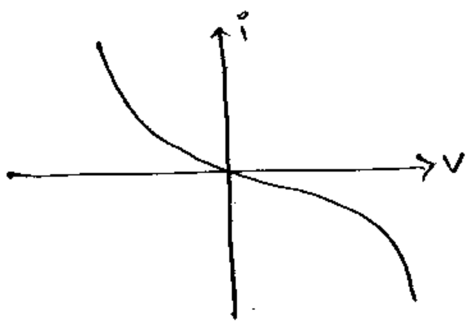
NonLinear passive Bilateral

* Static V-I. char. of perticular Components are shown below then the Components is



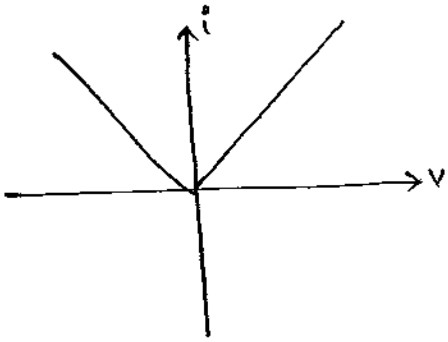
Non Linear Both Active & passive
Non Linear globally Active Unilateral

$\boxed{As}$ → Non linear Active unilteral



Non linear Active Bilateral

gate *



→ Non Linear Both passive & Active uniteral

ans: Non linear Active unilateral

Note:

(i) A Transistor BJT is globally passive but locally as an Amplifier is said to be Active

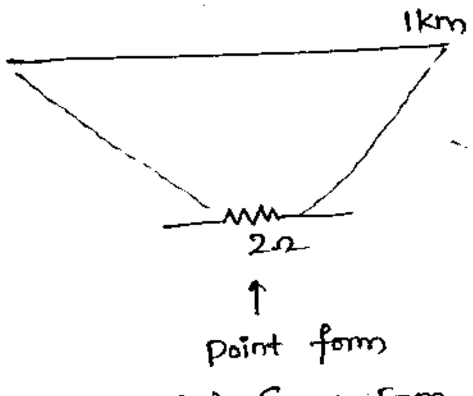
(ii) Most of Semiconductor devices when Biased with internal cut in voltages & leakage currents are said to be Active.

(iii) Inductors & Capacitors are globally passive But locally during Transient conditions are said to be Active. When they release energy due to initial

(iv) Op-amp is globally non linear. But locally below saturation is said to be linear.

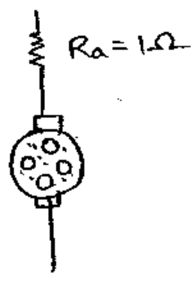
(v) The time duration of each operating mode of the device must be consider first & then decide its property.

<u>Lumped parameters:</u> → (Abstract Model)
↓
Used in Electric circuit Analysis (or) Networks.



We neglect any parametric change in length, Area, Temp, shape etc.

Ex: PCB Components

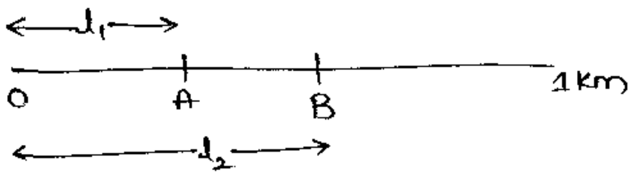


Ex: Model of Medium distance Transmission lines as T, π Networks etc.

Lumped parameters are

1. easy to Represent
2. Simple maths (Linear Algebra, Matrices etc)
3. Solutions are Faster
4. But Approximate Answer.

Distributed parameters: (Absoluted Models)
↳ Used in EMF.



$R = \frac{\rho l}{a}\ \Omega$ ⟹ We consider parametric changes in Modelling N/w Components.

$R_{actual} = \frac{\partial R}{\partial l}$

Ex: Model of Long distance T-lines [Rigorous Solution]

⟹ EMF Concepts

⟹ Antenna

⟹ Wave guide principles etc.

Distributed parameters

* Complex to Represent
* Advanced Maths (Transform Theory, D.E, Calculus etc)
* Solutions are Tedious
* But Very accurate Answer

} principles.

* The relationship $\boxed{V = n\lambda}$ is valid for ~~distributed~~ ______ parameters
↳ wave Equation

IES

(a) Lumped only

(b) distributed only

(c) Both lumped & distributed

(d) None.

Topological definitions of Network :

node (n): a node is a point of interconnection or function b/w two or more Components.

Branch (b): Branch is an elemental Connection b/w two nodes.

Degree of a node (δ): The no. of Branches in sit at any node represents its degree.

if $\delta > 2 \Rightarrow$ principle node (n_p)

$\delta = 2 \Rightarrow$ simple node (n_s)

Note: for any ckt or network

$$\boxed{\sum_{i=1}^{n} \delta_i = 2(b)}$$

mesh (m): mesh is a closed path of ckt or n/w. it should not have further closed paths in it.

Loop (l): Loops are all possible closed paths of ckt or n/w

Note:

→ for any ckt or n/w

$$m = (b-n+1)$$

→ The minimum number of KVL Equations required to solve ckt or n/w is

$$m = (b-n+1)$$

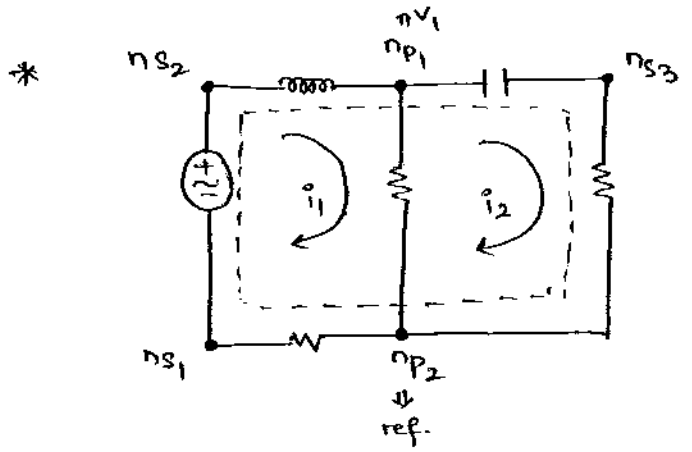
→ meshes are specifically known as independent loops.

→ all meshes are by default loops. but all loops are not meshes

→ in nodal analysis we may neglect simple nodes and one of the principle node is taken as reference. So the minimum number of KCL Equations required to solve ckt or n/w is $= (n_p - 1)$

$$= (n_p - 1)$$

*



$n = 5 \quad b = 6$

$m = 2 = [6-5+1]$ 8

$l = \underset{\text{mesh}}{2} + 1 = 3.$

$\sum \delta_i = 2+2+2+3+3$

$= 12$

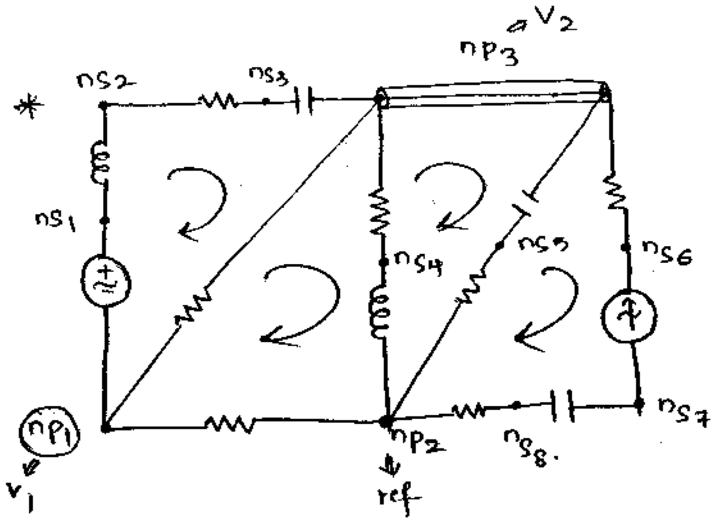
$= 2(6)$

$\sum \delta_i = 2(b)$

Mesh
↳ KVL ⇒ m=2 i_1 i_2

Nodal
↳ KCL ⇒ $(n_p - 1) = (2-1) \longrightarrow V_1$
$= 1.$

*



$n = 11, \quad b = 14$

$m = 4 = [14-11+1]$

$l = 4+3+2+1 = 10.$

Mesh
↳ KVL ⇒ m=4 ⟶ i_1 i_2 i_3 i_4

Nodal
↳ KCL ⇒ $(n_p - 1) = (3-1) = 2 \to V_1, V_2$

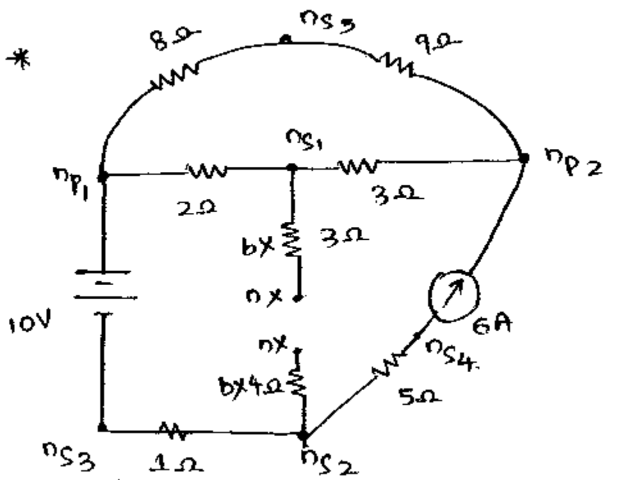
$$\sum \delta_i = \underset{\substack{\text{8 nodes} \\ \text{of deg '2'} \\ (ns_1 \text{ to } ns_8)}}{8(2)} + \overset{(np_1)\text{ one 3rd deg node}}{3} + \underset{\substack{\text{4deg} \\ (np_2)}}{4} + \overset{\text{5deg }(np_3)}{5} = 28$$

$= 2(14)$

$= 2(b)$

Dasor & ku

*

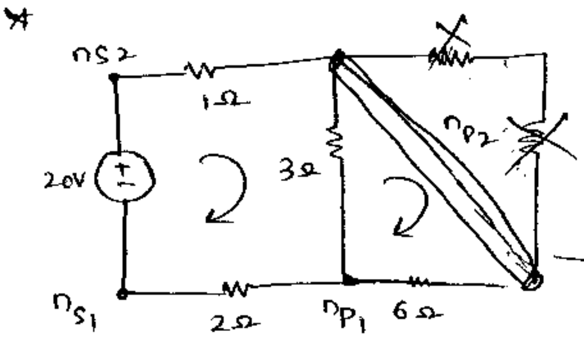


$n = 7$

$b = 8$

$m = 2 = (8-7+1)$

*



$n = 4$

$b = 5$

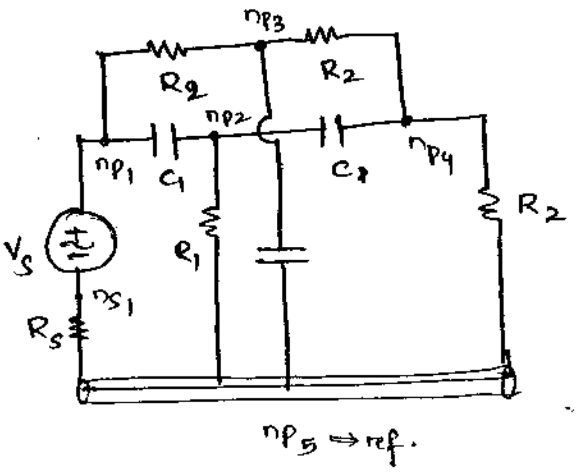
$m = 2 = [5-4+1]$

⟶ elements parallel to s.c path are redundant neglect (it is a N/w not ckt)

gate

* The min, no. of eqns required to solve the given ckt below is ——

(a) 2 (b) 3 ~~(c)~~ 4 (d) 5



sol mesh ⟶ KVL ⇒ $m = [b - n + 1]$

$= 9 - 6 + 1$

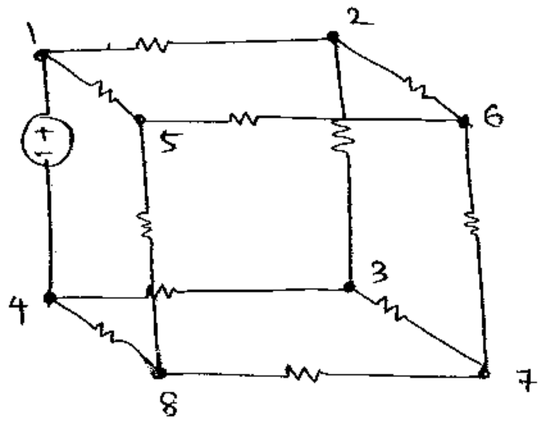
$m = 4$

Nodal ⟶ KCL ⇒ $(n_p - 1) = (5-1) = 4$

↳ is this ckt PLANAR or Not ? ⇒ planar

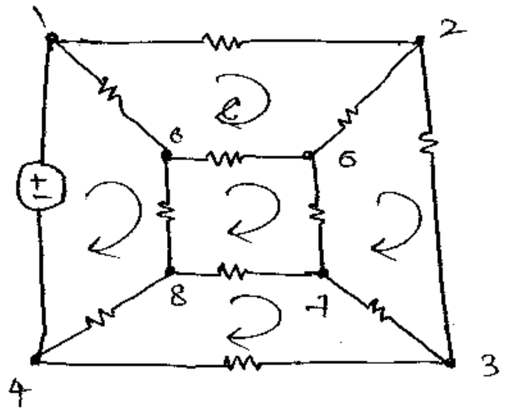
(without any overalap) ⇒ if we represent on 2-D plane without any overlap is Called planar

9



is it PLANAR or Not?

⇓



$n = 8$

$b = 12$

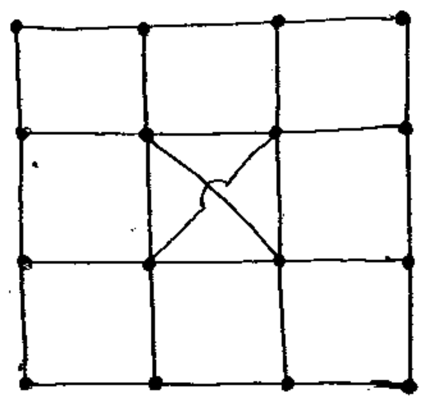
$m = 5$

$= [12-8+1] = 5.$

⟹ it is PLANAR.

→ Mesh analysis requires PLANAR arrangement in the N/w.

Example for Non planar graph: (graph is skeleton of N/w)



* for Non-planar N/w better to go for Nodal analysis (mesh analysis requires PLANAR N/w)

Q N/w has n - principles nodes , b - no. of branches
if mesh analysis simpler than Nodal analysis then n is greater than —

(a) $b-1$ $\qquad$ $m = (b-n+1)$

(b) $b+1$ $\qquad$ nodal $= (n_p - 1) = (n-1)$

(c) $\frac{b}{2} - 1$ $\qquad$ mesh < Nodal

~~(d)~~ $\frac{b}{2} + 1$ $\qquad$ $b-n+1 < n-1 \Rightarrow b+2 < 2n$

$\cancel{b < 2n+2}$

$2n > b+2$

$n > \frac{b}{2} + 1$

* Generally or most of the time nodal is faster than mesh.
* Generally or most of the time mesh analysis is faster than nodal.
· but when $n > \frac{b}{2} + 1 \Rightarrow$ then mesh analysis

OHM's Law:

I. LTI Domain:

→ Assume Temp is Constant
→ Assume Uniform Cross-Sectional area of material.

$$\boxed{J = \sigma E}$$ → 1st form of OHM's law.

J → Electric Current density.
σ → Conductivity
E → Electric field Intensity

$$\frac{I}{a} = \sigma . \frac{V}{l} \Rightarrow V = \left[\frac{l}{\sigma a}\right] . I$$

$$V = \left[\frac{\rho l}{a}\right] . I \qquad \left(\because \frac{1}{\sigma} = \rho\right)$$

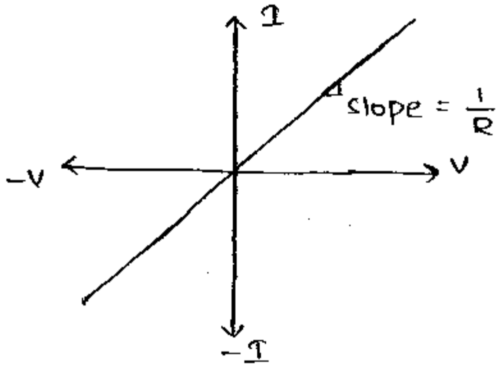
ρ → Resistivity.

$$\boxed{V = [R] I}$$ → 2nd form of OHM's law.

R → Resistance
units : ohms (Ω)

Graphically.

$$I = \left[\frac{1}{R}\right] \cdot V$$



⇒ Linear
⇒ passive
⇒ Bilateral [Symmetry]

If permeability is uniform
Inductance is constant.

II. Electromagnetic Domain :

$$\boxed{\psi = L i} \longrightarrow$$ 3rd form of OHM's law.

since $\psi = N \cdot \phi$

↳ flux linkages (wb-T)

$N \cdot \phi = L i$

↓

we cann't represent ϕ in lumped form
∴ to represent it in linear we consider small differential length (small Incremental length)

$$N \cdot \frac{d\phi}{dt} + \phi \cdot \cancel{\frac{dN}{dt}}^{=0} = L\frac{di}{dt} + i\cancel{\frac{dL}{dt}}^{=0}$$

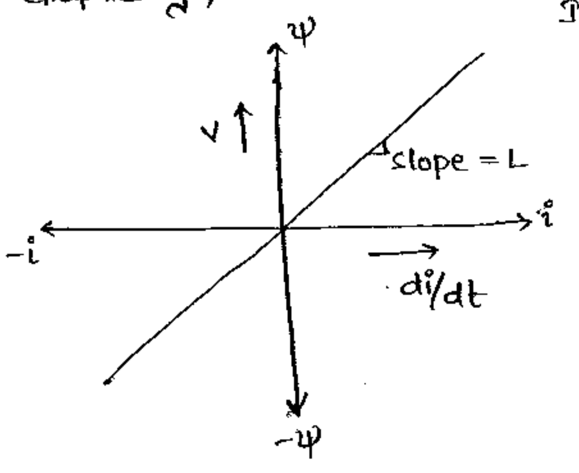
∵ turns const

∵ Inductance = const
(∵ we assume permeability is uniform

$$\boxed{V = L \cdot \frac{di}{dt}} \longrightarrow$$ 4th form of OHM's law

↓
Inductance
units : Henry.

Graphically,



III. Electrostatic Domain:

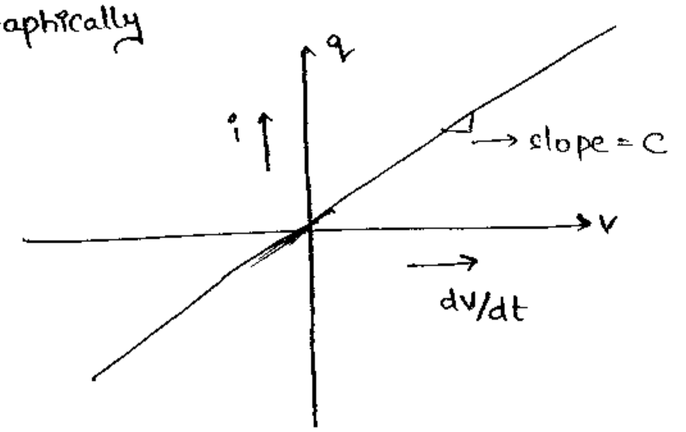
$$\boxed{q = CV}$$ 5th form of OHM's law

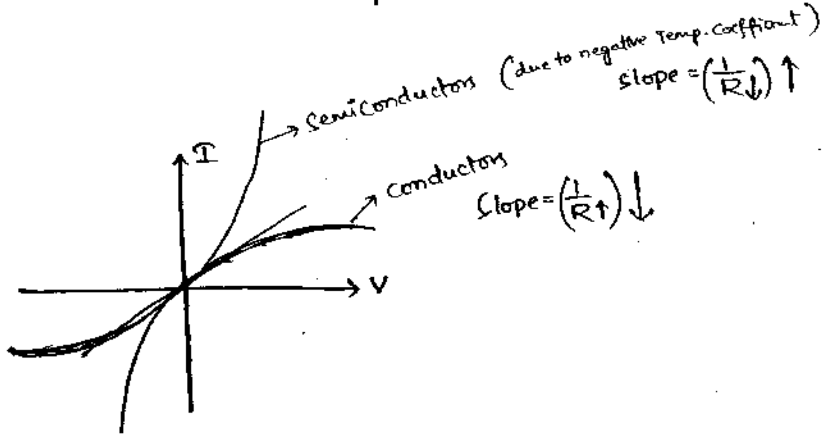
$$\frac{dq}{dt} = C\frac{dV}{dt} + V\cancel{\frac{dC}{dt}}^{=0}$$

$$\boxed{i = C\frac{dV}{dt}}$$ 6th form of OHM's law

$C \rightarrow$ capacitance units: Farads.

Graphically





* properties of DC Supply Systems:

⇒ They are unipolar in Voltage,
unidirectional in Current,
no change in phase,
power frequency is zero (= 0Hz)

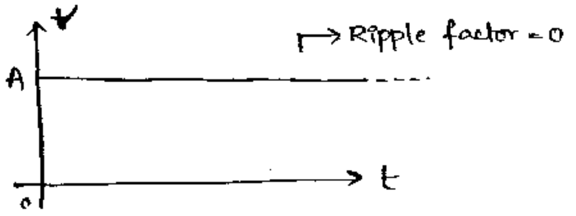
⇒ They are used in Small Independent Isolated power supply systems, where elec. Energy can be stored in Small capacities.

Ex: Batteries in chemical form.

⇒ DC Supply Driven Systems are Superior with respect to precision, Accuracy, Speed, portable, Compact & easy in Control

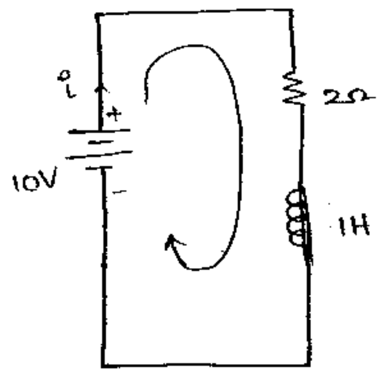
⇒ Ideal DC Waveform look like

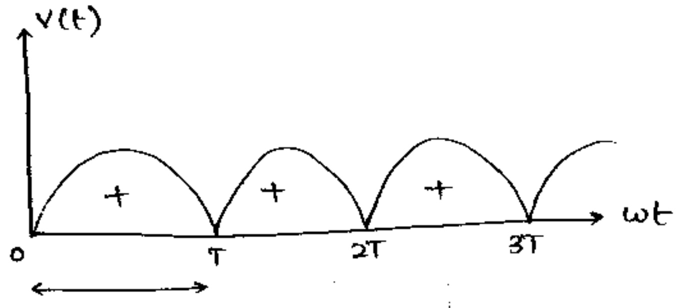
11



⇒ Example applications include toys, Cellphones, wireless Communication System, electronic Board operators like PCs laptops, DSP Drives etc, Automobiles, machine tools, medical Instrumentation etc.

* Conventional Current is opposite to e^- flow.





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

→ freq. where magnitude changes (no phase change)

∴ it is called ripple frequency.

→ By Increasing Ripple freq, Ripple factor Increases.

→ for Ideal DC, Ripple factor = 0 (∴ no filter Required)

⇒ $\underbrace{\text{Solar, Newly purchased battery, precision volt. regulators}}_{\text{pure DC}}$

→ as no. of pulses less ⇒ requires bulky filter ckts.

* properties of AC Supply System:

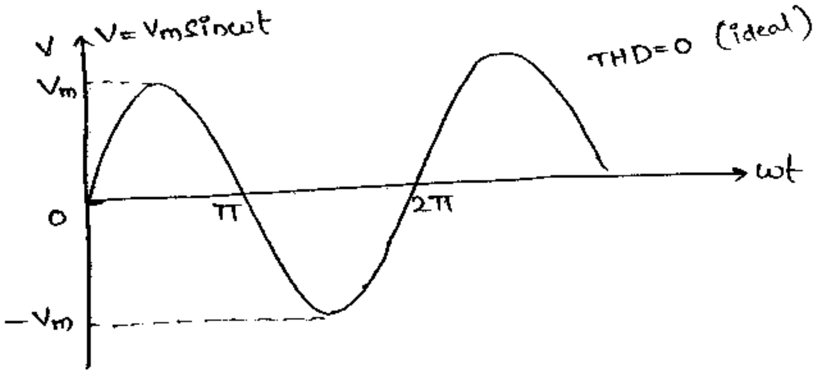
They are
- Bipolar in Voltage
- Bidirectional in Current
- Definite change in phase
- Power freq. Exists
  - in INDIA = 50Hz

⇒ They are used in large, Bulk, Continuosly driven power supply systems.

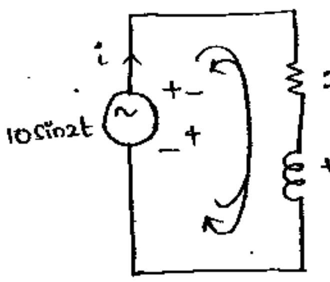
~~⇒~~ Where electrical Energy cannot be stored.

⇒ AC Supply driven systems are superior w.r.t large power ratings, Robust design, Continuosly duty cycle operation, High efficiency and less maintanance.

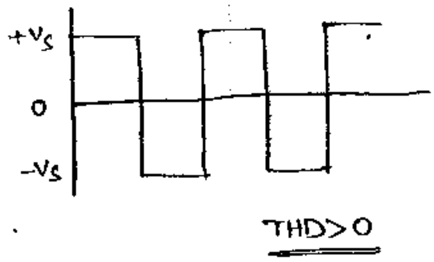
⇒ ideal AC Waveform is a sinusoid.



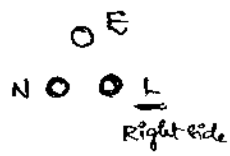
⇒ Example applications include generation, Transmission, Distribution, utilisation of Elec. Energy at power level is through sinusoidal wave-form that to 3ϕ and then 1ϕ.



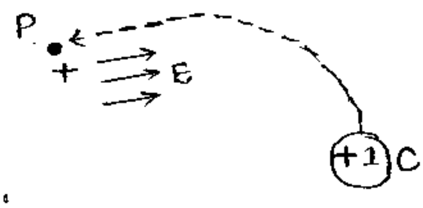
$$Z = 2 + j2\,\Omega$$
$$\phi = \tan^{-1}\left(\frac{2}{2}\right) = 45^\circ$$

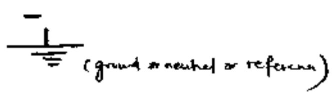


I. Voltage: it is defined as the amount of work done in moving one unit positive charge from "∞" to that "point" against the intensity of electric field.



$$\boxed{V = \frac{dW}{dq}}$$





⇒ it is like a force [EMF], which can drive charge.

Units : Volts (or) $\frac{J}{C}$

12

Range : mV, V, kV, MV

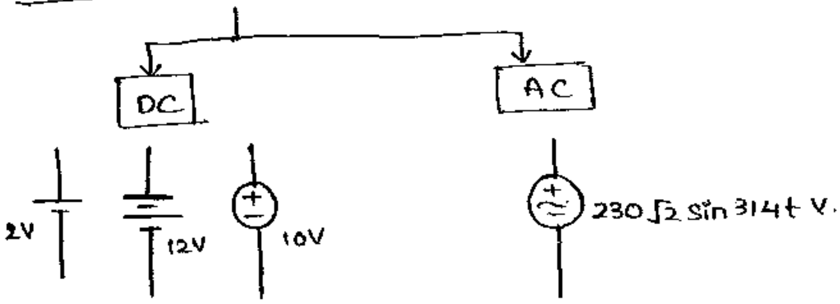
Symbols : → v → to represents Instantaneous Value

V → DC steady state

$\bar{V}$ → RMS of sinusoid

$V(t)$ → for any function.

Circuit Symbols :



DC : cell, Battery, Fuel cell, PV solar cell, Rectifiers, DC-DC Converters, SMPS, DC Generators.

AC : Alternators [S.G],
UPS,
Inverters

II. Current : it is rate of flow of charge in any material.

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

$$\boxed{I = \frac{Q}{t}}$$

* 1MW Gen & Tran Cost
↓
21 crores

⇒ Units : Ampere (or) C/sec.

Range : mA, A, kV → fault analysis.

⇒ Symbols : i → Instantaneous

I → DC

$\bar{I}$ → Sinusoidal or RMS

$i(t)$ → any function.

Circuit Symbols

DC | AC

<u>DC:</u> BJT is dependent Current Source

DC Series Generator

<u>AC:</u> Feeder line in P.S

CSI Drive in P.E

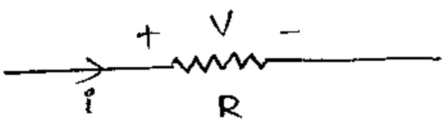
III. Resistance :

it is L.T.I electrical property of matter.

<u>Resistor:</u> is a Component to model & design this property.

it is classified based on material.

- Nichrome (Heater coils)
- Tungsten — High melting & Boiling points.
- Carbon
- Cu, Al.



when V is applied to R charges scatter & collide
elec. Energy conv. Heat Energy
∴ the symbol is —www—
when V is applied to Conductor charges smoothly Travel

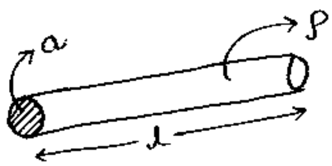
units : ohms(Ω), $\frac{V}{A}$

Range : $\mu\Omega$, $m\Omega$, Ω, $k\Omega$, $M\Omega$, $G\Omega$

OHM's Law : $\boxed{V = IR}$

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

Basic Formulae : $\boxed{R = \frac{\rho l}{a} = \frac{l}{\sigma . a}}$



$\rho \rightarrow$ Specific Resistance (or) Resistivity (Ω-m)

→ practically Resistance depends upon Temperature.

$$R_t = R_0[1+\alpha t]$$
(or)
$$R_2 = R_1[1+\alpha(t_2-t_1)]$$

'α' is temperature Coeff. of resistance

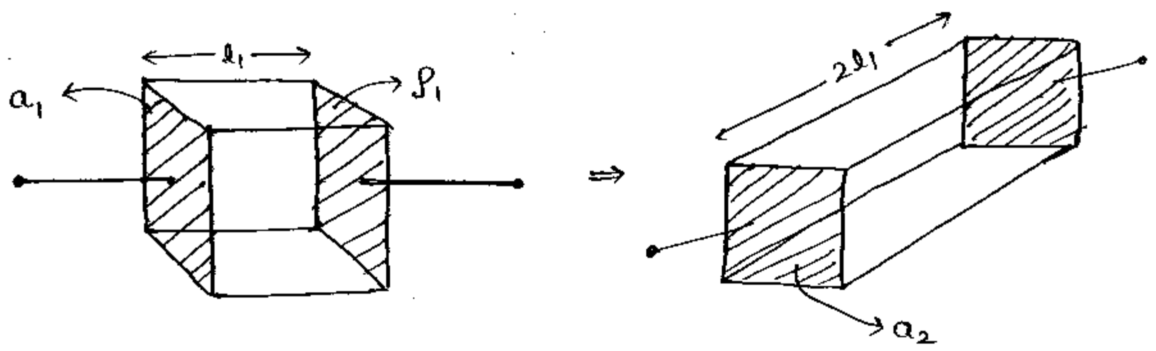
α is (+ve) ⟶ Metals (Conductors)

α is (-ve) ⟶ Semiconductors.

Ex:

⟶ Heater
⟶ Incandescent bulb
⟶ Iron Box
⟶ PCB
⟶ Domestic & Industrial wiring
⟶ Machine winding
⟶ Motor Starters & Braking.
⟶ Tr. lines ⟶ Ω/ph/km

Q the Resistance of a Cube shaped (solid cube) material between any of its opposite phases is 3Ω, if this material is stretched in one direction by applying Linear force to double its original length then the Resistance b/w its opposite stretched phases is ——



$$R_1 = \frac{\rho_1 l_1}{a_1} = 3\Omega$$

$$R_2 = \frac{\rho_2 l_2}{a_2} = \frac{\rho_1 (2l_1)}{a_1/2}$$

$$V_1 = V_2$$
$$l_1 a_1 = l_2 a_2$$
$$\cancel{l_1} a_1 = 2\cancel{l_1} a_2$$
$$\underline{\underline{a_2 = \frac{a_1}{2}}}$$

$$= 4 \cdot \frac{\rho_1 l_1}{a_1} = 4R_1$$
$$= 4(3)$$
$$= \underline{\underline{12\Omega}}$$

$\Rightarrow$ if length $\uparrow$ by $\underline{\underline{n}}$ times then Resistance $\uparrow$ by $\underline{\underline{n^2}}$ times

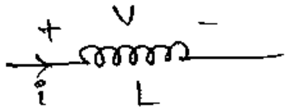
IV Inductance : it is electro magnetic property of matter

$\downarrow$

Inductor : is a Component to model & design this property

$\downarrow$

it is Classified based on CORE material.



→ Iron
→ Ferrite
→ SiFe
→ air

units : Henry (or) $\frac{\text{Volt-sec}}{\text{amp.}}$

Range : μH, mH, H.

OHM's Law :

$$\boxed{V = L\frac{di}{dt}} \qquad \boxed{i = \frac{1}{L}\int V\,dt}$$

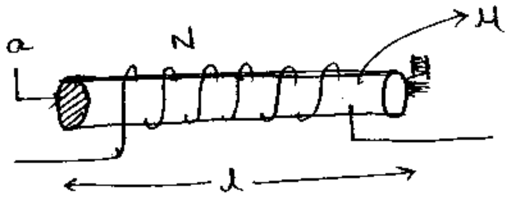
$$i = \frac{1}{L}\int_{-\infty}^{t} V\,dt = \frac{1}{L}\int_{-\infty}^{0} V\,dt + \frac{1}{L}\int_{0}^{t} V\,dt$$

→ I.C (Initial Condition)

$$i(t) = I(0) + \frac{1}{L}\int_{0}^{t} V(t)\,dt.$$

Basic formulae :

$$L = \frac{\mu N^2 a}{l}$$

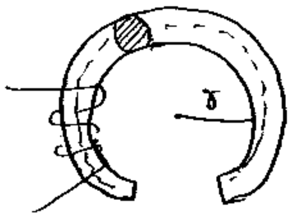


$\mu = \mu_0\mu_r$] permeability of CORE

$\mu_0 = 4\pi\times10^{-7}$ H/m.

$\mu_r = 1$ (air)

$\mu_r > 1000$ (iron)



$l = 2\pi r$

$N \longrightarrow$ no. of Turns of coil

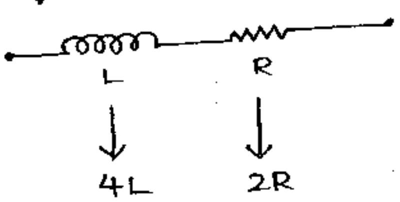
$a \longrightarrow$ Cross-Sectional area of CORE (m^2)

$l \longrightarrow$ effective length of magnetic flux path (m)

Ex:
- $\longrightarrow$ choke Coil
- $\longrightarrow$ C.L.R (current limiting Reactor)
- $\longrightarrow$ Transformer
- $\longrightarrow$ Electromagnets
- $\longrightarrow$ A/c machine wdg
- $\longrightarrow$ Tr lines $\longrightarrow$ mH/ph/km

Q. a practical Coil has a time Constant of $\tau = \frac{L}{R}$ sec. if no. of turns in the coil are doubled then its new time Constant is ——

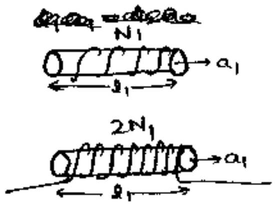
$N_2 = 2N_1$



$$L_1 = \frac{\mu N_1^2 a_1}{l_1}$$

$$L_2 = \frac{\mu . (2N_1)^2 a_1}{l}$$

$$L_2 = 4L_1$$



$$\tau_{new} = \frac{4L}{2R} = 2\frac{L}{R} \text{ sec}$$

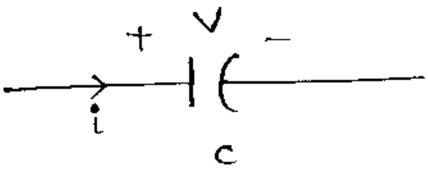
V. Capacitance: it is electro-static property of matter.

$\downarrow$

Capacitor: is a Component to model & design this property.

$\downarrow$

it is Classified based on Dielectric material.
- polyster
- mica
- distilled water
- oil
- paper
- glass.



units: Farad (or) $\frac{\text{Amp-sec}}{\text{Volt}}$

Range: pF, nF, μF, mF

OHM's Law: $\boxed{i = C\frac{dV}{dt}}$ $\boxed{V = \frac{1}{C}\int i\,dt}$

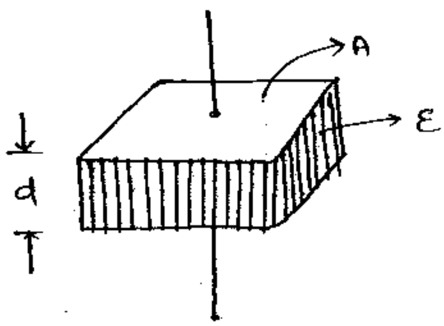
$$V = \frac{1}{C}\int_{-\infty}^{t} i\,dt = \frac{1}{C}\int_{-\infty}^{0} i\,dt + \frac{1}{C}\int_{0}^{t} i\,dt$$

Initial Condition

$$\boxed{V(t) = V(0) + \frac{1}{C}\int_{0}^{t} i(t)\,dt}$$

Basic formulae :

$$\boxed{C = \frac{\varepsilon A}{d}} \text{ F.}$$



$\varepsilon = \varepsilon_0 \varepsilon_r \longrightarrow$ permitivity of dielectric

$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$\varepsilon_r = 1$ (air)

$\varepsilon_r = 6$ (polyster) , $\varepsilon_r = 200$ (glass)

$A \longrightarrow$ Common cross sectional area b/w electrodes (m^2)

$d \longrightarrow$ distance b/w electrodes (m)

Ex:

→ passive R.C filter

→ phase shifting

→ pulse, digital, wave shaping

→ P.F & VAR Correction

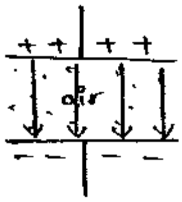
→ Touch - Screen of Cell phone.

→ Tr. lines → μF/ph/km

* Touchscreen of Cellphone is Capacitor
Screen is one plate (electric field)
glass is dielectric
our finger is another plate acts as

Q a parallel plate Capacitor is dipped in ethyl alcohol with rel. permittivity $\varepsilon_r = 25$ upto half the distance b/w Plates. determine the ratio of Capacitance before & after dipping in ethyl alcohol.

$$C_{Before} = \frac{\varepsilon_0 (1) . A}{d}$$



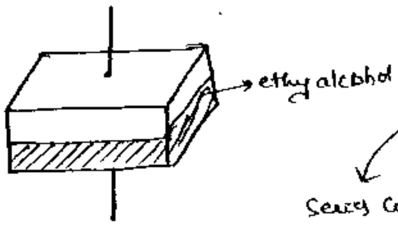
as $\varepsilon_r = 1$
Very less charge distribution across plates & less uniform Elec. fld Intensity

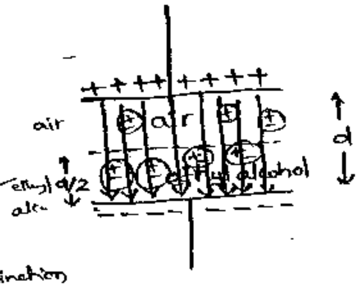
$C = \frac{\varepsilon A}{d}$ $\quad$ $\varepsilon_1 = \varepsilon_0 \varepsilon_r$ $\quad$ $\varepsilon_2 = \varepsilon_0 . 25$.

$C = \frac{\varepsilon_0 . 25 \times A}{d \times 2}$

15

after dipping





as ε_r is more
very More charge distribution
as uniform elec. fld Intensity
it acts as series combination of Capacitors

Series Combination of capacitor

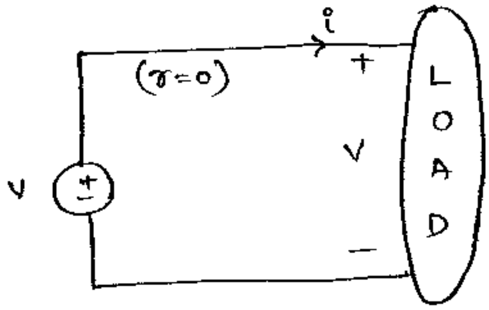
$$C_{After} = \frac{\frac{\varepsilon_0 (1) A}{d/2} + \frac{\varepsilon_0 (25) A}{d/2}}{\frac{\varepsilon_0 A}{d/2} [1+25]}$$

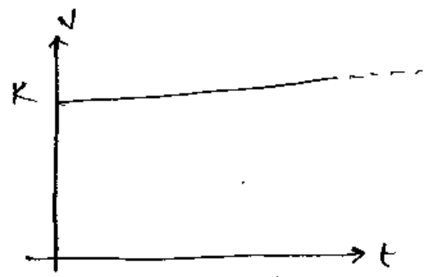
$$C_{After} = \frac{50}{26} \left[\frac{\varepsilon_0 A}{d} \right] \longrightarrow C_{Before}$$

$$\frac{C_{Before}}{C_{After}} = \frac{26}{50} = \frac{13}{25}.$$

Ideal voltage Source:

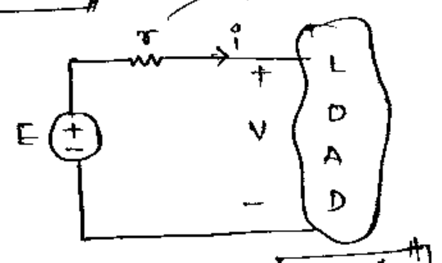
$\Rightarrow$ no volt. Reg
$\Rightarrow$ 100% eff.

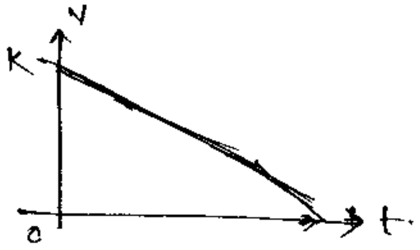




small 'r' in series with voltage source.
to model the losses

practical:

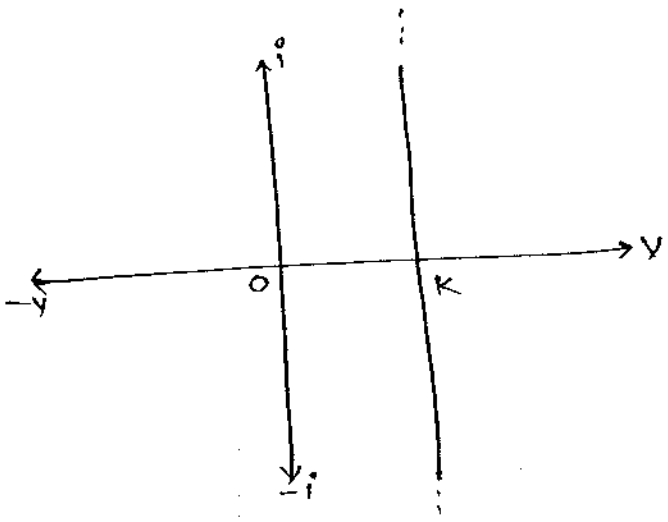




$\boxed{V = E - ir}$

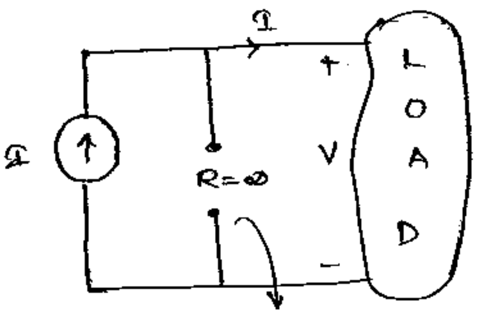
as load ↑ ⇒ V < E

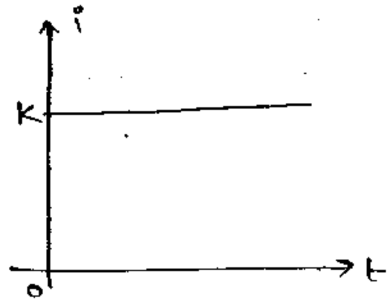
Based on static V-i:



voltage should be stiff for any current.

Ideal Current Source.

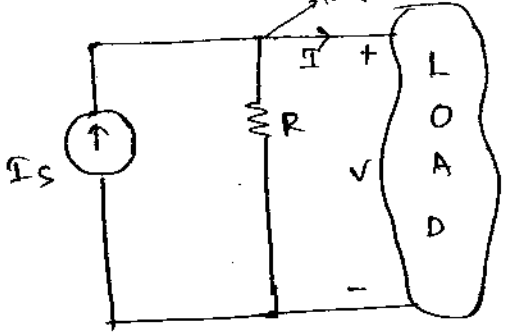


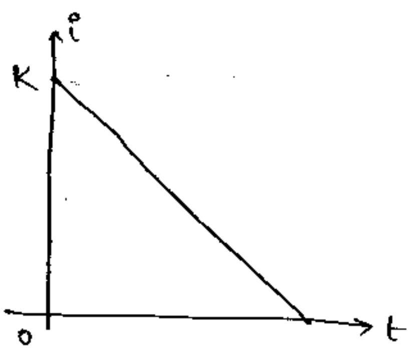


(no leakage current)

large 'R' in parallel with I_s to model the losses

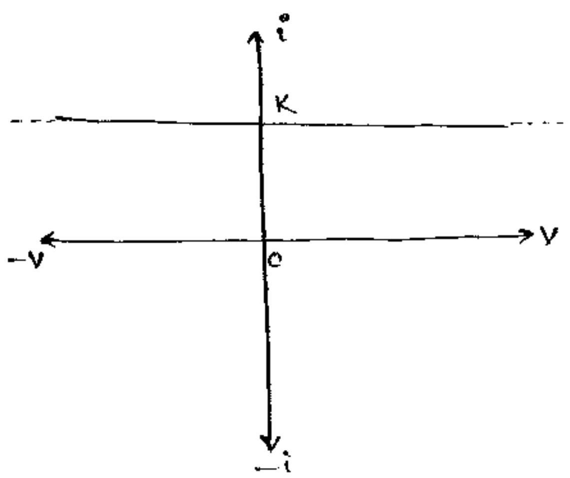
practical:





$$I = I_s - \frac{V}{R}$$

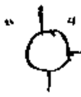
Based on Static V-i :



Independent Sources :

⇒ if the properties & characteristics are Independent to any other parameter within or outside the ckt.

⇒ We assume ideal Sources to be Independent.

⇒ They are Represented by  → circle Symbol.

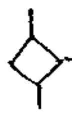
dependent Sources :

⇒ if the properties & characteristics depends upon any other parameter within or outside the ckt.

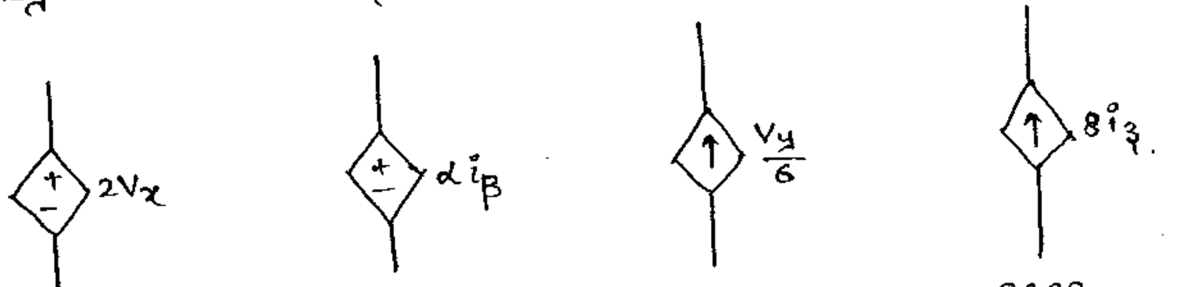
Example : 1. a BJT acts as Current Controlled current Source

2. a Solar cell is the light dependent Voltage Source

3. power electronic Converters are dependent Sources as their characteristics depends upon Type of load (R, RL, RLE etc)

⇒ They are represented by  → diamond Symbol.

⇒ They are standard 4-types.



VDVS (or) VCVS | CDVS (or) CCVS | VDCS (or) VCCS | CCCS (or) CDCS

Note: unlike independent Source these dependent Sources will have Internal Subcircuit Resistance which must be Considered during analysis of ckt.

power: it is Rate of change in Elec. Energy.

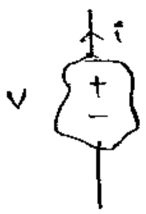
$$P = \frac{dE}{dt} = \frac{dw}{dt}$$

$$\boxed{P = \frac{E}{t}}$$

units: Watts (or) $\frac{\text{Joule}}{\text{sec}}$.

1 hp = 746 Watts.

Range: mw, w, kw, Mw, Gw.



$\longrightarrow$ Source

$$P_{delivered} = +V.i \quad w$$

$$= \frac{dw}{dq} \cdot \frac{dq}{dt}$$

$$= \frac{dw}{dt}$$

$\boxed{R}$

$$P_R(t) = V_R(t) \cdot I_R(t) = [I_R(t)]^2 \cdot R = \frac{[V_R(t)]^2}{R} \quad w.$$

$\rightarrow$ if Excitation is T.I [S.S]

$$P_R = V_R I_R = I_R^2 R . \frac{V_R^2}{R}$$

for AC $\rightarrow$ RMS Value

$\boxed{L}$

$\rightarrow P_{avg} = 0 \longrightarrow$ for one cycle Supply waveform

$\rightarrow$ Instantaneous Value

$$P_L = V_L \cdot i_L = L.i \frac{di}{dt} \quad w$$

C

→ $P_{avg} = 0$ → for one cycle of supply waveform

→ instantaneous value.

for AC → RMS values.

$$P_c = V_c \cdot i_c = C \cdot V \cdot \frac{dv}{dt} \rightarrow W.$$

Energy: it is the capacity to do work. (or to drive system)

$$E = \int_{-\infty}^{t} p\,dt = \int_{-\infty}^{0} p\,dt + \int_{0}^{t} p\,dt$$

Initial stored energy.

$$E(t) = E(0) + \int_{0}^{t} p(t)\,dt \quad .J$$

$$\boxed{E = P * t}$$

→ units: J (or) Watt-sec.

→ 1 unit of elec. energy = 1 KWH.

$$1\,KWH = 1000\,w * 1\,hr$$
$$= 500\,w * 2\,hr$$
$$= 100\,w * 10\,hr$$
$$= 2000\,w * \tfrac{1}{2}\,hr.$$

→ Source

$$E_{delivered} = +V \cdot i \cdot \underset{\to (sec)}{t} \quad J$$

$$1\,KWH = 36 * 10^5\,J.$$

R

$$E_R(t) = \int P_R(t)\,dt = \int V_R(t) \cdot I_R(t) \cdot dt = \int [I_R(t)]^2 \cdot R\,dt \quad J$$

⇒ in S.S

$$E_R = V_R \cdot I_R\,t = I_R^2 \cdot R \cdot t = \frac{V_R^2}{R} \cdot t \quad J.$$

$\boxed{L}$

$$E_L(t) = \int P_L(t).dt = \int L i(t). \frac{di(t)}{dt} .dt \quad J.$$

in L

$i \to$ is state variable

$\rightarrow$ in S.S [if Excitation is T.I]

$$E_L = \int L i . \frac{di}{\cancel{dt}} . \cancel{dt} = \frac{1}{2} L i^2 \quad J.$$

$$\boxed{\psi = Li}$$

$$E_L = \frac{1}{2} L i^2 = \frac{1}{2}\psi . i = \frac{\psi^2}{2L} \quad J.$$

$\boxed{C}$

$$E_c(t) = \int P_c(t)\,dt = \int c.v(t). \frac{dv(t)}{dt} . dt$$

in C

$v \to$ state variable.

$\rightarrow$ in S.S [if Excitation is T.I]

$$E_c = \int c.v. \frac{dv}{\cancel{dt}} \cancel{dt} = \frac{1}{2} cv^2 \quad J.$$

$$\because \boxed{q = cv}$$

$$E_c = \frac{1}{2} cv^2 = \frac{1}{2} qV = \frac{q^2}{2c}$$

In Batteries Energy storage Capacity is given by Ampere-Hour Rating (assuming Voltage is Constant)

Ex: AA pencil cell $\longrightarrow$ 1.5V, 500 mAHr

cell phone $\longrightarrow$ 3.7V, 5400 mAHr.

CAR $\longrightarrow$ 12V, 40AHr.

$$\begin{aligned} 40\,AHr &= 40A * 1hr \\ &= 20A * 2hr \\ &= 10A * 4hr \\ &= 80A * \tfrac{1}{2}hr \\ &= 1A * 40hr. \end{aligned}$$

* P.F of P.E devices is low

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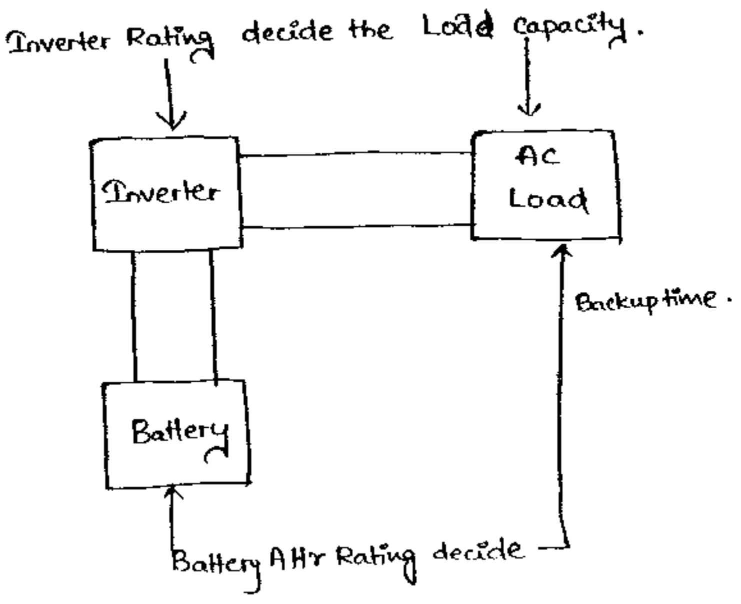
*



* Kirchoff's Laws :

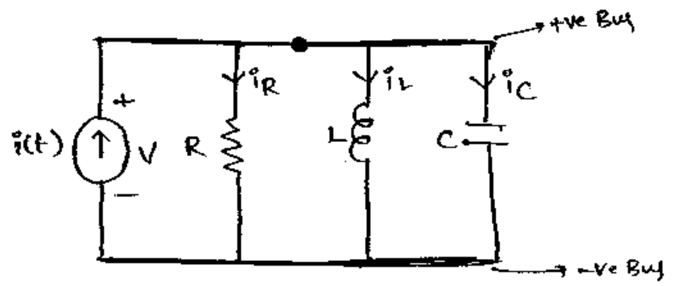
I. KCL (or) K "Node" L

→ Based on Law of Conservation of charge.

$$\boxed{\sum i_{@node} = 0}$$

$$\frac{V}{R} \qquad \frac{1}{L}\int V dt \qquad C\frac{dV}{dt}.$$

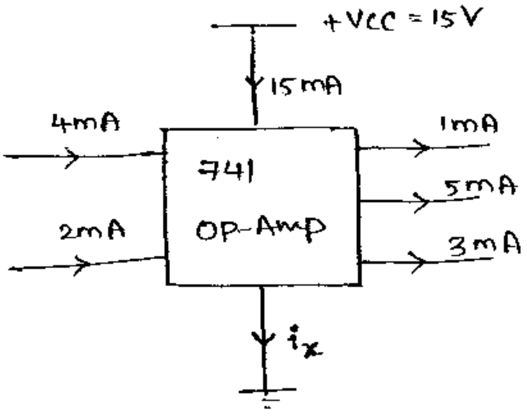
→ Notation :



KCL: $-i(t) + i_R + i_L + i_C = 0$

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

Q.



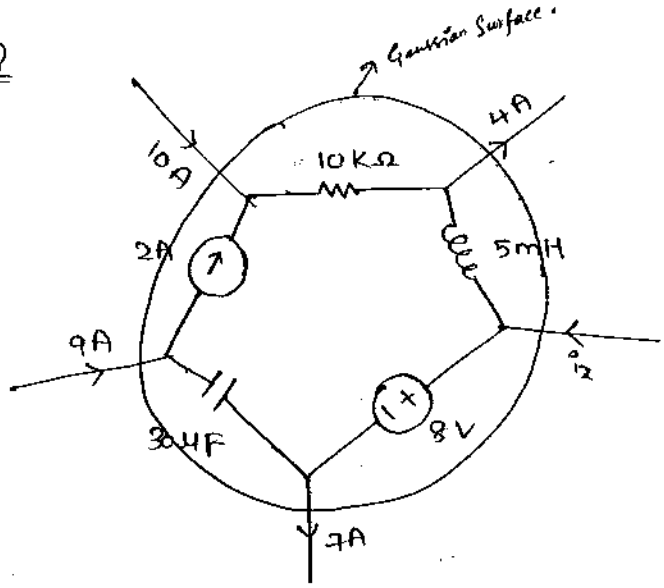
$i_x =$

$15 + 4 + 2 = i_x + 5 + 1 + 3$

$i_x = 21 - 9 = +12\,mA$

Analog IC
↓
741-op-amp
↓
Int. ckt
↓
It DC 130 Math fn
Texas Inst
min 60 Transistors

Q



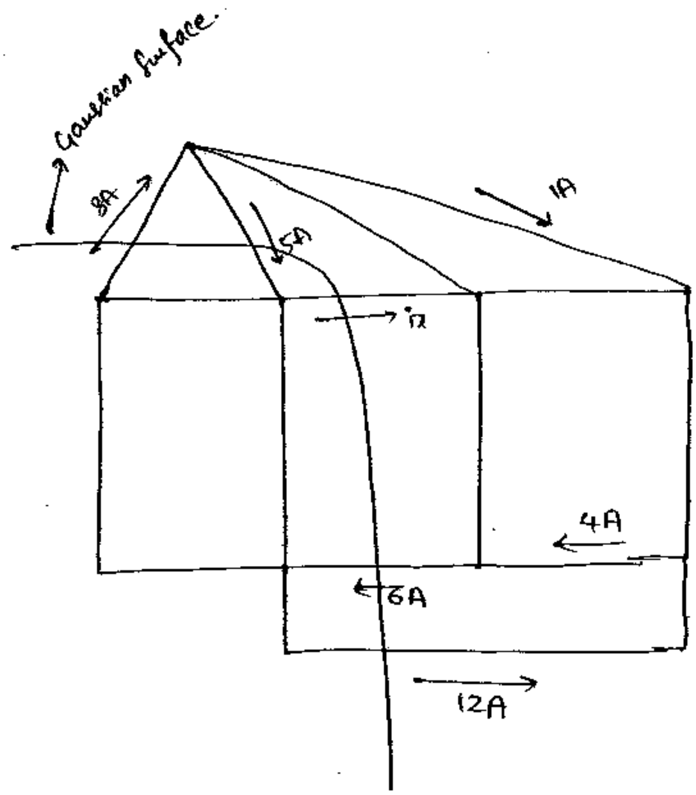
$i_x =$

$10 + i_x + 9 = 4 + 7$

$i_x = -8A.$

8A =

Q



Gaussian surface divide the n/w into two parts.

$8 + i_x + 12 = 5 + 6$

$i_x = -9A.$

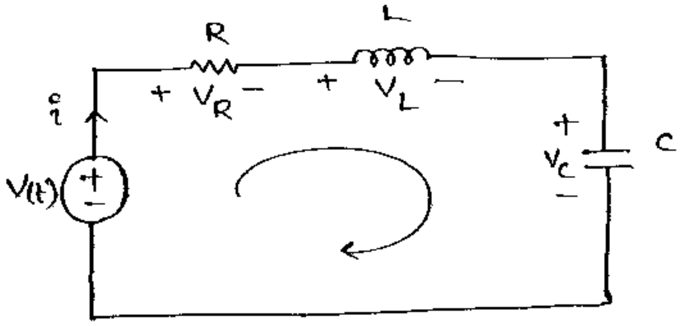
II]. KVL ⟶ K. "Mesh" L

⟶ Based on Law of Conservation of Energy.

$$\boxed{\sum V_{@mesh} = 0}$$

iR $L\frac{di}{dt}$ $\frac{1}{c}\int i\,dt$

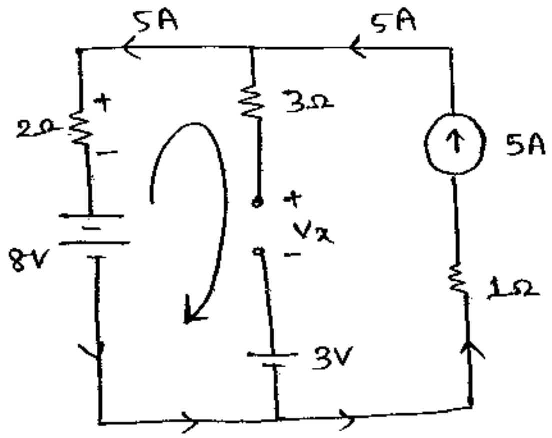
⟶ Notation:



KVL → $-V(t) + V_R + V_L + V_c = 0$

$$\boxed{V(t) = iR + L\frac{di}{dt} + \frac{1}{c}\int i\,dt}$$

Q

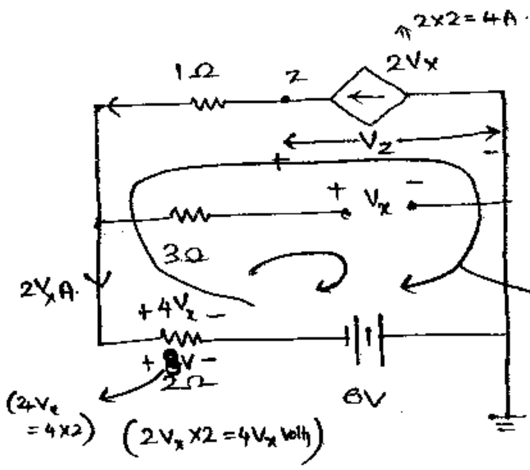


$V_x =$

$-8 - 10 + V_x + 3 = 0$

$V_x = +15V.$

Q



$V_z =$

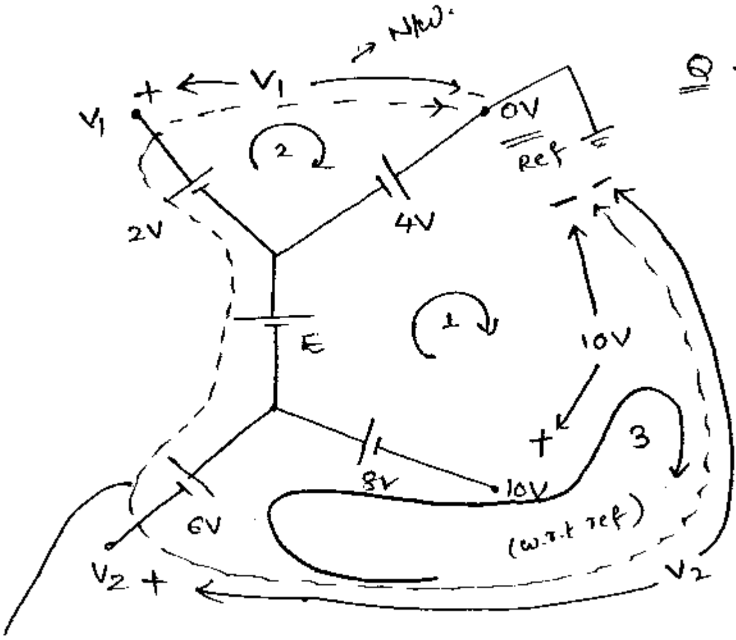
$6 - 4V_x + V_x = 0$

$V_x = 2V$

$+6 - 8 - 4 + V_z = 0$

$V_z = +6$ Volts.

Q find $E =$ ___, $V_1 =$ ___, $V_2 =$ ___



if zero v 0V is not given take any ref. outside the N/W

KVL 1: $-10-8-E-4=0 \Rightarrow E = -22V$.

KVL 2: $4-2+V_1=0 \Rightarrow V_1 = -2V$

KVL 3: $-V_2-6+8+10=0 \Rightarrow V_2 = +12V$.

Check:

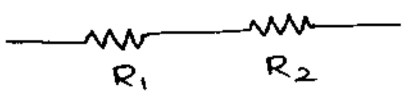
$-V_1+2+E+6+V_2$

$+2+2-22+6+12=0$ ✓

Series Connection of elements:

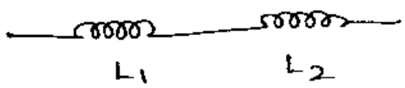
↳ if current through them is Equal.

$\boxed{R}$



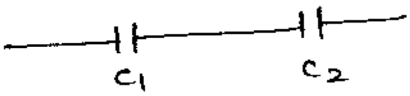
$R_S = R_1 + R_2$

$\boxed{L}$



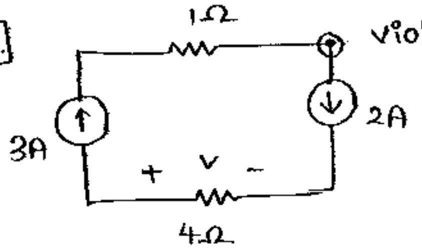
$L_S = L_1 + L_2$

$\boxed{C}$



$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$

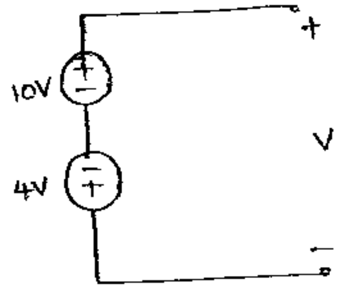
$\boxed{I}$



Violating KCL

3A ≠ 2A

$\boxed{V}$

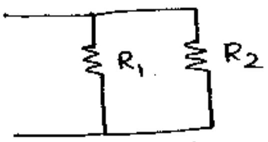


$V = +6V$

<u>parallel Connection of elements :</u>

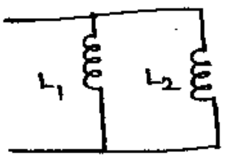
↳ Voltages across them is Equal (in magnitude & direction.

$\boxed{R}$



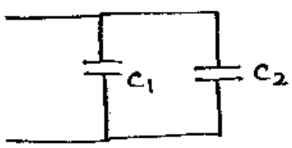
$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

$\boxed{L}$



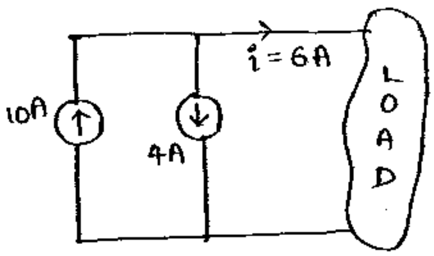
$$\frac{1}{L_P} = \frac{1}{L_1} + \frac{1}{L_2}$$

$\boxed{C}$

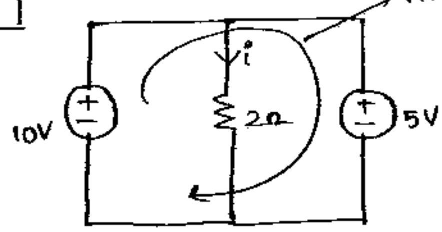


$$C_P = C_1 + C_2$$

$\boxed{I}$



$\boxed{V}$



Violating KVL

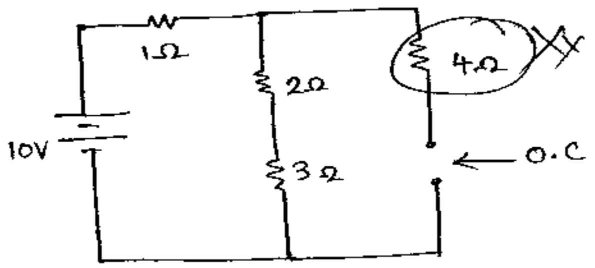
HVDC Single pole = 500 kV.
Thyristor Blocking voltage = 10 KV
Blocking current = 5 KA

Open circuit : (OC)

⇒ In an O.C , $i = 0$ for any Voltage

$$R_{OC} = \frac{V}{0} = \infty\,\Omega$$

⇒ Any passive element Completely in Series to O.C Can be neglected.

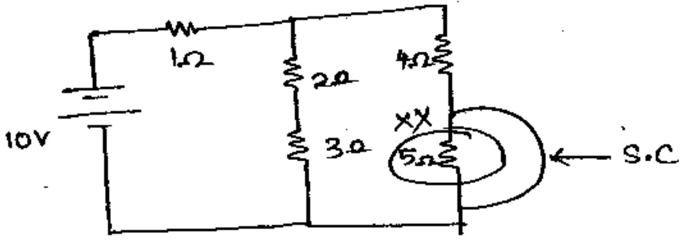


Short circuit (S.C):

⇒ In a S.C , $V = 0$, for any Current

$$R_{SC} = \frac{0}{i} = 0\,\Omega$$

⇒ any passive element Completely is parallel to S.C, Can be neglected.

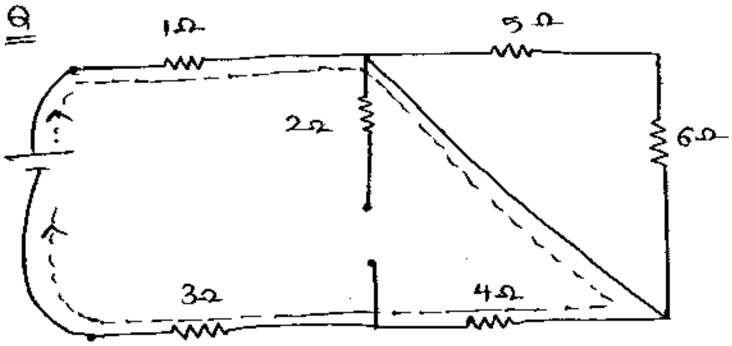


C.B
ON → UP → Becz going against gravity is more
OFF → down

S.C are protectable at H.V, L.V side by providing fuses & C.B

⇒ open ckt live wire faults in High voltage Engineering are more dangerous than S.C due to insulation material limitations. However S.C can always be protected both at L.V & H.V level by using fuses & C.Bs.

⇒ Resistance is offered by the path where current can flow, as seen by target terminals



$R = 1+4+3 = 8\Omega$

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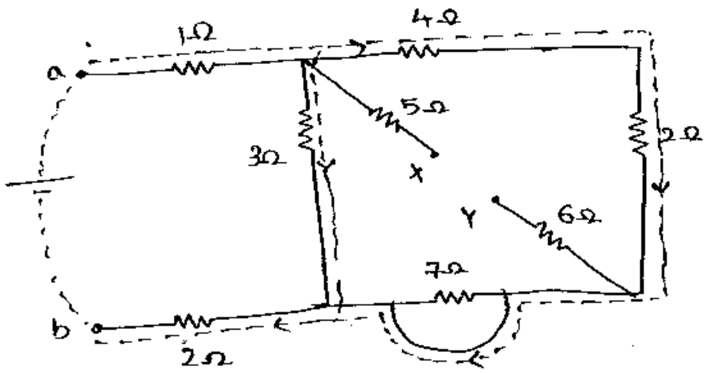
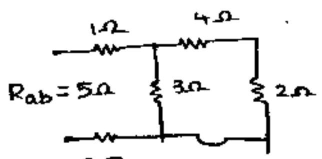
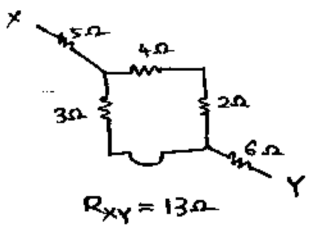
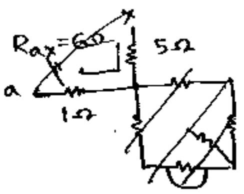
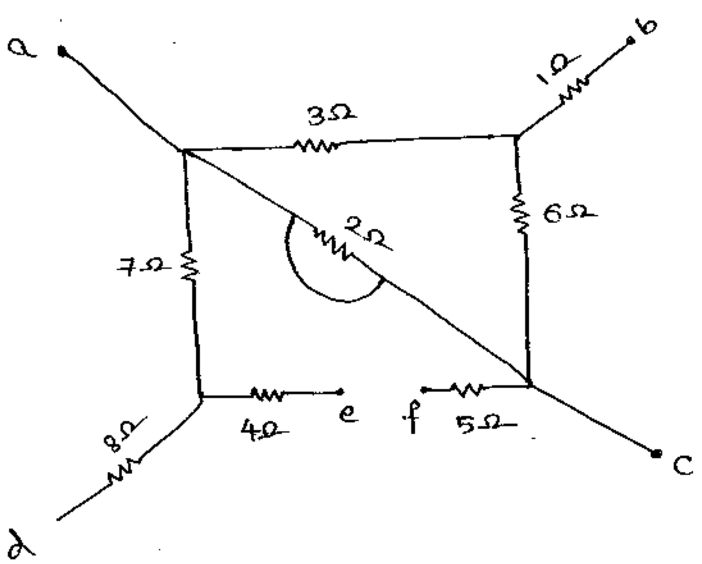


$R_{ab} = \underline{5\Omega}$, $R_{XY} = \underline{13\Omega}$, $R_{aX} = \underline{6\Omega}$, $R_{bY} = \underline{8\Omega}$.









$R_{ab} = 3\Omega$

$R_{ac} = 0\Omega$

$R_{ad} = 15\Omega$

$R_{bd} = 18\Omega$

$R_{ef} = 16\Omega$

$R_{fb} = 8\Omega$

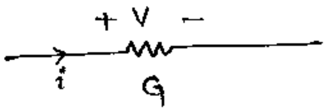
Conductance: it is the ability to conduct electrically.

⇒ it is used to further classify metals (conductors)

$$\boxed{G = \frac{1}{R}}$$

units : (℧) mho

Siemens



OHM's Law : $\boxed{V = \frac{I}{G}}$

$\boxed{I = V.G.}$

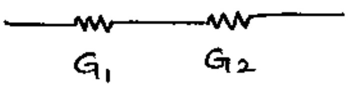
$\rho \rightarrow \Omega\text{-m.}$

Basic Formulae : $\boxed{G = \frac{a}{\rho l} = \frac{\sigma . a}{l}}$

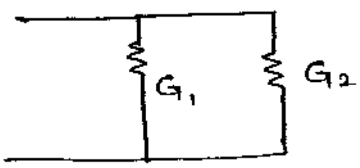
$\sigma \rightarrow$ conductivity

units of $\sigma \Rightarrow [\Omega\text{-m}]^{-1}$

℧/m (or) S/m



$$\frac{1}{G_S} = \frac{1}{G_1} + \frac{1}{G_2}$$



$$G_P = G_1 + G_2$$

⇒ power

$$P_G = V_G . i_G = \frac{i_G^2}{G} = V_G^2 . G$$

Cu density = 13 × density of Al.

Based on Conductivity

Rank I ⟶ Silver

- II ⟶ Copper ⟶ it is used in High current Density (Compact)
  used in — Domestic, Industrial, machines

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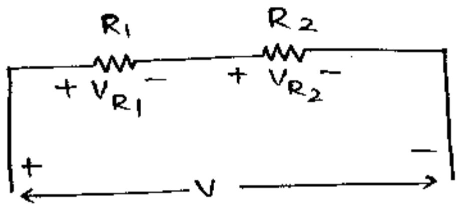
- III ⟶ Gold
- IV ⟶ Aluminium ⟶ light weight / ⟶ cheap } used in External 'T & D' lines
  ⇒ A.C.S.R.

* Voltage division Rule :
  ↳ applicable for Series Connected elements only.

$\boxed{R}$



$$V_{R_1} = V\left[\frac{R_1}{R_1+R_2}\right]$$

$$V_{R_2} = V\left[\frac{R_2}{R_1+R_2}\right]$$

$\boxed{L}$

$$V_{L_1} = V\left[\frac{L_1}{L_1+L_2}\right]$$

$$V_{L_2} = V\left[\frac{L_2}{L_1+L_2}\right]$$

$\boxed{C}$

$$V_{C_1} = V\left[\frac{C_2}{C_1+C_2}\right]$$

$$V_{C_2} = V\left[\frac{C_1}{C_1+C_2}\right]$$

$\boxed{G}$

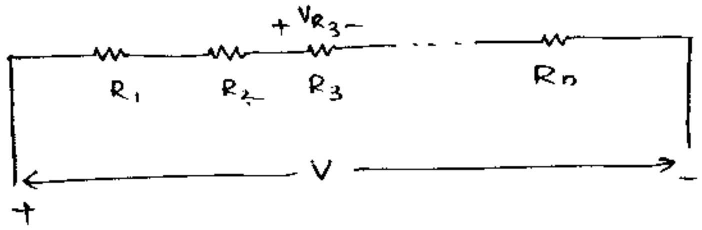
$$V_{G_1} = V\left[\frac{G_2}{G_1+G_2}\right]$$

$$V_{G_2} = V\left[\frac{G_1}{G_1+G_2}\right]$$

Note:

'R' Ω ⟷ 'L' H ⟷ 'X' Ω ⟷ 'Z' Ω
'G' ℧ ⟷ 'C' F ⟷ 'B' ℧ ⟷ 'Y' ℧
} for Voltage division & Current division

*



$$V_{R_3} = V\left[\frac{R_3}{\sum_{i=1}^{n} R_i}\right]$$

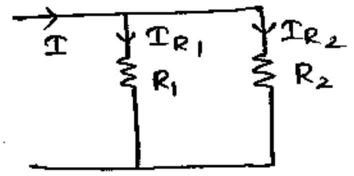
* for 'n' capacitors in series.

$$V_{C_3} = V\left[\frac{\frac{1}{C_3}}{\sum_{i=1}^{n} \frac{1}{C_i}}\right]$$

Current division Rule:

↳ applicable for parallel Connected elements only.

$\boxed{R}$



$$I_{R_1} = I\left[\frac{R_2}{R_1+R_2}\right]$$

$$I_{R_2} = I\left[\frac{R_1}{R_1+R_2}\right]$$

$\boxed{L}$

$$I_{L_1} = I\left[\frac{L_2}{L_1+L_2}\right]$$

$$I_{L_2} = I\left[\frac{L_1}{L_1+L_2}\right]$$

$\boxed{C}$

$$I_{C_1} = I\left[\frac{C_1}{C_1+C_2}\right]$$

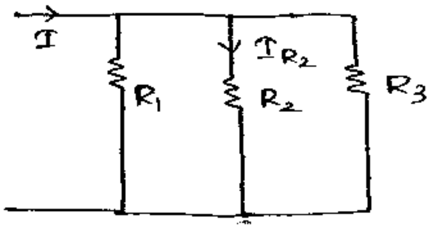
$$I_{C_2} = I\left[\frac{C_2}{C_1+C_2}\right]$$

$\boxed{G}$

$$I_{G_1} = I\left[\frac{G_1}{G_1+G_2}\right]$$

$$I_{G_2} = I\left[\frac{G_2}{G_1+G_2}\right]$$

⇒

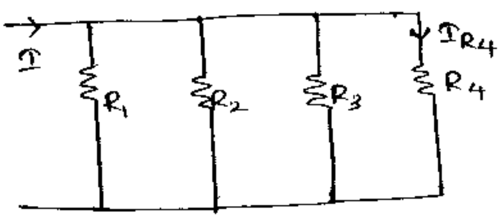


$$I_{R_2} = I\left[\frac{R_1R_3}{R_1R_2+R_2R_3+R_3R_1}\right]$$

⇒ for 3 capacitors is parallel

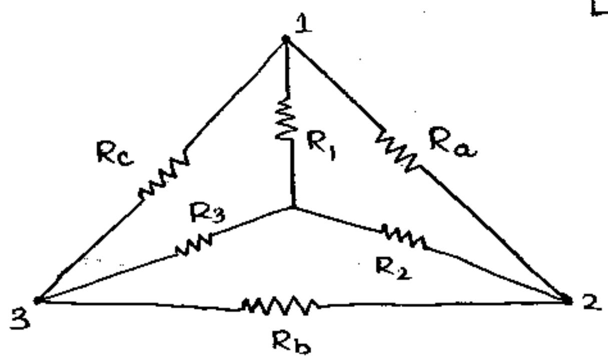
$$I_{C_2} = I\left[\frac{\frac{1}{C_1}\cdot\frac{1}{C_2}}{\frac{1}{C_1}\cdot\frac{1}{C_2}+\frac{1}{C_2}\cdot\frac{1}{C_3}+\frac{1}{C_3}\cdot\frac{1}{C_1}}\right]$$

⇒



$$I_{R_4} = I\left[\frac{R_1R_2R_3}{R_1R_2R_3+R_2R_3R_4+R_3R_4R_1+R_4R_1R_2}\right]$$

Δ - Y Transformation : (increas 1 node)



$\boxed{R}$

$$R_1 = \frac{R_aR_c}{R_a+R_b+R_c}$$

$$R_2 = \frac{R_a.R_b}{R_a+R_b+R_c}$$

$$R_3 = \frac{R_b.R_c}{R_a+R_b+R_c}.$$

$\boxed{L}$

$$L_1 = \frac{L_aL_c}{L_a+L_b+L_c}$$

$$L_2 = \frac{L_aL_b}{L_a+L_b+L_c}$$

$$L_3 = \frac{L_bL_c}{L_a+L_b+L_c}$$

$\boxed{C}$

$$\frac{1}{C_1} = \frac{\frac{1}{C_a}\cdot\frac{1}{C_c}}{\frac{1}{C_a}+\frac{1}{C_b}+\frac{1}{C_c}}$$

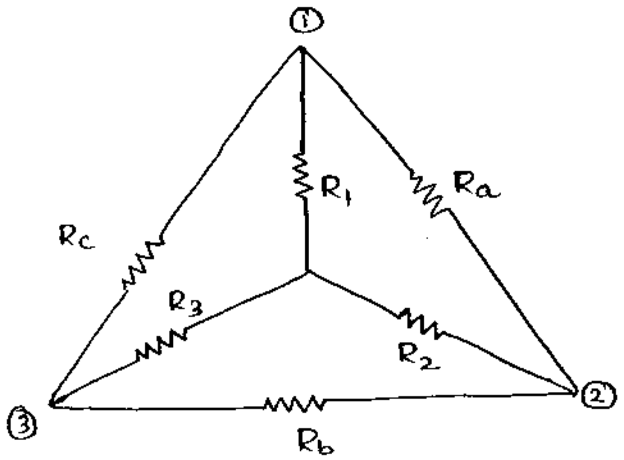
$$\frac{1}{C_2} = \frac{\frac{1}{C_a}\cdot\frac{1}{C_b}}{\frac{1}{C_a}+\frac{1}{C_b}+\frac{1}{C_c}}$$

$$\frac{1}{C_3} = \frac{\frac{1}{C_b}\cdot\frac{1}{C_c}}{\frac{1}{C_a}+\frac{1}{C_b}+\frac{1}{C_c}}$$

$\boxed{G}$

$$\frac{1}{G_1} = \frac{\frac{1}{G_a}\cdot\frac{1}{G_c}}{\frac{1}{G_a}+\frac{1}{G_b}+\frac{1}{G_c}}.$$

Y - Δ Transformation: (reduces 1 node)



R

$$R_a = \frac{R_1R_3 + R_2R_3 + R_1R_2}{R_3}$$

$$R_b = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

$$R_c = \frac{R_2R_3 + R_1R_2 + R_3R_1}{R_2}$$

L

$$L_a = \frac{L_1L_3 + L_2L_3 + L_1L_2}{L_3}$$

$L_b = -$

$L_c = -$

C

$$\frac{1}{C_a} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{\frac{1}{C_1}\cdot\frac{1}{C_2}}{\frac{1}{C_3}}$$

$\frac{1}{C_b} =$

$\frac{1}{C_c} =$

G

$$\frac{1}{G_a} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{\frac{1}{G_1}\frac{1}{G_2}}{\frac{1}{G_3}}$$

$\frac{1}{G_b} =$

$\frac{1}{G_c} =$

Ratings (or) Specifications:

⇒ They represent the maximum permissible Safe Values for Continuous operation of an electrical device or application.

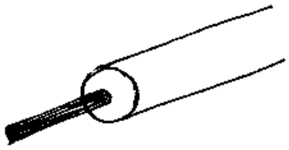
Continuous operation of an electrical device or application. Voltage, Current, power, frequency, Insulation class

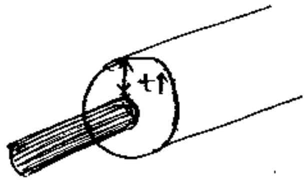
⇒ We generally Consider Voltage, Current, power rating with Temperature limitations.

⇒ operating any device or application above the rated values leads to detoriation & damage

⇒ but operating below the rated Values leads to under utilisation ie, degeneracy.

practical wire:



230V, 5A $\xrightarrow[\text{rating to}]{\text{to increase}}$ a↑ 

800V, 20A

to $I\uparrow \Rightarrow$ Conductor Cross-Sectional Area↑

$V\uparrow \Rightarrow$ Insulation level↑

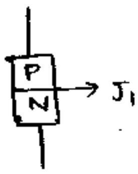
* Signal Diode vs Power diode.

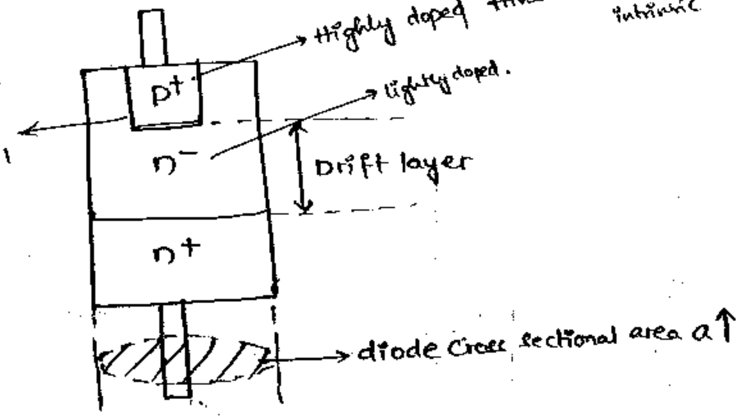
D104

1N4007

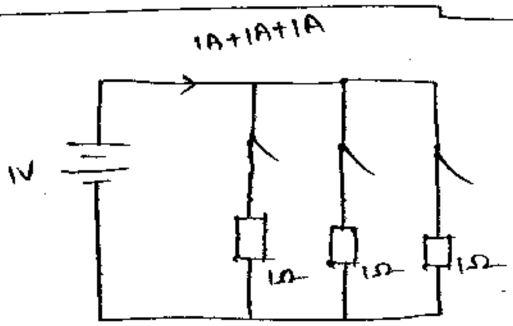
- 60V, 800mA.

→1000V, 40A





$$\begin{bmatrix}\text{Breakdown} \\ \text{Voltage}\end{bmatrix} \propto \frac{1}{\text{Doping density}}$$



Note: most of our applications are designed to work for constant Rated voltage only.

⇒ But current through them depends upon Loading level.

Low Wattage	High Wattage
V	V
$I\downarrow$	$I\uparrow$
$a\downarrow$ (thin wire)	$a\uparrow$ (thick wire)
$R_{High}\uparrow$	$R_{Low}\downarrow$

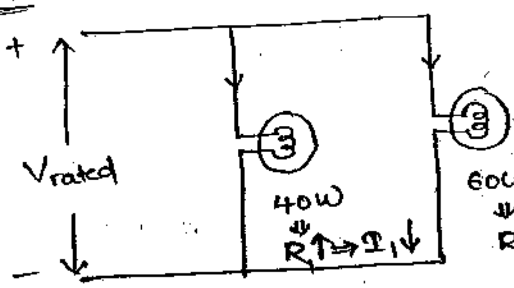
⇒ DC Motors

$220V,\ R_a = 1\,\Omega \longrightarrow$ R is High $\Rightarrow a\downarrow \Rightarrow I\downarrow \Rightarrow P(=V.I)$ is less $\Rightarrow$ Low H.P

$220V,\ R_a = 0.2\,\Omega \longrightarrow$ R is low $\Rightarrow a\uparrow \Rightarrow I\uparrow \Rightarrow P(=V.I)$ is more $\Rightarrow$ more H.P.

CFL - III Gen. lamp
↳ Inverter, 400Hz
High freq ⇒ less weight

IESQ



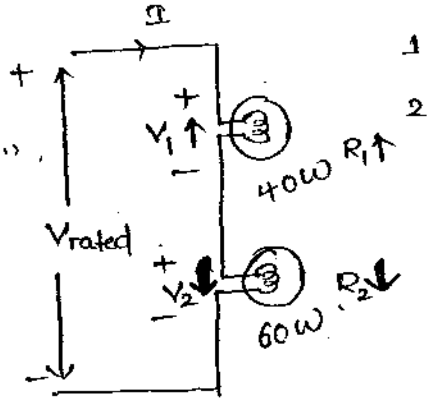
↳ Rated operation

1. Which bulb glows brighter 60W
2. Total power absorbed 60+40 = 100W

→ tungsten filament lamps, pure Resistive., consumes more Energy for less lumens. (unity P.F)

$V = V_1 + V_2$

Gate:



↳ under-Rated operation

1. Which bulb glows brighter 40W.
2. Total power absorbed 100W

$$= \frac{P_1 P_2}{P_1 + P_2}$$

$$= \frac{40 \times 60}{40 + 60}$$

$= 24$ Watts only.

lowest thermal const ⇒ Tungsten.
lowest thermal time const

Heater – Nichrome.

$$\boxed{R_{designed} = \frac{[V_{rated}]^2}{P_{rated}} \ \Omega} \rightarrow \text{for under rated.}$$

$$\therefore \ P_T = \frac{V_r^2}{R_1+R_2} = \frac{V_r^2}{\frac{V_r^2}{P_1}+\frac{V_r^2}{P_2}}$$

$$P_T = \frac{V_r^2}{V_r^2\left[\frac{1}{P_1}+\frac{1}{P_2}\right]} = \frac{P_1 P_2}{P_1+P_2}$$

Ex: INDIA.

Incandescent Bulb.

220V, 40W.

OFF

$R_{cold} = 20\,\Omega$ [Multimeter]

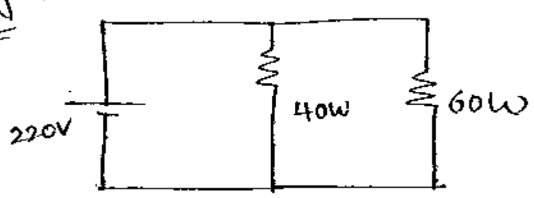
$$I = \frac{V}{R_{cold}} = \frac{220}{20} = \underset{\text{Wrong}}{11\,A} \ \times$$

ON

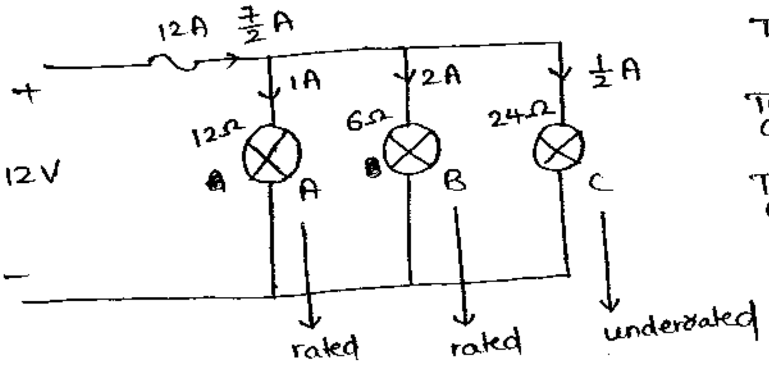
$$R_{HOT} = \frac{(220)^2}{40} = 1210\,\Omega.$$

$$I = \frac{V}{R_{HOT}} = \frac{220}{1210} \approx \underline{180\,mA} \checkmark \ \text{Correct.}$$

HW Same bulb problem with 'R'



Q How many Extra type 'c' bulbs can be Connected to the Supply without Blowing off the fuse.



Type (A) Bulb] 12V, 12W

Type (B) Bulb] 12V, 24W

Type (C) Bulb] 24V, 24W.

$$R_A = \frac{(12)^2}{12} = 12\Omega \qquad i_A = \frac{12V}{12\Omega} = 1A$$

$$R_B = \frac{(12)^2}{24} = 6\Omega \qquad i_B = \frac{12V}{6\Omega} = 2A$$

$$R_C = \frac{(24)^2}{24} = 24\Omega. \qquad i_C = \frac{12V}{24\Omega} = \frac{1}{2}A.$$

Extra current allowed by fuse $< \left[12 - \frac{7}{2}\right]$

$< \frac{17}{2}A$

But each bulb (c) $\longrightarrow \frac{1}{2}A$

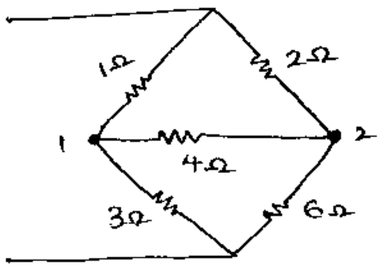
$$[N_c].\left[\frac{1}{2}\right] < \frac{17}{2}$$

$$N_c < 17$$

$\hookrightarrow$ 16 Bulbs only.

Module-II

Resistor Reduction Techniques:

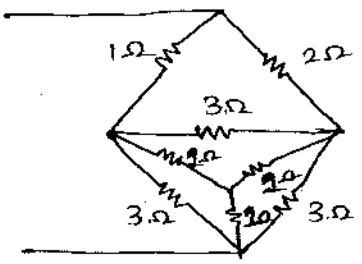


$(1)(6) = 2(3) \Rightarrow$ Balance

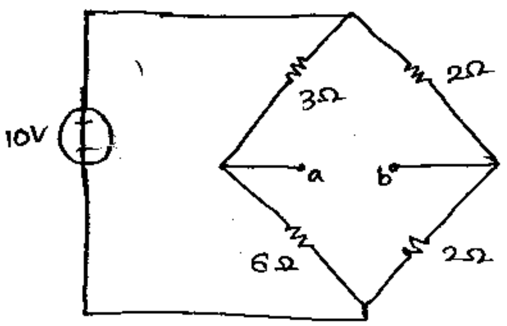
P.D doesn't exists b/w 1 & 2 nodes

$\therefore$ no current flows through $4\Omega \Rightarrow$ O.C

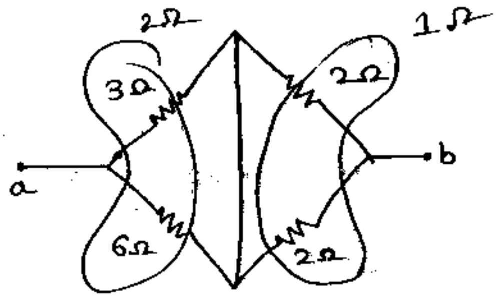
$\therefore 4 \| 8 = \frac{4\times 8}{12} = \frac{8}{3}\,\Omega$



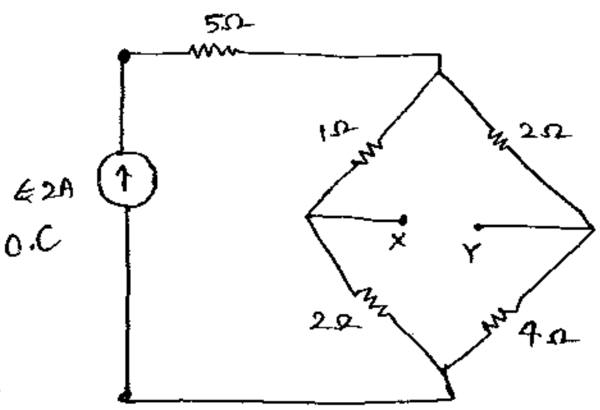
$1 + [2\|3] = 1 + \frac{6}{5} = \frac{11}{5}\,\Omega.$

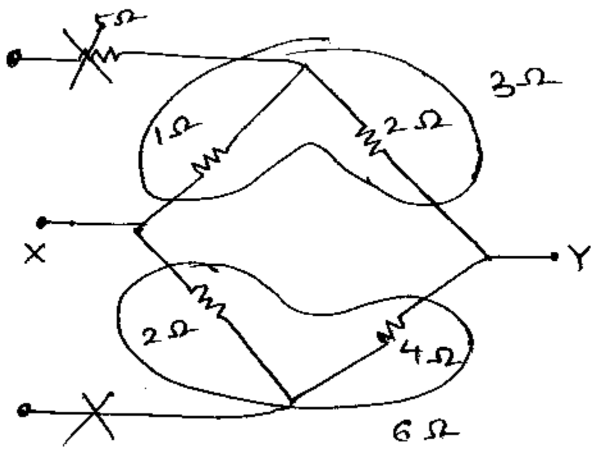


$\Rightarrow$

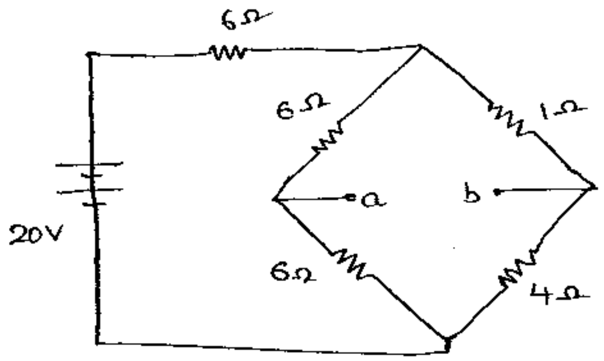


$\Rightarrow 2+1 = 3\Omega$

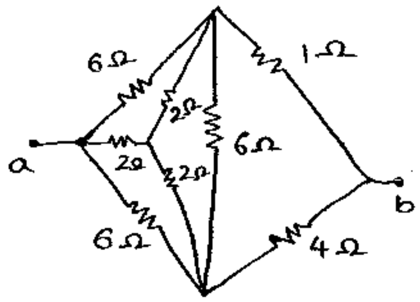




$\Rightarrow 3\|6.$



$\Rightarrow$

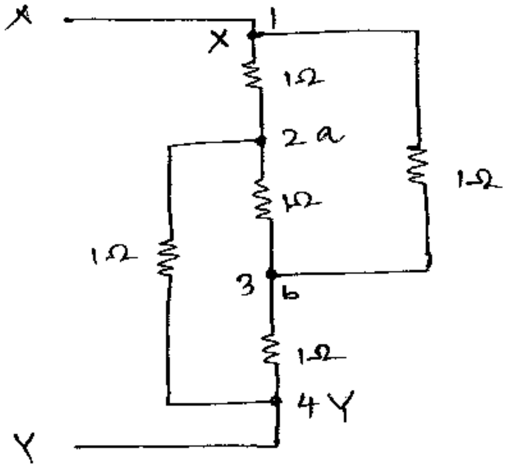


$\Rightarrow 2\Omega + [(2+1) \| (2+4)]$

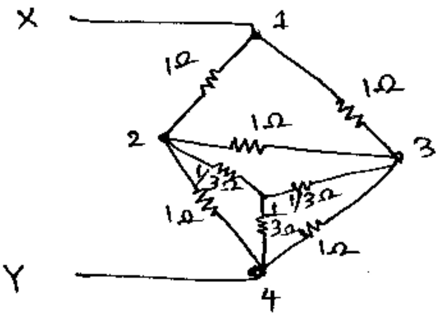
$\Rightarrow 2\Omega + [3 \| 6]$

$\Rightarrow 2+2$

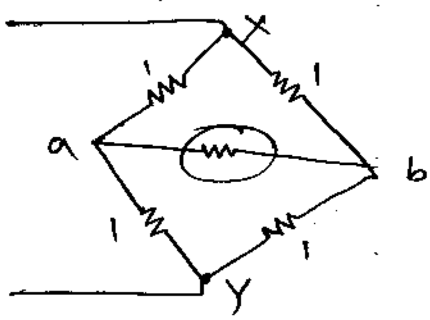
$\Rightarrow 4\Omega$



$R_{XY} = \underline{2/3\,\Omega}$



⇓ node shifing .



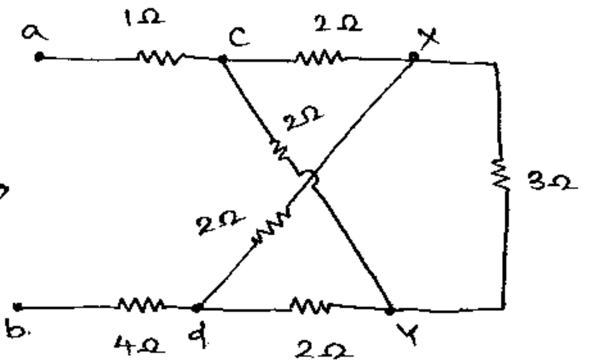
$\Rightarrow$ bridge balanced

$1\times1 = 1\times1$

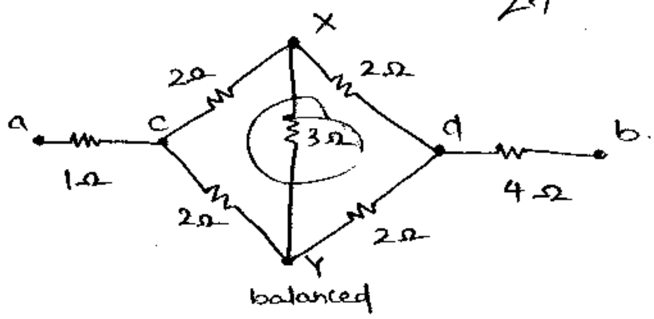
$\therefore\ 2 \| 2 = 1\,\Omega.$

$1+(2\|4)+4$

⇒

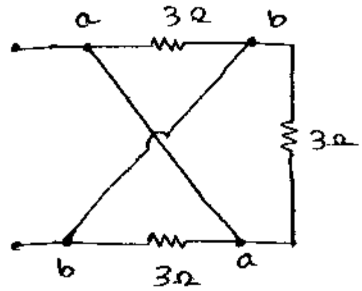


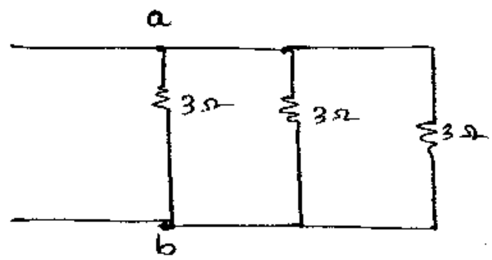
⇒



$1\Omega + (4\|4) + 4\Omega = 7\Omega.$

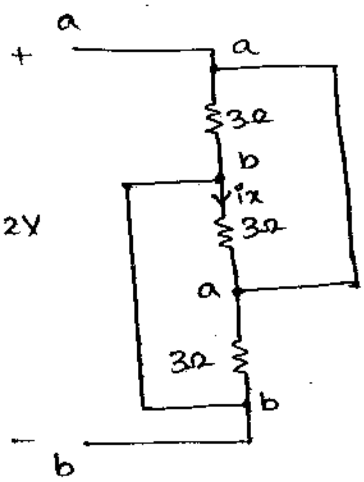
⇒

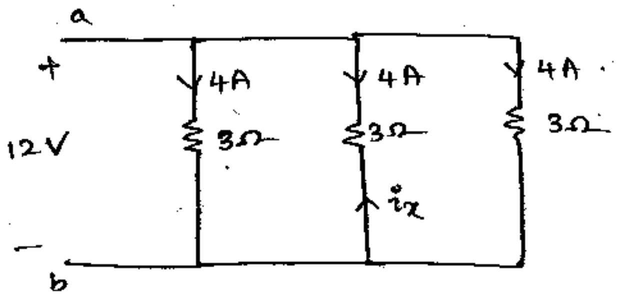




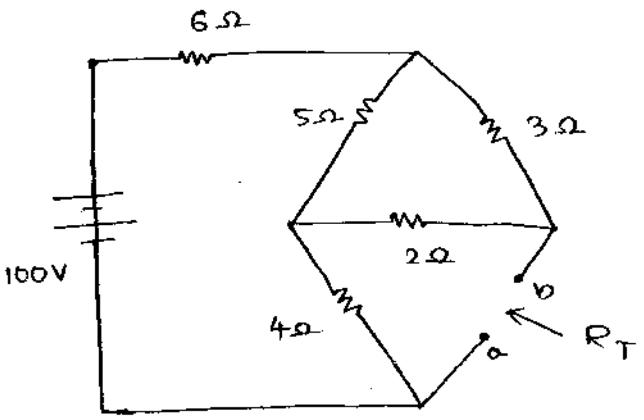
⇒ 1Ω.

⇒

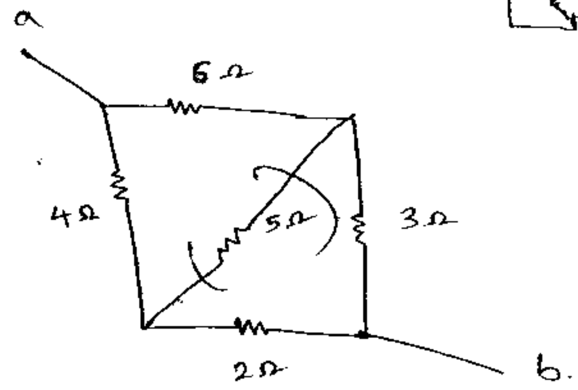




$i_x = -4A.$

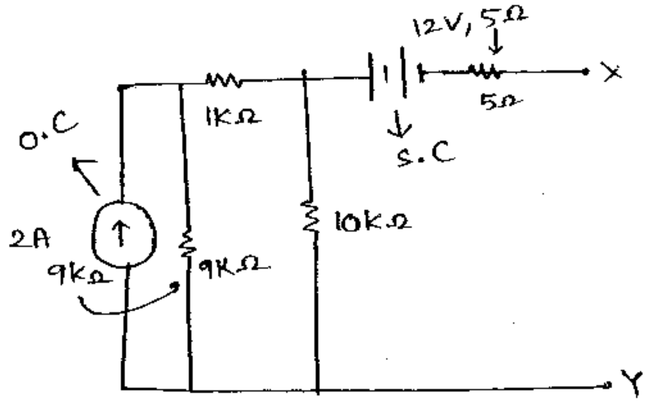


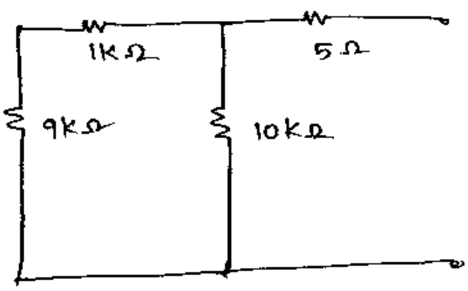
$\Rightarrow$



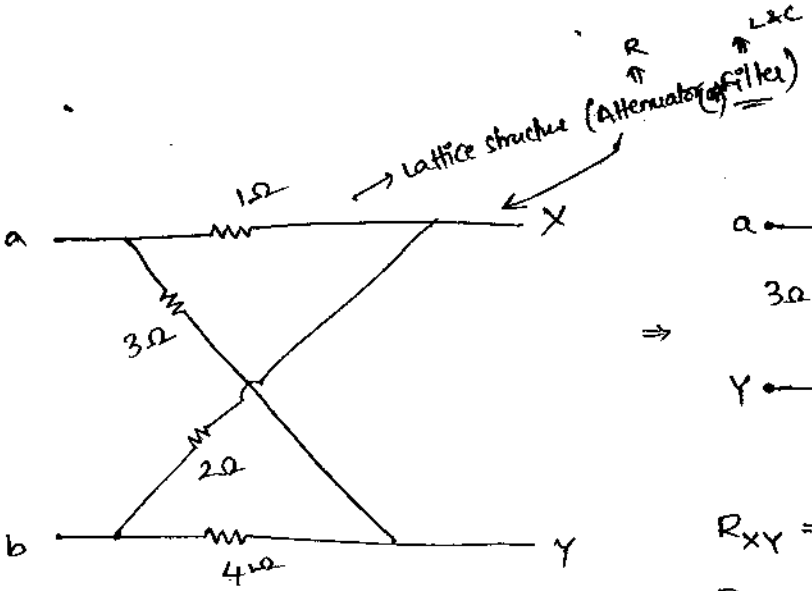
Bridge is Balanced $\Rightarrow$ $6 \times 2 = 3 \times 4$

$\therefore\ 9\Omega \parallel 6\Omega = \frac{18}{5}\ \Omega$

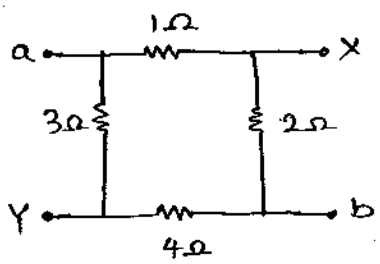




$= 5005\ \Omega$



$\Rightarrow$

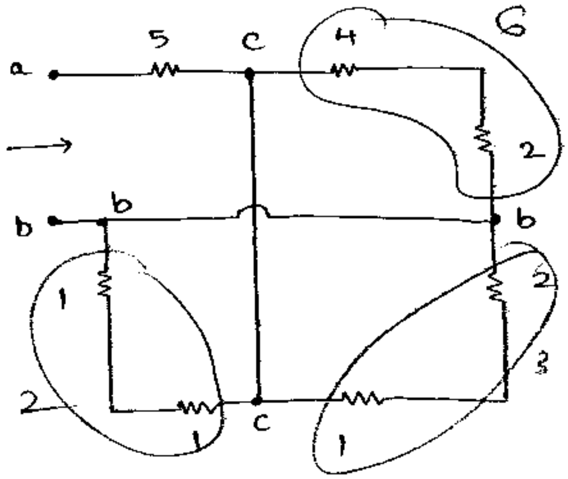


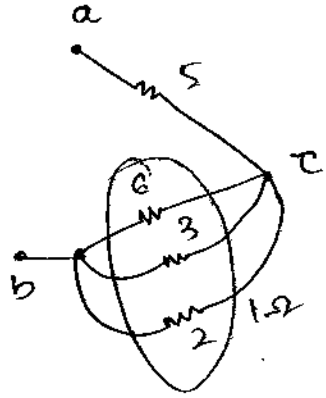
$R_{XY} = 4\Omega \parallel 6\Omega = 2.4\Omega$

$R_{ab} = 7\Omega \parallel 3\Omega = 2.1\Omega$

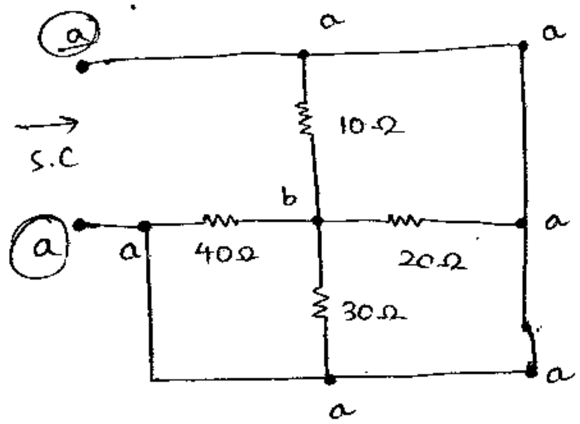
$R_{aY} = 3\Omega \parallel 7\Omega = 2.1\Omega$

$R_{bY} = 4\Omega \parallel 6\Omega = 2.4\Omega$





$\Rightarrow 5+1 = 6\Omega$.



~~10||20||30||40~~

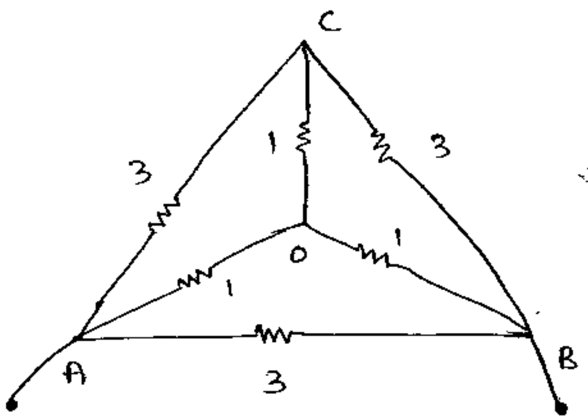
$\Rightarrow$ dead S.C

$\Rightarrow 0$

10//20

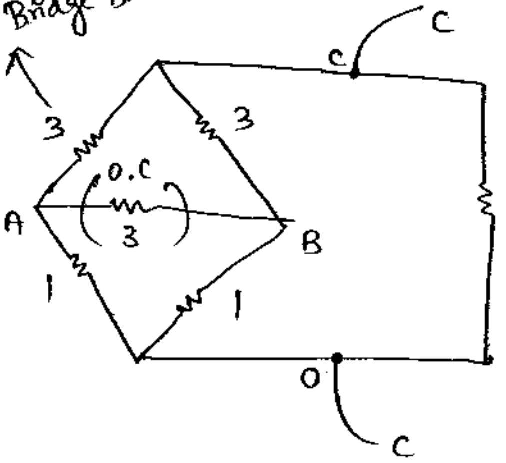
10||20||30

10|



$\Rightarrow$

Bridge Balanced.



$R_{AB} = 1$

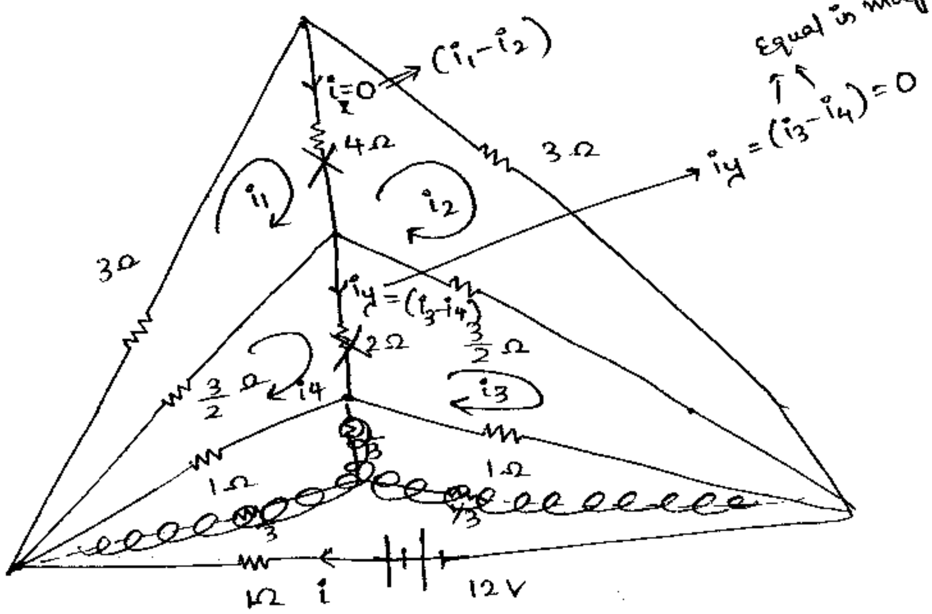
$R_{CO} = 2 // 1$

$= \frac{2}{3}$

$\frac{R_{AB}}{R_{CO}} =$

$$\frac{R_{AB}}{R_{CO}} = \frac{1}{2/3} = \frac{3}{2}.$$

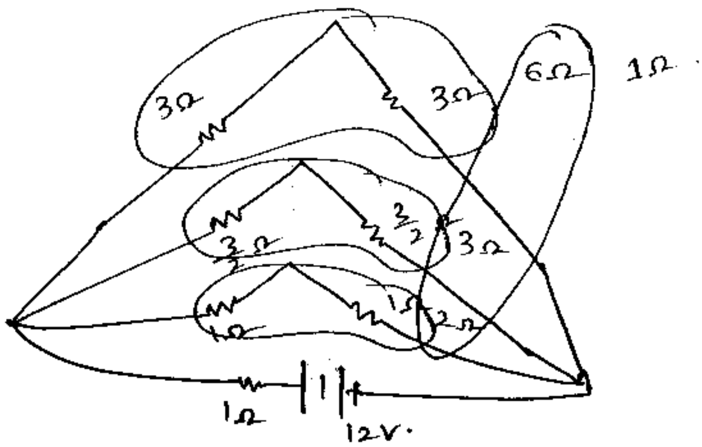
$i_x =$

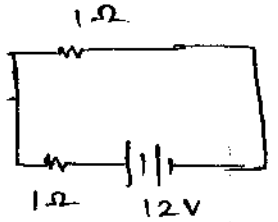


$$i = \frac{12}{1+1} = 6A.$$

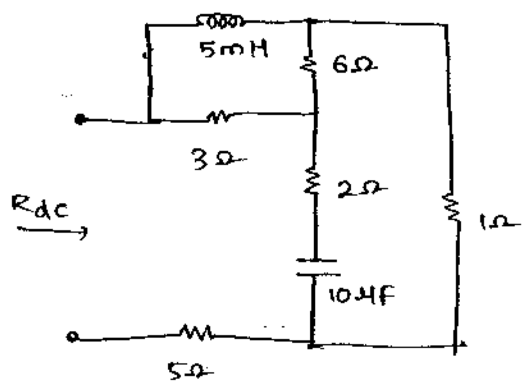
$\frac{1}{3} + 2 = \frac{7}{3}$

⇓

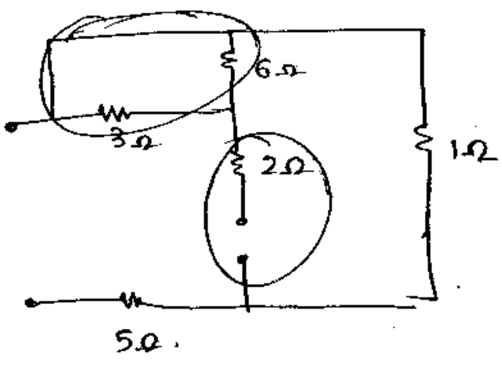




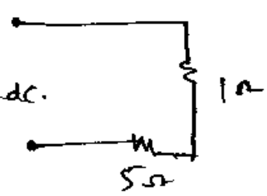
$$\Rightarrow i = \frac{12}{1+1} = 6A$$



$R_{dc} = (1+5) = 6\Omega$



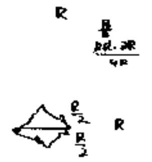
⇓

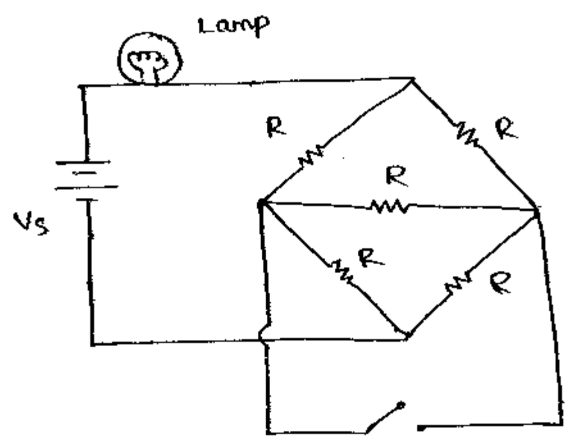


$\Rightarrow 6\Omega$

If. Switch 'S' is closed then intensity of Lamp is

29





(a) Increases

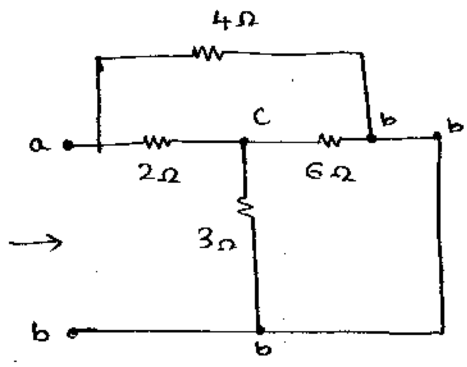
(b) Decreases

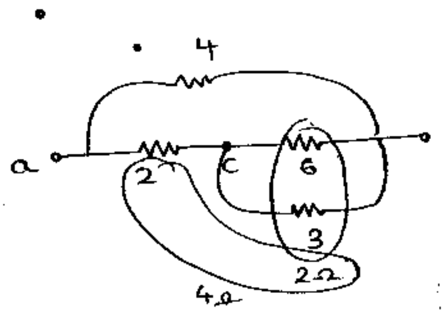
~~(c)~~ Remains Same

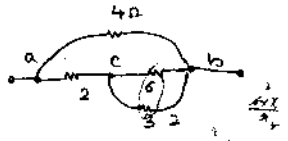
(d) Blow off

⇒ Eff. Resistance seen by ckt before & After closing switch is Same.

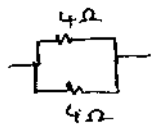
⇒







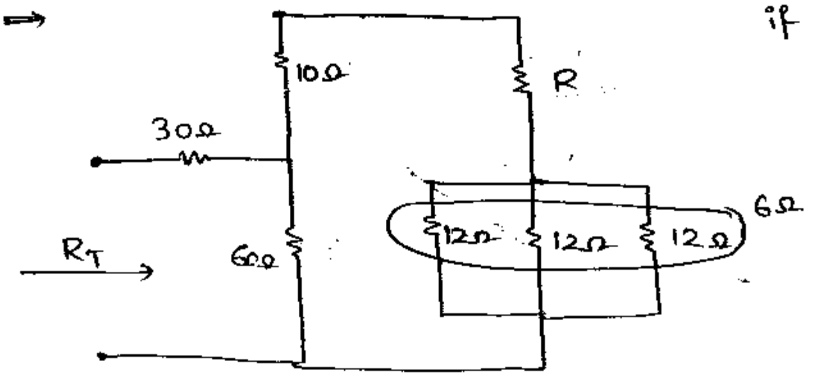
⇒



2Ω

$4 \| 4 = 2\Omega$

⇒



if $R_T = 50\Omega$ then $R = ?$

$$50 = 30 + \left[60 \| (14+R)\right]$$

$$\cancel{20} = \frac{\cancel{60}^{\,3} \times (14+R)}{74+R}$$

$$74R = 42 + 3R$$

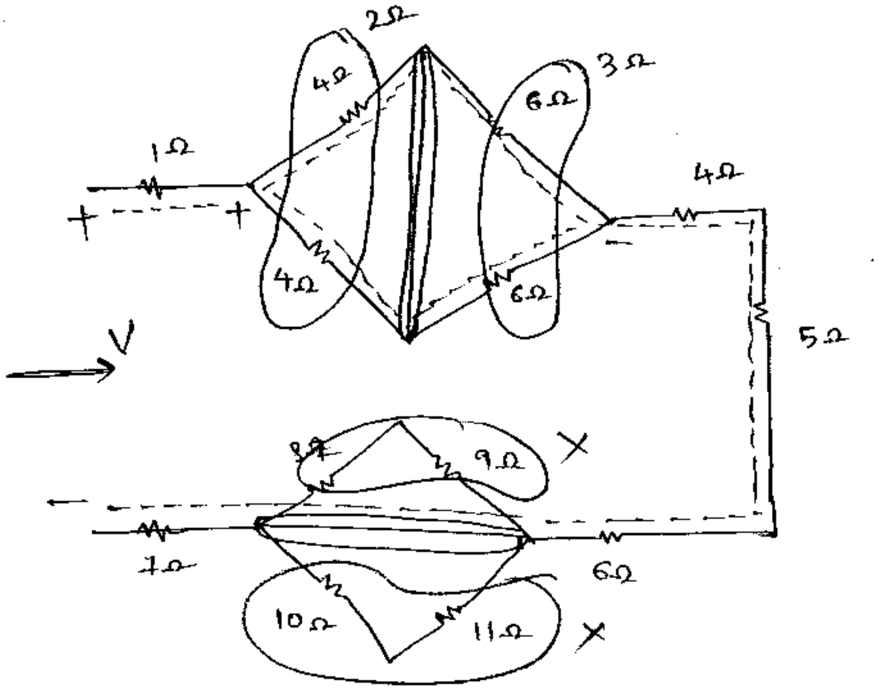
$$R = 16\Omega$$

$(14+(R\|6))$

$50 = 30 + (14+R)\|60$

$20 = \frac{(14+R)\times 60}{74+R}$

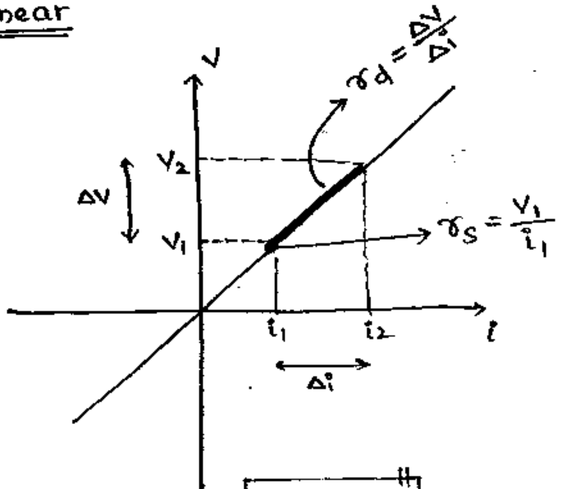
$\sim 1+3+5+5+6+(17 \| 21)+7$



$$\Rightarrow \Sigma(1,7) = 1\Omega + 2\Omega + 3\Omega + 4\Omega + 5\Omega + 6\Omega + 7\Omega = 28\,\Omega$$

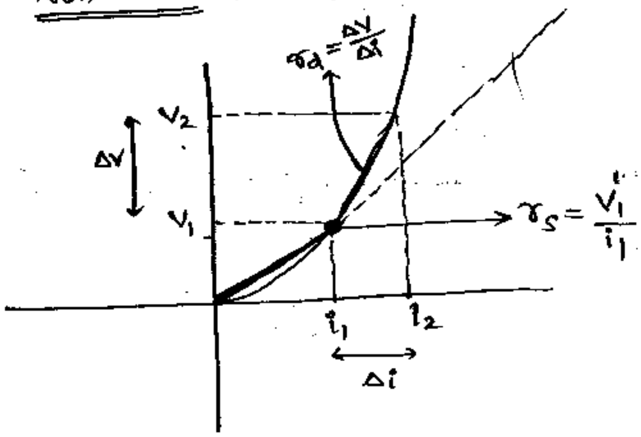
Q. The voltage-current relation in a non-Linear Component is $V = i^2$ then the relation b/w static resistance (r_s) & dynamic Resistance (r_d) is.

Linear



$$\boxed{r_d = r_s}$$

Non Linear $(V = i^2)$



(a) $r_d = 2r_s$

(b) $r_d = \frac{r_s}{2}$

(c) $r_d = r_s^2$

(d)

$$V = i^2$$

$$\frac{dv}{dt} = 2i\frac{di}{dt}$$

$$V = i^2$$

$$\frac{V}{i} = i$$

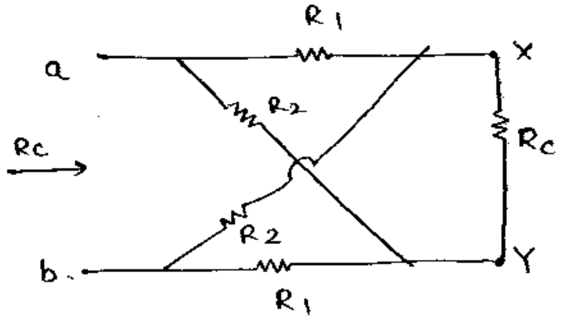
$$r_s = i$$

$$\frac{dv}{di} = r_d = 2i$$ → steady state op. point where we initially calculate 'r_s'

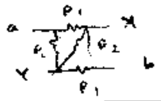
$$r_d = 2i$$

$$\boxed{r_d = 2r_s}$$

Find. characteristic resistance of N/w at terminals a-b, if Load is Connected b/w terminals X-Y



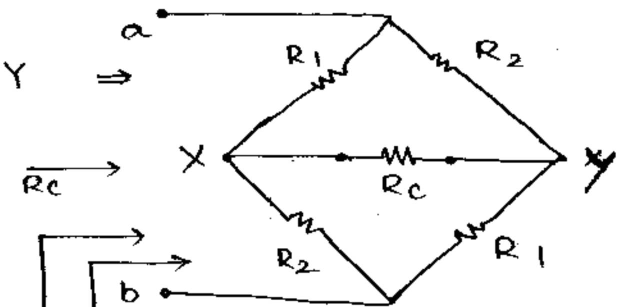
Here
$\Rightarrow$ this N/w is balanced & Symmetrical lattice.



(Balanced lattice

30

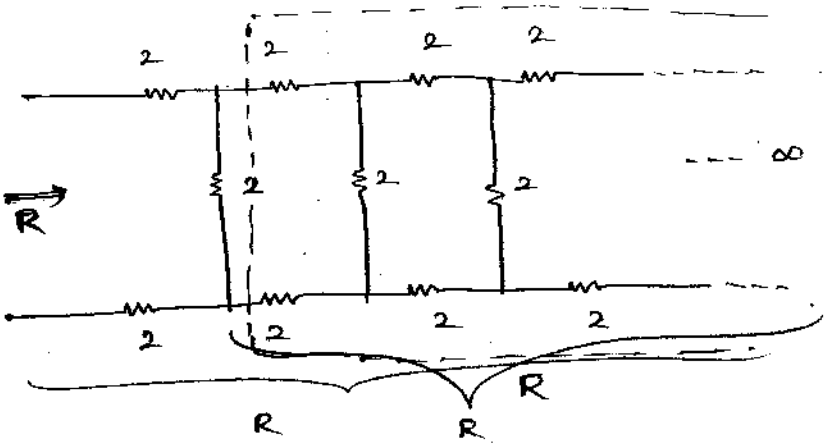
$\Rightarrow$



$\frac{R_1+R_2}{2} = R_{oc}$ | $R_{sc} = \frac{2R_1R_2}{R_1+R_2}$

$$R_c = \sqrt{R_{oc} * R_{sc}}$$

$$= \sqrt{\cancel{\frac{R_1+R_2}{2}} \times \frac{2 \times R_1R_2}{\cancel{R_1+R_2}}} \Rightarrow R_c = \sqrt{R_1R_2}$$



$\Rightarrow$ all 'R' are linear Passive. Bilateral N/W

$\Downarrow$

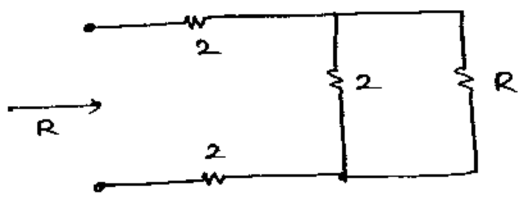
$R = \frac{V}{I}$

$\Downarrow$ Q.

R = +ve slope

$\Downarrow$

R = +ve



$$R = 4 + [2 \| R]$$

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

$$R^2 + \cancel{2R} = 8 + 4R + \cancel{2R}$$

$$R^2 - 4R - 8 = 0$$

$$R = \frac{4 \pm \sqrt{16 - 4(-8)}}{2(1)} = \frac{4 \pm 4\sqrt{3}}{2} = (2 \pm 2\sqrt{3})\Omega$$

$R = (2+2\sqrt{3})\Omega$

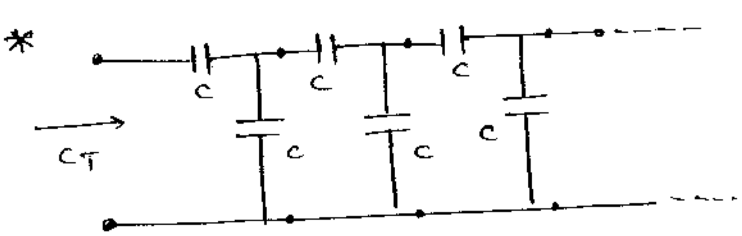
Characteristic Resistance :

it is that Resistance with which if we terminate the n/w the total Reflected ~~N/w~~ Resistance including the N/w is same

it is possible to construct char. Resistance only if the N/w is balanced and Symmetrical.

Condition for Char. Resistance $\boxed{R_c = \sqrt{R_{oc} \cdot R_{sc}}}$

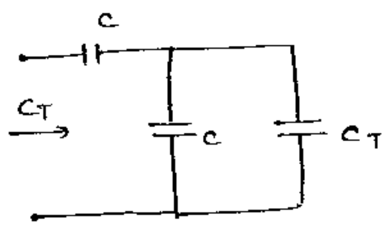
*



⇓

Linear

$\Rightarrow$



$$C_T = C \; (S) \; [C_T + C]$$

$$C_T = \frac{C.C_T + C^2}{C_T + 2C}$$

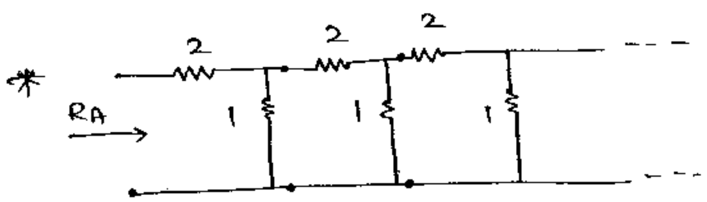
$$C_T^2 + 2C\,C_T = C.C_T + C^2$$

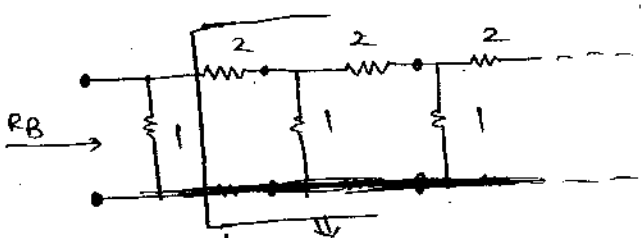
$$C_T^2 + C.C_T - C^2 = 0$$

$$C_T = \frac{-C \pm \sqrt{C^2 - 4(-C^2)}}{2(1)}$$

$$C_T = \frac{-C \pm \sqrt{5}\,C}{2}$$

*





⇓

RA

$\Rightarrow$

$$R_B = \frac{R_A \cdot 1}{1 + R_A}$$

$$R_B = \frac{R_A}{1 + R_A}$$

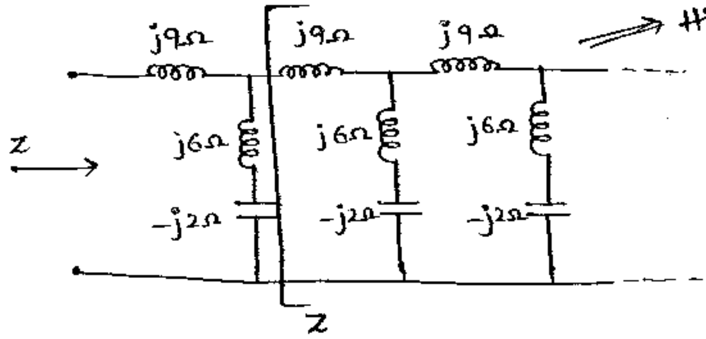
(a) $R_A = R_B$

(b) $R_B = R_A = 0$

(c) $R_A = \frac{R_B}{1+R_B}$ ~~(d)~~ $R_B = \frac{R_A}{1+R_A}$.

$j \Rightarrow$ max operator

31



$\Longrightarrow$ Highly Inductive N/W.

reactance = +ve ⇒ Inductive

= −ve ⇒ capacitive

$$Z = j9 + \left[Z \,/\!/\, (j6 - j2)\right] = j9 + \frac{j4Z}{Z + j4}$$

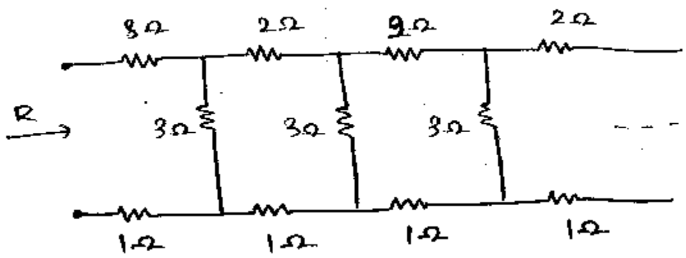
$$Z^2 + \cancel{Zj4} = j9Z - 36 + \cancel{j4Z}$$

$$Z^2 - j9Z + 36 = 0$$

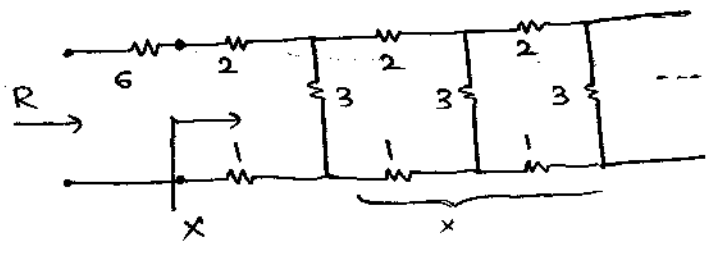
$$Z = \frac{j9 \pm \sqrt{-81 - 4(36)}}{2(1)} = \frac{j9 \pm \sqrt{-225}}{2}$$

$$Z = \frac{j9 \pm j15}{2} \begin{cases} \longrightarrow \underline{\underline{+j12\,\Omega}} \\ \longrightarrow \underline{\underline{-j3\,\Omega}} \Rightarrow \end{cases}$$

✓ ∵ Inductive.



accurate value of R.



$$x = 2 + (x \,/\!/\, 3) + 1$$

$$x = 2 + \frac{3x}{3+x} + 1$$

$$(3+x)x = 3(3+x) + 3x$$

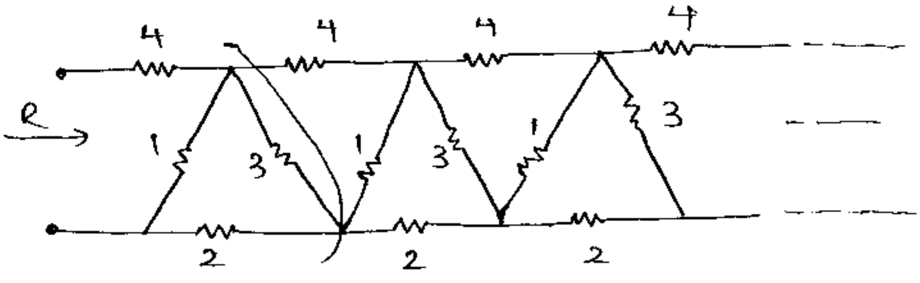
$$\cancel{3x} + x^2 = 9 + \cancel{3x} + 3x$$

$$x^2 - 3x - 9 = 0$$

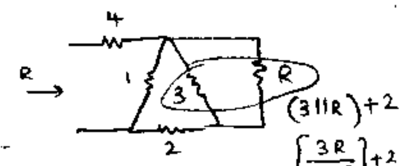
$$x = \frac{3 \pm \sqrt{9 - 4 \times 1(-9)}}{2(1)}$$

$$x = \frac{3 \pm \sqrt{45}}{2}$$

$$R = x + 6$$



$R =$ ______



$(3 \| R) + 2$

$\left[\frac{3R}{3+R}\right] + 2$

$\left[\frac{5R+6}{3+R}\right] \| 1$

$\dfrac{\frac{5R+6}{3+R}}{\frac{5R+6+3+R}{3+R}} = \frac{5R+6}{6R+9}$

$R = \frac{5R+6}{6R+9} + 4$

$6R^2 + 9R = 5R + 6 + 24R + 36$

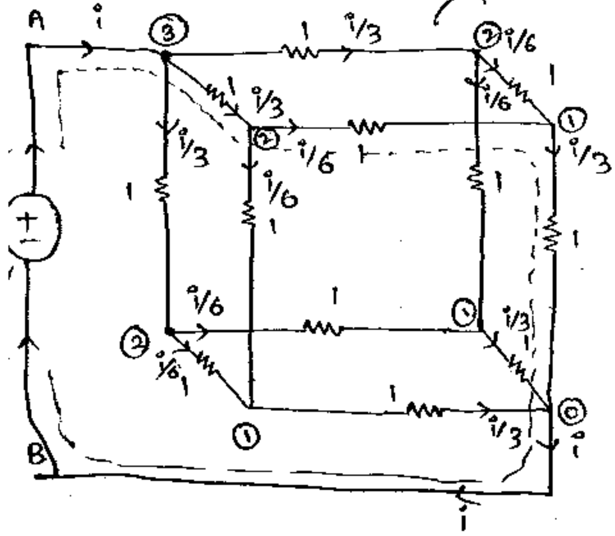
$6R^2 - 20R - 30 = 0$

$3R^2 - 10R - 15 = 0$

$R = \frac{10 \pm \sqrt{100 - 4 \times (3)(-15)}}{6}$

$R = \frac{10 \pm \sqrt{280}}{6}$

* find $R_{AB} = \frac{v}{i} = \frac{5}{6}\,\Omega$



Converte to PLANAR / λ to Δ } if 'R' are unequal.

⇒ Symmetrical

if (i) All resistors are Equal [not mandatory]

(ii) The path resistance b/w A & B in all the paths is Equal.
↳ must condition.

KVL: $-V + \frac{i}{3}(1) + \frac{i}{6}(1) + \frac{i}{3}(1) = 0$

$$V = i\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{3}\right]$$

$$V = i\,\frac{5}{6}$$

$$R_{AB} = \frac{V}{i} = \frac{5}{6}\,\Omega$$

for capacitors:, [Time-Variance]

$$-V(t) + \frac{1}{C}\int \frac{i(t)}{3}\,dt + \frac{1}{C}\int \frac{i(t)}{6}\,dt + \frac{1}{C}\int \frac{i(t)}{3}\,dt = 0$$

$$V(t) = \frac{1}{C}\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{3}\right]\int i(t)\,dt$$

$$V(t) = \frac{5}{6C}\int i(t)\,dt$$

$$V(t) = \frac{1}{(6C/5)}\int i(t)\,dt$$

for $r = X\,\Omega = Z\,\Omega$

$R_{AB} = \frac{5}{6} r\,\Omega$

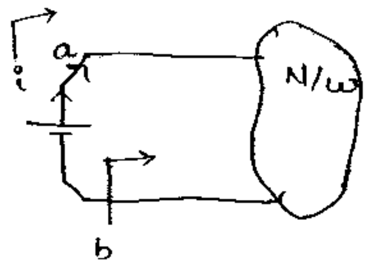
$\underline{\underline{l}}$ $L_{AB} = \frac{5}{6} l$ H

$\underline{\underline{C}}$ $C_{AB} = \frac{6C}{5}$ F

$g = B℧ = Y℧$

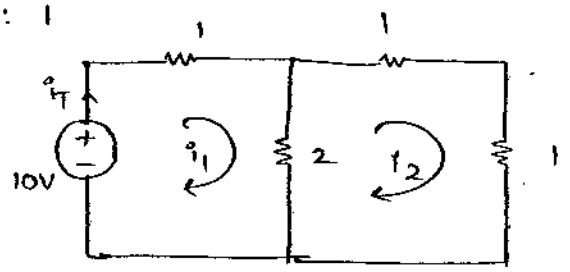
$G_{AB} = \frac{6g}{5}$ ℧

OHM'S Law



$R_{ab} = \frac{V}{i}$

EX: 1



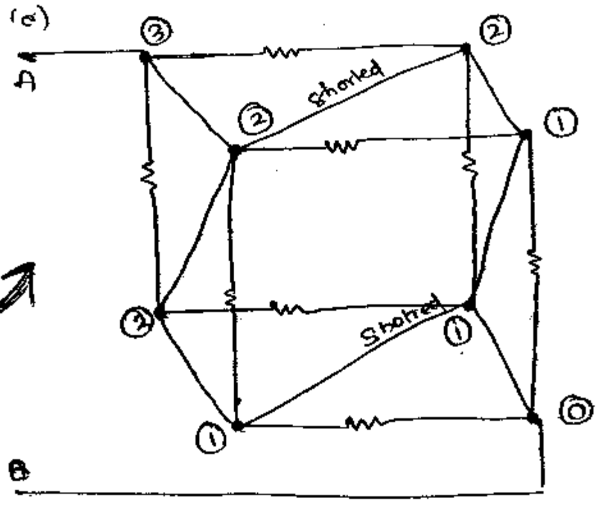
$$\left.\begin{aligned} -10 + i_1 + 2[i_1 - i_2] = 0 &\longrightarrow 3i_1 - 2i_2 = 10 \\ 2\{i_2 - i_1\} + 2i_2 = 0 &\longrightarrow -i_1 + 2i_2 = 0 \end{aligned}\right\} \quad \underline{\underline{i_T = 5A}}$$

$$R = \frac{V}{i_T} = \frac{10}{5} = 2\Omega.$$

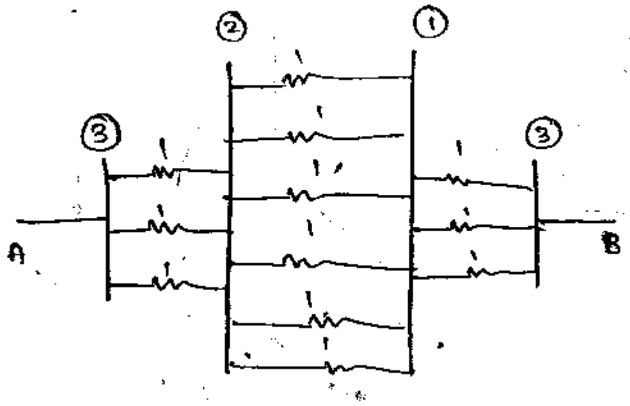
<u>Note: 1:</u>

if we can identify such nodes in any big n/w that are at same potential we can virtually join them to reduce faster

(a)



$\Rightarrow$



$R_{AB} = \frac{1}{3} + \frac{1}{6} + \frac{1}{3} = \frac{5}{6}.$

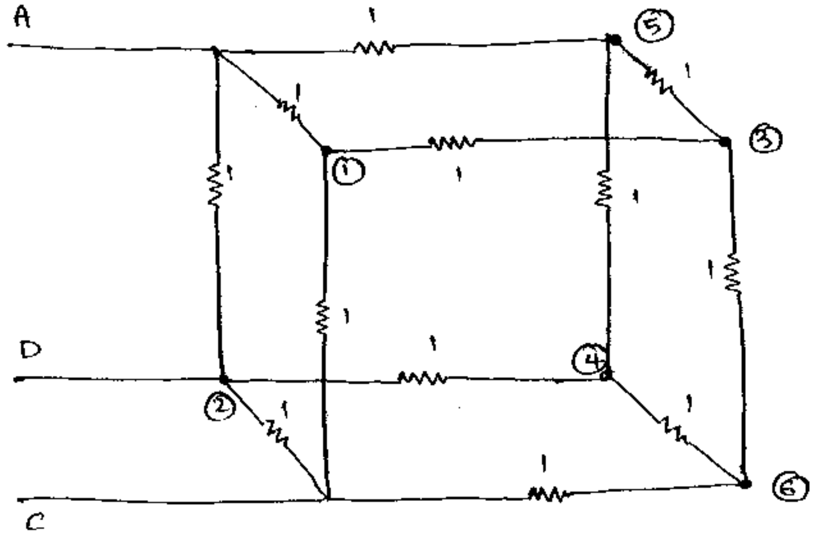
<u>Note: 2:</u>

another Important property of Symmetrical N/ws is that they can be Expressed as mirror images w.r.t Common axis drawn including the target terminals.

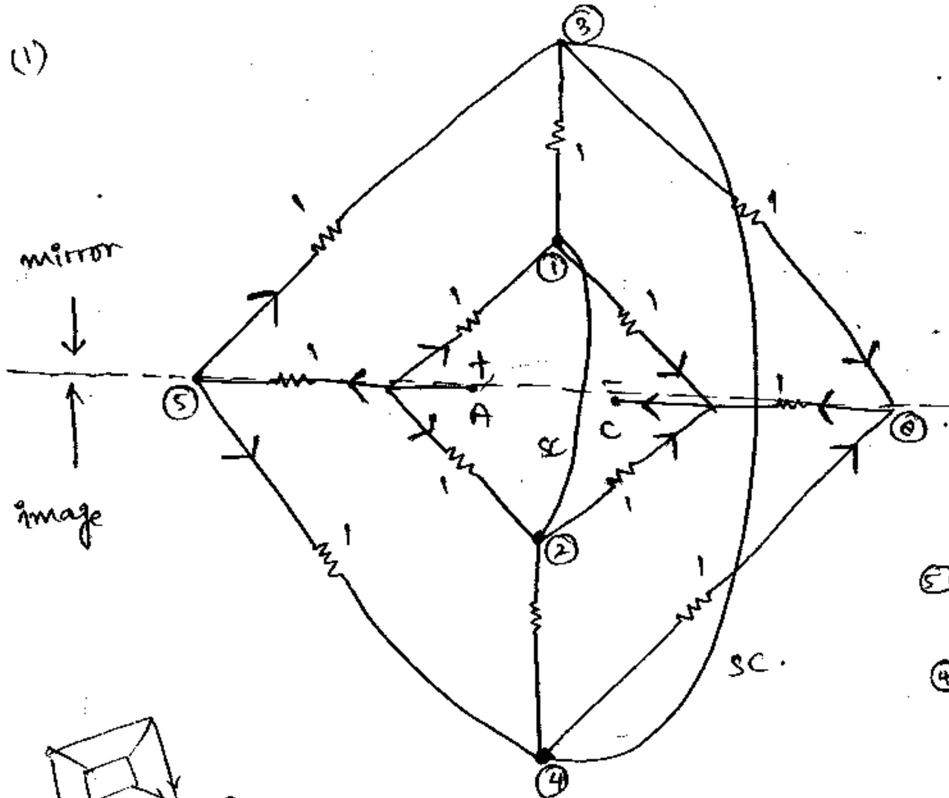
Q use the above two ideas given in notes1 & note2 to find.

(1) R_{AC} = ______ (2) $R_{AD} = \underline{7/12\ \Omega}$
HW

⇒ we can't apply Current division rule ∵ path Resistances of all paths from A to C is not Equal.

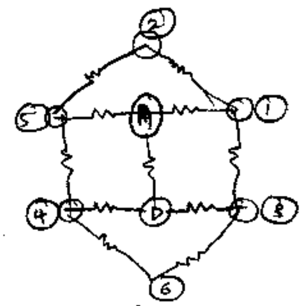


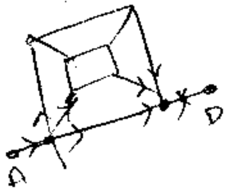
(1)

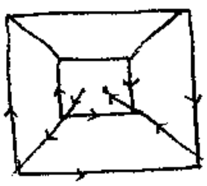


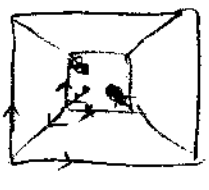
$\boxed{V_1 = V_2}$ → same potential (S.C)

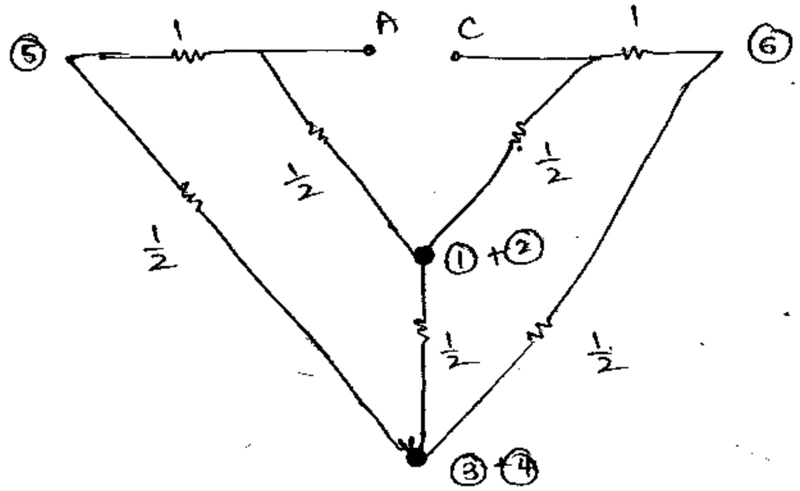
$\boxed{V_3 = V_4}$ "

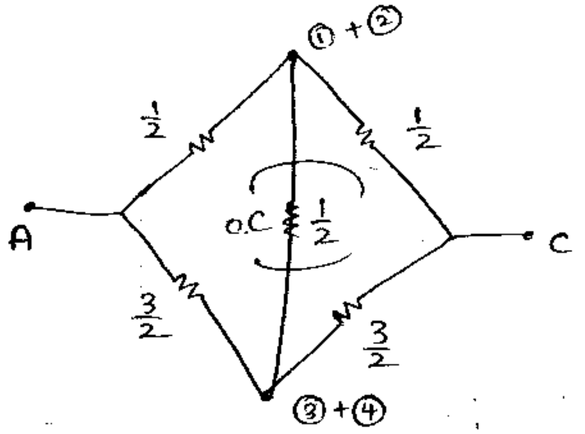






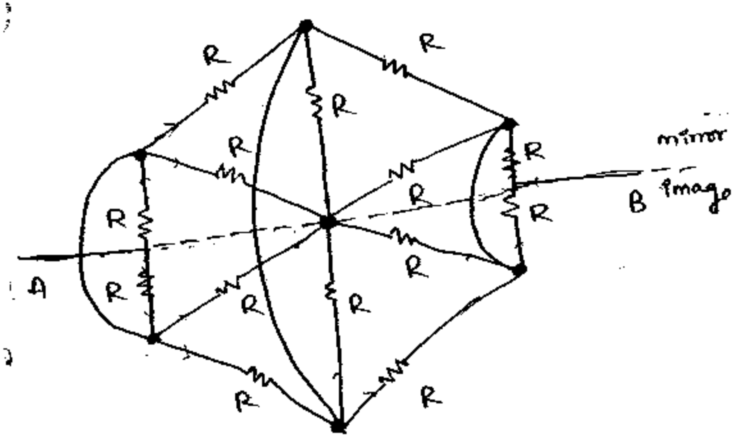


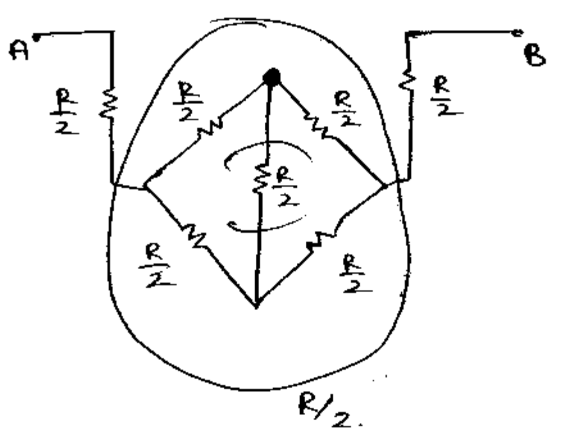




$$R_{AC} = 1 \,//\, 3 = \frac{3}{4}.$$

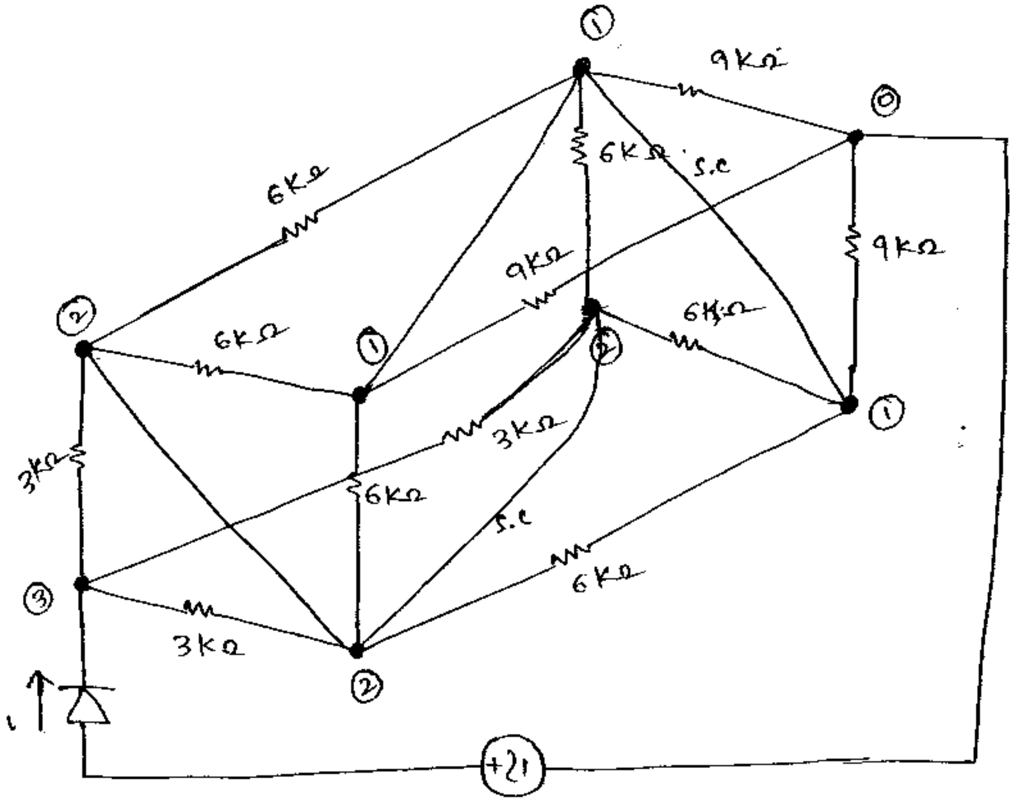
Q IES(O) $R_{AB} = \frac{3}{2} R\,\Omega$





$$R_{AB} = \frac{3}{2} R\,\Omega.$$

uncontrolled Halfwave diode rect

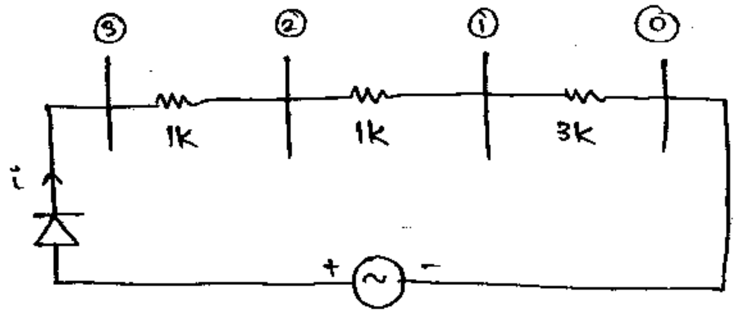


10 Sint V

⇒ Resistors are not Equal ×

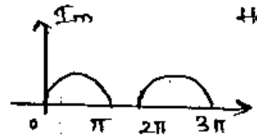
⇒ but path Resistance Equal. ✓

⇓



10 Sint

∴ uncontrolled Half wave



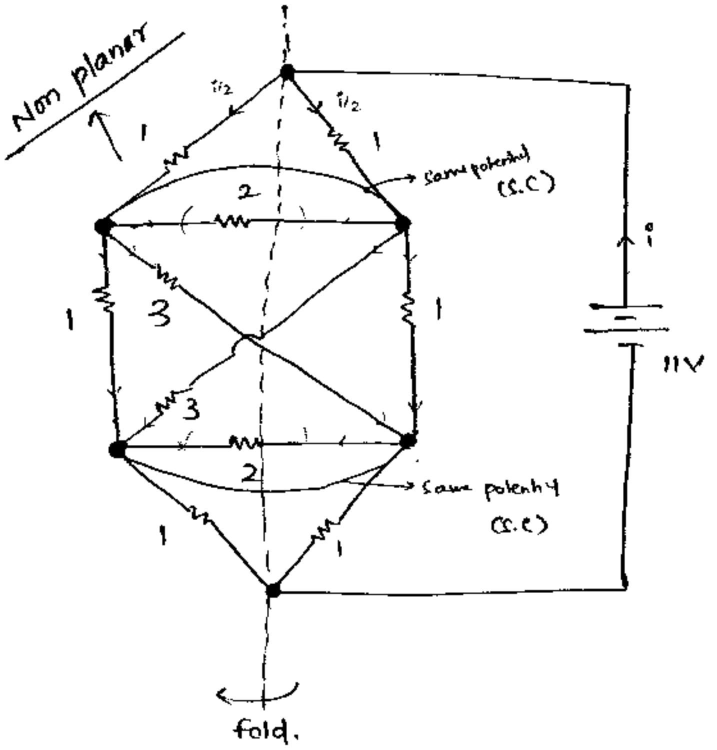
$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 t\, dt}$$

→ Without 'D',

$$i = \frac{V}{R_T} = \frac{10 \sin t}{5k} = 2\text{mill.} \sin t \ A.$$

→ with 'D'

$$I_{rms} = \frac{I_m}{2} = \frac{2m}{2} = \underline{\underline{1mA}}$$



$i = .$

$\frac{5}{2}$

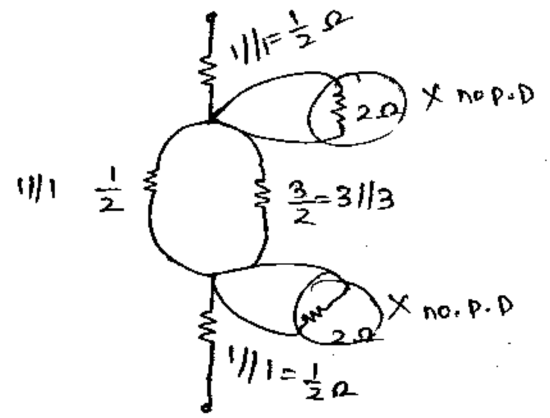
34

$V = \frac{i}{r}$

$i = VR$

$= 11 \times \frac{5}{2}$

$= \frac{55}{2}$

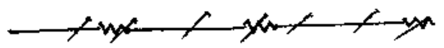


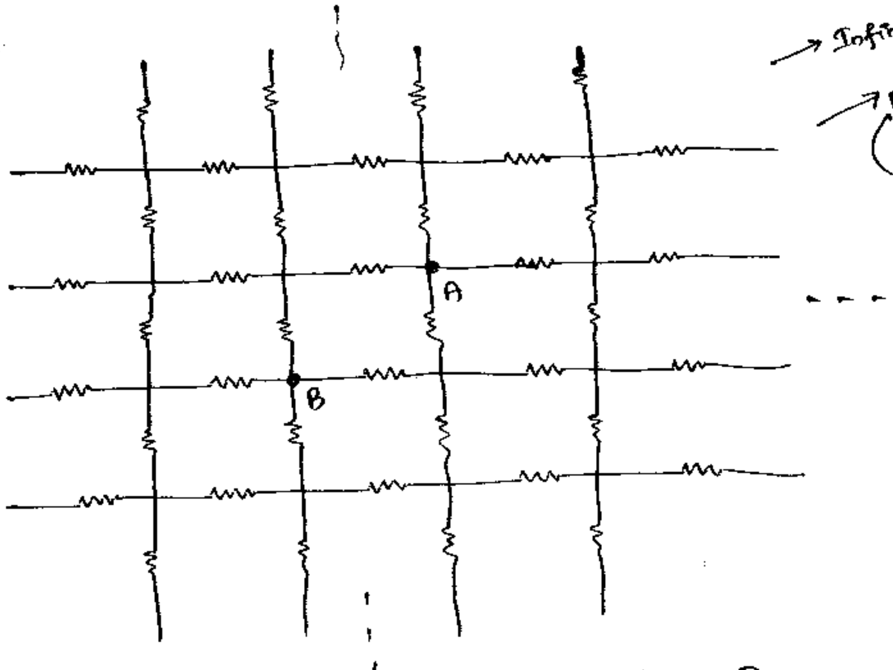
$$R_T = 1 + \left[\frac{1}{2} \| \frac{3}{2}\right] = 1 + \left[\frac{\frac{3}{4}}{2}\right]$$

$$R_T = 1 + \frac{3}{8} = \frac{11}{8}\,\Omega$$

$$i = \frac{V}{R_T} = \frac{11}{11/8} = \underline{\underline{8\,A}}$$

IES(c)





→ Infinite grid.

→ parallel Natured Network ($\because$ current division)

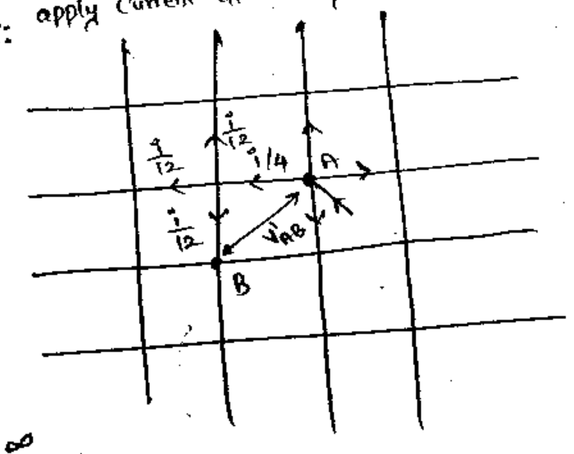
result is lower than least ($\because R_{AB} < 1\Omega$)

If each Branch Resistance is 1Ω then find R_{AB}.

Apply Superposition theorem:

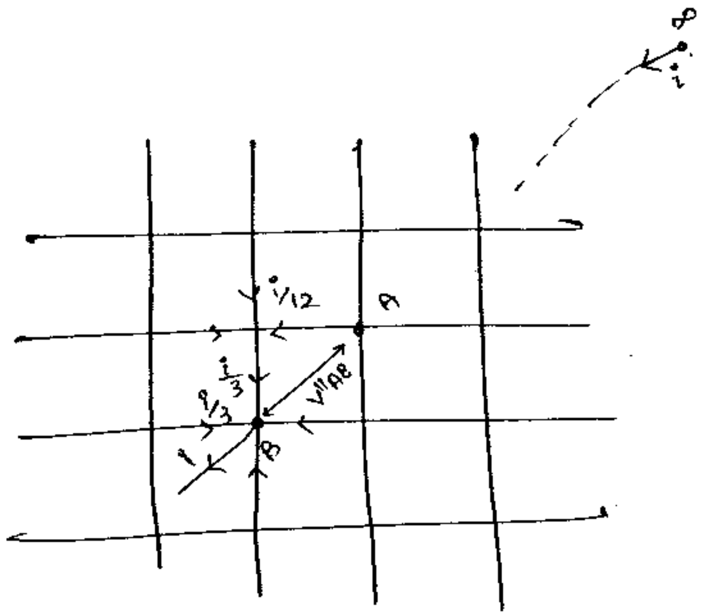
Step-I: apply Current division by inject current at A & collect current at ∞

$\Rightarrow$ ~~Paths of~~ of path Resistance is Equal from A to ∞



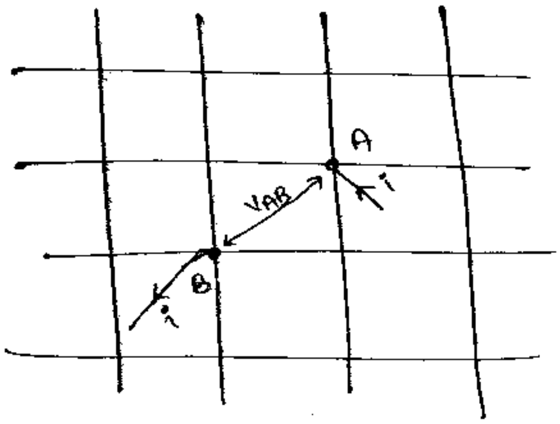
$$V'_{AB} = \frac{i}{4}(1) + \frac{i}{12}(1) = \frac{i}{3}$$

Step-II:



$$V''_{AB} = \frac{i}{12}(1) + \frac{i}{4}(1) = \frac{i}{3}$$

Superposition theorem: S-I + S-II

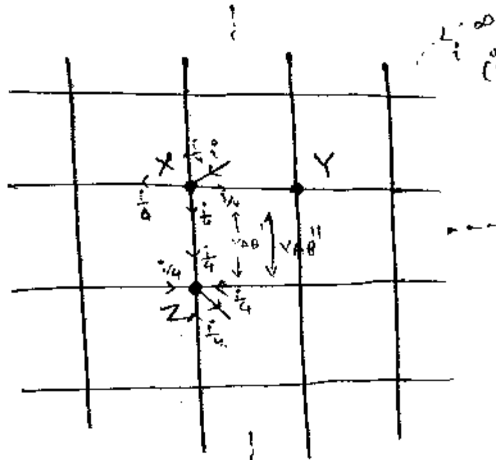


$$V_{AB} = V_{AB}' + V_{AB}''$$

$$V_{AB} = \frac{i}{3} + \frac{i}{3} = \frac{2i}{3}$$

$$R_{AB} = \frac{V_{AB}}{i} = \frac{2}{3}\,\Omega$$

HW-I



(i) if each Branch Resistance is $r\,\Omega$

find $R_{XZ} =$

(ii) if current of 1 Amp injected at X & collected at Y, then determine the current in Branch XY.

$$V_{xz}' = \frac{i}{4}(r)$$

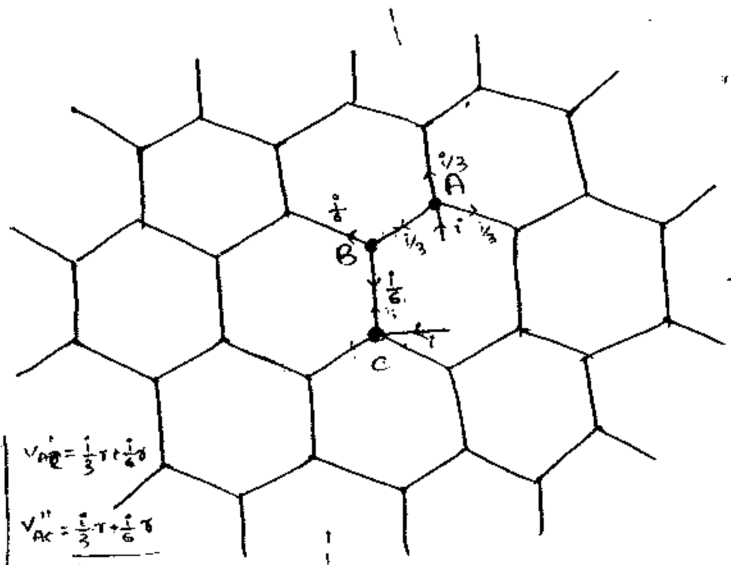
$$V_{xz}'' = \frac{i}{4}(r) =$$

$$V_{xz} = \frac{2ir}{4}$$

$$R_{xz} = \frac{V_{xz}}{i} = \frac{r}{2}$$

$$i_{xz} = \frac{V_{xz}}{R_{xz}} = \frac{\frac{ir}{2}}{\frac{r}{2}} = \frac{i}{4} = \frac{1}{4}$$

HW-2



if each Branch resistance is 'r' Ω

find R_{AB}

R_{AC}

$V'_{AB} = \frac{i}{3} r$

$V''_{AB} = \frac{i}{3} r$

$V_{AB} = \frac{2i}{3} r$

$R_{AB} = \frac{2r}{3}$

$V'_{AC} = \frac{i}{3} r + \frac{i}{6} r$

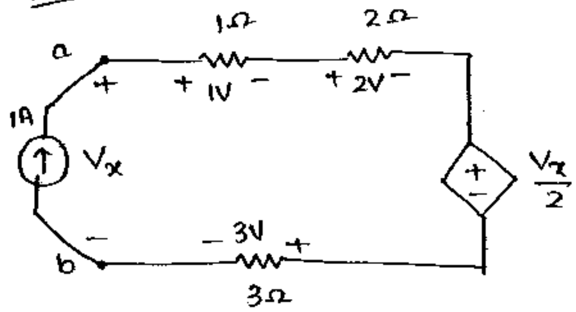
$V''_{AC} = \frac{i}{3} r + \frac{i}{6} r$

$\frac{2i}{3} r + \frac{2i}{6} r$

$V_{AC} = \frac{3i}{3} r$

$\frac{V_{AC}}{i} = R_{AC} = r$

IES(0)



$R_{ab} =$ ___

pure dependent ckts are not working.

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KVL:

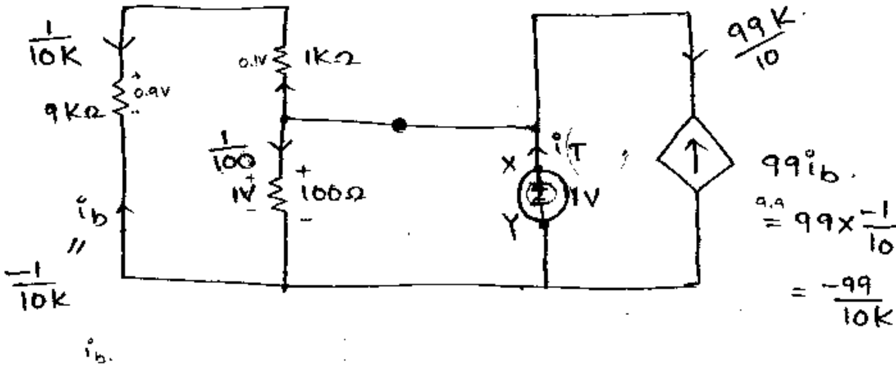
$$-V_x + 1 + 2 + \frac{V_x}{2} + 3 = 0$$

$$\frac{V_x}{2} = 6 \Rightarrow V_x = 12V$$

$$R_{ab} = \frac{V_x}{1A} = 12\,\Omega$$

* Gate 2012/IIT 'D'

$R_{XY} = ?$



$$= 99 \times \frac{-1}{10k}$$

$$= \frac{-99}{10k}$$

i_b.

KCL at node

$$i_T = \frac{1}{100} + \frac{1}{10k} + \frac{99}{10k}$$

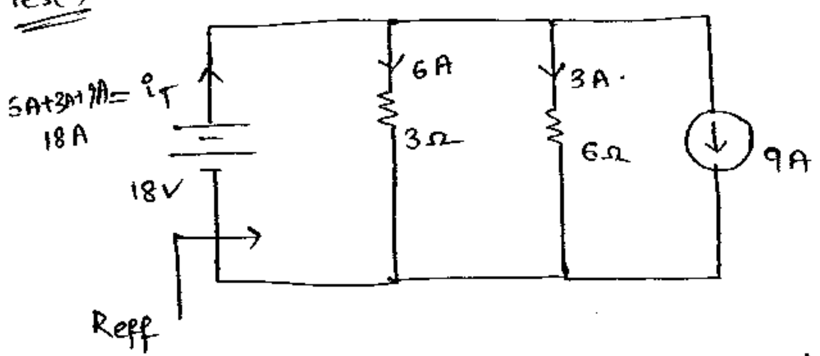
$$i_T = \frac{1}{100} + \frac{1}{10k}(1+99)$$

$$i_T = \frac{1}{100} + \frac{1}{100} = \frac{1}{50}$$

$$R_{XY} = \frac{1}{i_T} = \frac{1}{1/50} = 50\Omega.$$

IES(0)

Determine the eff. Resistance seen by the Voltage source



⇒ Effective Resistance is Resistance offered by the N/w to the Source under working Condition

⇒ if the N/w is purely passive then eff. Resistance = Thevenins Resistance

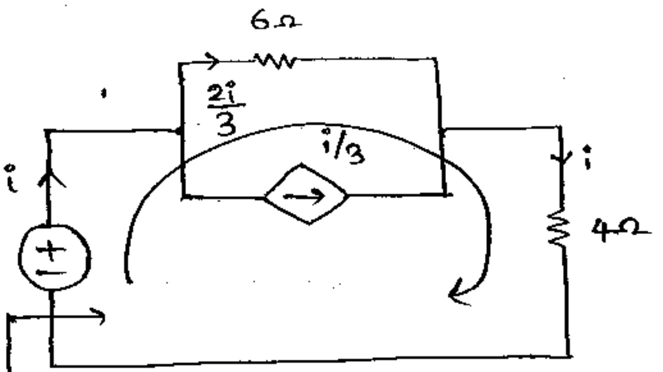
$$R_{eff} = R_{Th}$$

⇒ But if the N/w has an active element then Both are different

$$R_{eff} = \frac{18V}{i_T} = \frac{18}{18} = 1\Omega \qquad \left[R_{Th} = R_{oc} = 3 \| 6 = 2A \right]$$

IES(0)

What is the eff. Resistance seen by voltage source



$$R_{eff} = \frac{V}{i}$$

$$-V + \frac{2i}{3}(6) + 4i = 0$$

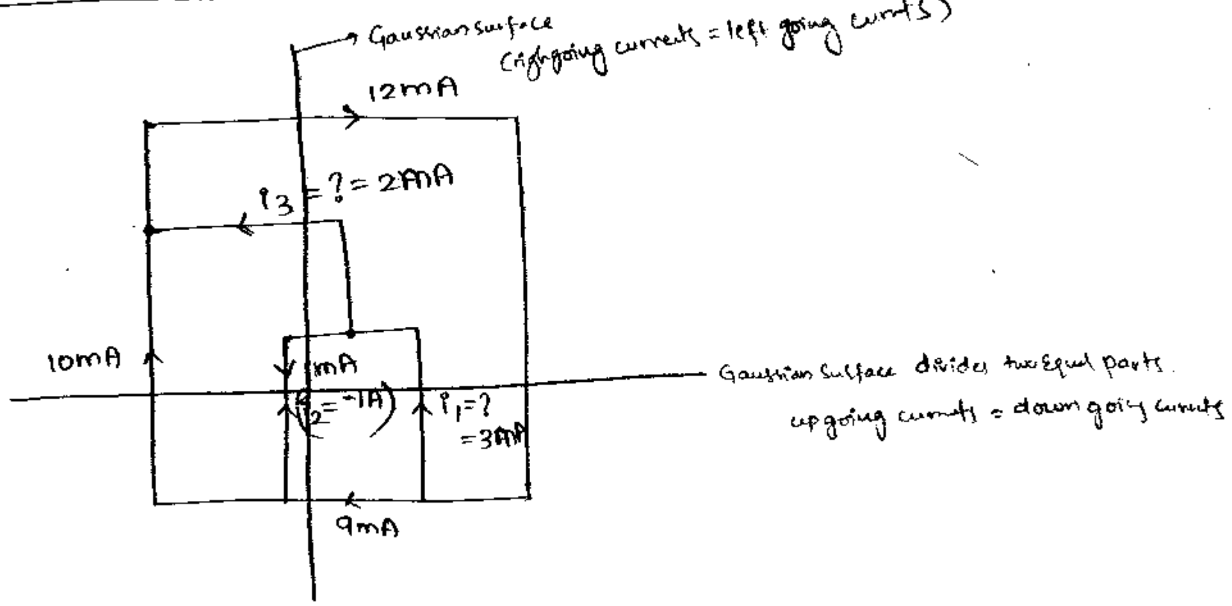
$$V = 8i$$

$$R_{eff} = \frac{V}{i} = 8\Omega$$

V=IR

Basic DC Circuit Analysis:

*



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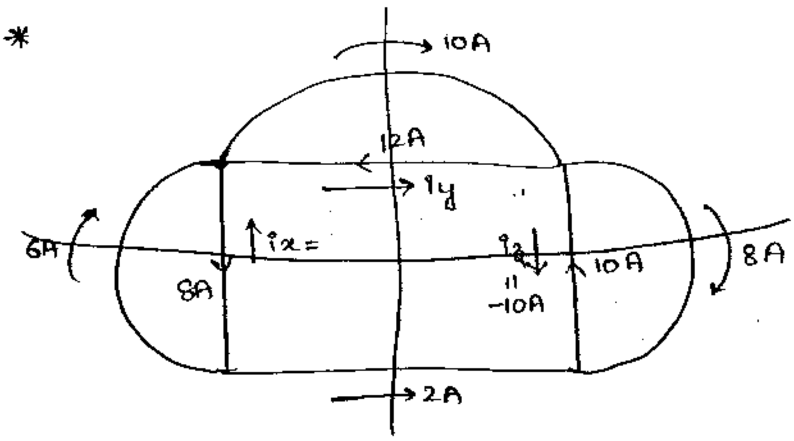

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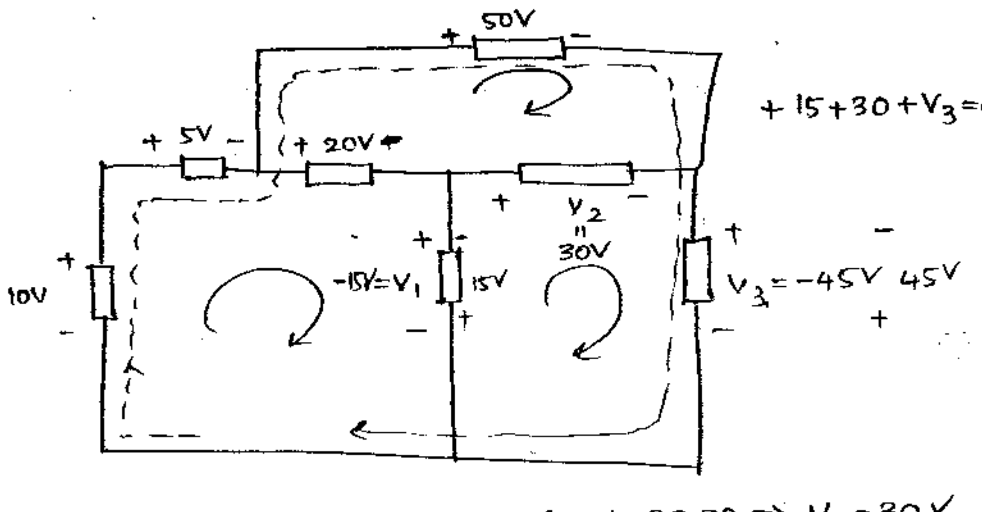


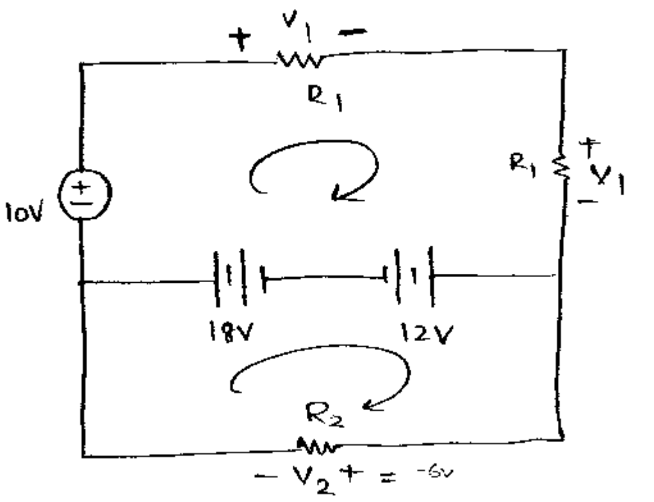
$+15+30+V_3=0 \longrightarrow V_3=-45V$

$-10+5V+20V+V_1=0$

$V_1=-15V$

$+50-V_2-20=0 \Rightarrow V_2=30V$

*



$$-10+2V_1+12-18=0$$

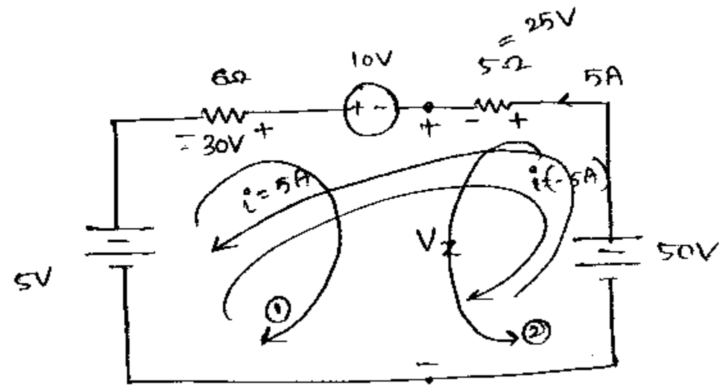
$$2V_1=16$$

$$V_1=8V$$

$$+18-12+V_2=0$$

$$V_2=-6V$$

*



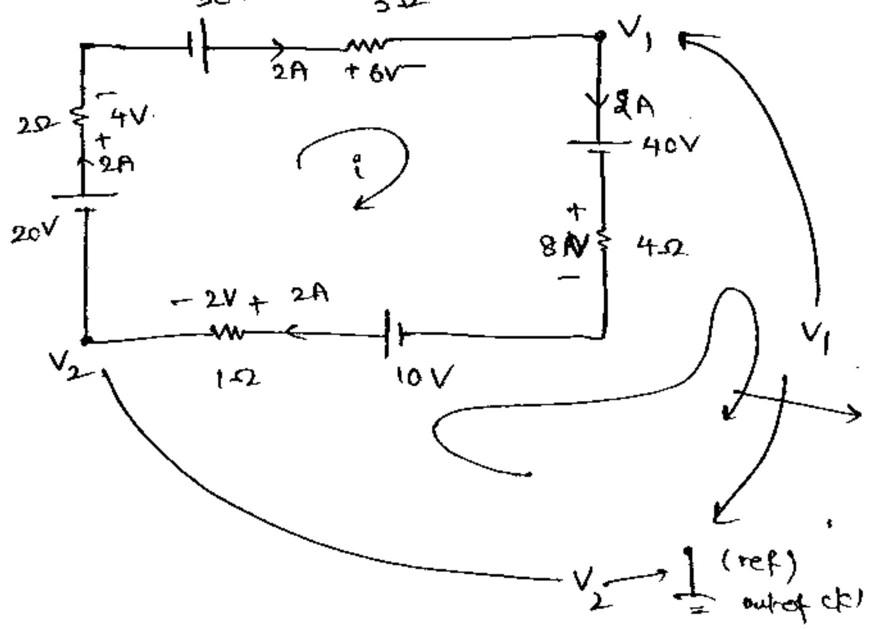
$$-5+6i+10+5i+50=0$$

$$i=-5A$$

① $-5-30+10+V_x=0 \Rightarrow V_x=+25V$

② $-50+25+V_x=0 \Rightarrow V_x=+25V$

*



V_2-V_1

$$\frac{V_2-20V-30V-V_1}{5}+\frac{V_2+10V-40V-V_1}{5}$$

$2V_2-2V_1 = 80-10\ 80V$

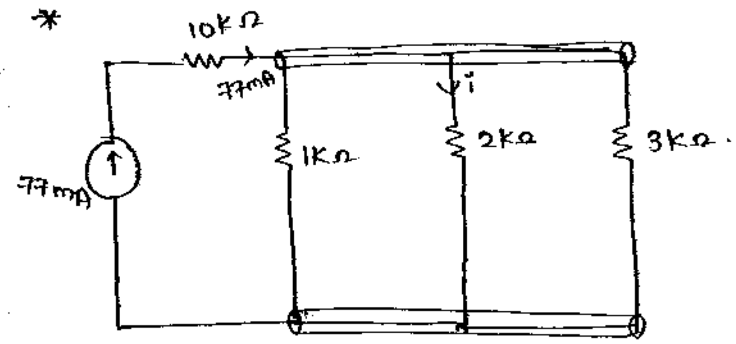
$$-20+10i-30+40-10=0$$

$$i=+2A$$

$$-V_2-2+10-8-40+V_1=0$$

$$(V_1-V_2)=40V$$

*

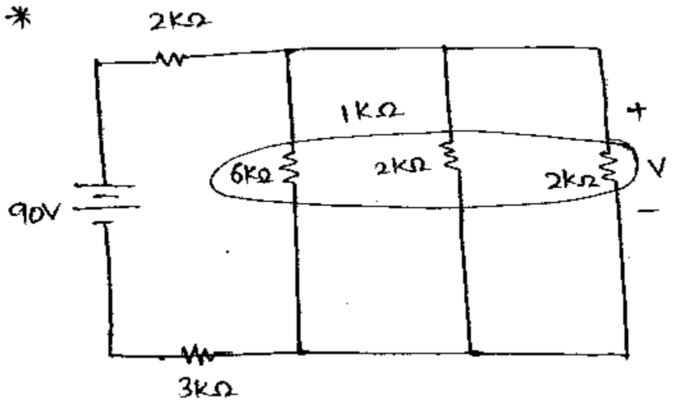


$$i = 77m\left[\frac{1K \times 3K}{1K\times 2K + 2K\times 3K + 3K\times 1K}\right]$$

$$= 77m\left[\frac{3M}{2M+6M+3M}\right]$$

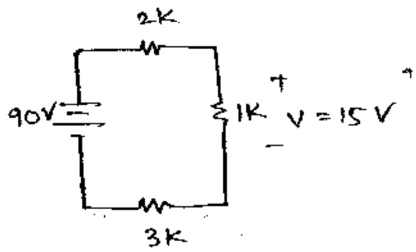
$$i = 21mA.$$

*



$$V = 90\left[\frac{1K}{6K}\right]$$

$$= 15V$$



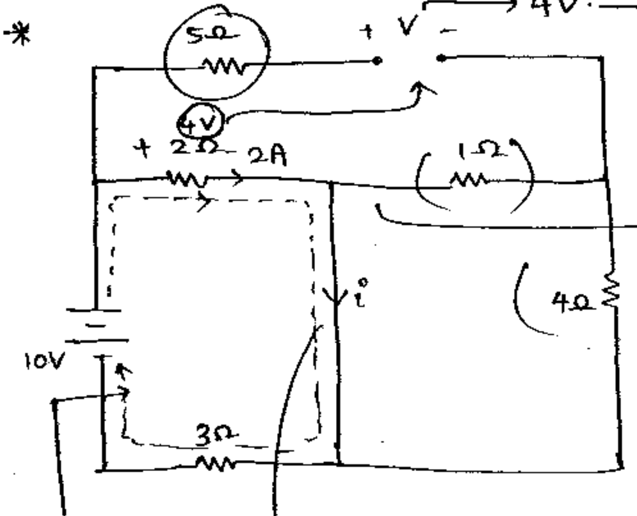
*

× no current flow O.C

$\rightarrow$ 4V. $\longrightarrow$ the total voltage across "2Ω" is appears across O.C

No Volt. appear across 5Ω

∵ no current flowing through 5Ω



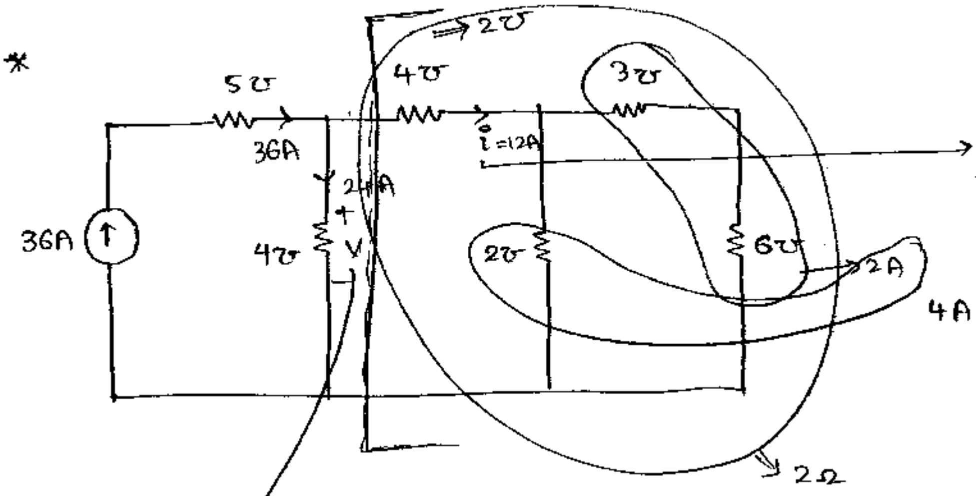
$\rightarrow$ no current flows ∵ S.C

$R_{seen} = 5\Omega$

$$i = \frac{10V}{5\Omega} = 2A$$

C.D done for parallel elements.

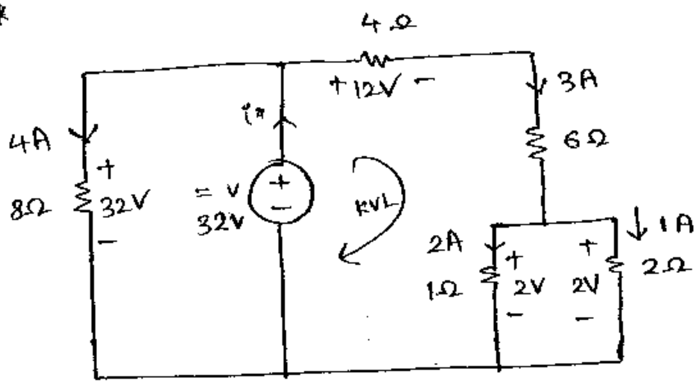
*



$i = 36\left[\frac{2}{2+4}\right] = 12A.$

$V = \frac{24A}{4℧} = \underline{\underline{6V}}$

*



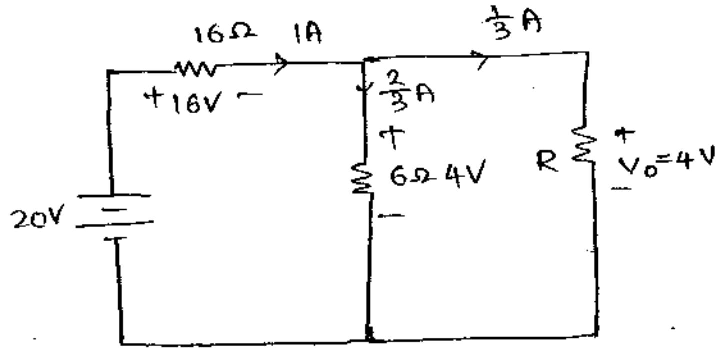
$V = , i = -$

KVL → $-V + 12 + 18 + 2 = 0$

$V = 32V.$

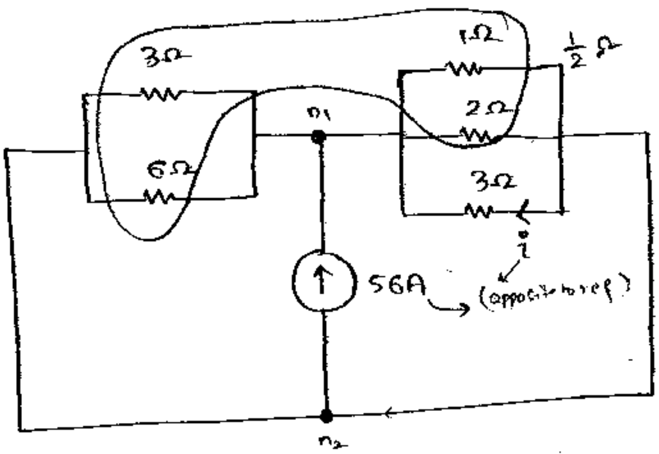
(KCL) $i = 4 + 3 = 7A.$

* if $V_o = 4$volts, then R =



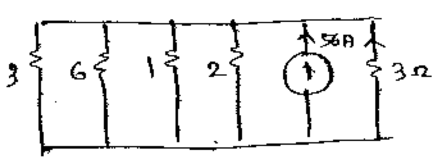
$R = \frac{V}{I} = \frac{4V}{1/3\,A} = 12\Omega.$

4V
16V
4V

* 

n_1 degree = 6 (6 branches)

n_2 degree = 6

$\Rightarrow$ 

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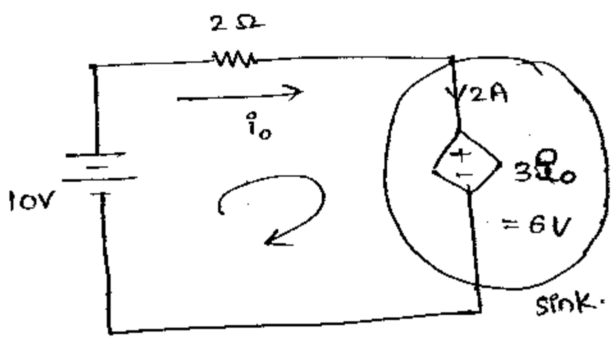
$$i = -56\left[\frac{\frac{1}{2}}{\frac{7}{2}}\right] = -8\,A.$$

* power delivered by dependent source

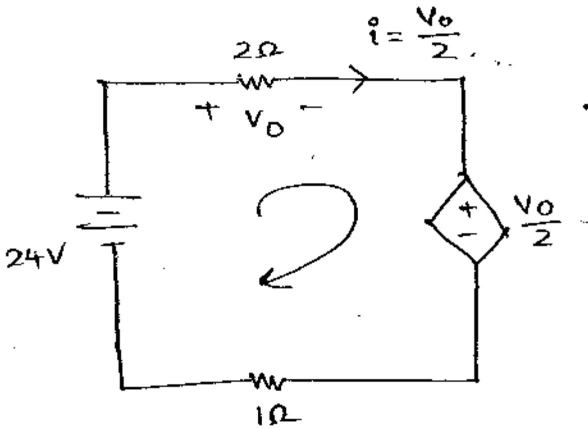


$$-10+2i_o+3i_o=0$$

$$i_o = 2A.$$

$$P_{deliv} = -6(2) = -12\omega.$$

* $V_o =$

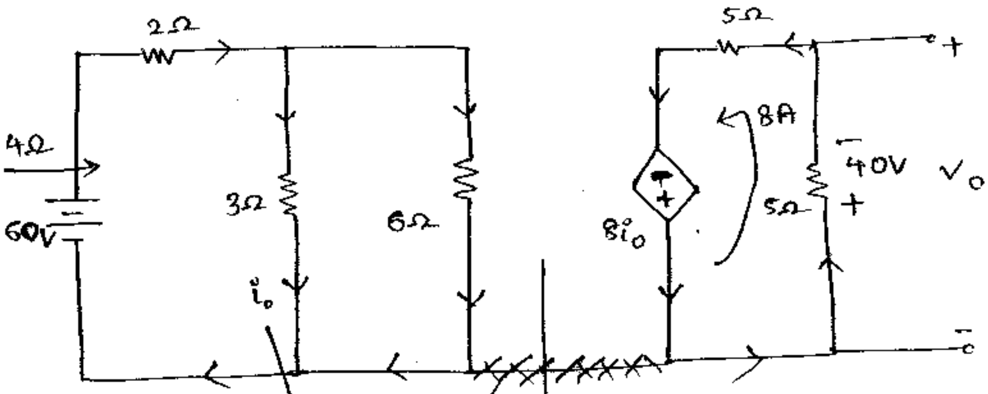


$$-24 + V_o + \frac{V_o}{2} + \frac{V_o}{2}(1) = 0$$

$$V_o = 12V$$

VDCS $\xrightarrow{\simeq}$ TV & Remote

* V_o =



$\longrightarrow V_o = -40V$.

Inter dependent meshes works on Interconnection but not by direct connection

$$i_o = 15\left[\frac{6}{9}\right] = 10A.$$

These two are not electrically connected

∴ Independent meshes

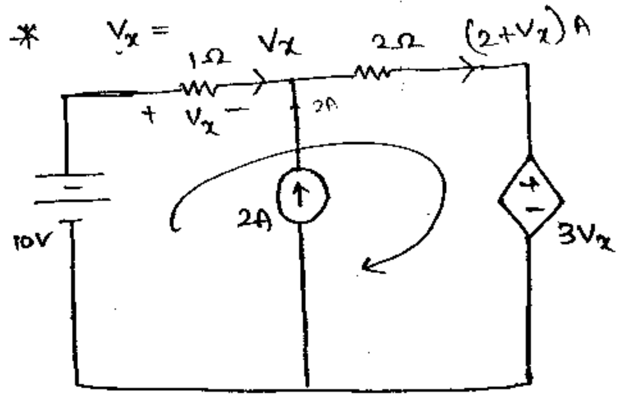
∴ no current flows through ⇒ Bcz no closed path.

∴ no significant of this wire

∴ Remove

(this is similar to Bluetooth or TV & remote)

* V_x =

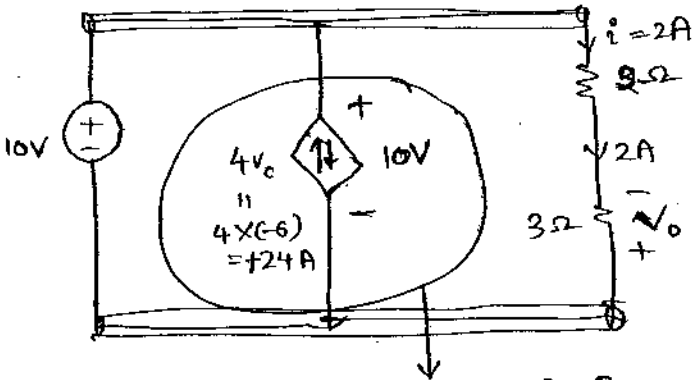


~~$-10 + V_x(1)$~~

$$-10 + V_x + (2+V_x)\cdot 2 + 3V_x = 0$$

$$6V_x = 6 \rightarrow V_x = 1V.$$

* power delivered by dependent source



$$\Rightarrow i = \frac{10V}{(2+3)} = 2A$$

$$\longrightarrow V_o = -2(3) = -6V$$

source ⇒ $P_{del} = 10V(24A) = 240W$.

$4V_o = 10$

$V_o = \frac{10}{4} = \frac{5}{2}$

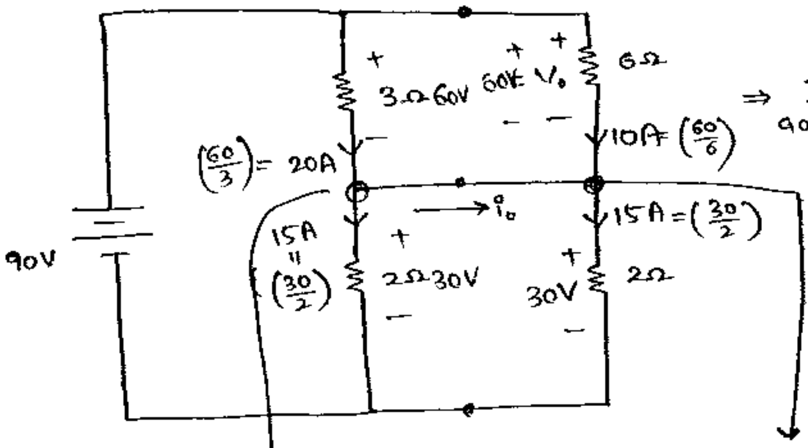
$2\times\frac{10}{8}$

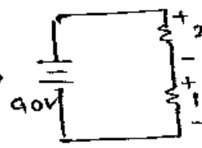
$3\times\frac{10}{8}$

Gate.

*

$V_o = 60V \quad i_o = 5A$





$\Rightarrow V_{2\Omega} = 90\left[\frac{2}{3}\right] = 60V$

$\Rightarrow V_{1\Omega} = 90\left[\frac{1}{3}\right] = 30V$

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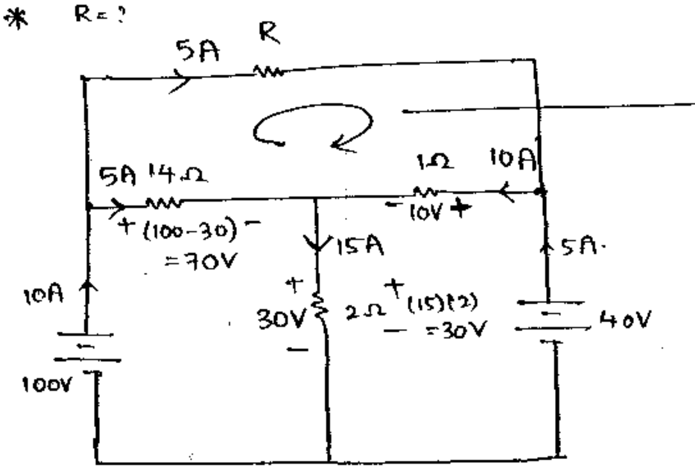
$\rightarrow i_o = 20 - 15 = 5A$

$i_o + 10 = 15$

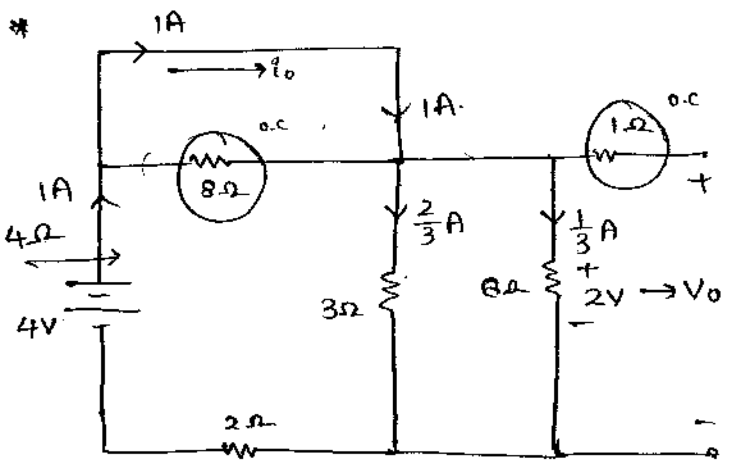
$i_o = 5A$

* R = ?



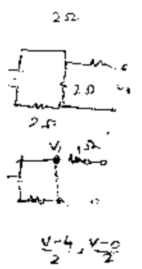
$\rightarrow 5R + 10 - 70 = 0 \longrightarrow R = 12\Omega$

*



$i_o = 1A$

$V_o = 2V$.



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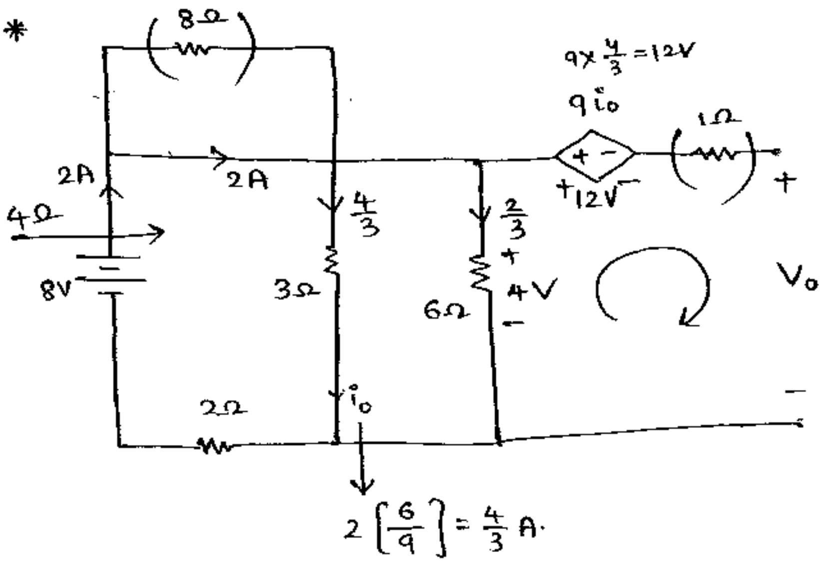
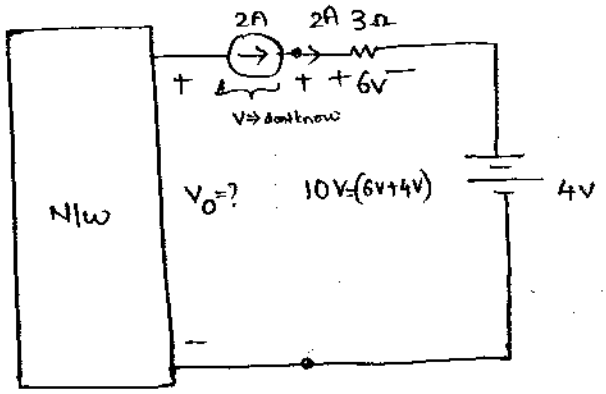


4V

$$-4 + 12V + V_o = 0$$

$$V_o = -8V$$

*

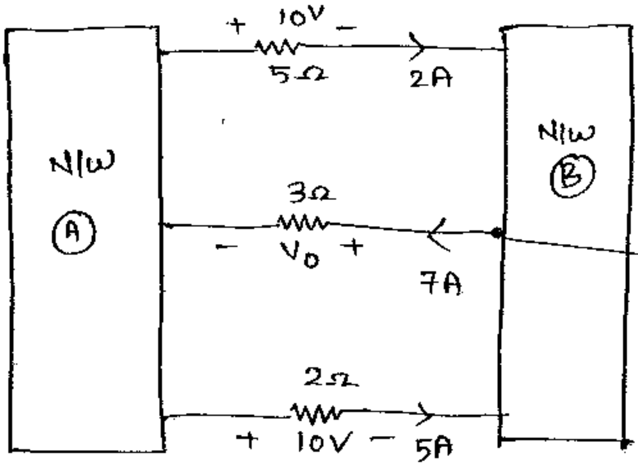


(a) 4V (b) 10V (c) 12V (d) None.

∴ data is insufficient

∵ we don't know Volt. across "2A" source.

*



(a) 10V (b) −10V (c) +21V (d) −21V

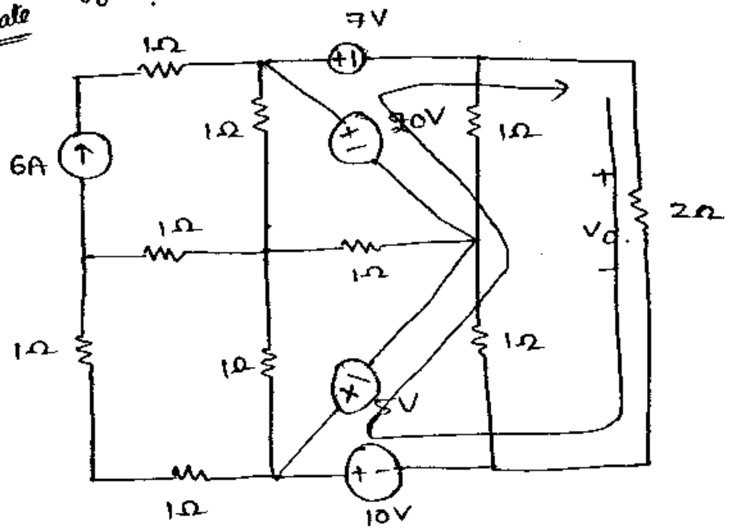
By KCL 2A + 5A = 7A.

$= 7A \times 3\Omega$

$= 21\ V$

Gate $V_o = ?$

KVL is law of cons. energy
Valid in any path



Write KVL in which voltages visible.

$$-10+5-20+7+V_o=0$$

$$V_o = +18\,V.$$

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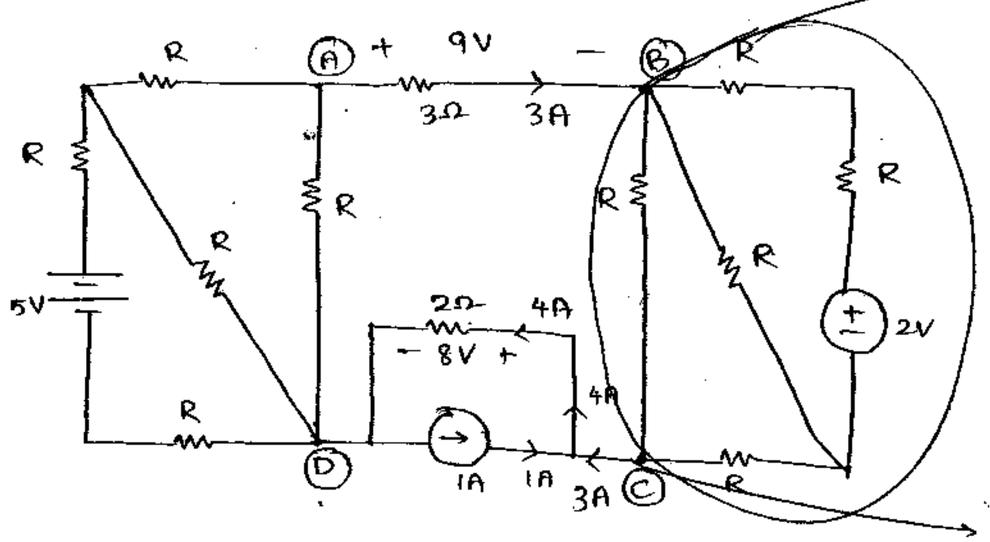
Gate, 115 D

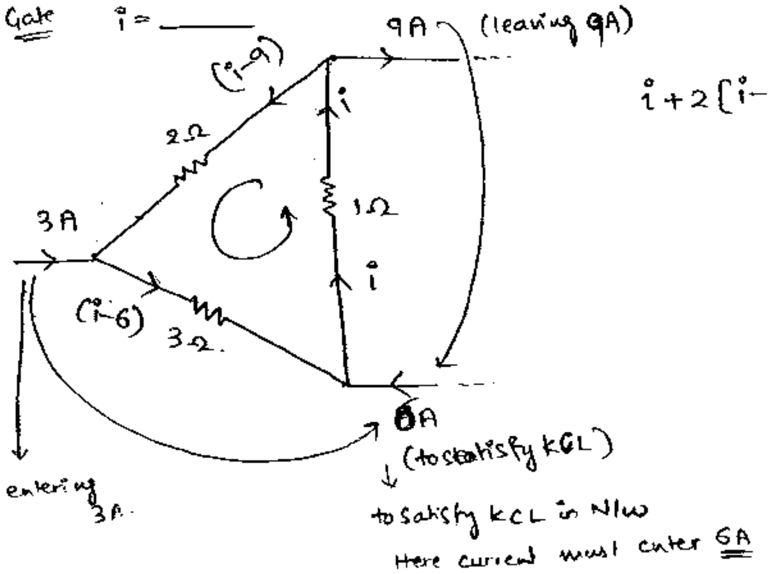
If $[V_A - V_B] = 9V$ then $[V_C - V_D] = \underline{+8V}$



current leaving this N/w
⇓
leaving 3A

Current entering this n/w
enters 3 A.

Gate $i =$ ______

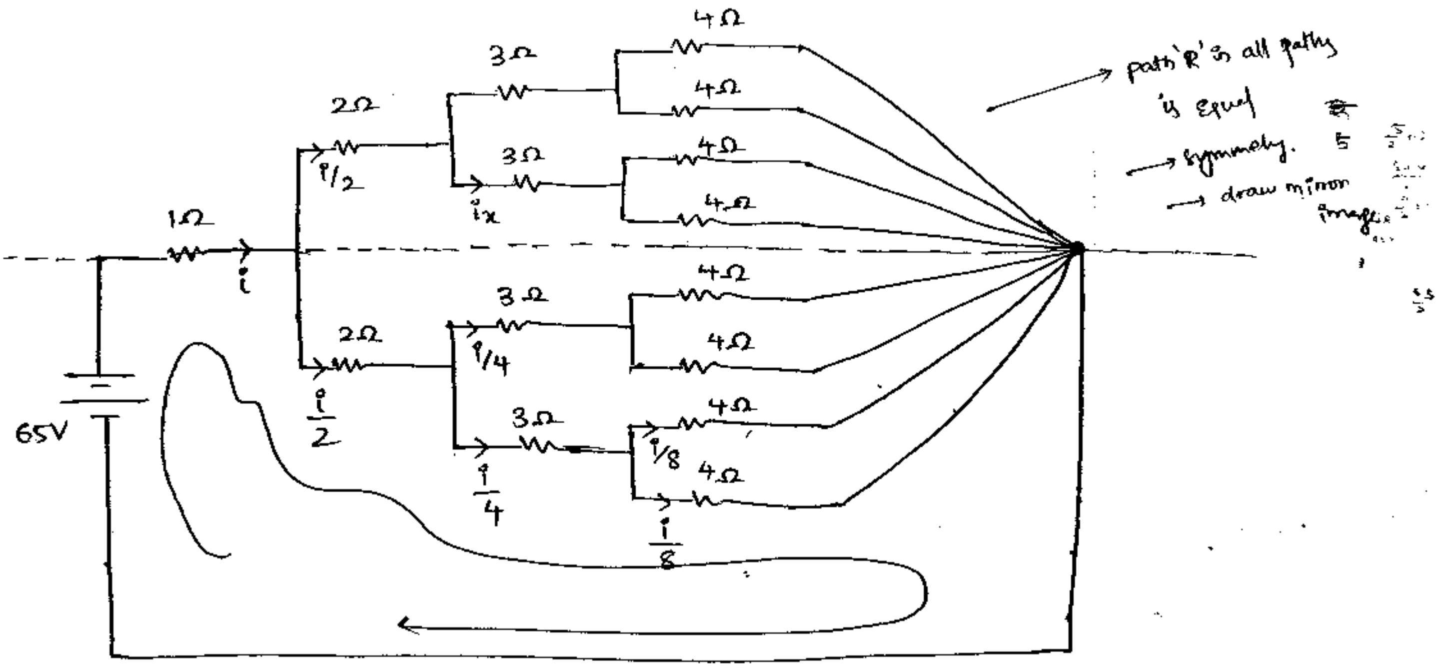


$$i + 2[i-9] + 3[i-6] = 0$$

$$6i = 36$$

$$i = 6A.$$

gate $i_x =$ ______



$$-65 + i\left[1 + \frac{1}{2}\times 1 + 3\times\frac{1}{4} + 4\times\frac{1}{8}\right] = 0$$

$$i\left[\frac{13}{4}\right] = 65$$

$$i = 20A.$$

But $i_x = \frac{i}{4} = \frac{20}{4} = \underline{5A}$

IES If $R=2\Omega$, then $i=5A$

Now if $R=5\Omega$ then $i=$ 5A

$R=2\Omega \longrightarrow i=5A$

$R=5\Omega \longrightarrow i=5A$

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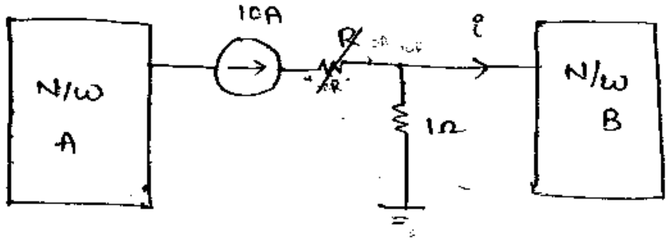
$\because$ 'R' dissipates no loss in current value

$\therefore$ for any value of R current will be same

Current source to any element is Redundant.

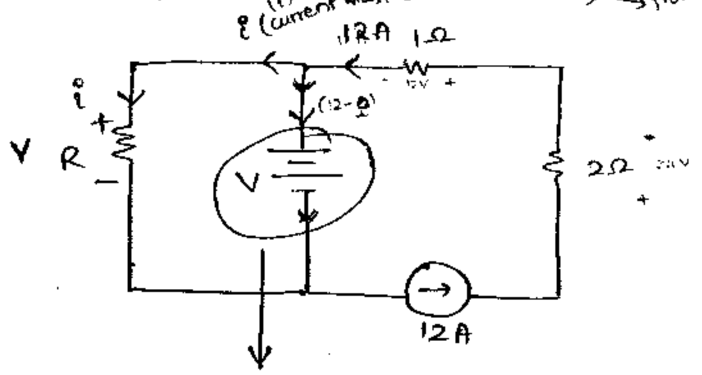


Gate

If Voltage Source absorb power then Current $i=$ ____

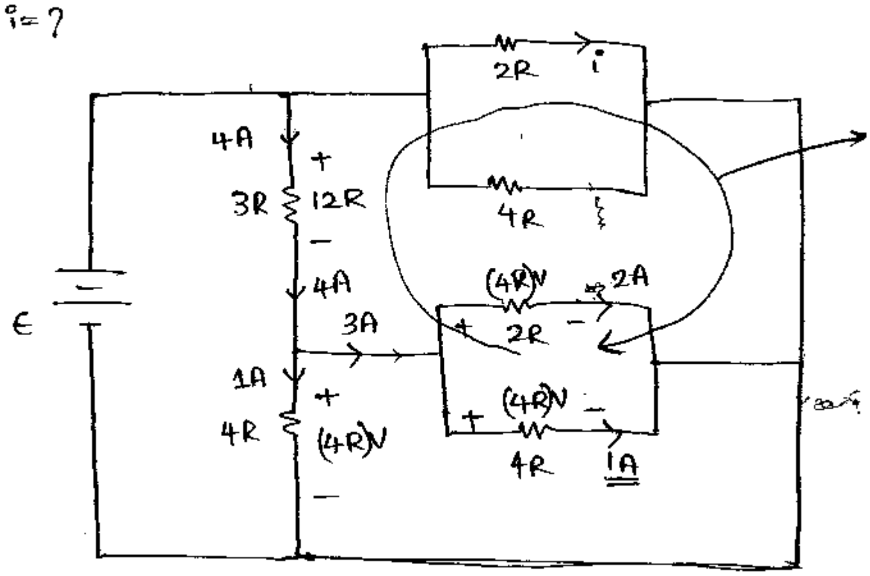
i (current must be less than 12A) → from options

(a) 10A (b) 12A (c) 13A (d) 14A



Sink $\because$ V source absorbing power

Q $i=?$

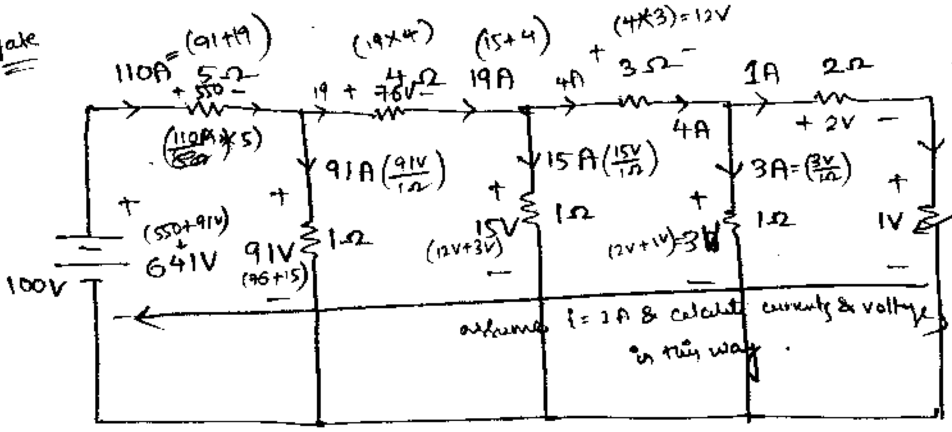


$-12R+2Ri-4R=0$

$2i=16$

$i=8A$

gate



→ apply principle of Homogenity.

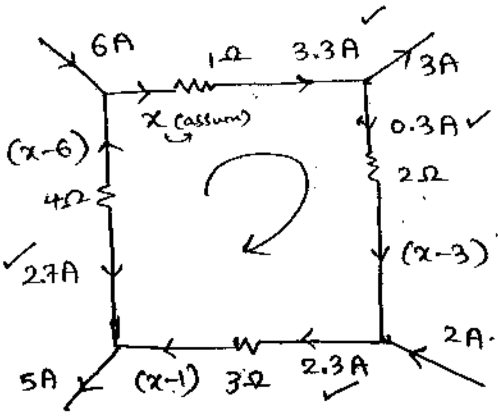
641 V ⟶ 1 A

100 V ⟶ ?

$$i = \frac{100}{641}\ \mathrm{A}.$$

IES (C)

* Total power Lost in N/W



$$x + 2[x-3] + 3[x-1] + 4[x-6] = 0$$

$$10x = 33$$

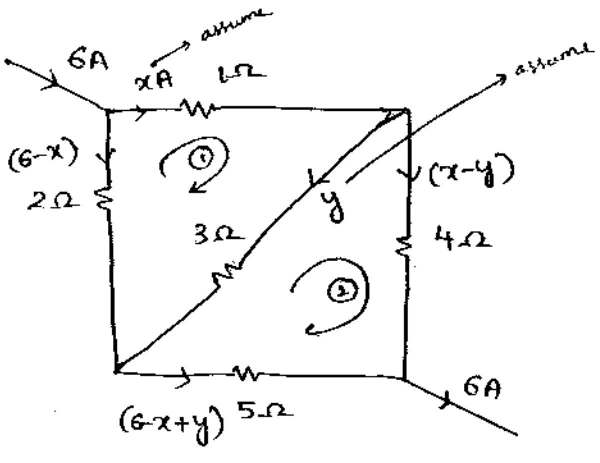
$$x = 3.3\ \mathrm{A}.$$

$$\text{Total power loss} = (3.3)^2(1) + (0.3)^2(2) + (2.3)^2(3) + (2.7)^2(4)$$

$$=$$

IES (C)

Determine all Branch currents



$(1)x + 3(y) + 2(6-x) = 0 \longrightarrow (1)$

$4[x-y] - 5[6-x+y] - 3y = 0 \longrightarrow (2)$

Solve (1) & (2)

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$x =$ ___

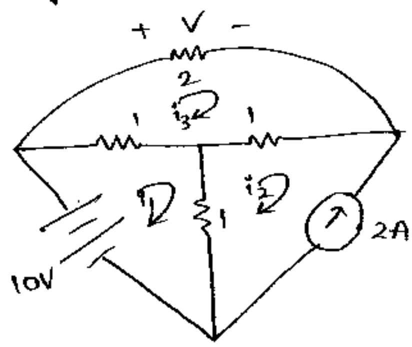
$y =$ ___

Methods of Analysis

1. Mesh Analysis ⟶ KVL + OHM's law (More Current Sources than Voltage sources) Mesh is faster.
   ⟶ PLANAR N/w is Required.

2. Nodal Analysis ⟶ KCL + OHM's law (more voltage sources than Current sources) Nodal is faster.

determine voltage 'V' by mesh & Nodal analysis



Mesh:

$$-10+1[i_1-i_3]+1[i_1-i_2]=0$$

$$2i_1-i_2-i_3=10 \longrightarrow (1)$$

$$i_2=-2 \text{ (comparision Eqn)} \longrightarrow (2)$$

Current sources in mesh analysis is comparision Eqn.

$$2i_3+1[i_3-i_2]+1[i_3-i_1]=0$$

$$-i_1-i_2+4i_3=0 \longrightarrow (3)$$

$i=-2$

$$(1) \longrightarrow \cancel{2i_1}-i_3=8$$

$$(3)\times 2 \longrightarrow \cancel{-2i_1}+8i_3=-4$$

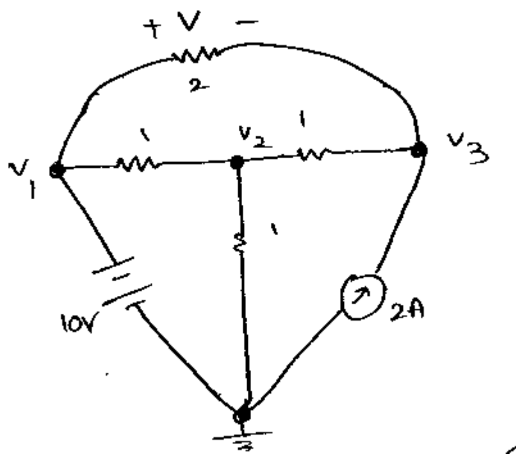
$$7i_3=4$$

$$i_3=\frac{4}{7}\ A$$

But $V=2i_3$

$$V=2\left[\frac{4}{7}\right]$$

$$V=\frac{8}{7} \text{ volts}$$



Voltage sources in Nodal analysis Comparision Eqn

Nodal:

$$V_1=10V \longrightarrow (1) \text{ (comparision Eqn)}$$

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

$$3V_2-V_3=10 \longrightarrow (2)$$

$$-2+\frac{(V_3-V_2)}{1}+\frac{(V_3-10)}{2}=0$$

$$-2V_2+3V_3=14 \longrightarrow (3)$$

$$(2)\times 2 \quad \cancel{6V_2}-2V_3=0$$

$$(3)\times 3 \quad \cancel{-6V_2}+9V_3=42$$

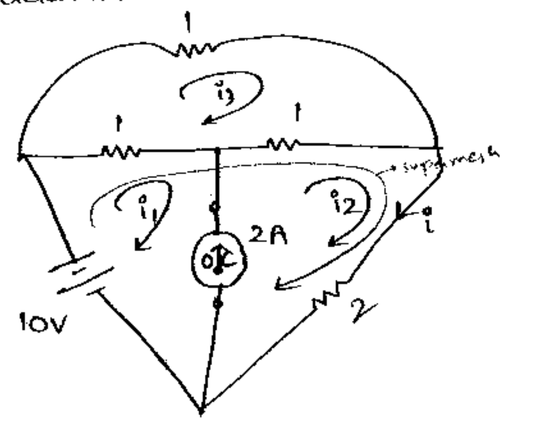
$$7V_3=62$$

$$V=V_1-V_3$$

$$=10-\frac{62}{7}$$

$$V=\frac{8}{7}\ V$$

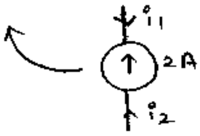
Q determine Current (i) in ~~current~~ ckt shown below by using mesh & nodal analysis



$$-10+1[i_1-i_3]+1[i_2-i_3]+2i_2=0$$

$$i_1+3i_2-2i_3=10 \longrightarrow (1)$$

$$-i_1+i_2=2A \longrightarrow (2)$$



$= i_2 + i_1 = 2A$

Current Sources b/w two meshes treat as O.C

↓

ie, KVL for Both meshes

↓

Super mesh

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$$i_3+1[i_3-i_2]+1[i_3-i_1]=0$$

$$-i_1-i_2+3i_3=0 \longrightarrow (3)$$

$$4i_2-2i_3=12$$

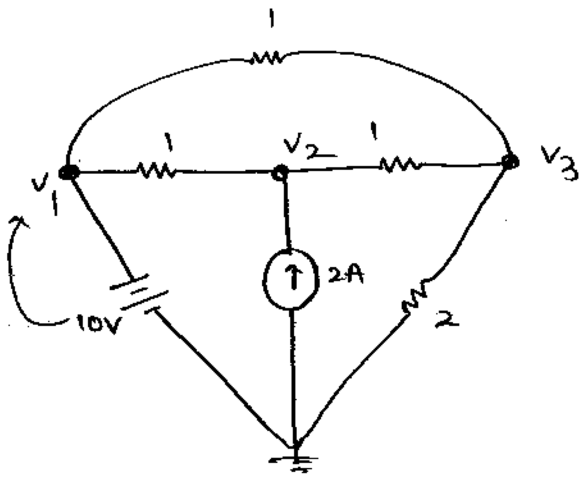
$$2i_2+i_3=10$$

$$8i_2 = 32$$

$$i_2 = 4A$$

But $i_2 = i$

$\Rightarrow i = 4A.$



Nodal

KCL

$$V_1 = 10 \longrightarrow (1)$$

$$\frac{V_2-10}{1} - 2 + \frac{(V_2-V_3)}{1} = 0$$

$$2V_2-V_3=12 \longrightarrow (2)$$

$$\frac{V_3}{2} + \frac{(V_3-V_2)}{1} + \frac{(V_3-10)}{1} = 0$$

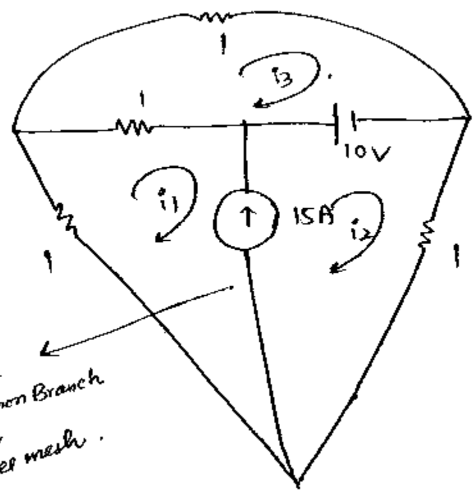
$$-2V_2+5V_3=20 \longrightarrow (3)$$

(2)+(3)

$$4V_3 = 32 \longrightarrow V_3 = 8V$$

But $i = \frac{V_3}{2} = \frac{8}{2} = \underline{4A}$

Q determine the power delivered by the Voltage Source using Mesh & Nodal Analysis.



current source in Common Branch ⇒ Super mesh.

Mech

$$i_1 + 1[i_1 - i_3] + 10 + i_2 = 0$$

$$2i_1 + i_2 - i_3 = -10 \longrightarrow (1)$$

$$-i_1 + i_2 = 15 \longrightarrow (2)$$

$$i_3 - 10 + 1[i_3 - i_1] = 0$$

$$-i_1 + 2i_3 = 10 \longrightarrow (3)$$

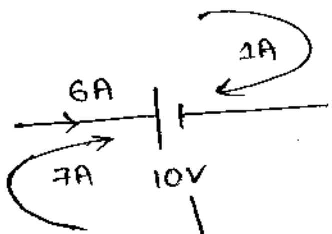
$$3i_1 - i_3 = -25$$

$$\frac{-3i_1 + 6i_3 = 30}{5i_3 = 5}$$

$$i_3 = 1A$$

$$i_1 = -8A$$

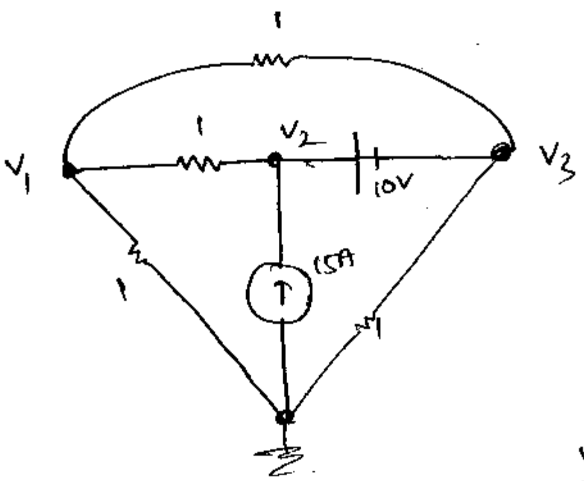
$$i_2 = 7A.$$



sink (no deliver)

$$P_{deliver} = -10(6) = -60W.$$

ideal volt sources b/w two principle nodes treat it like short circuit ($R_{V.S} = 0$) ⇒ i.e Super mesh. & write KCL combining for two nodes which is S.C.



Nodal

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

$$3V_1 - V_2 - V_3 = 0 \longrightarrow (1)$$

$$\underbrace{\frac{V_2 - V_1}{1} - 15}_{@ V_2} + \underbrace{\frac{V_3}{1} + \frac{V_3 - V_1}{1}}_{@ V_3} = 0$$

$$-2V_1 + V_2 + 2V_3 = 15 \longrightarrow (2)$$

$$V_2 - V_3 = 10 \longrightarrow (3) \text{ (Comp. eqn)}$$

① × 2 $\quad 6V_1 - 2V_2 - 2V_3 = 0$

② × 3 $\quad -6V_1 + 3V_2 + 6V_3 = 45$

$$V_2 + 4V_3 = 45$$

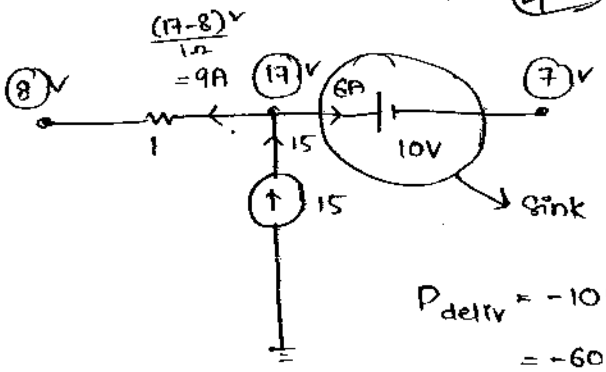
$$5V_3 = 35$$

$V_3 = 7V$

$V_2 = 17V$

$V_1 = 8V$.

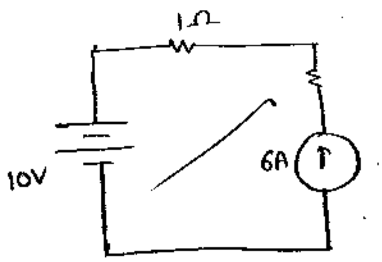
(45)



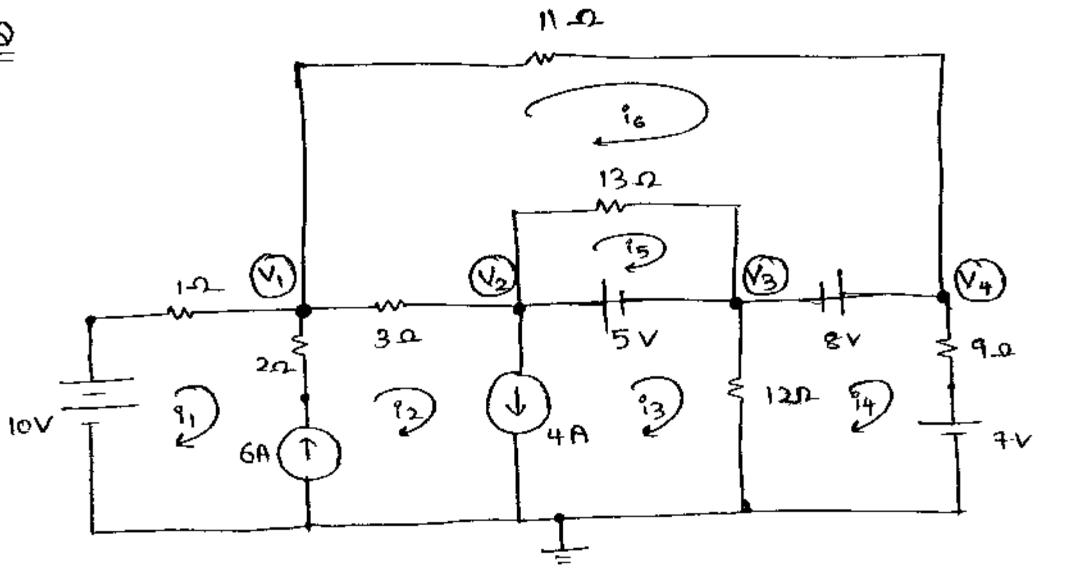
$P_{deliv} = -10(6)$

$= \underline{-60W}$

Q



Q



$n = 8$

$b = 13$

$m = 13 - 8 + 1$

$= 6.$

Mesh

$-10 + i_1(1) + \cancel{2(i_1 - i_2)}\ 3(i_2 - i_6) + 5V + 12(i_3 - i_4) = 0$

$-i_1 + i_2 = 6$

$i_2 - i_3 = 4$

$12(i_4 - i_3) - 8V + 9(i_4) + 7V = 0$

$-5V + 13(i_5 - i_6) = 0$

$3(i_6 - i_2) + 11(i_6) + 8V + 13(i_6 - i_5) = 0$

Nodal

$\frac{V_1 - 10}{1\Omega} + 6A + \frac{V_1 - V_2}{3} + \frac{V_1 - V_4}{11} = 0$

$\frac{V_2 - V_1}{3} + 4A + \frac{V_2 - V_3}{13} + \frac{V_3 - 0}{12} + \frac{V_3 - V_2}{13} + \frac{V_4 - V_1}{11} + \frac{V_4 - 7}{9} = 0$

$V_2 - V_3 = 5V$

$V_4 - V_3 = 8V.$

Mesh

$-10 + i_1(1) + 2(i_1 - \cancel{i_2}) + 2(\cancel{i_2} - i_1) + 3[i_2 - i_6] + 5 + 12[i_3 - i_4] = 0 \longrightarrow (1)$

$-i_1 + i_2 = 6 \longrightarrow (2)$

$i_2 - i_3 = 4 \longrightarrow (3)$

$12[i_4 - i_3] - 8 + 9i_4 + 7 = 0 \longrightarrow (4)$

$13[i_5 - i_6] - 5 = 0 \longrightarrow (5)$

$11i_6 + 8 + 13[i_6 - i_5] + 3[i_6 - i_2] = 0 \longrightarrow (6)$

Nodal

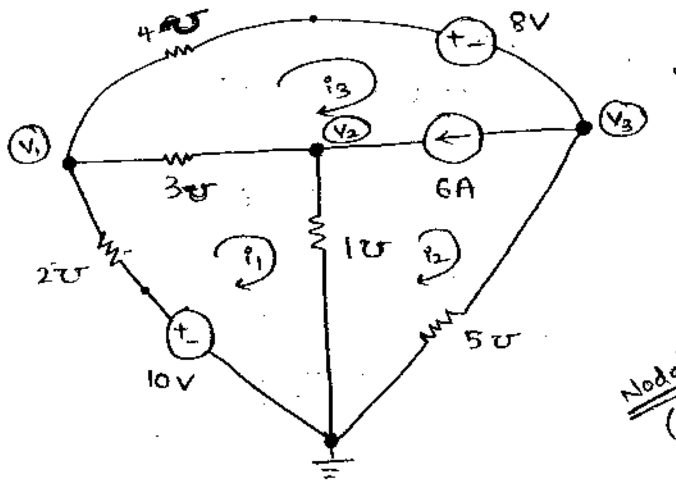
$$\frac{V_1-10}{1} + 8V + \frac{(V_1-V_2)}{3} + \frac{(V_1-V_4)}{11} = 0 \rightarrow ①$$

$$\frac{V_2-V_1}{3} + 4 + \cancel{\frac{V_2-V_3}{3}} + \cancel{\frac{V_3-V_2}{3}} + \frac{V_3}{12} + \frac{(V_4-7)}{9} + \frac{(V_4-V_1)}{11} = 0 \rightarrow ②$$

$$V_2 - V_3 = 5 \rightarrow ③$$

$$-V_3 + V_4 = 8V \rightarrow ④$$

Q Determine power absorbed by (3 Siemens) Conductance by using Mesh & nodal.



$n=6$, $b=8$, $m = 8-6+1 = 3$.

Mesh

$$-10 + \frac{i_1}{2} + \frac{(i_1-i_3)}{3} + \frac{(i_1-i_2)}{1} = 0$$

$$\frac{(i_2-i_1)}{1} + \frac{(i_2)}{5} + \frac{(i_3-i_1)}{3} + \frac{(i_3)}{4} + 8V = 0$$

$$i_3 - i_2 = 6A$$

Nodal

$$(V_1-10)2 + (V_1-V_2)(3) + (V_1-8-V_3)(4) = 0$$

$$(V_2-0)(1) + (V_2-V_1)(3) + (-6)A = 0$$

$$(V_3-0)(5) + (V_3+8V-V_1)(4) + (6)A = 0$$

Mesh

$$-10 + \frac{i_1}{2} + \frac{(i_1-i_3)}{3} + \frac{(i_1-i_2)}{1} = 0 \rightarrow ①$$

$$\frac{(i_2-i_1)}{1} + \frac{(i_3-i_1)}{3} + \frac{i_3}{4} + 8 + \frac{i_2}{5} = 0 \rightarrow ②$$

$$-i_2 + i_3 = 6 \rightarrow ③$$

solve $i_1 =$ ___ A

$i_3 =$ ___ A

Then

$$P_{3℧} = \left|\frac{[i_1-i_3]}{3}\right|^2 = \text{\_\_\_ w}$$

Nodal

$$2[V_1-10] + 3[V_1-V_2] + 4[V_1-V_3-8] = 0 \rightarrow ①$$

$$3[V_2-V_1] + 1(V_2) + (-6)A = 0 \rightarrow ②$$

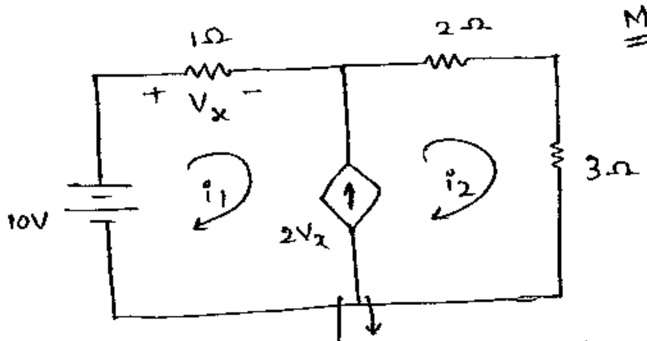
$$5V_3 + 4(V_3+8V-V_1) + (6)A = 0 \rightarrow ③$$

$V_1 =$ ___ V

$V_2 =$ ___ V

$$P_{3℧} = |V_1 - V_2|^2 (3) = \text{\_\_\_ w.}$$

Q Determine Voltage V_x by using mesh & Nodal Analysis.



Current sources common Super mesh

even dependent source treat as Normal source.

Mesh

$$-10+i_1(1)+2(i_2)+3(i_2)=0$$

$$-10+i_1+5i_2=0 \longrightarrow (1)$$

$$-i_1+i_2=2V_x \longrightarrow (2)$$

$V_x = 1.i_1$ [link Eqn]

link a link b/w mesh current & dependent parameter

* if dependent Sources involved
  no.of Eqns required
  = no.of mesh Eqns + no.of dependent source link Eqns
  = no.of nodal Eqns + no.of dependent source link Eqns

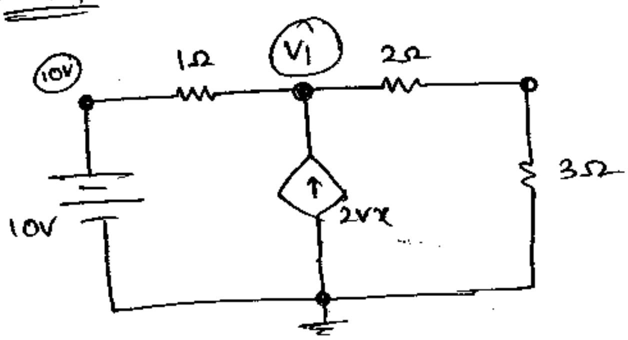
$$3i_1-i_2=0$$

$$15i_1-5i_2=0$$

$$16i_1=10 \longrightarrow i_1=\frac{5}{8}\,A$$

But $V_x = i_1(1) = \frac{5}{8}\,V.$

Nodal



$$\frac{V_1-10}{1}-2V_x+\frac{V_1}{5}=0$$

$$6V_1-10V_x=50$$

$$3V_1-5V_x=25 \longrightarrow (1)$$

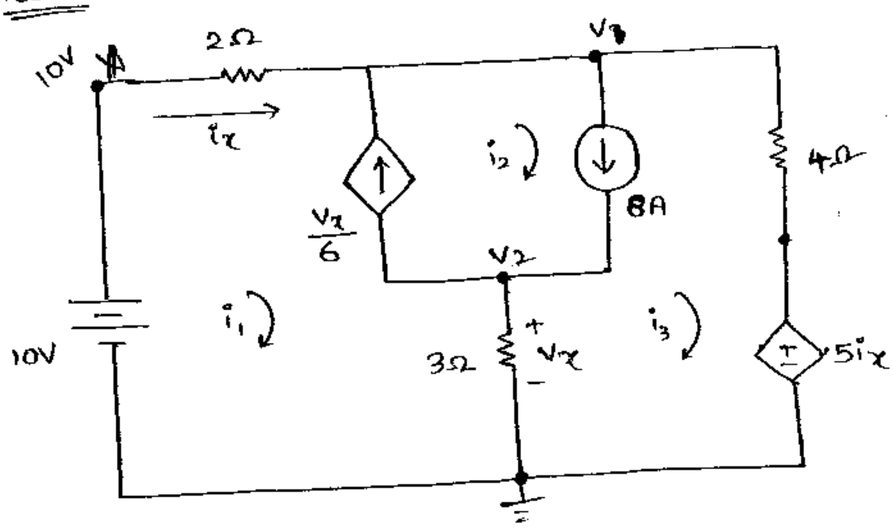
$$V_x=10-V_1 \longrightarrow (2)$$

$$3[10-V_x]-5V_x=25$$

$$8V_x=5$$

$$V_x=\frac{5}{8}\,V$$

IES(C)



Write mesh & nodal Analysis.

$n = 5 \quad b = 7 \quad m = 3$

Mesh = 3 mesh Eqns + 2 link Eqns

(∵ 2 depenat Source)

Nodal = 2 nodal Eqns + 2 link Eqns.
principle

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Mesh

$$-10 + 2i_1 + 4i_3 + 5i_x = 0 \longrightarrow (1)$$

$$-i + i_2 = \frac{V_x}{6} \longrightarrow (2)$$

$$i_2 - i_3 = 8 \longrightarrow (3)$$

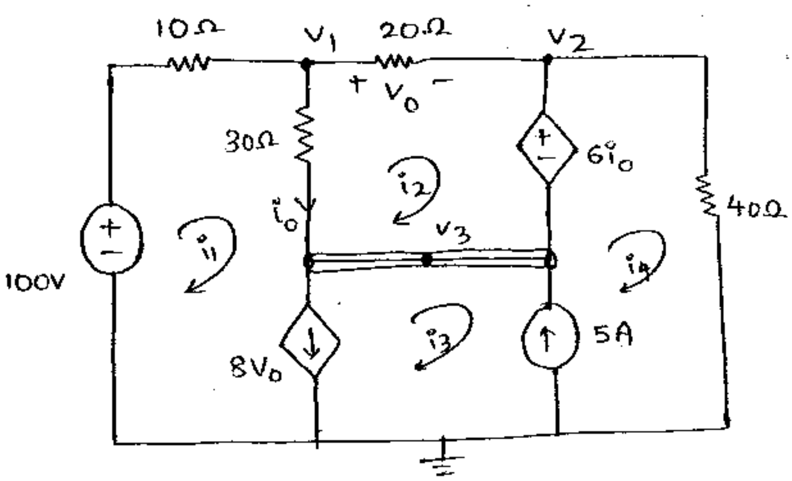
$$\left.\begin{array}{l} i_x = i_1 \longrightarrow (4) \\ V_x = 3[i_1 - i_3] \longrightarrow (5) \end{array}\right\} \text{link}$$

Nodal

$$\frac{(V_1 - 10)}{2} - \frac{V_x}{6} + 8 + \frac{(V_1 - 5i_x)}{4} = 0 \longrightarrow (1)$$

$$+\frac{V_x}{6} - 8 + \frac{V_2}{3} = 0 \longrightarrow (2)$$

$$\left.\begin{array}{l} i_x = \frac{10 - V_1}{2} \longrightarrow (3) \\ V_x = V_2 \longrightarrow (4) \end{array}\right\} \text{link.}$$



$n = 5,\ b = 8,\ m = 4$

mesh = 4 + 2 = 6

Nodal = 3 + 2 = 5.

Mesh

$$-100 + 10i_1 + 30[i_1 - i_2] - 6i_0 + 40i_4 = 0 \longrightarrow ①$$

$$30[i_2 - i_1] + 20i_2 + 6i_0 = 0 \longrightarrow ②$$

$$(i_1 - i_3) = 8V_0 \longrightarrow ③$$

$$(-i_3 + i_4) = 5 \longrightarrow ④$$

$$i_0 = (i_1 - i_2) \longrightarrow ⑤$$

$$V_0 = 20i_2 \longrightarrow ⑥$$

Nodal

$$\frac{(V_1 - 100)}{10} + \frac{(V_1 - V_2)}{20} + \frac{(V_1 - V_3)}{30} = 0 \longrightarrow ①$$

$$\frac{(V_2 - V_1)}{20} + \frac{V_2}{40} - 5 + 8V_0 + \frac{(V_3 - V_1)}{30} = 0 \longrightarrow ②$$

$$(V_2 - V_3) = 6i_0 \longrightarrow ③$$

$$i_0 = \frac{(V_1 - V_3)}{30} \longrightarrow ④$$

$$V_0 = (V_1 - V_2) \longrightarrow ⑤$$

DC Network Theorems

Theorem 1: Source Transformation Technique (S.T.T)

Can be converted into an ideal Voltage Source in Series with Resistance across the Same two ideal Current Source in parallel to the Same Resistance terminals and Vice Versa.

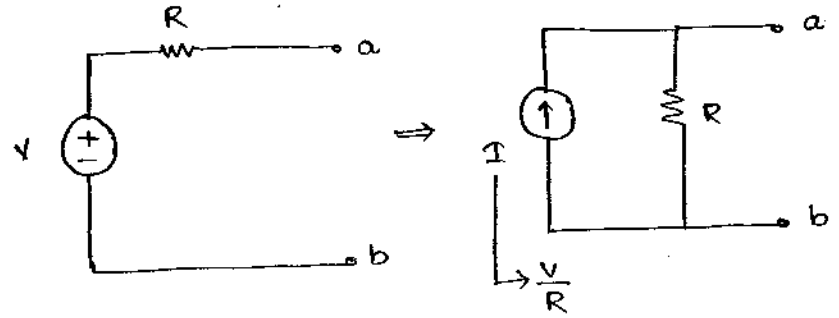
Volt. Reg → MOSFET

Cur. Reg → BJT used

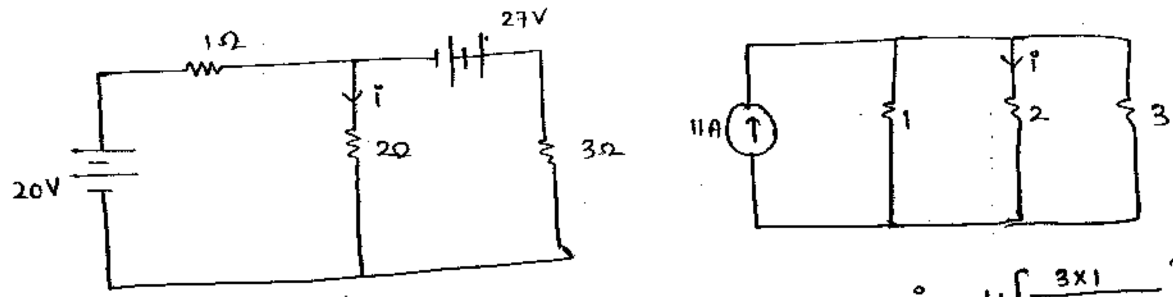
↓

Const. current

STT based on ohm's law based Reduction Technique.

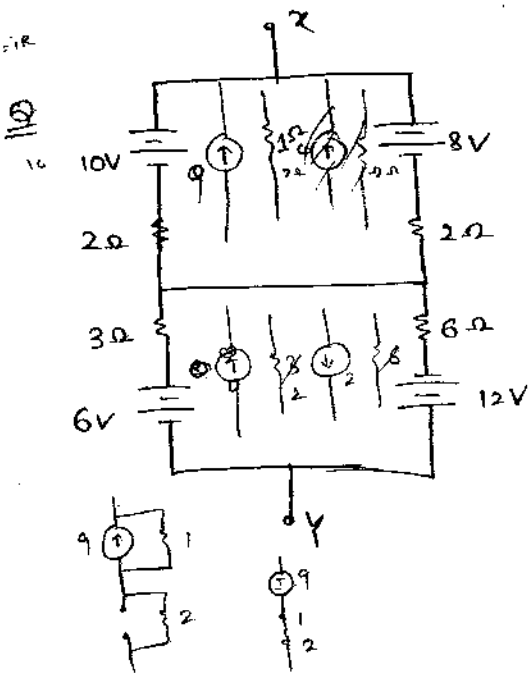


Q Determine the Current "i" in the ckt shown by S.T.T.



$$i = 11\left[\frac{3\times 1}{2+6+3}\right] = 3A.$$

Q



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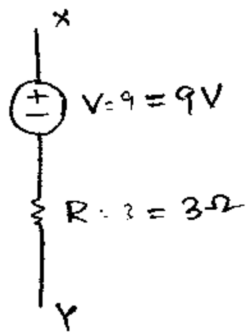
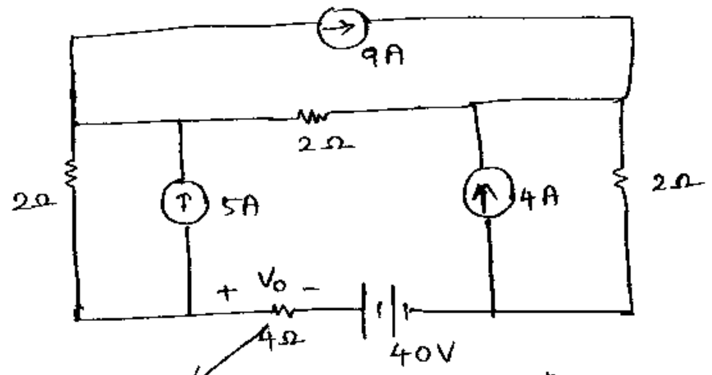


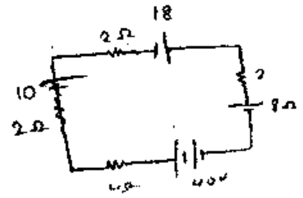
IES(0) $V_0 = \_\_\_$

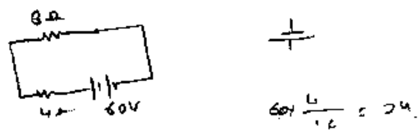


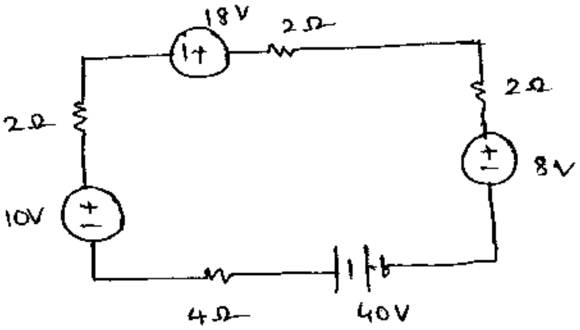
Target

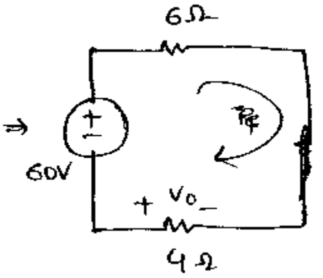
Should all attach to Target

w.r.t Target rest of N/w reduce.





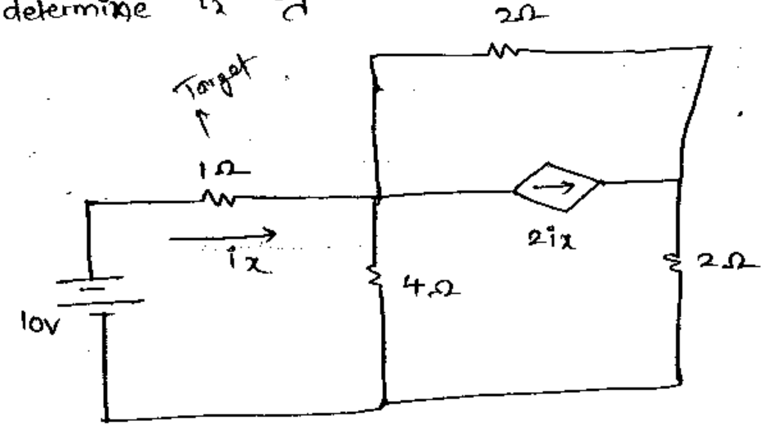


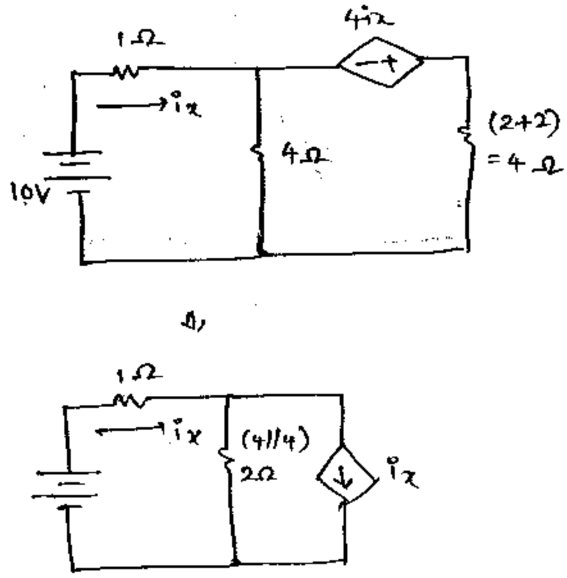


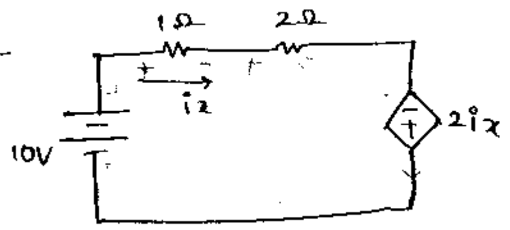
$$V_0 = -60\left[\frac{4}{10}\right]$$

$$= -24V.$$

Q determine 'i_x' by S.T.T







KVL

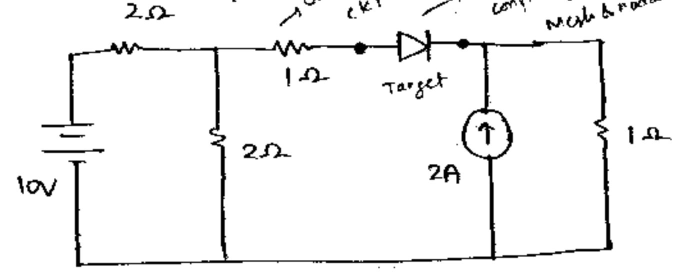
$$-10 + i_x(1) + i_x(2) - 2i_x = 0$$

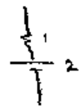
$$i_x = 10\text{ A}$$

gate

Q Determine current through diode.

Nonlinear unilateral ckt → without confirming state of diode Mesh & nodal not possible.





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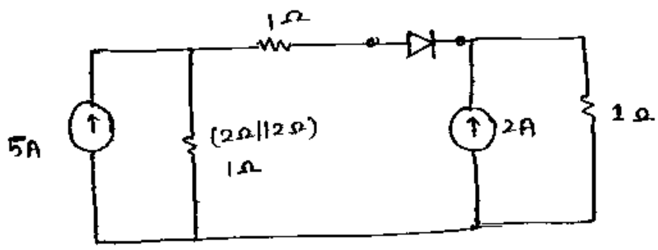
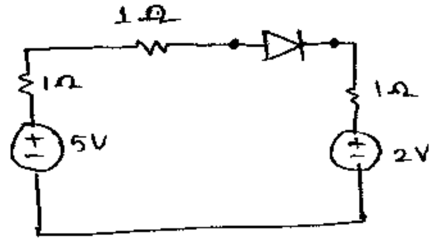
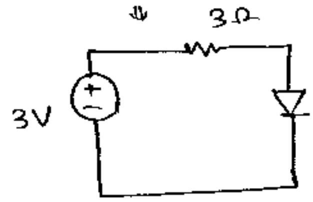


⇒



⇓



→ F.B

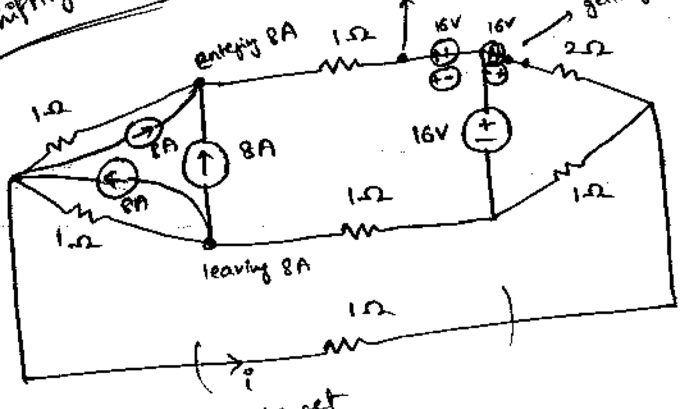
→ ~~Diode~~

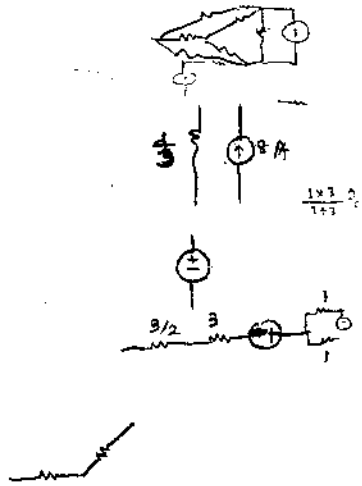
→ $R_{ON} = 0\Omega$

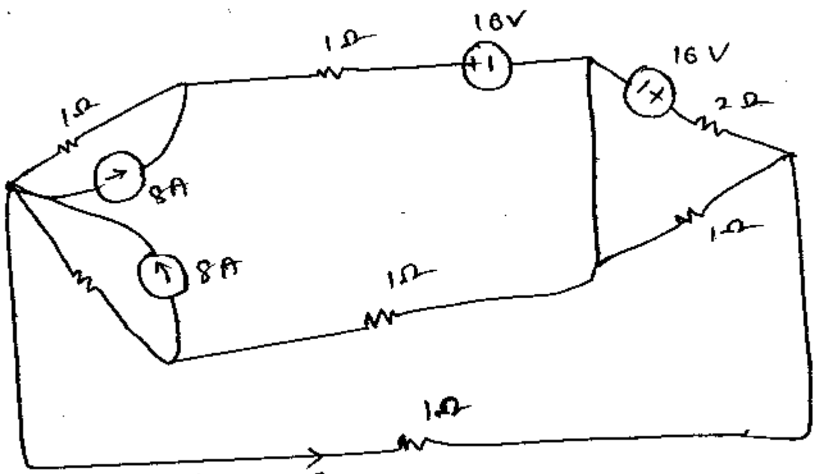
$I_D = \frac{3}{3} = 1A$

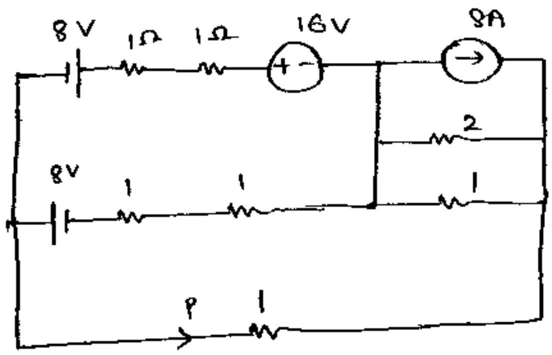
Q Determine Current 'i' by S.T.T

Source shifting Technique

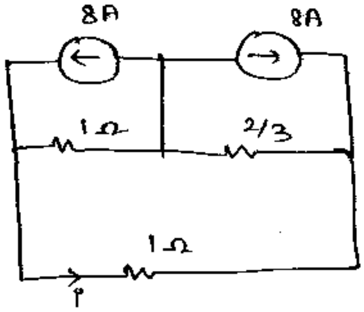


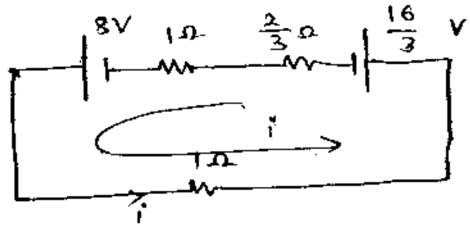






⇒





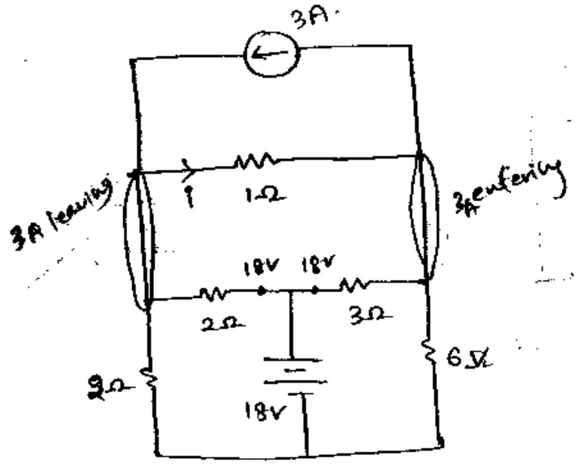
$$+\frac{16}{3}+\frac{2}{3}i+i-8+i=0$$

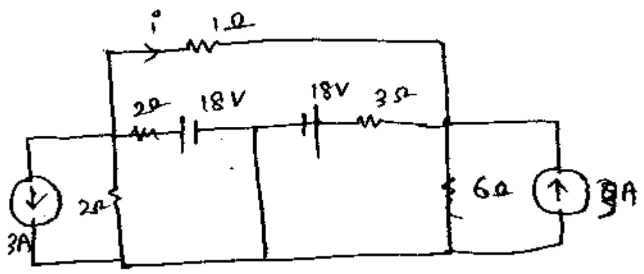
$$i\left[\frac{2}{3}+2\right]=8-\frac{16}{3}$$

$$i\,\frac{8}{3}=\frac{8}{3}$$

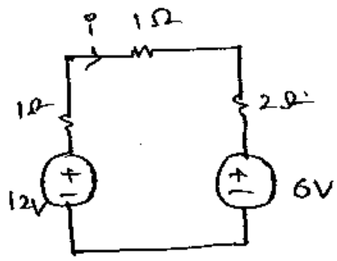
$$i=1\,A$$

Determine Current 'i' by using S.T.T





⇒

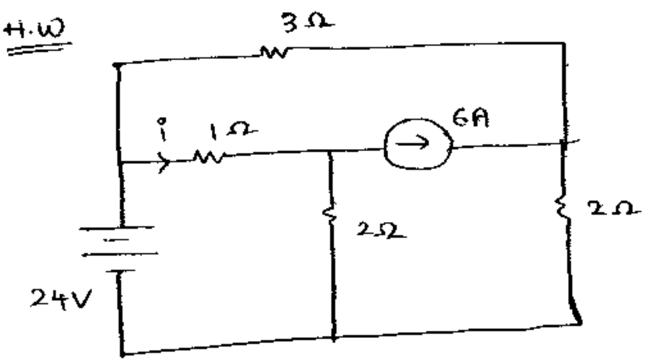


$$-12+4i+6=0$$

$$4i=6$$

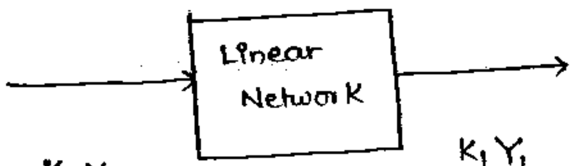
$$i=1.5A$$

H.W



Theorem 2: Superposition theorem (S.P.T)

In any Linear active Bilaternal N/w Consisting of ~~of~~ no. of energy Sources, Restances etc. the effect produced in any element when all ~~eleme~~ Sources act at a time is Equal to sum of effects produced in the Same elements when each Source is Considered individualy.



K_1X_1	K_1Y_1
K_2X_2	K_2Y_2
$(K_1X_1+K_2X_2)$	$((K_1Y_1)+(K_2Y_2))$

SPT: Combination of

(1) Linearity (ohms law) $X_1 \rightarrow Y_1$

(2) Homogenity $X_1 \longrightarrow Y_1$, $KX_1 \longrightarrow KY_1$ (proportionality)

(3) Additive.

Q The no. of sub ckts to be solved while applying SPT is no. of Independent Sources only.

(dependent sources can't be considered)

Q Which of the following elec. parameter can't be directly evaluated by using SPT ?

(a) V

(b) I

(c) P ⇒ ∵ Power is non linear (additive property not satisfies) electrical parameter

(d) q

[additive property is applicable for Linear & Homogenity]

Note: While applying SPT each subcircuit has only one Independent Source.

The other Independent Sources are deactivated

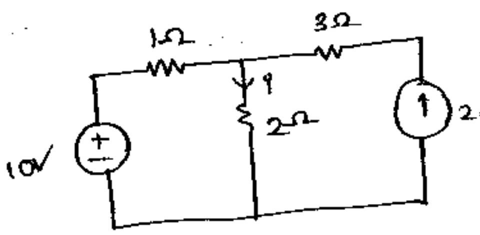
V ⟶ Short circuited

I ⟶ open circuited

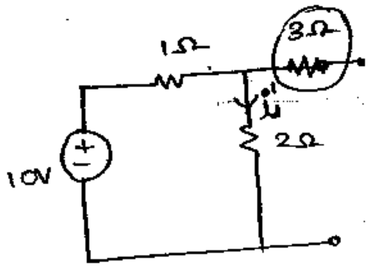
However dependent sources can't be suppressed

* Voltages have specific polarities & Currents have unique directions. they must be Respected while applying this theorem

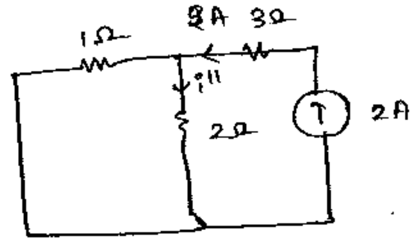
Q determine Current 'i' in the ckt shown below by using SPT.



S-I



$i' = \frac{10}{3}$ A



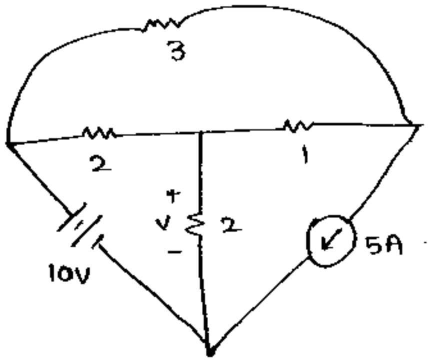
$i'' = 2\left[\frac{1}{3}\right]$

$= \frac{2}{3}$ A

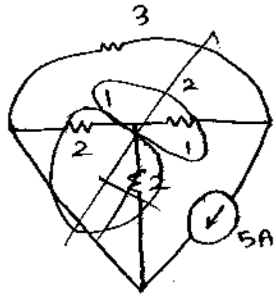
$i = i' + i''$

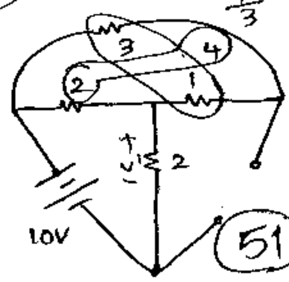
$i = \frac{10}{3} + \frac{2}{3} = 4A$

determine Voltage 'V' by using SPT



I



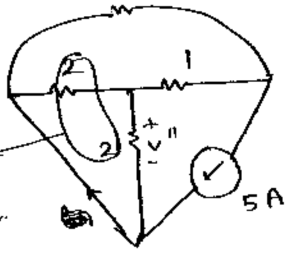


$$V' = 10\left[\frac{2}{2+\frac{4}{3}}\right]$$

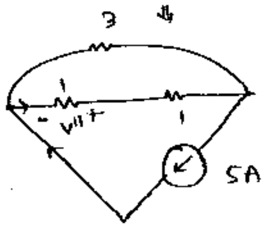
$$= 6V$$

no. of sub ckts = 2 Sources = 2

II



parallel & Volt across parall same



$$i'' = 5\left(\frac{3}{3+2}\right)$$

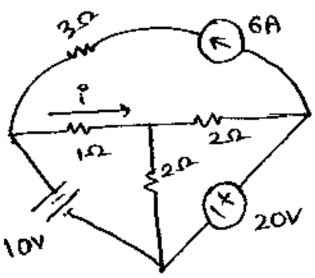
$$V'' = -1\left[5\left(\frac{3}{3+2}\right)\right]$$

$$V'' = -3.$$

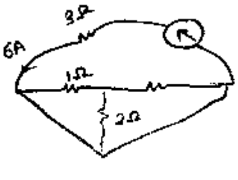
$$V = V' + V''$$

$$= (6-3) = 3V.$$

Q Determine Current through 1 Ω Resistance using SPT



let i be the current through 1Ω.



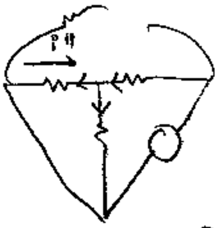
$$\cancel{6}^{2} \times \frac{2}{\cancel{3}} = 4A$$

S-I 10 V only

$$i' = \frac{10}{1+[2\|2]} = \frac{10}{2}$$

$$= 5A$$

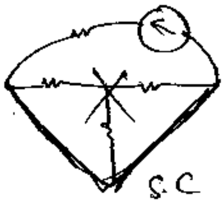
S-II : 20V only



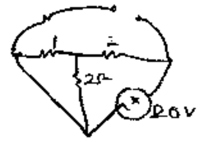
$$i'' = -\left[\frac{20}{2+\frac{2}{3}}\right]\frac{2}{3}$$

$$= -\frac{20}{4} = -5A$$

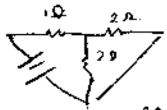
S-III :



$$i''' = 0$$



$$\cancel{20}^{5} \times \frac{2}{\frac{2+2}{3}} = 10A$$



$$20 \times \frac{2\times3}{6+2} =$$

$$20 \times \frac{6}{8}$$

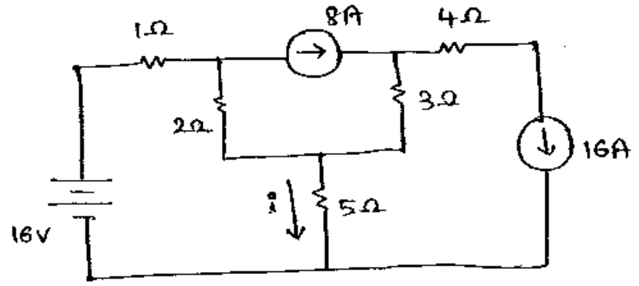
$$20V \frac{1}{3}$$

$$\frac{20}{3} + 10 + 4$$

$$= \frac{20+30+12}{3} = \frac{62}{3}.$$

$$\text{By SPT} = i = i' + i'' + i'''$$
$$= +5 - 5 + 0$$
$$i = 0A$$

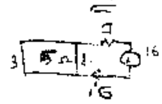
Q Determine power abs. by 5Ω using SPT.



let i be current (assume)

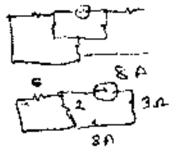
$V' = \frac{16}{8}\,' =$

$i = 2A$



$-\left[16 \times \frac{3}{8}\right]$

$-6A$



$8 \times \frac{2}{8} = 2$

$-2A$

16V only

$$i' = \frac{16}{1+2+5}$$
$$= 2A$$

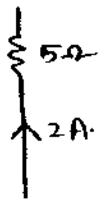
8A only

$$i'' = 8\left[\frac{2}{2+6}\right]$$
$$= 2A$$

16A only

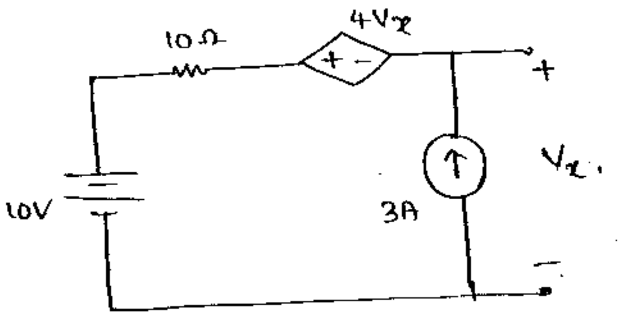
$$i''' = -16\left[\frac{3}{3+5}\right]$$
$$= -6A$$

$$\text{By SPT} \quad i = i' + i'' + i'''$$
$$= 2 + 2 - 6$$
$$i = -2A$$



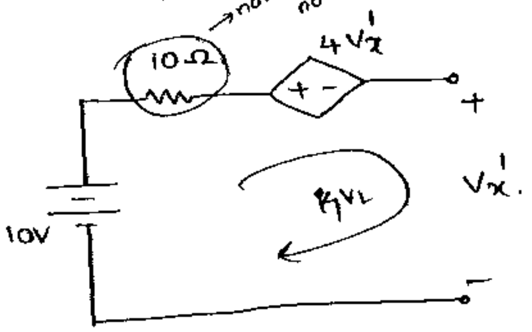
$$P_{abs} = [I_{net}]^2 R$$
$$= (2)^2 \cdot (5)$$
$$= 20W$$

Q determine Voltage V_x by using S.P.T.



10V only.

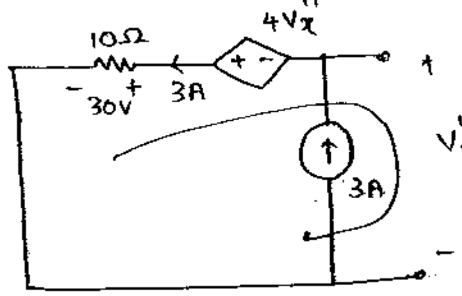
→ not a closed path, no current flows ∴ no Volt across 10Ω



$-10+4V_x'+V_x'=0$

$V_x'=2V$

3A only



52

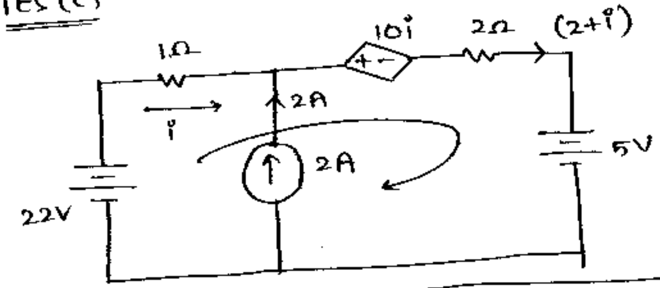
KVL $-30+4V_x''+V_x''=0$

$V_x''=6V.$

By SPT = $V_x=V_x'+V_x''$

$=2V+6V=\underline{8\text{ Volts}}$

IES (C) determine 'i' by SPT



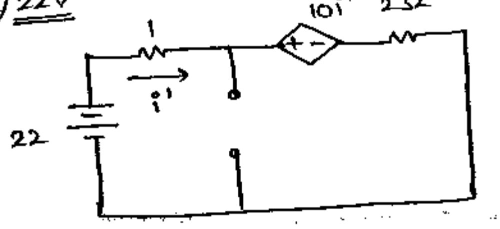
Direct method.

$-22+i+10i+2(2+i)+5=0$

$13i=13 \rightarrow i=1A.$

By SPT

I) 22V

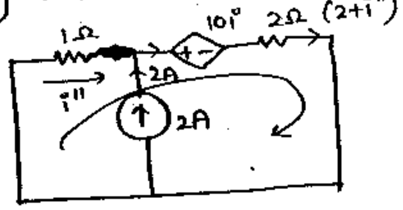


KVL $-22+i'+10i'+2i'=0$

$13i'=22$

$i'=\frac{22}{13}$

II) 2A only

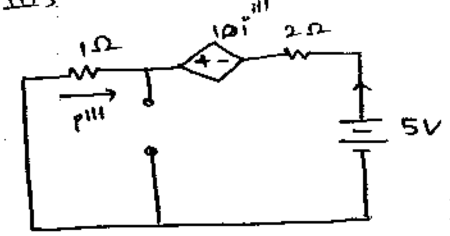


KCL+KVL

$i''+10i''+2(2+i'')=0$

$i''=\frac{-4}{13}A$

III) 5V only



$i'''+10i'''+2i'''+5=0$

$13i'''+5=0$

$i'''=\frac{-5}{13}.$

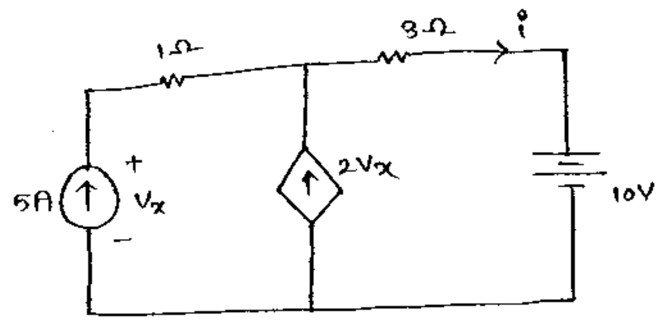
By SPT

$i=i'+i''+i'''$

$=\frac{22}{13}-\frac{4}{13}-\frac{5}{13}=\frac{13}{13}=1A.$

HW

Q Determine current 'i' in ckt shown below by using SPT.



Gate

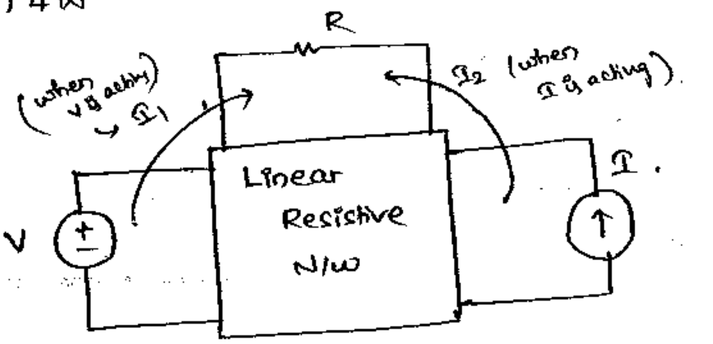
Q The power lost in Resistor 'R' when voltage source alone acts is 25W. and current source alone acts is 9W. determine the total power lost in Resistor 'R' when both sources act simultaneously

(a) 4 W ~~(b) 16 W~~ ~~(c) 34 W~~ (d) 64 W.

power is non linear

∴ powers can't be added

$(25 \pm 9) = 16 \text{ (or) } 34$ ✗



(V) alone

$P_1 = 25W = I_1^2 R$

$|I_1| = \frac{5}{\sqrt{R}}$

(I) alone

$P_2 = 9W = I_2^2 R$

$|I_2| = \frac{3}{\sqrt{R}}$

by SPT

$I_T = [\pm I_1 \pm I_2]$

∵ we don't know the inside of N/w

∴ we dont the direction of I_1 & I_2

$\longrightarrow I_1$ $\longrightarrow I_1$
$\longrightarrow I_2$ $\longleftarrow I_2$

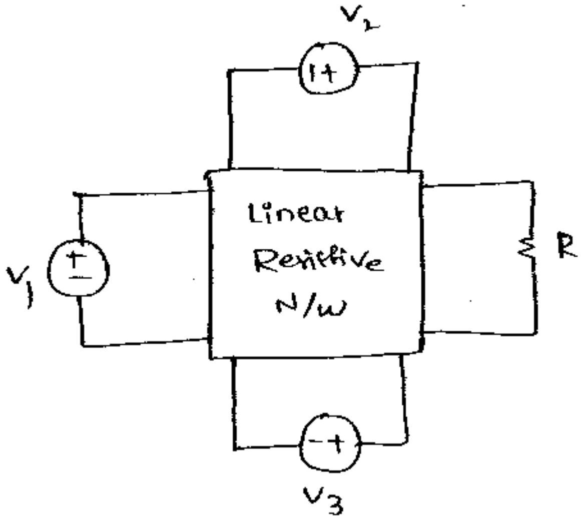
$\longleftarrow I_2$ $\longleftarrow I_1$
$\longleftarrow I_2$ $\longrightarrow I_2$

$P_T = [I_T]^2 R$

$= [\pm I_1 \pm I_2]^2 R = \left[\pm \frac{5}{\sqrt{R}} \pm \frac{\sqrt{3}}{R}\right]^2 R$

$P_T = [\pm 5 \pm 3]^2_w$ → 64, → 4w

Q determine the Values of max & min power lost in Resistance 'R' when all Sources act simultaneously



If,

V_1 alone $\longrightarrow$ 18W

V_2 alone $\longrightarrow$ 50W

V_3 alone $\longrightarrow$ 98W

53

$P_1 = I_1^2 R$

$18 = I_1^2 R$

$I_1 = \frac{18}{\sqrt{R}}$

$I_2 = \frac{50}{\sqrt{R}}$

$I_3 = \frac{98}{\sqrt{R}}$

$I_T = \left(\frac{18}{\sqrt{R}} + \frac{50}{\sqrt{R}} + \frac{98}{\sqrt{R}}\right)$

18+50+98

18
50
18
166

98
68
900

$$P_T = \left[\pm\sqrt{P_1} \pm \sqrt{P_2} \pm \sqrt{P_3}\right]^2$$

$$P_T = \left[\pm\sqrt{18} \pm \sqrt{50} \pm \sqrt{98}\right]^2$$

$$P_T = 2\left[\pm 3 \pm 5 \pm 7\right]^2$$

$\longrightarrow$ for max $P_T = 2\left[3+5+7\right]^2 = 450W_{max}$

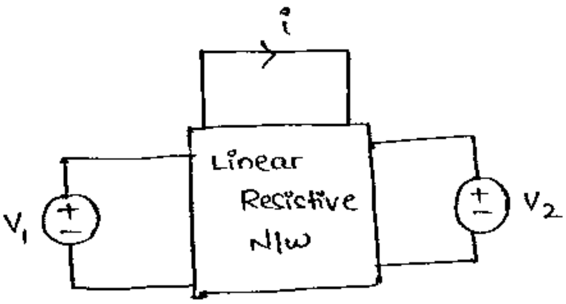
$\longrightarrow$ for min $P_T = 2\left[+3+5-7\right]^2 = 2W_{min.}$

if two sources acting simultaneously

then $P_T = \left[\pm\sqrt{P_1} \pm \sqrt{P_2}\right]^2$

if three Sources acting simultaneously on 'R'

$$P_T = \left[\pm\sqrt{P_1} \pm \sqrt{P_2} \pm \sqrt{P_3}\right]^2$$



if $V_1 = V_2 = 15V$ then $i =$ ____

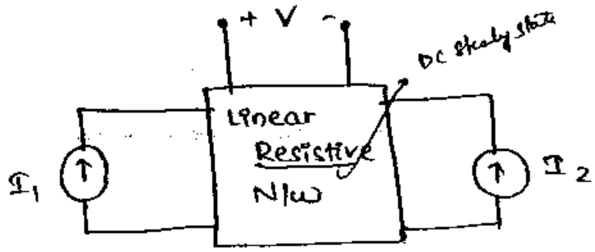
If

V_1	V_2	i
10V	0V	5A
0V	−5V	1A

V_1 alone ($V_2 = 0$) } 10V ⟶ 5A
15V ⟶ 7.5A

V_2 alone ($V_1 = 0$) } −5V ⟶ 1A
+5V ⟶ −1A
15V ⟶ −3A

When both $V_1 = V_2 = 15V$ acting ⟶ $i = (7.5 - 3)\,A = \underline{\underline{4.5\,A}}$



If $I_1 = I_2 = 15A$ then $V =$ ____

I_1	I_2	V
10A	5A	20V
5A	−10A	5V

$$\boxed{V = k_1 I_1 + k_2 I_2}$$

$20 = k_1 10 + k_2 5 \longrightarrow (1)$

$5 = k_1 5 + k_2 (-10) \longrightarrow (2)$

$k_1 = 9/5$

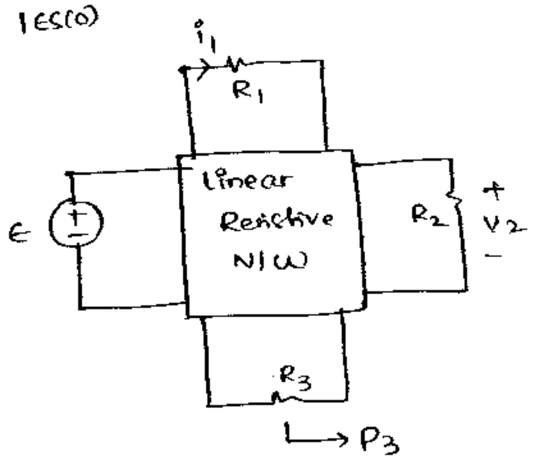
$k_2 = 2/5$

$V = \frac{9}{5} I_1 + \frac{2}{5} I_2$

$V = \frac{9}{5}(15) + \frac{2}{5}(15)$

$V = 33$ volts.

IES(O)



if E = 20V then $i_1 = 5A$, $V_2 = 15V$, $P_3 = 12W$

if E = 30V then $i_1 =$ __ ; $V_2 =$ ___ , $P_3 =$ ___

(i_1)

20V ⟶ 5A

30V ⟶ $i_1 = 7.5A$

(V_2)

20V ⟶ 15V

30V ⟶ $V_2 = 22.5V$

(P_3)

$$P = \frac{V^2}{R}$$

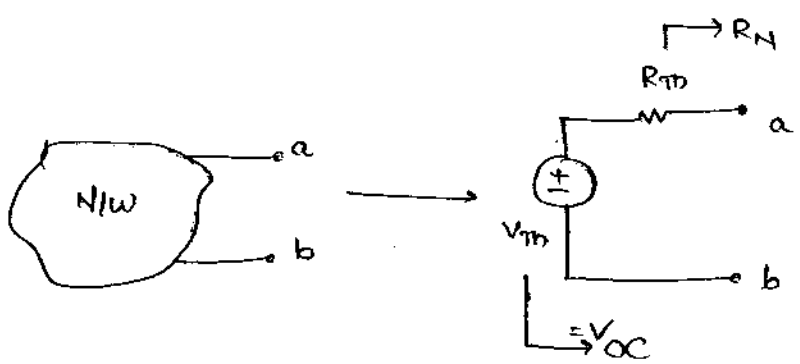
$(20)^2 \longrightarrow 12W$

$(30)^2 \longrightarrow P_3 = \frac{(30)^2(12)}{(20)^2}$

$= 27\ W$.

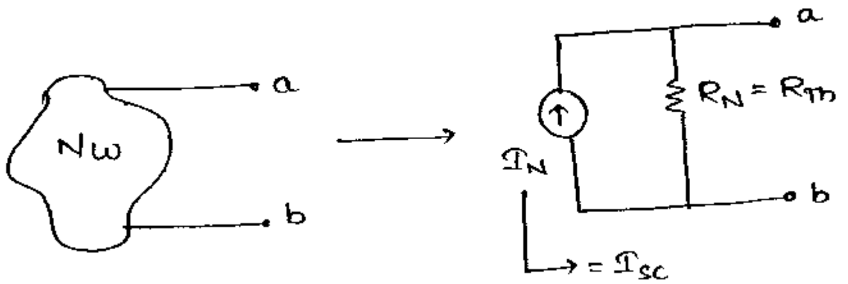
Theorem-3 "Thevenin's Theorem:" ⟶ (Active Reduction) i.e., Including active elements.

In any Linear active Bilateral N/w Consisting of no. of Energy Sources, Resistances etc., with open output target terminals defined can be Converted into Simple network Consisting of Voltage Source in Series with Resistance



Theorem 4: Norton's Theorem:

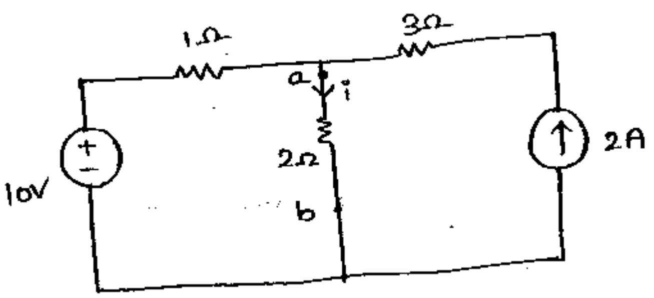
In any linear active Bilateral N/w Consisting of no.of Energy Sources, Resistances etc. with open o/p target terminals defined can be Converted into a simple N/w Consisting of current source in parallel with Resistance.



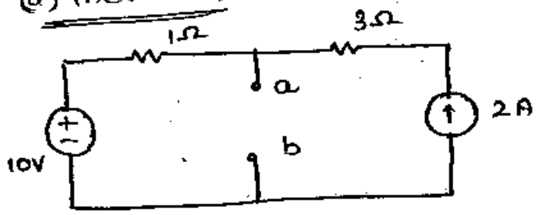
Note: Thevenins & Norton's Equivalents are dual of Each other i.e, they are Source Transformable.

Category-I problems : problems with only Independent Sources.

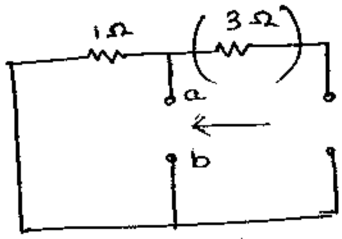
Q determine Current i by using (a) Thevening (b) Nortons theorem.



(a) Thevenins

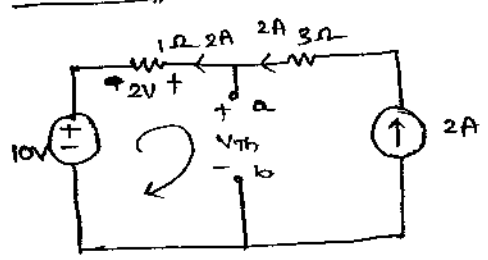


Step-I: R_{Th}



$R_{Th} = 1\Omega$

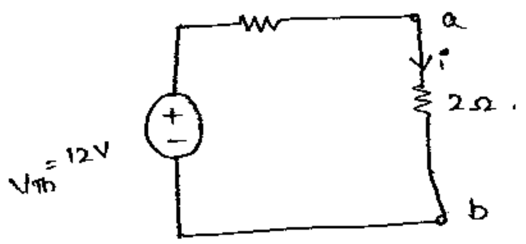
Step-II: V_{Th}.



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

$V_{Th}=+12V$

Thevenins Eq:

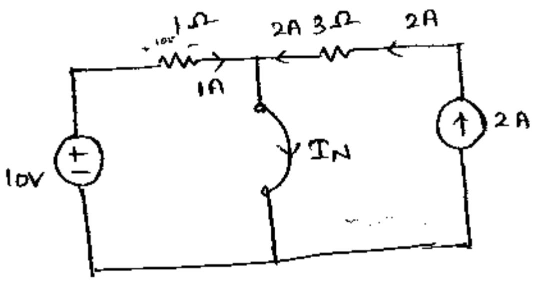


$i = \frac{12}{1+2} = 4A$

(b) Nortons:

Step-I: $R_N = R_{Th} = 1$.

Step-II: I_N

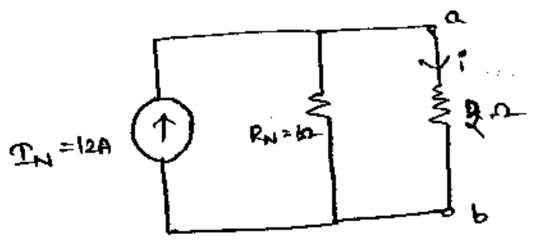


KCL

$10 + 2 = I_N$

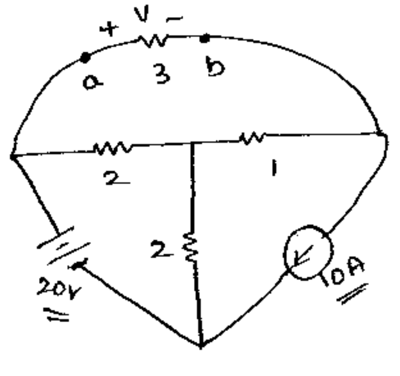
$I_N = 12A$

Nortons Eq.:



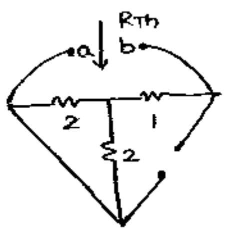
$i = 12\left[\frac{1}{3}\right] = 4A$.

Q determine Voltage 'V' by (i) Thevenins (ii) Nortons.



(a) Thevenins.

[I] R_{Th}

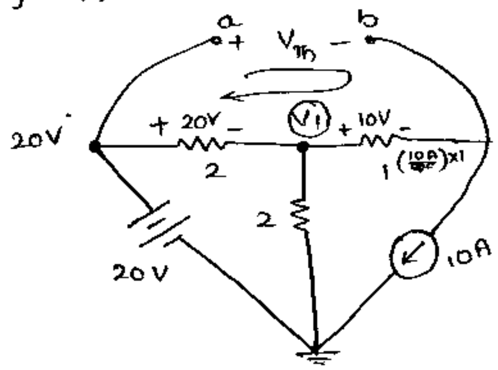


[II] V_{Th}

$R_{Th} = (2 \| 2) + 1$

$= 2\Omega$

[II] V_{Th}.



Nodal :

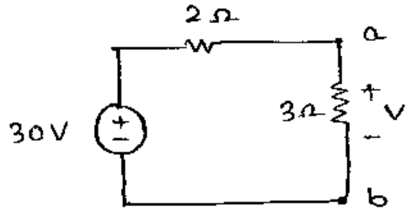
$$\frac{V-20}{2} + \frac{V}{2} + 10 = 0$$

$$\underline{\underline{V = 0}}$$

KCL

$$+V_{Th} - 10 - 20 = 0 \Rightarrow V_{Th} = 30V$$

Thevenins N/w:

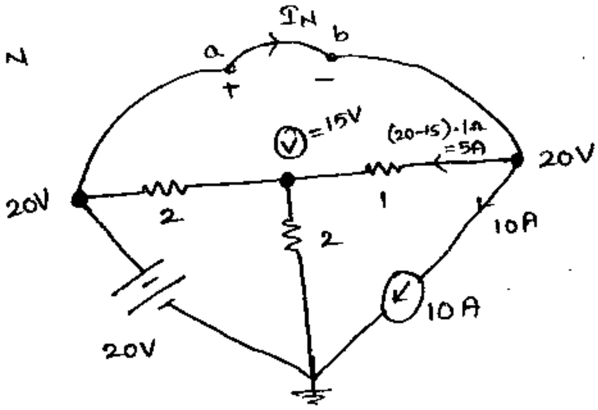


$$V = 30\left[\frac{3}{3+2}\right] = 18\,V.$$

(b). Nortons :

[S-I] : $R_N = R_{Th} = 2\Omega$

[S-II] : I_N



Nodal :

$$\frac{V-20}{2} + \frac{V-20}{1} + \frac{V-0}{2} = 0$$

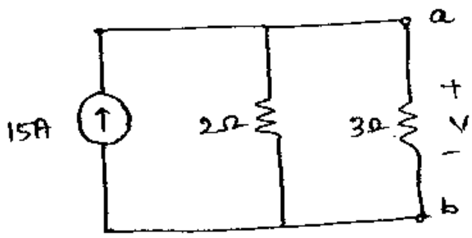
$$4V = 60$$

$$V = 15v$$

KCL.

$$I_N = 10+5 = 15A$$

Nortons. N/w:

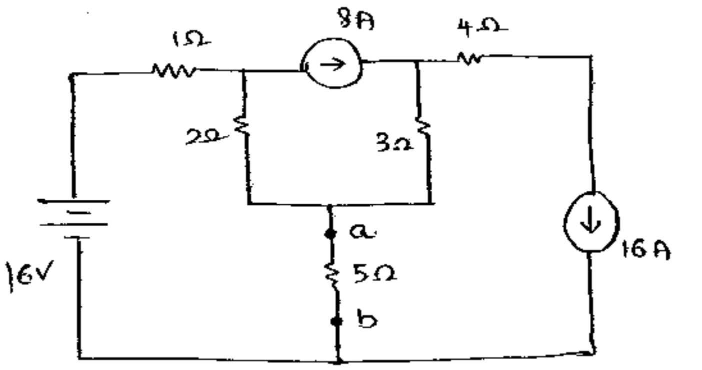


$$= 3\Omega\left[15\left[\frac{2}{2+3}\right]\right]$$

$$= 3\left(15 \times \frac{2}{5}\right)$$

$$\underline{\underline{= 18\ V}}$$

Q Determine the power absorbed by 5Ω Resistance using Thevnins & Nortons theorem.



Thevnins:

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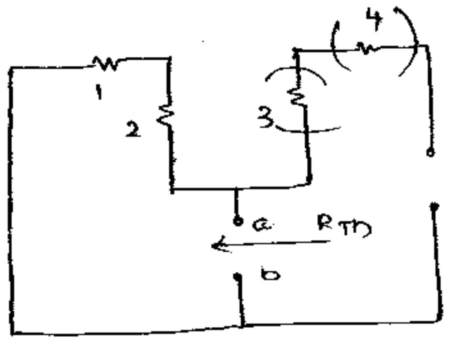
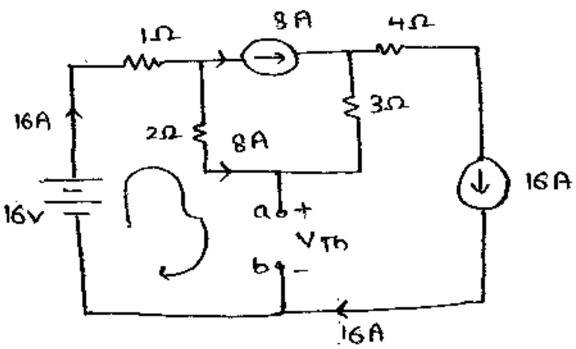
Step-I : R_{Th}



$R_{Th} = 3\Omega$

Step-II : V_{Th}

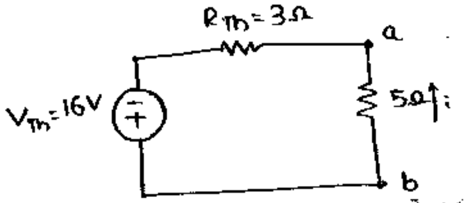


KVL:

$$-16 + 16(1) + 2(8) + V_{Th} = 0$$

$$V_{Th} = -16\,V$$

Thevenins Eq.



$$I_{5\Omega} = \frac{16}{8} = 2A \uparrow$$

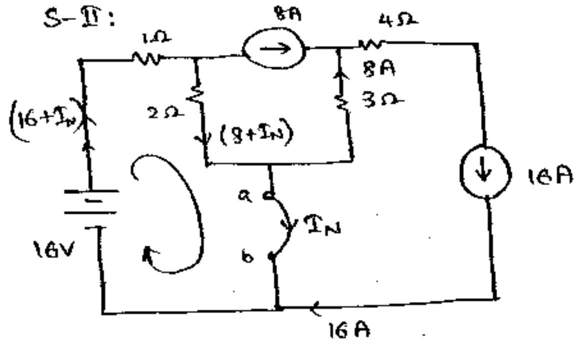
$$P_{5\Omega} = (2)^2(5)$$

$$= 20W$$

Nortons:

S-I : $R_N = R_{Th} = 3\Omega$

S-II:

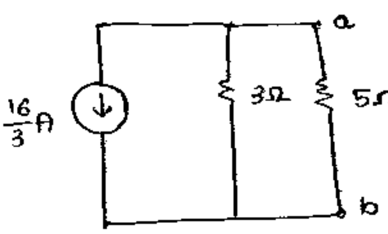


KCL+KVL:

$$-16 + 1[16 + I_N] + 2[8 + I_N] = 0$$

$$I_N = \frac{-16}{3}\,A.$$

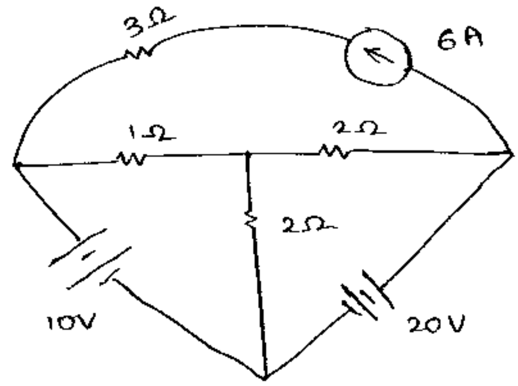
N.E:



$$I_{5\Omega} = \frac{16}{3}\left[\frac{3}{8}\right] = 2A \uparrow$$

$$P_{5\Omega} = (2)^2(5) = 20W$$

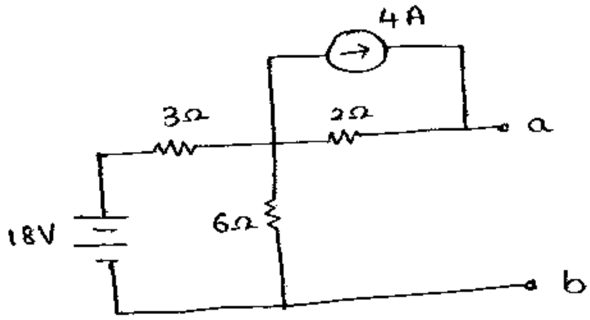
H.W



Determine Current through 1Ω Resistance using Thevenins & Nortons theorem

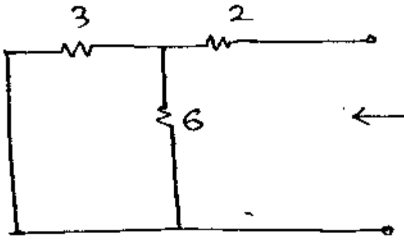
gate

Q Determine the Thevenins & Nortons Equivalent across terminals a, b



Thevenins

R_{Th}

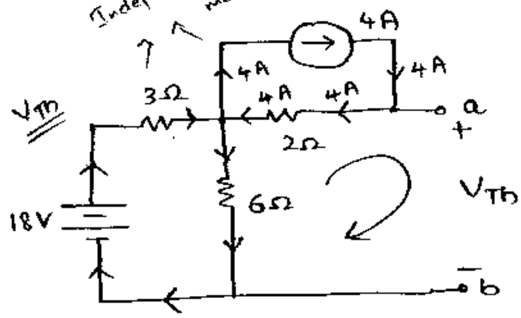


$R_{Th} = (3 \| 6) + 2$

$= 4\Omega.$

Independent meshes

V_{Th}

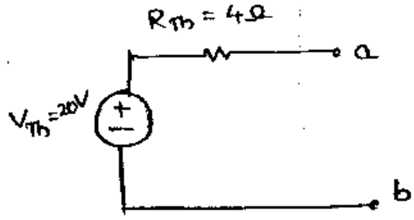


KVL

$-[2(6)]-[4(2)]+V_{Th}=0$

$V_{Th}=12+8$

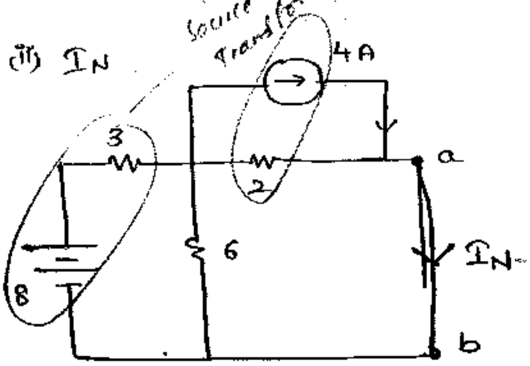
$= 20V.$

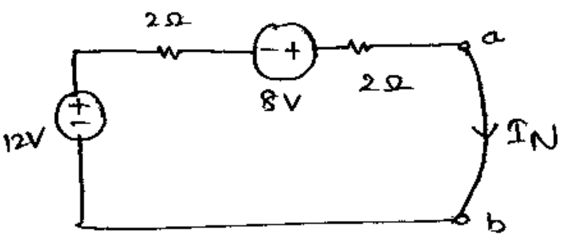


Nortons:

(i) $R_{Th} = R_N = 4\Omega$

(ii) I_N Source transformation.



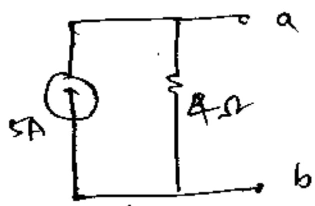


$I_N \Rightarrow$ STT+KCL

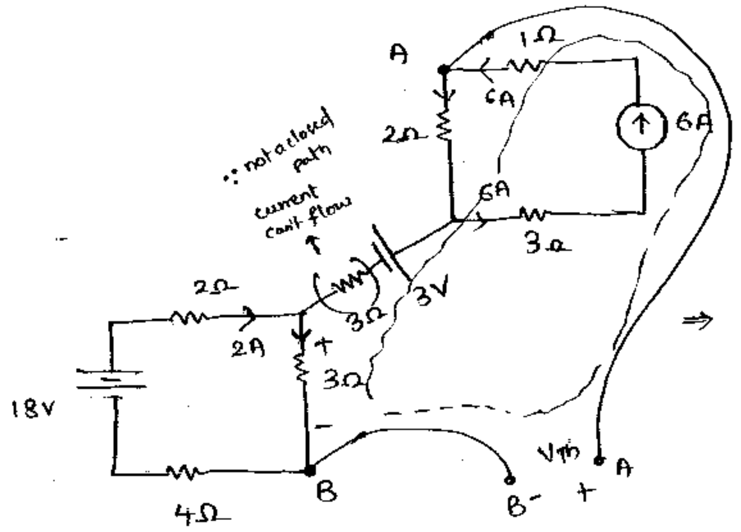
$-12+2I_N-8+2I_N=0$

$4I_N=20$

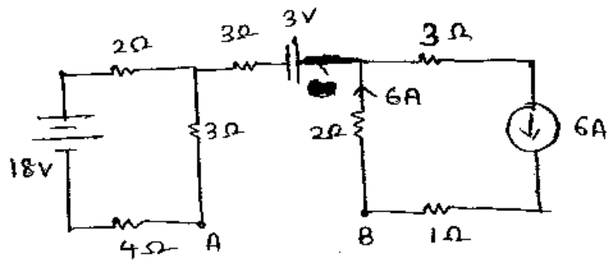
$I_N=5A$ $\Rightarrow$



Determine the Thevenin's Equivalent across terminals AB.



⇒



$R_{Th} = 7\Omega$

$R_{Th} = 2+3+[3 \| 6]$

$= 2+3+2$

$= 7\Omega$.

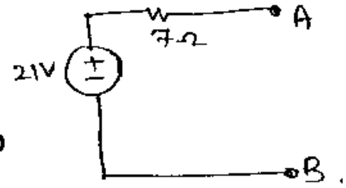
V_{Th}

↳ KVL

$-[2(3)]+0-3-[6(2)]+V_{Th}=0$

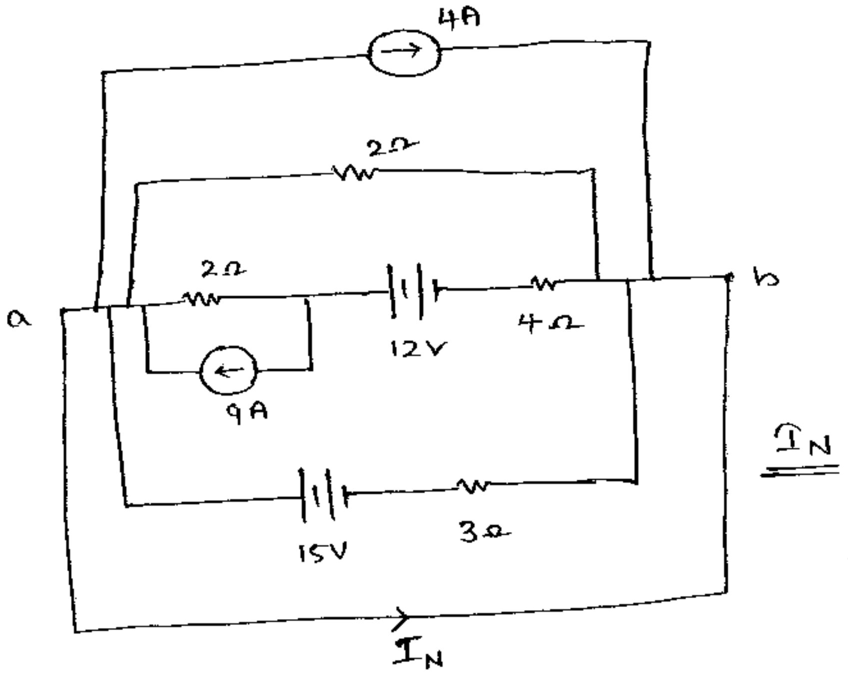
$V_{Th}=21V$.

T.E



for the above problem, find the Nortons Eq. across AB.

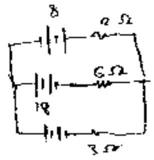
Q determine the Nortons Equivalent across terminals AB.



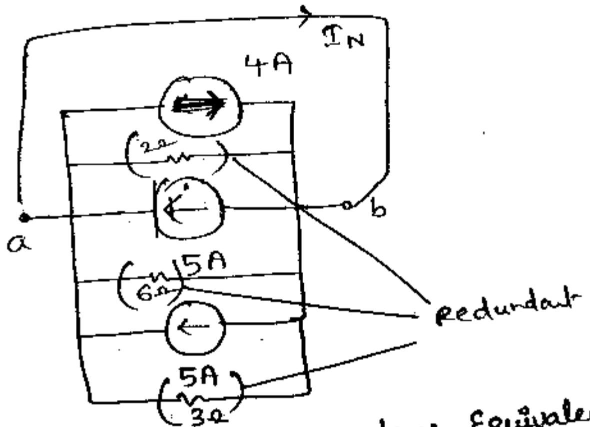
Nortons

$R_N = 2 \| 6 \| 3$

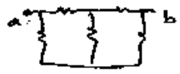
$= \underline{1}$

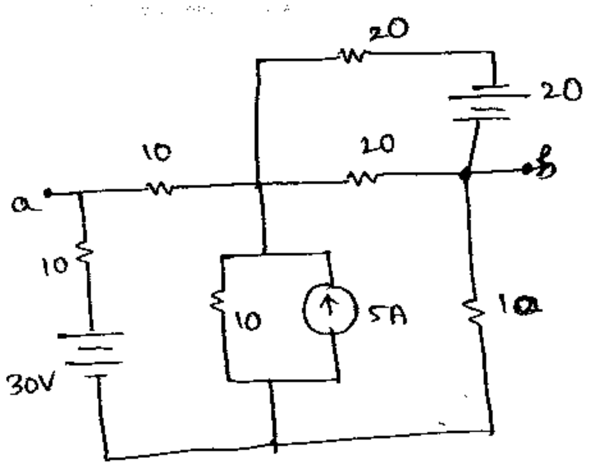


S.C to passive elements & Redundant ⇒ no p.D ⇒ no current flows.

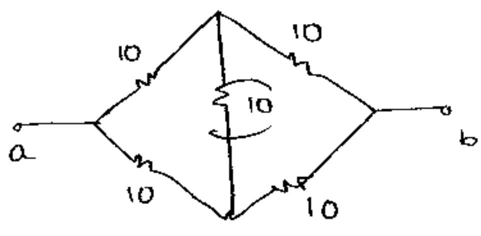


Q determine Thevenins & nortons Equivalent across AB.



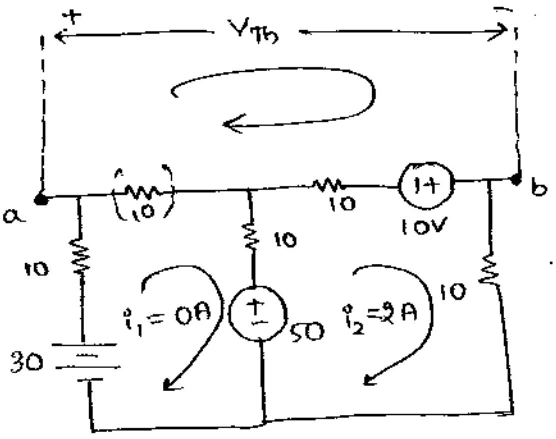


[I] $R_{Th} = R_N$



$= 20 // 20 = 10\,\Omega$

S-II] V_{Th}.



Mesh

$$-3\cancel{0}+2\cancel{0}i_1+1\cancel{0}[i_1-i_2]+5\cancel{0}=0$$

$$3i_1-i_2=-2 \longrightarrow (1)$$

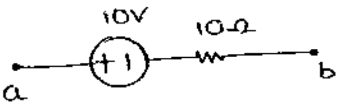
$$-50+10[i_2-i_1]+20i_2-10=0$$

$$-i_1+3i_2=6 \longrightarrow (2)$$

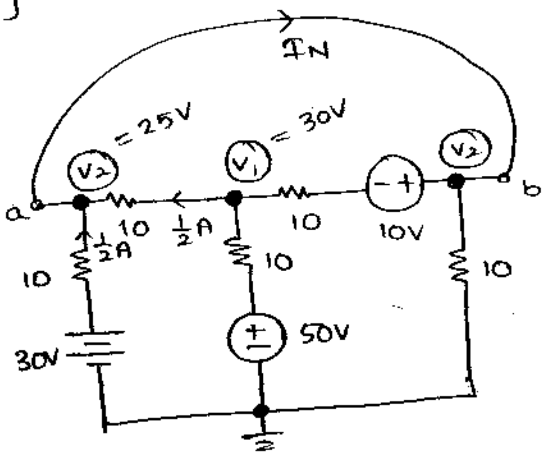
Solving (1) & (2) $\quad i_2 = 2A$

$i_1 = 0A$

T.E:



S-III] I_N



Nodal-1

$$\frac{(V_1-V_2)}{10}+\frac{(V_1-50)}{10}+\frac{(V_1-V_2+10)}{10}=0$$

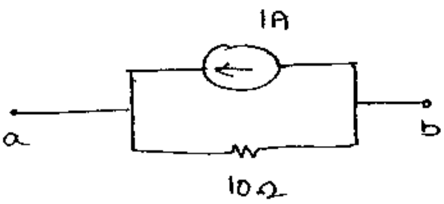
$$3V_1-2V_2=40 \longrightarrow (1)$$

$$\frac{(V_2-V_1)}{10}+\frac{(V_2-30)}{10}+\frac{V_2}{10}+\frac{(V_2-V_1-10)}{10}=0$$

$$-2V_1+4V_2=40$$

$$-V_1+2V_2=20 \longrightarrow (2)$$

N.E:

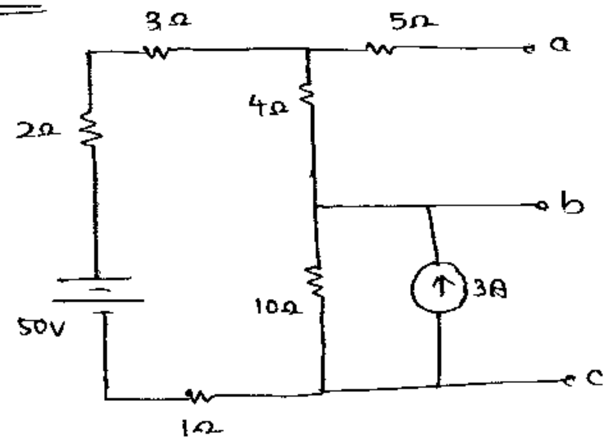


KCL

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

$$I_N = 1A$$

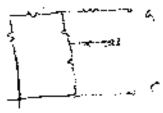
H.W



Determine

(1) Th & N. across terminals ac

(2) Th. & N Eq. across terminals bc



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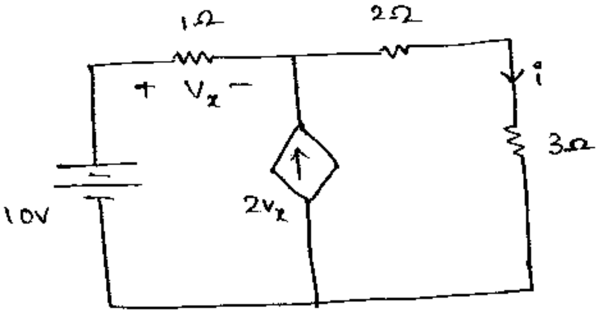
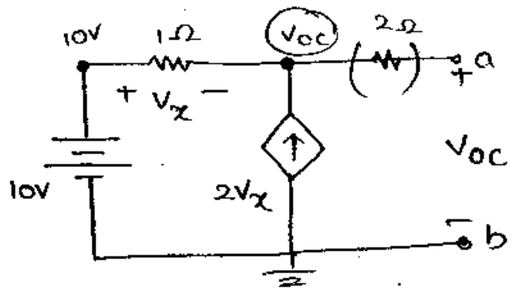
Category-II problems with Both Independent & dependent Sources.

In Such Networks determining R_{Th} or R_N's not possible directly due to the presence of dependent Sources Moreover the N/w is already active & working due to the presence of Independent Sources in it. in Such N/w we use OHM's law to indirectly find Resistance where $R_{Th} = R_N = \frac{V_{oc}}{I_{sc}}$ at target terminals.

Q determine Current 'i' In the ckt shown by using Thevenins & Nortons Theorem.



S-I $V_{oc} = V_{Th}$



Nodal:

$$\frac{V_{oc}-10}{1} - 2V_x = 0 \longrightarrow (1)$$

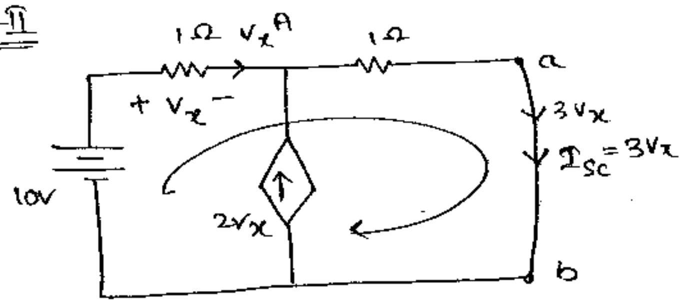
$$V_x = 10 - V_{oc} \longrightarrow (2)$$

$$V_{oc} - 10 - 20 + 2V_{oc} = 0$$

$$3V_{oc} = 30$$

$$V_{oc} = 10V = V_{Th}$$

S-II



$$-10 + V_x + 2(3V_x) = 0$$

$$V_x = \frac{10}{7}$$

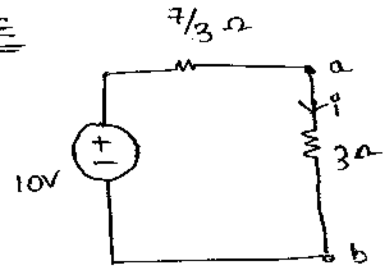
But $I_{sc} = 3V_x$

$$= 3\left(\frac{10}{7}\right)$$

$$I_{sc} = \frac{30}{7} = I_N$$

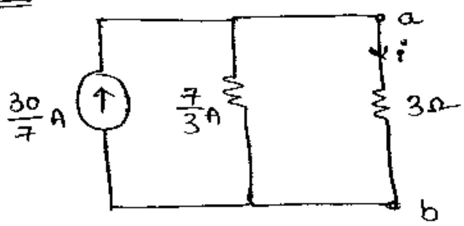
$$R_{Th} = R_N = \frac{V_{oc}}{I_{SC}} = \frac{10}{30/7} = \frac{7}{3}\,\Omega.$$

T.E



$$i = \frac{10}{3+\frac{7}{3}} = \frac{30}{18} = \frac{15}{8}\,A$$

N.E



$$i = \frac{30}{7}\left[\frac{\frac{7}{3}}{3+\frac{7}{3}}\right] = \frac{15}{8}\,A.$$

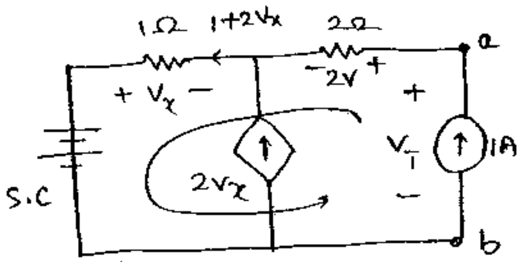
Note: In this Category Sometimes if it is Required only to find Resistance but not Equivalent then deactivate N/w & apply ohm's law directly.

Ex: In determining i/p Impedence, o/p impedence of electronic devices & ckts, Time Constant problems.

In Maximum power Transfer Theorem,

In determining two port N/w parameters etc

Q find only R_{Th} (or) R_N:



KVL

$$-V_T + 2 + 1\left[1+2V_x\right] = 0$$

$$V_T = 3 + 2V_x \longrightarrow (1)$$

$$V_x = -1\left[1+2V_x\right]$$

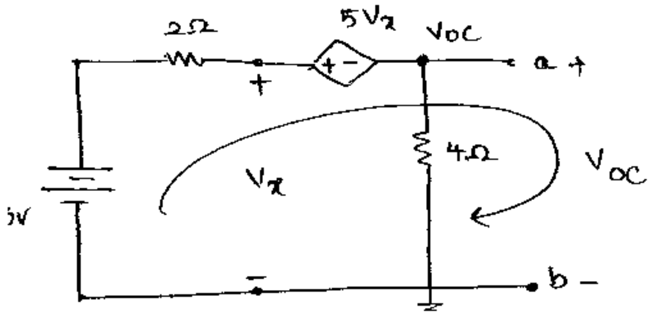
$$3V_x = -1 \longrightarrow (2)$$

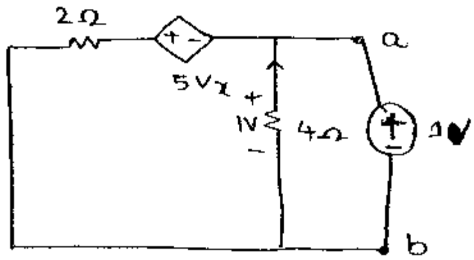
$$V_T = 3 + 2\left[\frac{-1}{3}\right] = \frac{7}{3}\,V$$

$$R_{Th} = R_N = \frac{V_T}{1A} = \frac{7}{3}\,\Omega.$$

Prob

Determine the Norton Eq. across terminals ab





Voc

Nodal:

$$\frac{(V_{oc}-6+5V_x)}{2}+\frac{V_{oc}}{4}=0$$

$$3V_{oc}+10V_x=12 \longrightarrow (1)$$

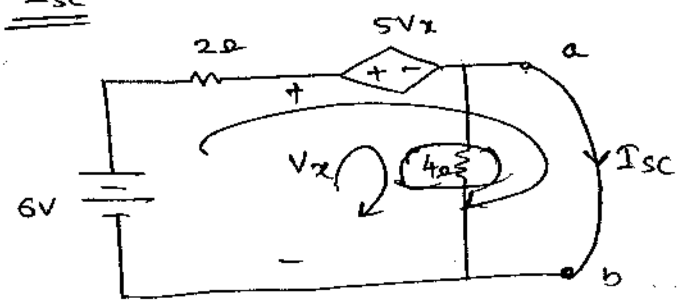
KCL

$$-V_x+5V_x+V_{oc}=0 \longrightarrow V_{oc}=-4V_x \longrightarrow (2)$$

$$3V_{oc}+10\left[\frac{-V_{oc}}{4}\right]=12$$

$$V_{oc}=24V.$$

I_{sc}



Mesh

$$-6+2I_{sc}+5V_x=0 \longrightarrow (1)$$

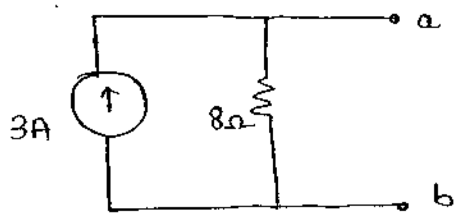
$$-V_x+5V_x=0$$

$$V_x=0 \longrightarrow (2)$$

$$2I_{sc}=6 \longrightarrow I_{sc}=3A$$

$$R_N=\frac{V_{oc}}{I_{sc}}=\frac{24}{3}=8\Omega$$

N.E



Gate

Determine the Thevenins Eq. across the load.

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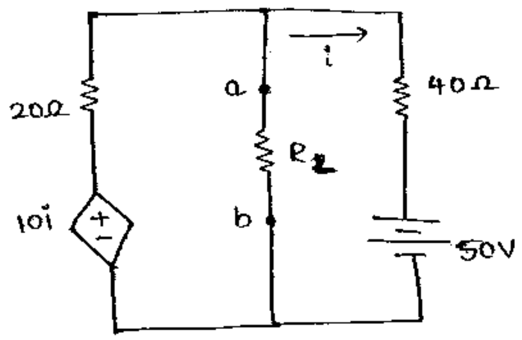
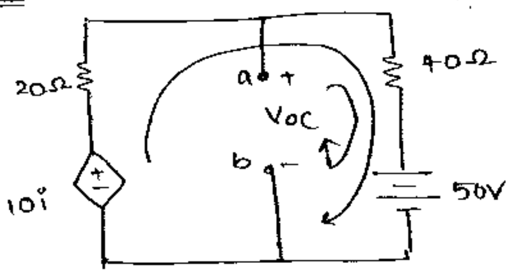


Voc



Mesh

$$-10i + 20i + 40i + 50 = 0$$

$$i = -1 \longrightarrow (1)$$

KVL

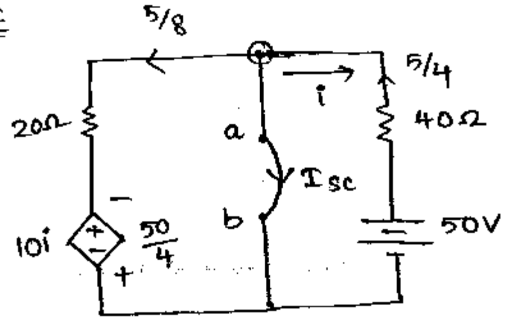
$$-V_{oc} + 40i + 50 = 0$$

$$V_{oc} = 40i + 50 \longrightarrow (2)$$

$$V_{oc} = 40(-1) + 50$$

$$= 10V$$

Isc



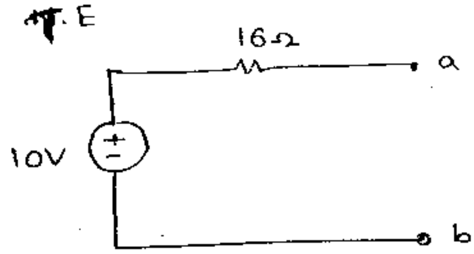
KCL

$$\frac{5}{4} = I_{SC} + \frac{5}{8}$$

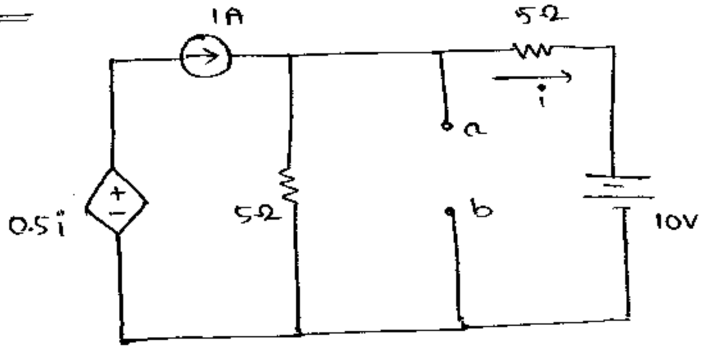
$$I_{SC} = \frac{5}{8} A$$

$$R_{Th} = \frac{V_{oc}}{I_{SC}} = \frac{10}{5/8} = 16\,\Omega$$

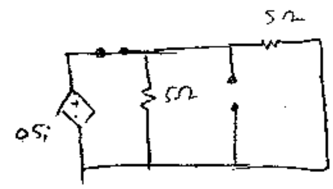
T.E



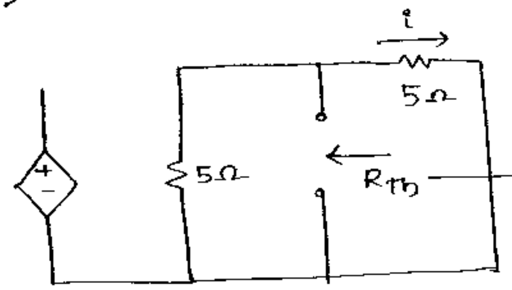
Gate:



The Thevening Resistance across terminals ab.



(a) 0Ω ~~(b)~~ 2.5Ω (c) 5Ω (d) 7.5Ω

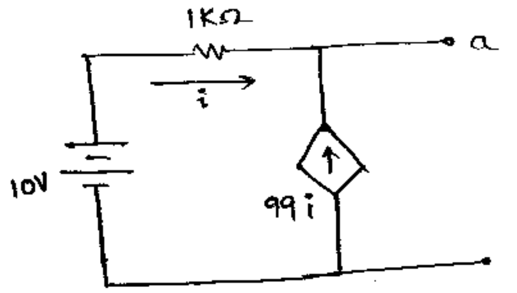


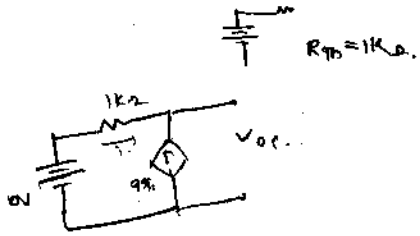
→ 5//5 = 2.5Ω

Q T.E b/w ab

(a) 1V, 1Ω (b) 10V, 1Ω

(b) 1V, 10Ω ~~(d)~~ 10V, 10Ω



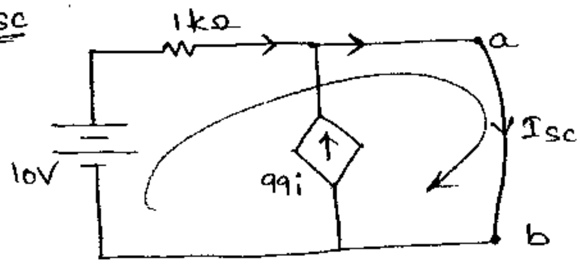


−10V + KI −

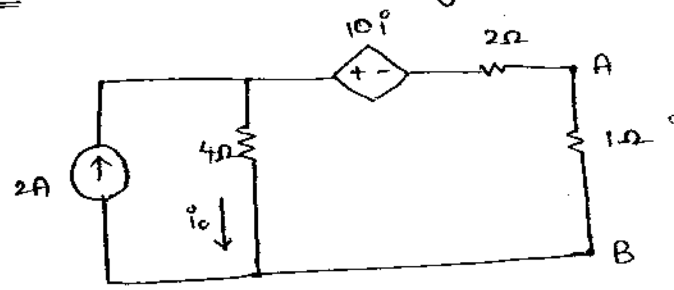
Isc

99i = −Isc

Isc



Q determine Current through 1Ω Resistance Using Norton's theorem.



→ actively generative n/w

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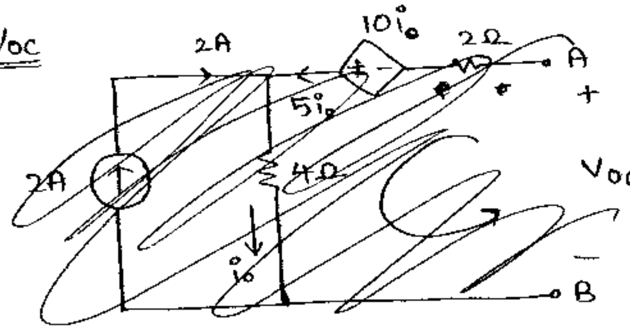
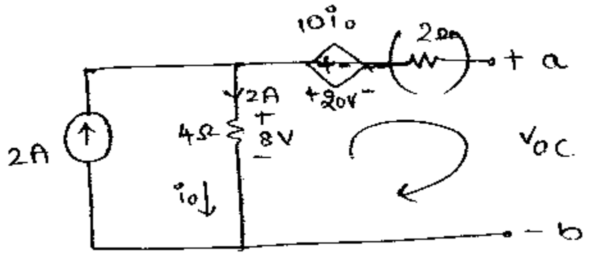
Voc



$\cancel{V_{oc} + 2\Omega(5i) - 10i + 4\Omega(5i+2) = 0}$

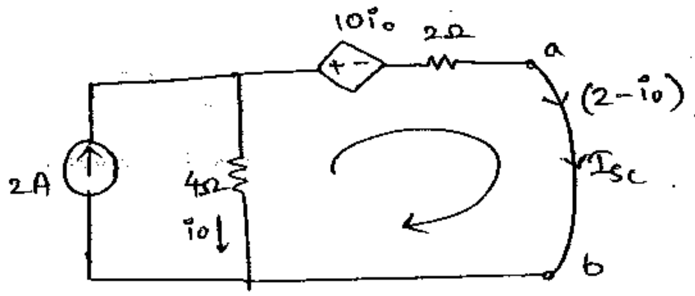
Voc



$\Rightarrow -8 + 20 + V_{oc} = 0$

$V_{oc} = -12V$

I_{sc}



$-4i_o + 10i_o + 2(2-i_o) = 0$

$i_o = -1A$

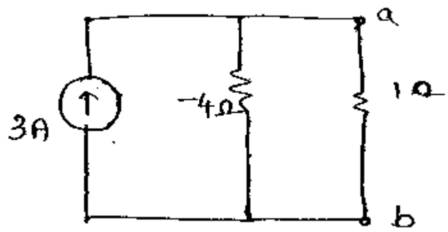
$I_{sc} = 2 - i_o$

$= 2 - (-1)$

$= +3\ A$

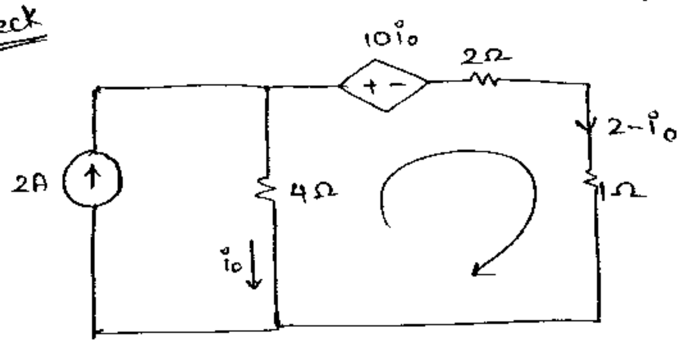
$R_N = \frac{V_{oc}}{I_{sc}} = \frac{-12}{+3} = -4\Omega$

N.E



$I_{1\Omega} = 3\left[\frac{-4}{-4+1}\right] = +4A$

check



$$-4i_0 + 10i_0 + 3(2-i_0) = 0$$

$$i_0 = -2A.$$

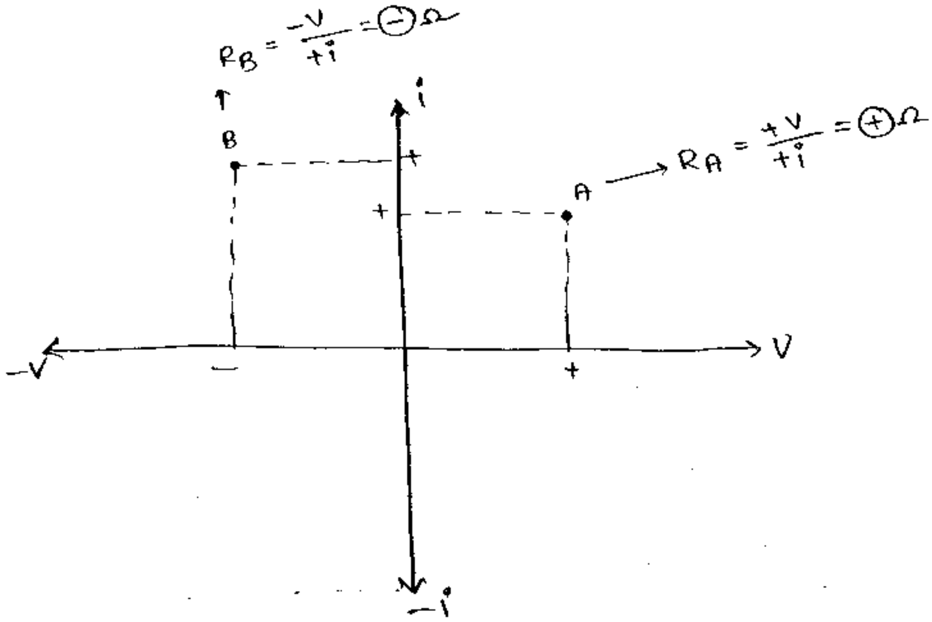
But

$$I_{1\Omega} = 2 - i_0$$

$$= 2-(-2)$$

$$= +4A$$

*



+ve feedback
ex: solarcell, Oscillator

Note: In the above problem R_{Th} or R_N is -ve, -ve Resistance is characteristic where to model active Regenerative N/w in electrical Engg. whose operating V-i characteristics appears in Q-II or Q-IV

Ex: High gain amplifiers, photo Transistors, Solar cells, +ve feedback N/w like Oscillators etc.

$\Longrightarrow$ However, -ve Resistance is a not a physically Realisable Quantity

Category III : problems with only dependent Sources.

Such N/ws donot work on their own as their is no Independent active element to drive them. In such N/w $V_{Th} = 0V$, $I_N = 0A$. However they have Resistance. This Resistance can be Indirectly determined by ohm's law but by Externally Exciting them where $R_{Th} = R_N = \frac{1V}{i_T}$ (or) $= \frac{V_T}{1A}$.

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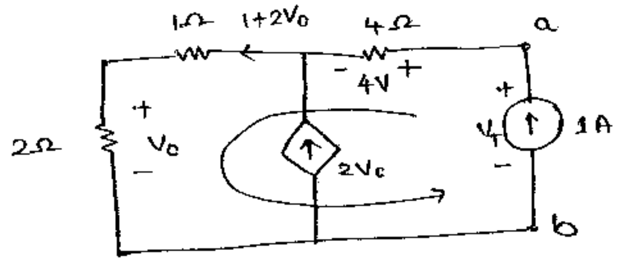
Gate:

Determine Thevenins & Nortons Equivalent across terminals ab.



$$-V_T + 4 + 3[1+2V_0] = 0$$

$$V_T = 7 + 6V_0 \longrightarrow (1)$$

$$V_0 = 2[1+2V_0]$$

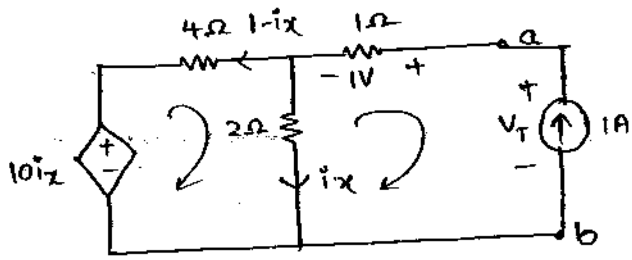
$$3V_0 = -2 \longrightarrow (2)$$

$$V_T = 7 + 6\left[\frac{-2}{3}\right] = 3V$$

$$R_{Th} = R_N = \frac{V_T}{1} = 3\Omega.$$

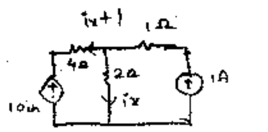
ISRO.

T. E across a-b



~~(a) 1V, 1Ω (b) 1V, 1Ω~~

(c) 0V, 1Ω ~~(d)~~ 0V, −1Ω



$-10i_x + 4(i_x+1) + 2i_x = 0$

$-14 i_x - 4 + 2i_x$

$3i_x = 4$

$i_x = \frac{-1}{3}$

$$-10i_x - 4[1 - i_x] + 2i_x = 0$$

$$i_x = -1$$

$$-2i_x - 1 + V_T = 0$$

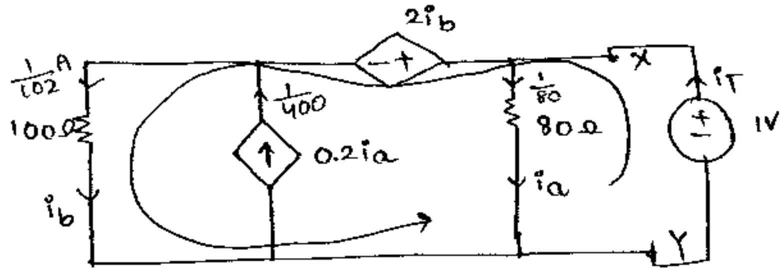
$$V_T = 1 + 2i_x$$

$$= 1 - 2$$

$$= -1$$

$$R_{Th} = \frac{V_T}{1A} = \frac{-1}{1A} = -1\Omega$$

Gate/2m. T.E & N.E across X – Y



KVL

$$-1+2i_b+100i_b+0$$

$$i_b = \frac{1}{102}$$

KCL

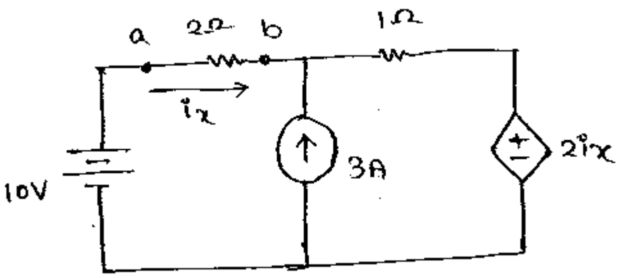
$$\frac{1}{102}+\frac{1}{80} = \frac{1}{400}+i_T$$

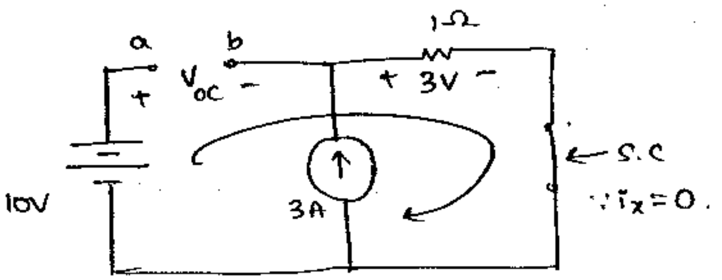
$$i_T = 0.0198\ A$$

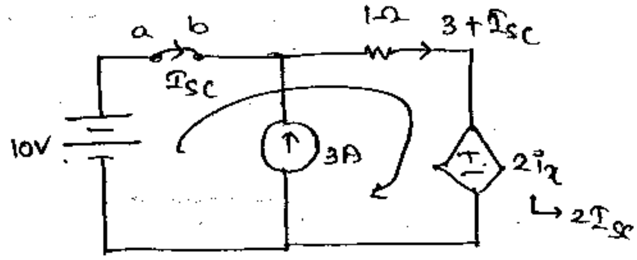
$$R_{Th} = R_N = \frac{1V}{i_T} = 50.5\,\Omega$$

* Special model.

Determine i_x by using Norton's Theorem.







$$-10+1[3+I_{sc}]+2I_{sc}=0$$

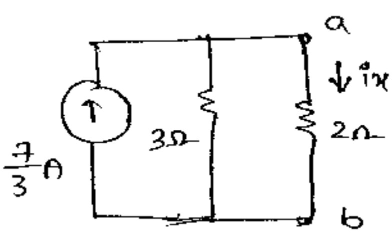
$$I_{sc} = \frac{7}{3}\ A$$

$$-10+V_{oc}+3=0$$

$$V_{oc} = 7V$$

N.C

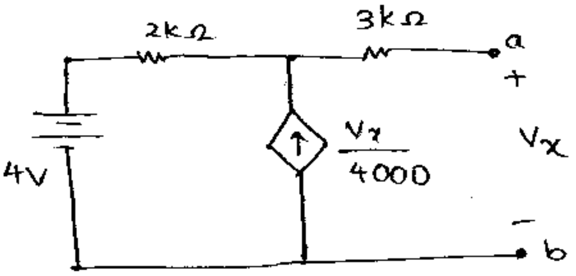
$$R_N = \frac{V_{oc}}{I_{sc}} = \frac{7}{7/3} = 3\Omega$$



$$i_x = \frac{7}{3}\left[\frac{3}{5}\right] = \frac{7}{5}\ A$$

Gat

T.E b/w a-b



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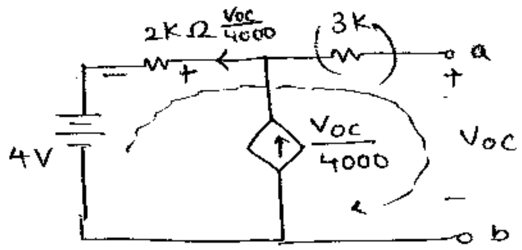
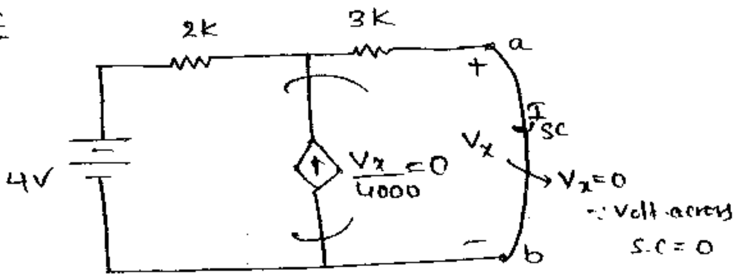
V_{oc}



$$-4-\left[\frac{V_{oc}}{4000}\right]\times 2000+V_{oc}=0$$

$$V_{oc}=8V.$$

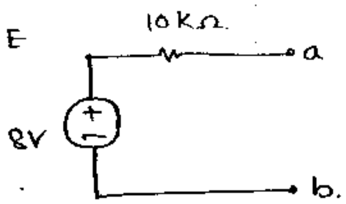
I_{sc}



$$I_{sc}=\frac{4}{5K}.$$

$$R_{Th}=\frac{V_{oc}}{I_{sc}}=\frac{8}{4/5K}=10k\Omega$$

T.E



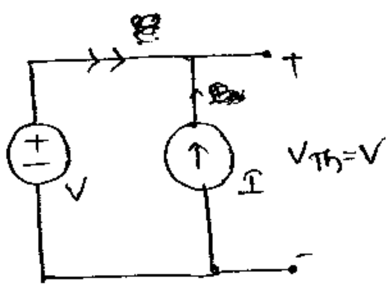
an Ideal 'V' source is in parallel to Ideal 'I' source across two terminals then This Combination has

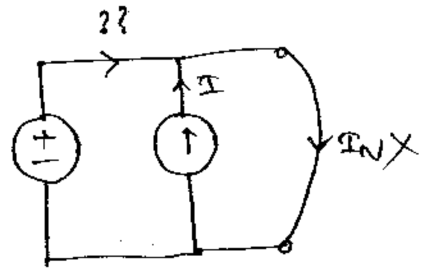
(a) Thevenins Eq. only

(b) Nortons Eq. only

(c) Both

(d) none



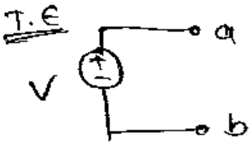


$R_{Th}=R_N=0\Omega$

I_N ✗

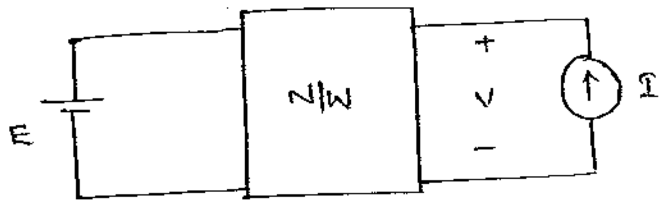
$V_{Th}=V$

T.E



* an Ideal 'I'-source ~~series~~ is in series with Ideal 'V' source this Combination has Norton's Equivalent only.

IES(O)

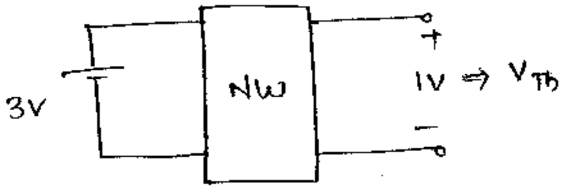


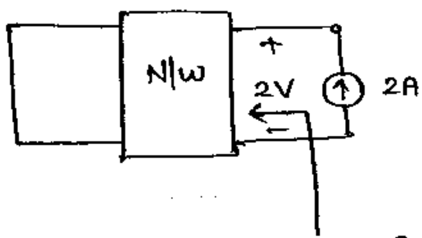
If

	E	V	I
1.	3V	1V	0A
2.	0V	2V	2 A

Now if $E = 30V$, & I is replaced by 2Ω

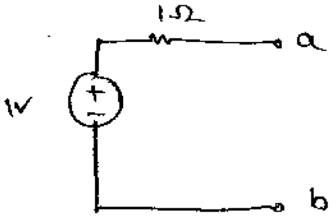
then $V =$ ______



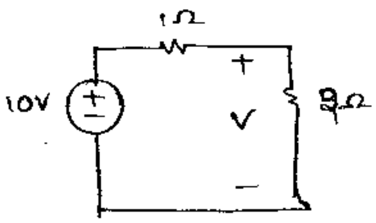


$R_{Th} = \frac{2}{2} = 1\Omega$

T.E for $E = 3V$



T.E = $E = 30V$

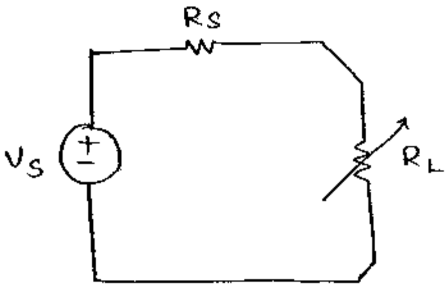


$V = 10\left[\frac{2}{3}\right]$

$= \frac{20}{3} V$

V Maximum power Transfer Theorem in D.C N/w:

In any linear active Bilateral N/w Consisting of No. of Energy sources with their Internal Resistances is driving an External load then Max. power is transferred to the load when Load Resistance is Equal to Source Resistance i.e., the Thevenins Equivalent Resistance Seen by the load.



$$I_L = \frac{V_S}{R_S+R_L}$$

$$P_L = I_L^2 R_L$$

$$= \left(\frac{V_S^2}{(R_S+R_L)^2}\right)\cdot R_L$$

$$\text{At } P_{Lmax},\ \frac{dP_L}{dR_L} = 0$$

$$\Rightarrow V_S^2\left[\frac{(R_S+R_L)^2(1)-(R_L)(2)(R_S+R_L)}{(R_S+R_L)^4}\right] = 0$$

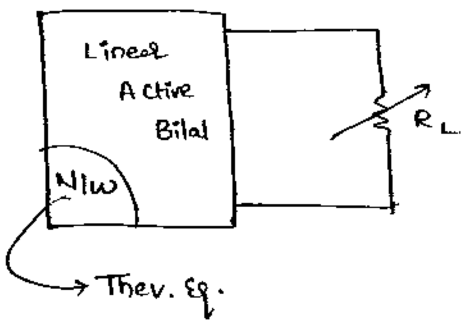
$$2R_L(R_S+R_L) = (R_S+R_L)^2$$

$$2R_L = R_S+R_L$$

$$R_L = R_S$$

$$P_{Lmax} = \frac{V_S^2}{4R_S}\ W$$

In General:



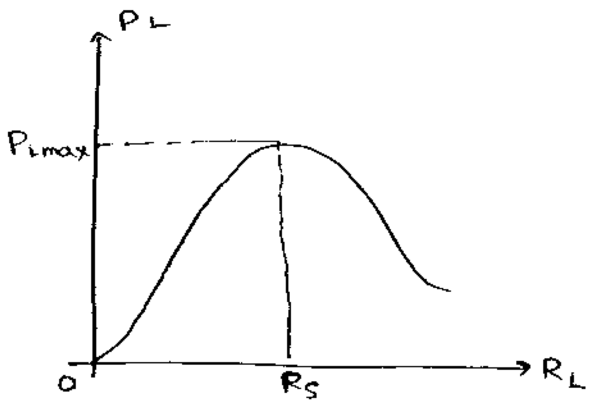
→ Thev. Eq.

Then for

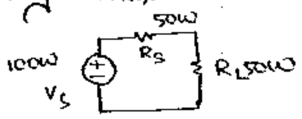
$$P_{max} \Rightarrow R_L = R_{Th}$$

$$P_{max} = \frac{[V_{Th}]^2}{4R_{Th}}\ W$$

IES



IES(O) During P_{max} transfer to the Load, output efficiency is <u>50%</u>



$\% \eta = \frac{50}{100} \times 100\% = 50\%$

IES(O) During P_{max} transfer to the Load, 50% % of Supply voltage will appear across the load.

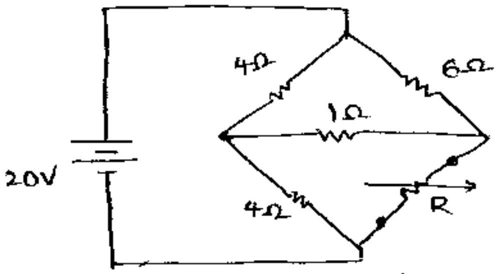
Applications:

(1) Audio Speaker Design

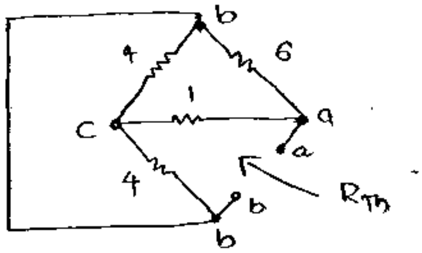
(2) Automobile lightning

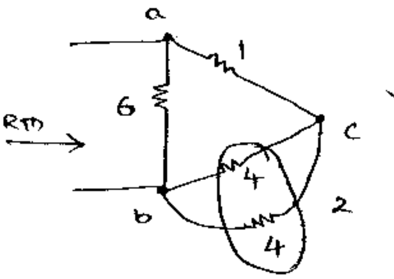
(3) Cascaded Connection of multistage amplifier with Impedence matching.

Q for what value of Resistance 'R' max. power is transferred to it



$\Rightarrow$



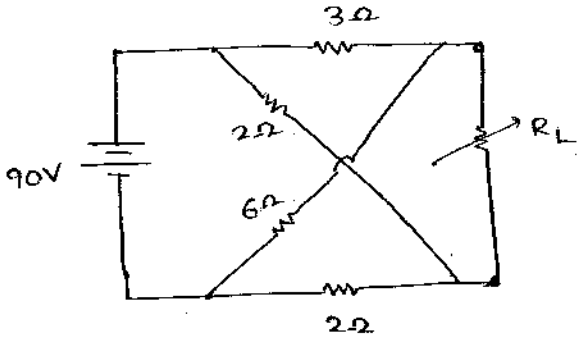


$R_{Th} = R = 3 \| 6$

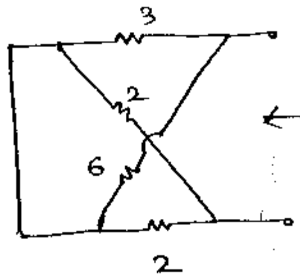
$= 2\Omega$

gate 2007

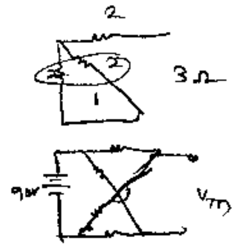
Q



What is the max power Transferred to th load



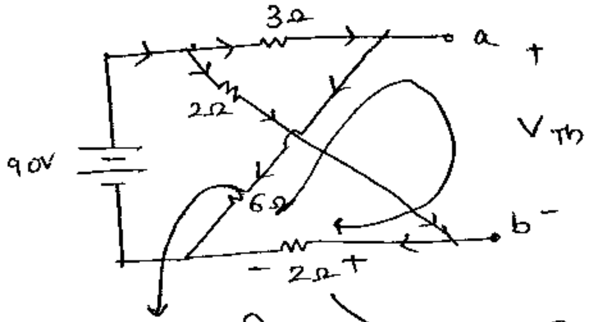
$\leftarrow R_{Th} = 3\Omega$



$\rightarrow \quad R_L = R_{Th} = [3 \| 6] + [2 \| 2] = 3\Omega$

$\rightarrow$ V_{Th}

↳ Volt. Div. Rule + KVL



$90\left[\frac{6}{2+6}\right]$ $\quad 90\left[\frac{2}{2+2}\right]$

$$+V_{Th} + \left[90\left(\frac{2}{2+2}\right) - 90\left(\frac{6}{6+3}\right)\right] = 0$$

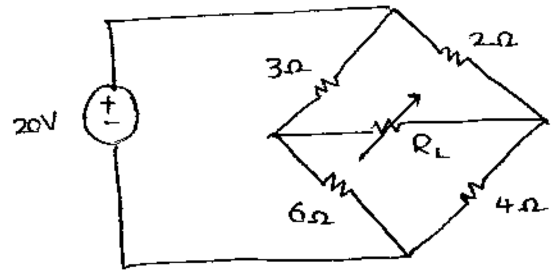
$$V_{Th} = 60 - 45$$

$$= 15V$$

$$P_{max} = \frac{[V_{Th}]^2}{4R_{Th}}$$

$$= \frac{(15)(15)}{4 \times (7)} = 18.75\ W$$

IES(0) What is the max power Transferred to the load.



∵ Bridge is Balanced

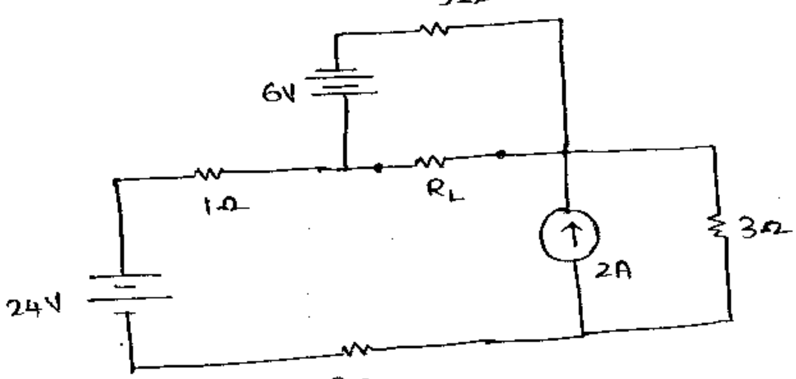
Current can never flow through R_L for any value.

$\therefore P_{max} = 0W.$

In a Balance Bridge V_{Th} across Cross arm element is $\underline{\underline{0V}}$.

Gate IM

What is the max power Transferred to the load.

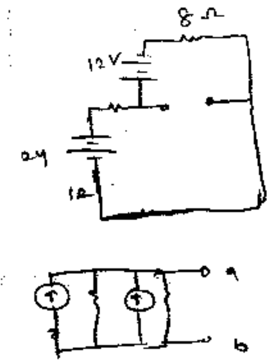


$R_{Th} = (1+2+3) \parallel 3\Omega$

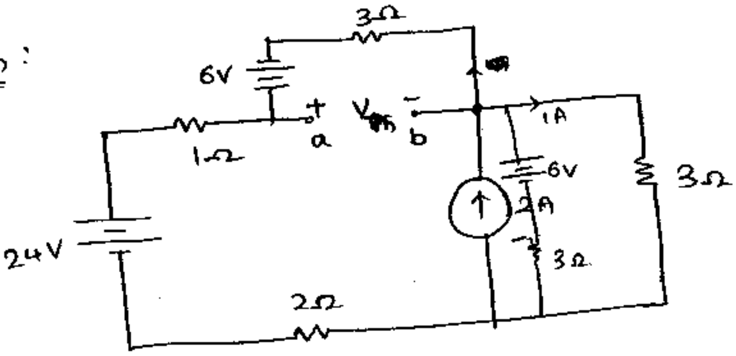
6//1

$= 6\Omega \parallel 3\Omega$

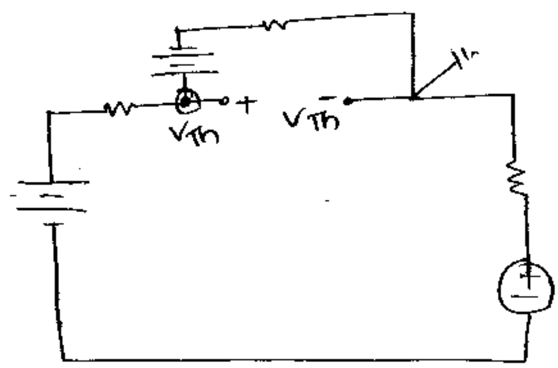
$= 2\Omega$.



$\underline{\underline{V_{Th}}}$:



⇓



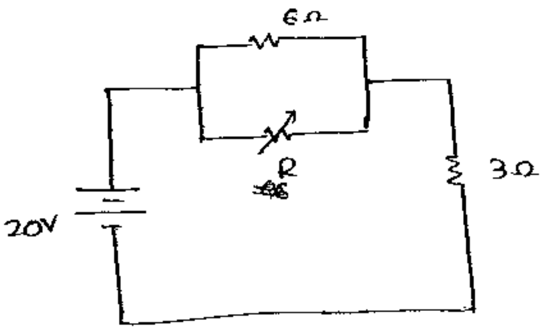
$\underline{\underline{V_{Th}}}$
└→ S.T.T + Nodal

$$\frac{(V_{Th}-24+6)}{6} + \frac{(V_{Th}-6)}{3}$$

$$P_{max} = \frac{[V_{Th}]^2}{4R_{Th}} = \frac{(10)^2}{4(2)} = 12.5W.$$

200

Q for What value of Resistance 'R' max power is Transferred to 3Ω Resistance.



~~(a) 2Ω~~
(b) 3Ω
(c) 6Ω
~~(d) infinity.~~

(a) 2Ω
(b) 3Ω
(c) 6Ω
(d) zero

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The Question has no Relation with original statement of Pmax theorem as here Source Side Resistance is being Varied.

When $R = 6\Omega \Rightarrow$ current through $3\Omega \Rightarrow \frac{20}{6} \Rightarrow P_{max} = \left(\frac{20}{6}\right)^2 \times 3\Omega$

$R = 3\Omega \Rightarrow$ " " $3\Omega \Rightarrow \frac{20}{5}$ $= \left(\frac{20}{5}\right)^2 \times 3\Omega$

~~$R = 2\Omega$~~ $\Rightarrow$ " " $3\Omega \Rightarrow \frac{20}{4.5}$ $= \left(\frac{20}{4.5}\right)^2 \times 3\Omega$ max

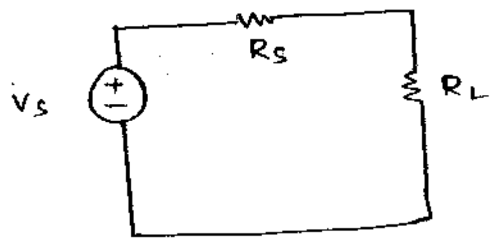
When $\underline{R = 0\Omega} \Rightarrow$ " " $3\Omega \Rightarrow \frac{20}{3} \Rightarrow P_{max} = \left(\frac{20}{3}\right)^2 \times 3\Omega$

H.W

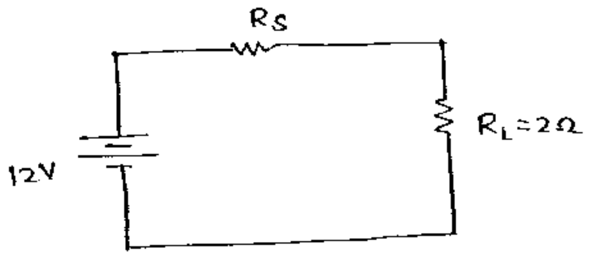
Q Derive mathematically the condition Req. to maximise power in the load by Varying Source Side Resistance.

$\frac{dP_L}{dR_s}$

$\boxed{R_s = 0}$



IES(a) What is the max power Transferred to the load.



If $(1 \le R_s \le 10)\Omega$

$\left(\frac{12}{1+2}\right)^2 \cdot 2$

$16 \times 2 = 32\,W.$

for P_{max} in R_L

R_s should be min (i.e., ∵ we are varying R_s)

i.e. $R_s = 1\,\Omega$

$$P_{Lmax} = (I_L)^2 R_L$$

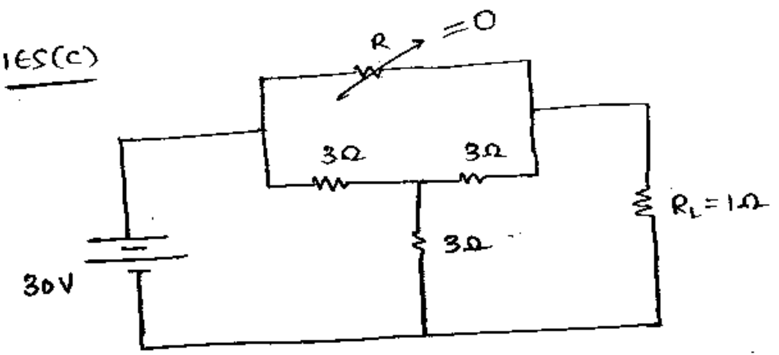
$$= \left(\frac{12}{1+2}\right)^2 \cdot (2)$$

$$= 16 \times 2$$

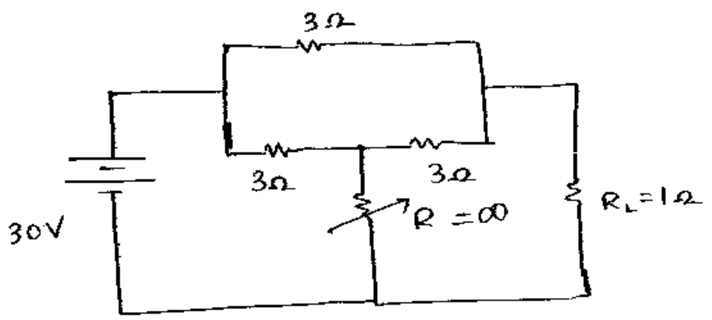
$$= 32\,W$$

for the following ckts shown determine the value of Resistance 'R' for which max Power Transferred to the load.

IES(c)



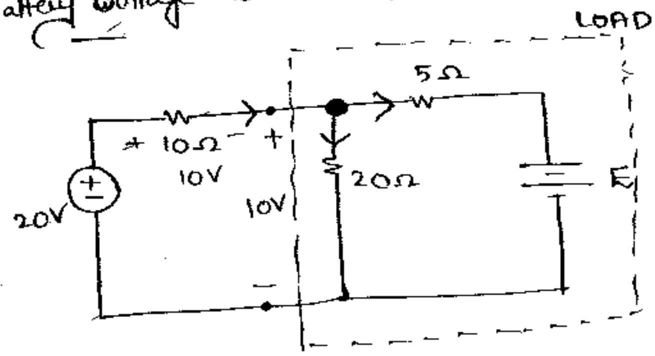
R=0 will make High power..

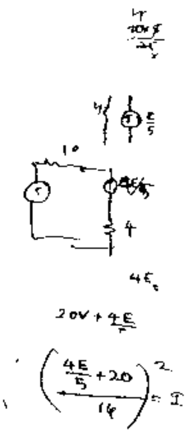


R=∞ will make Highest power.

68

Q the ckt represent an approx. DC Equivalent of a Battery charger for what value of Battery woltage 'E' max power is Transferred to the entire Load.





P_{max} occurs in load when R_s is Equal to Resistance of total load

Including the effect of 'E' Battery Voltage.

$R_S = (R_{LOAD})$ including Battery voltage 'E'

then if $R_S = R_{Load}$ then total Voltage appears. half across R_s & R_{Load}.

KCL

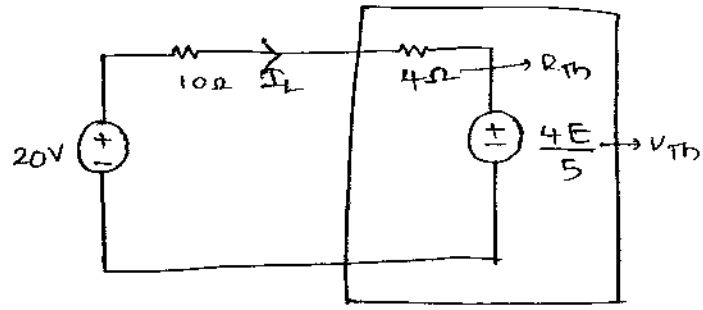
$$\frac{20-10}{10} = \frac{10}{20} + \frac{(10-E)}{5}$$

$$1 = \frac{1}{2} + \frac{10-E}{5}$$

$$\frac{10-E}{5} = \frac{1}{2}$$

$$E = 10 - \frac{5}{2} = 7.5$$

Exact method:



$$I_L = \frac{20 - \frac{4E}{5}}{14} = \frac{100-4E}{70} = \left[\frac{50-2E}{35}\right]$$

$$P_L = I_L^2(4) + I_L\left(\frac{4E}{5}\right)$$

$$P_L = \left[\frac{50-2E}{35}\right]^2 4 + \left[\frac{50-2E}{35}\right]\left[\frac{4E}{5}\right]$$

$$P_L = \frac{4}{35}\left[50-2E\right]\left[50+5E\right]$$

$$P_L = \frac{40}{(35)^2}(25-E)(10+E)$$

$$P_L = \frac{40}{(35)^2}\left[-E^2+15E+250\right]$$

for P_{Lmax} $\quad \frac{dP_L}{dE} = 0$

$$\frac{40}{(35)^2}\left[-2E+15\right] = 0$$

$$2E = 15 \longrightarrow E = 7.5V$$

Q The static V-I characteristics of N/w shown in figure (a) are plotted in fig(b) What is max power that can be drawn from the N/w.

69

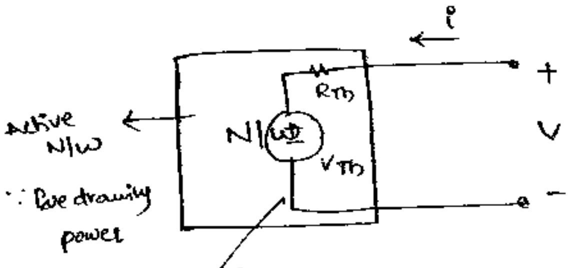
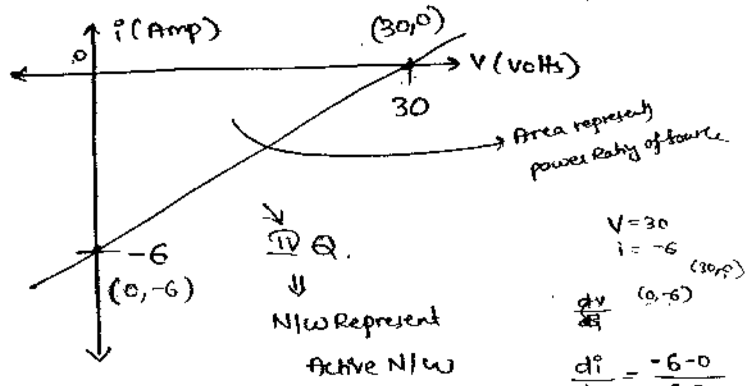


fig (a)



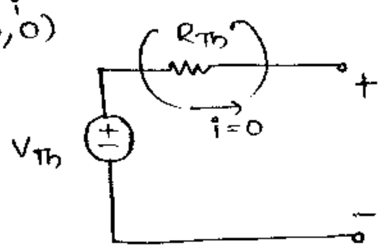
$V=30$
$i=-6$
(30,0)
(0,−6)

$$\frac{di}{dv} = \frac{-6-0}{0-30}$$

$$\frac{di}{dv} = \frac{1}{5}$$

assume N/w conv. Thevenin's ckt.

V i
(30,0)



$V_{Th} = 30V$

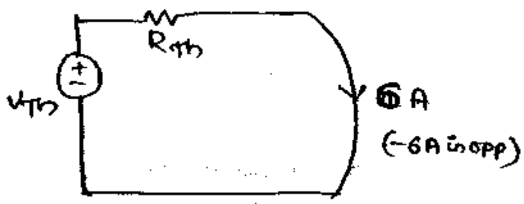
⇒ When $i=0$

R_{Th} = O.C

∴ Voltage across terminals $= V_{Th} = 30V$. ⟶(1)

(0,−6)

when $V=0$, $i=-6A$.



$$V_{Th} = 6R_{Th}$$

$$R_{Th} = \frac{V_{Th}}{6} = \frac{30}{6} = 5\Omega$$

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{30\times 30}{4\times 5} = 45W.$$

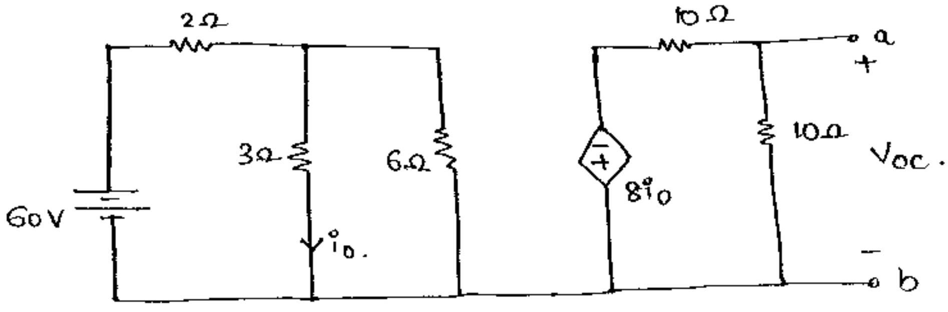
(or)

$$P_S = \underbrace{\frac{1}{2}(6)(30)}_{Area} = 90W. (100\%)$$

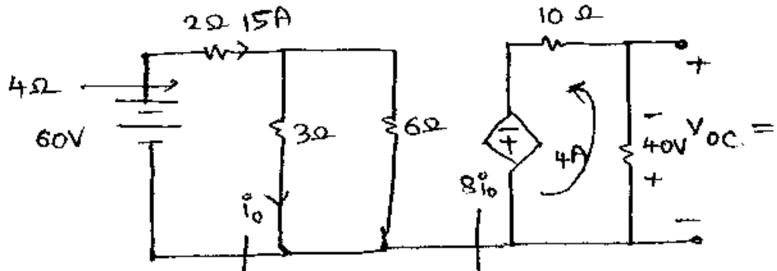
at P_{max}

$$\%\eta = 50\% \Rightarrow P_{S\,max} = 45W\ (50\%)$$

What Resistance Connected b/w terminals AB will draw max power from the N/w & also find P_{max}.



$\underline{V_{oc}}$



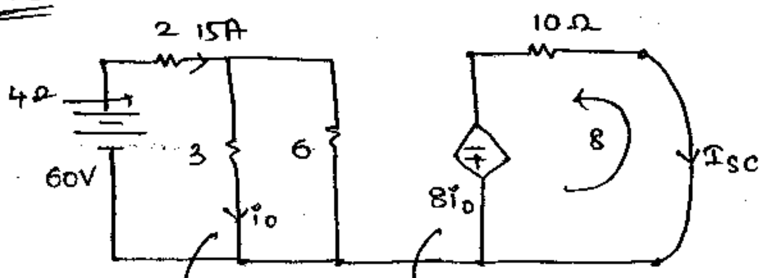
$V_{oc} = \underline{-40V}$

$8i_0 = 80V$.

$i_0 = 15\left[\frac{6}{9}\right]$

$= 10A$

$\underline{I_{sc}}$



$I_{sc} = -8A$

$i_0 = 10A$

$80V$.

$$R_{ab} = R_{th} = \frac{V_{oc}}{I_{sc}}$$

$$= \frac{-40}{-8} \Big\} \text{III Q.}$$

$$= +5\Omega$$

→ sink

$$P_{max} = \frac{[V_{th}]^2}{4R_{th}} = \frac{40 \times 40}{4 \times 5}$$

$$= 80W.$$

VI Tellegan's Theorem:

This theorem is about Clerification of law of Conservation of Energy. However in any linear Time Invariant N/w or System we can also Verify this theorem by Measuring power at an Instant. 70

$$\boxed{\because\ E = \int P\,dt\ .\ J}$$

So, Here in this theorem we need to mathematically verify

$$\sum_{k=1}^{b} V_k . I_k = 0$$

b = no. of branches in the N/w.

i.e.,
$$\sum V.I \Big|_{\text{Sources}} = \sum V.I \Big|_{\text{Sinks}}$$

$$P_{\text{delivered by Sources}} = P_{\text{absorbed by Sinks}}$$

Note: (1) Tellegans theorem is the only theorem in elec. ckt analysis Which is also valid for any nonlinear element or Network.

(2) While applying this theorem the topological arrangement of N/w shouldn't be altered. However we can still verify Tellegan's theorem independently ~~for the with~~ SubCircuits involved either before reduction or after reduction in the N/w.

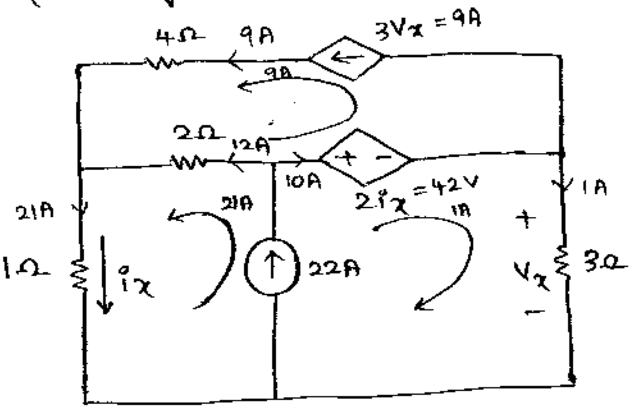
(3) Tellegan's theorem Can also be verified for any LTI N/w but for Time Variance in the input Excitations Where we can mathematically prove

$$\sum_{k=1}^{b} V_k(t_1) I_k(t_2) = \sum_{k=1}^{b} V_k(t_2) I_k(t_1)$$

t_1 & t_2 are two different Instances in time ~~for~~ measuring Voltages & Currents in N/w

$b \rightarrow$ no. of branches in N/w.

Q. Verify Tellegans theorem for the ckt shown below.



$1(i_1)+(i_1-i_3)2+2i_x+3i_2=0$

Mesh

$$i_1+2[i_1-i_3]+2i_x+3i_2=0 \longrightarrow (1)$$

$$-i_1+i_2=22 \longrightarrow (2)$$

$$i_3=-3V_x \longrightarrow (3)$$

$$i_x=-i_1 \longrightarrow (4)$$

$$V_x=3i_2 \longrightarrow (5)$$

Solve

$$\begin{cases} i_1+3i_2-2i_3=0 \\ -i_1+i_2=22 \end{cases}$$

$$9i_2+i_3=0$$

$$4i_2-2i_3=22$$

$\times 2$

$$18i_2+2i_3=0$$

$$\underline{\underline{i_2=1\,A}} \qquad V_x=3i_2$$

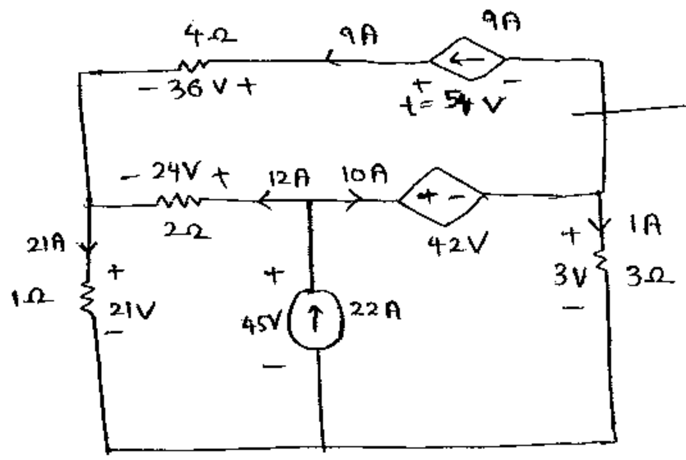
$$V_x=\underline{\underline{3\,V}}$$

$$i_3=-3V_x$$

$$=\underline{\underline{-9\,A}}$$

$$i_1=i_2-22=\underline{\underline{-21\,A}}$$

$$i_x=\underline{\underline{+21\,A}}$$



let t be volt. across 9A dep. source.

KVL → $-42+24-36+t=0$

$t = 54V$

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$\sum P_{deli} = 45(22) + (54)(9) = \underline{1476W}$ ✓

$\sum P_{abs} = (21)(21) + (24)(12) + (3)(1) + (42)(10) + (36)(9) = \underline{1476W}$ ✓

1ES(O)

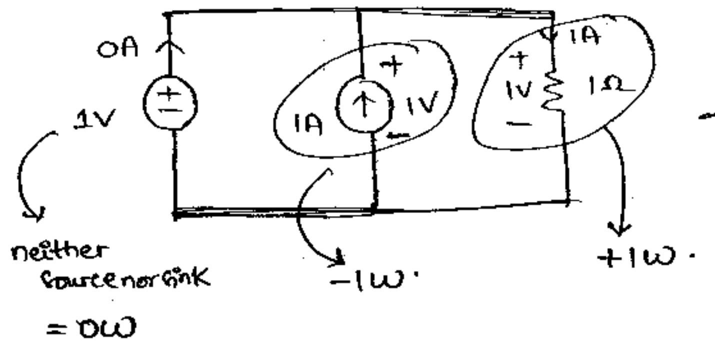
The power absorbed by each element is order is ______

(a) 1W, 0W, −1W

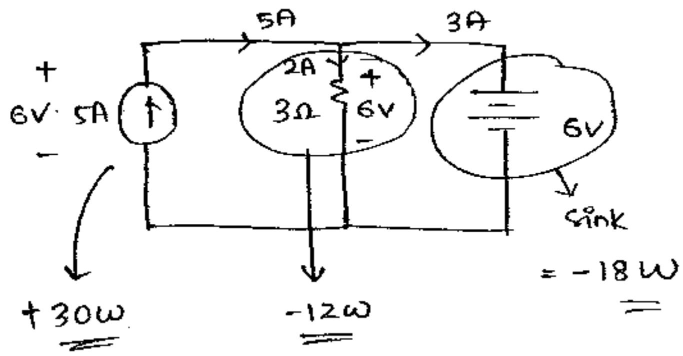
(b) −1W, 0W, 1W

(c) 0W, −1W, 1W

(d) 0W, 1W, −1W

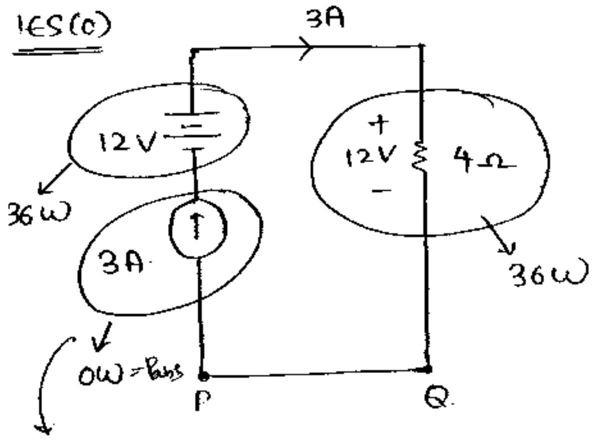


The power delivered by each element is order is ______



$\underline{\sum P = 0}$

IES(C)



neither source not sink.

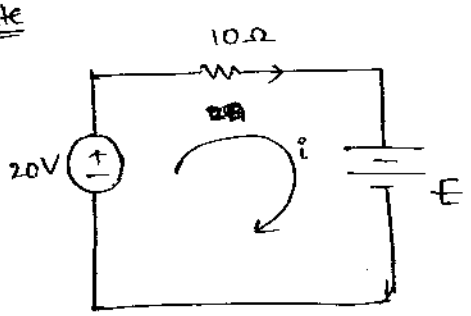
The power absorbed by each element Traveling from CW from P to Q in order is (virtual travelling)

OW, −36W, +36W
(I) source. (V.) source. (R) sink

$\sum P = 0$

current source to any element is Redundant

Gate



If the power absorbed by the battery is 10W then determine its Voltag E.

$E.i = 10W$ (given)

By Tellegans theorem

$P_{deli} = P_{abs}$.

$20(i) = i^2(10) + E.i$

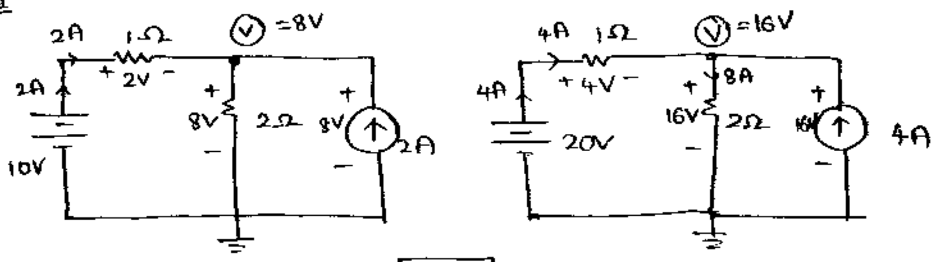
$20i = 10i^2 + 10$ → gets satisfied if $i = 1$

$\therefore$ $i = 1$

$E(1A) = 10W$

$E = 10V$

Q N/w at time $-t_1$ N/w at time $-t_2$



$\boxed{b=4}$

Verify Tellegan's theorem for LTI N/w shown but for Time Variance is the i/p Excitations referred at two different instances in time as shown

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

$$V=8V$$

We need to prove

$$\sum_{K=1}^{4} V_K(t_1)\,I_K(t_2)=\sum_{K=1}^{4} V_K(t_2)\,I_K(t_1)$$

L.H.S,, $\overset{t_1}{(10)}\overset{t_2}{(4)}+\overset{t_1}{(2)}\overset{t_2}{(4)}+\overset{t_1}{(8)}\overset{t_2}{(8)}+\overset{t_1}{(8)}\overset{t_2}{(4)} = 144W$

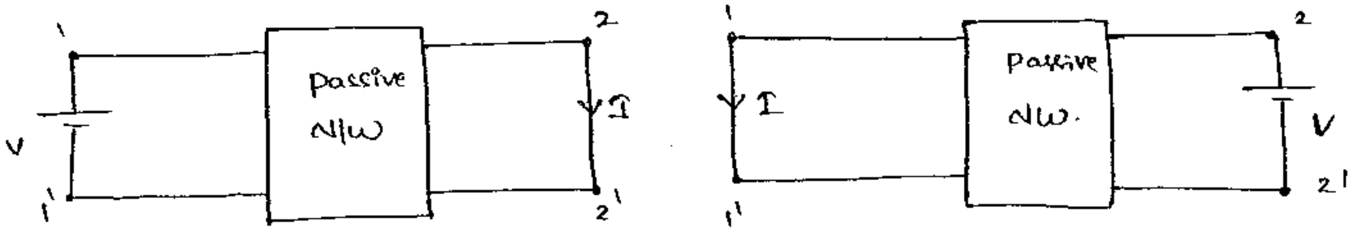
R.H.S,, $\underbrace{\overset{t_2}{(20)}\overset{t_1}{(2)}}_{\text{V source branch}}+\underbrace{(4)(2)}_{1\Omega}+\underbrace{(16)(4)}_{2\Omega}+\underbrace{(16)(2)}_{\text{C.Source}} = 144W$

**

VII Resiprocity Theorem :

In any linear passive Bilateral N/w the Ratio of Response to Excitation Remains Constant even if the positions of Source & load are Interchanged

fig (a) fig (b)



If N/w is Reciprocal, then

$$\boxed{\frac{I}{V}=\text{Constant}} \xrightarrow[\text{Homogenity}]{\text{also by}} \boxed{\frac{I_1}{V_1}=\frac{I_2}{V_2}}$$

Note: 1. This theorem is Valid for N/ws Excited with only a single source
2. This theorem is Not Valid for N/ws with dependent Sources.
3. While writing the Reciprocal N/w of a given N/w Ideal voltage source must be Connected in Series ~~do~~ the Target branch & Ideal current source must be connected parallel to the Target branch.
4. any linear passive bilateral N/w is by default Reciprocal. Since, Reciprocity means passivity.

$$\text{Reciprocity} \rightleftharpoons \text{passivity}.$$

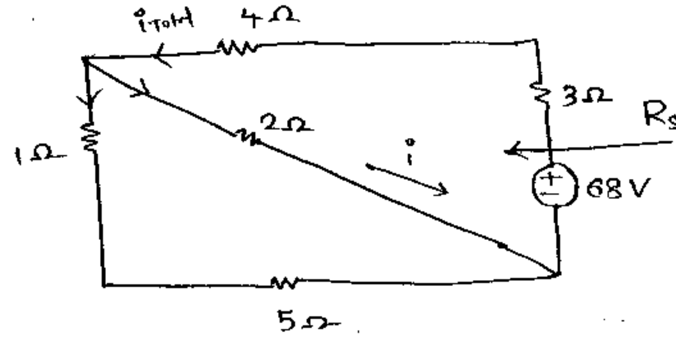
5. The principle of Reciprocity Can be Verified for any passive N/w as a Ratio b/w Response to Excitation being Constant by Considering any parameter as i/p or o/p.

applications:
Ideally our P.S Tr. line N/w & Telephone line in Communication system are Reciprocal where In terms of Transmission line parameters the following Condition Exists.

$$\boxed{AD-BC=1.}$$

V source parallel to any element is Redundant.

Q verify Reciprocity for ckt shown below by determining Current "i"



$$R_{seen} = 7+[2\|6]$$

$$i_{Total} = \frac{68}{7+[2\|6]}$$

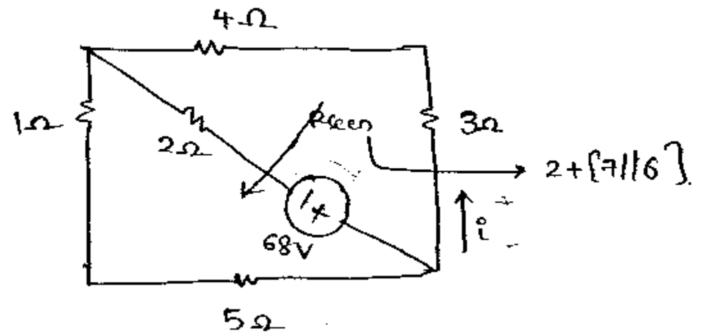
$$i_{2\Omega} = i = i_{Total} \times \left[\frac{6}{2+6}\right]$$

$$i = \frac{68}{7+[2\|6]} \times \frac{6}{8}$$

$$= \frac{68}{7+\frac{12}{8}} \times \frac{6}{8} = \frac{\cancel{68}}{\frac{\cancel{68}}{\cancel{8}}} \times \frac{6}{\cancel{8}}$$

$$i = 6A$$

Reciprocal N/w.



$$i_{Total} = \frac{68}{2+[7//6]}$$

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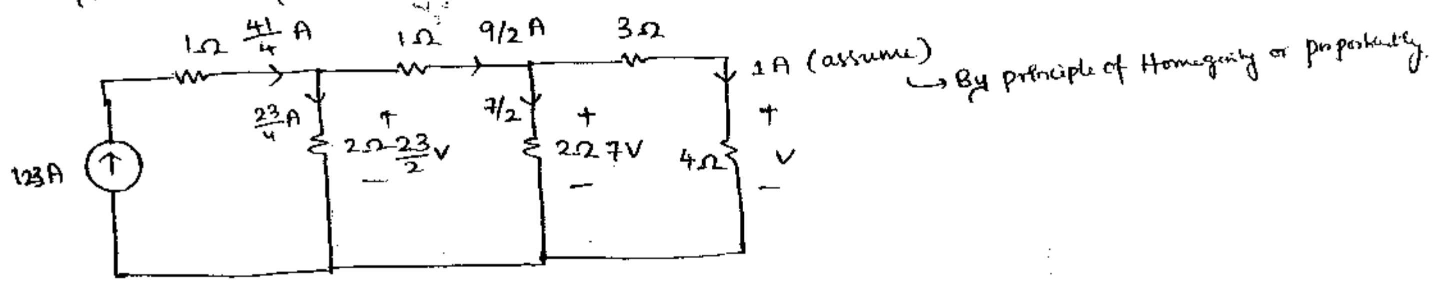
$$i_{3\Omega} = i = \frac{68}{2+42} \quad i_{Total} \times \frac{6}{13}$$

$$= \left[\frac{68}{2+\frac{42}{13}}\right] \times \frac{6}{13}$$

$$= \frac{\cancel{68}}{\frac{\cancel{68}}{\cancel{13}}} \times \frac{6}{\cancel{13}}$$

$$i = 6A$$

Verify Reciprocity principle for ckt shown by determining Voltage V



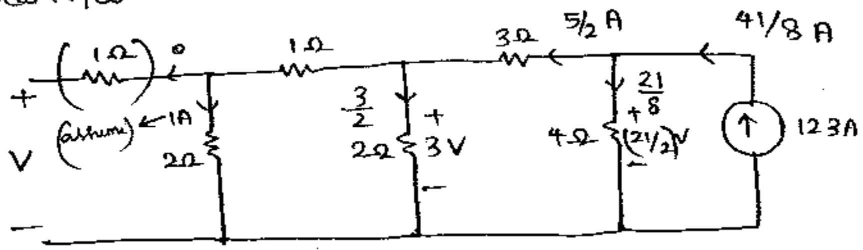
$$\frac{41}{4}A \longrightarrow 1A$$

$$123\,A \longrightarrow ?\quad i = \frac{123}{\frac{41}{4}} = 12A.$$

But

$$V = i[4]$$
$$= 12(4)$$
$$V = 48V$$

Reciprocal N/w



$$\frac{41}{8}A \longrightarrow 1A$$

$$123\,A \longrightarrow i = \frac{123}{\frac{41}{8}}$$

$$= 24\,A$$

$$V = i[2]$$
$$= 24[2]$$
$$= 48 \text{ volts.}$$

Q Use the data given in fig.(a) to find Current "i" in fig (b).

fig (a)

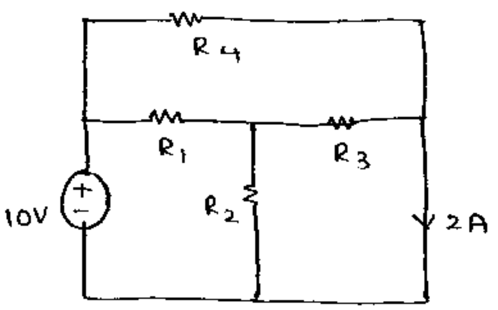
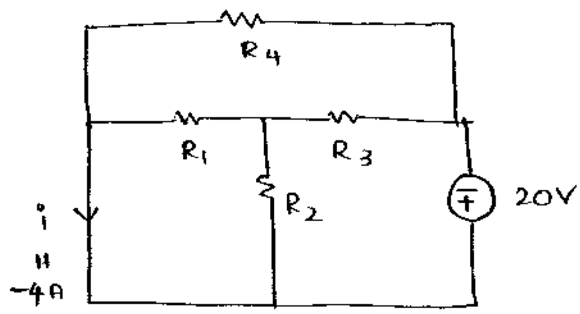
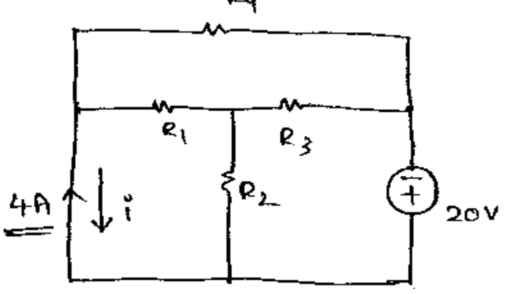


fig (b)



⇓

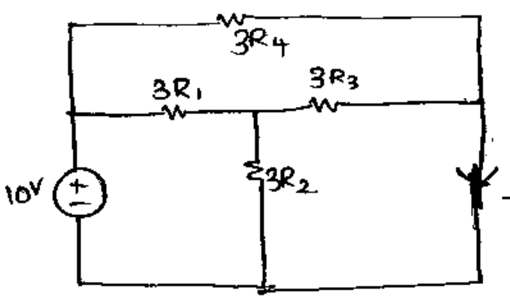
Reciprocal N/w



$\Rightarrow$ $i = -4A$

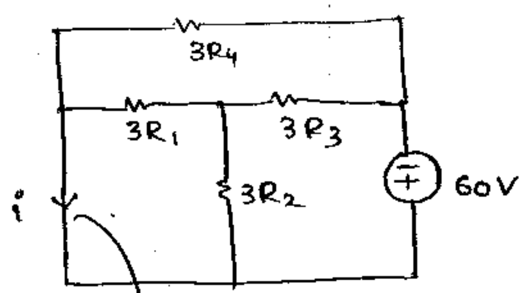
Q Use the data given in fig (a) to find curnt "(i)" in fig (b)

fig (a)

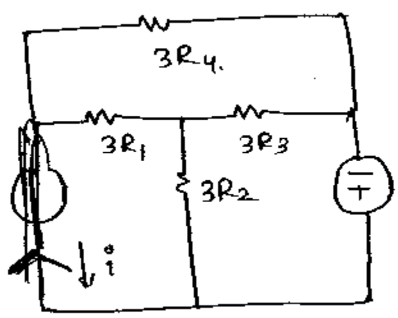


$\frac{2A}{3}$ ⇓ $\frac{2}{3}$A. } By Thev. eq. if R↑ by 3 time I↓ by 3 times

fig (b)



$i = -4A$

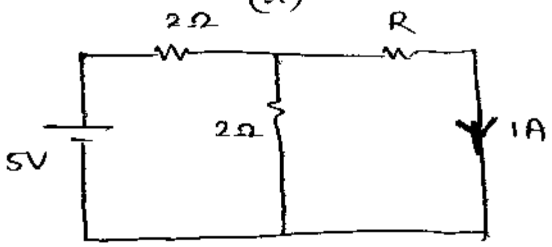


10V × 6 = 60 V

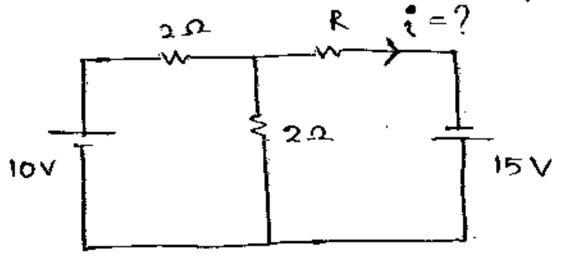
$6 \times \frac{2}{3}$ A = 4A.

Q use data given in fig (a) to find 'i' in fig (b)

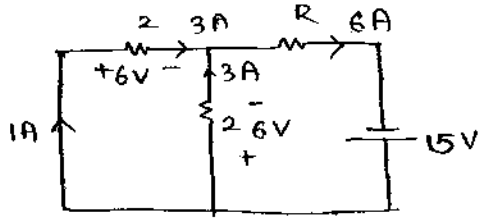
(a)



(b)



⇓

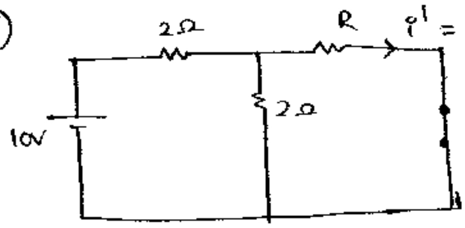


⇓

apply S.P.T

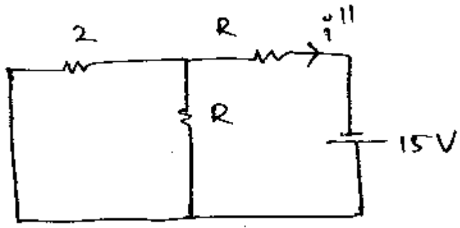
(∵ 5V → 1A
10V → 2A)

(I)



$\Rightarrow i = 2A$

(II)



$i'' = 6A$

By applying (1) SPT
(2) R.T.
(3) H.R
(4) KCL

$i = i' + i''$

$= 2 + 6 = 8A.$

Q find 'i' in fig (b) by using fig (a) data & verify Result by using Tellegan's Theorem

fig (a) → t_1

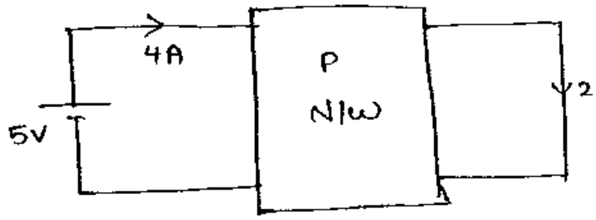
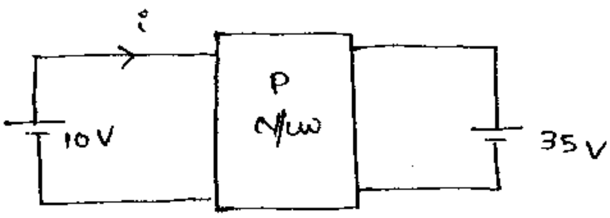
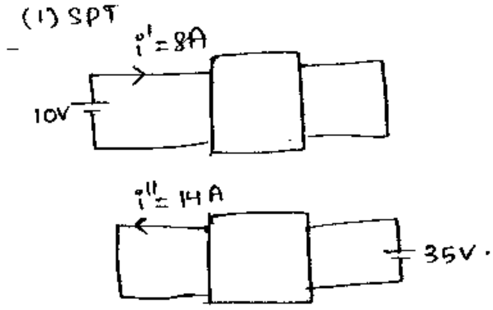
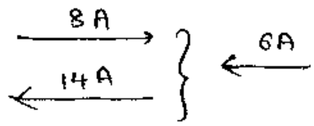


fig (b) → t_2



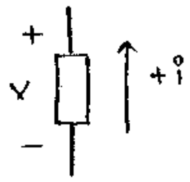
(1) SPT





⇒ i = −6A

assume +ve Notation



By Tellegan's

$$\sum_{K=1}^{2} V_K(t_1)\, I_K(t_2) = \sum_{K=1}^{2} V_K(t_2)\, I_K(t_1)$$

$$(+5)(+i) + (0)(\underset{\substack{\uparrow \\ \text{unknown}}}{X}) = (+10)(+4) + (35)(-2)$$

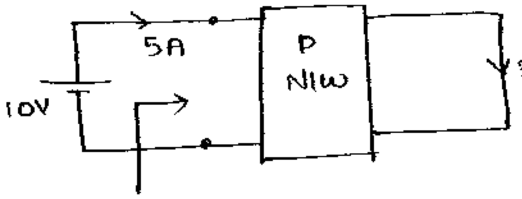
$$5i = 40 - 70$$

$$5i = -30$$

$$i = -6A$$

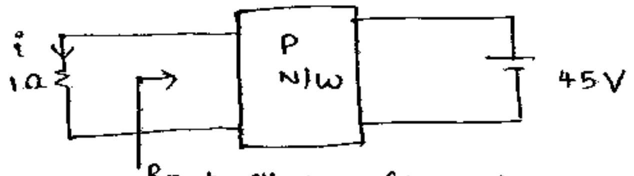
Q Use the data given in fig(a) to find current 'i' in fig(b)

fig(a) $\longrightarrow t_1$



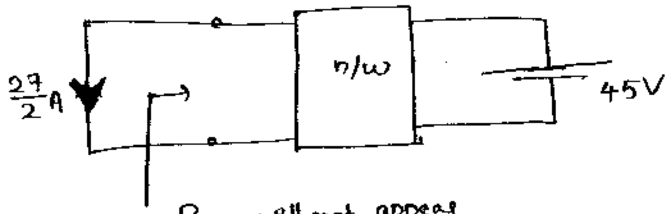
$R_{port} = \frac{10}{5} = 2\,\Omega.$

fig(b) $\longrightarrow t_2$



R_{port} will appear ($\because$ not s.c)

Without 1Ω

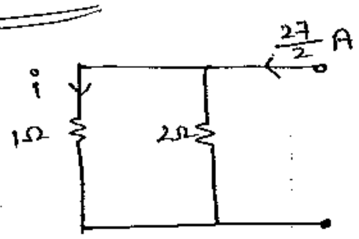


R_{port} will not appear

$\because$ s.c across N/w is Redundant.

s.c Bipass the port N/w & draws full current.

With 1Ω



$$i = \frac{27}{2}\left(\frac{2}{3}\right) = 9A$$

(or)

By Tellegans.

$$\sum_{K=1}^{2} V_K(t_1)\, I_K(t_2) = \sum_{K=1}^{2} V_K(t_2)\, I_K(t_1)$$

$$(10)(-i) + (0)\cdot(\underset{\substack{\uparrow \\ \text{(unknow)}}}{x}) = (\underset{\text{volts}}{i})(+5A) + (45)(-3)$$

$$-10i = 5i - 135$$

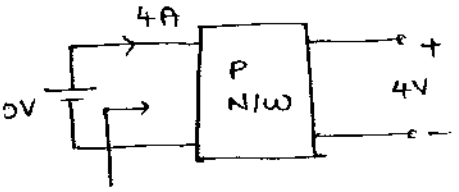
$$15i = 135$$

$$\underline{i = 9A}$$

IES(0)

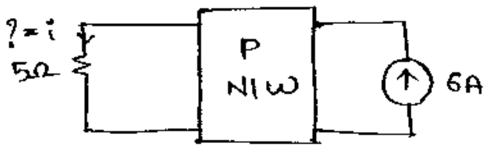
use data in fig (a) to find 'i' in fig (b)

fig (a)



$R_{port} = 2.5\Omega$

fig (b)



from Note (5)

Ratio. $\frac{\text{Excitation}}{\text{Respons}}$ = same.

$10V \longrightarrow 4V$

$6A \longrightarrow ?\ i = \frac{6\times 4}{10}$

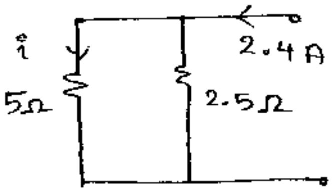
$i = 2.4A$.

Without 5Ω

$10V \longrightarrow 4V$

$6A \longrightarrow i = \frac{6\times 4}{10}$

$i = 2.4A$.



$i = 2.4\left[\frac{2.5}{7.5}\right] = \underline{\underline{0.8A}}$

By tellegan.

$$\sum_{k=1}^{2} V_k(t_1) I_k(t_2) = \sum_{k=1}^{2} V_k(t_2) I_k(t_1)$$

$$(10)(-i) + (4)(6) = (5i)(4) + (x)(0)$$

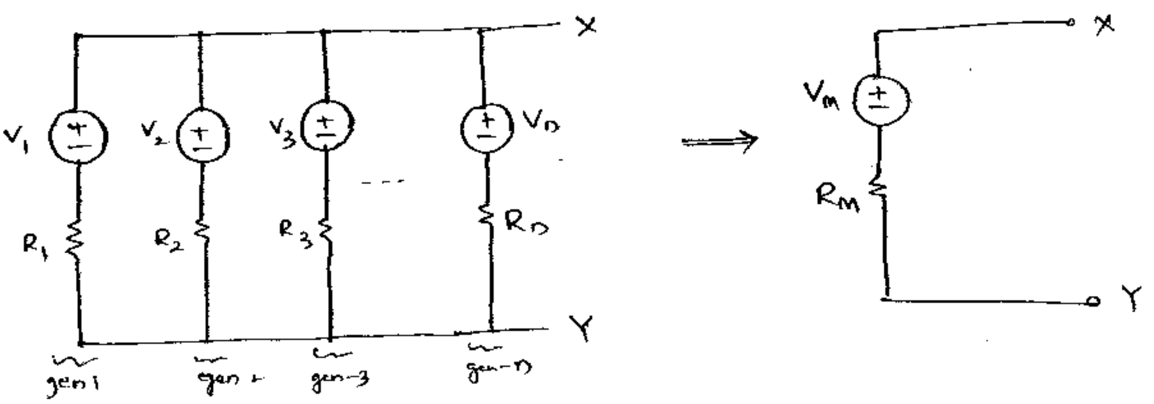
unknown.

$$-10i + 24 = 20i$$

$$30i = 24$$

$$i = 0.8A$$

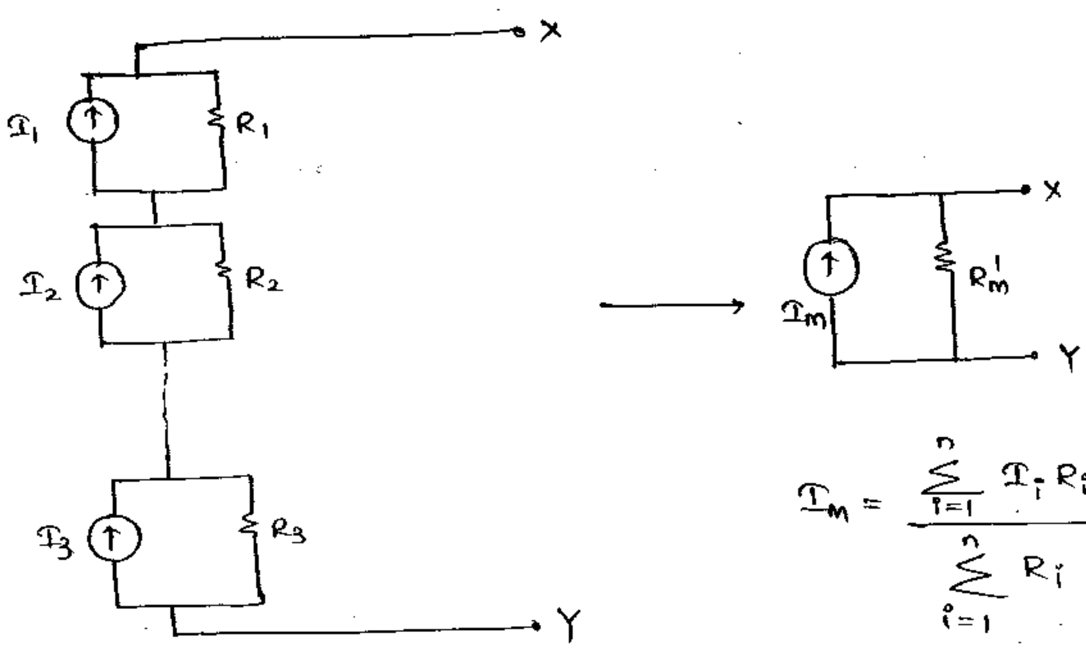
VIII. Millimans's Theorem: (or) parallel Generator Theorem.



$$V_M = \frac{\sum_{i=1}^{n} \frac{V_i}{R_i}}{\sum_{i=1}^{n} \frac{1}{R_i}} = \frac{\sum_{i=1}^{n} V_i G_i}{\sum_{i=1}^{n} G_i}$$

$$R_M = \frac{1}{\sum_{i=1}^{n} \frac{1}{R_i}} = \frac{1}{\sum_{i=1}^{n} G_i}$$

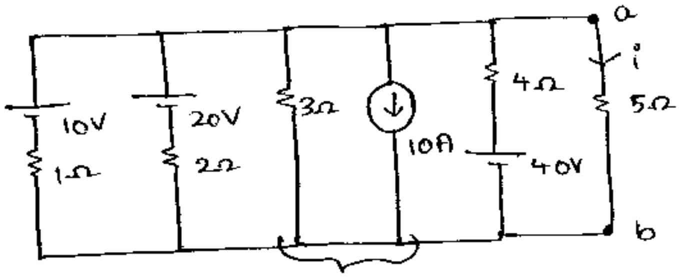
Dual of Millimans.



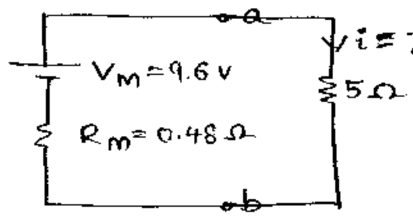
$$I_M = \frac{\sum_{i=1}^{n} I_i R_i}{\sum_{i=1}^{n} R_i}$$

$$R_m' = \sum_{i=1}^{n} R_i$$

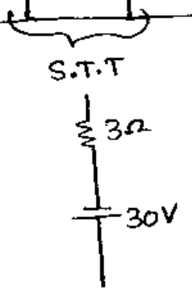
Q determine Current 'i' by using milliman's Theorem



$\Rightarrow$



$i = 1.75A = \dfrac{9.6}{0.48+5}$

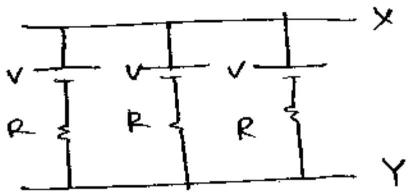


$$V_m = \frac{\frac{+10}{1} + \frac{20}{2} - \frac{30}{3} + \frac{40}{4}}{\frac{1}{1} + \frac{1}{2} + \frac{1}{3} + \frac{1}{4}} = 9.6\,V$$

$$R_m = \frac{1}{\frac{1}{1} + \frac{1}{2} + \frac{1}{3} + \frac{1}{4}} = 0.48\,\Omega$$

$$i = \frac{9.6}{5+0.48} = 1.75A.$$

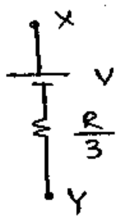
IES(O)



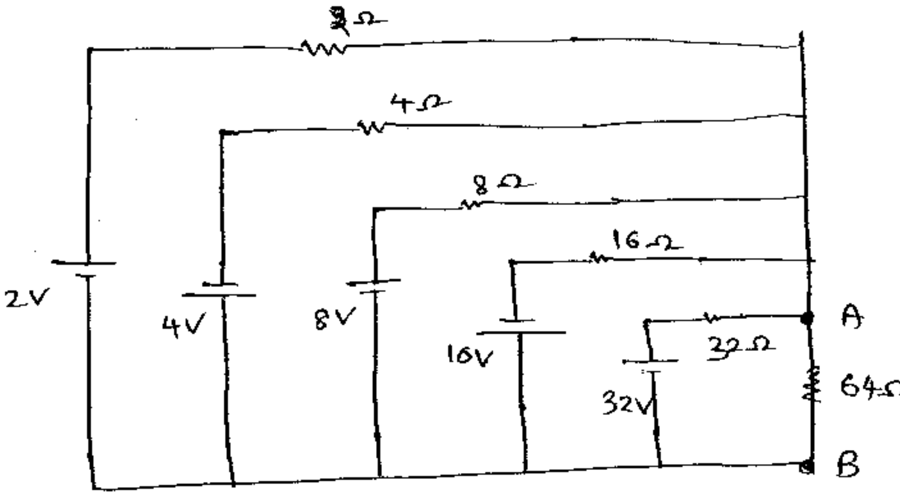
$$V_m = \frac{\frac{V}{R} + \frac{V}{R} + \frac{V}{R}}{\frac{1}{R} + \frac{1}{R} + \frac{1}{R}} = \frac{\frac{\cancel{3}V}{\cancel{R}}}{\cancel{3}\left(\frac{1}{\cancel{R}}\right)} = V.$$

$$R_m = \frac{1}{\frac{1}{R} + \frac{1}{R} + \frac{1}{R}} = \frac{1}{\frac{3}{R}} = \frac{R}{3}$$

Milliman ckt $\Rightarrow$



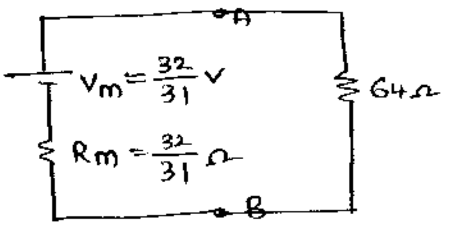
IES (O) Find V_{AB} = ______



$$V_m = \frac{\cancel{\frac{2}{2}} - \cancel{\frac{4}{4}} + \cancel{\frac{8}{8}} - \cancel{\frac{16}{16}} + \frac{32}{32}}{\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}} = \frac{32}{31}\,V$$

$$R_m = \frac{1}{\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}} = \frac{32}{31}\,\Omega$$

Milliman Eq.



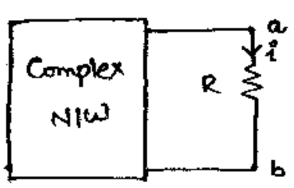
$$V_{AB} = \frac{32}{31}\left[\frac{64}{64+\frac{32}{31}}\right]$$

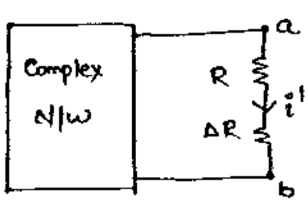
$$V_{AB} = \frac{64}{63}\,V.$$

IX Compensation Theorem:

This Theorem allows to determine the Correct Value of Current in any Branch of the N/w directly in one step when N/w is subjected to any parametric change.

This Theorem is Exclusively used in electrical measurements to determine the steady state error Introduced by the meters by writing the Compensated N/w of the Given N/w.



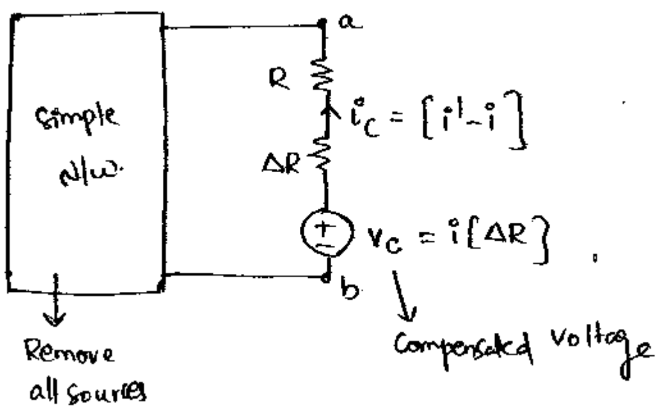


as ΔR is Extra then i' is ~~very~~ low compared to i

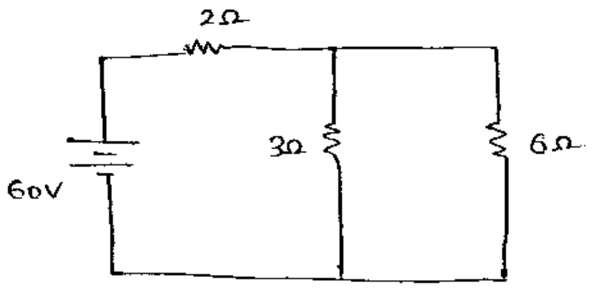
$\therefore i_c = [i' - i] = -ve$

$\therefore i_c$ direction is reversed

Compensated N/w:



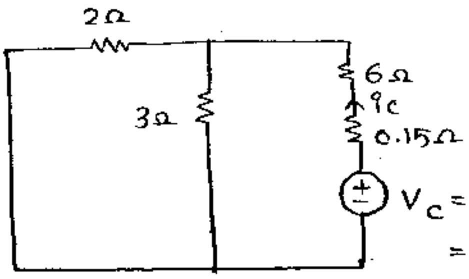
determine the Change (compensation) in Current in 6Ω Resistance Branch when an ammeter with Internal Resistance of 0.15Ω is used to measure Current through it. & also determine the steady state error Introduced by the meter.



original Current in 6Ω :

$$i = \frac{60}{2+[3//6]} * \frac{3}{9} = \frac{20}{4} = 5A$$

Compensated N/W :



$V_c = i \times \Delta R$

$= 5 \times 0.15$

$= \frac{3}{4} V$

$$i_c = \frac{3/4}{6.15+[2//3]} = \underline{\underline{0.102A}}$$

By Connecting a practical Ammeter with Small Internal Resistance in Series to 6Ω Branch the Current in that Branch is reduced by $\underline{\underline{0.102A}}$

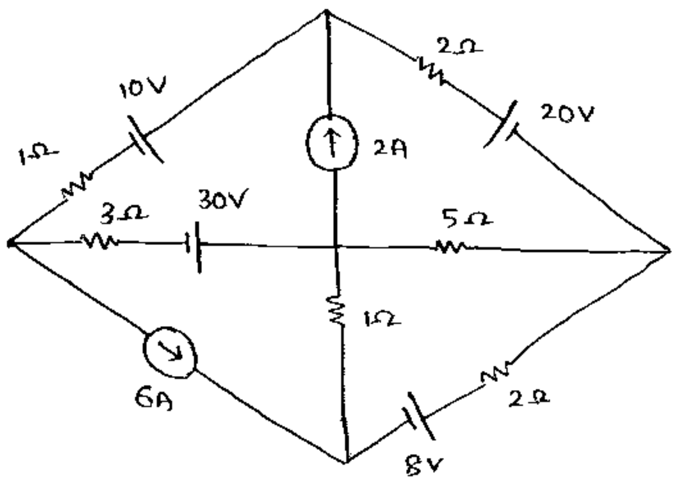
$$\% \text{ Error} = \frac{i_c}{i} \times 100\%$$

$$= \frac{0.102}{5} \times 100\%$$

$$= 2.04\%$$

↳ acceptable error.

H.W



Determine the change in Current in 5Ω Resistance Branch when an additional 1Ω Resistance is Connected in Series to it.

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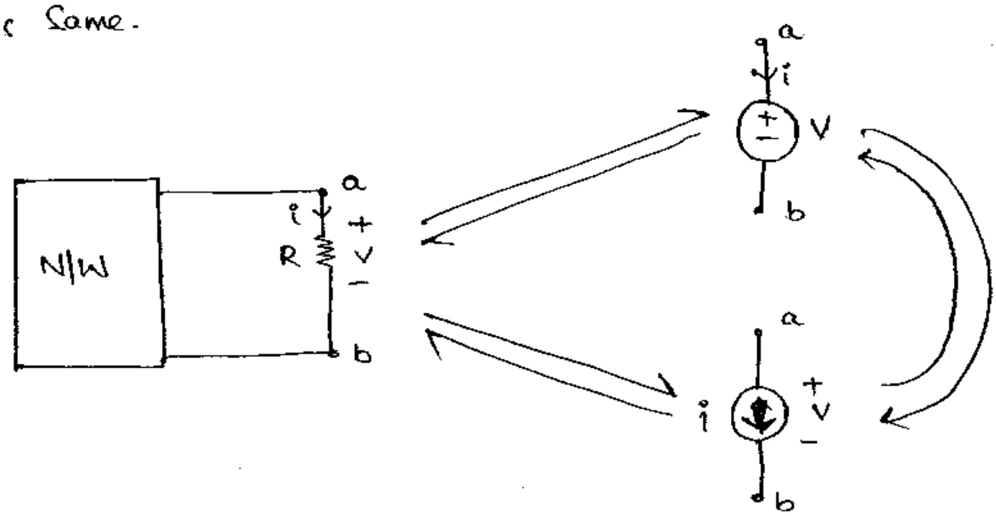
Roychowdy – conv. #

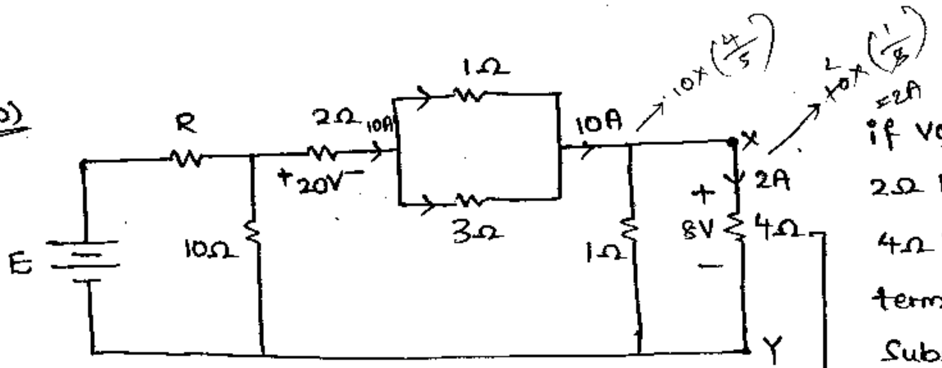
* Substitution :

In any linear active Bilateral N/w Consisting of no. of Energy Sources & Resistances etc. any passive element Can be Substituted in terms of its Equivalent Voltage or Current & Vice Versa. for further analysis & Reduction in the N/w Without disturbing the Rest of the N/w provided the power absorbed By the passive element & its Equivalent Substituted Voltage or Current Remains Same.



$$P_{abs} = i^2 R = \frac{V^2}{R} = V.i \ W$$

IES(O)



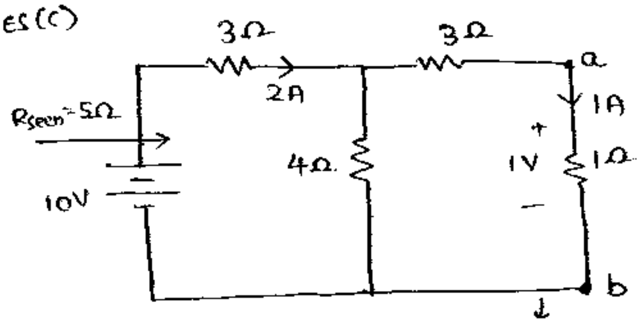
if voltage across 2Ω Resistance 20V then 4Ω Resistance branch b/w terminals XY Can be Substituted by voltage of Source 8V Value ___ polarity

$$P_{abs} = 2^2(4)$$
$$= 16W$$

$$P_{abs} = (8)(2)$$
$$= 16 \ W.$$

X is +ve w.r.t Y

IES (C)



use Substitution theorem to represent 1Ω Resistance branch b/w a b atleast in 5 different ways.

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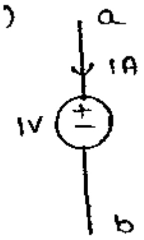
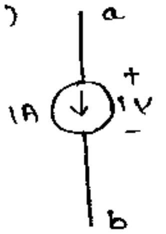
$P_{abs} = 1^2(1) = 1W$

(1)



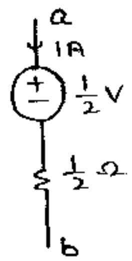
$P_{abs} = \underline{1W}$

(2)



$P_{abs} = \underline{1W}$

(3)

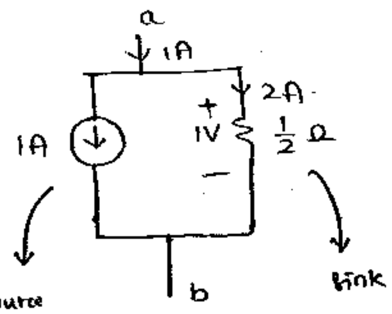


$P_{abs} = \frac{1}{2}(1) + (1)^2\frac{1}{2}$

$= \underline{1W}$

(4)

(4)



Source

$P_{abs} = -1W$

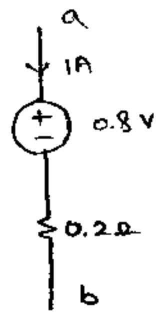
Sink

$P_{abs} = 2^2(\frac{1}{2})$

$= 2W$

$P_{Total\,abs} = (-1+2) = \underline{1W}$

(5)

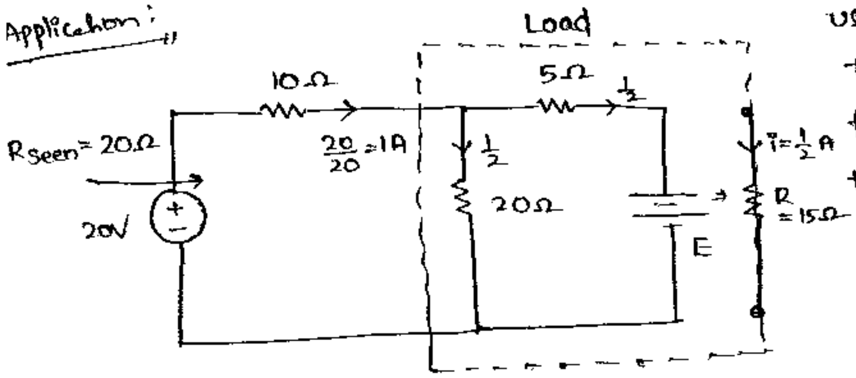


– – – – – ∞ ways.

$P_{abs} = 0.8(1) + 1^2(0.2)$

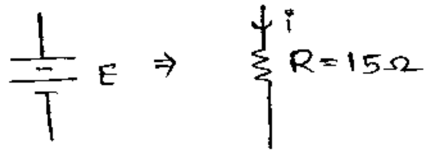
$= \underline{1W}.$

Application:



Use Substitution theorem to determine the value of Battery voltage "E" for which max power is Transferred to entire load

Let $E = iR$ → sink



for P_{max}

load R = Source R

$$[20 \| (5+R)] = 10$$

$$\frac{20(5+R)}{25+R} = 10$$

$$R = 15\Omega.$$

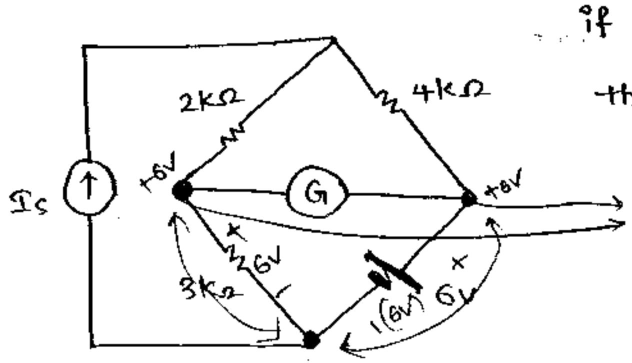
For P_{max}

$$E = iR$$

$$E = \frac{1}{2}(15) = 7.5 \text{ Volts}.$$

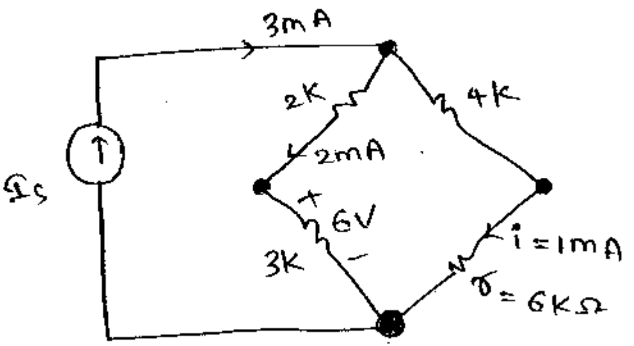
IES (O)

if Reading of Galvanometer is Zero. find the Value of Source Current I_s.



when Bridge is Balance P.D. b/w these terminals is Zero w.r.t to any ref.

∴ Voltage across these terminals w.r.t any of the ref (or) terminals is same.



let $V = ir$

∵ Bridge Balanced

$$(2K)(r) = (3K)(4K)$$

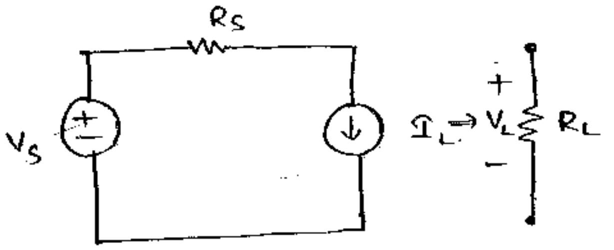
$$r = 6K\Omega$$

$$i = \frac{6}{6K} = 1mA$$

If V_s is Const. Source Voltage & I_L is Const load Current then P_{max} occurs in the load if I_L is ______

(a) $\frac{V_s}{R}$ ~~(b)~~ $\frac{V_s}{2R}$ (c) $\frac{V_s}{4R}$ (d) $\frac{2V_s}{R}$

R_L =
example of const current load
↑
Const Torque DC motor draws const. current



let $I_L = \frac{V_L}{R_L}$

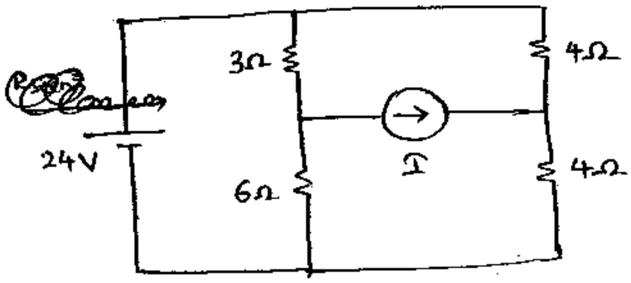
at P_{max}

$R_L = R_S$.

$V_L = \frac{V_S}{2}$

$I_L = \frac{V_L}{R_L} = \frac{V_S}{2R_S}$.

Q for what value of current i max power absorbed



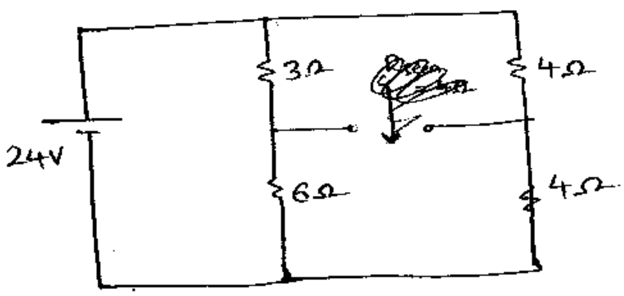
$R_L = [3 \| 6] + [4 \| 4] = 4\Omega$

$V_L = 12V$

$I = \frac{V_L}{R_L} = \frac{12}{4} = 3A$

at P_{max} 50% appears.

$V_L = 12V$.



Basis of Time Variance

Properties of Inductors & Capacitors.

Properties of Inductors :

$\Rightarrow \quad \because V = L\dfrac{di}{dt}$

$\Rightarrow$ for Ideal dc Excitation $\dfrac{di}{dt} = 0 \Rightarrow$ Voltage across Inductor = 0

ie., Inductor acts as S.C for Ideal DC in Steady State

$\Rightarrow$ Inductor will never allow Sudden change in Current through it (ie, in Zero time)

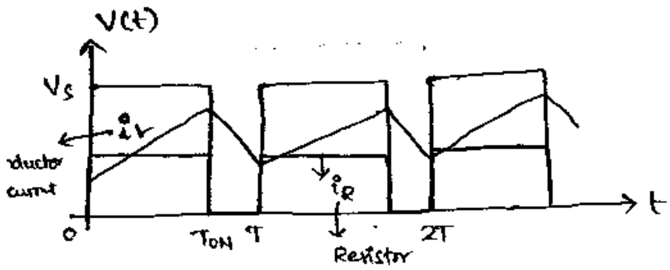
$\Rightarrow$ But if we do allow Sudden Change in Current through Inductor in a Short Interval of time it develops large Impulse Voltage. Ex: Flourescent lamp (tubelight)

$\Rightarrow$ Ideal Inductors are Coiled Wires with Zero Internal Resistance. So powerloss is Zero. L (r=0)

$\Rightarrow$ practical Inductors do have Some Internal Wdg Resistance & they are Represented as Coils as shown. L r |Coil

$\Rightarrow$ Inductor is a Versatile freq. dependent Component & its analysis is different in different applications based on the type of input & mode of operation.

High freq $\rightarrow$ compact in size
High power density
$\rightarrow$ power density Handling is High.



$$V = L\frac{di}{dt}$$

$$\int di = \frac{V}{L}\int dt$$

$$\boxed{i = \frac{V}{L}t}$$

Inductor doesn't allow Sudden change in current bcz Inductor is large Inertia magdomain element for current

$\infty \uparrow V = L\dfrac{di}{dt \to 0}$

& it is violation of law of Conservation of Energy.

$0 < t < T_{ON}$

$V \longrightarrow V_S$ (pulse)

$i = \left[\dfrac{V_S}{L}\right]t$

$y = mx$

Current is Ramp fn.

choke in tubelight is impulse voltage generator to ignite gas

Properties of Capacitors:

$\Rightarrow \because i = C\dfrac{dV}{dt}$

$\Rightarrow$ for ideal DC Excitation $\dfrac{dv}{dt} = 0 \Rightarrow$ current through cap $i = 0$

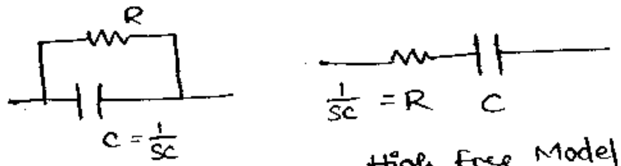
$\Rightarrow$ cap. acts as O.C for Ideal DC in steady state.

$\Rightarrow$ Cap. will never allow sudden change in Voltage ~~time~~ across it in zero time

$\Rightarrow$ if we do allow sudden change in Voltage across cap in short interval of time they drive large Impulse Currents.

$\Rightarrow$ Ideal Capacitors are Considered to have Infinite dielectric Resistance so, no leakage Currents so, P_{losses} are zero. $C\,(R \to \infty)$

$\Rightarrow$ practical Capacitors do have large dielectric Resistance which (incur) undergo losses & they are modelled as



Low freq Model $(f \to 0)$

High freq Model $(f \to \infty)$ (used in modelling of the losses of cap at High freq)

$\Rightarrow$ Capacitor is a Versatile freq dependent Component & its analysis is different in different application based on type of i/p & mode of operation

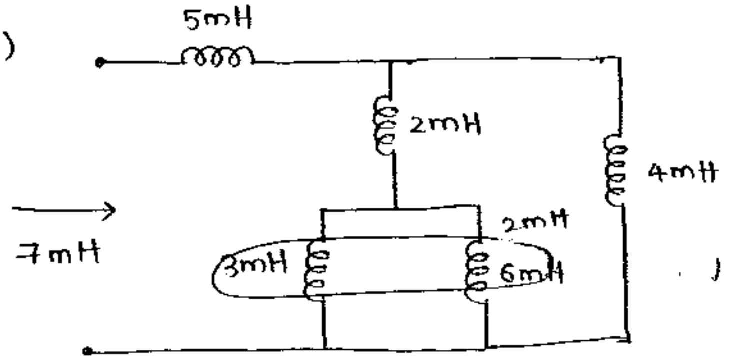
Capacitors Inertia element in electrostatic domain

$\Rightarrow$ $i = C\dfrac{dV}{dt=0}$ (∞ Impulse) $\longrightarrow$ violation of law of Conservation of charge.

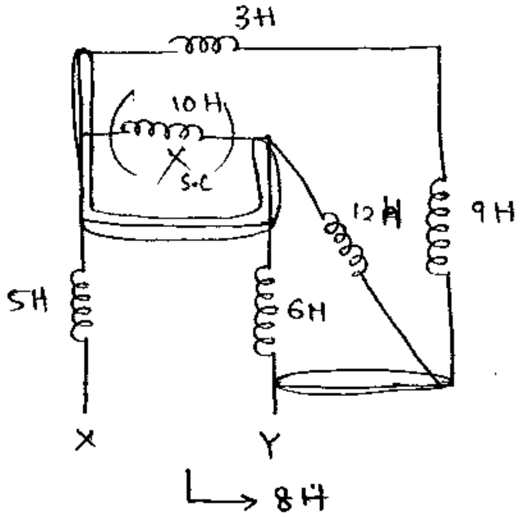
Camera flash is Impulse current

Reduction Techniques :

1)

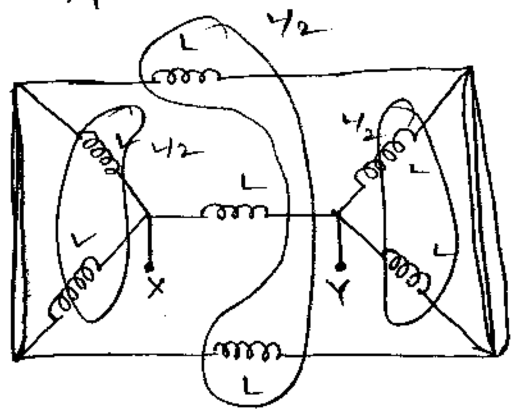


* L_{XY} = ____



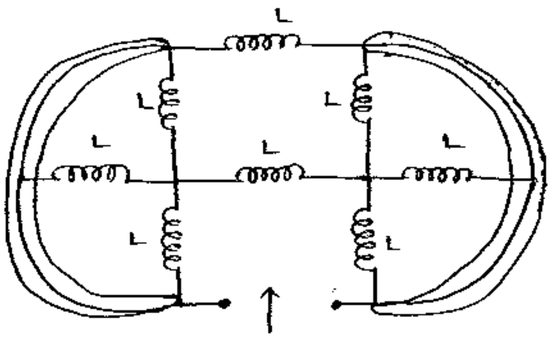
*

IES L_{XY} = ____



$L_{XY} = L \,//\, \frac{3L}{2} = \frac{3}{5} L$ H.

IES

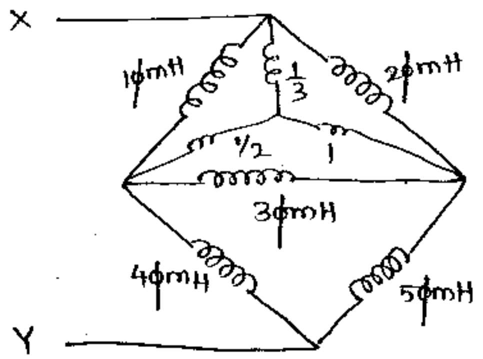


$L_T = \left(5L/3\right) \| L$ 82

$= \frac{5L}{8}$ H.

Gate

$L_{XY} =$ ____



magnitude scaling i.e. divide by 10mH

$\Delta - \lambda$ Conversion.

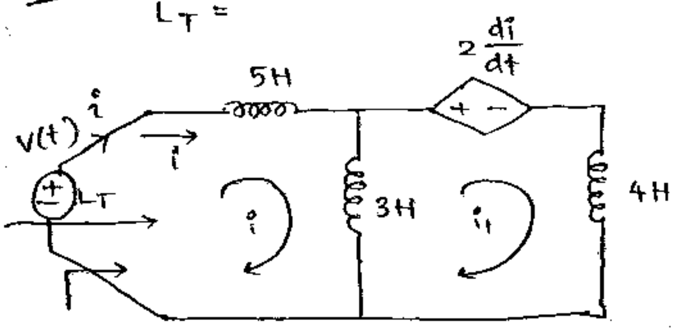
$L_{XY} = \left[\frac{1}{3} + \left(6 \| \frac{9}{2}\right)\right] \times 10mH$

$= 29.04$ mH bcz mag. scaling.

Thev. cat. III

IES(C)

$L_T =$



$V(t) = L_T \frac{di}{dt}$

$-V(t) + 5\frac{di}{dt} + 3\left[\frac{di}{dt} - \frac{di_1}{dt}\right] = 0$

$8\frac{di}{dt} - 3\frac{di_1}{dt} = V(t) \longrightarrow (1)$

$3\left[\frac{di_1}{dt} - \frac{di}{dt}\right] + 2\frac{di}{dt} + 4\frac{di_1}{dt} = 0$

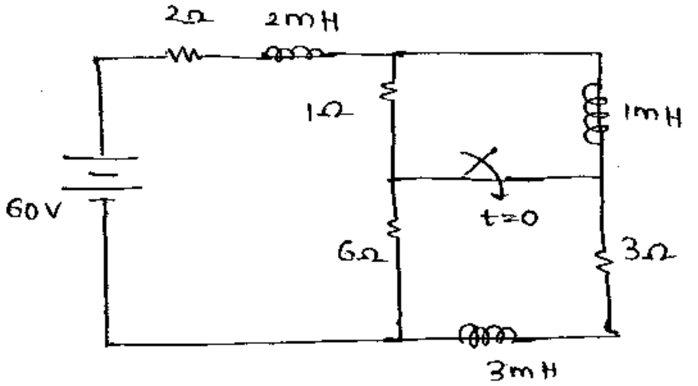
$\frac{di}{dt} = 7\frac{di_1}{dt} \longrightarrow (2)$

$V(t) = \frac{di}{dt}\left[8 - 3\left(\frac{1}{7}\right)\right]$

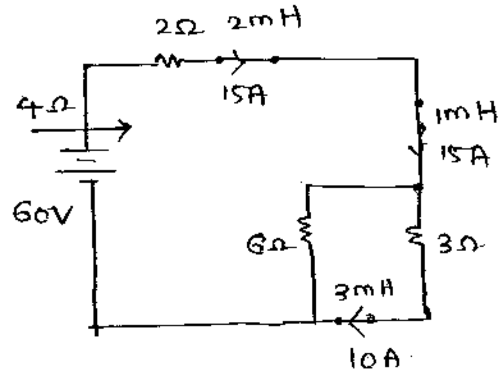
$V(t) = \left[\frac{53}{7}\right]\frac{di}{dt}$

$\hookrightarrow L_T = \frac{53}{7}$ H

Q Find steady state currents in each inductor & energy stored in each.
↳ for dc $L \to S.C$



⇒



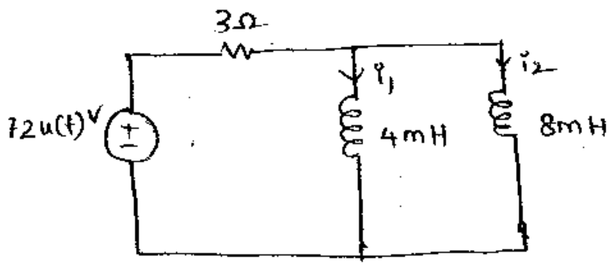
$$E_{2m} = \frac{1}{2}(2m)(15)^2 = 225\ mJ$$

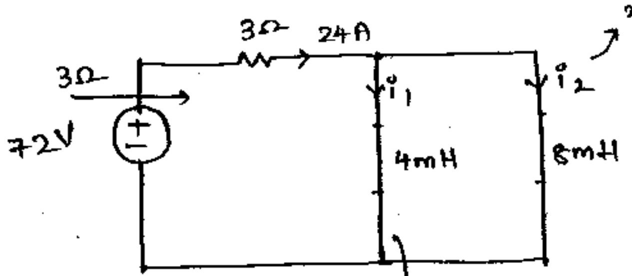
$$E_{1m} = \frac{1}{2}(1m)(15)^2 = 112.5\ mJ$$

$$E_{3m} = \frac{1}{2}(3m)(10)^2 = 150\ mJ$$

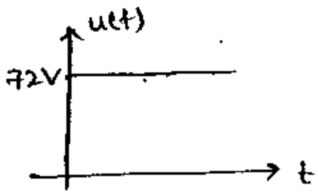
Electro mag form
E-M Form
↓
DC flux

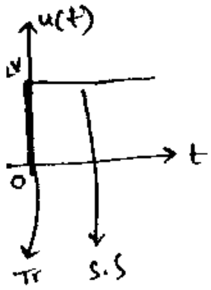
IES(O) Find currents i_1 & i_2





$$24\left(\frac{4}{8+4}\right) = 8A$$





$$i_1 = 24\left[\frac{8m}{8+4m}\right]$$

$= 16A$

$t = 0^+ \to$ Transient state

$e_1 = e_2$ [∵ parallel]

$\psi_1 = \psi_2$ [∵ $\psi = Li$]

$L_1 i_1 = L_2 i_2$

$4m(i_1) = 8m(i_2)$

$i_1 = 2i_2 \longrightarrow ①$

as $t \to \infty$

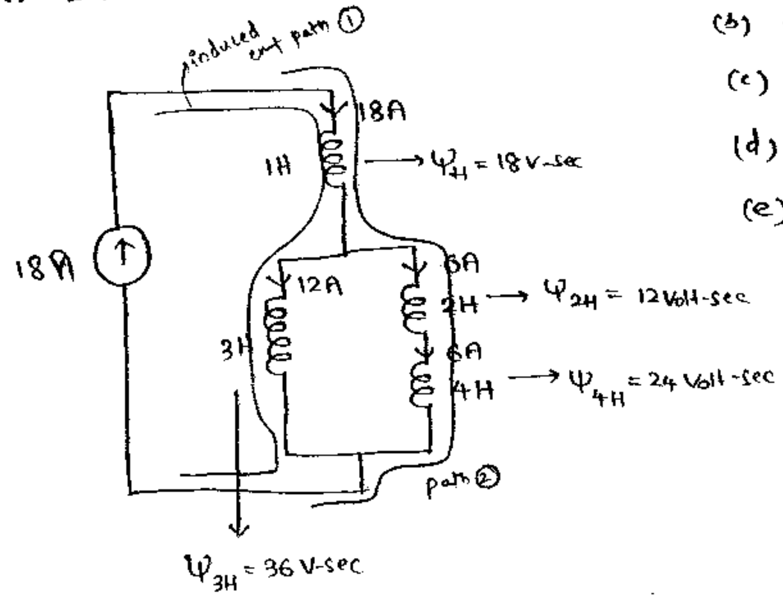
$i_1 + i_2 = 24 \longrightarrow ②$

By law of Conv. charge

① & ② sloving $i_1 = 16\ A$, $i_2 = 8A$

for Inductive ckt shown determine

(a) S.S currents in each Inductor
(b) flux linkage in each Inductor
(c) Energy stored in Inductor
(d) Verify law of Consv. of Energy
(e) Verify law of Cons. of flux



83

$\Psi = \Phi . N$

$\Psi = L . i$

$= \frac{Vdt}{di} \times i$

$= \frac{V\text{-sec}}{Amp} \times Amp$

$\Psi = V\text{-sec}$

(c) $E_{1H} = \frac{1}{2} L i^2 = \frac{1}{2}(1)(18)^2 = 162$ J

$E_{2H} = \frac{1}{2} \times 2 \times 6^2 = 36$ J

$E_{3H} = \frac{1}{2}(3)(12)^2 = 216$ J

$E_{4H} = \frac{1}{2}(4)(6)^2 = 72$ J

E-M form
↓
DC flux

When Inductors are parallel current will divide & flux will be same.

when Ind. in series current same flux divid..

(d) $E_{deli} = E_{stored}$ (in 'L' $E_{stored} = E_{absor}$)

LHS $E_{deli} = \frac{1}{2} L_T i_T^2 = \frac{1}{2}[3].[18]^2 = 486$ J.

RHS $E_{stored} = [162 + 36 + 216 + 72] = 486$ J

law of Consv. Energy.

(e) L.C. of flux

$\Psi_{established} = \Psi_{retained}$

LHS $\Psi_{est} = L_T . i_T = [3][18] = 54$ volt-sec

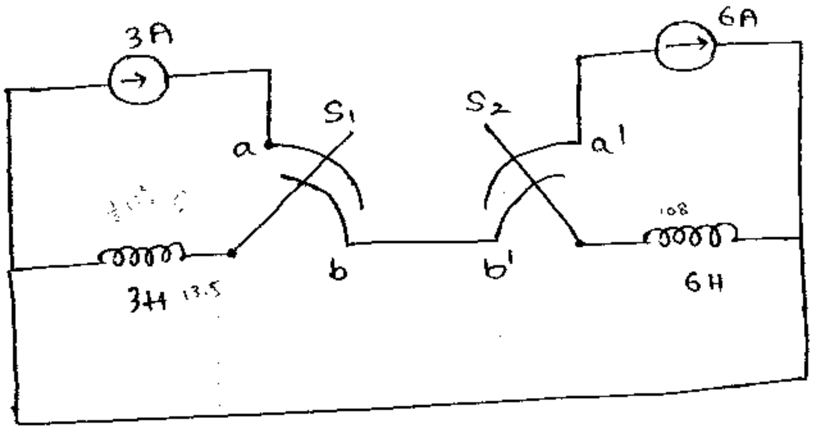
RHS

$\Psi_{retained}$

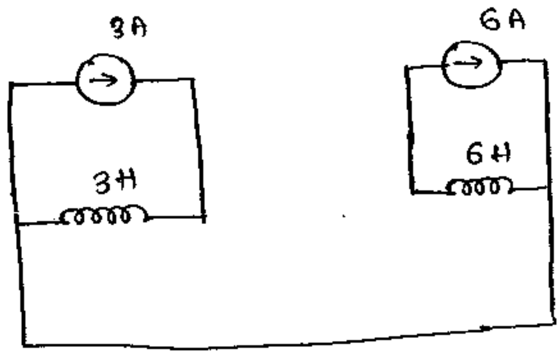
path 1 (KVL)
$= \Psi_{1H} + \Psi_{3H} = 18 + 36 = 54$ Volt.sec

path 2 (KVL)
$= \Psi_{1H} + \Psi_{2H} + \Psi_{4H} = [18 + 12 + 24] = 54$ volt.sec

Initially Switches are at position A & A' respectively then determine the Steady State Currents, flux linkages & Energy stored in each Inductor. Now if the Switches are Simultaneously moved to positions B & B' respectively & Remained there forever then determine their S.S current, flux linkages, & Energy stored in each Inductor. Verify L.C. of flux, L.C. of Energy before & after the change. assume the Switches are Ideal & there is no loss in Energy during the Transient as they are make before break Contacts.



Before



$i_1 = 3A$

$\psi = 9$ volt-sec

$E_1 = \frac{1}{2}(3)(3)^2$

$= 13.5\ J$

$i_2 = 6A$

$\psi_2 = 36$ volt-sec

$E_2 = \frac{1}{2}(6)(6)^2$

$= 108\ J$

$\psi_T = \psi_1 + \psi_2$ (independent loops)

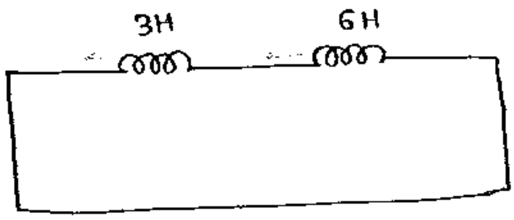
$= (9+36)$

$= 45$ volt-sec $\longrightarrow$ (1)

$E_T = E_1 + E_2 = (13.5 + 108)\ J$

$= 121.5\ J \longrightarrow$ (2)

After.



$\because$ in series $i_1 = i_2$ $[\psi = Li]$

$$\frac{\psi_1}{L_1} = \frac{\psi_2}{L_2} \Rightarrow \frac{\psi_1}{3} = \frac{\psi_2}{6}$$

$$\psi_2 = 2\psi_1 \longrightarrow (3)$$

Respecting L.C. of flux only

$$\psi_{T(\text{Before})} = \psi_{T(\text{after})}$$

So solving (1) & (3)

$$\psi + \psi_2 = 45$$

$$3\psi_1 = 45$$

$$\psi_1 = 15 \text{ Volt-sec}$$

$$\psi_2 = 30 \text{ Volt-sec.}$$

Then $i_1 = i_2 \Rightarrow \frac{15}{3} = \frac{30}{6} = 5A \longrightarrow i_1 = i_2$

$$E_1 = \frac{1}{2}(3)(5)^2 = 37.5 \text{ J}$$

$$E_2 = \frac{1}{2}(6)(5)^2 = 75 \text{ J}.$$

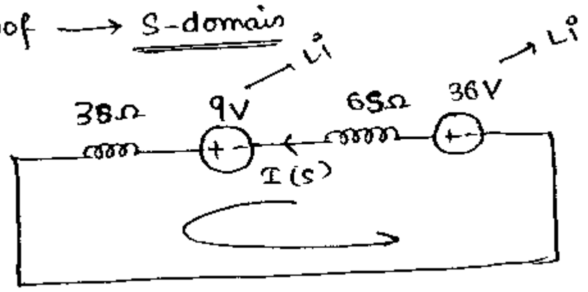
Now $\psi_T = [15+30] = 45$ Volt-sec $\longrightarrow (4)$

$E_T = [37.5+75]$ J $= 112.5$ J $\longrightarrow (5)$

Here L.C. of flux satisfied

But L.C. of Energy has to be Justified.

proof → S-domain



KCL

$$-36 + I(s)6S - 9 + I(s)3S = 0$$

$$I(s)[9S] = 45$$

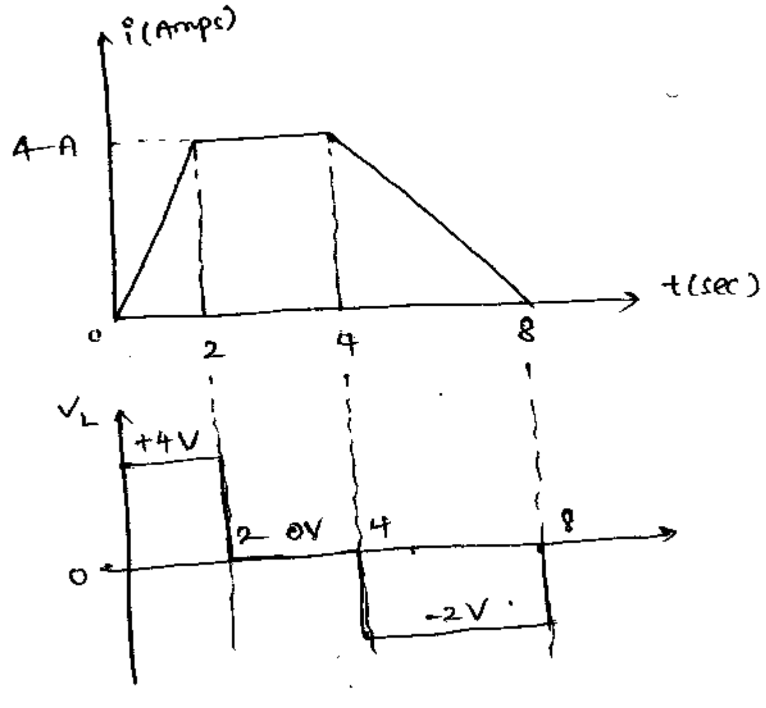
$$I(s) = \frac{45}{9S} = \frac{5}{S}$$

$$i(t) = L^{-1}[I(s)] = 5A \longrightarrow i_1 = i_2.$$

Here flux is only Considered as matter but Energy can be in any form. Sum of the Energy from previous state has been utilised to redistribute the flux among Inductors to maintain Constant Equal Currents.

Q Plot the Voltage across 2H Inductor if Current through it as shown below also plot Power & Energy fn. in the Inductor & verify law. of Conc. of Energy. Hence determine (a) Pow. in Inductor at t = 5 sec

(b) energy stored in Inductor upto t = 5 sec.



$$V = L\frac{di}{dt}$$

0<t<2

$$i(t) = 2t \rightarrow V = L\frac{di}{dt}$$

$$V = 2.\frac{d}{dt}(2t)$$

$$V = +4V \text{ (pulse)}$$

2<t<4

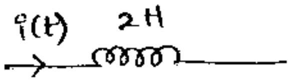
$$i(t) = 4 \rightarrow V = 2\frac{d}{dt}(4) = 0V$$

4<t<8

$$y - 0 = \frac{4-0}{4-8}(x-8)$$

$$i(t) = (-t+8)$$

$$V = 2\frac{d}{dt}(-t+8) = -2V \text{ (pulse)}$$



$\frac{di}{dt} = \oplus \rightarrow$ 0A → 4A $+\ 4V\ -$ } E stored

$\frac{di}{dt} = 0$ 4A $+\ 0V\ -$ } E retained $= \frac{1}{2}(2)(4)^2 = 16J$

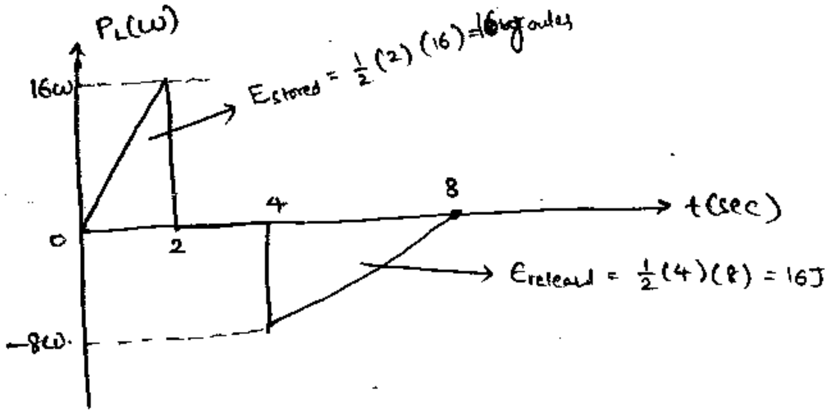
$\frac{di}{dt} = \ominus$ 4A → 0A $-\ 2V\ +$ $(+\ (-2)\ -)$ } E released

$$P_L(t) = V_L(t) \cdot i_L(t) \ W$$

$0 < t < 2$: $P_L(t) = 8t \ \omega$

$2 < t < 4$: $P_L(t) = 0W$

$4 < t < 8$: $P_L(t) = (+2t - 16)\omega.$



$$E_L(t) = \int_{-\infty}^{t} P_L(t)\,dt = \int_{-\infty}^{0} P_L(t)\,dt + \int_{0}^{t} P_L(t)\,dt \longrightarrow \left[E_L(t) = E(0) + \int_0^t P_L(t)\,dt\right] J$$

~~$0 < t < 2$~~

~~E~~

$0<t<2$

$$E_L(t) = E(0) + \int_0^2 8t\,dt$$

$$= 0 + 4t^2 \Big|_0^2$$

$t=0 \longrightarrow E_L = 0J$

$t=2 \longrightarrow E_L = 16J$

parabolic

$2<t<4$

$$E_L(t) = E(0) + \int_2^4 0\,dt$$

$$= 16 + 0$$

$$= 16J$$

E remain at 16 J

$4<t<8$

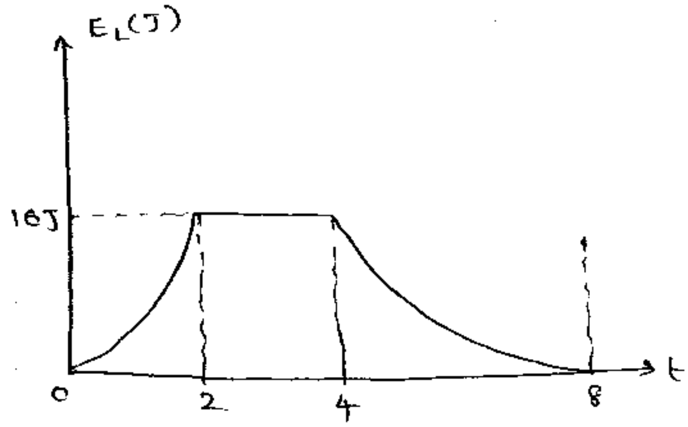
$$E_L(t) = E(0) + \int_4^8 (2t-16)\,dt$$

$$= 16 + t^2\Big|_4^8 - 16t\Big|_4^8$$

$t=4 \longrightarrow E_L = 16J$

$t=8 \longrightarrow E_L = 0J$

parabolic.



power is Instantaneous

we use at that instant

(a) $P_L(t=5) = 2(5)-16$

$$= -6W$$

-ve power Indicates at that Instant of 6^{th} second Energy is released by the Inductor Back to the Supply.

(b) E_L (4 to 5 sec)

$$E_2(t) = E(0) + \int_4^5 (2t-16)\,dt$$

$$= 16 + t^2\Big|_4^5 - 16t\Big|_4^5$$

$$= 16 + [25-16] - 16$$

$$= 9J$$

(or) ∵ Energy stored upto 5 sec = Energy at 5 sec.

$4<t<8$:

$$i(t) = (-t+8)$$

$$i(t=5) = (-5+8) = 3A$$

$$E_L = \frac{1}{2} \times (2)(3)^2$$

$$= 9J$$

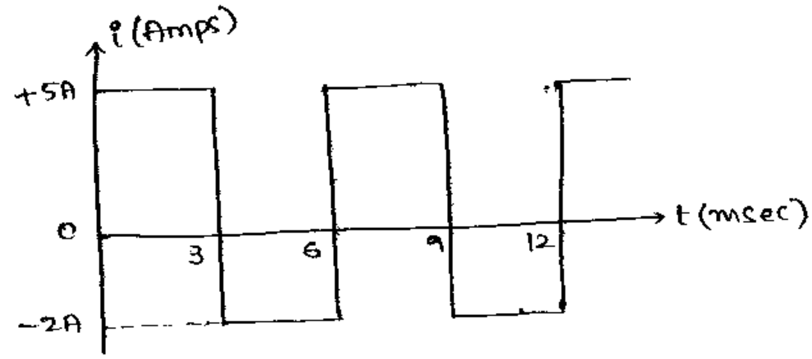
Repeat the above prower to plot V, Power, Energy for the same given Current function in the case of 2Ω Resistor

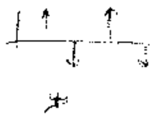
86

Gate

plot the Voltage across 5mH Inductor if Current through it is as shown below.

87

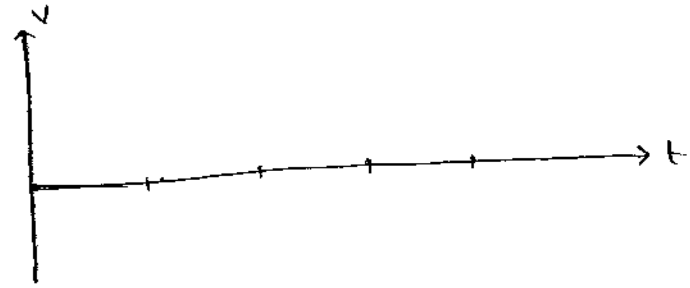




$0 < t < 3 \Rightarrow i(t) = 5\,A$

$$V = L\frac{di}{dt}$$

$$= 5\,\frac{d(5)}{dt} = 0$$



$\boxed{V = L\frac{di}{dt}}$ → if $\frac{di}{dt} = 0$ then $\underline{V = 0}$

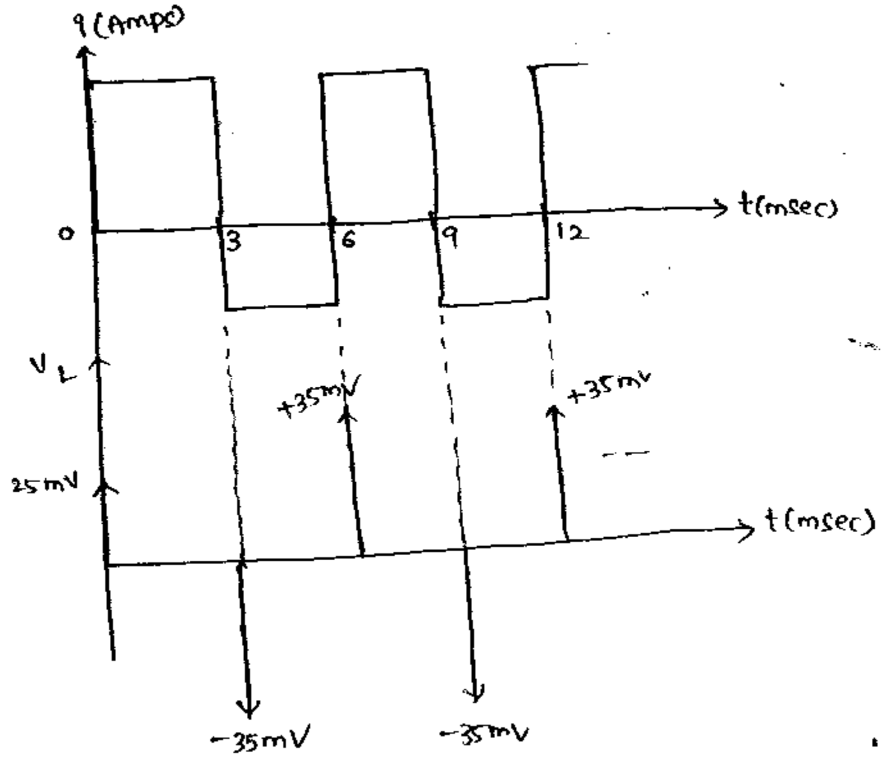
→ if $dt \to 0$ then V = Impulse

it controls the magnitude of Impulse.

$$V = \left(L\left[\frac{i_{final} - i_{initial}}{\Delta t}\right]\right)$$

Δt → '0'

↓ impulse



$\underline{t=0}$,

$$V = 5m\left[\frac{5-0}{\Delta t}\right] = +25mV$$

(impulse)

$\underline{t=3m}$

$$V = 5m\left[\frac{-2-(+5)}{\Delta t}\right] = -35V$$

(impulse)

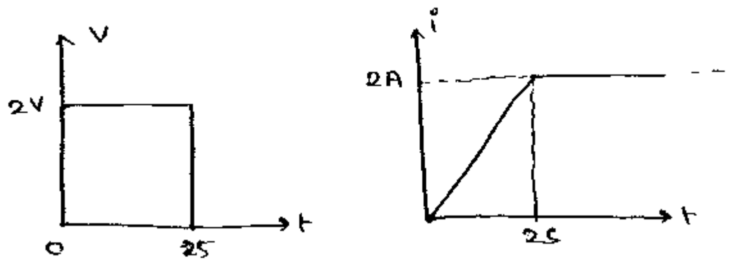
$\underline{t=6m}$

$$V = 5m\left[\frac{5-(-2)}{\Delta t}\right] = +35\,mV$$

(impulse)

IES (0)

If Voltage - current plot in a passive Component is shown below, then Component is



(a) $L = 1H$

(b) $L = 2H$

(c) $C = \frac{1}{2}F$

(d) $C = 2F$.

$V = iR$ ✗
↓ ↓
V & i WF should be same

$V = \frac{1}{C}\int i\,dt$ ✗
↓ parabolic ↓ Ramp

$V = L\frac{di}{dt}$ → Ramp ✓
↓ step.

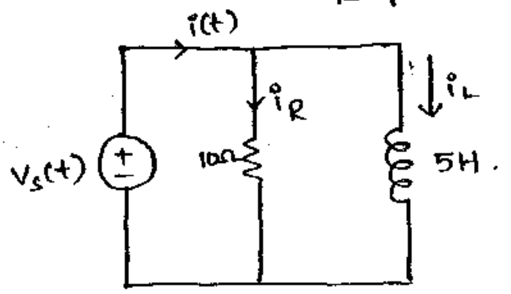
$V = L.\left[\frac{i_2 - i_1}{t_2 - t_1}\right]$

$2 = L.\left[\frac{2-0}{2-0}\right]$

$\underline{\underline{L = 2H}}$

Gate

If $V_s(t) = 40t$ V, $i_L(0) = 5A$, then find Current 'i' at t = 2 sec.
↓ Ramp



V → Excitation is Ramp

∴ for R → i ⇒ Ramp

for L → i ⇒ parabolic

$i(t) = i_R + i_L$

$= \frac{V_s(t)}{R} + \left\{ i_L(0) + \frac{1}{L}\int_0^t V_s(t)\,dt \right\}$

$i(t) = \frac{40t}{10} + 5 + \frac{1}{5}\int_0^t 40t\,dt.$

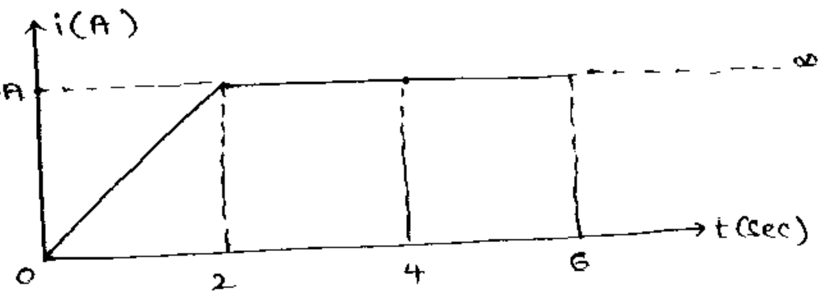
$i(t) = (4t + 5 + 4t^2)$

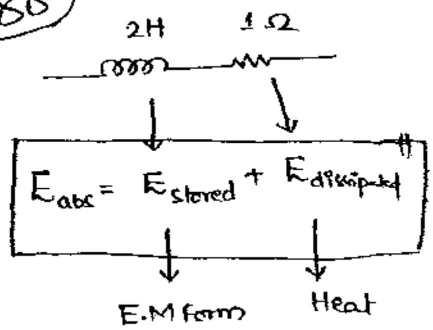
$i(t=2) = 8 + 5 + 16 = \underline{29A}$

gate

a practical Coil of 2H Inductance & 1Ω Resistance is Excited by Time Varying Current shown. determine the total Energy absorbed by the Coil upto first 4 sec.

(88)





→ ~~Ediss~~ $0<t<2$: $i(t) = 3t$

$2<t<4$: $i(t) = 6$.

$$E_{diss} = \int P_R\,dt = \int_0^4 [i(t)]^2 \cdot R\,dt = \int_0^2 \underbrace{(3t)^2(1)\,dt}_{24\,J} + \int_2^4 \underbrace{(6)^2(1)\,dt}_{72\,J} = 96\,J$$

$$E_{stored} = \int P_L\,dt = \int_0^4 L\,i(t)\cdot\frac{di}{dt}\,dt = \int_0^2 \underbrace{2(3t)\cdot\frac{d}{dt}(3t)\,dt}_{36\,J} + \int_2^4 \underbrace{2(6)\cdot\frac{d(6)}{dt}\,dt}_{0\,J} = 36\,J$$

total $E_{abs} = 96 + 36 = 132\,J$

Note: In the above problem ~~Resistor~~ Resistor will Convert & dissipate Energy in the form of Heat External to the ckt Where ckt Cannot Recover it Back. So Resistor is Converting & lossy Component of Energy.

However Inductor is a state element (memory ele) & inductor Current is its state Variable as this Component Response when there is change in Current through it which actually happened from 0 to 2secs as its stored Energy. later it will Retain this Energy as a memory element as long as the Excitation is maintained Constant. Hence We Can Say Energy stored in inductor upto 4 secs is a Energy at 4th sec provided we know State Variable ie, Current at 4 sec. Which is $E_L(t=4) = \frac{1}{2}(2)(6)^2 = 36\,J$ → 'i' at t=4sec

⇒ Similarly for capacitor its voltage is its state variable

→ Energy stored in Inductor for one sine cycle is $\underline{\underline{0J}}$

Q in the above problem determin

(1) Energy dissipated by the coil 4 sec to ∞

(2) Energy stored by coil upto $t = \infty$

(3) total Energy absorbed by the coil 4^{th} sec to ∞

(4) Change in stored Energy in coil from 4^{th} sec to ∞

(1) $E_{\substack{diss.\\(t=4 \text{ to } \infty)}} = \int_4^\infty (6)^2(1)dt = \infty J$

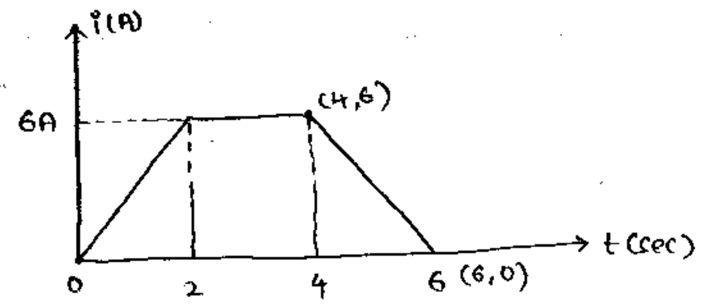
(2) $E_{stored} = \frac{1}{2}(2)(6)^2 = 36 J$

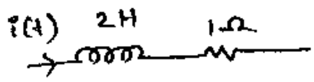
$\hookrightarrow i_1$ at $t=\infty$

(3) $(\infty + 36) J = \infty J$

(4) $\underline{\underline{0J}}$

Q In the above problem determine total Energy absorbed by coil if current function changed to





$0 < t < 2$: $i(t) = 3t$

$2 < t < 4$: $i(t) = 6$

$4 < t < 6$: $i(t) = ?$

$y - 0 = \frac{6-0}{4-6}(x-6)$

$i(t) = (-3t + 18)$

$$E_{\substack{diss.\\(R)}} = \int_0^6 P_R\, dt = \int_0^6 \left(i(t)\right)^2 \cdot R\, dt$$

$$= \underbrace{\int_0^2 (3t)^2(1)\,dt}_{24J} + \underbrace{\int_2^4 (6)^2(1)\,dt}_{72J} + \underbrace{\int_4^6 (-3t+18)^2\cdot(1)\,dt}_{24J}$$

$$= \underline{\underline{120J}}.$$

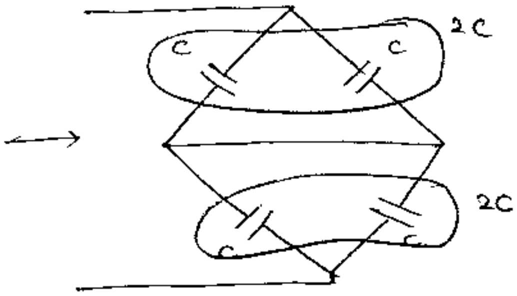
$$E_{\substack{stored\\(L)}} = \int_0^6 P_L\, dt = \int_0^6 L\, i(t)\frac{di(t)}{dt}\,dt = \underbrace{\int_0^2 2(3t)\cdot\frac{d(3t)}{dt}\,dt}_{36J} + \underbrace{\int_2^4 2(6)\cdot\frac{d(6)}{dt}\,dt}_{0J} + \underbrace{\int_4^6 (2)(-3t+18)\cdot\frac{d(-3t+18)}{dt}\,dt}_{-36J}$$

$$= \underline{\underline{0J}}$$

$$\text{Total } E_{abs} = (120+0)J$$

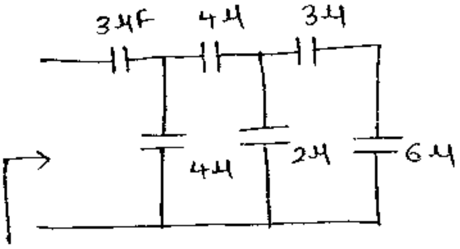
$$= \underline{\underline{120J}}.$$

IES (O)



$\underline{\text{"c"}}$

*

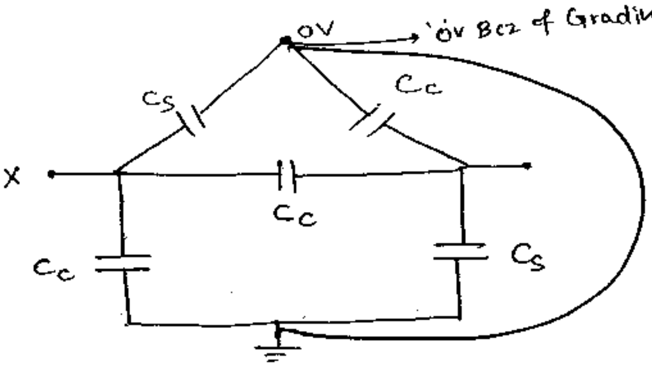


$C_T = \underline{2\mu F}$

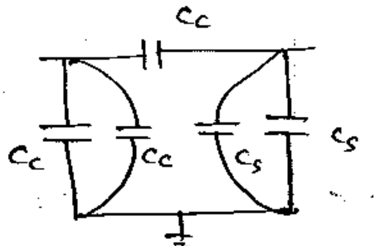
* gate $C_{XY} =$ ____

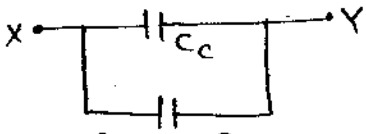
→ P.S application (cable grading)

0V → '0V' Bcz of Grading.



⇒

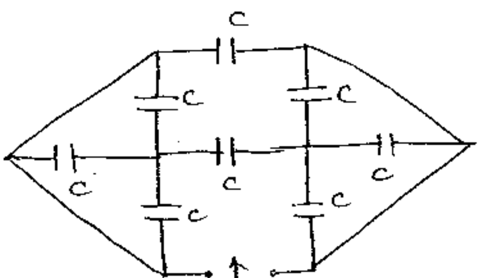




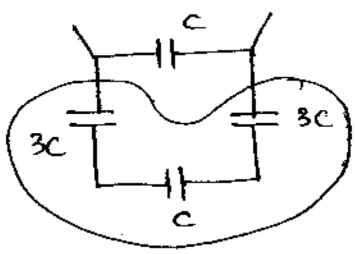
$\left[\frac{C_c + C_s}{2}\right]$

$C_{XY} = \left[\frac{3C_c + C_s}{2}\right] F$

IES



⇒



$C' = \frac{3C}{5}$

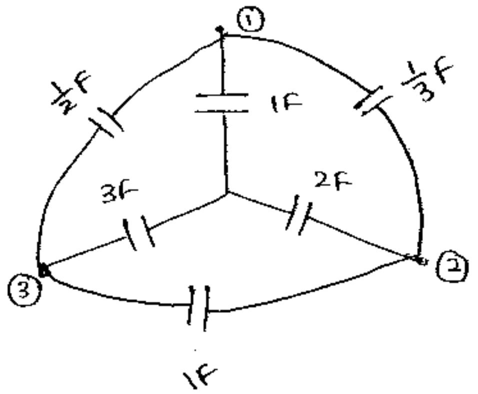
$C_T = C + \frac{3C}{5} = \frac{8C}{5}$

$\frac{1}{C'} = \frac{1}{3C} + \frac{1}{C} + \frac{1}{3C} = \frac{5}{3C}$

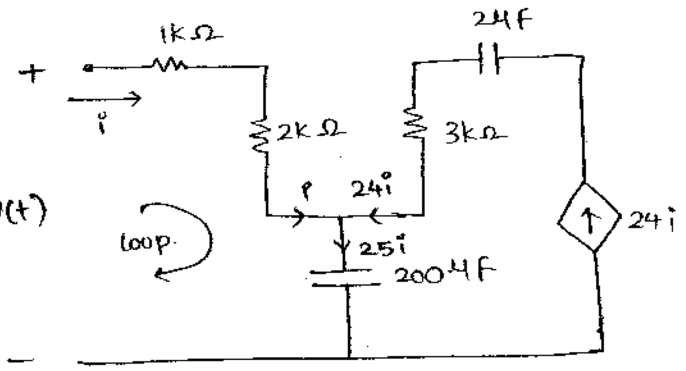
$C_T = C + C' = C + \frac{3C}{5} = \frac{8C}{5}$

IES Convert into △

90



Gate Determine Input loop capacitance



$$-V(t)+i[3k]+\frac{1}{200\mu}\int 25\,i\,dt=0$$

$$V(t)=i(3000)+\frac{1}{8\mu}\int i\,dt$$

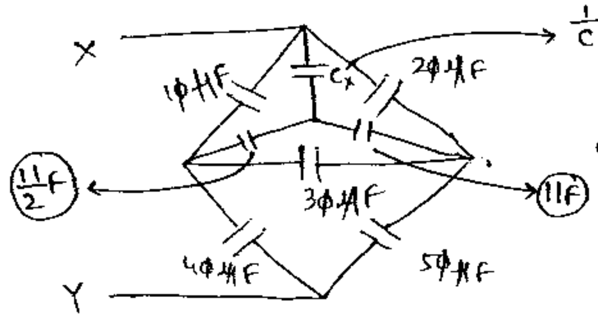
iR $\quad \frac{1}{C}\int i\,dt$

$C_{loop}=8\mu F.$

Stat

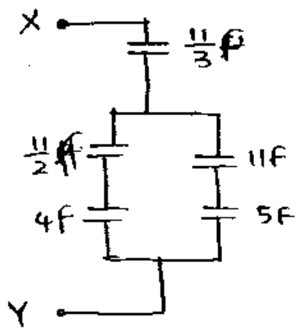
Gate $C_{XY}=$ ______

Magnitude scaling $\longrightarrow 10\mu F$.



$$\frac{1}{C_x}=\frac{\frac{1}{1}\cdot\frac{1}{2}}{\frac{1}{1}+\frac{1}{2}+\frac{1}{3}}=\frac{3}{11}$$

$C_x=\frac{11}{3}f.$



$C_{XY}=22.39\,\mu F$

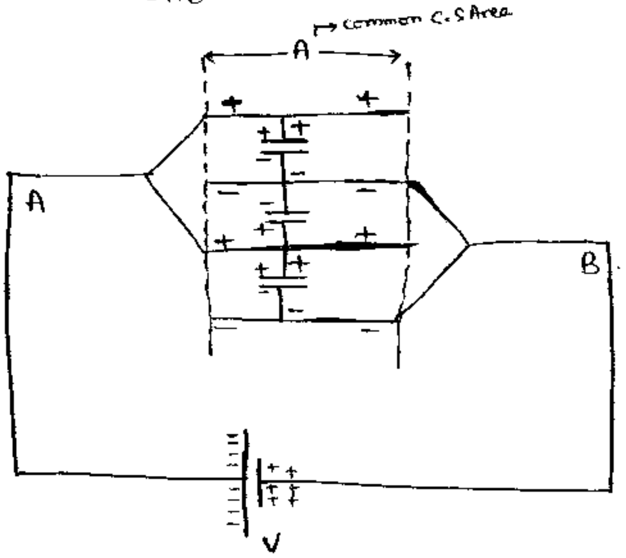
$\frac{55}{12}$

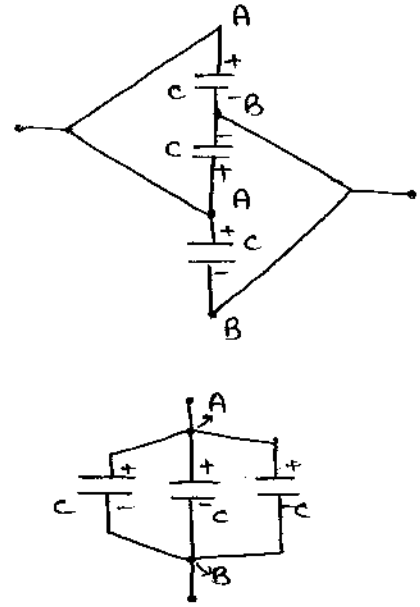
$\frac{\frac{11}{2}\times 4}{\frac{11}{2}+4}$

$\frac{44}{19}+\frac{55}{16}$

IES if Equivalent Capacitance b/w the opposite electrodes is 'c' farads then

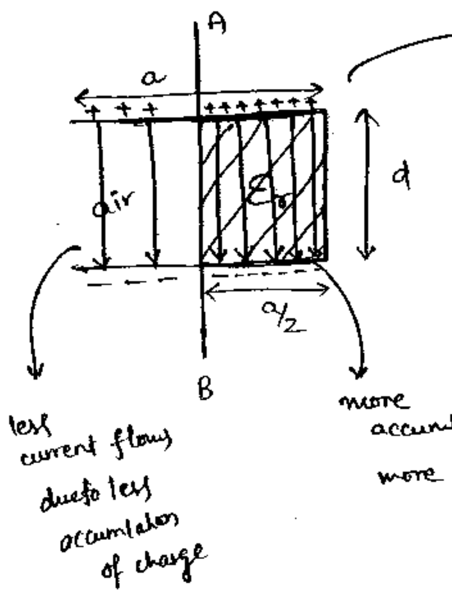
total C_{AB} = ____





$C_{AB} = 3C$ farads.

Gate C_{AB} = ____

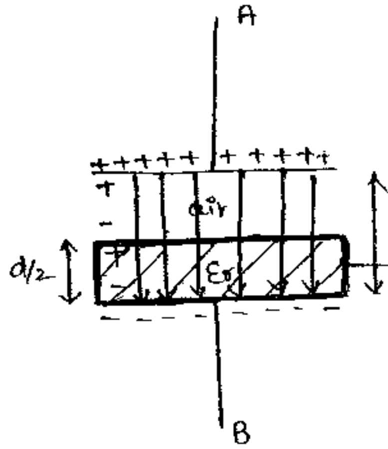


Working voltages are same but currents differed ⇒ parallel

$$C_{AB} = \frac{\varepsilon_0 (1)\, a}{2d} + \frac{\varepsilon_0 \varepsilon_r . a}{2d}$$

$$C_{AB} = \frac{\varepsilon_0 . a}{2d}(1+\varepsilon_r)$$

Gate $C_{AB} =$ ____



→ overall permittivity Increased by adding ε_r across c.s.A

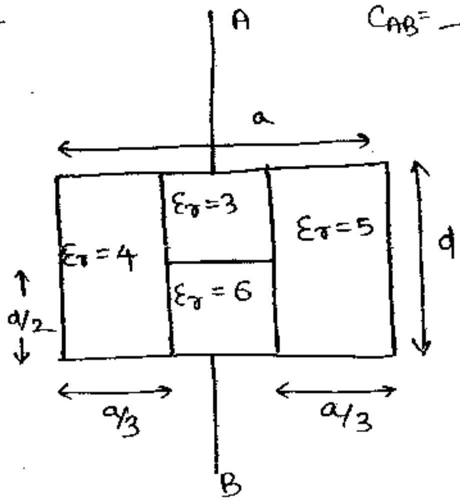
→ Working Voltages are different but same current ⇒ series.

$$C_{AB} = \frac{\frac{\varepsilon_0 (a)}{d/2} * \frac{\varepsilon_0 . \varepsilon_r . a}{d/2}}{\frac{\varepsilon_0 a}{d/2}(1+\varepsilon_r)}$$

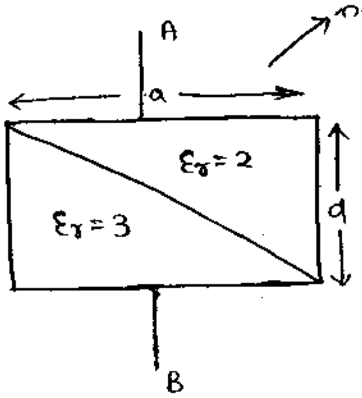
$$C_{AB} = \frac{2\varepsilon_0 \varepsilon_r a}{d(1+\varepsilon_r)}$$

HW-1

$C_{AB} =$ ___



$C_{AB} =$ ____



non

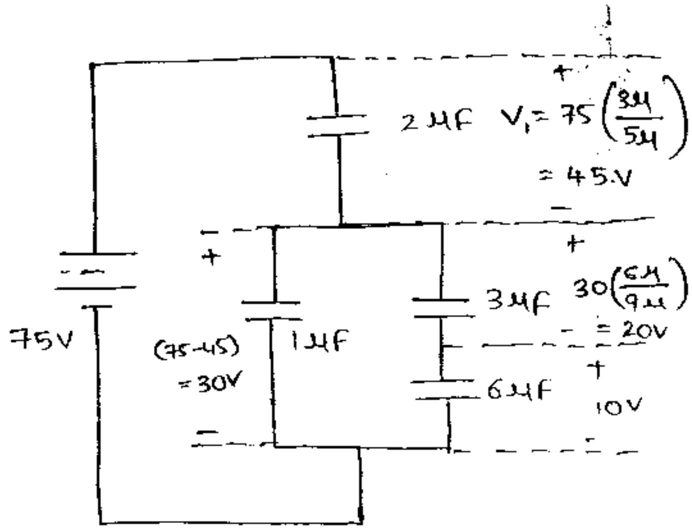
⇒ non Homogeneous distribution of dielectric Capacitor for the Capacitive N/w shown determine (1) Steady state Voltages across each ~~plate~~ capacitor

(2) Charge accumulated by each cap.

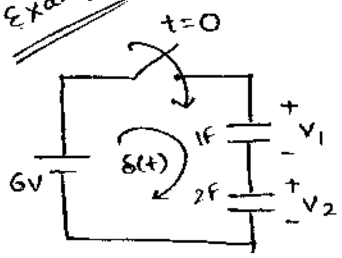
(3) Energy stored in each Cap.

(4) Verify law of Consv. Energy

(5) Verify law of Consv. charge



Example



In Series

$q_1 = q_2$

$C_1 V_1 = C_2 V_2$

$1(V_1) = 2(V_2) \longrightarrow ①$

$V_1 + V_2 = 6V \longrightarrow ②$

(or) By Voltage division Rule.

$V_1 = 6\left[\frac{2}{3}\right] = 4V$

$V_2 = 6\left[\frac{1}{3}\right] = 2V.$

L.C. of Energy

Solve eqns ① & ②

$3V_2 = 6V \longrightarrow V_2 = 2V$

$V_1 = 4V$

---

(1)

$V_{2\mu} = 75\left(\frac{3\mu}{2\mu + 3\mu}\right) = 45V$; $V_{1\mu F} = 30V$

$V_{3\mu} = 30\left(\frac{6\mu}{3\mu + 6\mu}\right) = 20V$; $V_{6\mu} = 10V$ (30-20)

(2) $q = CV$

$q_{2\mu} = 90\mu C$

$q_{1\mu} = 30\mu C$

$q_{3\mu} = 60\mu C$

$q_{6\mu} = 60\mu C$

92

(3). $E_{2\mu} = \frac{1}{2}(2\mu)(45)^2 = 2025\,\mu J$

$E_{1\mu} = \frac{1}{2}(1\mu)(30)^2 = 450\,\mu J$

$E_{3\mu} = \frac{1}{2}(3\mu)(20)^2 = 600\,\mu J$

$E_{6\mu} = \frac{1}{2}(6\mu)(10)^2 = 300\,\mu J$

Electrostatic form

$\downarrow$

charge

(4) L.C. Energy

$E_{deli} = E_{stored}$

LHS $E_{deli} = \frac{1}{2} C_T V_T^2 = \frac{1}{2}\left[\frac{6}{5}\mu\right]\left[75\right]^2 = 3375\,\mu J$

RHS $E_{stored} = [2025 + 450 + 600 + 300]\,\mu J = 3375\,\mu J$

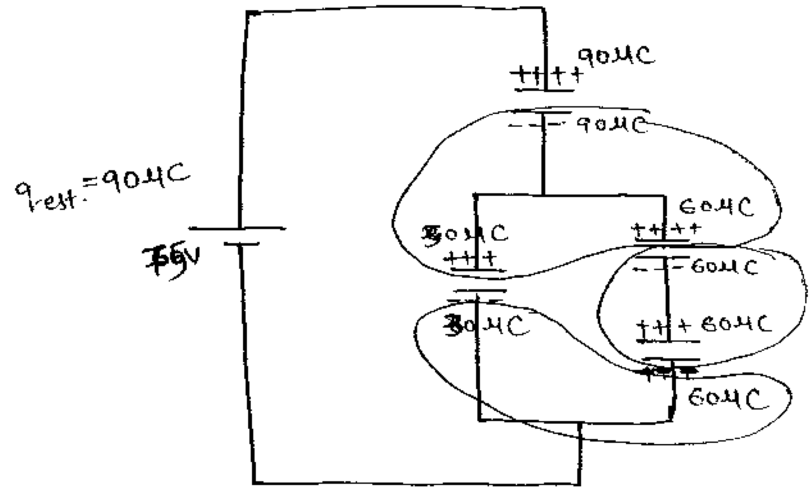
(5). L.C. charge

$q_{established} = q_{accumlated}$

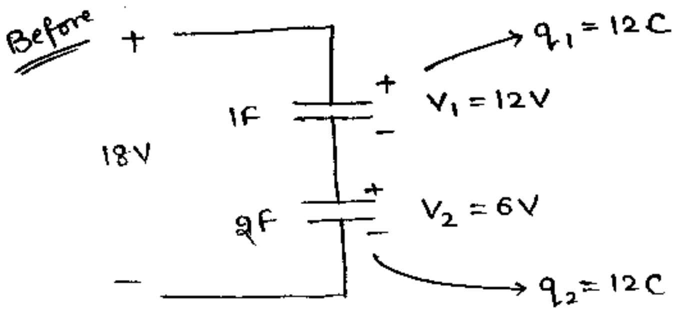
L.H.S $q_{est.} = C_T . V_T = \left[\frac{6}{5}\mu\right]\left[75\right] = 90\mu C$

RHS $q_{acc} = 90\mu C$

Here the total charge accumlated by the ckt is the charge stored on one series capacitor to the source which $2\mu F$ capacitor which is equal to $90\mu F$ only Hence law of conseration of charge verified



Q two capacitors of 1F & 2F are connected in series across 18V DC source. determine their steady state voltages & charge & energy stored in it. now if these two capacitors are disconnected from supply & connected with like polarities together then determine their steady state voltage & charge & energy stored in each. Verify L.C of charge & L.C of energy before and after the change.

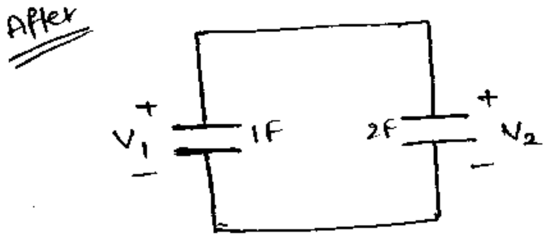


$E_1 = \frac{1}{2}(1)(12)^2 = 72J$

$E_2 = \frac{1}{2}(2)(6)^2 = 36J$

$q_T = C_T \cdot V_T = \frac{2}{3}[18] = 12C \longrightarrow (1)$

$E_T = (72+36) = 108J \longrightarrow (2)$



$\because$ parallel

$V_1 = V_2$

$q = CV \Rightarrow V = \frac{q}{C}$

$\frac{q_1}{C_1} = \frac{q_2}{C_2}$

$q_1 \times 2F = q_2 \times 1F$

$q_2 = 2q_1 \longrightarrow (3)$

q_1

$q = cv$

$\frac{q_1}{c_1} = \frac{q_2}{c_2}$

$\frac{q_1}{1} = \frac{q_2}{2}$

$q_2 = 2q_1$

$q_1 + q_2 =$

$q_1+q_2 = 24 \longrightarrow (4)$ $\left(q_1+q_2 \neq 12C\right.$ bcz

But the moment when we separate them from source they become Isolated Bodies

$\therefore$ charge on each cap. $= 12C$

(93)

then total charge

$q_T = q_1+q_2 = 12C+12C$

$q_1+q_2 = 24C \longrightarrow (4)$

solving (3) & (4)

$3q_1 = 24$

$q_1 = 8C$

$q_2 = 16C$

$V_1 = V_2$

$\frac{8}{1} = \frac{16}{2} = 8V$

$E_1 = \frac{1}{2}C_1V_1^2 = \frac{1}{2}(1)(8)^2 = 32J$

$E_1 = \frac{1}{2}C_2V_2^2 = \frac{1}{2}\times 2\times(8)^2 = 64J$

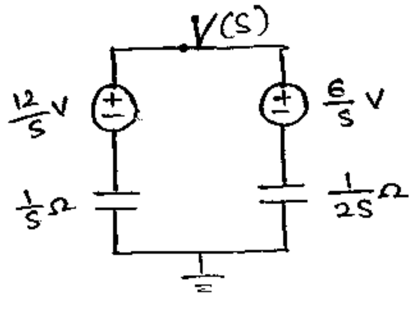
$q_T = q_1+q_2 = 8+16 = 24C \longrightarrow (5)$

$E_T = E_1+E_2 = 32+64 = 96J \longrightarrow (6)$ } 12 J of Energy lost (or) utilised to redistribute the charge to maintain same Voltage across each cap.

$\Rightarrow$ Here, L.C of Charge satisfied

$\Rightarrow$ L.C. of Energy has to be Justified

proof (S-domain):



Nodal

$$\frac{\left[V(S)-\frac{12}{S}\right]}{\frac{1}{S}} + \frac{\left[V(S)-\frac{6}{S}\right]}{\frac{1}{2S}} = 0$$

$V(S)\left[S+2S\right] = 24$

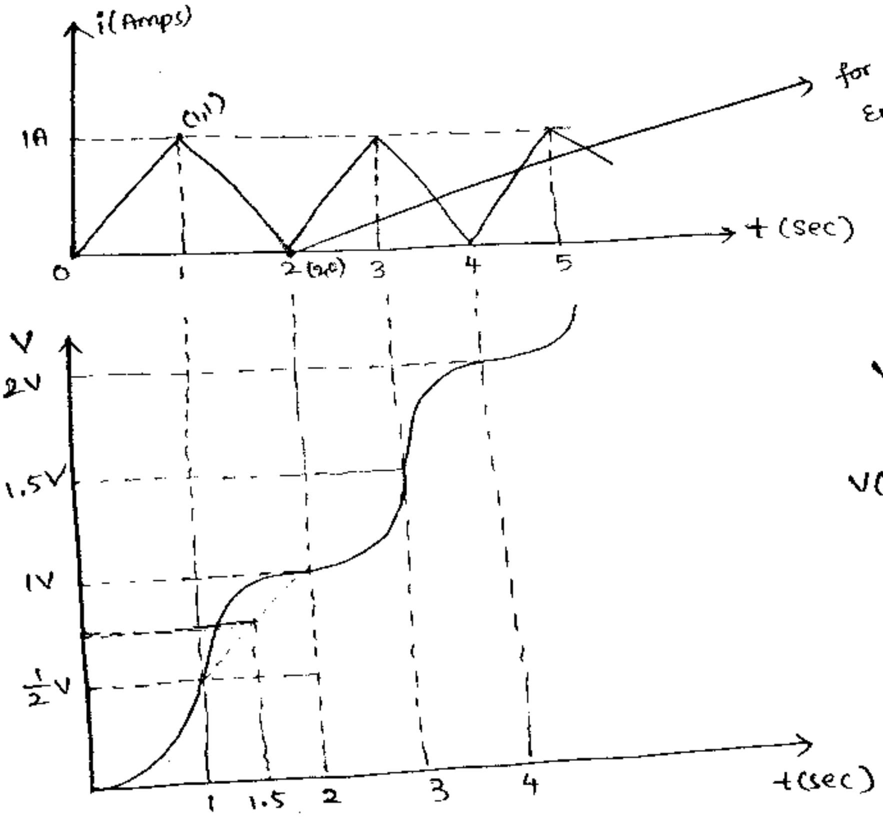
$V(S) = \frac{24}{3S} = \frac{8}{S}$

$V(t) = L^{-1}\left[V(S)\right] = 8$ Volts $\longrightarrow V_1 = V_2$

Here, charge is considered as matter but Energies can be in any form. So, law of Conservation of charge is satisfied but some of the Energy from previous state has be utilised to redistribute the charge among Capacitors to maintain Constant Equal Voltages.

GATE

Q if $V(0) = 0V$ plot the Voltage across 1F capacitor if Current through it as shown below.



for $i=0$
Energy stored in cap $\frac{1}{2}CV^2$
$\frac{1}{2} \times 1 \times 1^2$

even $i=0$, the Energy stored is not zero
∴ cap are better storing element than 'L'
But in 'L' to store energy current has to flow
in 'L', if $i=0$ energy stored is zero

$$V = \frac{1}{C}\int_{-\infty}^{t} i\,dt$$

$$V(t) = V(0) + \frac{1}{C}\int_{0}^{t} i(t)\,dt$$

$0<t<1$:

$i(t) = t$

$1<t<2$:

$i(t) = (-t+2)$

$0<t<1$

$$V(t) = V(0) + \frac{1}{1}\int_0^1 t\,dt$$

$$= 0 + \frac{t^2}{2}\Big|_0^1$$

$$V(t) = \frac{t^2}{2} \Rightarrow \text{parabolic}$$

$t=0 \longrightarrow V=0$

$t=1 \longrightarrow V=\frac{1}{2}V$

$1<t<2$

$$V(t) = V(0) + \frac{1}{1}\int (-t+2)\,dt$$

$$= \frac{1}{2} + \left(\frac{-t^2}{2}\right)\Big|_1^2 + 2t\Big|_1^2$$

$$V(t) = \frac{1}{2} - \frac{t^2}{2} + 2t \Rightarrow \text{parabolic}$$

$t=1 \longrightarrow V=\frac{1}{2}V$

$t=2 \longrightarrow V=1V$

Check

Value of 'v' at $t = 1.5$ sec

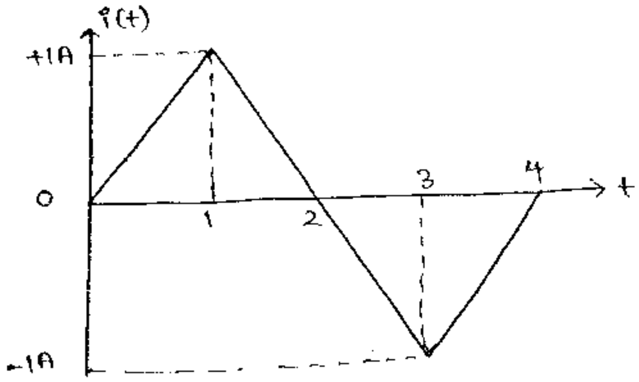
$$= \frac{1}{2} - \frac{t^2}{2}\Big|_1^{1.5} + 2t\Big|_1^{1.5}$$

$$= \frac{1}{2} - \frac{1}{2}[2.25 - 1] + 2[1.5 - 1]$$

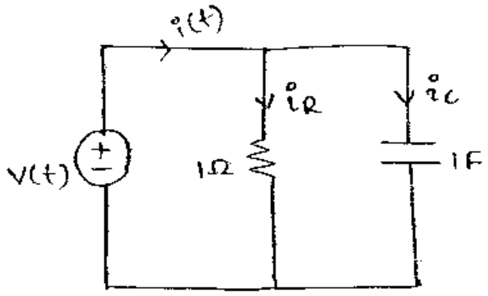
$$= 1.5 - 0.625$$

$$= 0.875 \text{ volts.}$$

Q In the above problem plot V, P, Energy in 1 farad Capacitor if the current w/f is changed to [V(0) = 0V]

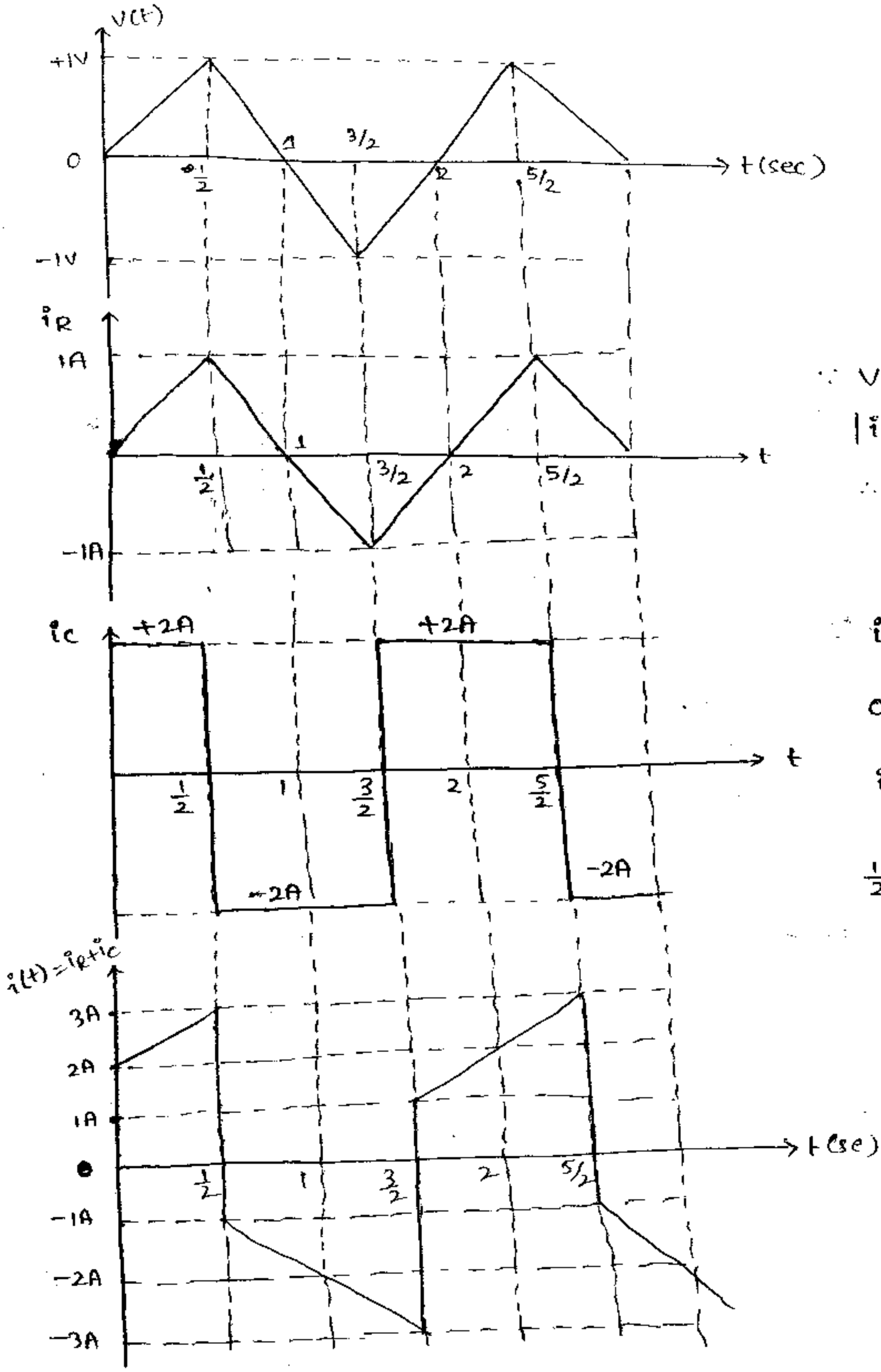


Q plot $i(t)$ if voltage $V(t)$ is given.



KCL

$i(t) = i_R + i_C$



$\because V = iR$

$|i| = \frac{V}{R} = \frac{1}{1} = 1.$

$\therefore$ in Resistor i follows V

$\because i_c = C\frac{dv}{dt}$

$0 < t < \frac{1}{2}$

$i_c = 1.\frac{d}{dt}(2t) = +2A$ (pulse)

$\frac{1}{2} < t < \frac{3}{2}$

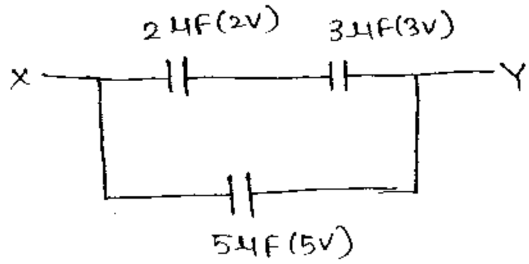
$i_c = 1.\frac{d}{dt}(-2t + C_1) = -2A$ (pulse)

$\frac{3}{2} < t < \frac{5}{2}$

$i_c = 1.\frac{d}{dt}(+2t - C_2)$

$i_c = +2A$ (pulse)

Gate/IES



5μF,

$$V_{max} = 5V \longrightarrow (1)$$

3μF,

$$V_{max} * \left[\frac{2\mu}{5\mu}\right] = 3V \longrightarrow V_{max} = \frac{15}{2} V = 7.5 \text{ volts} \longrightarrow (2)$$

2μF,

$$V_{max} * \left[\frac{3\mu}{5\mu}\right] = 2V \longrightarrow V_{max} = \frac{10}{3} V = 3.33 \text{ volts} \longrightarrow (2)$$

overall

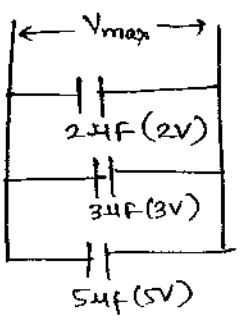
$$\text{safe}, V_{max} = \frac{10}{3} V = 3.33V.$$

$$q_{max} = C_T \cdot V_{max}$$

$$= \left[\frac{6}{5} + 5\right]\mu \left[\frac{10}{3}\right]$$

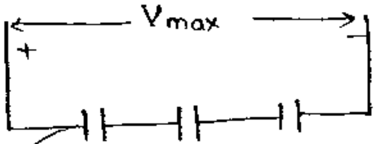
$$q_{max} = \frac{62}{3} \mu C.$$

Ex:
Suppose



$$\text{Safe}, V_{max} = 2V$$

*



2μF(2V) 3μF (3V) 5μF(5V)

∵ this has the total pressure of Vmax on 2μF (small) rated cap

∴ if we provide safety to this capacitor then overall safety can be provided.

$$V_{max}\left[\frac{\frac{1}{2\mu}}{\frac{1}{2\mu}+\frac{1}{3\mu}+\frac{1}{5\mu}}\right] = 2\text{Volts}.$$

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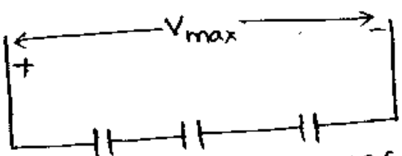
$$V_{max}\left[\frac{\frac{1}{2\mu}}{\frac{31}{30\mu}}\right] = 2\text{Volts}.$$

$$V_{max} = \frac{62}{15} = 4.133 \text{ Volt}$$

⇓ if Blocks 4.133V.

* Suppose all cap. are symmetrically rate.



2μF(2V) 2μF(2V) 2μF(2V)

Safe, $V_{max} = 6V$.

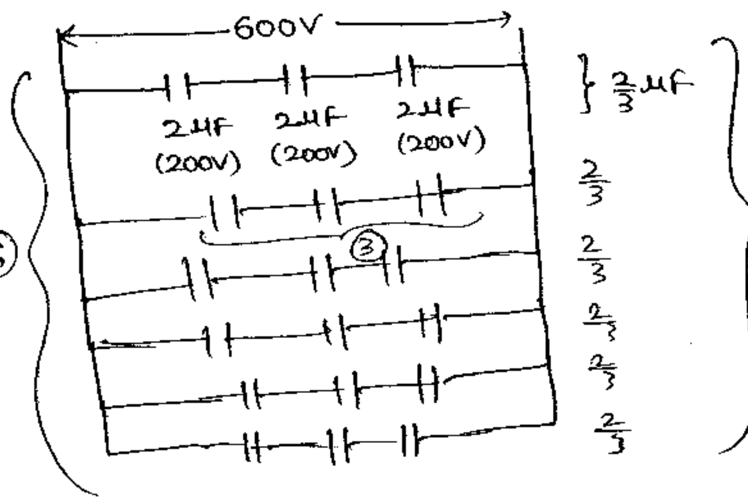
⇒ Symmetrical rated are much more Better Performance if blocks 6V

Q- How many capacitors of each rated 200V, 2μF are required to be connected to work at an application level of 600V, 4μF.

to Increase Voltage Rating Insulation level has to be Increased

∴ In cap. dielectric is the Insulation

∴ Connect 3, 200V cap. in Series



600V

2μF (200V) 2μF (200V) 2μF (200V)

$\} \frac{2}{3}\mu F$

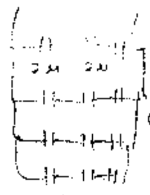
$\frac{2}{3}$ $\frac{2}{3}$ $\frac{2}{3}$ $\frac{2}{3}$ $\frac{2}{3}$

(3)

(6)

$\frac{2}{3} \times 6 = 4\mu F$.

⇒ 6×3 = 18 capacitors



(18)

$\frac{4}{4}$

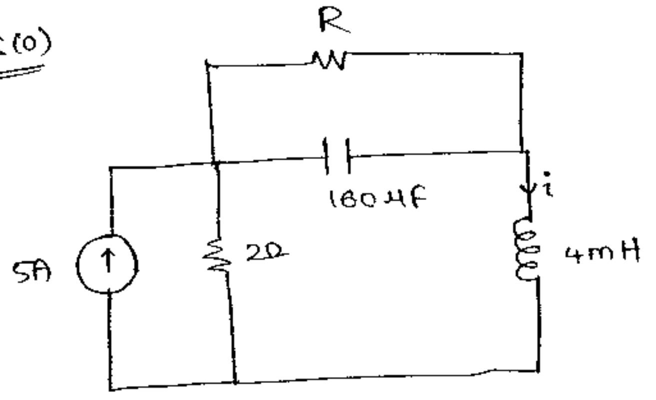
$\frac{2}{3}$

$\frac{2}{3}+\frac{2}{3}+\frac{2}{3}$

$\frac{2}{3} \times x = 4$

$\frac{2}{3}+\frac{2}{3}=4$

IES(O)



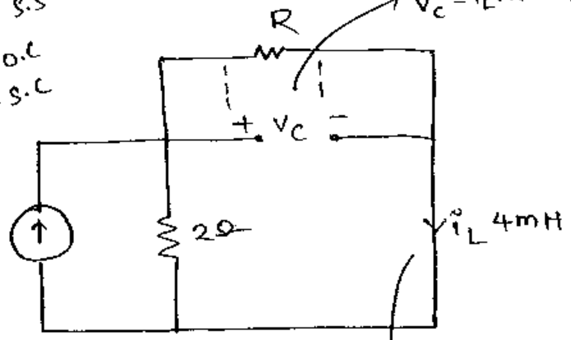
for What value of 'R' Energy stored in Inductor & Capacitor are Equal in S.S

$\frac{1}{2}CV_c^2 = \frac{1}{2}Li_L^2$

$160\mu V_c^2 = \frac{1}{2} 4\times 10^{-3} i^2$

$\frac{4}{100}V_c^2 = i_L^2$

For D.C S.S
Cap - O.C
Ind - S.C



$V_c = i_L \cdot R = \frac{10R}{2+R}$

$i_L = 5\left[\frac{2}{2+R}\right] = \frac{10}{2+R}$

$$\frac{\left(\frac{10R}{2+R}\right)^2}{\left(\frac{10}{2+R}\right)^2} = \frac{100}{4}$$

$$\frac{\cancel{100}R^2}{100} = \frac{\cancel{100}}{4}$$

$R^2 = 25$

$R = 5\Omega$

Steady State AC Circuit Analysis

$S^3A \rightarrow$ Steady state Sinusoidal Analysis. 97

$\rightarrow V = V_m \sin\omega t$ [IES]

$\rightarrow V = V_m \cos\omega t$

The Best waveform in electrical power Engg. where our entire generation, Transmission, distribution & utilisation of Elec. Energy where our major Components such as alternator, Transformers, Tr. lines & I. Motors gives Highest Efficiency & power factor to only Sinusoid.

$\Rightarrow$ T.F $\rightarrow \%\eta = 90\%$

Alternator $\rightarrow 92\%$

Tr. lines $\rightarrow > 70\%$

$>70\%$ of Elec Energy generated

↳ used to drive Mech. loads

gives Highest %η for Sinusoid.

$\Rightarrow$ King of loads of pow. sys $\rightarrow$ Ind. motors

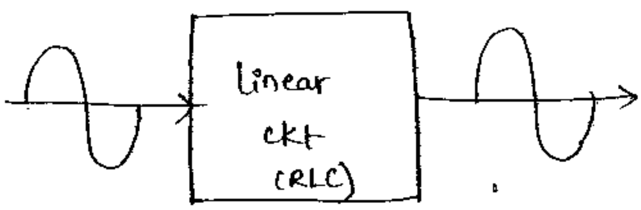
↳ Best performance only for Sinusoid.

Sideeffects:

if we Excite our components in power Engg. with other than Sinusoidal w/f then we have Torque ripples, Harmonics, electromag. Interference, additional losses, low p.f & so low efficiency

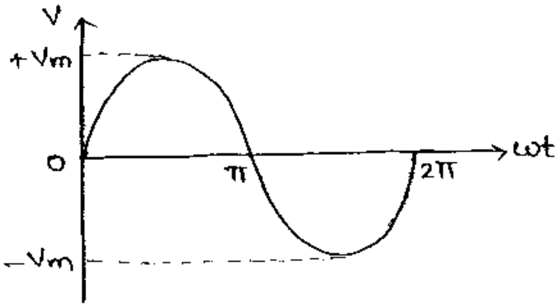
—x—

The only w/f if we give as Input to any linear circuit will also the same o/p is Sinusoid.



(a) Radian

$V = V_m \sin\omega t$



$V_m \rightarrow$ Amplitude [volts]

$\omega \rightarrow$ angular Velocity [rad/sec]

$\omega t \rightarrow$ Argument

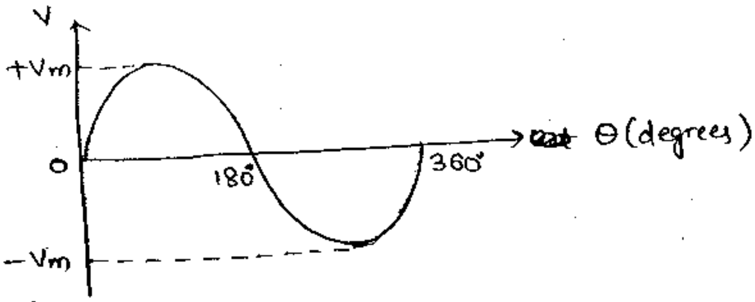
$$\boxed{\omega = 2\pi f}$$

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

$$\boxed{\omega = \frac{2\pi}{T}}$$

(b) degree

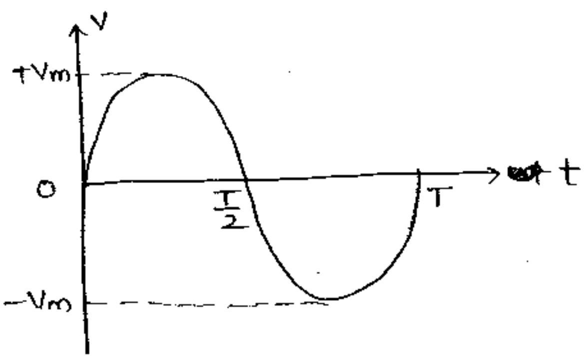
$V = V_m \sin\theta$



(c) Time

$V = V_m \sin\left(\frac{2\pi}{T} \cdot t\right)$

$f = 1/T$



INDIA

$f = 50\,Hz$

$1T = \frac{1}{50} = 20\,m\,Sec$

$\omega = 2\pi f = 2\pi(50)$

$= 100\pi$ } rad/sec.
≈ 314 }

INDIA @ 50 HZ

$1T = 2\pi = 360^\circ = 20\,msec$

$2\pi \downarrow$ Radian, $360^\circ \downarrow$ degrees, $20\,msec \downarrow$ Time

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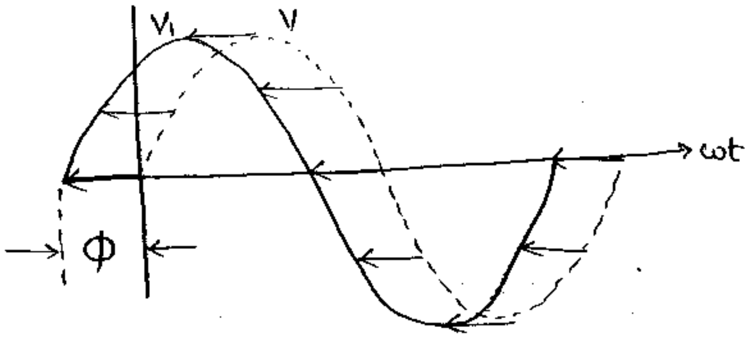
Standard Sinusoid:

$$V_X = V_m \sin(\omega t \pm \phi)$$

$\phi \rightarrow$ phase shift [deg.]

$\hookrightarrow$ Time shift.

Example 1: $V_1 = V_m \sin(\omega t + \phi)$

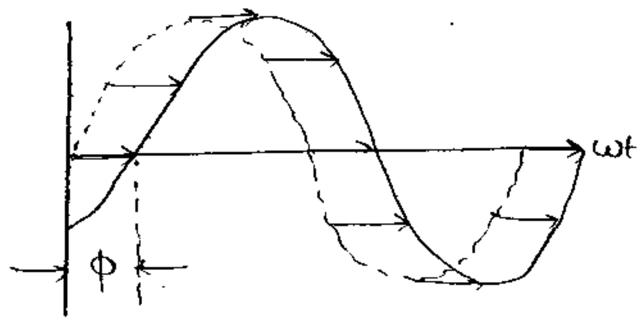


V_1 comes early than V by ϕ

V_1 leads V by ϕ.

$+\phi \rightarrow$ leading.

Example: 2: $V_2 = V_m \sin(\omega t - \phi)$



V_2 comes late than V by ϕ

V_2 lags V by ϕ

$-\phi \rightarrow$ lagging.

INDIA, $f = 50Hz$,

let $\phi = 60°$

$360° \longrightarrow 20msec$

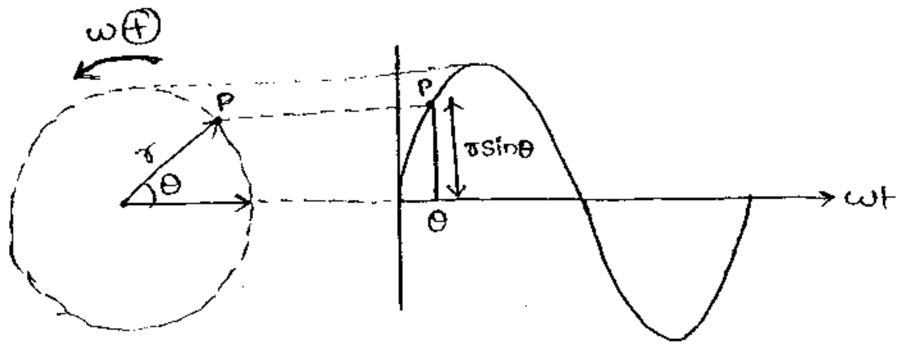
$60° \longrightarrow t_{shift}$

$$t_{shift} = \frac{60°}{360°} * 20m\,Sec$$

$$t_{shift} = 3.33\ msec$$

Convolute
↓
operate

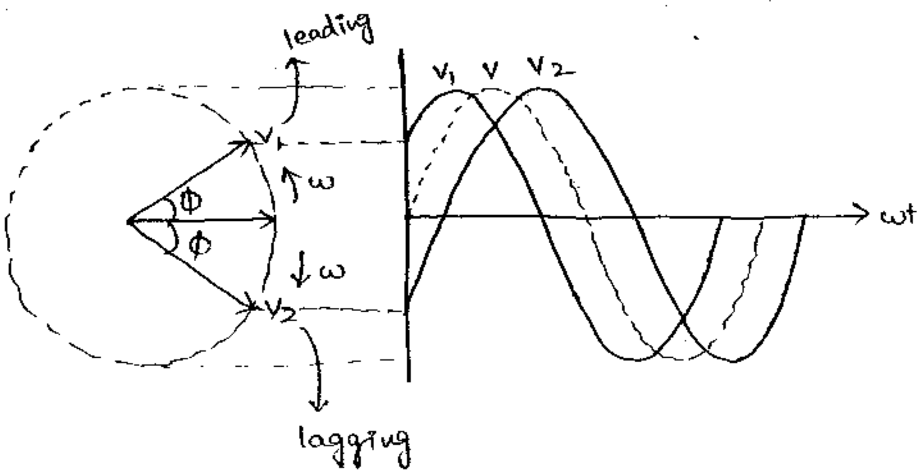
phasor ⟶ Represent Sinusoids only



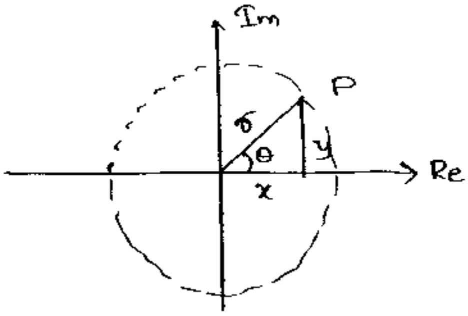
+ new

$P = r\angle\theta$

$\overline{V} = |V_m|\angle 0°$, $\overline{V_1} = |V_m|\angle +\phi°$, $\overline{V_2} = |V_m|\angle -\phi°$



S-plane,,



Electrical Quantity:

↓

P

└→ Rectangular form → $x+iy$

Polar form → $r\angle\theta$

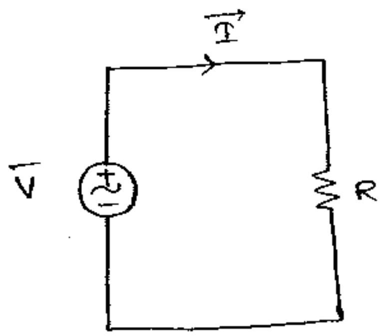
Euler form → $re^{i\theta}$.

RECT		POL
$0+j0$	→	$0\angle 0°$
$1+j0$	→	$1\angle 0°$
$\boxed{0+j1 \rightarrow 1\angle 90°}$	→	maths operator in E.E
$1+j1$	→	$\sqrt{2}\angle 45°$
$0-j1$	→	$1\angle -90°$

j operator shifts the phase by 90° & multiplies mag by "1"

phasor Relationship b/w Voltages & Currents in passive elements:

(a) Resistor.



let $\bar{V} = V_m \sin\omega t \longrightarrow (1)$

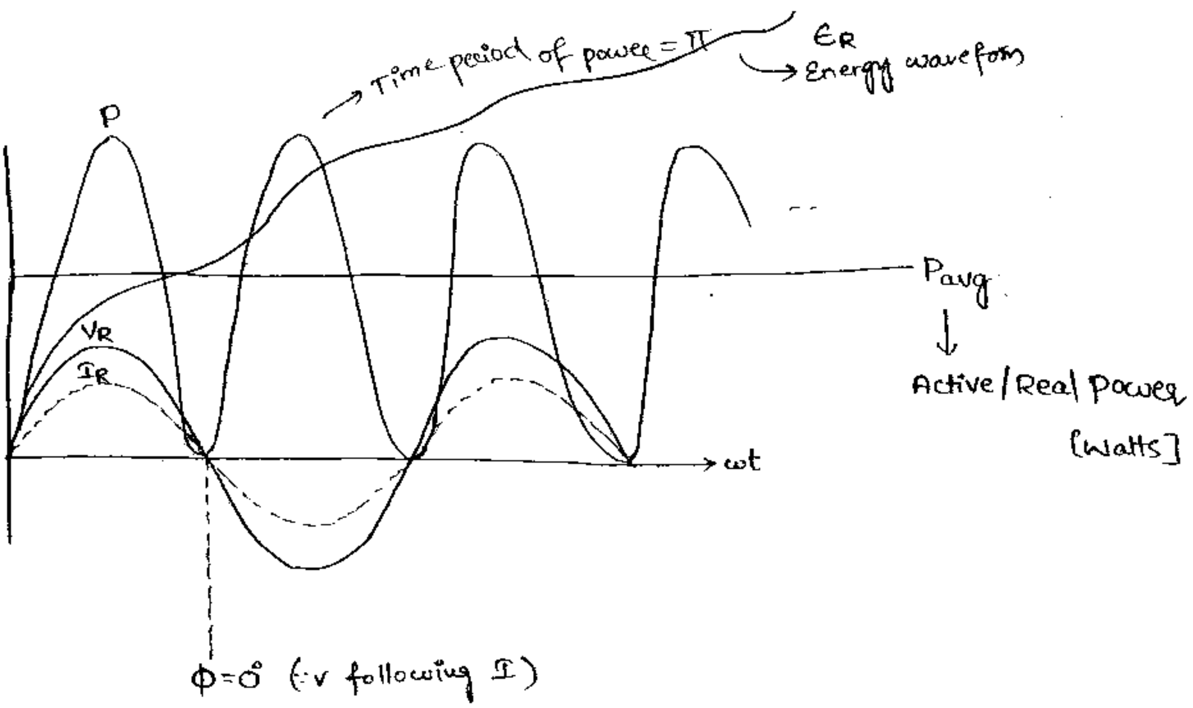
$$I = \frac{V}{R}$$

$$\bar{I} = \frac{V_m \sin\omega t}{R} = \left[\frac{V_m}{R}\right]\sin\omega t$$

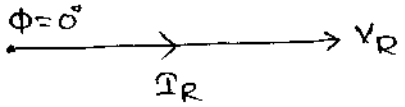
$$\bar{I} = I_m \sin\omega t \longrightarrow (2)$$

$$\boxed{\bar{V} = \bar{I}\cdot R}$$ → 4th form of ohms law.

→ Resistor is In phase element (V & I are in phase)



phasor diagram:



power factor:

$$\cos\phi = \cos 0^\circ = 1 \,[\text{UPF}]$$

$$P_{avg} = \frac{1}{T}\int_0^T P(t)\,dt$$

Time period of p is π

$$P_{avg} = \frac{1}{\pi}\int_0^{\pi} V_m I_m \sin^2\omega t \, d\omega t.$$

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

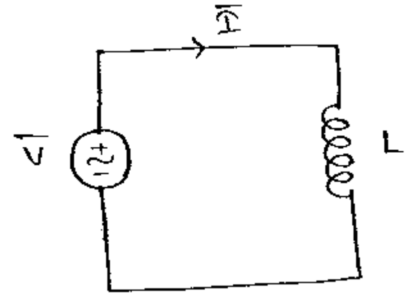
$$P_{avg} = \frac{V_m I_m}{2}\left[\underbrace{\frac{1}{\pi}(\pi-0)}_{1} - \underbrace{\frac{1}{2}(0-0)}_{0}\right]$$

$$P_{avg} = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}}\cdot\frac{I_m}{\sqrt{2}}$$

$$P_{avg} = V_{rms}\cdot I_{rms}$$

* Instantaneous freq. of Power of ~~Indian~~ $\underbrace{\text{Heater}}_{\text{Resistor}}$ in Indian System = 100Hz

(b) Inductor: 100



$$\overline{I} = I_m \sin\omega t \longrightarrow (1)$$

$$V = L\frac{dI}{dt}$$

$$V = \omega L I_m \cos\omega t$$

$$V = \omega L I_m \sin(90^\circ + \omega t)$$

$$V = \omega L I_m \sin(\omega t + 90^\circ) \longrightarrow (2)$$

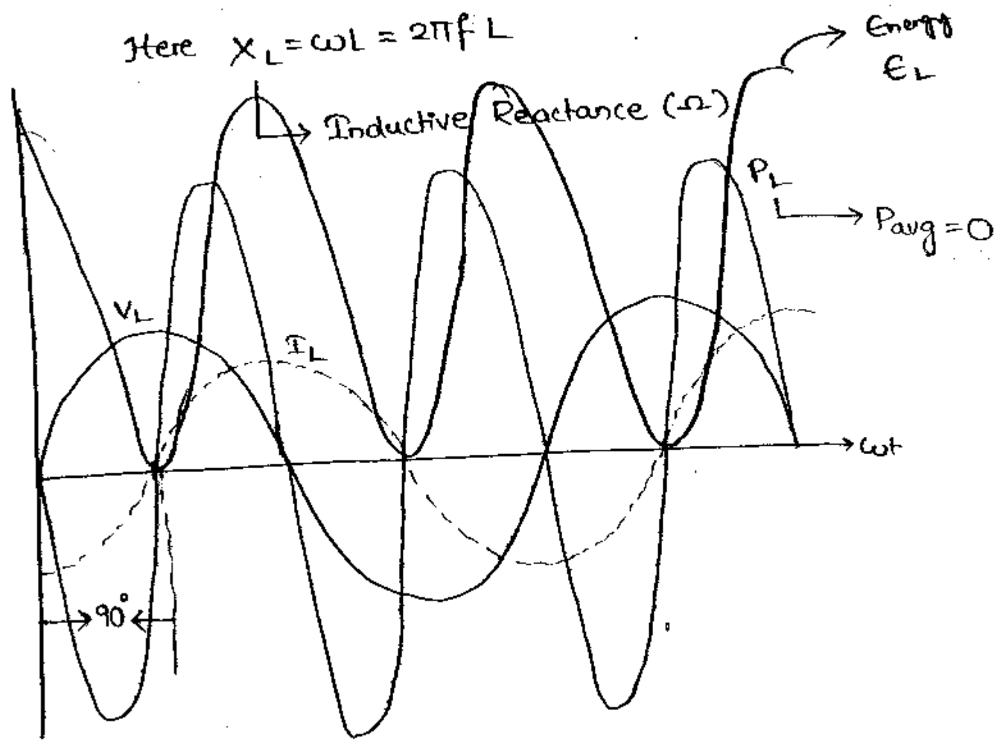
$$V = \omega L I_m \sin\omega t\,[j]$$ → ∵ j shifts by 90° phase

$$\overline{V} = j\omega L \overline{I}$$

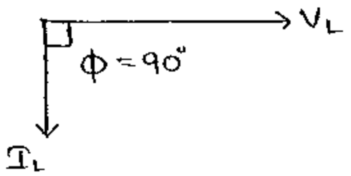
$$\boxed{\overline{V} = +jX_L\overline{I}}$$ ⟶ 8th form of ohmslaw.

⇒ 'L' is lagging element (w.r.t Voltage Current is lagging)

Here $X_L = \omega L = 2\pi f L$ → Inductive Reactance (Ω)



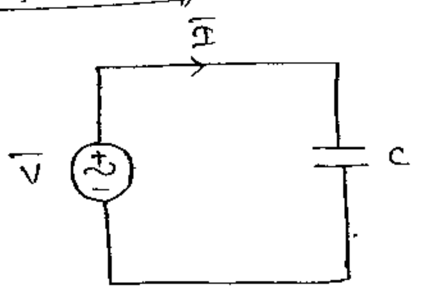
phasor diagram :



power factor :

$$\cos\phi = \cos 90^\circ = 0$$

(c) Capacitor :



Let $\bar{V} = V_m \sin\omega t$

$$I = C\frac{dV}{dt}$$

$$I = \omega C V_m \cos\omega t$$

$$I = \omega C V_m \sin(90^\circ + \omega t)$$

$$I = \omega C V_m \sin(\omega t \underset{\downarrow}{+90^\circ}) \longrightarrow (2)$$

$$I = \omega C \underbrace{V_m \sin\omega t}\ [j]$$

$$\bar{I} = j\omega C\,\bar{V}$$

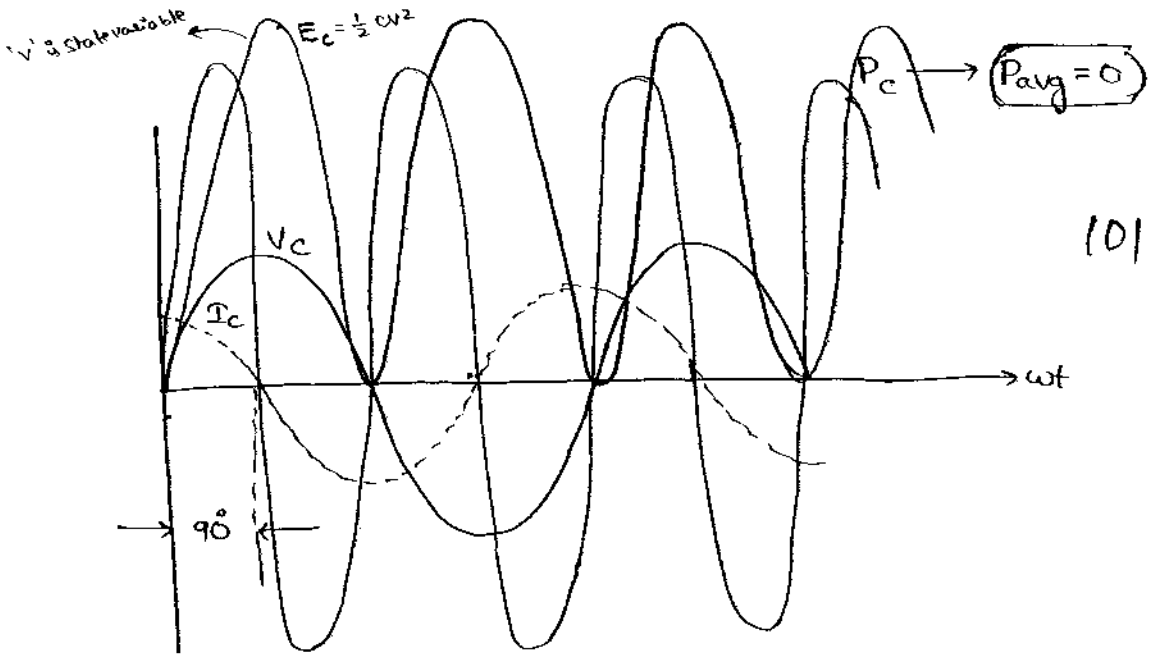
$$\bar{V} = \frac{\bar{I}}{j\omega C} = \frac{-j}{\omega C}\cdot\bar{I}$$

$$\boxed{\bar{V} = -jX_C\,\bar{I}} \longrightarrow 9^{th} \text{ form of ohms law.}$$

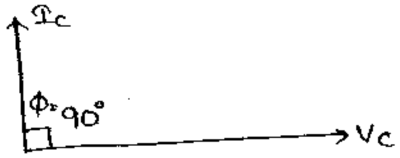
$\Rightarrow$ capacitor is leading element (current leading voltage)

Here $\boxed{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}}$

$\longrightarrow$ capacitive Reactance (Ω)
↓
(AC Resistance)



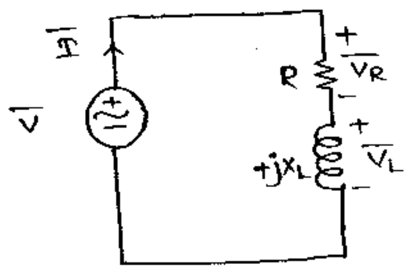
phasor diagram:



power factor:

$$\cos\phi = \cos 90° = 0$$

(d) Series RL



KVL

$$\bar{V} = \bar{V_R} + \bar{V_L}$$

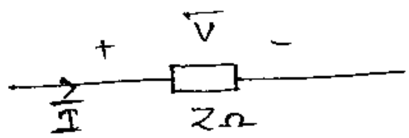
$$\bar{V} = \bar{I}.R + jX_L.\bar{I}$$

$$\bar{V} = \bar{I}\,[R + jX_L]$$

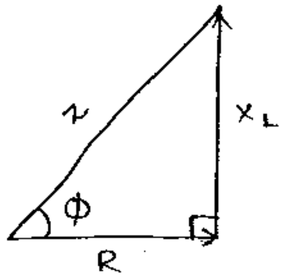
$$\boxed{\bar{V} = \bar{I}\,Z}$$

$$Z = R + jX_L$$

→ Impedence (Ω)



→ Impedence Δlé.



$$|Z| = \sqrt{R^2 + X_L^2}$$

$$= \sqrt{R^2 + (\omega L)^2}$$

$$\underbrace{\phi}_{\text{Impedence angle}} = \tan^{-1}\left[\frac{X_L}{R}\right] = \tan^{-1}\left[\frac{\omega L}{R}\right]$$

→ power factor

$$\cos\phi = \frac{R}{|Z|}$$

Phasor addition is vector addition at instant

$$\text{also, } \sin\phi = \frac{X_L}{|Z|}$$

$$I^2 Z = I^2 R + j X_L I^2$$

$$V.I = I^2 R + j I^2 X_L$$

$$S = P + jQ_L$$

~~un accountable~~

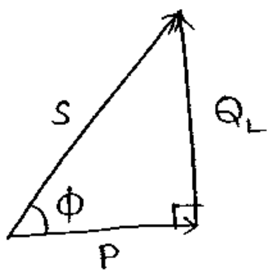
Q_L → Reactive power (VAR's) → chokes, power Inductors & power Capacitors — Ratings given in VAR's

P → Real / active / True power (watts) (speakers, lights, heaters, ..etc) (electricity → utilisable) → Ratings given in watts

Convertable & utilisable part of power (R)

S → Total / Apparent power (VA's) (Stabiliser, Inverter, UPS alternators, T/f,) → Rating given in VA ratings

⇒ power Δle



$$|S| = \sqrt{P^2 + Q_L^2}$$

$$\phi = \tan^{-1}\left[\frac{Q_L}{P}\right]$$

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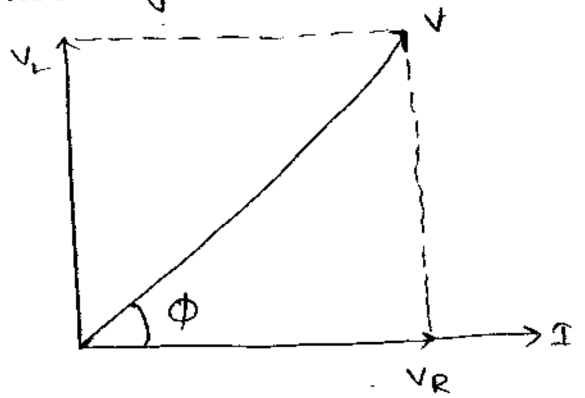
power factor:

$\cos\phi = \frac{P}{S} \longrightarrow P = S\cos\phi = V.I.\cos\phi$ W

also $\sin\phi = \frac{Q_L}{S} \longrightarrow Q_L = S\sin\phi = V.I.\sin\phi$ VARS.

} Here V, I are Rms Values

phasor diagram:



RL is

$\bar{I}$ lags $\bar{V}$ by $\phi < 90°$ (lagging element)

$$\bar{I} = \frac{\bar{V}}{Z} = \frac{V_m \sin\omega t}{R+jX_L} = \frac{V_m \sin\omega t}{|Z| \underline{|+\phi}}$$

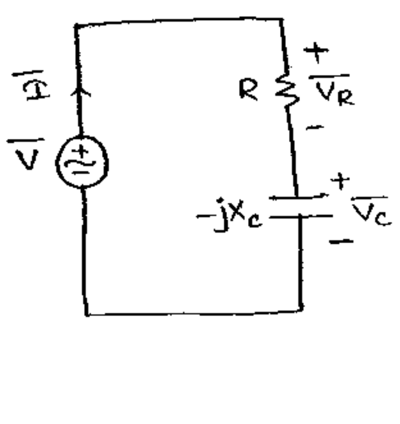
$$\bar{I} = \frac{V_m}{|Z|}\sin(\omega t - \phi) \text{ Amp}$$

~~Here V, I~~

Note: In Linear ckt analysis Impedence angle, phasor angle, power factor angle all are Same.

AC sources referred with Apparent (Ω) Total power (VA)

(e) Series RC:



KVL

$\bar{V} = \bar{V}_R + \bar{V}_c$

$\bar{V} = \bar{I}R + (-jX_c)\bar{I}$

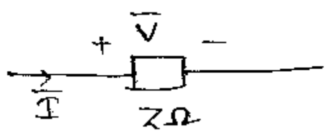
$\bar{V} = \bar{I}R - jX_c\bar{I}$

$\bar{V} = \bar{I}[R - jX_c]$

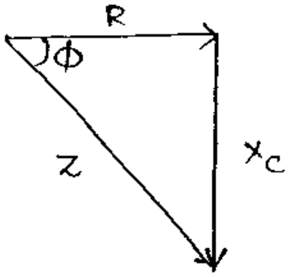
$\bar{V} = \bar{I}.Z$

$Z = R - jX_C$

$\longrightarrow$ Impedance (Ω)



Impedence Δle.



for series
for easy
series - I ref take
parallel - V ref take

$$|Z| = \sqrt{R^2 + X_c^2} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$\phi = \tan^{-1}\left(\frac{X_c}{R}\right) = \tan^{-1}\left(\frac{1}{\omega RC}\right)$$

$\downarrow$

Impedence angle.

$\Rightarrow$ power factor

$$\cos\phi = \frac{R}{|Z|}$$

also $\sin\phi = \dfrac{X_c}{|Z|}$

$$I^2 Z = I^2 R - jX_c I^2$$

$$V.I = I^2 R - j I^2 X_c$$

$\downarrow \quad \downarrow \quad \downarrow$

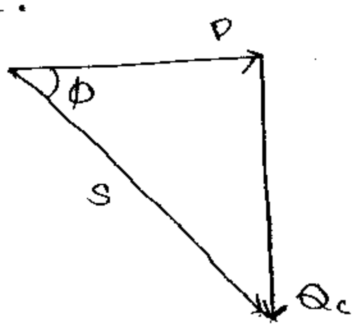
$S = P$ [redacted] jQ_c

Q_c → Reactive power (VAR's)

P → Real / Active / True power (watts)

S → Total / Apparent power (VA's).

power Δle :



$$|S| = \sqrt{P^2 + Q_c^2}$$

$$\phi = \tan^{-1}\left[\frac{Q_c}{P}\right]$$

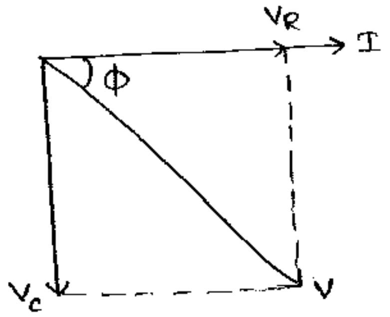
power factor:

$$\cos\phi = \frac{P}{S} \longrightarrow P = S\cos\phi = V.I.\cos\phi \ \underline{\omega}$$

also $$\sin\phi = \frac{Q_c}{S} \longrightarrow Q_c = S\sin\phi = V.I\sin\phi \ \underline{VARs}$$

Here V, I are RMS values.

phasor diagram:



RC is

$\bar{I}$ leads $\bar{V}$ by $\phi < 90°$ (leading element)

$$\bar{I} = \frac{\bar{V}}{Z} = \frac{V_m \sin\omega t}{R - jX_C} = \frac{V_m \sin\omega t}{|Z| \angle -\phi}$$

$$= \frac{V_m}{|Z|}\sin(\omega t + \phi) \text{ Amps.}$$

as L, C are ~~stake~~ passive

in passive sinks

+P → absorb Energy

−P → generate Energy

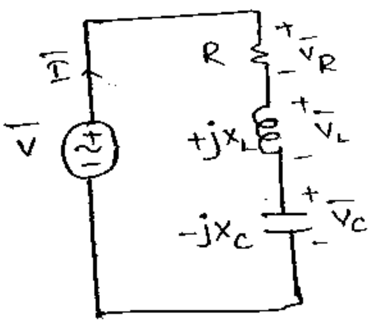
R-L,, $\boxed{+Q_L}$ ⟶ absorbing VAR's (lagging)

$\boxed{-Q_c}$ ⟶ generating VAR's (leading)

$$\overset{L}{\downarrow} Q \underset{c}{\uparrow} = \frac{\underset{c}{\uparrow} V_2 \overset{L}{\downarrow}}{X}[V_1\cos\delta - V_2]$$

Compensation.

(f) Series R-L-C



KVL

$$\bar{V} = \bar{V}_R + \bar{V}_L + \bar{V}_C$$

$$\bar{V} = \bar{I}R + jX_L\bar{I} - jX_C\bar{I}$$

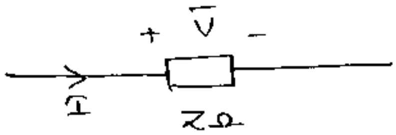
$$\bar{V} = \bar{I}\left[R + j(X_L - X_C)\right]$$

$$\bar{V} = \bar{I} \cdot Z$$

$$Z = R + j\underbrace{(X_L - X_c)}_{X_{net}}$$

$\downarrow$

Impedence (Ω)



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

$$\phi = \tan^{-1}\left(\frac{X_L - X_c}{R}\right)$$

$\hookrightarrow$ net Impedence angle

power factor:

$$\cos\phi = \frac{R}{|Z|}$$

also $$\sin\phi = \frac{X_{net}}{|Z|} = \frac{[+X_L - X_c]}{|Z|}$$

$$I^2 Z = I^2 R + j\left[I^2 X_L - I^2 X_c\right]$$

$$V.I = I^2 R + j\left[I^2 X_L - I^2 X_c\right]$$

$$\downarrow \quad \downarrow \quad \swarrow \quad \swarrow$$

$$S = P + j\underbrace{[Q_L - Q_c]}_{Q_{net}}$$

$$|S| = \sqrt{P^2 + (Q_L - Q_c)^2}$$

$$\phi = \tan^{-1}\left[\frac{Q_L - Q_C}{P}\right]$$

power factor:

$$\cos\phi = \frac{P}{S} \Rightarrow P = S\cos\phi = V.I.\cos\phi$$

also $$\sin\phi = \frac{Q_{net}}{S} = \frac{[Q_L - Q_C]}{S}$$

$$Q_{net} = [+Q_L - Q_C] = S\sin\phi = V.I.\sin\phi \text{ VAR's.}$$

case(i):

If $|X_L| > |X_C|$

$Z = R + jX_{net}$

$\hookrightarrow$ R-L

'I' lags 'V' by $\phi < 90°$

(lagging P.F)

General Nature of Electrical power System

case(ii):

If $|X_L| < |X_C|$

$Z = R - jX_{net}$

$\hookrightarrow$ R-C

'I' leads 'V' by $\phi < 90°$

(leading P.F)

case(iii):

If $|X_L| = |X_C|$

$Z = R$

$\hookrightarrow$ purely Resistive

'I' inphase with 'V'

$\phi = 0°$ [UPF]

$\longrightarrow$ Electrical Resonance

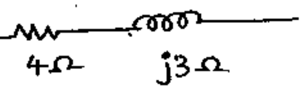
$$\boxed{Z = R \pm jX}$$

$\rightarrow Z = R + \underbrace{jX_L}$ $\rightarrow$ +ve Reactance is Inductive

$\rightarrow Z = R - \underbrace{jX_C}$

$\hookrightarrow$ -ve Reactance is Capacitive

Ex: $Z = (4 + j3)\,\Omega$



$Y = \frac{1}{Z}$

$\downarrow$

admittance

Units: mho(℧)

Siemens.

$$Y = \frac{1}{4+j3} \times \frac{4-j3}{4-j3}$$

$$Y = \frac{4-j3}{25} = \frac{4}{25} - j\frac{3}{25}$$

$$Y = 0.16 \underbrace{- j0.12}\ ℧$$

$\hookrightarrow$ -ve Suceptance is Inductive.

$$\boxed{Y = G \pm jB}$$

$Y = G - j\underbrace{B_L}$ → (Where $B_L \propto \frac{1}{X_L} \propto \frac{1}{\omega L} \propto \frac{1}{2\pi f L}$)

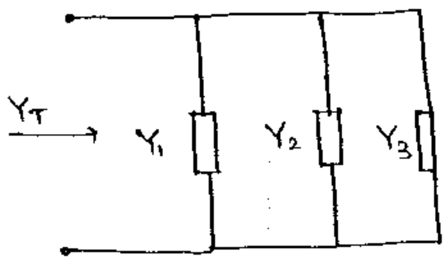
→ Inductive Susceptance ($\mho$)

→ -ve Susceptance is Inductive

$Y = G + j\underbrace{B_C}$ → ($B_C \propto \frac{1}{X_C} \propto \omega C \propto 2\pi f C$)

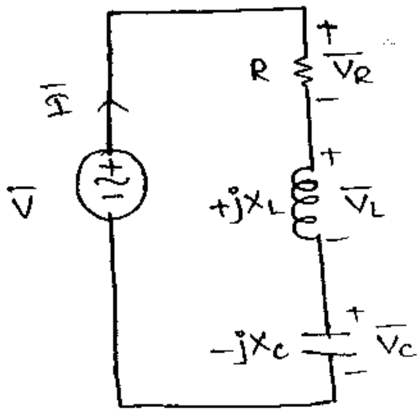
→ Capacitive Susceptance ($\mho$)

→ +ve Susceptance is Capacitive



$$Y_T = Y_1 + Y_2 + Y_3$$

Q Draw the phasor diagram of Series RLC ckt if $|X_L| > |X_C|$



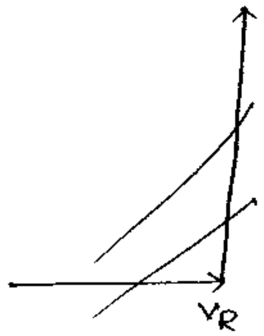
$$\bar{V}_R = I.R \angle 0$$

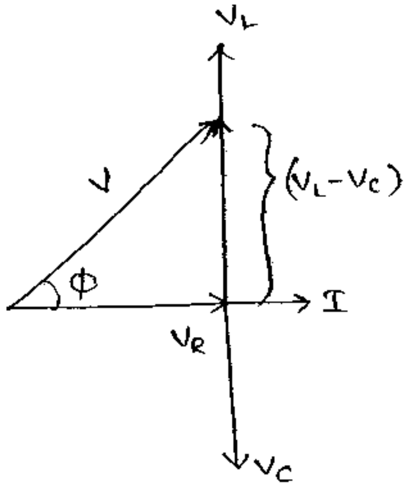
$$V_L = +jX_L I = I.X_L \angle +90^\circ$$

$$V_C = -jX_C I = I.X_C \angle -90^\circ$$

$$\because |X_L| > |X_C|$$

$$|V_L| > |V_C|$$





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

$$\phi = \tan^{-1}\left[\frac{V_L - V_C}{V_R}\right]$$

$$PF,\ \cos\phi = \frac{V_R}{V}\ [\text{lag}]$$

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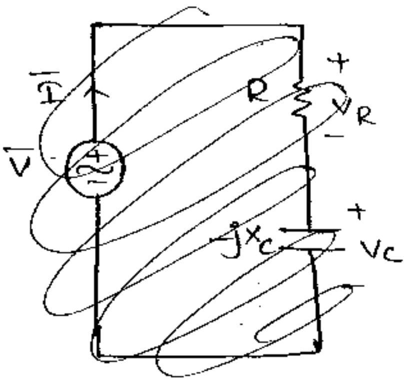
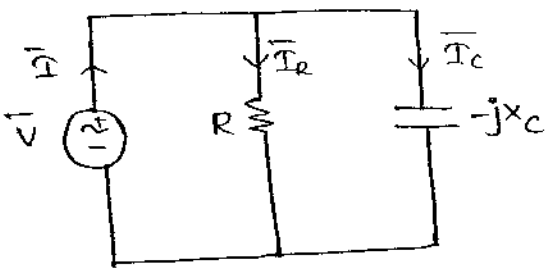
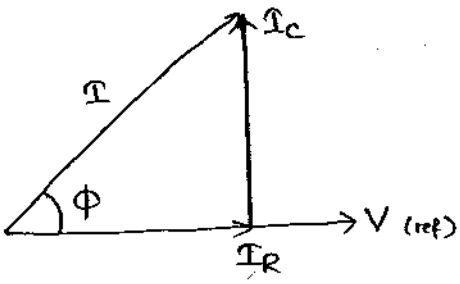
draw the phasor diagram of a parallel R-C ckt.





$$\bar{I}_R = \frac{V}{R}\angle 0^\circ$$

$$\bar{I}_C = \frac{V}{-jX_C} = \frac{V}{X_C}\angle +90^\circ$$

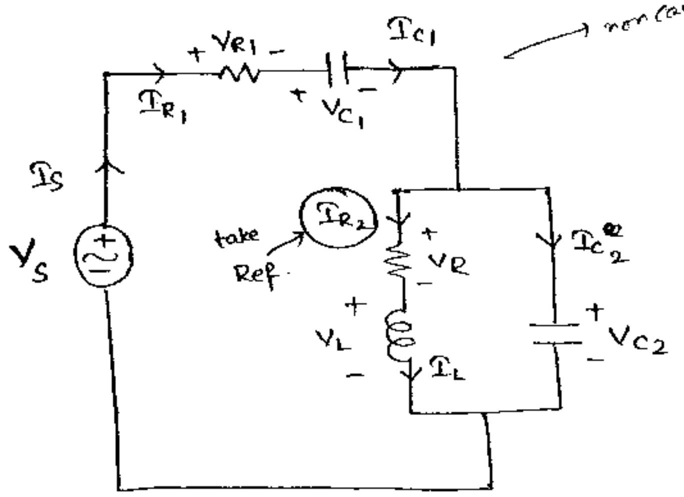


$$|I| = \sqrt{I_R^2 + I_C^2}$$

$$\phi = \tan^{-1}\left[\frac{I_C}{I_R}\right]$$

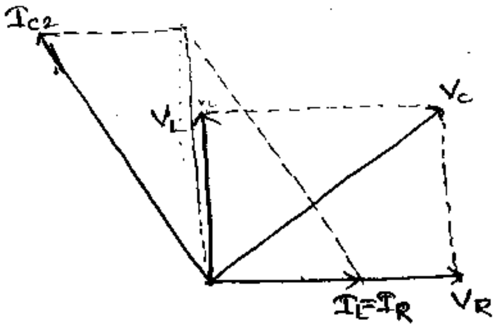
$$P.F: \cos\phi = \frac{I_R}{I}\ (\text{lead})$$

Draw the phasor diagram Relating all the elemental Voltages & Currents in the ckt shown.



→ non cannonical form
neither V, nor I is same for each element

if V, or I is same for all elements → canonical form
(parallel → V same)
(series → I same)



Gate/IN.

If (A) = 10A , (A1) = 8A then (A2) = ——

ckt power factor is

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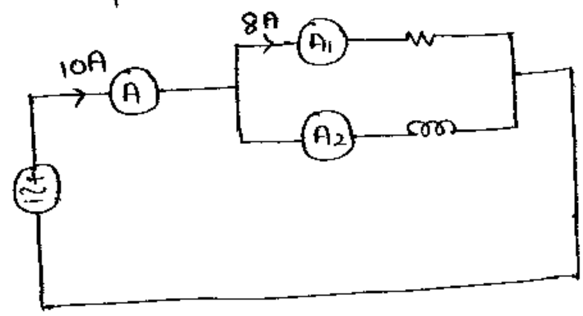
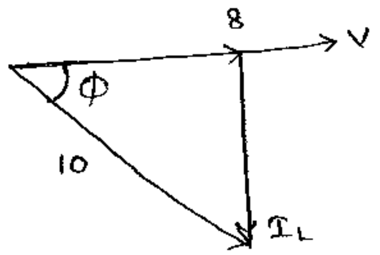




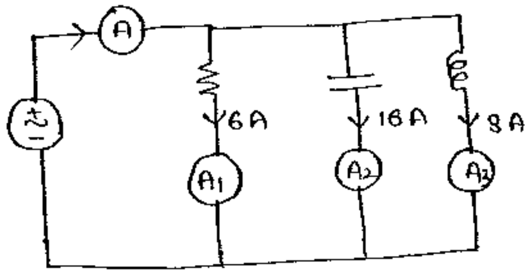
$$I_L = \sqrt{10^2 - 8^2} = 6\text{ A}$$

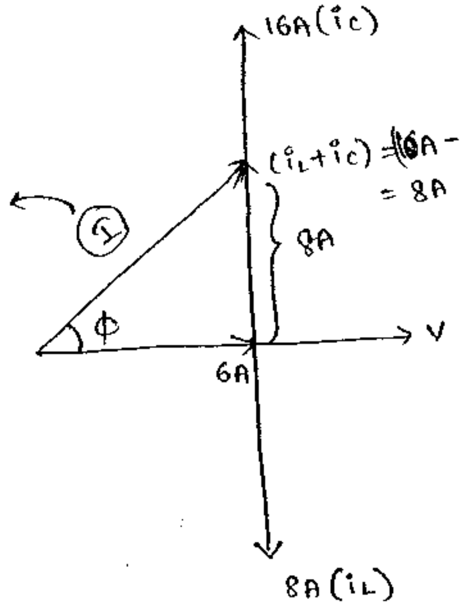
$$P.F = \cos\phi = \frac{8}{10} = 0.8 \text{ (lag)}$$

($\because$ current lagging)

IES(O) If $A_1 = 6A$, $A_2 = 16A$, $A_3 = 8A$ then $A = \underline{10A}$

total supply P.F is $\underline{0.6 \text{ lead}}$





$I = \sqrt{6^2+8^2}$

$= 10A$

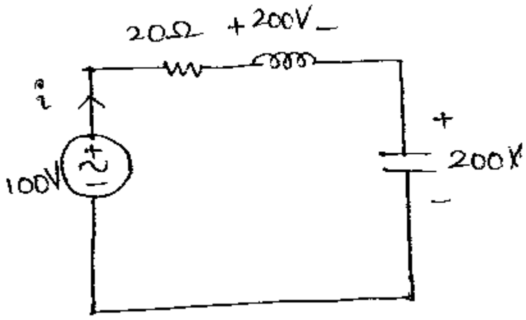
$(i_L + i_C) = (16A - 8A)$

$= 8A$

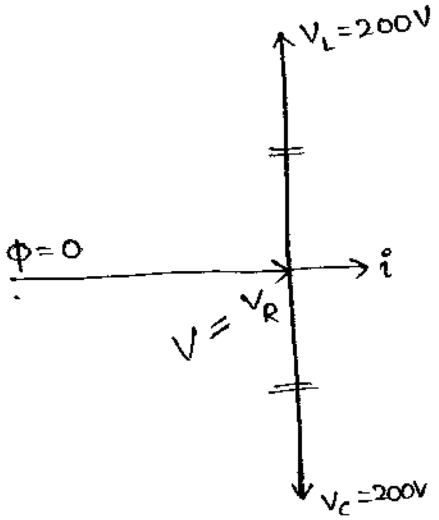
$\cos\phi = \frac{6}{10} = 0.6(\text{lead})$

Find Current i = ______

Total input P.F = ______



$I_R = \frac{V_R}{R} = \frac{V}{R} = \frac{100}{20} = 5A = i$



$P.F = \cos\phi$

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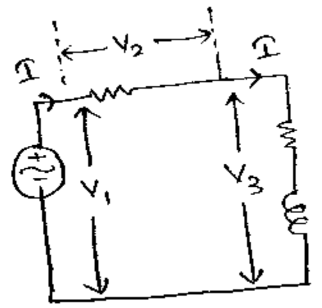
$= \cos 0$

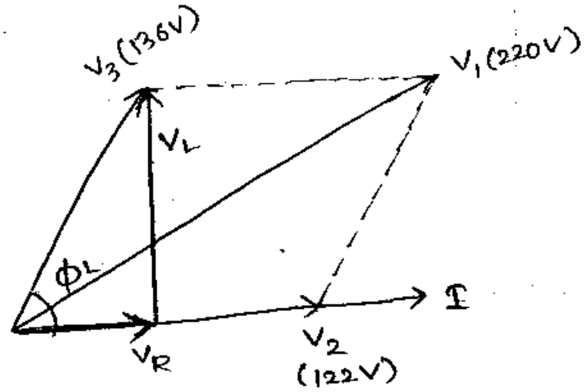
$= 1$ (UPF)

If $V_1 = 220V$, $V_2 = 122V$, $V_3 = 136V$, then load P.F = ——

If $V_1 = 220V$, $V_2 = 122V$, $V_3 = 136V$, then average power absorbed by load is also if Load Resistance is 5Ω, then average power

Active (or) Real power in watts
($\because$ for Pavg for pure L & C = 0)
avg. pow. only Exists of Resistor.





$R_T = \sqrt{R_1^2 + R_2^2 + 2R_1R_2\cos\theta}$

$V_1 = \sqrt{V_2^2 + V_3^2 + 2V_2V_3\cos\phi}$

$220 = \sqrt{122^2 + 136^2 + 2(122)(136)\cos\phi_L}$

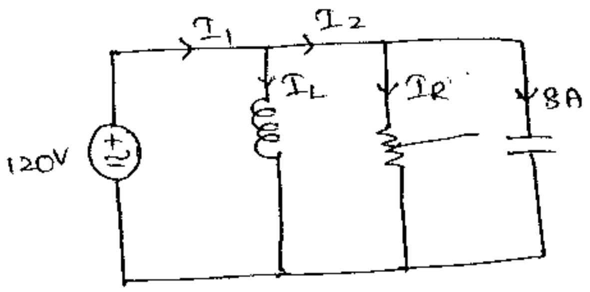
$\cos\phi_L = 0.45$ (lag)

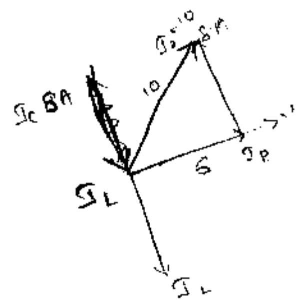
$\cos\phi_L = \frac{V_R}{V_3} \longrightarrow V_R = V_3\cos\phi_L = 136(0.45) = 61.2$ Volts

$P_{avg} = P = \frac{[V_R]^2}{R} = \frac{(61.2)^2}{5} = 750W$

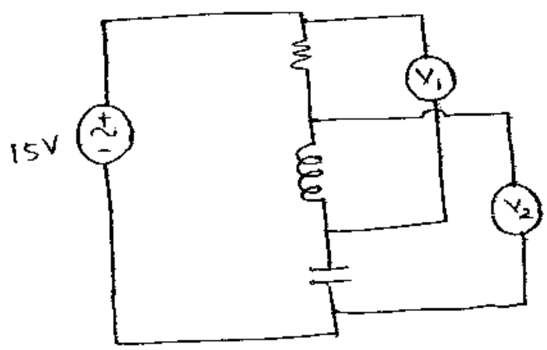
H.W. If $|I_1| = |I_2| = 10A$ then find $I_R =$ 6A , $I_L =$ 16A

Total Current P.F =





7.Gen If $V_1 = 20V$, $V_2 = 9V$ then Voltage across Capacitor alone is



(a) 12V
(b) 16V
~~(c)~~ 25V
(d) none.

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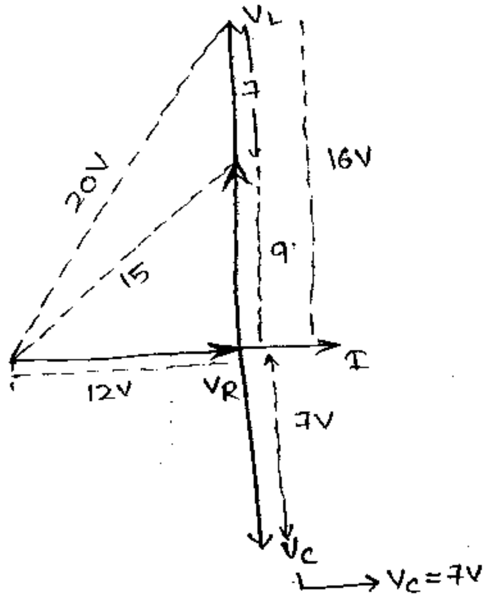
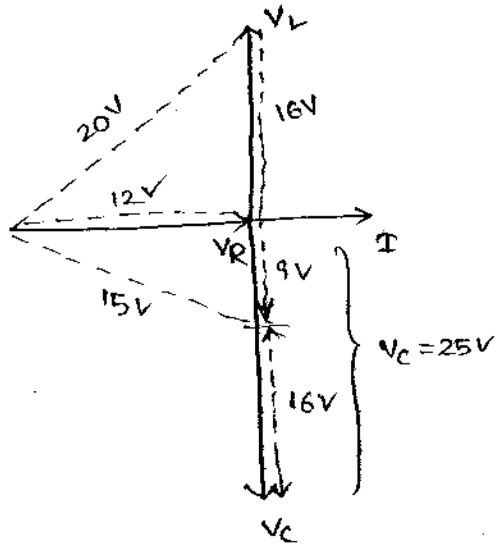
lag P.F
$(X_L > X_C)$
$(V_L > V_C)$



lead P.F
$(X_L < X_C)$
$(V_L < V_C)$



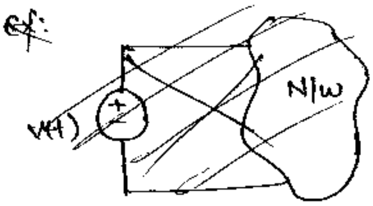
I. RMS/ EFFECTIVE/ TRUE VALUE of a Time Varying Signal :

It is that steady Equivalent value of Time Varying waveform which Could also develop the Same amount of heat as given by the Original Wafeform for a definite period of Time in the circuit.

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T [v(t)]^2\, dt} \quad \text{Volts.}$$

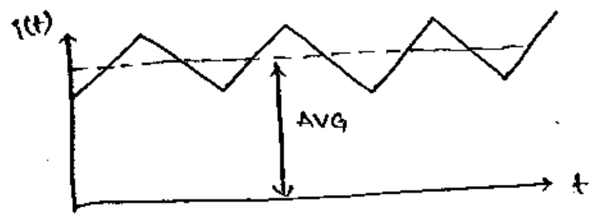
RMS : V, I, ϕ
- Exists for single elec. parameter
- do not Exists for "P"
  - ∵ Power is product of V, I
  - two elec. Parameters.

Ex:

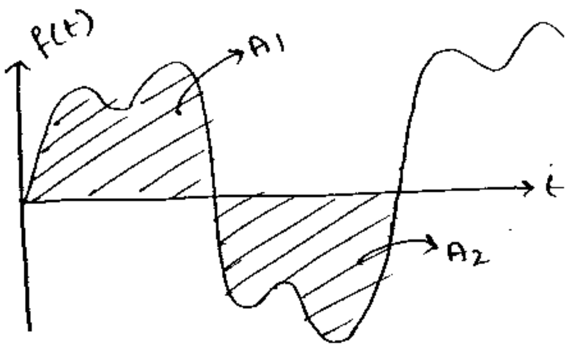


II. MEAN/ AVERAGE VALUE

It is that steady Equivalent value of Time Varying waveform which Could also Transfer the Same amount of charge as given by original waveform for a definite period of Time in the ckt.



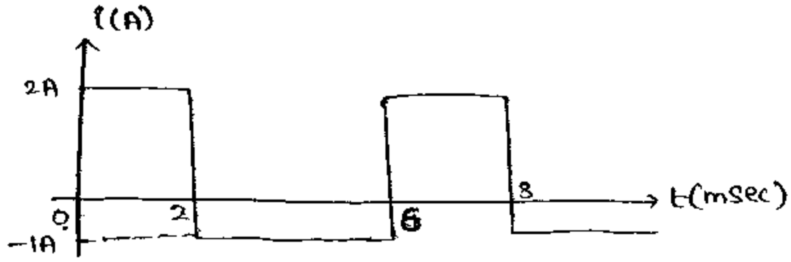
Concept of Symmetry in Waveform:



if $|A_1| = |A_2| \longrightarrow$ Symmetrical

$|A_1| \neq |A_2| \longrightarrow$ Asymmetrical

Q



+ve Area = $|+2 * 2m| = \underline{\underline{4mC}}$
-ve Area = $|-1 * 4m| = \underline{\underline{4mC}}$ } Symmetrical.

Note:
The avg value of any Symmetrical Waveform for one full cycle is always zero.

(a) For Symmetrical Waveform:

$$V_{AVG} \begin{cases} \rightarrow 0 \rightarrow \text{Full cycle} \\ \rightarrow \dfrac{1}{T/2}\displaystyle\int_0^{T/2} v(t).dt \rightarrow \text{Half cycle.} \end{cases}$$

(b) Assymmetrical Waveform:

$$V_{AVG} = \frac{1}{T}\int_0^T v(t).dt$$

III]. peak / crest factor $= \dfrac{V_{max}}{V_{RMS}}$

IV] Form / shape factor $= \dfrac{V_{RMS}}{V_{AVG}}$

V] peak - to - peak $= |V_{max} - V_{min}|$

Note:

1. AC Analog meter $\longrightarrow$ M.I Type $\longrightarrow$ RMS Values

2. DC Analog meter $\longrightarrow$ PMMC Type $\longrightarrow$ Average Values

3. Rectifier Type meter.

$$[\text{Actual Value}] = [\text{Average Value}] * [F.F]$$

$\downarrow$ if calibrated for sinusoid $\rightarrow$ (1.11)

Note:

In most of our Elec. Engg applications directly or Indirectly lot of Heat is generated during InterConversion and Transfer of elec. Energy. & Hence we prefer Calculating RMS Values in general.

ex: In India for domestic Supply System

1Φ, 230 Volts, 50Hz

$\downarrow$ RMS Voltage [V_{L-N} (phase voltage)]

$$V(t) = 230\sqrt{2}\sin(2\pi 50t)$$

$$V(t) = 325\sin(314t) \text{ Volts.}$$

Ex: INDIA, in power System,

$3\text{-}\Phi$, 66kV, 50Hz (Balanced)

$\downarrow$ RMS value [V_{L-L} (line voltage)]

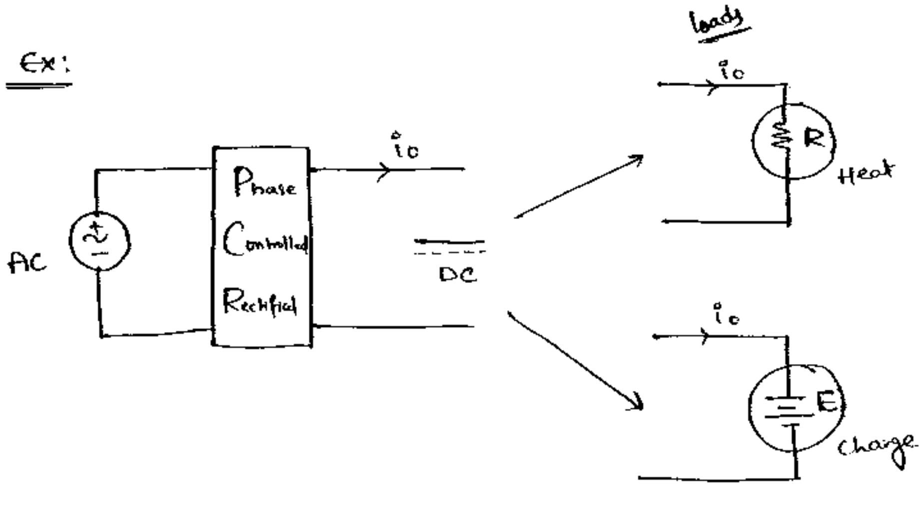
$$V_{RY} = 66000\sqrt{2}\sin(314t)$$

$$V_{YB} = 66000\sqrt{2}\sin(314t - 120)$$

$$V_{BR} = 66000\sqrt{2}\sin(314t - 240)$$

However, in Certain specific. appl. like Battery charging, electroplating, electrometallurgical Refinaries, electrolysis, Speed Control of DC motor with Back emf etc., We prefer Calculating Average Values.

<u>Ex:</u>

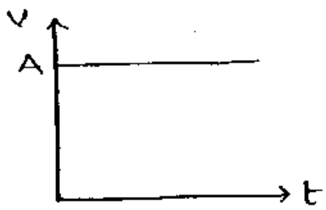


$P_o = i_o^2 R$ W
↑
<u>RMS</u>

$P_o = E\, i_o$ W
↑
<u>avg</u>

Standard Waveforms:

(1) Ideal DC.



$V_{RMS} = A$

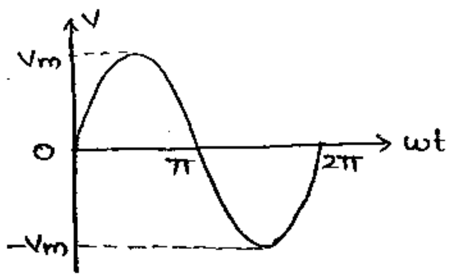
$V_{AVG} = A$

Peak Factor = 1

F.F = 1

$V_{P-P} = A$

(2) Ideal AC



$$V_{RMS} = \frac{V_m}{\sqrt{2}}$$

V_{AVG} → 0 → full cycle

V_{AVG} → $\frac{2V_m}{\pi}$ → Half cycle.

P.F = $\sqrt{2}$

$$F.F = \frac{\pi}{2\sqrt{2}} = 1.11$$

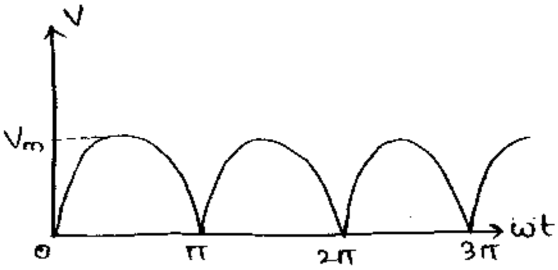
$V_{PP} = 2V_m$

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

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \, d\omega t$$
(Half cycle)

unconrolled

(3) Full Wave Rectifier



$$V_{RMS} = \frac{V_m}{\sqrt{2}}$$

$$V_{AVG} = \frac{2V_m}{\pi}$$

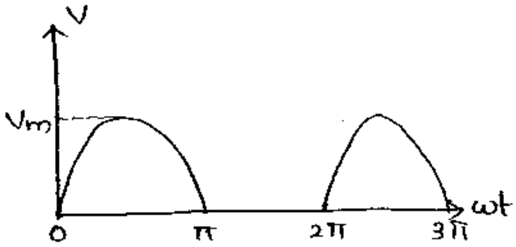
$P.F = \sqrt{2}$

$F.F = 1.11$

$V_{p\text{-}p} = V_m$

Uncontrolled

(4) Half wave Rectifier



∴ conducting Time

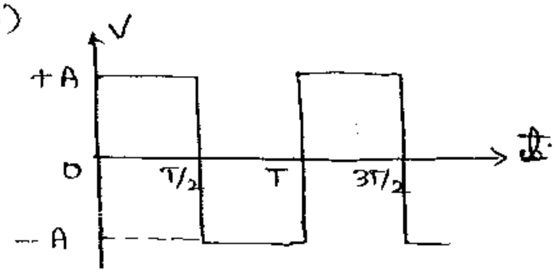
$$V_{RMS} = \frac{V_m}{2} \qquad \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \, d\omega}$$

$$V_{AVG} = \frac{V_m}{\pi}$$

$P.F = 2$, $F.F = \frac{\pi}{2} = 1.57$

$V_{p\text{-}p} = V_m$.

(5)



$V_{RMS} = A$

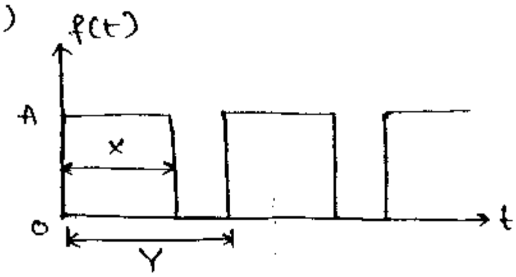
$V_{AVG} =$ → 0 → Full cycle
→ A → Half cycle.

$P.F = 1$, $F.F = 1$

$V_{p\text{-}p} = 2A$

Chopped DC

(6)

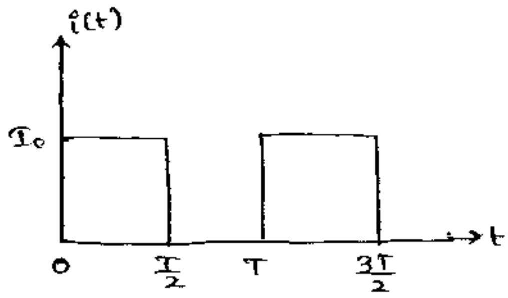


$$f_{RMS} = A\sqrt{\frac{X}{Y}}$$ X → on period, Y → Total period

$$f_{avg} = A\left[\frac{X}{Y}\right]$$

$$RMS = Amp \times \sqrt{\frac{ON\ Period}{Total\ period}}$$

(7)



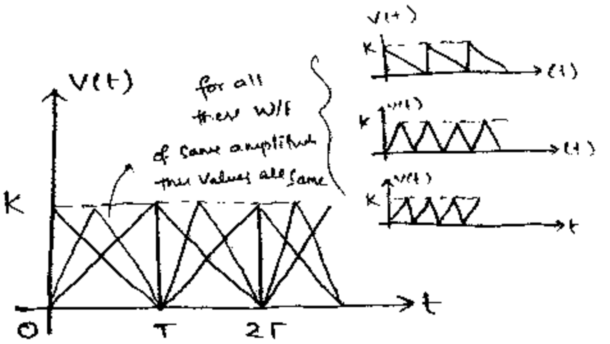
$$I_{RMS} = \frac{I_o}{\sqrt{2}}$$

$$I_{AVG} = \frac{I_o}{2}$$

$$P.F = \sqrt{2}, \quad F.F = \sqrt{2}$$

$$I_{PP} = I_o.$$

(8)



$$V_{RMS} = \frac{k}{\sqrt{3}} = \sqrt{\frac{1}{T}\int_0^T \left(\frac{k}{T} \cdot t\right)^2 dt}$$

$$V_{AVG} = \frac{k}{2}$$

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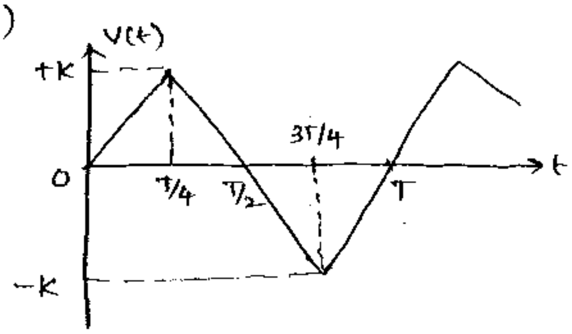
$$P.F = \sqrt{3}, \quad F.F = \frac{2}{\sqrt{3}}$$

$$V_{P\text{-}P} = k.$$

(9)



$$V_{RMS} = \frac{k}{\sqrt{3}}$$

V_{AVG} → $= 0$ → Full cycle

V_{AVG} → $\frac{k}{2}$ → Half cycle

$$P.F = \sqrt{3}, \quad F.F = \frac{2}{\sqrt{3}}$$

$$V_{P\text{-}P} = 2k$$

Note: In practical applications to Signals & Systems at Signal level & power electronics are at power level the w/Fs are neither ideal nor Standard but mostly periodic. Hence we do fourier Series Expansion to Express any periodic non Sinusoidal w/F interms of Sine & Cosine of Higher order frequencies.

Conclusion I]

$$V(t) = \underbrace{V_0}_{DC} + V_1 \sin\omega_1 t + V_2 \sin\omega_2 t + V_3 \sin\omega_3 t + \dots$$

$\rightarrow V_{AVG} = V_0$

$\rightarrow V_{RMS} = \sqrt{V_0^2 + \left(\frac{V_1}{\sqrt{2}}\right)^2 + \left(\frac{V_2}{\sqrt{2}}\right)^2 + \left(\frac{V_3}{\sqrt{2}}\right)^2 + \dots}$

multiple frequencies } fourier series

II]

$$i(t) = I_0 + I_1 \cos(\omega_1 t - \phi_1) + I_2 \cos(\omega_2 t - \phi_2) + I_3 \cos(\omega_3 t - \phi_3) + \dots$$

→ phase shift has no Impact on RMS

$\longrightarrow I_{AVG} = I_0$

$\longrightarrow I_{RMS} = \sqrt{I_0^2 + \left(\frac{I_1}{\sqrt{2}}\right)^2 + \left(\frac{I_2}{\sqrt{2}}\right)^2 + \left(\frac{I_3}{\sqrt{2}}\right)^2 + \dots}$

III]

$$V(t) = V_0 + V_1 \sin(n\omega t + \phi_1) + V_2 \sin(n\omega t - \phi_2)$$

Same frequencies $\Rightarrow$ not fourier series,

$\longrightarrow V_{avg} = V_0$

$\longrightarrow V(t) = V_0 + \underbrace{\left[V_1 \angle{+\phi_1}\right] + \left[V_2 \angle{-\phi_2}\right]}_{\text{add phasor}}$

let $V(t) = V_0 + \left[V_x \angle{+\phi_x}\right]$

$V(t) = V_0 + V_x \sin(n\omega t + \phi_x)$

$V_{rms} = \sqrt{V_0^2 + \left(\frac{V_x}{\sqrt{2}}\right)^2}$ $\underline{\underline{V}}$

Case [I] Sinusoidal Supply to linear load. $\Longrightarrow$ Elec. ckt Analysis / Network Theory.

Let $v(t) = V \sin(\omega t + \theta)$ $\underline{\underline{V}}$

$i(t) = I \sin(\omega t + \phi)$ $\underline{\underline{A}}$

Then $P = \frac{V}{\sqrt{2}} \cdot \frac{I}{\sqrt{2}} \cdot \cos(\theta - \phi)$ $\underline{\underline{W}}$

$Q = \frac{V}{\sqrt{2}} \cdot \frac{I}{\sqrt{2}} \sin(\theta - \phi)$ $\underline{\underline{\text{VAR's}}}$

$S = \frac{V}{\sqrt{2}} \cdot \frac{I}{\sqrt{2}}$ VA's

$P.F = \frac{P}{S} = \cos(\theta - \phi)$

Case [II] Non Sinusoidal Supply to linear load. $\Longrightarrow$ Signals & Systems.

Let $v(t) = V_0 + V_1 \sin(\omega_1 t + \theta_1) + V_2 \sin(\omega_2 t + \theta_2) + V_3 \sin(\omega_3 t + \theta_3) + \ldots$

$i(t) = I_0 + I_1 \sin(\omega_1 t + \phi_1) + I_2 \sin(\omega_2 t + \phi_2) + I_3 \sin(\omega_3 t + \phi_3) + \ldots$

$P = V_0 I_0 + \frac{V_1}{\sqrt{2}} \cdot \frac{I_1}{\sqrt{2}} \cos(\theta_1 - \phi_1) + \frac{V_2}{\sqrt{2}} \cdot \frac{I_2}{\sqrt{2}} \cos(\theta_2 - \phi_2) + \frac{V_3}{\sqrt{2}} \cdot \frac{I_3}{\sqrt{2}} \cos(\theta_3 - \phi_3) + \ldots$ $\underline{\underline{W}}$ $\longrightarrow (1)$

$Q = \frac{V_1}{\sqrt{2}} \cdot \frac{I_1}{\sqrt{2}} \sin(\theta_1 - \phi_1) + \frac{V_2}{\sqrt{2}} \cdot \frac{I_2}{\sqrt{2}} \sin(\theta_2 - \phi_2) + \frac{V_3}{\sqrt{2}} \cdot \frac{I_3}{\sqrt{2}} \sin(\theta_3 - \phi_3) + \ldots$ $\underline{\underline{\text{VArs}}}$

for DC
Reactive pow = 0
$\therefore V_0 I_0 = 0$

$S = [V_{rms}][I_{rms}]$

$= \left[\sqrt{V_0^2 + \left(\frac{V_1}{\sqrt{2}}\right)^2 + \left(\frac{V_2}{\sqrt{2}}\right)^2 + \ldots}\right]\left[\sqrt{I_0^2 + \left(\frac{I_1}{\sqrt{2}}\right)^2 + \left(\frac{I_2}{\sqrt{2}}\right)^2 + \ldots}\right]$ $\underline{\text{VA's}}$ $\longrightarrow (2)$

$P.F = \frac{P}{S} = \frac{(1)}{(2)}$

Case [III]: Sinusoidal Supply to Non Linear Load. $\Rightarrow$ pow. Electronics or Analog Electronics,

Let $v(t) = V_1 \sin(\omega_1 t + \theta_1)$ V

$$i(t) = I_0 + I_1 \sin(\omega_1 t + \phi_1) + I_2 \sin(\omega_2 t + \phi_2) + I_3 \sin(\omega_3 t + \phi_3) + \ldots \quad A$$

$$P = \frac{V_1}{\sqrt{2}} \cdot \frac{I_1}{\sqrt{2}} \cos(\theta_1 - \phi_1) \quad W$$

$$Q = \frac{V_1}{\sqrt{2}} \cdot \frac{I_1}{\sqrt{2}} \sin(\theta_1 - \phi_1) \quad VAR's$$

$$S = [V_{TRMS}][I_{TRMS}] \quad VA's$$

$$S = \left[\frac{V_1}{\sqrt{2}}\right]\left[\sqrt{I_0^2 + \left(\frac{I_1}{\sqrt{2}}\right)^2 + \left(\frac{I_2}{\sqrt{2}}\right)^2 + \ldots}\right] \quad VA's$$

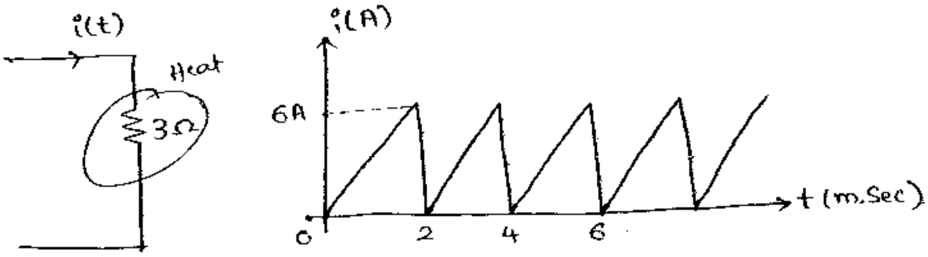
$$P.F = \frac{P}{S} = \frac{\left[\cancel{\frac{V_1}{\sqrt{2}}}\right] \cdot \left[\frac{I_1}{\sqrt{2}}\right] \cdot \cos(\theta_1 - \phi_1)}{\left[\cancel{\frac{V_1}{\sqrt{2}}}\right]\left[\sqrt{I_0^2 + \left(\frac{I_1}{\sqrt{2}}\right)^2 + \left(\frac{I_2}{\sqrt{2}}\right)^2 + \ldots}\right]}$$

$$P.F = \left[\frac{I_{1RMS}}{I_{TRMS}}\right] \cdot \cos(\theta_1 - \phi_1)$$

$\downarrow$ $\quad (<1) \quad (<1)$

$$\begin{bmatrix}\text{Total} \\ \text{power} \\ \text{factor}\end{bmatrix} = \begin{bmatrix}\text{Distortion} \\ \text{factor}\end{bmatrix}\begin{bmatrix}\text{fundamental} \\ \text{power factor}\end{bmatrix}$$

IES(O) power absorbed =



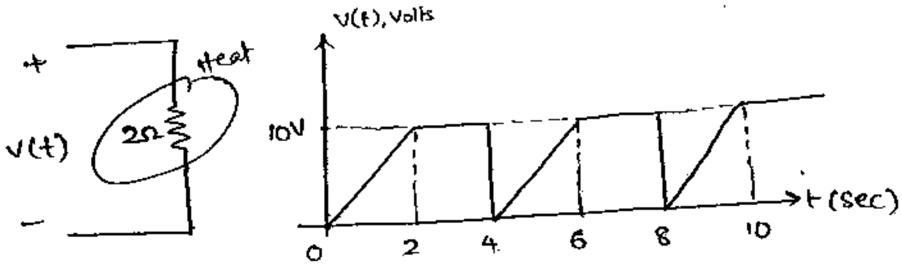
for Saw tooth $I_{rms} = \frac{A}{\sqrt{3}}$

$$P_{abs} = I^2_{RMS} \cdot R$$

$$= \left[\frac{6}{\sqrt{3}}\right]^2 \cdot 3$$

$$= 36\,\omega.$$

B. power absorbed = ____



$0 < t < 2$: $V(t) = 5t$

$2 < t < 4$: $V(t) = 10$

$$V_{rms} = \sqrt{\frac{1}{4}\left[\int_0^2 (5t)^2 dt + \int_2^4 (10)^2 dt\right.}$$

$$= \frac{1}{2}\sqrt{\frac{25}{3}(8) + [100 \times 2]}$$

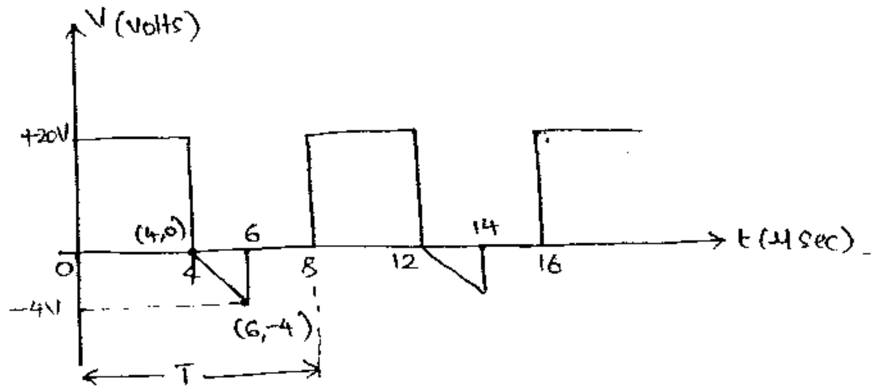
$$= \frac{\cancel{10}\,5}{\cancel{2}}\sqrt{\frac{2}{3} + 2} = \frac{5\sqrt{8}}{\sqrt{3}}$$

$$P_{abs} = \frac{(V_{rms})^2}{R}$$

$$= \frac{(8.16)^2}{2}$$

$$= 33.33\,\omega.$$

Q find V_{RMS}, V_{AVG}, Peak factor, f.f, V_{PP}



$0<t<4\mu$: $V(t)=20$

$4\mu<t<6\mu$: $V(t)=(-2t+8)$ $\left[\because (y-0)=\frac{-4-0}{6-4}(x-4)\right]$

$6\mu<t<8\mu$: $V(t)=0$

$$V_{rms}=\sqrt{\frac{1}{8}\left[\int_0^4 (20)^2 dt+\int_4^6 (-2t+8)dt+\int_6^8 (0)^2 dt\right.} = 14.18\,\omega.$$

$$V_{AVG}=\frac{1}{8}\left[\int_0^4 (20).dt+\int_4^6 (-2t+8)dt+\int_6^8 (0)dt\right] = 9.5\,\omega.$$

$$P.F=\frac{+20}{14.18}=1.41$$

$$F.F=\frac{V_{rms}}{V_{AVG}}=\frac{14.18}{9.5}=1.49$$

$$V_{P-P}=\left|+20-(-4)\right|= 24 \text{ volts.}$$

IES(o) Total power absorbed by the Battery

avg → charging (Battery)
RMS → Sink (R)

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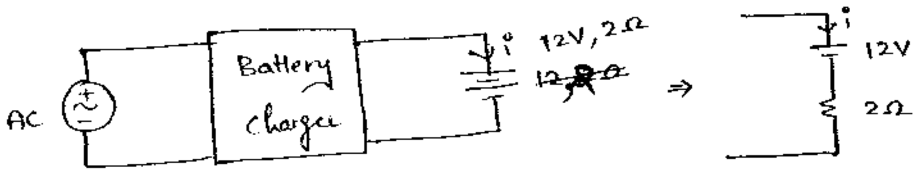
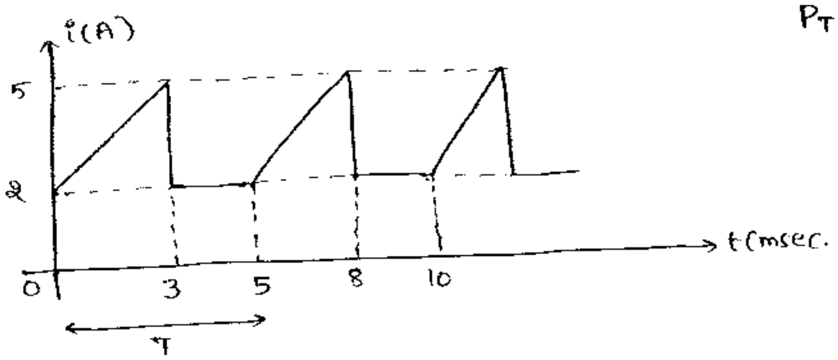




$P_T = 12[i] + [i]^2 \cdot R$

$\downarrow$ avg $\quad \downarrow$ Rms

$\therefore P_T = 12[2.9] + [3.06]^2 \cdot 2$

$= 34.8 + 18.72$

$= \underline{\underline{53.52 \, W}}$

$0 < t < 3m$

$i(t) = (t+2)$

$3m < t < 5m$

$i(t) = 2$

$$I_{rms} = \sqrt{\frac{1}{5}\left[\int_0^3 (t+2)^2 dt + \int_3^5 (2)^2 dt\right]} = 3.06A$$

$\frac{1}{5} \times \left(\frac{9}{2} + 2.3 + 2(2)\right)$

$4.5 + 6 + 4$

10.4

$$I_{avg} = \frac{1}{5}\left[\int_0^3 (t+2)dt + \int_3^5 (2)dt\right] = 2.9A$$

<u>Gate</u> If $v(t) = 8 + 20\sin(\omega_1 t + 25) + 10\cos(\omega_2 t - 25)$

find

(a) V_{AVG}

(b) V_{rms} if $\omega_2 = 2\omega_1$

(c) V_{rms} if $\omega_2 = \omega_1$

(a) $V_{AVG} = 8\,V$ (DC only)

(b) $v(t) = 8 + 20\sin(\underline{\omega_1} t + 25) + 10\cos(\underline{\underline{2\omega_1}} t - 25) \Rightarrow$ F.S

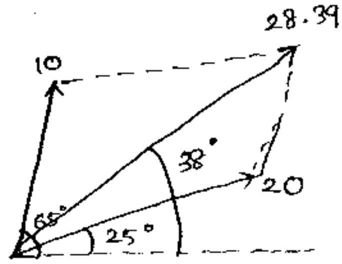
$$V_{rms} = \sqrt{8^2 + \left(\frac{20}{\sqrt{2}}\right)^2 + \left(\frac{10}{\sqrt{2}}\right)^2} = 17.7\ V$$

(c) $V(t) = 8 + 20\sin(\underline{\omega_1 t} + 25) + 10\cos(\underline{\omega_1 t} - 25)$ $\Longrightarrow$ not F.S

$\downarrow$

$10.\sin(90 + \omega_1 t - 25)$

$10\sin(\omega_1 t + 65^\circ)$



$$V(t) = 8 + (\underbrace{20\angle 25^\circ + 10\angle +65^\circ}_{\text{add phasors.}})$$

$$V(t) = 8 + [18.12 + j8.45] + [4.22 + j9.03]$$

$$= 8 + [22.34 + j17.5]$$

$$= 8 + [28.39\angle 38^\circ]$$

$$V(t) = 8 + 28.39\sin(\omega_1 t + 38^\circ)$$

$$V_{Rms} = \sqrt{8^2 + \left(\frac{28.39}{\sqrt{2}}\right)^2}$$

$$= 21.61\text{V}$$

jak If a current of $i(t) = 5\cos(1000t + 100^\circ)$ A is flowing through a load Impedence of $\underbrace{(4 - j3)\Omega}_{RC}$ then the avg power absorbed by the load is ______

Q-243

$$i(t) = 5.\cos(1000t + 100^\circ)\text{ A}$$

$$P_{avg} = \text{activepower} = I_{Rms}^2 \cdot R$$

$$= \left[\frac{5}{\sqrt{2}}\right]^2 \cdot (4)$$

$$= 50\text{W}.$$

$Q_{net} = ?$

$$Q_{net} = I_{Rms}^2 X_{net} = \left(\frac{5}{\sqrt{2}}\right)^2 (3) = 37.5 \text{ VAR (generated } \because \text{ capacitor)}$$

$$S = I_{Rms}^2 \cdot Z = \left(\frac{5}{\sqrt{2}}\right)^2 (5) = 62.5 \text{ VA's}$$

check pow. Δle

$$|S| = \sqrt{P^2 + Q_{net}^2}$$

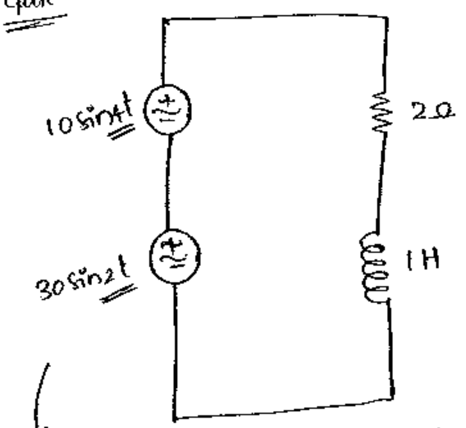
$$= 62.5 \text{ VA}$$

$$\text{P.F} = \frac{R}{|Z|} = \frac{4}{5} = 0.8 \text{ (lead)}$$

(or)

$$= \frac{P}{S} = \frac{50}{62.5} = 0.8$$

Gate



two sinusoidal functionals of different freq $\Rightarrow$ non sinusoidal supply
$\Rightarrow$ Fourier series
$\Rightarrow$ case (ii)

Find (a) P_{avg}

(b) Total supply power factor.

$\Rightarrow$ two sources $\Rightarrow$ apply S.P.T (Superposition Theorem)

Step. I: When 30 sin 4t alone acting

$$I_1 = \frac{V_1}{Z_1} = \frac{30\sin 2t}{2+j(2)(1)} = \frac{30\sin 2t}{2+j2}$$

$$= \frac{30\sin 2t}{2\sqrt{2}\,\angle 45^\circ}$$

$$I_1 = 10.6\sin(2t-45^\circ)\ \text{A}$$

Step - II: when 10 sin 4t alone acting

$$I_2 = \frac{V_2}{Z_2} = \frac{10\sin 4t}{2+j(4)(1)} = \frac{10\sin 4t}{2+j4}$$

$$= \frac{10\sin 4t}{\sqrt{20}\,\angle 63.43^\circ}$$

$$= 2.235\sin(4t-63.43^\circ)\ \text{A}$$

(a) $$P_{avg} = \frac{30}{\sqrt{2}}\times\frac{10.6}{\sqrt{2}}\cos(45^\circ) + \frac{10}{\sqrt{2}}\cdot\frac{2.23}{\sqrt{2}}\cos(63.45^\circ)$$

$$= 117.41$$

(b) $$S = \sqrt{\left(\frac{30}{\sqrt{2}}\right)^2+\left(\frac{10}{\sqrt{2}}\right)^2}\cdot\sqrt{\left(\frac{10.6}{\sqrt{2}}\right)^2+\left(\frac{2.23}{\sqrt{2}}\right)^2}$$

$$= 171.26$$

Then

$$P.F = \frac{P}{S} = 0.68\ (\text{lagging})$$

IES (0) If $V(t) = 230\sqrt{2}\sin(100\pi t)$

$$i(t) = 8 + 15\sqrt{2}\sin(\underbrace{100\pi t - 40}_{\text{lag}}) + 12\sqrt{2}\sin(300\pi t - 60^\circ) + 9\sqrt{2}\sin(500\pi t - 80^\circ)$$

(a). $P = \left[\frac{230\sqrt{2}}{\sqrt{2}}\right]\left[\frac{15\sqrt{2}}{\sqrt{2}}\right] \cdot \cos(40^\circ)$

$= 2642 W$

(b) $Q = \left[\frac{230\sqrt{2}}{\sqrt{2}}\right]\left[\frac{15\sqrt{2}}{\sqrt{2}}\right] \sin(40^\circ)$

$= 2217$ VAR

(c) $S = [230]\sqrt{8^2 + 15^2 + 12^2 + 9^2}$

$= 5212$ VA

(d) $F.P.F = \cos 40^\circ = 0.76$.

(e) $D.F = \frac{15}{\sqrt{8^2 + 15^2 + 12^2 + 9^2}} \approx 0.66$

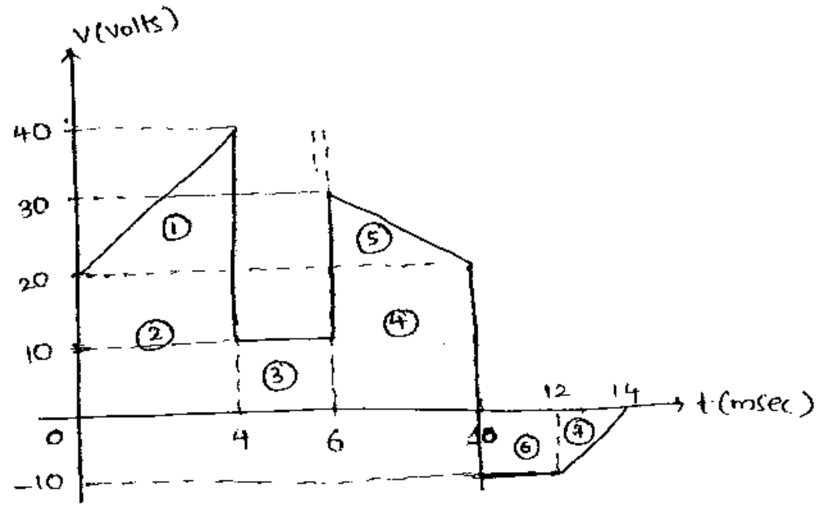
(f) $T.P.F = \frac{P}{S} = (D.F)(F.P.F) = 0.5$ (lag) $\Rightarrow$ Fundamental P.F = lag

Here, power triangle is not Valid

∵ ~~Extra P~~ ∵ utilisation is fundamental only but some power is utilised for Harmonics

$$|S| = \sqrt{P^2 + Q^2 + (\text{Harmonic factor})^2}$$

Gate



periodic Voltage W/F shown is given to a PMMC Voltmeter then what is its Reading.

PMMC ↓ reads avg value.

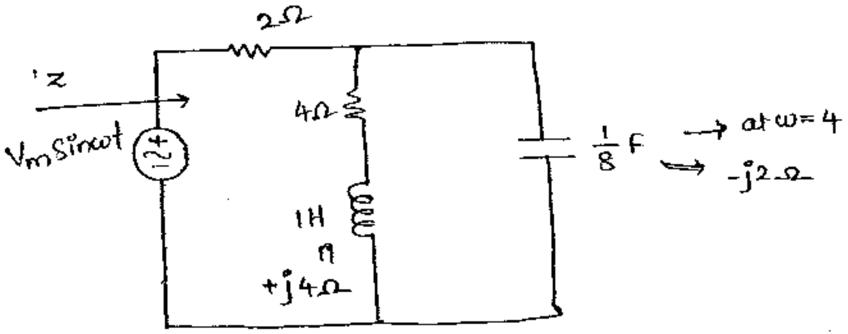
$$V_{Avg} = \frac{1}{T}\int_0^T v(t)\,dt \Rightarrow \text{Area under curve.}$$

$$(+)\text{ Area} = \frac{1}{2}(4)(10) + (20)(4) + (2)(10) + \frac{1}{2}(4)(20) + \frac{1}{2}\times 10\times 4 = 240$$

$$(-)\text{ Area} = 10\times 2 + \frac{1}{2}\times(2)\cdot(10) = 30$$

$$V_{AVG} = \frac{\text{Area}}{T} = \frac{(240-30)}{T} = \frac{210}{14} = 15\,V$$

Gate At $\omega = 4$ rad/sec. find Total ckt P.F.



$$\frac{(4+j4)\times(-j2)}{4-j2}$$

$$Z = 2 + [(4+j4)\,//\,(-j2)]$$

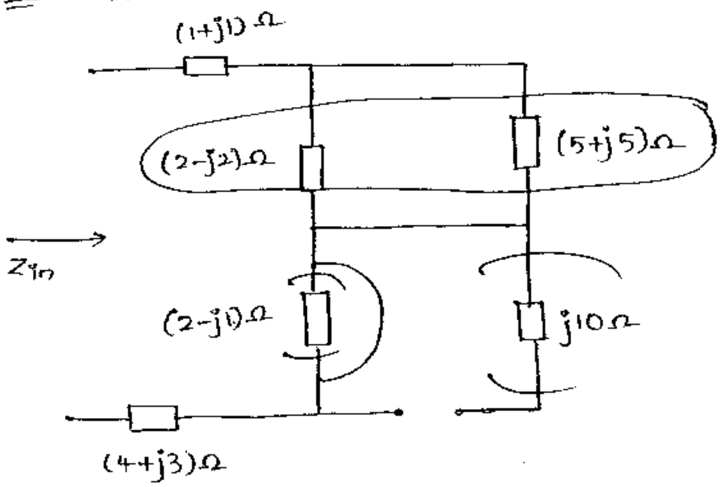
$$= (2.8 - j2.4)$$

overall it behaving like RC Network ⇒ leading

$$P.F = \frac{R}{|Z|}$$

$$= \frac{2.8}{\sqrt{(2.8)^2+(2.4)^2}} = 0.75\text{ (lead)}$$

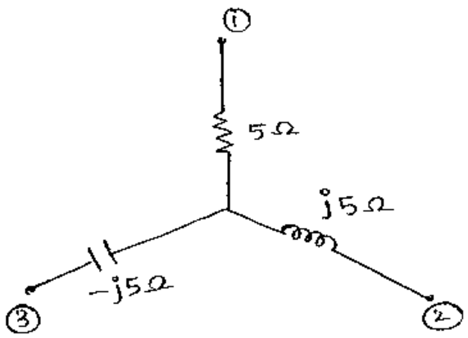
Q $Z_{in} =$



$$Z_{in} = (1+j1) + \left[(2-j2) \parallel (5+j5)\right] + (4+j3)$$

$$= 7.4 + j2.96.$$

ES(O) Convert into Δ.

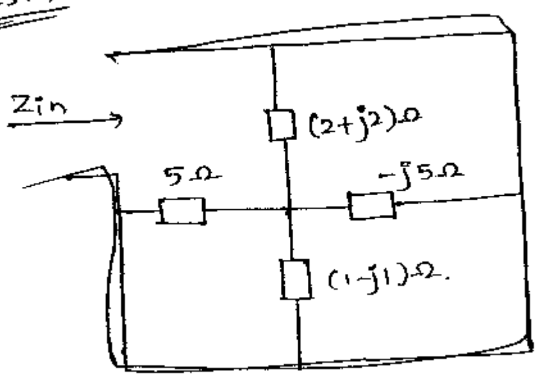


$$R_{12} = 5 + (j5) + \frac{(5)(j5)}{-j5} = j5\ \Omega$$

$$R_{23} = \cancel{j5} - \cancel{j5} + \frac{(j5)(-j5)}{5} = +5\ \Omega$$

$$R_{31} = \cancel{-j5} + \cancel{5} + \frac{(j5)(5)}{j5} = \underline{-j5}\ \Omega$$

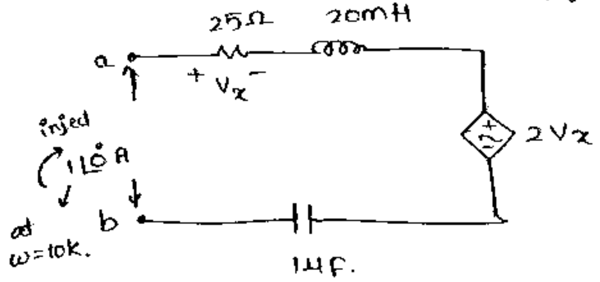
IES(O)

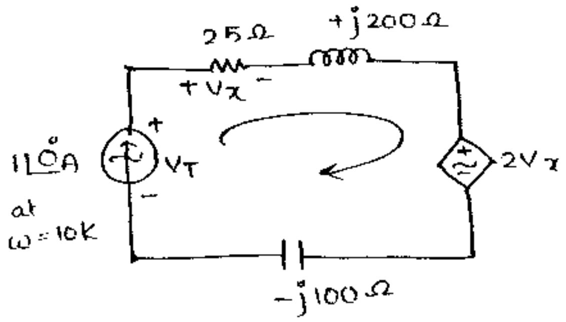


$\Rightarrow 0$ (dead S.C)

GATE At $\omega = 10k$ rad/sec, find total input Impedence & n/w power factor

→ if freq. given in rad/sec ⇒ sin. but if given in Hz it may square, tri, sa ....etc.





KVL

$$-V_T + 1\angle 0° \left[25 + j200 - j100\right] + 50\angle 0° = 0$$

$$V_T = (75 + j100)\ V$$

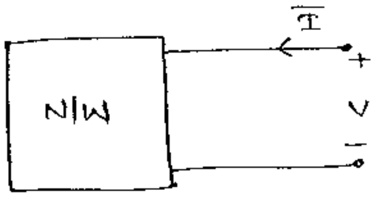
$$Z_{in} = \frac{V_T}{1\angle 0°} = (75 + j100)\ \Omega$$

$$P.F = \frac{R}{|Z|}$$

$$= \frac{75}{\sqrt{75^2 + 100^2}} = 0.6\ (\text{lag})$$

$$(\because X_L > X_C)$$

ES(o) The minimal realisation of N/w has ________ components.

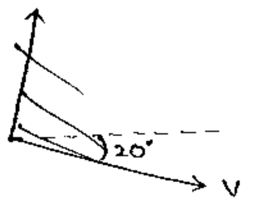


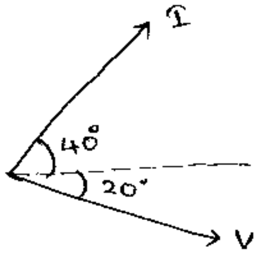
If $\bar{V} = 30 \sin(1000t - 20)\,V = 30\angle{-20°}\,A$

$\bar{I} = 5\cos(1000t - 50)\,A. = 5\sin(1000t - 50 + 90°) = 5\sin(1000t + 40°)$

$= 5\angle 40°\,A$

(a) R only
~~(b)~~ R & C
(c) R & L
(d) L & C





⇒ "I" leading Voltage by 60°

⇒ acts R-C circuit

$$Z = \frac{V}{I} = \frac{30\angle{-20°}}{5\angle 40°} = 6\angle{-60°}\,\Omega$$

$Z = [3 - j5.19]\,\Omega$

$\downarrow$ $R = 3\Omega$; $\rightarrow X_C = 5.19\Omega$

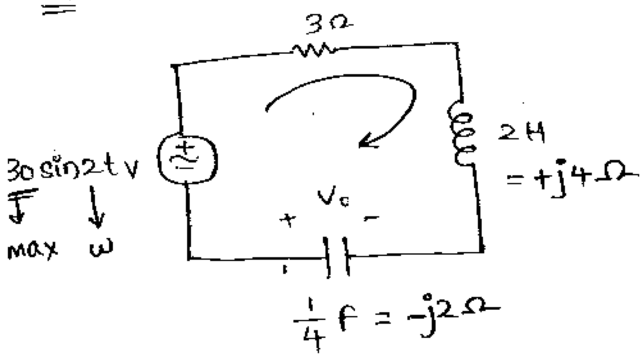
But $X_C = \frac{1}{\omega C} \rightarrow C = \frac{1}{\omega X_C}$

$$C = \frac{1}{(1000)(5.19)}$$

$= 192.6\mu F$

without mentioning anything if given in polar representation it is RMS value
if given functions ⇓ avg value

Q Find V_o = ______



Q / Find $V_o = -\left[30\angle 0^\circ\right]\left[\dfrac{-j2}{3+j4-j2}\right] = \dfrac{60\angle 90^\circ}{(3+j2)}$

-ve due to cap. (sink) current entering -ve side

$= \dfrac{60\angle 90^\circ}{3.6\angle 33.6}$

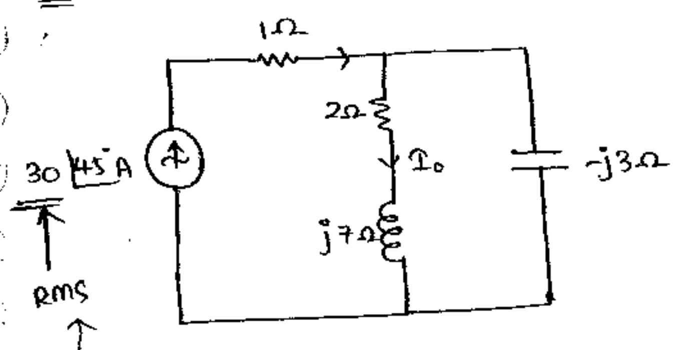
$= 16.66\angle 56.4^\circ$

$V_o = \underbrace{16.666}_{\text{max value}}\angle 56.4^\circ\ V$ ⟶ Phase value

$V_o = 16.66\ \sin(2t + 56.4^\circ)$ ⟶ function

$V_o = \underbrace{\dfrac{16.66}{\sqrt{2}}}_{\text{RMS}}\angle 56.4^\circ = 11.78\angle 56.4^\circ$ ⟶ RMS value (or) Meter value (or) Working value

Q find I_o = —

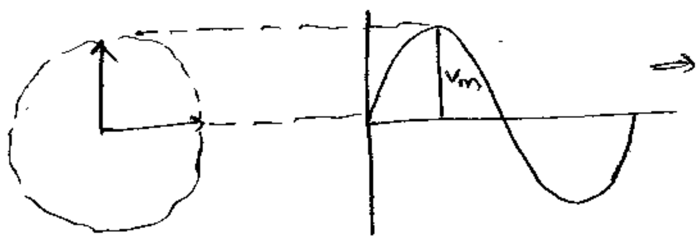


$I_{o\,(\text{RMS})} = 30\angle 45^\circ\left[\dfrac{-j3}{2+j7-j3}\right]$

$= \dfrac{90\angle -45^\circ}{(2+j4)}$

$I_{o\,(\text{RMS})} = \dfrac{90\angle -45^\circ}{4.47\angle 63.43^\circ}$

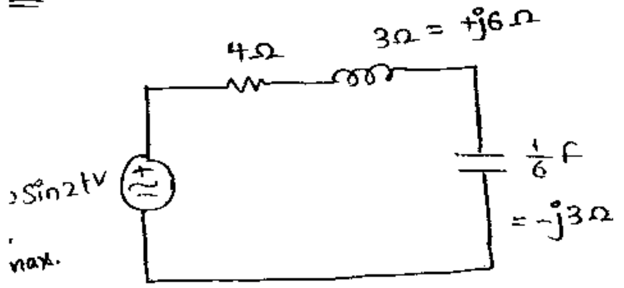
$= 20.13\angle -108.43^\circ$



⟹ phasor represents max value.

* The length of phacor Represents maximum Value of the Electrical Quantity.

Q Calc. problems



Z
Y
I
V_R, V_L, V_C
Verify KVL

P, Q, S
P.F [$\cos\phi$]
Phasor diagram

(a) $Z = (4+j6-j3) = (4+j3)\,\Omega$

$|Z| = 5\Omega$

(b) $Y = \frac{1}{Z} = \frac{1}{4+j3}\,\frac{(4-j3)}{(4-j3)} = (0.16 - j\,0.12)\,\mho$

$|Y| = \frac{1}{|Z|} = \frac{1}{5} = 0.2\,\mho$

(c) $I_{rms} = \frac{V_{rms}}{Z} = \frac{\frac{50}{\sqrt{2}}\angle 0^\circ}{(4+j3)} = 7.07\,\underbrace{\angle -36.86^\circ}_{\phi \text{ (lagging)}}\ A.$

$\hookrightarrow I_S = I_R = I_L = I_C$ [series]

(d) $V_R = I_R \cdot R = [7.07\angle -36.86^\circ][4] = 28.28\angle -36.86^\circ\ V$

$V_L = +jX_L I_L = [7.07\angle -36.86^\circ][j6] = 42.42\angle 52.14^\circ\ V$

$V_C = -jX_C I_C = [7.07\angle -36.86^\circ][-j3] = 21.21\angle -126.86^\circ\ V.$

(e) Verify KVL

$\bar{V_S} = \bar{V_R} + \bar{V_C} + \bar{V_L}$

LHS $\quad \underset{(rms)}{V_S} = \frac{50}{\sqrt{2}}\angle 0^\circ = 35.35\angle 0^\circ\ V$

$\underline{RHS}$ $= \left[28.28\angle{-36.86^\circ}\right] + \left[42.42\angle{53.14^\circ}\right] + \left[21.21\angle{-126.86^\circ}\right]$

$\cong 35.35\angle{0.009}$

KVL $\longrightarrow$ verified.

(f) for power calculations Consider RMS magnitudes only.

$$P = V_R \cdot I_R (1) = I_R^2 \cdot R = \frac{V_R^2}{R}$$

$$= (28.28)(7.07) = (7.07)^2(4) = \frac{(28.28)^2}{4} = 200\,W$$

$$Q_{net} = [+Q_L - Q_c]$$

$$Q_L = V_L I_L (1) = I_L^2 X_L = \frac{V_L^2}{X_L}$$

$$= (42.42)(7.07) = (7.07)^2(6) = \frac{(42.42)^2}{6} = 300\,VARs$$

$$Q_c = V_c I_c (1) = I_c^2 X_c = V_c^2 / X_c$$

$$= (21.21)(7.07) = (7.07)^2(3) = \frac{(21.21)^2}{3} = 150\,VARs$$

$$Q_{net} = [+300 - 150] = +150\,VAR$$

$$S = V_S I_S = I_S^2 Z = \frac{V_S^2}{Z}$$

$$S = [35.35][7.07] = (7.07)^2(5) = \frac{(35.35)^2}{5}$$

$$S = 250\,VARs.$$

(g) $P.F = \cos\phi = \frac{R}{|Z|} = \frac{P}{S}$

$$\cos(36.86^\circ) = \frac{4}{5} = \frac{200}{250}$$

$$= 0.8 \text{ (lagging)}.$$

also check

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

$$\phi = \tan^{-1}\left[\frac{X_L-X_C}{R}\right]$$

$$|S| = \sqrt{P^2+(Q_L-Q_C)^2}$$

$$\phi = \tan^{-1}\left[\frac{Q_L-Q_C}{P}\right]$$

$$P = S\cos\phi = V_S I_S \cos\phi$$

$$Q_{net} = [+Q_L-Q_C] = S\sin\phi = V_S I_S . \sin\phi \text{ VARs}$$

(b) phasor diagram:
→ Max. values.

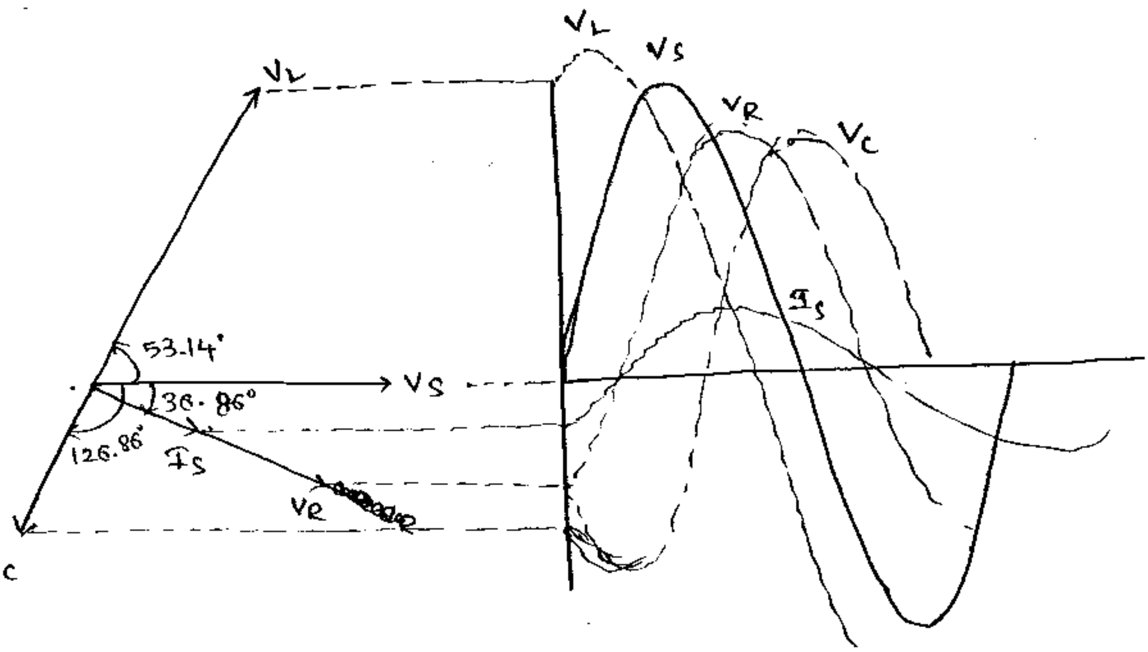
$V_S = 50 \angle 0^\circ$ [Ref]

$I_S = I_R = I_L = I_C = 10 \angle -36.86^\circ$ A.

$V_R = 40 \angle -36.86^\circ$ V

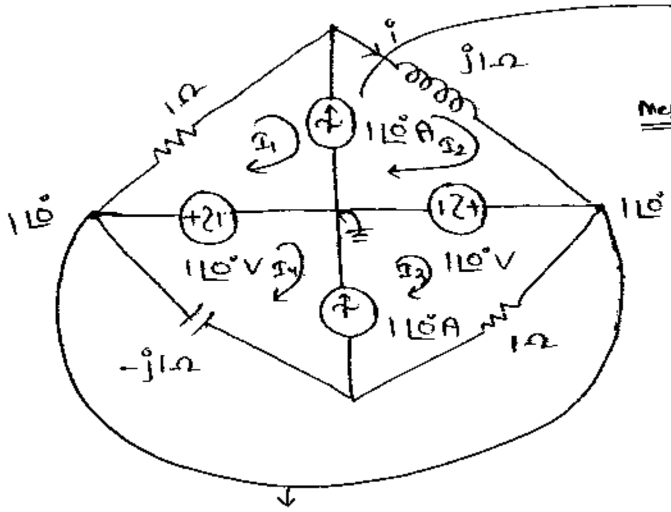
$V_L = 60 \angle +53.14^\circ$ V

$V_C = 30 \angle -126.86^\circ$ V



Gate determine Current "i" in the Circuit shown.

120



→ current source in parallel

∴ super mesh

Mesh

$$I_1(1) + j1[I_2] + [\cancel{1\angle 0}] - [\cancel{1\angle 0}] = 0$$

$$\cancel{I_1} + jI_2 = 0$$

$$-\cancel{I_1} + I_2 = 1\angle 0^\circ \quad \text{(link eqn)}$$

$$(1+j)I_2 = 1\angle 0^\circ$$

$$I_2 = \frac{1\angle 0^\circ}{1+j} = \frac{1\angle 0^\circ}{\sqrt{2}\angle 45^\circ}$$

$$i = I_2 = 0.707\angle -45^\circ \text{ A}$$

Nodal

∵ at same potential

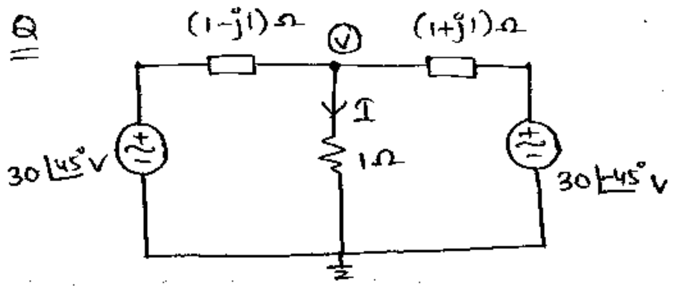
Short & fold

∴ By current division (1Ω & j1Ω are in parallel)

$$i = 1\angle 0^\circ \text{ A}\left[\frac{1\Omega}{1+j1}\right]$$

$$i = 0.707\angle -45^\circ \text{ A}$$

Q



Determine current 'I' by using Nodal analysis & verify result by applying any theorem in the easiest possible way

Nodal

$$\frac{V-[30\angle 45^\circ]}{(1-j)} + \frac{V}{1} + \frac{[V-[30\angle -45^\circ]]}{1+j} = 0$$

$$\frac{(V-(30\angle 45^\circ))(1+j)}{2} + \frac{V}{1} + \frac{(V-(30\angle -45^\circ))(1-j)}{2} = 0$$

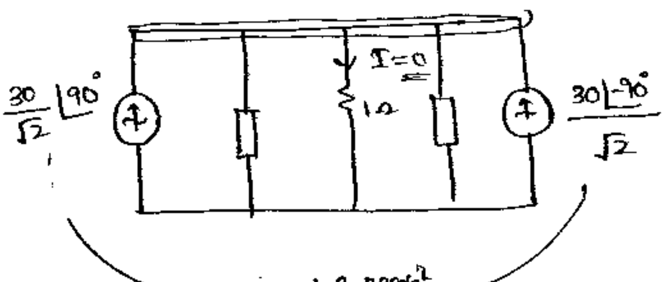
$$4V = (30\angle 45^\circ)(1+j) + (30\angle -45^\circ)(1-j)$$

$$4V = 30\sqrt{2}\angle 90^\circ + 30\sqrt{2}\angle -90^\circ$$

$$V = 0 \Rightarrow I = 0 \text{ A}$$

SPT

Source Tr. Tech.



Equal & opposite

$\therefore I = 0$

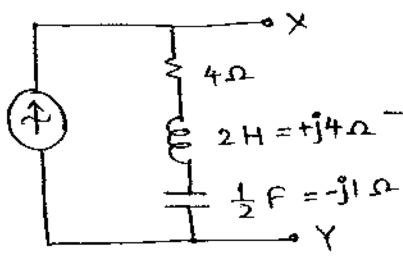
AC Network Theorems

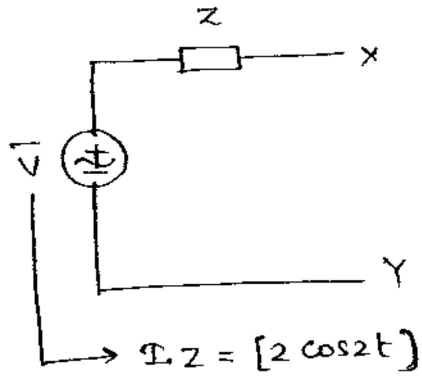
Theorem 1 : Source Transformation Theorem

$\rightarrow (4+j4-j1) = (4+j3)\ \Omega$

Gate

2cos2t
↓ ↓
max ω





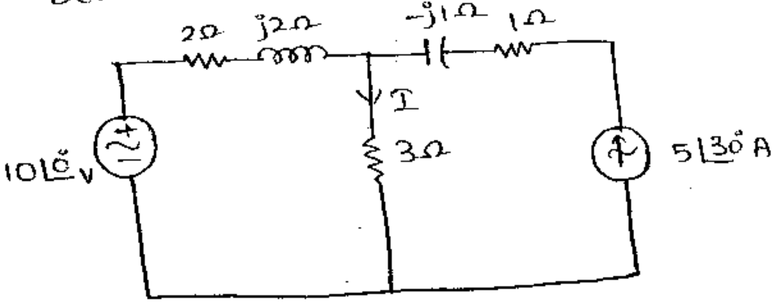
$\rightarrow I.Z = [2\cos 2t][4+j3]$

$= [2\cos 2t][5\angle 36.86^\circ]$

$\bar{V} = 10\cos(2t+36.86^\circ)$

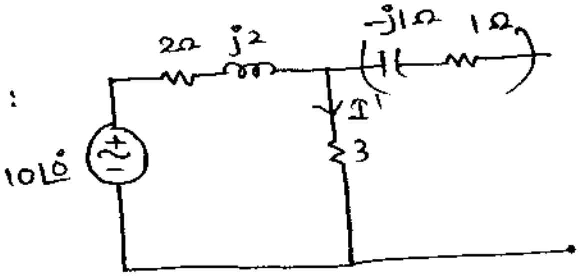
Theorem-II, III, IV.

Determine Current "I" by using (a) SPT (b) Thevenins (c) Nortons.



(a) SPT

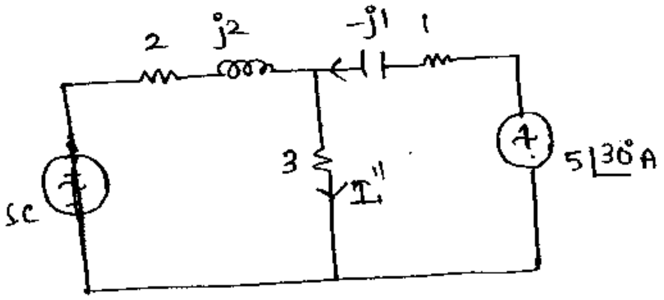
Step I :



$I' = \dfrac{10\angle 0^\circ}{(5+j2)}$

$= 1.85\angle -21.8^\circ$

Step II :



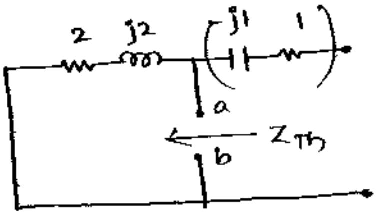
$I'' = 5\angle 30^\circ \left[\dfrac{2+j2}{2+j2+3}\right]$

$= 2.62\angle 53.19^\circ A$

$I = I' + I'' = 3.58\angle 23.2^\circ A$

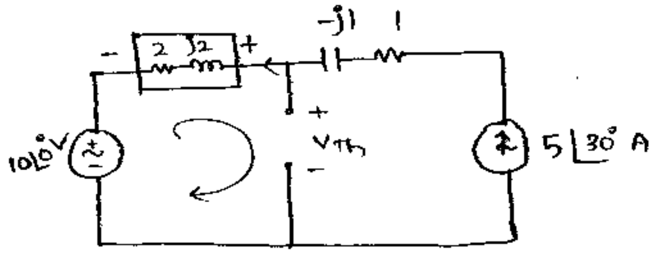
(b) Thevnins.

S-I Z_{Th}



$Z_{Th} = (2+j2)$

S-II V_{Th}

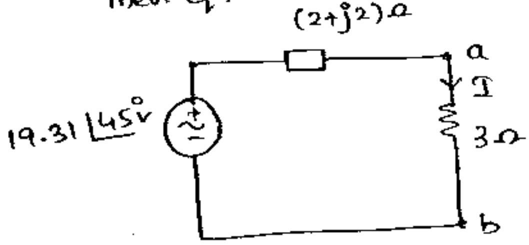


KVL

$$-[10\angle 0^\circ] - [5\angle 30^\circ][2+j2] + V_{Th} = 0$$

$$V_{Th} = 19.31\angle 45^\circ$$

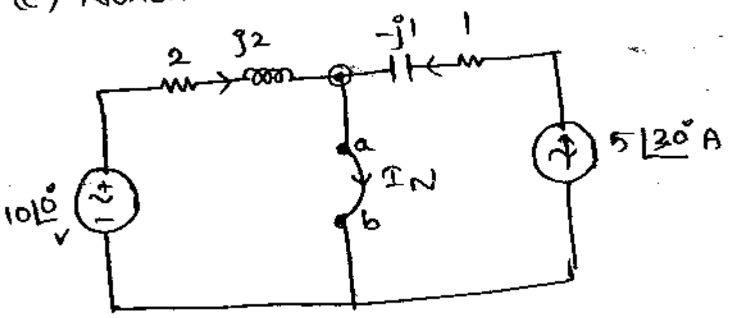
Thev. Eq.



$$I = \frac{19.31\angle 45^\circ}{(5+j2)}$$

$$= 3.58\angle 23.2^\circ \text{ A}$$

(c) Nortons.

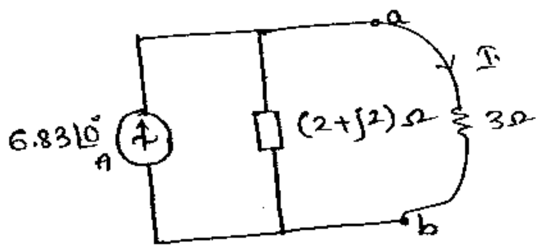


KCL

$$\frac{10\angle 0^\circ}{(2+j2)} + [5\angle 30^\circ] = I_N$$

$$I_N = 6.83\angle 0^\circ$$

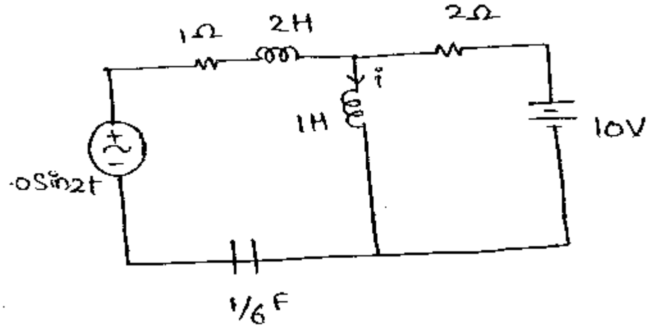
Nortons Eq.



$$I = 6.83\angle 0^\circ \left[\frac{2+j2}{5+j2}\right]$$

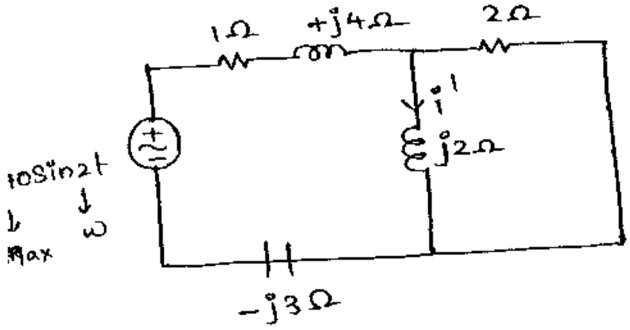
$$I = 3.58\angle 23.2^\circ \text{ A}$$

Q determine 'i' in the ckt shown.



⇒ It is a multifreq. (AC : ω=2, DC : ω=0) Excited N/w & Solution in time domain be easily determined by SPT.

I. AC Source only



total currt (V/Z)   Currt division

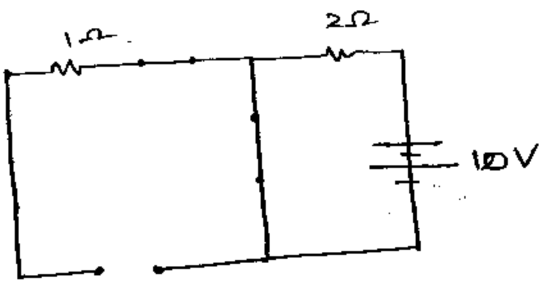
$$i' = \left(\frac{40\sin 2t}{(1+j\ ) + [2 \,||\, j2]}\right) * \frac{2}{(2+j2)}$$

$(1+j4-j3) + (2 \,||\, j2)$

$$= (40\sin 2t) / (4\,\angle 90^\circ)\,\Omega$$

$$i' = 10.\sin(2t-90)\text{ A}$$

II DC Source only



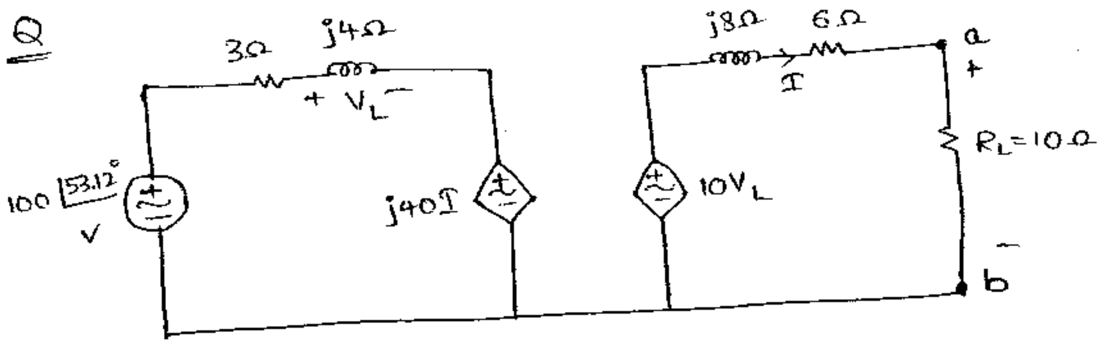
$$i'' = \frac{10}{2} = 5\text{ A}$$

⇒ SPT

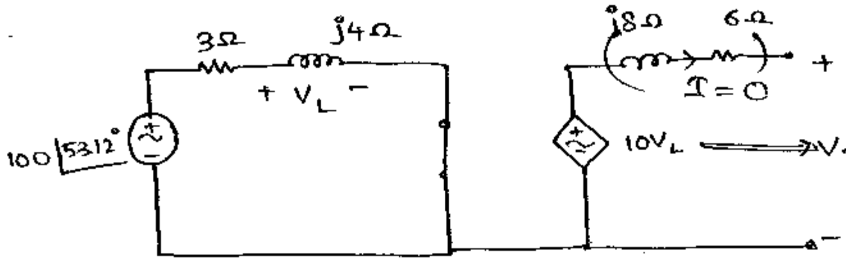
$$i = i' + i''$$

$$i = 10\sin(2t-90) + 5 \quad \text{A}$$

Q



determine Thevenins Voltage across load



$$V_{Th} = 10V_L = 10[80\angle 90^\circ]$$

$$V_{Th} = 800\angle 90^\circ$$

$$= j800\ V.$$

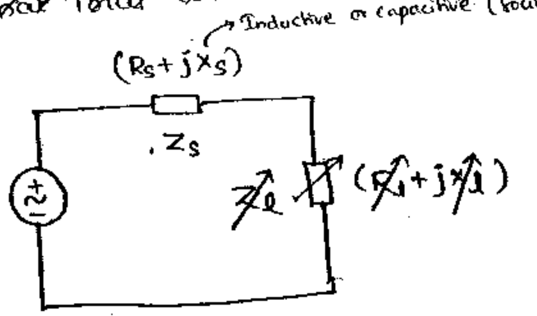
$$V_L = 100\angle 53.12^\circ \left[\frac{j4}{3+j4}\right] = 80\angle 90^\circ\ V$$

Theorem-V

maximum power Transfer Theorem in AC N/ws:

Though There are 3 types of physical powers in AC N/w ie, P, Q, S but the power that is Convertable or Utilisable in any form is active power or Real power "P" Watts. So, maximum power Transfer theorem in AC Networks is Confined to Real Power "P" & that to in the Resistive part of load N/w.

Show that Total load Variab



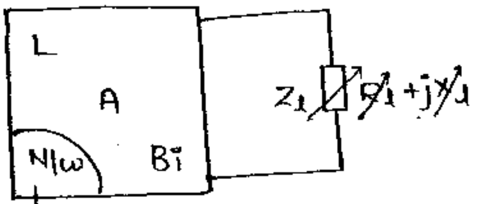
$$\rightarrow \boxed{\begin{array}{l} P.F = 1 \\ \%\eta = 50\% \end{array}}$$

Here both load Resistance & Reactance Can be Independently Controlled. So, we can Compensate the Net Reactance to Zero & ckt operates at UPF (ie, only R). So, Here Both phase Balancing & Magnitude Balancing of Impedences can be acheived. So, P_{max} Occurs in the load if load Impedence is Complex Conjugate of Source Impedence

$$\boxed{Z_l = Z_s^*}$$

$$P_{max} = \frac{|V_s|^2}{4R_s} \text{ Watts}$$

In General



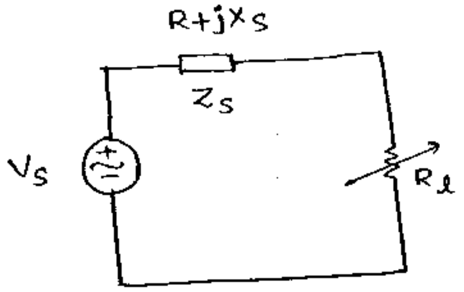
→ First Convert to Thevenin Equivalent.

Then for P_{max}

$$\boxed{Z_l = Z_{Th}^*}$$

$$\boxed{P_{max} = \frac{[V_{Th}]^2}{4R_{Th}} \text{ W.}}$$

Special case (a)



$\boxed{P.F < 1.}$

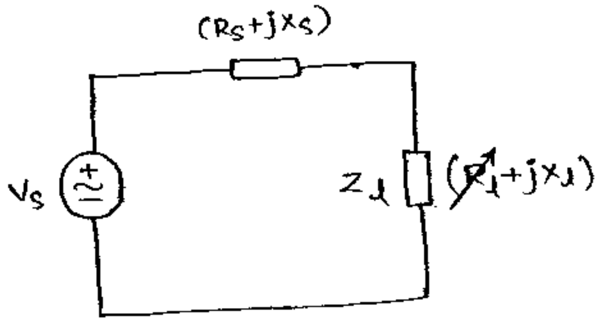
∵ Here load is purely Resistive but Source has Impedence, therefore phase Balancing of Impedence is not possible. So, atleast match the Impedence

So, P_{max} occurs in load if

$$R_l = |Z_s| = \sqrt{R_s^2 + X_s^2}$$

but to find the P_{max}, Resubstitute this R_l Back into ckt & find RMS Current through it.

Special Case (b)



Here, Though Both Source & load have Impedences, only load Resistances is adjustable, So we Cann't Compensate the net Reactance to Zero. Here also phase Balancing of Impedence is not possible. So, atleast match the magnitude.

$$\boxed{P.f < 1}$$

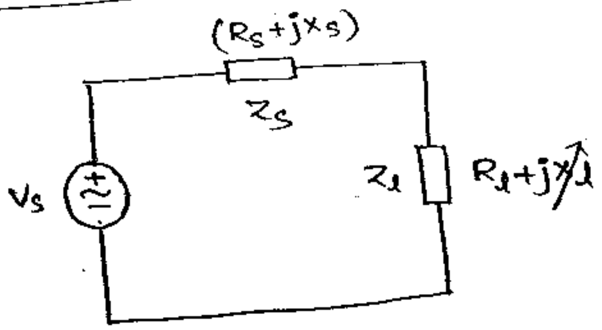
So P_{max} occurs in load if,

$$R_l = |R_s + jX_s + jX_l|$$

$$R_l = |R_s + j(X_s + X_l)|$$

$$R_l = \sqrt{R_s^2 + (X_s + X_l)^2}$$

Special Case (c)



Here, Since only load Reactance is adjustable we Can Compensate the net Reactance to Zero. So, Here phase Balancing of Impedence Can be acheived but magnitudes are fixed bcz R_l is Constant. So,

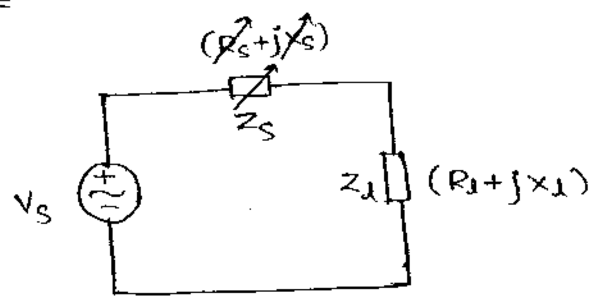
$$\boxed{\begin{array}{c} P.f < 1 \\ \%0 < \%\eta < \%100 \end{array}}$$

So, P_{max} Occurs in the load,

if, $X_l = -X_s$

$$\boxed{X_l + X_s = 0}$$

Q for What Value of Source Impedence Z_s, P_{max} Occurs in the load.

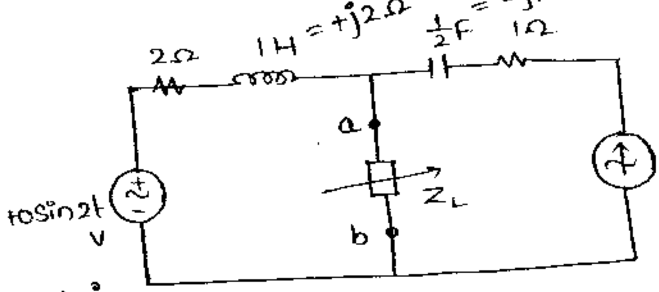


$X_s = -X_l$ → Reactive power Compensation

$R_s = 0$ → Minimization of losses

$$\underline{\underline{Z_s = -jX_l}}$$

Q What is the max power Transferred to load.



$40\angle 0°$

$5\cos(2t-30°)$ A

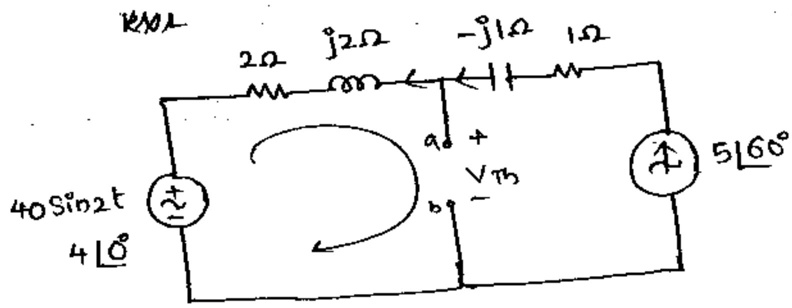
$5\sin(90+2t-30°)$

$5\angle 60°$

Z_{Th}: $(2+j2)\,\Omega$

V_{Th}:

KVL

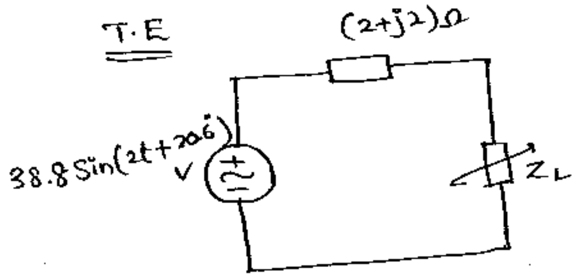


KVL

$$-[40\angle 0°]-[5\angle 60°][2+j2]+V_{Th}=0$$

$V_{Th} = 38.8\angle 20.6°$ V.
↳ phasor (max)

T.E



for P_{max}

$$Z_L = Z_s^*$$

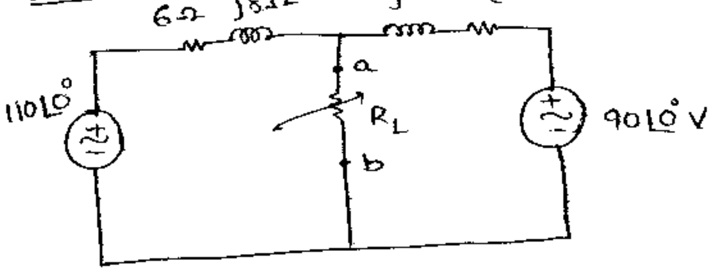
$$Z_L = 2-j2$$

$$P_{max} = \frac{(V_{Th})^2}{4R_{Th}} = \frac{\left[\frac{38.8}{\sqrt{2}}\right]^2}{4[2]}$$

RMS.

$$= 94.1\,W$$

Gate



What is the max power Transfered to the load

(a) 500 W (c) 1000 W

(b) 625 W (d) 1250 W

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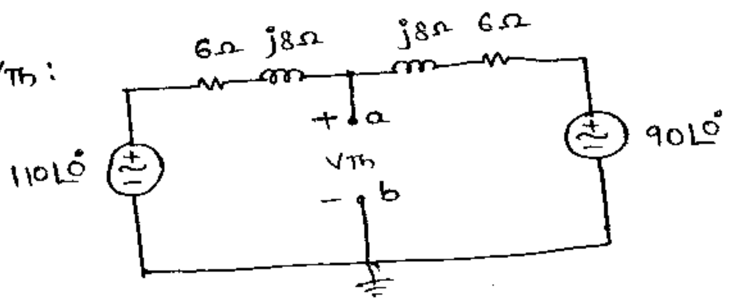
Z_{Th} : $(6+j8) \parallel (6+j8) = 3+j4$

V_{Th} :



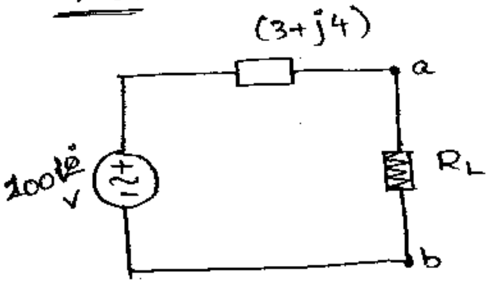
$$\frac{V_{Th} - 110\angle 0^\circ}{6+j8} + \frac{V_{Th} - 90\angle 0^\circ}{6+j8} = 0$$

$$V_{Th} - 110\angle 0^\circ - 90\angle 0^\circ = 0$$

$$2V_{Th} = 200$$

$$V_{Th} = 100 \text{ V.}$$

T.E :



at P_{max}

$$R_L = |Z_s|$$

$$= \sqrt{9+16}$$

$$R_L = 5.$$

$11.18\angle -26.56$

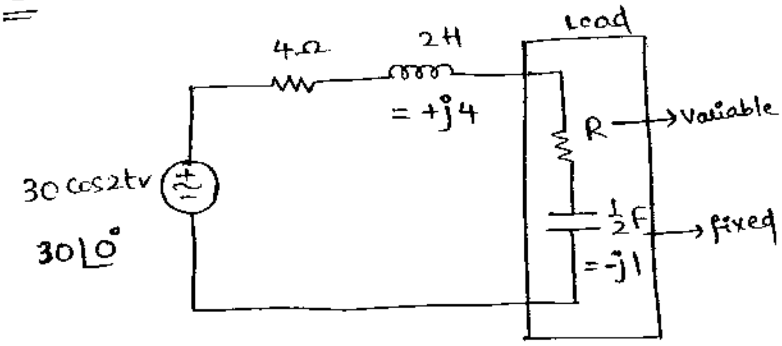
$$I_{L(rms)} = \frac{100\angle 0^\circ}{(3+j4+5)} = 11.18\angle -26.56.$$

$$P_{max} = |I_L|^2 \cdot R_L = (11.18)^2(5)$$

$$= 624.9 \text{ W}$$

Date

Q. What is the max power Transferred to the load.



$= \cancel{30\angle 0° \left(\frac{R-jr}{R+4+j3}\right)}$

∴ special case (b)

$$R_\ell = \sqrt{R_S^2 + (X_S + X_l)^2}$$

$$= \sqrt{4^2 + (4-1)^2}$$

$$R = R_\ell = 5$$

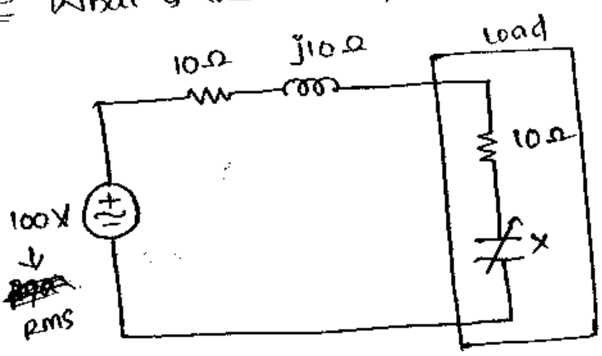
for Pmax

$$R_l = |4 + j4 - j1| = 5\,\Omega$$

$$I_{L\,(Rms)} = \frac{\left[\frac{30}{\sqrt{2}}\angle 0°\right]}{(4 + j4 + 5 - j1)} = 2.276\angle -18.14°$$

$$P_{max} = I_L^2 \cdot R = 25\,W.$$

IES What is the max power Transferred to the load.



→ special case (c)

→ For Pmax $X = -j10\,\Omega$

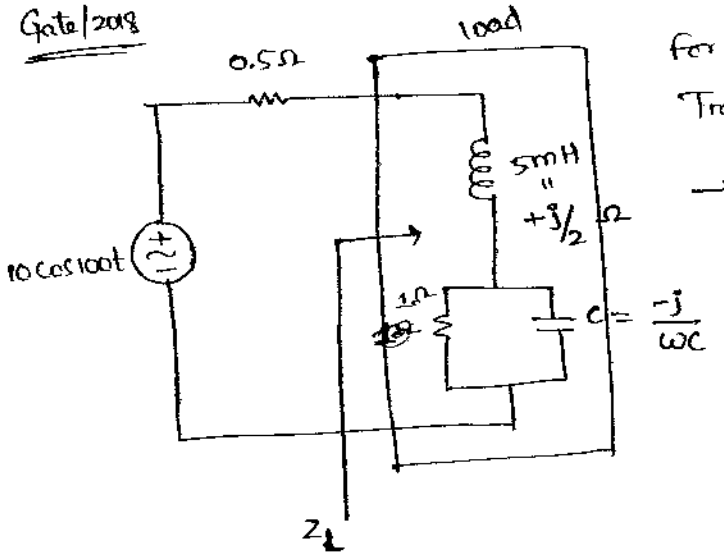
$$I_{L\,(Rms)} = \frac{100}{10 + j10 + 10 - j10} = 5A$$

$$P_{max} = I_L^2 R_L$$

$$= (5)^2 (10)$$

$$= 250\,W$$

Gate/2018



For what ~~value~~ value of capacitor 'c' max power Transferred to entire load.

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→ case (c)

'c' should be such that net load Reactance is zero

$$Z_L = \frac{j}{2} + \left[1 \,//\, \frac{-j}{\omega C} \right]$$

$$= \frac{j}{2} + \left[\frac{-j/\omega C}{1 - \frac{j}{\omega C}} \right]$$

$$= \frac{j}{2} + \left[\frac{-j/\cancel{\omega C}}{\omega C - j/\cancel{\omega C}} \right]$$

$$= \frac{j}{2} + \left[\frac{-j\,(\omega C + j)}{(\omega C - j)(\omega C + j)} \right]$$

$$= \frac{j}{2} + \frac{(1 - j\omega C)}{\omega^2 C^2 + 1}$$

$$= \left[\frac{1}{\omega^2 C^2 + 1} \right] + j \underbrace{\left[\frac{1}{2} - \frac{\omega C}{\omega^2 C^2 + 1} \right]}_{X_{net}}$$

for Pmax,

$$X_{net} = 0$$

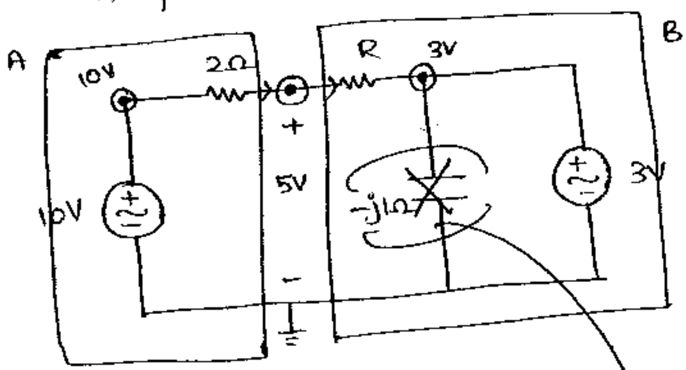
$$\frac{1}{2} - \frac{\omega C}{\omega^2 C^2 + 1} = 0 \Rightarrow \omega^2 C^2 + 1 = 2\omega C$$

$$\omega^2 C^2 - 2\omega C + 1 = 0$$

$$(\omega C - 1)^2 = 0 \Rightarrow \omega C = 1 \Rightarrow C = \frac{1}{\omega}$$

$$C = \frac{1}{100} = \underline{10\,mF.}$$

Gate Assuming Both the Sources are in phase for What Value of "R" max. power Transferred from ckt A to ckt B.



parallel to Ideal voltage sources are Redundant

Redundant ∵ Parallel to Voltage Source.

∴ −j1Ω is Redundant

∴ Voltage drop is 50% across each side

$$\frac{10-5}{2} = \frac{5-3}{R}$$

$$R = \frac{4}{5} = 0.8\Omega$$

do above problem in Exact Method

Concept of Complex power ($S^* = VI^*$)

Complex power is a mathematical Concept which will allows us to evaluate at three physical powers P, Q, S in any element or N/w or System directly by absorbing the Voltage & Current phasors but without declaring the N/w & its Components.

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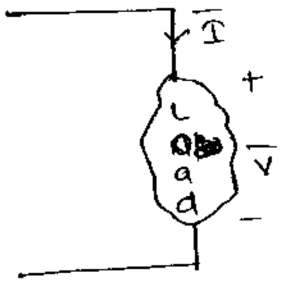
Here I^* is Complex Conjugate of total Current "I" & units of Complex power is also Volt amperes.

Assuming Lagging P.F load.



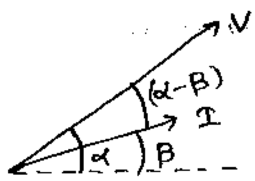
$$\bar{V} = |V| \angle \alpha$$

$$\bar{I} = |I| \angle \beta$$

$$S = V.I = |V||I| \angle \alpha+\beta \longrightarrow \text{Wrong phase angle}$$

$$S^* = V.I^* = |V|\angle\alpha \cdot |I|\angle -\beta$$

$$= |V||I| \angle \alpha-\beta \longrightarrow \text{Correct phase angle}$$



Note: In verifying Tellegans Theorem in AC Network & to derive the Power Flow Eqn in power N/w we should Consider the Complex power S^* only. Where we need Mathematically prove

$$\boxed{\sum_{K=1}^{b} V_K . I_K^* = 0}$$

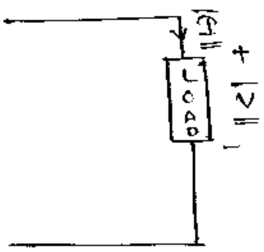
where b = no. of Branches in N/w.

continued

i.e., $\sum V.I^* \Big|_{\substack{\text{Sources} \\ \downarrow \\ (V, I)}} = \sum V.I^* \Big|_{\substack{\text{Sinks} \\ \downarrow \\ (R, L, C)}}$

Gate: If $\underline{\underline{\bar{V}}} = (7+j2)\,V$ Determine $\underline{\underline{P}}, \underline{\underline{Q}}, \underline{\underline{S}}$ & total load N/w P.F

$\underline{\underline{\bar{I}}} = (1+j5)\,A$



$\underline{\underline{S^*}} = V.I^*$

$= [7+j2][1+j5]^*$

$= (7+j2)(1-j5)$

$S^* = 17 - j33 \longrightarrow Q_c = 33$ VARS (generating) $\Downarrow$ Capacitive

$\downarrow$

$P = 17\,W$

$|S^*| = \sqrt{P^2 + Q_c^2}$

$= \sqrt{17^2 + 33^2}$

$= 37.1$ VA

$P.F = \dfrac{P}{S} = \dfrac{17}{37.1} = 0.45$ ($\underline{\underline{\text{lead}}}$)

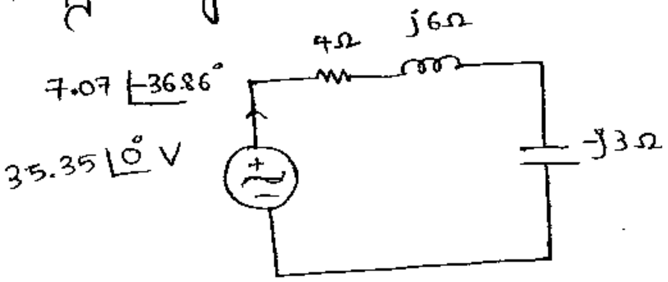
(or)

$\bar{V} = 7.28\,\angle 15.9^\circ$

$\bar{I} = 5.09\,\angle 78.9^\circ$

current leading V by 62° $\Downarrow$ RC N/w.

Verify Tellegans Theorem in previous Calculation problem (before 8 pages)



Tellegans:

$V_S I_S^* = V_R I_R^* + V_L I_L^* + V_C I_C^*$

L.H.S:

$\Rightarrow (35.35\,\angle 0^\circ)(7.07\,\angle +36.86^\circ)$

$= 250\,\angle 36.86^\circ$ VAs

RHS

$$\Rightarrow (28.28\angle{-36.86^\circ})(7.07\angle{+36.86})+(42.42\angle{53.14^\circ})\ (7.07\angle{+36.86^\circ}) +$$

$$(21.21\angle{-126.96})\ (7.07\angle{+36.86})$$

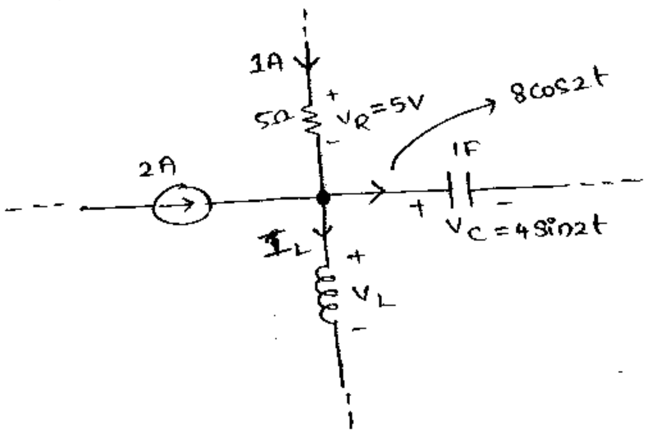
$= 250\angle{36.86^\circ}$

$= (200+j150)VA.$

LHS = RHS $\longrightarrow$ verified.

Gate

If $V_R = 5V$, $V_c = 4\sin 2t$ V then $V_L =$ ______



$i = c\dfrac{dv}{dt}$

$= 1F \times \dfrac{d}{dt}(4\sin 2t)$

$= 1F \cdot 4\cos 2t \cdot 2$

$I_c = i = 8\cos 2t$

$I_c = \dfrac{V}{-jX_C} = 4\sin 2t$

KCL

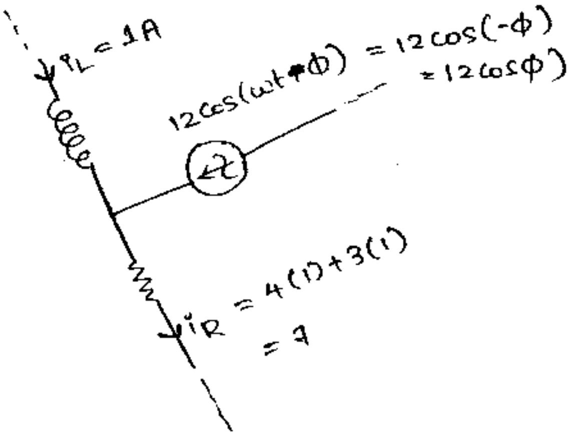
$2+1 = 8\cos 2t + I_L$

$I_L = 3 - 8\cos 2t$

$V_L = L\dfrac{dI_L}{dt} = 2[0+8.2.\sin 2t]$

$V_L = 32\sin 2t$

Gate If $i_L(0) = 1A$, $i_R(t) = 4 e^{-3t} + 3 e^{-4t}$, $t > 0$ find $\phi =$ ____



KCL at $t = 0$

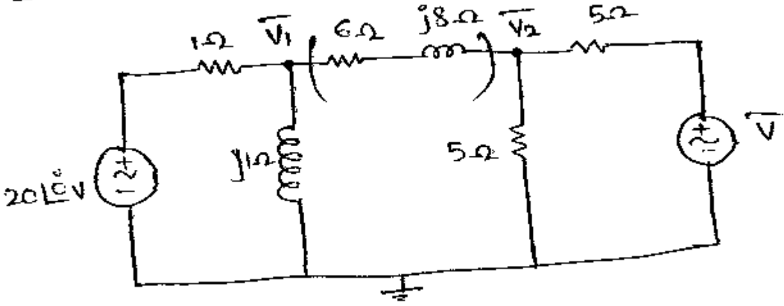
$1 + 12\cos\phi = 7$

$12\cos\phi = 6$

$\cos\phi = \frac{1}{2}$

$\phi = 60^\circ$.

IES if power lost in 6Ω is Zero, then Voltage $\bar{V}$ = ——



power lost = 0
when Current doesn't flow
i.e. Voltage diff. is Same
i.e. in AC Same volt. mag, phase & freq.

$\bar{V}_1 = \bar{V}_2$

$$V_1 = 20\angle 0^\circ \left[\frac{j1}{1+j}\right]$$

$$V_1 = 10\sqrt{2}\,\angle 45^\circ$$

$$V_2 = V\left[\frac{5}{5+5}\right]$$

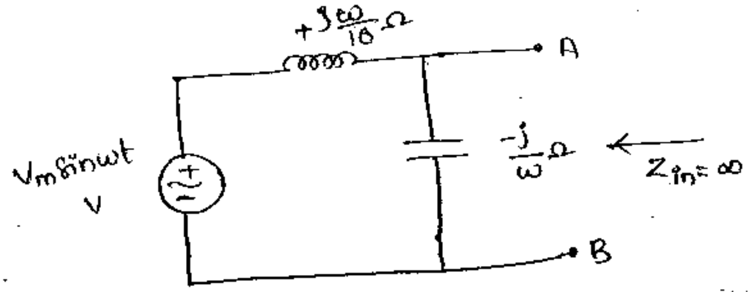
$$V = 2V_2$$

$$V = 2\,(10\sqrt{2}\,\angle 45^\circ)$$

$$V = 20\sqrt{2}\,\angle 45^\circ$$

Gate for What Supply freq. 'ω' the N/w b/w 'A' 'B' acts as Ideal Current Source.

$Z_{internal} = \infty$



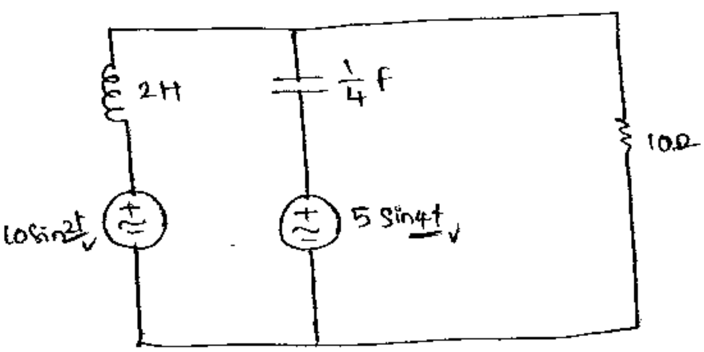
$$Z_{in} = \left[\frac{j\omega}{16} \,//\, \frac{-j}{\omega}\right]$$

$$Z_{in} = \frac{\frac{1}{16}}{j\left[\frac{\omega}{16} - \frac{1}{\omega}\right]} = \infty$$

$\left[\frac{\omega}{16} - \frac{1}{\omega}\right] \rightarrow 0$

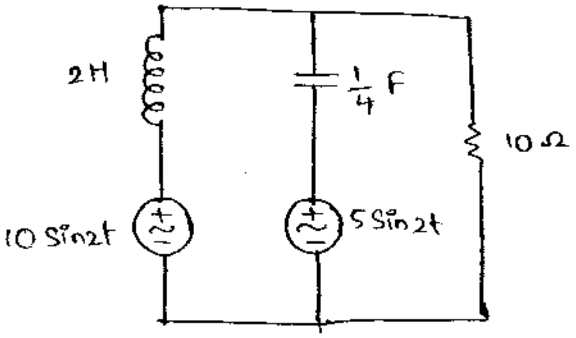
$$\frac{\omega}{16} = \frac{1}{\omega} \Rightarrow \omega^2 = 16$$

$$\omega = 4 \text{ rad/sec}$$



Which is the Best theorem to evaluate Response in 10Ω Resistance.

two multiple Sources with multiple freq.
↪ Superposition Theorem



which is best theorem to evaluate Response in 10 Ω.

⇒ Millimans.

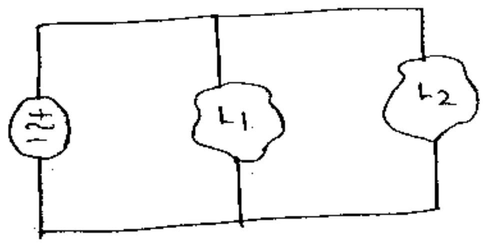
$$\overline{V}_M = \frac{\sum_{i=1}^{n} \frac{V_i}{Z_i}}{\sum_{i=1}^{n} \frac{1}{Z_i}} = \frac{\sum_{i=1}^{n} V_i Y_i}{\sum_{i=1}^{n} Y_i}$$

$$Z_M = \frac{1}{\sum_{i=1}^{n} \frac{1}{Z_i}} = \frac{1}{\sum_{i=1}^{n} Y_i}$$

Q determine the total Supply power factor &

Load 1 : 5 kVA, 0.6 (lag)

Load 2 : 1 kW, 0.8 (lead)



Load - I

$S_1 = 5000\,VA$

$\cos\phi_1 = 0.6(\text{lag})$

$P_1 = S_1 \cos\phi_1 = 3000\,W$

$Q_1 = S_1 \sin\phi_1 = 4000\,VArs$

$S_1 = P_1 + jQ_1$

Load - II

$P_2 = 1000\,W.$

$\cos\phi_2 = 0.8\,(\text{lead})$

$S_2 = \frac{P_2}{\cos\phi_2} = 1250\,VA$

$Q_2 = S_2 \sin\phi_2 = 750\,VArs.$

$S_2 = P_2 - jQ_2$

Tellegans : $S_T = S_1 + S_2$

$S_T = \{P_1 + P_2\} + j[\overset{\text{lag}}{Q_1} - \overset{\text{lead}}{Q_2}]$

$S_T = [3000 + 1000] + j[4000 - 750]$

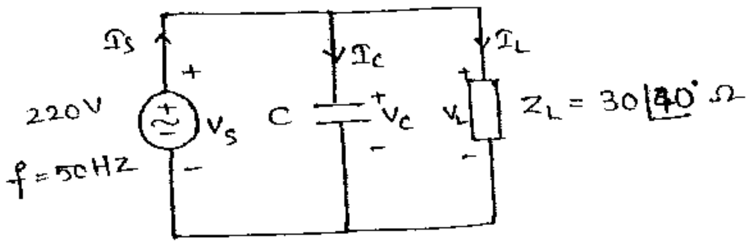
$S_T = 4000 + j3250$ → overall lag

$$P.F. = \frac{P_T}{|S_T|} = \frac{4000}{\sqrt{4000^2 + 3250^2}} = 0.77\,(\text{lag})$$

power Factor & its Correction:

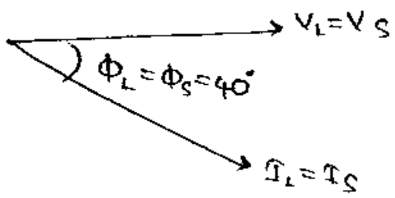
I. Correction at UPF level:

Q determine the Value of Capacitor 'C' required to ~~make~~ Correct the Supply power Factor to Unity.



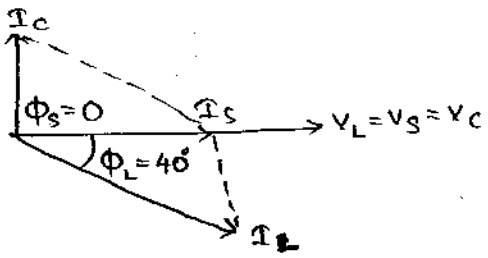
KCL: $\bar{I}_S = \bar{I}_L + \bar{I}_C$

Without 'C'



$\begin{bmatrix} \text{load} \\ \text{P.F} \end{bmatrix} = \begin{bmatrix} \text{Supply} \\ \text{P.F} \end{bmatrix} = \cos 40^\circ = 0.766(\text{lag})$

With Capacitor:



$\Rightarrow$ Load P.F $= \cos 40^\circ = 0.7666(\text{lag})$

Supply P.F $= \cos 0^\circ = 1$ [UPF]

$\rightarrow$ E.C.A (elec. ckt analysis)

(a) Series : $Z = R \pm jX_{net}$

at UPF, $Z = R$, so $\boxed{X_{net} = 0}$

(b) parallel : $Y = G \pm jB_{net}$

at UPF, $Y = G$, so $\boxed{B_{net} = 0}$

sol parallel.

$$Y_T = Y_1 + Y_2$$

$$Y_T = \frac{1}{-jX_C} + \frac{1}{Z_L} = \frac{1}{-j/\omega C} + \frac{1}{30\angle 40^\circ}$$

$$Y_T = j2\pi fC + \frac{1}{30}\angle -40^\circ$$

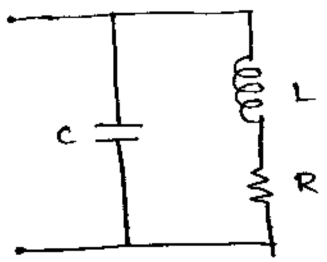
$$Y_T = j100\pi C + [0.0255 - j0.02142]$$

$$Y_T = 0.0255 + j[100\pi C - 0.02142]$$

at UPF, $B_{net} = 0$

$$100\pi C = 0.02142$$

$$C = \frac{0.02142}{100\pi} = 0.8\ \mu F$$



$$Y_T = Y_1 + Y_2 = \frac{1}{-jX_C} + \frac{1}{R + jX_L}$$

$$Y_T = \frac{R - jX_L}{R^2 + X_L^2} + \frac{j}{X_C}$$

$$Y_T = \left[\frac{R}{R^2 + X_L^2}\right] + j\left[\frac{1}{X_C} - \frac{X_L}{R^2 + X_L^2}\right]$$

at UPF, $\longrightarrow B_{net} = 0$

$$\frac{1}{X_C} = \frac{X_L}{R^2 + X_L^2}$$

$$\cancel{\omega} C = \frac{\cancel{\omega} L}{R^2 + (\omega L)^2}$$

$$\boxed{C = \frac{L}{R^2 + \omega^2 L^2}\ F}$$

II. power factor Correction at desired level:

Q In the above ckt determine the "C" value. to improve supply P.F to 0.85 lagging

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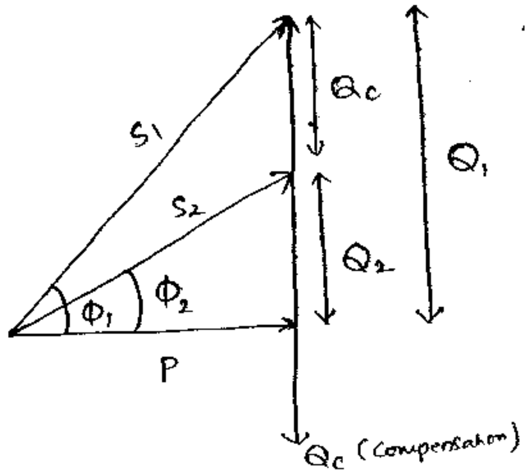
power Triangle [lagging P.F]



Before Correction $\longrightarrow \cos\phi_1$

After Correction $\longrightarrow \cos\phi_2$

$$\cos\phi_2 > \cos\phi_1$$

$$\phi_2 < \phi_1$$

$$\tan\phi_1 = \frac{Q_1}{P} \longrightarrow Q_1 = P\tan\phi_1$$

$$\tan\phi_2 = \frac{Q_2}{P} \longrightarrow Q_2 = P\tan\phi_2$$

$$Q_c = [Q_1 - Q_2]$$

$$Q_c = P[\tan\phi_1 - \tan\phi_2]$$

$$Q_c = \frac{V^2}{X_c} = \frac{V^2}{1/\omega C} = \omega C V^2$$

$$\boxed{C = \frac{Q_c}{\omega V^2}} \text{ F}$$

Sol Before Correction $\longrightarrow \phi_1 = 40^\circ$

After Correction, $\cos\phi_2 = 0.85 \longrightarrow \phi_2 = \cos^{-1}(0.85)$

$$\phi_2 = 31.78^\circ$$

$$P = V_L I_L \cos\phi_1$$

$$I_L = \frac{V_L}{Z_L} = \frac{220\angle 0^\circ}{30\angle 40^\circ} = 7.33\angle -40^\circ$$

$$P = (220)(7.31)\cos 40^\circ$$

$$P = 1235 \text{ Watts}$$

$$Q_c = 1235\left[\tan 40^\circ - \tan 31.78^\circ\right]$$

$$= 271 \text{ VArs}$$

$$C = \frac{Q_c}{\omega V^2} = \frac{(271)}{2\pi 50(220)^2}$$

$$= 17.8\ \mu f$$

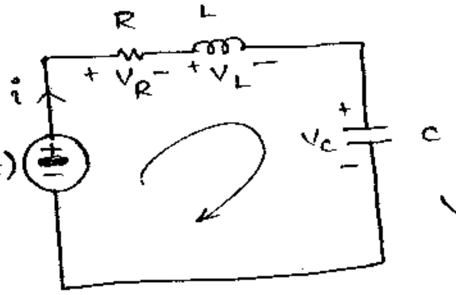
Duals & Duality

Duals: Two ckts are said to be duals of each other if Mesh Eqns that characterised one of them has the same Mathematical form as the Nodal Eqns that characterise the other.

Principle of Duality:

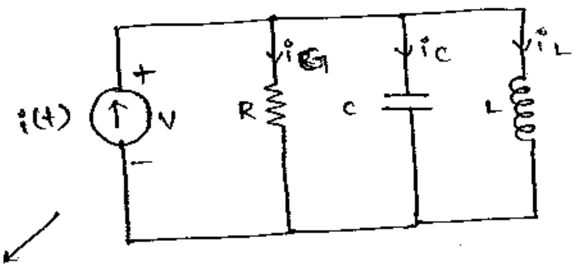
Identical Behaviour patterns observed b/w Voltages & Currents of two Independent Nlws demonstrate the principle of duality.

ex: Series R-L-C



Duals

parallel R-L-C



Mesh → KVL

$$-V(t) + V_R + V_L + V_c = 0$$

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

Mathematically identical

Nodal ⟶ KCL

$$-i(t) + i_G + i_C + i_L = 0$$

$$\boxed{i(t) = V.G + C.\frac{dV}{dt} + \frac{1}{L}\int v.dt}$$

List of Dual Elements:

$V(t) \longleftrightarrow i(t)$	$\int V dt \longleftrightarrow \int i dt$
$V \longleftrightarrow I$	$\frac{di}{dt} \longleftrightarrow \frac{dV}{dt}$
$V_m \sin\omega t \longleftrightarrow I_m \sin\omega t$	$Z \longleftrightarrow Y$
$R \longleftrightarrow G$	$X \longleftrightarrow B$
$C \longleftrightarrow L$	O.C ⟷ S.C
KVL ⟷ KCL	Thevenins ⟷ Nortons
Series ⟷ parallel	$Y \longleftrightarrow \Delta$
Mesh ⟷ Node	

$\pi \longleftrightarrow T$

$q \longleftrightarrow \phi$

$\sigma \longleftrightarrow \mu$

Tree $\longleftrightarrow$ Co-Tree

Twigs $\longleftrightarrow$ Links/chords

Cut-set $\longleftrightarrow$ Tie-set

$[Q] \longleftrightarrow [B]$

$V_c(0) \longleftrightarrow i_L(0)$

$E_c \longleftrightarrow E_L$

Time const of voltage $T_v \longleftrightarrow T_i$ (Time const of current)

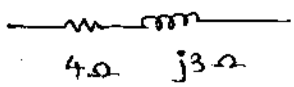
Switch in Series (getting closed) $\longleftrightarrow$ Switch in parallel (getting opened)

V (polarity) $\longleftrightarrow$ i (direction)

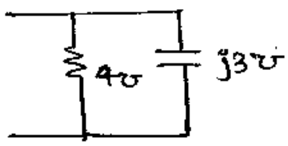
Note: Dual of 5Ω is $5\mho$ (or) element only.

Q What is the dual of $(4+j3)\Omega$

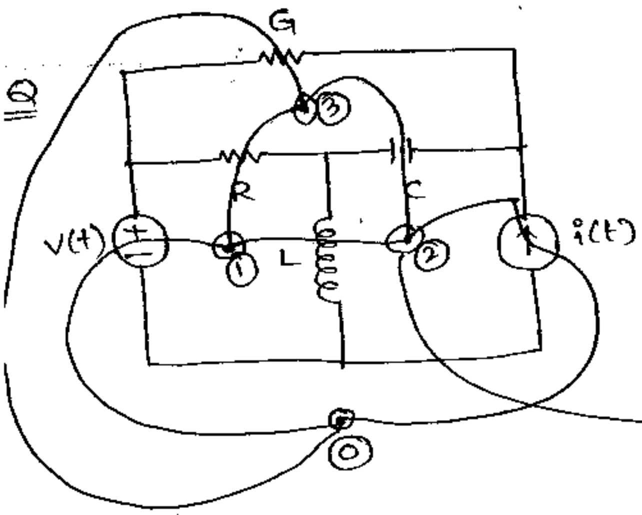
$Z = (4+j3)\Omega \Rightarrow$



$Y = (4+j3)\mho \Rightarrow$



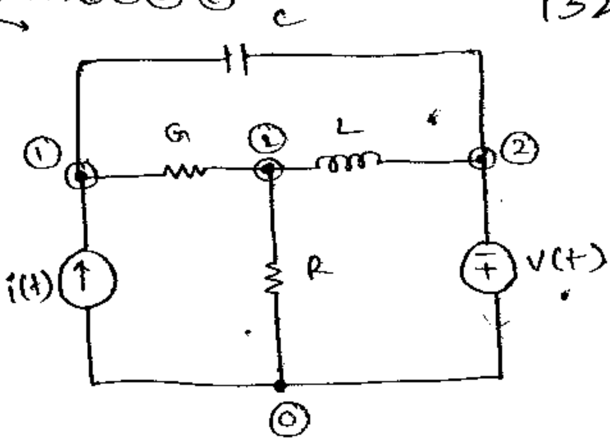
Q



Construct the dual of the following ckt & verify by writing Mesh & Nodal eqns.

→ meshes Becomes nodes.

① ② ③ ⓪ Meshes becomes nodes ① ② ③ ⓪

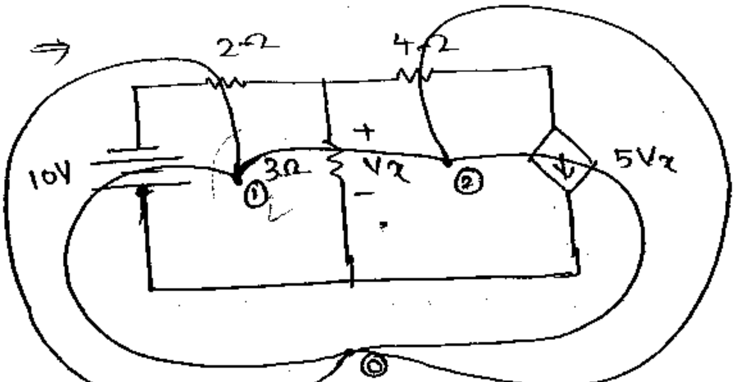


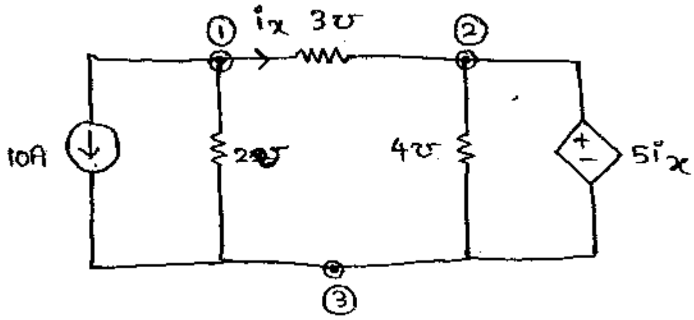
Mesh — Nodal

$$-V(t)+R[i_1-i_3]+L\left[\frac{di_1}{dt}-\frac{di_2}{dt}\right]=0 \longrightarrow ① \quad \xleftrightarrow{\text{dual}} \quad -i(t)+G[V_1-V_3]+C\left[\frac{dV_1}{dt}-\frac{dV_2}{dt}\right]=0 \longrightarrow ①$$

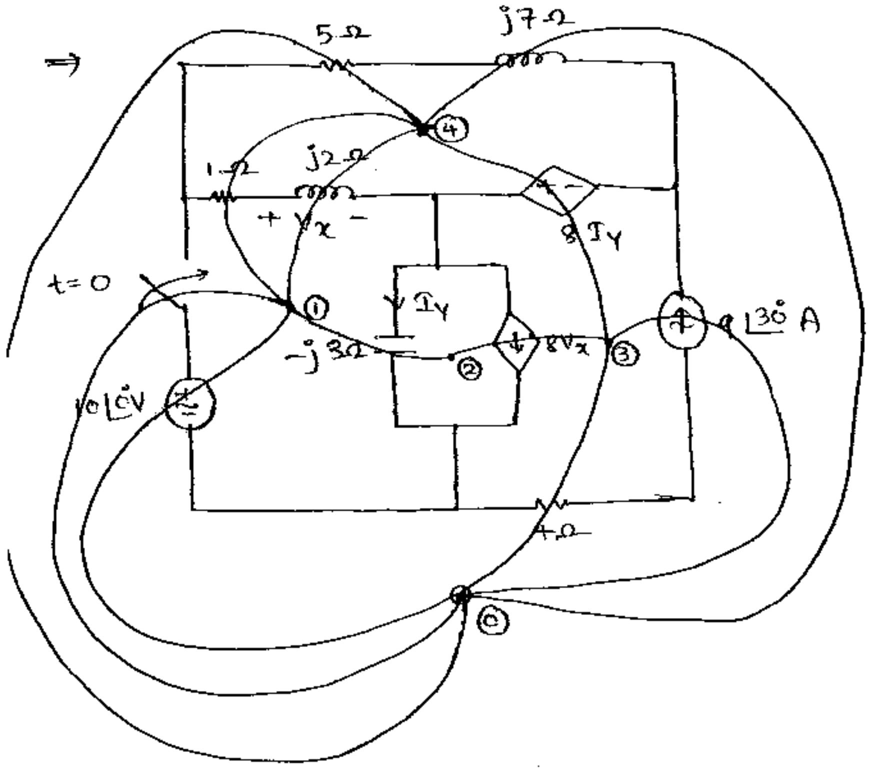
$$i_2=-i(t) \longrightarrow ② \quad \xleftrightarrow{\text{dual}} \quad V_2=-V(t) \longrightarrow ②$$

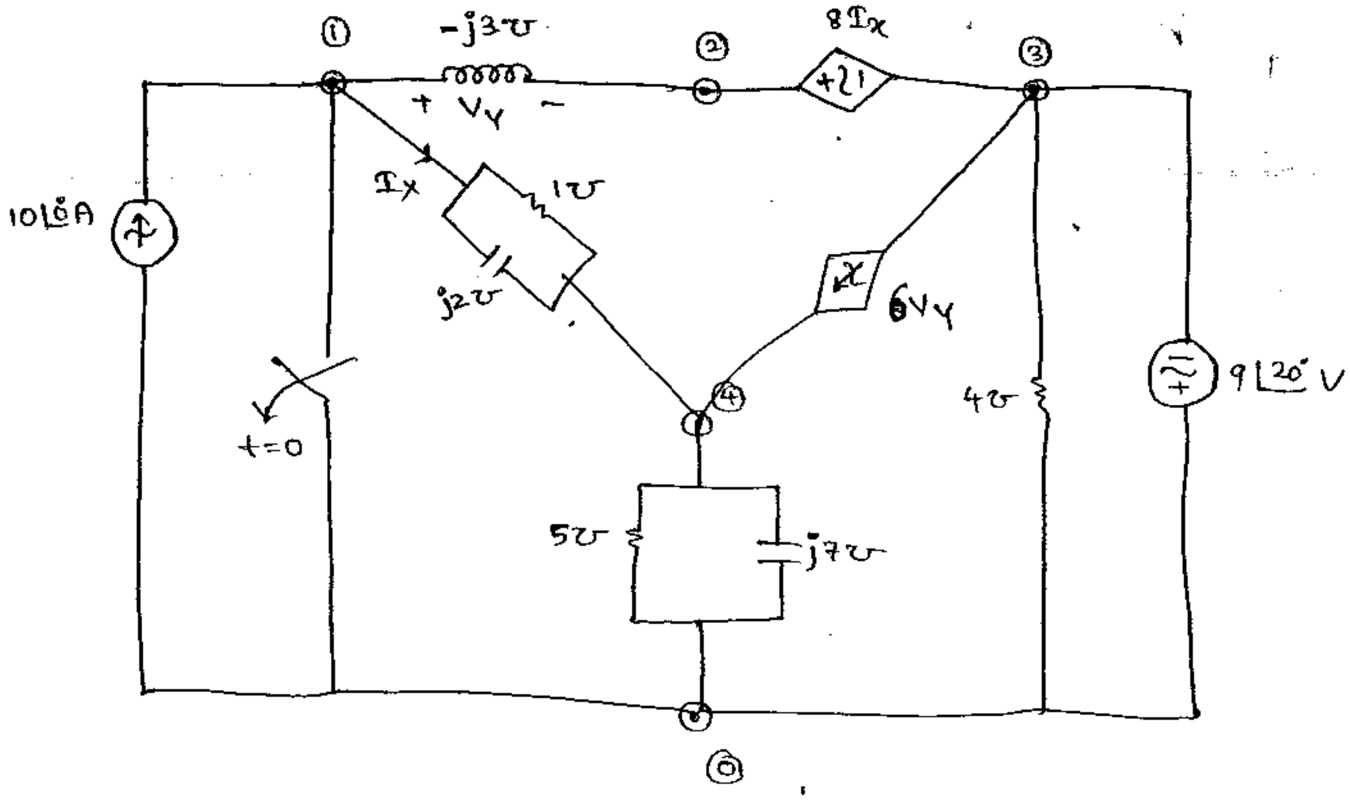
$$\frac{i_3}{G}+\frac{1}{C}\int(i_3-i_2)dt+R[i_3-i_1]=0 \longrightarrow ③ \quad \xleftrightarrow{\text{dual}} \quad \frac{V_3}{R}+\frac{1}{L}\int(V_3-V_2)dt+G[V_3-V_1]=0 \longrightarrow ③$$





⇒


5Ω
j7Ω
④
1Ω
j2Ω
+ Vx −
8 IY
t=0
IY
①
−j3Ω
②
8Vx
③
9∠30° A
10∠0°V
4Ω
⓪


①
−j3℧
②
8Ix
③
+ Vy −
Ix
1℧
10∠0°A
j2℧
6Vy
t=0
④
4℧
9∠20° V
5℧
j7℧
⓪

Locus diagram

These are Variable ~~ph~~ phasor diagrams when one of the electrical ckt parameter is Varied.

The parameters that can be Varied are Values of R, L, C, load current, Supply freq. .. etc.

Locus diagrams allows us to predetermine all the possible Operating points of a Network application from Which We can observe the optimum operating point for the best performance of the N/w application

Ex: (1) Circle diagram of a Ind. Motor is a locus diagram from which we can determine the load at which Highest running power factor of Motor can be acheived.

(2) Resonance plots are locus diagrams from which we can observe the performance of N/w & its Natural frequency.

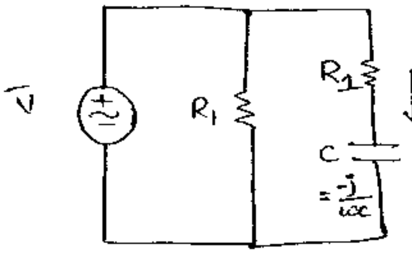
(3) Relay characteristics in P.S for its Zonal protection of Tr. line such as mho Relay, Reactance Relay .. etc are also locus diagrams.

Since most of our Network applications are designed to work for Rated Supply Voltage, We observe their Current locus diagrams.

Since most of our Network applications are Connected in parallel We prefer their admittance locus diagrams.

Q plot the locus of Current 'i' w.r.t Voltage 'v' as Supply freq ω is ~~f~~ varied from 0 to ∞

(or) What is the Radius of Current locus in ckt shown When Supply freq ω varied from 0 to ∞



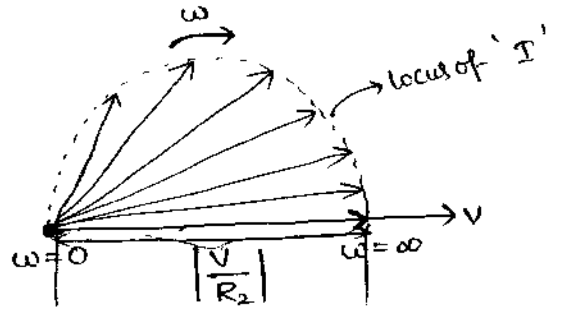
→ when ω=0 ⇒ open circuit

→ when ω=∞ ⇒ Short circuit

$$I = \frac{V}{Z} = \frac{V}{R_2 - jX_C}$$

$$\to |I| = \frac{|V|}{\sqrt{R_2^2 + \left(\frac{1}{\omega C}\right)^2}}$$

$$\to \phi = +\tan^{-1}\left[\frac{1}{\omega R_2 C}\right]$$



$0<\omega<\infty$

→ R-C Branch

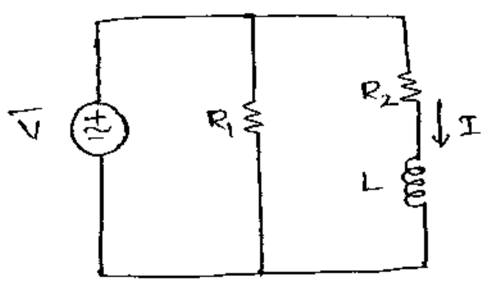
$$\left.R_C^2 + \left(\frac{1}{\omega C}\right)^2 = \left[\frac{V}{I}\right]^2\right\} \; X^2+Y^2=K^2 \text{ circle}$$

only 'ω' is varied

Radius of 'I' → $\frac{V}{2R_2}$

→ Semi circle shape in Variation

Q plot the locus 'i' w.r.t Voltage 'v' if R_2 is Varied from 0 to ∞ also determine the radius of Current locus



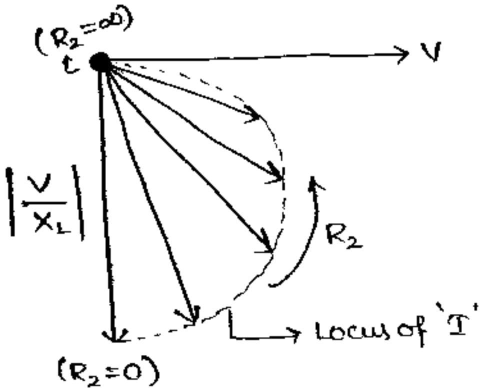
$$I = \frac{V}{Z} = \frac{V}{R_2 + jX_L}$$

$$\to |I| = \frac{|V|}{\sqrt{R_2^2 + X_L^2}} \quad \Big\} \quad R_2^2 + X_L^2 = \left[\frac{V}{I}\right]^2$$

only R_2 is Varied

→ Semi circle shape in Variation

$$\to \phi = -\tan^{-1}\left(\frac{X_L}{R_2}\right)$$



Radius of 'I' $= \frac{V}{2X_L} = \frac{V}{2\omega L}$ A.

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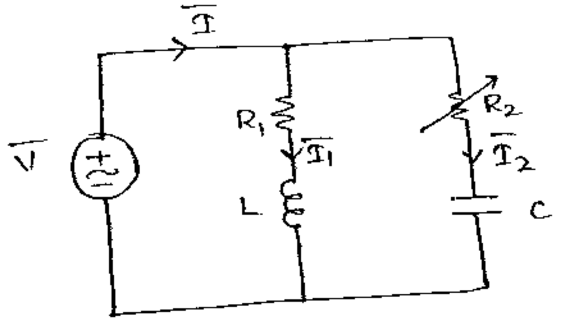
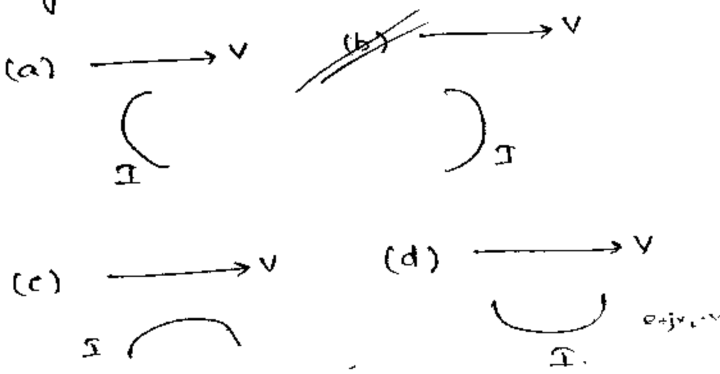
Q plot the locus of Current I w.r.t Voltage 'V' as R_2 is Varied from 0 to ∞





→ Based on options [N/w is lagging]

V, I in Q_4 ⇒ ∵ Current lagging.

KCL

$\bar{I} = \bar{I_1} + \bar{I_2}$ $\quad (|I_1| > |I_2|)$

$\bar{I}$ → Varied; $\bar{I_1}$ → Const.; $\bar{I_2}$ → Varied ∵ R_2 is Varied

$I_1 = \frac{V}{Z_1} = \frac{V}{R_1 + jX_L}$

↳ $|I_1| = \frac{|V|}{\sqrt{R_1^2 + X_L^2}}$

↳ $\phi_1 = -\tan^{-1}\left[\frac{X_L}{R_1}\right]$

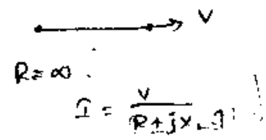
} Const.

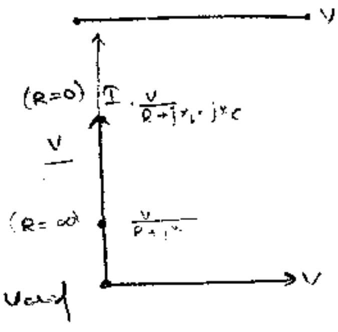
$I_2 = \frac{V}{Z_2} = \frac{V}{R_2 - jX_C}$

↳ $|I_2| = \frac{|V|}{\sqrt{R_2^2 + X_C^2}}$

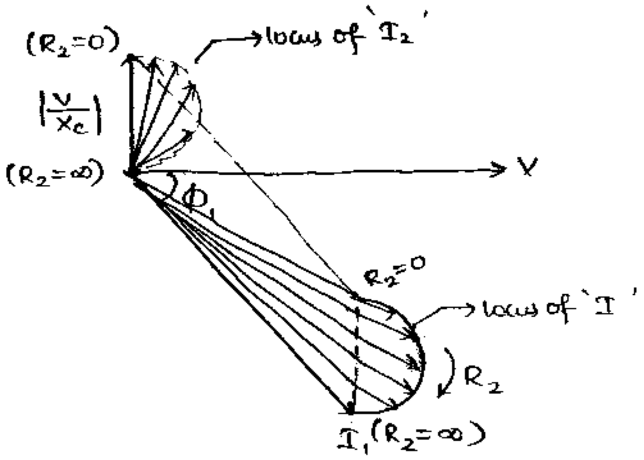
↳ $\phi_2 = +\tan^{-1}\left[\frac{X_C}{R_2}\right]$

} Varied

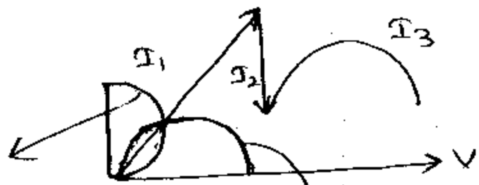




$x^2 - y^2 = k^2$



Q draw the Relevant ckt & Identify the Variable passive parameter in the ckt whose Current locus diagram is as shown



This comes when R_3 in RC Branch is Varied

X R_3 is not a Variable.

This Comes when "C" is Varied

$\therefore$ 'C' is Variable

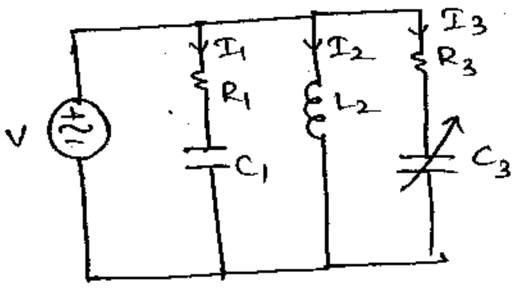
$\Rightarrow$ parallel ckt $\because$ V is Constant & Currents are dividing.

($\phi<90°$)

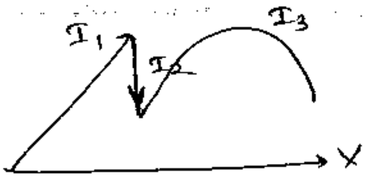
$\Rightarrow$ $I_1 \Rightarrow$ R-C Branch $\because$ current leading Voltage.

$I_2 \Rightarrow$ pure Inductor $\because$ Current lagging V by 90°

$I_3 \Rightarrow$ R-C Branch $\because$ current leading & it is Variable



Q



Electrical Resonance.

⇒ Resonance is the freq Responce of a ckt or N/w when it is operating at its Natural freq. called Resonance freq.

⇒ Under Resonance, the total Supply Voltage & Supply Current are in phase So, phase angle $\phi = 0^\circ$ & Ckt Exhibits Unity power factor (UPF)

⇒ Under Resonance, the Nature of the N/w is purely Resistive & maximum power is Transferred to the entire Network by the Source.

⇒ Resonance Can happen in Such electrical N/ws when we have two similar but opposite Natured Energy storage Components L & C.

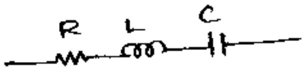
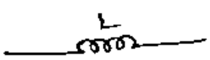
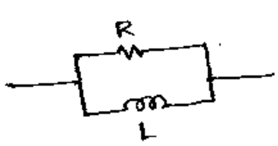
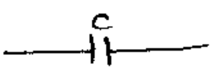
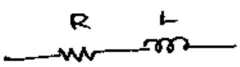
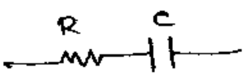
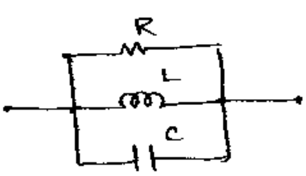
⇒ These Energy storage Components Used in Such Tuned circuits must have Very High Quality which is defined as Quality factor or figure of Merit, given by

$$Q_{factor} = 2\pi * \left[\frac{\text{Max. Stored Energy per cycle of Supply}}{\text{Energy dissipated per cycle of Supply}}\right]$$

$$Q_{factor} \approx \frac{Q_{VAR's}}{P_{Watts}}$$

In practical applications of Resonance to passive filter design at power levels analog Communication Based Receivers & Antennas, Q should be $\geqslant 5$

$Q \geqslant 5$ [index for design]

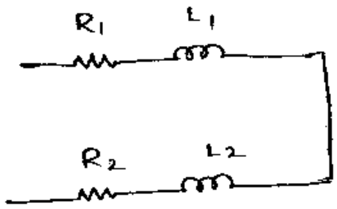
Element	Q-factor		
	0		$Q_0 = \frac{1}{R}\sqrt{\frac{L}{C}}$
	∞		$\frac{R}{\omega L}$
	∞		ωRC
	$\frac{\omega L}{R}$		
	$\frac{1}{\omega RC}$		$Q_0 \doteq R\sqrt{\frac{C}{L}}$

Note: The Combined Quality factor of a Series Combination of one Inductor & one Capacitor including their losses modelled either in Series or shunt Resistance is given by

$$Q_T = \frac{1}{\frac{1}{Q_L} + \frac{1}{Q_C}} = \frac{Q_L \cdot Q_C}{Q_L + Q_C}$$

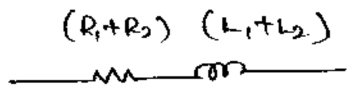
Q two practical Coils with Internal Resistances of R_1, R_2 have Quality factors of Q_1, Q_2 Respectively. if Both these Coils are Connected in Series then the Combined Quality factor is ______

$$\cancel{Q_T = \frac{Q_1 Q_2}{Q_1 + Q_2}} \qquad \cancel{Q \; \frac{1}{R_1+R_2}\left[\frac{Q_1 Q_2}{Q_1+Q_2}\right]}$$



$$Q_1 = \frac{\omega L_1}{R_1}$$

$$Q_2 = \frac{\omega L_2}{R_2}$$

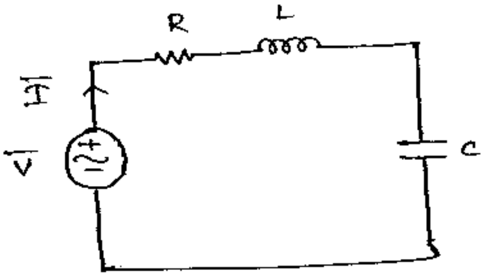


$$Q_T = \frac{\omega(L_1+L_2)}{R_1+R_2}$$

$$Q_T = \frac{\left(\frac{\omega L_1}{R_1}\right) * R_1 + \left(\frac{\omega L_2}{R_2}\right) * R_2}{R_1+R_2}.$$

$$Q_T = \frac{Q_1 R_1 + Q_2 R_2}{R_1 + R_2}$$

I]. Series Resonance,,



at Resonance,,

$\bar{V}$ & $\bar{I}$ ⟶ inphase

$\phi = 0^\circ$ [UPF]

$$\boxed{Z = R}$$

$$Z = R + j\left[X_L - X_C\right]$$

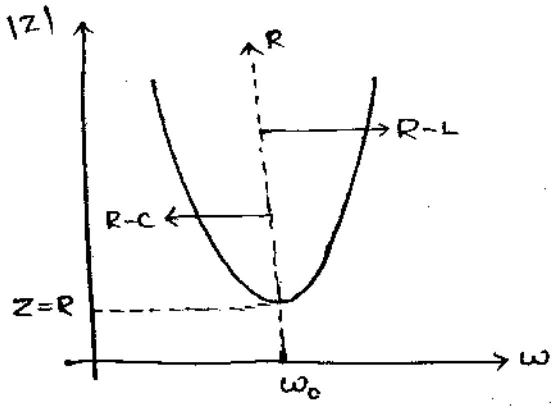
$$\boxed{\begin{array}{l}\text{at Resonance } (\omega_0) \\ \qquad X_{net} = 0\end{array}}$$

$$X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C}$$

$$\boxed{\begin{array}{l}\omega_0 = \dfrac{1}{\sqrt{LC}} \ \text{rad/sec} \\[2ex] f_0 = \dfrac{1}{2\pi\sqrt{LC}} \ \text{Hz.}\end{array}}$$

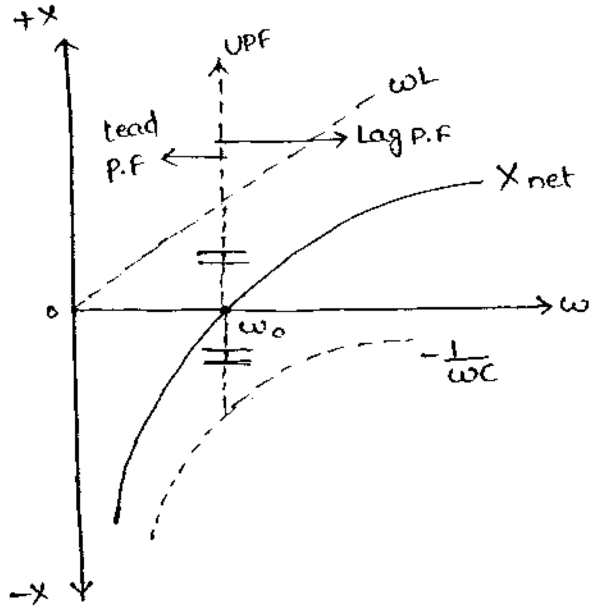
Graph-I $|Z|$ vs 'ω'

$$|Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$



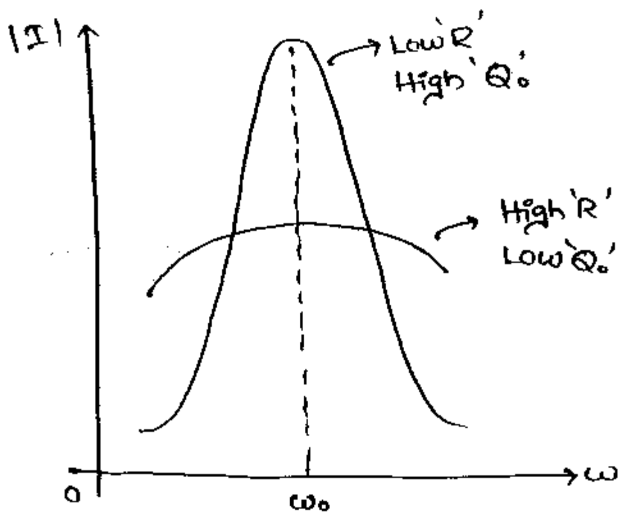
Graph-II

X_{net} vs ω $\left[Z = R + j\underbrace{\left(\omega L - \frac{1}{\omega C}\right)}_{X_{net}} \right]$



Graph-III

$|I|$ vs. ω



Phasor diagram:

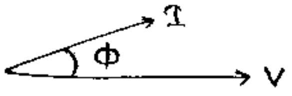
case (i) : If $\omega < \omega_0$

$Z = R - jX_{net}$

$\hookrightarrow$ R-C

'I' leads 'V' by $\phi < 90°$

(leading P.F)



$\phi \longrightarrow +ve.$

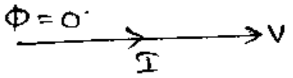
case (ii): $\omega = \omega_0$

$Z = R$

$\hookrightarrow$ purely Resistive

'I' inphase with 'V'

$\phi = 0°$ [UPF]



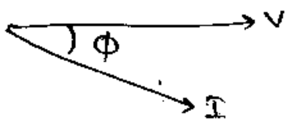
Case (iii) $\omega > \omega_0$

$Z = R + jX_{net}$

$\hookrightarrow$ R-L

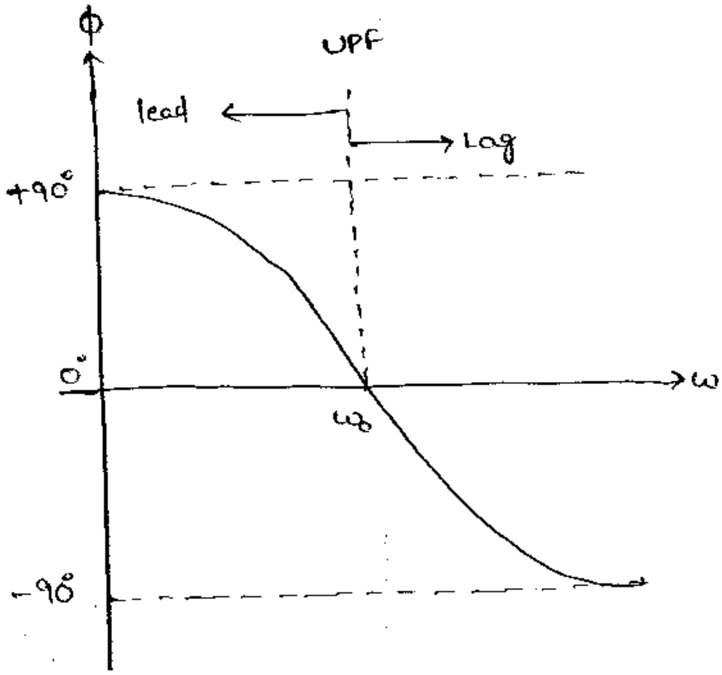
'I' lags 'V' by $\phi < 90°$

(lagging P.F)

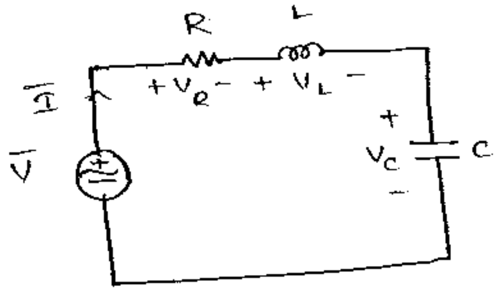


$\phi \longrightarrow -ve.$

Graph IV ϕ vs ω



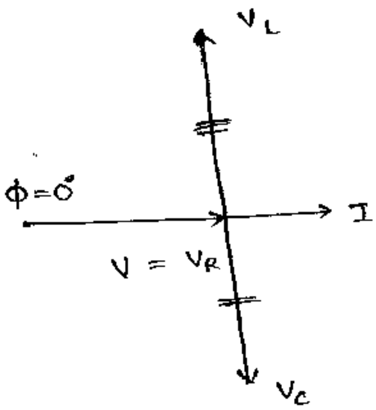
Complete phasor diagram Under Resonance.



at Resonance

$|X_L| = |X_C|$

$|V_L| = |V_C|$



$V = |V_R|$

$\phi = 0^\circ$

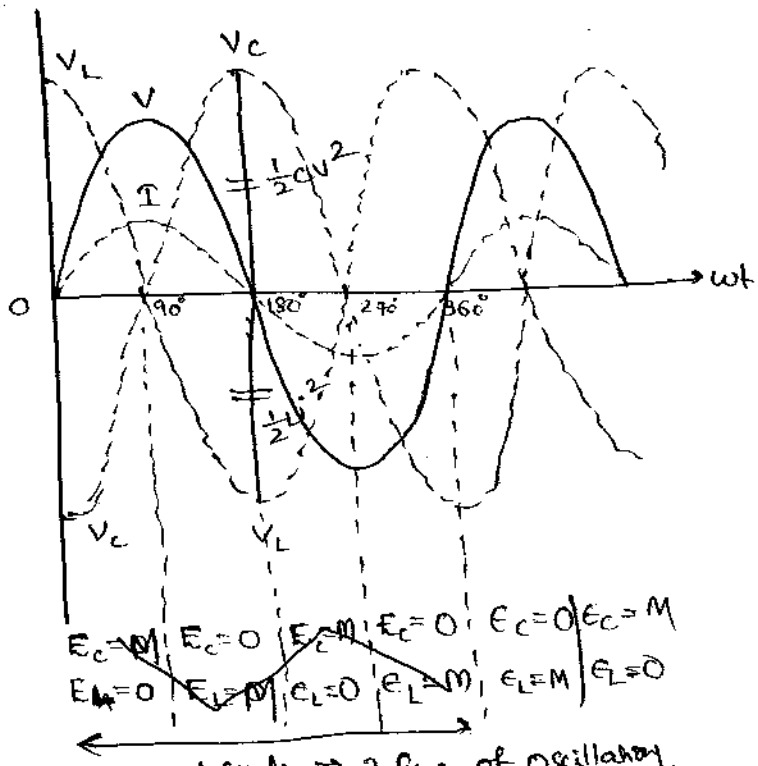
P.F = 1 (UPF)

<u>Note:</u> Under Series Resonance Condition the pure Series LC Segment of ckt acts like a short circuit & Source Supply Energy only to Resistor. However L&C Components Work Together by Exchanging the stored mag. (Em) & static (Ec) Energies b/w them as an Oscillatory phenomena.

<u>Q</u> the freq. of Energy Oscillations b/w L&C Components under Resonance is —

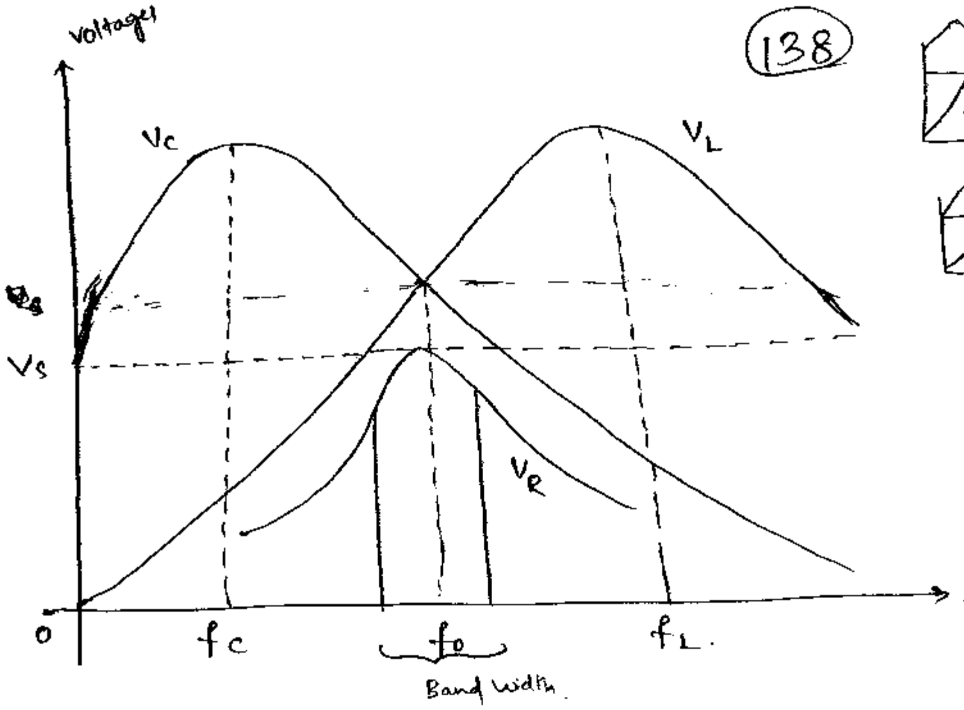
$= 2f_0$

$E_c \rightarrow$ static Energy stored

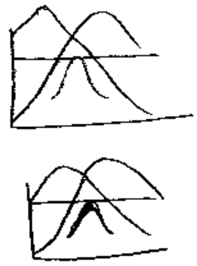


1 cycle ⇒ 2 freq. of oscillation.

Variation of Voltages across passive elements with change in supply f



(138)



Q the freq. at which max Voltage appears across Capacitor is

Derive, $\dfrac{dV_C}{d\omega} = 0$

$$f_C = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{2L^2}} \text{ Hz}$$

$$= \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R^2C}{2L}}$$

$$f_C = f_0\sqrt{1 - \frac{R^2C}{2L}} \text{ Hz.}$$

The freq. at which max voltage appears across Inductor is

derive, $\dfrac{dV_L}{d\omega} = 0$

$$f_L = \frac{1}{2\pi\sqrt{LC - \frac{R^2C^2}{2}}}$$

$$f_L = \frac{1}{2\pi\sqrt{LC}\sqrt{1 - \frac{R^2C}{2L}}}$$

$$f_L = \frac{f_0}{\sqrt{1 - \frac{R^2C}{2L}}} \text{ Hz.}$$

from ckt

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

at $\omega = \omega_0 \longrightarrow X_{net} = 0$

$$|I| = \frac{|V|}{\sqrt{R^2 + 0^2}} \Rightarrow |I| = \frac{|V|}{R}$$

$\longrightarrow$ maximum

$\Rightarrow$ so, power Transferred to entire circuit is also maximum, $P_0 = |I_0|^2 . R = \frac{V^2}{R}$ ω

at $\omega = \omega_0$

$\boxed{R}$

$$V_R = I_R . R = I_0 . R = \frac{|V|}{R} . R \longrightarrow \boxed{V_R = V}$$

$\boxed{L}$

$$V_L = +jX_L I_L = +j\omega_0 L . I_0 = +j\left[\frac{\omega_0 L}{R}\right] . V \longrightarrow \boxed{V_L = +jQ_0 V}$$

Voltage amplifications

$\boxed{C}$

$$V_C = -jX_C I_C = \frac{-j}{\omega_0 C} . I_0 = -j\left[\frac{1}{\omega_0 RC}\right] . V \longrightarrow \boxed{V_C = -jQ_0 V}$$

Note: Under Series Resonance Condition, the Net Impedence is minimum. So Current is Maximum, ~~this~~ Hence it is an acceptor ckt.

at Series Resonance freq. the Voltages across L&C are Quality factor times the Supply Voltage. Hence this ckt is Considered as Voltage amplification ckt

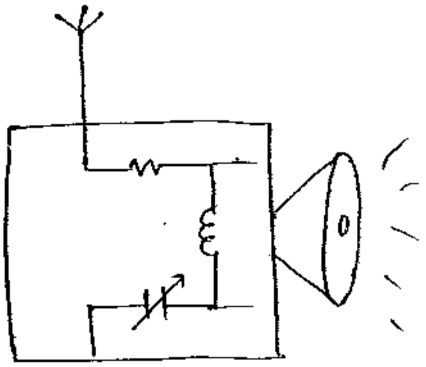
This Series Resonance phenomena Can be Used in design of Analog Communication based Receivers Using passive elements before Transistor Technology.

Ex: Old Radios

Application of Series Resonance phenomena to Communication:

Band Width (BW):

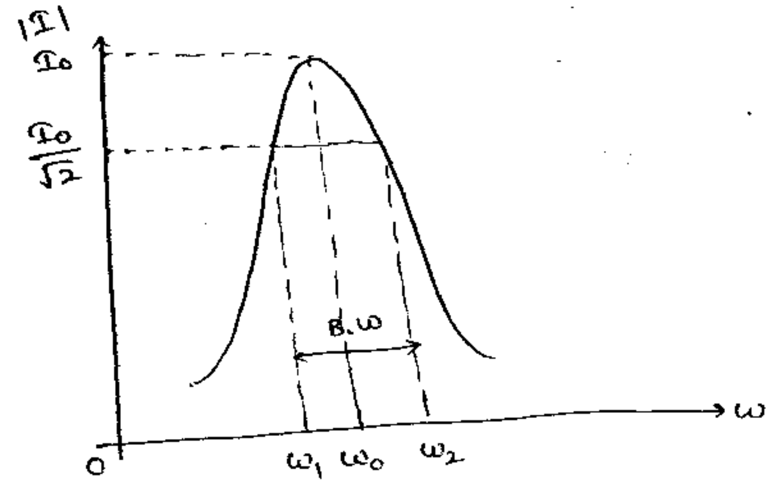
B.W represents the Range of frequencies where the power level in the signal is atleast half of max power what ckt can handle.



for Tuning Variable Cap is used ∵ if Inductor is used it Bulky to handle & lossy

at cut off frequencies:

$$P = \frac{P_0}{2} = \frac{I_0^2 R}{2} = \left[\frac{I_0}{\sqrt{2}}\right]^2 . R = [0.707\, I_0]^2 R$$



$\omega_1 \to$ lower cut off frequency

$\omega_2 \to$ Upper cut off frequency.

At cut-off frequencies

$$|I| = \frac{I_0}{\sqrt{2}}$$

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

$$\left[\omega L - \frac{1}{\omega C}\right]^2 = R^2$$

$$\omega L - \frac{1}{\omega C} = \pm R$$

Radio Bc in India

88 - 110 MHz

at $\omega = \omega_2$

$$\left[\omega_2 L - \frac{1}{\omega_2 C}\right] = \underline{\underline{+R}} \longrightarrow (A)$$

at $\omega = \omega_1$

$$\left[\omega_1 L - \frac{1}{\omega_1 C}\right] = \underline{\underline{-R}} \longrightarrow (B)$$

From Graph II concept

$\underline{\underline{X_{net}}}$ vs $\underline{\underline{\omega}}$ graph

(A)+(B)

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

$$L = \frac{1}{C\omega_1\omega_2}$$

$$\boxed{\omega_1\omega_2 = \frac{1}{LC} = \omega_0^2}$$

$$\boxed{\begin{aligned}\omega_0 &= \sqrt{\omega_1\omega_2} \\ f_0 &= \sqrt{f_1 f_2}\end{aligned}} \rightarrow \text{Geometric progression}$$

Resonance freq is geometric mean of cut off frequencies

(A)-(B) $\quad L(\omega_2-\omega_1) + \frac{1}{C}\left(\frac{\omega_2-\omega_1}{\omega_1\omega_2}\right) = 2R$

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

$$(\omega_2-\omega_1)\left[L+\frac{1}{\cancel{q}\cdot\frac{1}{Lq}}\right]=2R$$

$$[\omega_2-\omega_1][\cancel{2}L]=\cancel{2}R$$

$$\boxed{\begin{aligned} B.\omega &= \omega_2-\omega_1=\frac{R}{L} \text{ rad/sec.} \\ (f_2-f_1) &= \frac{R}{2\pi L} \text{ Hz.}\end{aligned}}$$

$$\underline{\underline{B.W \propto R}}$$

But f_0 is Independent to 'R'

Most accurate values of ω_1 & ω_2

$$(\omega_2-\omega_1)=\frac{R}{L} \longrightarrow ①$$

$$\omega_1\omega_2=\frac{1}{\cancel{\sqrt{}}LC} \longrightarrow ② \Rightarrow \omega_1\omega_2=\frac{1}{LC} \longrightarrow ②$$

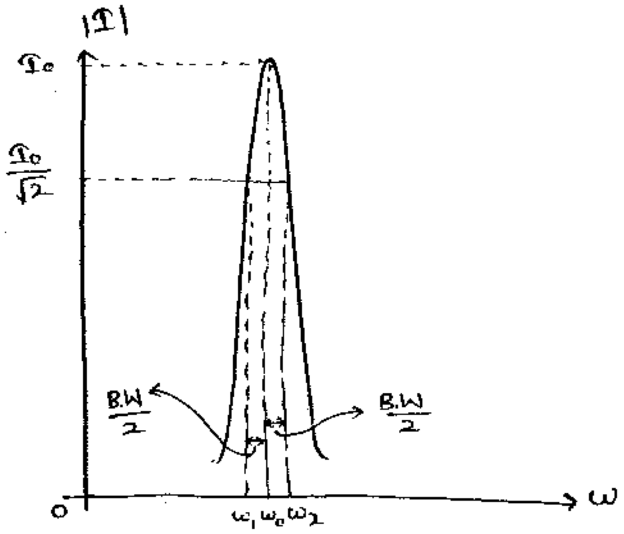
$$(\omega_2+\omega_1)=\sqrt{(\omega_2-\omega_1)^2+4\omega_1\omega_2} \longrightarrow ③$$

Solve ① & ②, we get

$$\left.\begin{aligned}\omega_1 &= \frac{-R}{2L}+\sqrt{\left(\frac{R}{2L}\right)^2+\left(\frac{1}{\sqrt{LC}}\right)^2} \\ \omega_2 &= \frac{+R}{2L}+\sqrt{\left(\frac{R}{2L}\right)^2+\left(\frac{1}{\sqrt{LC}}\right)^2}\end{aligned}\right\} \text{rad/sec}$$

* if $Q_0 \geq 10$ then the Current vs frequency graph becomes Very narrow & steep. then the following approximate mathematical Ralations Hold good.

if $Q_0 \geq 10$



$$[\omega_0-\omega_1] = \frac{B.W}{2} \longrightarrow \omega_1 = \omega_0 - \frac{BW}{2}$$

$$\boxed{\omega_1 = \omega_0 - \frac{R}{2L}}$$

$$\boxed{f_1 = f_0 - \frac{R}{4\pi L}}$$

$$\omega_0 = \frac{\omega_1+\omega_2}{2} \Rightarrow \text{Arithmetic progression}$$

$$[\omega_2-\omega_0] = \frac{B.W}{2} \longrightarrow \omega_2 = \omega_0 + \frac{B.W}{2}$$

$$\boxed{\omega_2 = \omega_0 + \frac{R}{2L}}$$

$$\boxed{f_2 = f_0 + \frac{R}{4\pi L}}$$

Q determine the Power factor of Series RLC ckt at lower & Upper Cutoff frequencies.

$$Z = R+j\left(\omega L - \frac{1}{\omega C}\right)$$

at $\omega = \omega_1 \Rightarrow Z = R - jR$ $\quad \because \omega_1 L - \frac{1}{\omega_1 C} = -R$

$$P.f = \frac{R}{Z} = \frac{R}{\sqrt{R^2+R^2}} = \frac{1}{\sqrt{2}} = 0.707 \text{ (lead)}$$

at $\omega = \omega_2 \Rightarrow Z = R+jR$ $\quad \because \omega_2 L - \frac{1}{\omega_2 C} = +R$

$$P.F = \frac{R}{Z} = \frac{R}{\sqrt{R^2+R^2}} = \frac{1}{\sqrt{2}} = 0.707 \text{ (lag)}$$

IES determine the Relation b/w Quality factor & damping Ratio in a Series RLC ckt

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Series R-L-C :

$$Q_o = \frac{1}{R}\sqrt{\frac{L}{C}}$$

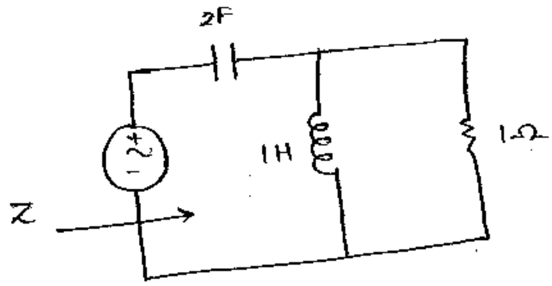
$$\xi = \frac{R}{2}\sqrt{\frac{C}{L}}$$

$$\Rightarrow \quad \xi = \frac{1}{2Q_o} \quad *$$

$$Q_o = \frac{1}{2\xi}$$

Gate

determine the Resonance freq. of ckt shown.



$$Z = \frac{-j}{2\omega} + [1 // j\omega]$$

$$= \frac{-j}{2\omega} + \frac{j\omega}{1+j\omega} \times \frac{(1-j\omega)}{(1-j\omega)}$$

$$= \frac{-j}{2\omega} + \frac{\omega^2 + j\omega}{1+\omega^2}$$

$$Z = \frac{\omega^2}{1+\omega^2} + j\left[\frac{\omega}{1+\omega^2} - \frac{1}{2\omega}\right]$$

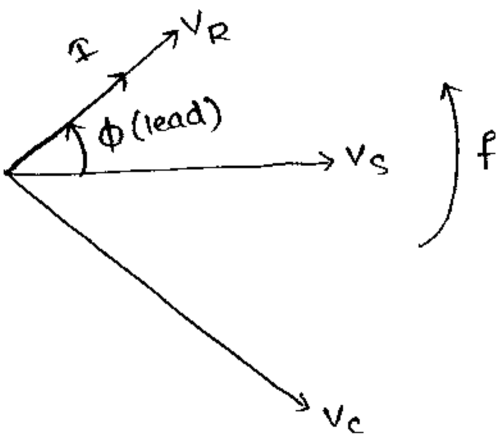
at $\omega = \omega_0 \longrightarrow X_{net} = 0$

$$\frac{\omega_0}{1+\omega_0^2} = \frac{1}{2\omega_0}$$

$$2\omega_0^2 = 1 + \omega_0^2$$

$$\omega_0^2 = 1 \Rightarrow \omega_0 = 1 \text{ rad/sec}.$$

Q The partial phasor diagram of a Series RLC ckt is shown as below. then the operating freq. of a ckt is.



(a) $f = f_0$

~~(b)~~ $f < f_0$

(c) $f > f_0$

(d) $f = 0$

In RLC Series Current Same

in R Current is in phase.

∴ ~~V_R & I~~ ~~sam~~ ∴ I leading V_S

⇒ major RC N/W

is RC $\underline{f < f_0}$

Slectivity (S):

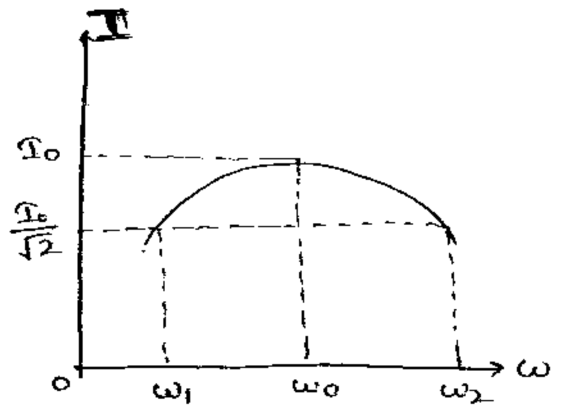
Selectivity is the ability of Communication N/w to discriminate or distinguish b/w desired & undesired frequencies. mathematically

Selectivity is given by

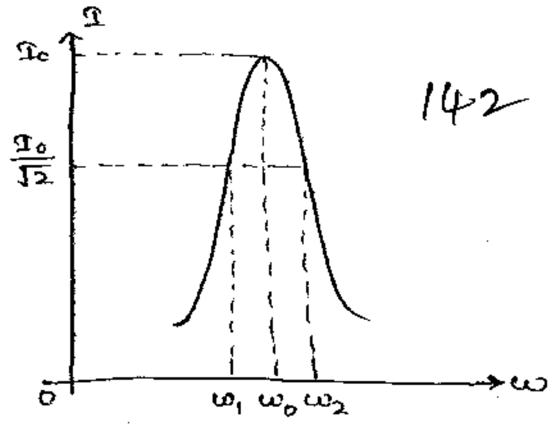
$$S = \frac{f_0}{|B.W|} = \frac{f_0}{|f_2 - f_1|} = \frac{\frac{1}{\cancel{2\pi}\sqrt{LC}}}{\frac{R}{\cancel{2\pi} L}} = \underbrace{\frac{1}{R}\sqrt{\frac{L}{C}}}_{Q_0},$$

$$\boxed{S = Q_0}$$ Selectivity is Quality factor under Resonance.

$$S \propto \frac{1}{B.\omega}$$



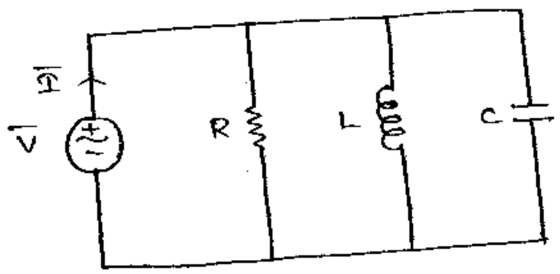
B.W ↑, S ↓, Q_0 ↓



B.W ↓, S ↑, Q_0 ↑

II] Parallel Resonance :

(a) General Circuit.



At Resonance :

$\bar{V}$ and $\bar{I}$ ⟶ in phase

$\phi = 0^\circ$ [UPF]

$Y = G$

$$Y_T = Y_R + Y_L + Y_C$$

$$= \frac{1}{R} + \frac{1}{+jX_L} + \frac{1}{-jX_C}$$

$$Y_T = \frac{1}{R} + j\left[\frac{1}{X_C} - \frac{1}{X_L}\right]$$

at $\omega = \omega_0 \longrightarrow B_{net} = 0$

$$\frac{1}{X_C} = \frac{1}{X_L} \Rightarrow \omega_0 L = \frac{1}{\omega_0 C}$$

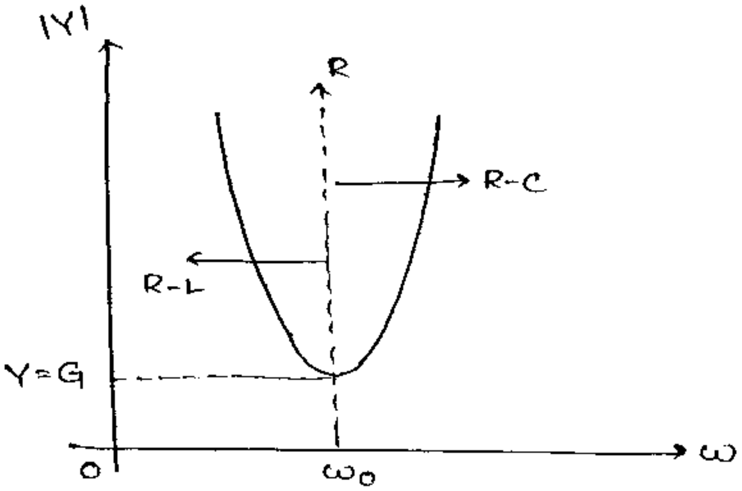
$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}} \text{ rad/sec}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}} \text{ Hz.}$$

Graph-I

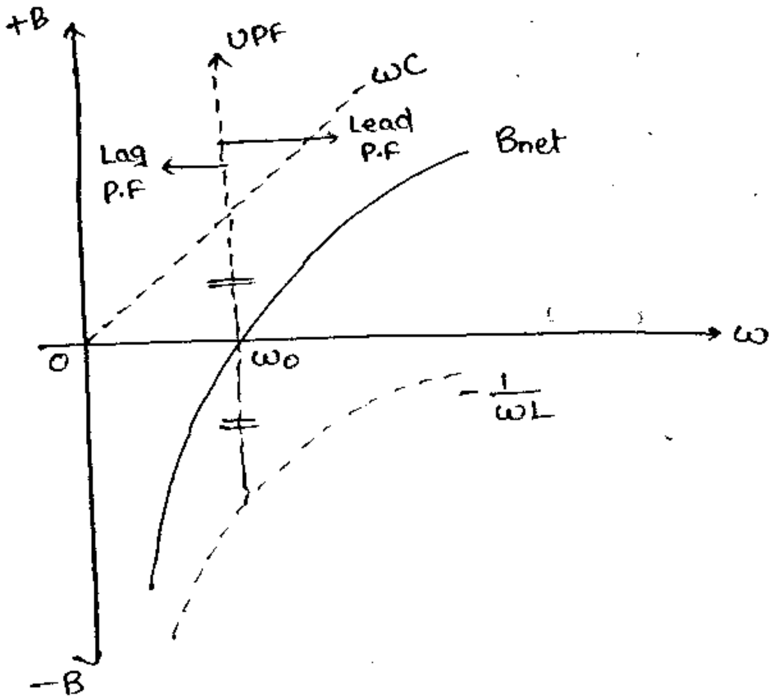
$|Y|$ vs ω

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



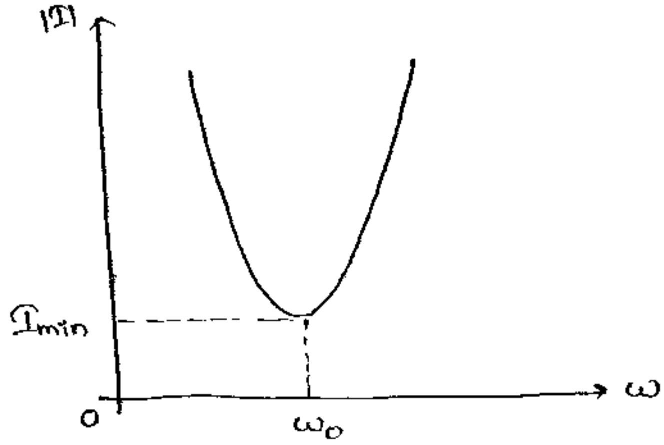
Graph-II

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



Graph III

$|I|$ vs ω



phasor diagram:

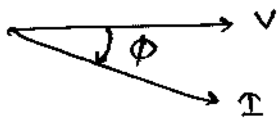
case (i) $\omega < \omega_0$

$Y = G - jB_{net}$

└→ R-L

'I' lags 'V' by $\phi < 90°$

(lagging P.F)



$\phi \longrightarrow$ -ve

case (ii) $\omega = \omega_0$

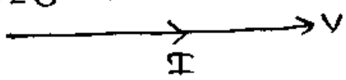
$Y = G$

└→ purely Resistive.

'I' in phase with 'V'

$\phi = 0°$ [UPF]

$\phi = 0°$



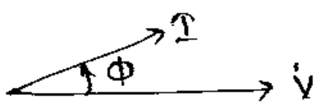
case (iii) $\omega > \omega_0$

$Y = G + jB_{net}$

└→ R-C

'I' leads 'V' by $\phi < 90°$

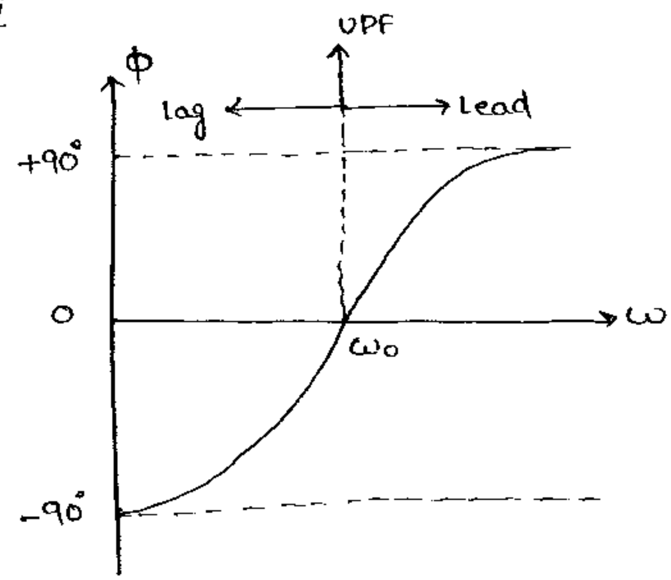
(leading P.F)



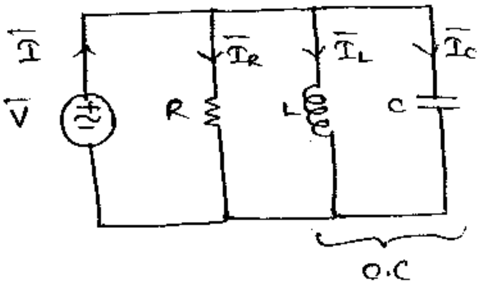
$\phi \longrightarrow$ +ve

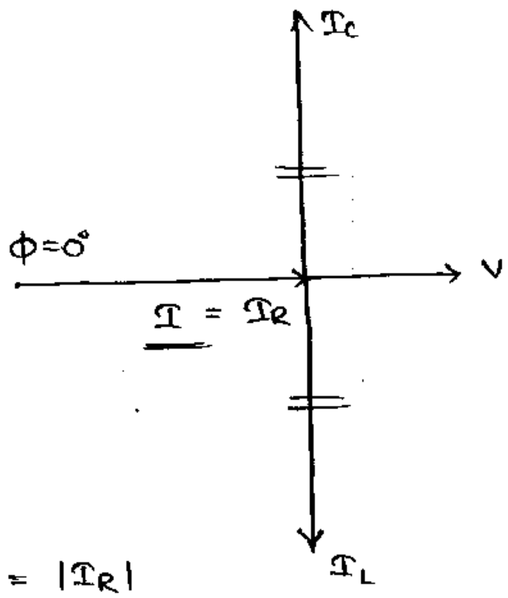
Graph - IV

ϕ vs ω



Complete phasor diagram Under Resonance :





At Resonance :

$|B_L| = |B_C|$

$|I_L| = |I_C|$

$I = |I_R|$

$\phi = 0°$

P.F = 1 (UPF)

under Resonance : $\underbrace{LC}$ acts as O.C $\because$ $B_{net} = 0$

Reactance $= X_{net} = \underline{\underline{\infty}}$
$\left(\frac{1}{B}\right)$

at parallel Resonance Condition, the pure parallel LC segment of the ckt acts as Open circuit. and Source Supplying Energy only to Resistor. However, L&C Components Work together by Exchanging the store magnetic & static Energies Between them as an Oscillatory phenomena.

$\Rightarrow$ The freq. of these Energy Oscillations B/w L&C is $\underline{2\omega_0 \text{ (or) } 2f_0}$

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From ckt

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

$$\text{at } \omega = \omega_0 \longrightarrow \underline{B_{net} = 0}$$

$$|V| = \frac{|I|}{\sqrt{\frac{1}{R^2} + 0^2}}$$

$$|V| = |I| . R$$

$\hookrightarrow$ minimum

at $\omega = \omega_0$

[R] $$I_R = \frac{V_R}{R} = \frac{V}{R} = \frac{|I|.R}{R} \longrightarrow \boxed{I_R = I}$$

[L] $$I_L = \frac{V_L}{+jX_L} = \frac{V}{+j\omega_0 L} = -j\left[\frac{R}{\omega_0 L}\right].I \longrightarrow \boxed{I_L = -jQ_0 I}$$

[C] $$I_C = \frac{V_C}{-jX_C} = \frac{V}{-j/\omega_0 C} = +j\left[\omega_0 RC\right].I \longrightarrow \boxed{I_C = +jQ_0 I}$$

Current Amplification

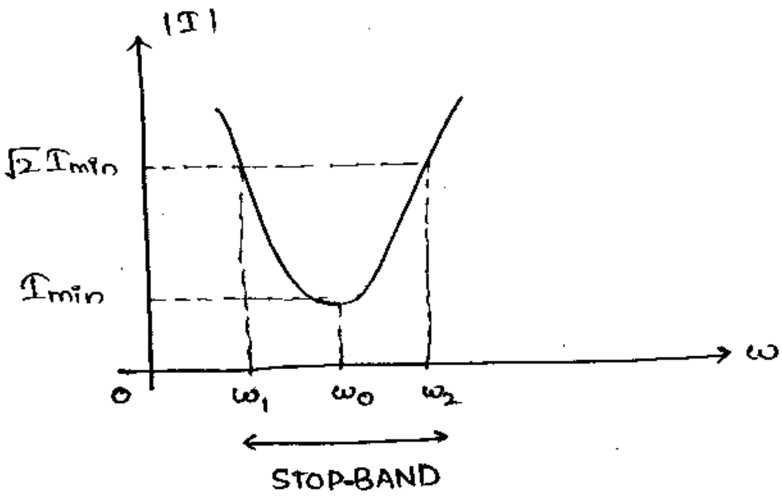
Note:

1. At parallel Resonance Condition the Net admittance is minimum. So, Current also minimum. Hence it is a Rejector circuit

2. At parallel Resonance freq. the Currents through L & C Components are Quality factor times the Supply Current. Hence this circuit is Considered as Current Amplification circuit.

Note

This parallel Resonce phenomena Can be used in design of Band stop filter or Band Rejection filter.



→ STOP BAND

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

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

STOP-BAND:

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

(b) practical parallel Resonance circuit [TANK Circuit]

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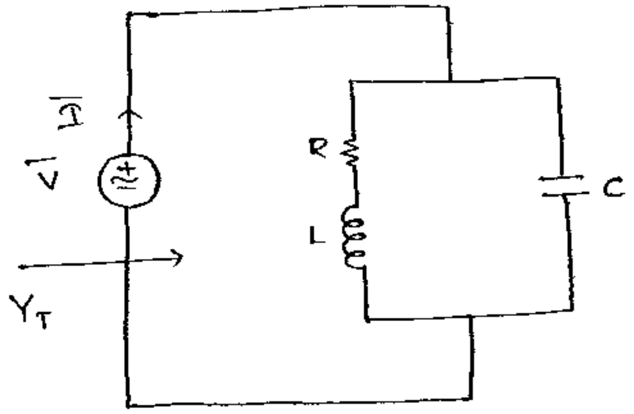


$$Y_T = Y_1 + Y_2$$

$$Y_T = \frac{1}{R+jX_L} + \frac{1}{-jX_c}$$

$$Y_T = \frac{R-jX_L}{R^2+X_L^2} + \frac{j}{X_c}$$

$$Y_T = \left[\frac{R}{R^2+X_L^2}\right] + j\left[\frac{1}{X_C} - \frac{X_L}{R^2+X_L^2}\right]$$

at $\omega = \omega_0 \longrightarrow B_{net} = 0$

$$\frac{1}{X_c} = \frac{X_L}{R^2+X_L^2}$$

$$R^2+X_L^2 = X_c X_L = \omega_0 \cdot L \cdot \frac{1}{\omega_0 C}$$

$$\boxed{R^2+X_L^2 = \frac{L}{C}} \#$$

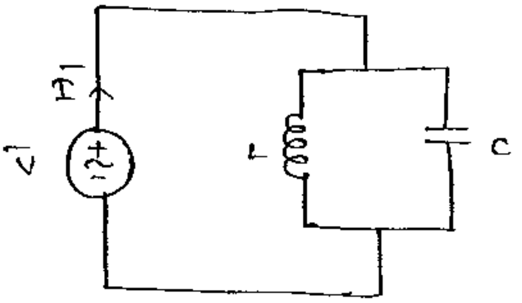
$$R^2+\omega_0^2L^2 = \frac{L}{C}$$

$$\omega_0^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

$$\boxed{\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}} \# \text{ rad/sec}$$

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \quad Hz.$$

(c) Ideal Tank $[R=0,\ Q_0=\infty]$



$$Y_T = Y_1 + Y_2$$

$$Y_T = \frac{1}{+jX_L} + \frac{1}{-jX_C}$$

$$\boxed{Y_T = +j\left[\frac{1}{X_C} - \frac{1}{X_L}\right]}$$

at $\omega = \omega_0 \longrightarrow B_{net} = 0$

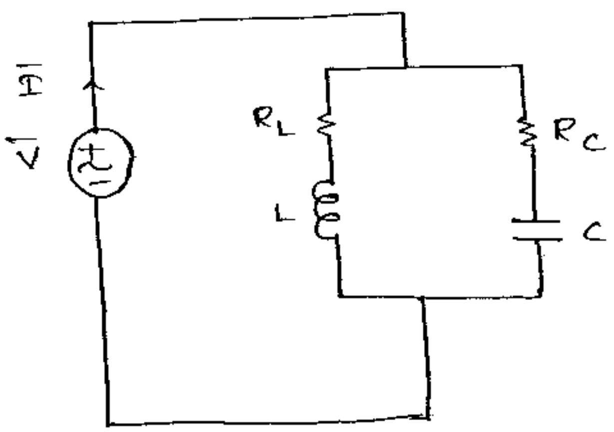
$$\frac{1}{X_C} = \frac{1}{X_L}$$

$$\omega_0 L = \frac{1}{\omega_0 C}$$

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}} \text{ rad/sec}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}} \text{ Hz.}$$

(d) most Accurate parallel Resonance circuit Including losses.



$$f_0 = \frac{1}{2\pi\sqrt{LC}}\sqrt{\frac{\left(\frac{L}{C}-R_L\right)^2}{\left(\frac{L}{C}-R_C\right)^2}} \text{ Hz}$$

Gate

For What Circuit Condition Shown above in (d) the circuit Resonates all frequencies?

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for circuit in (d)

$$Y_T = Y_1 + Y_2 = \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$= \left[\frac{R_L}{R_L^2+X_L^2} + \frac{R_C}{R_C^2+X_C^2}\right] + j\left[\frac{X_C}{R_C^2+X_C^2} - \frac{X_L}{R_L^2+X_L^2}\right]$$

$\Rightarrow$ if $R_L = R_C = \sqrt{\frac{L}{C}}$ then the net Susceptance part of total Admitance by default becomes Zero

$B_{net} = 0$

Hence, Circuit is purely Resistive $\Rightarrow Y_T = G_{net}$

So, We can say circuit Resonates at all frequencies

Dynamic Impedence ($Z_{dynamic}$):

$\Rightarrow$ it is Impedence offered by the Network to Source under Resonance Condition

$\Rightarrow$ (a) Series R-L-C : $Z_{dyn} = R\,\Omega$

(b) parallel R-L-C : $Z_{dyn} = R\,\Omega$ $\quad \left[\because Y_T = \frac{1}{R} \Rightarrow Z_{dyn} = R\right]$

(c) Tank circuit : $Z_{dyn} = \frac{L}{RC}$ $\quad \left[I_0 = \frac{V}{Z_{dyn}} = \frac{V}{L/RC} = \frac{VRC}{L}\,A\right]$

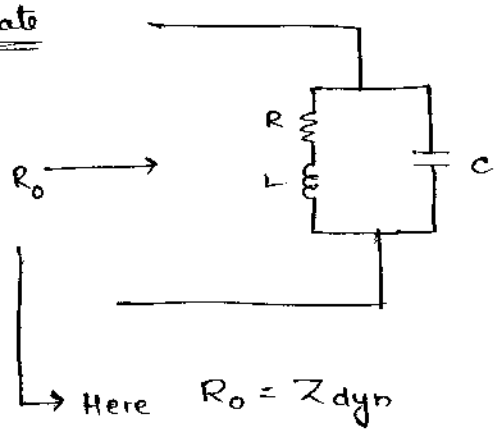
$$\because Y_T = \left[\frac{R}{R^2+X_L^2}\right] + j\left[\underbrace{\frac{1}{X_L} - \frac{X_L}{R^2+X_L^2}}_{=0}\right]$$

$$\downarrow$$

$$Z_{dyn} = \frac{R^2+X_L^2}{R} = \frac{L/C}{R} = \frac{L}{RC}\,\Omega \qquad \because R^2+X_L^2 = \frac{L}{C}.$$

(d) Ideal Tank : $Z_{dyn} = \underbrace{\infty\,\Omega}_{\to O.C}$

Gate



at Resonance

(a) $R_0 = R$

~~(b)~~ $R_0 > R$

(c) $R_0 < R$

(d) $R_0 = 0$

→ Here $R_0 = Z_{dyn}$

$$R_0 = \frac{L}{RC}$$

we know, $R^2 + X_L^2 = \frac{L}{C}$

$$R^2\left[1 + \frac{X_L^2}{R^2}\right] = \frac{L}{C}$$

$$\boxed{\begin{aligned} R^2\left[1 + \frac{\omega_0^2 L^2}{R^2}\right] &= \frac{L}{C} \\ R^2\left[1 + Q_0^2\right] &= \frac{L}{C} \end{aligned}}$$

* Q factor of RL = $\frac{\omega_0 L}{R}$

$$\frac{L}{RC} = R\left[1 + Q_0^2\right]$$

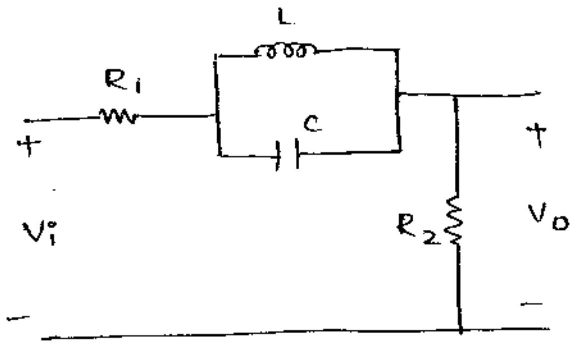
$$\Downarrow$$

$$Z_{dyn} = R\left[1 + Q_0^2\right]$$

$$R_0 = R\left[1 + Q_0^2\right]$$

$$\therefore R_0 > R$$

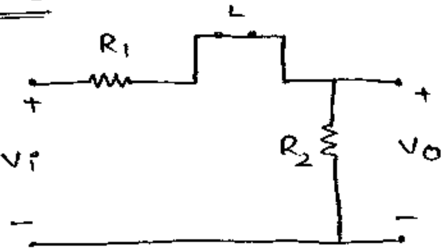
2 The N/w acts as ____ filter.



L (or) C ⇒ first order filter

L & C ⇒ second order filter

$\omega = 0$



$$V_o = V_i\left[\frac{R_2}{R_1+R_2}\right] \Rightarrow \text{Gain} = |H| = \left|\frac{V_o}{V_i}\right| = \frac{R_2}{R_1+R_2}$$

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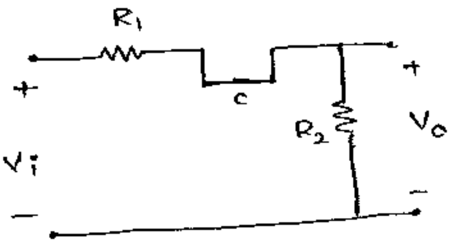
$\omega = \infty$

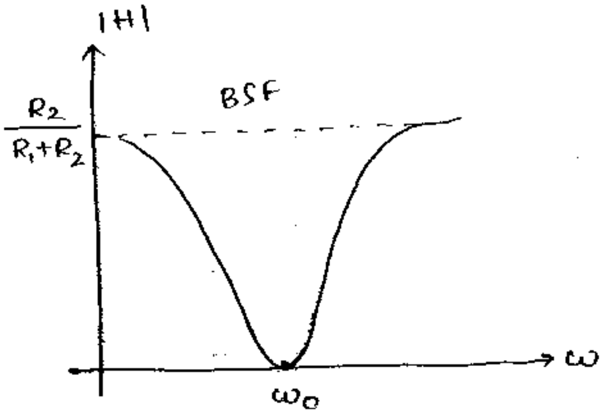


$$V_o = V_i\left[\frac{R_2}{R_1+R_2}\right] \Rightarrow |H| = \left|\frac{V_o}{V_i}\right| = \frac{R_2}{R_1+R_2}.$$

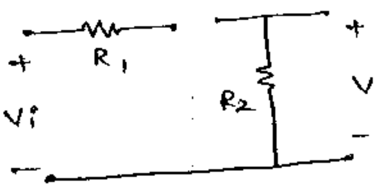
at $\omega = \omega_o$ (Resonance) $\Rightarrow \omega_o = \frac{1}{\sqrt{LC}}$

for Tank ckt

$Z_{dyn} = \infty \Rightarrow$ O.C



Band stop filter



$V_o = 0 \Rightarrow |H| = 0$

Gain $= 0$

Magnetic Circuits

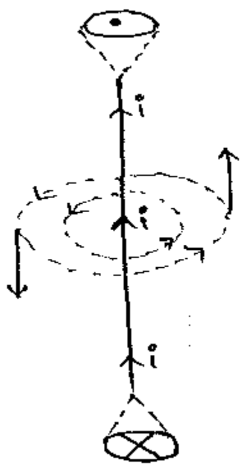
⇒ charge at rest produce only electric fld (Electrostatics)

⇒ charge in motion ie, Current electric fld, produce both elec. & mag flds.

(a) steady Currents DC produce Time Invariant mag. flds

(b) Time Varying Currents AC produce Time Varying mag. flds.

Ampere Right Hand Thumb Rule:



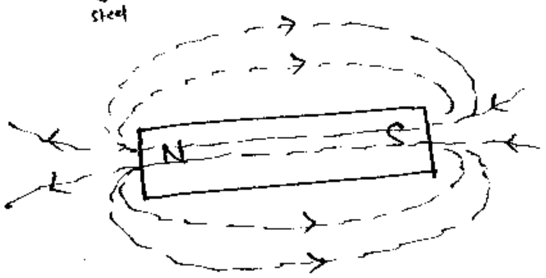
IEEE

permanent magnet:

↳ High Retentivity

↳ Hard magnetic Materials

Ex: Alnico's (steel), Se_2Co_3 (selenium cobalt)

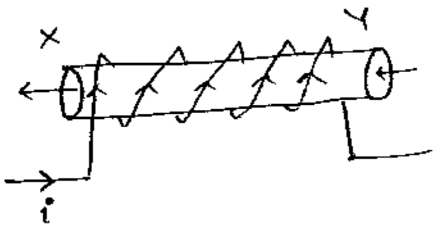


Electro magnet :

↳ Low Retentivity

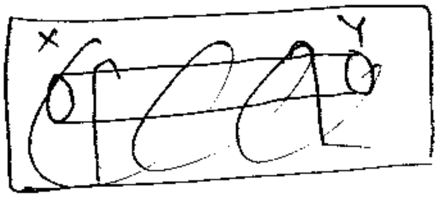
↳ Soft magnetic Materials

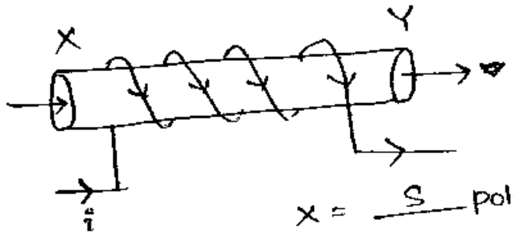
Ex: Soft Iron, SiFe, ferrites.



X = N pole

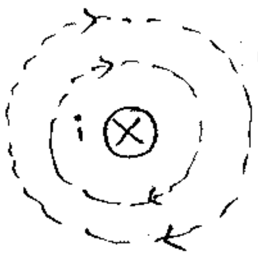
Y = S pole



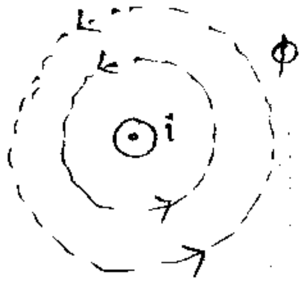


X = S pole

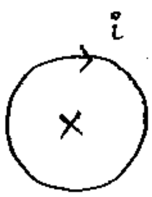
Y = N pole



ϕ = Clockoriented



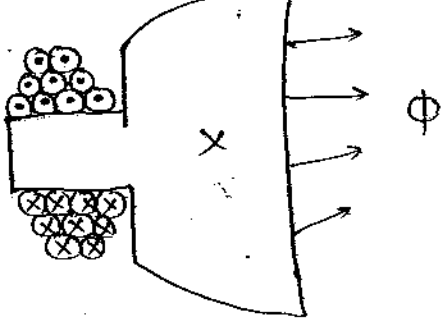
ϕ = anticlock oriented



X = South pole

Y = North pole.

Ex: pole Core → DC machine



X = North pole

Analogy between electric & magnetic circuit :

Elec. ckt

(1) Voltage / EMF

$\downarrow$

$V \longrightarrow$ (volts)

(2) Current

$\downarrow$

$I \longrightarrow$ (Amps)

(3) Resistance $= \frac{V}{i}$

$\downarrow$

$R \longrightarrow$ (ohms)

(4) $R = \frac{\rho l}{a} = \frac{l}{\sigma a}$

(5) $E = \frac{V}{d}$

$\longrightarrow$ (volt/m)

(6) $J = \frac{I}{a}$

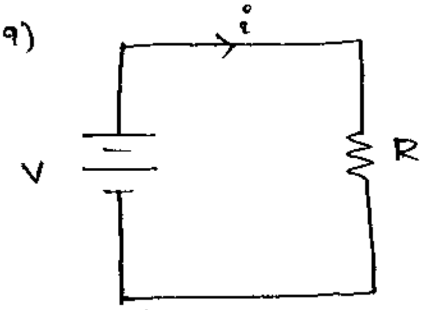
$\longrightarrow$ Amp/m^2

(7) $J = \sigma E$

(8) $R_S = R_1 + R_2$

$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$

(9)



$\hookrightarrow$ electric Conductor (cu, Al)

Mag. ckt

(1) MMF $= N.i$

$\downarrow$

MMF $\longrightarrow$ (AT)

(2) Flux

$\downarrow$

$\phi \longrightarrow$ (wb)

(3) Reluctance $= \frac{MMF}{\phi} = \frac{Ni}{\phi}$

$\downarrow$

$S \longrightarrow$ (AT/wb)

(4) $S = \frac{l}{\mu a}$

(5) $H = \frac{MMF}{l} = \frac{Ni}{l}$

$\longrightarrow$ (AT/m)

(6) $B = \frac{\phi}{a}$

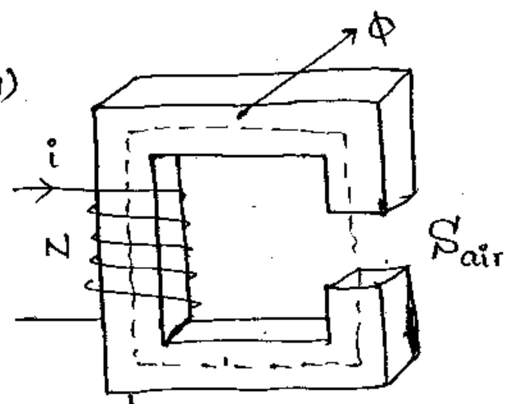
$\longrightarrow$ (wb/m^2) $\longrightarrow$ Tesla.

(7) $B = \mu H$

(8) $S_s = S_1 + S_2$

$\frac{1}{S_P} = \frac{1}{S_1} + \frac{1}{S_2}$

(9)



$\hookrightarrow$ Magnetic Conductor [Iron, SiFe]

Faraday's Law of Electromagnetic Induction:

The mathematical form of Faraday's Law is

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$$\boxed{e = -\frac{d\psi}{dt}}$$

$\psi = N\Phi$

└→ Flux linkages (wb-T)

$$\boxed{e = -N\frac{d\Phi}{dt}}$$

→ Rate of change in flux (wb/sec)

→ No. of Turns of Coil

→ -ve sign [lenz's law)

→ Induced emf in Coil (volts)

$$e = -N\left[\frac{\Phi_{final} - \Phi_{initial}}{\Delta t}\right] \text{ volts.}$$

Note:

(1) flux is a proportional function of Current

$$MMF = \Phi . S$$

$$\underset{\text{fixed}}{N}.i = \Phi . \underset{\text{fixed}}{S}$$

$$\frac{\Phi}{i} = \underbrace{\left(\frac{N}{S}\right)}_{\text{fixed}} \Rightarrow \frac{\Phi}{i} = K$$

$$\Phi = K.i$$

$$\boxed{\Phi \propto i} \Rightarrow \text{neglecting Saturation}$$

Note :

(2)

i_{dc} $\qquad\qquad$ i_{ac}

(1) Establishes flux (Electromagnetism)

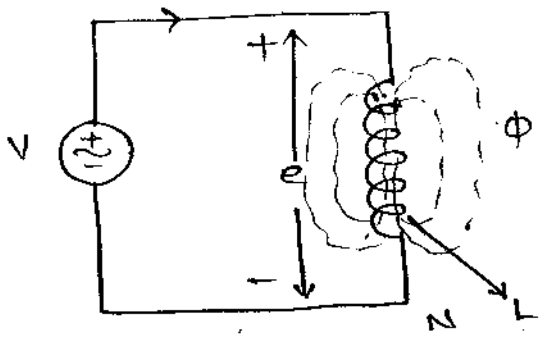
(2) Exhibits Inductive property

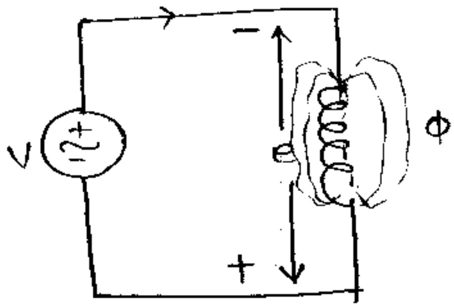
(3) Induces EMF [faraday's law]

(4) All the above.

Concept of Self Induced EMF & Self Inductance :

$i \longrightarrow$ if $\frac{di}{dt} = +ve$ $\qquad\qquad$ $i \longrightarrow$ if $\frac{di}{dt} = -ve$





$$\phi = \phi * \frac{i}{i}$$

$$\phi = \left[\frac{\phi}{i}\right] * i$$

$$\frac{d\phi}{dt} = \left[\frac{\phi}{i}\right]\frac{di}{dt} \longrightarrow (1)$$

$$e = -N\frac{d\phi}{dt} \longrightarrow (2)$$

~~e = N~~ $e = -\left[\frac{N\phi}{i}\right]\frac{di}{dt}$

$$\boxed{e = -[L]\frac{di}{dt}}$$

Self Induced emf (volts)

$$\boxed{L = \frac{N\phi}{i} = \frac{\psi}{i}}$$

self Inductance (H)

$\psi = L.i \longrightarrow \underset{\text{ohms law}}{O.L}$ (3rd form)

$$e = -L\left[\frac{i_{final} - i_{intial}}{\Delta t}\right] \text{ Volt.}$$

$MMF = \phi . S$

$N.i = \phi . S$

$N\left[\frac{N\cancel{\phi}}{L}\right] = \cancel{\phi} . S$

$$\boxed{L = \frac{N^2}{S}}$$

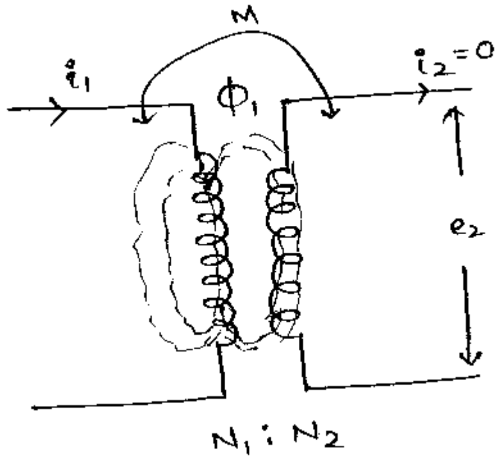
$L \propto N^2$

$S = \frac{l}{\mu a}$

$L = \frac{N^2}{l/\mu a}$

$$\boxed{L = \frac{\mu N^2 a}{l} \; H.}$$

Concept of Mutually Induced EMF & Mutual Inductance:



$$\phi_1 = \phi_{11} + \phi_{12}$$

Total Flux (ϕ_1)

ϕ_{11} → Leakage flux

ϕ_{12} → common flux (or)

$$\boxed{\phi_{12} = k\,\phi_1}$$

$$0 \leq k \leq 1$$

$$\phi_{12} = \phi_{12} * \frac{i_1}{i_1}$$

$$\phi_{12} = \left[\frac{\phi_{12}}{i_1}\right] * i_1$$

$$\frac{d\phi_{12}}{dt} = \left[\frac{\phi_{12}}{i_1}\right]\frac{di_1}{dt} \longrightarrow (1)$$

$$e_2 = -N_2 \frac{d\phi_{12}}{dt} \longrightarrow (2)$$

$$e_2 = -\left[\frac{N_2\phi_{12}}{i_1}\right]\frac{di_1}{dt}$$

$$e_2 = -\left[M_{12}\right]\frac{di_1}{dt} \text{ Volts}$$

e_2 → Mutually Induced emf

$$\boxed{M_{12} = \frac{N_2 \Phi_{12}}{i_1} = \frac{k.\Phi_1 N_2}{i_1}}$$

↓ Mutual Inductance.

|5|

also vice-versa

$$\Phi_{21} = k\Phi_2 \qquad (0 \leq k \leq 1)$$

so,

$$e_1 = -\left[\frac{N_1 \Phi_{12}}{i_2}\right]\frac{di_2}{dt}$$

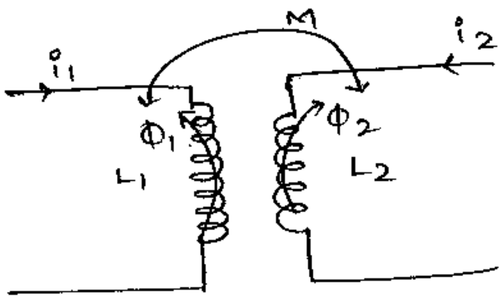
$$\boxed{e_1 = -[M_{21}] \cdot \frac{di_2}{dt} \quad \text{Volts.}}$$

$$\boxed{M_{21} = \frac{N_1 \Phi_{21}}{i_2} = \frac{k\Phi_2 N_1}{i_2} \quad H.}$$

Note:
If distance b/w coils & permeability of Medium is Constant

then,

$$\boxed{M_{12} = M_{21} = M}$$



$N_1 : N_2$

$$L_1 = \frac{N_1 \Phi_1}{i_1} \Bigg\} \text{ self Inductance of Coil-1}$$

$$L_2 = \frac{N_2 \Phi_2}{i_2} \Bigg\} \text{ self Inductance of Coil-2}$$

$$M = \frac{k\Phi_1 N_2}{i_1} = \frac{k\Phi_2 N_1}{i_2} \Bigg\} \text{ Mutual Inductance b/w coils}$$

Relationship B/w Self & Mutual Inductances :

$$[M][M] = \left[\frac{K\Phi_1 N_2}{i_1}\right]\left[\frac{K\Phi_2 N_1}{i_2}\right]$$

$$M^2 = K^2\left[\frac{N_1\Phi_1}{i_1}\right]\left[\frac{N_2\Phi_2}{i_2}\right]$$

$$M^2 = K^2[L_1][L_2]$$

$$M = K\sqrt{L_1 L_2}$$

$$\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$$

Coefficient of Coupling

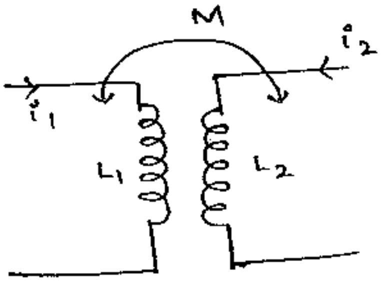
$(0 \leq K \leq 1)$

$$M \leq \sqrt{L_1 L_2}$$

Note: In Ideal Transformer $K = 1$.

then $M = \sqrt{L_1 L_2}$

Energy stored in a System of two mutually Coupled Coils :



$$E_T = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 \pm M i_1 i_2$$

$+$ → Mutually adding fluxes

$-$ → Mutually opposing fluxes

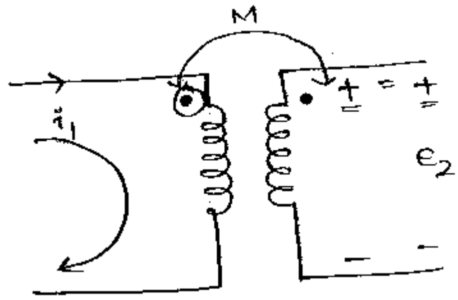
Note: Mutual Inductance is always a positive Quantity but mutually Induced emf can be +ve or −ve. determining the Correct polarity of Mutual Voltage is Not possible directly & Hence we Used "dot Convention" or "dot Notation".

St-I: If Current enters the dotted terminale of first Coil then the polarity of Mutual ~~Coil~~ Voltage will be +ve at dotted terminal of Second Coil.

St-II: if Current leaves the dotted terminal of first Coil then the polarity of Mutual Voltage is −ve at the dotted terminal of Second Coil.

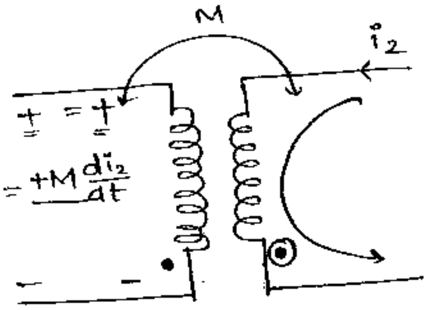
Example: determine the Correct polarity & magnitude of mutual Voltage w.r.t the given Reference Voltage for System of Coils shown below Using dot Convention.

(i)



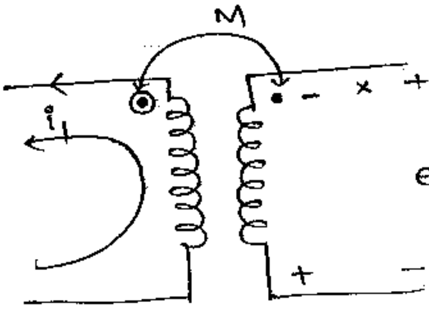
$e_2 = +M\frac{di_1}{dt}$

(ii)

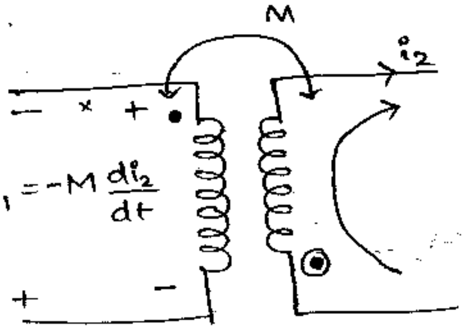


$e_1 = +M\frac{di_2}{dt}$

(iii)



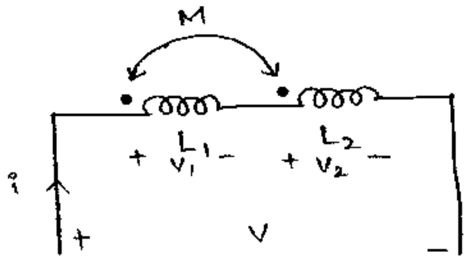
$e_2 = -M\frac{di_1}{dt}$



$e_1 = -M\frac{di_2}{dt}$

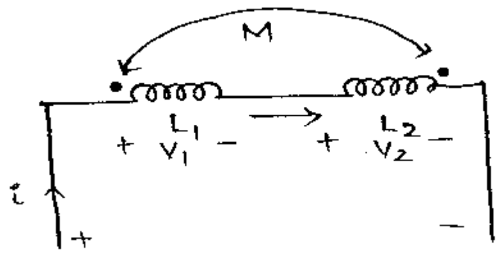
I] Coils in Series:

(a) Mutually adding:



$$v_1 = L_1\frac{di}{dt} + M\frac{di}{dt}$$
$$v_2 = L_2\frac{di}{dt} + M\frac{di}{dt}$$
$$L_T = L_1 + L_2 + 2M$$
$$V = V_1 + V_2 \Rightarrow V = (L_1 + L_2 + 2M)\frac{di}{dt}$$

(b) Mutually opposing:

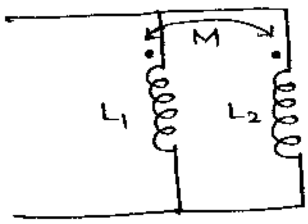


$$L_T = L_1 + L_2 - 2M$$

$$\left.\begin{aligned} V_1 &= L_1\frac{di}{dt} - M\frac{di}{dt} \\ V_2 &= L_2\frac{di}{dt} - M\frac{di}{dt} \end{aligned}\right\}$$
$$V = V_1 + V_2$$
$$V = (L_1 + L_2 - 2M)\frac{di}{dt}$$

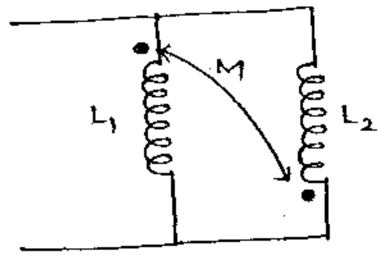
II] Coils in parallel:

(a) Mutually adding:



$$L_T = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$$

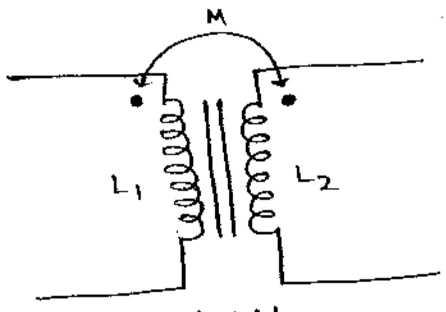
(b) Mutually opposing:



$$L_T = \frac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$$

Ideal Transformer circuit in Electrical circuits :

Ideal Transformer in Electrical ckt:



$N_1 : N_2$

$\underline{K = 1}$ ⇒ Coeff. of Coupling

Ideal Core : $\underline{\mu_r = \infty}$

⇒ $L_1 \rightarrow \infty$ H ⇒ No losses

⇒ $L_2 \rightarrow \infty$ H ⇒ No saturation

⇒ $M \rightarrow \infty$ H ⇒ ∴ Linear Transformer

⇒ $L \propto N^2$

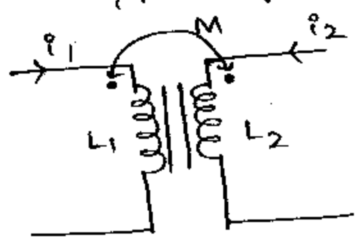
$$L_1 : L_2 : M = N_1^2 : N_2^2 : N_1 N_2$$

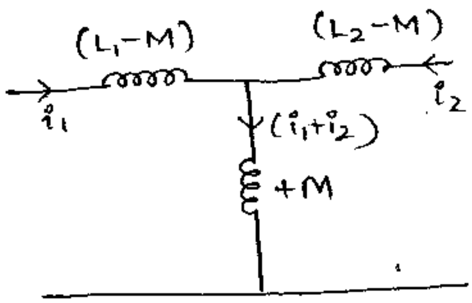
⇒ Turns Ratio

$$a = \frac{N_1}{N_2} = \sqrt{\frac{L_1}{L_2}} = \frac{L_1}{M} = \frac{M}{L_2}$$

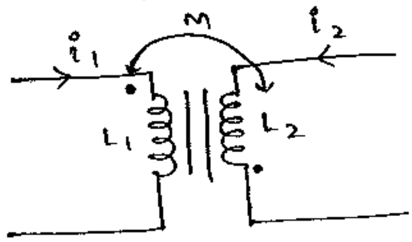
T-Equivalent representation of Ideal T/F: (circuit)

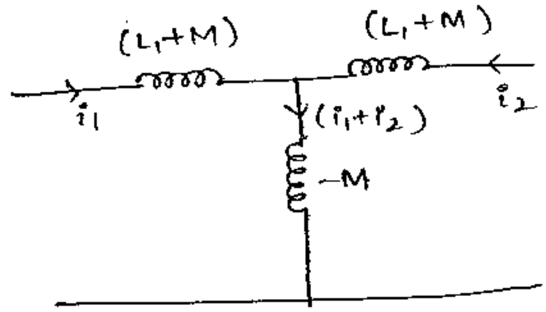
(a) Mutually aiding.



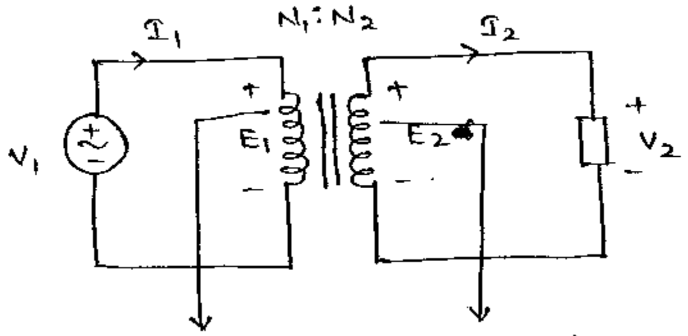


(b) Mutually opposing





Transformer [Machines]



$Z_1 = R_1 + jX_1$ $\qquad$ $Z_2 = R_2 + jX_2$

$$K = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

→ Voltage Transformation Ratio (Transformer Ratio)

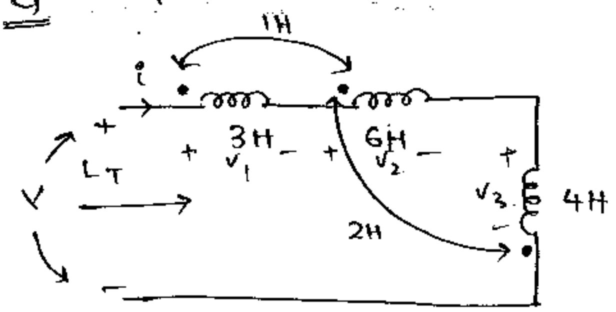
$$R_2' = \frac{R_2}{k^2} \qquad \left(\because K = \frac{N_2}{N_1}\right) \qquad R_1' = k^2 R_1$$

$$X_2' = \frac{X_2}{k^2} \qquad X_1' = k^2 X_1$$

$$Z_2' = \frac{Z_2}{k^2} \qquad Z_1' = k^2 Z_1$$

Gate

Q L_T = ______



current entering in both

$V_1 = 3 + 1 = 4$

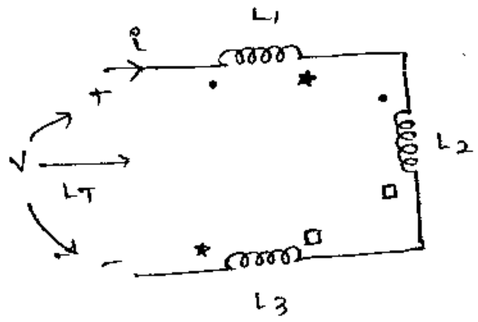
$V_2 = 6 + 1 - 2 = 5$

$V_3 = 4 - 2 = 2$

$L_T = 4 + 5 + 2$
$= 11$ H

Current entering at 6H
Current leaving at 2H } mutual will be opposing

IES $L_T =$ ______



$\bullet \longrightarrow M_{12}$

$\square \longrightarrow M_{23}$

$\star \longrightarrow M_{31}$

$V_1 = L_1 + M_{12} + M_{31}$

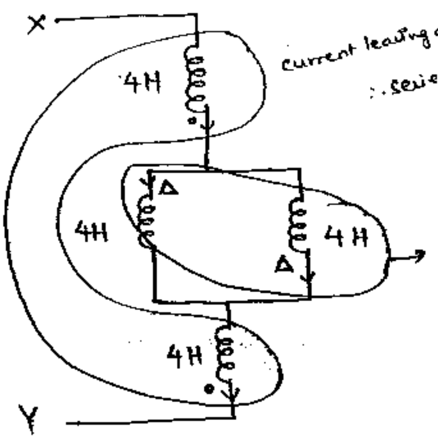
lead.

$V_2 = L_2 + M_{12} - M_{23}$

$V_3 = L_3 + M_{31} - M_{23}$

$L_T = L_1 + L_2 + L_3 + 2M_{12} - 2M_{23} + 2M_{31}$

Q $L_{XY} =$ ______



$\bullet = \Delta = 2H.$

current leaving at dot in Both
∴ series adding

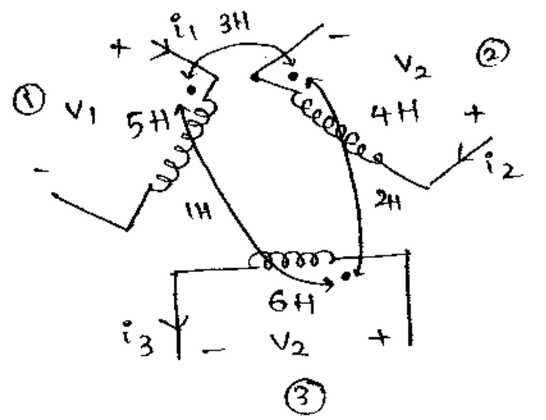
$\Rightarrow 4 + 4 + 2(2) = 12\,H$

current leaving at one dot
current entering at one dot
⇒ parallel opposing.

$\Rightarrow \dfrac{(4)(4) - 2^2}{4+4+2(2)} = 1\,H$

$L_{XY} = (12+1)H = 13H$

Es write Complete Inductance Matrix for mutually Coupled Coils Below.



⟹ open delta connection i.e. not electrically ie Conductively Connected
magnetically ie Inductively Connected

$$V_1 = 5\frac{di_1}{dt} - 3\frac{di_2}{dt} + 1\frac{di_3}{dt}$$

$$V_2 = -3\frac{di_1}{dt} + 4\frac{di_2}{dt} - 2\frac{di_3}{dt}$$

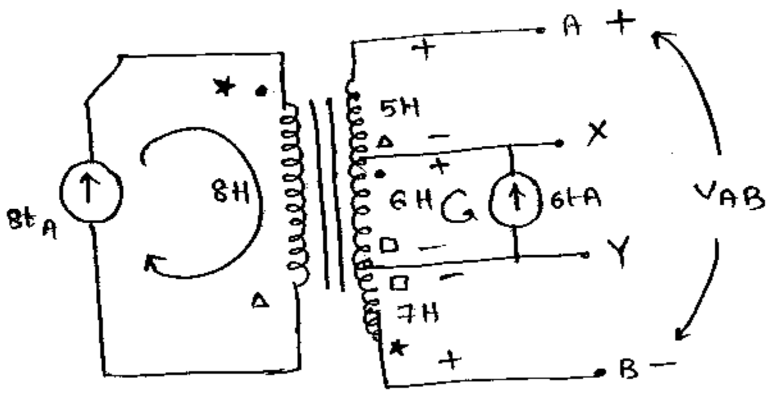
$$V_3 = +1\frac{di_1}{dt} - 2\frac{di_2}{dt} + 6\frac{di_3}{dt}$$

$$\Rightarrow \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 5 & -3 & +1 \\ -3 & 4 & -2 \\ 1 & -2 & 6 \end{bmatrix} \begin{bmatrix} \dot{i}_1 \\ \dot{i}_2 \\ \dot{i}_3 \end{bmatrix}$$

Gate

Find $V_{AB} =$ ______

$$V_{AB} = V_{AX} + V_{XY} + V_{YB}$$



● ⟶ 4H
★ ⟶ 3H
Δ ⟶ 2H
□ ⟶ 1H

$$V_{AX} = \underbrace{0\,V_{self}}_{\text{self volt} = 0 \;\because \text{no current circulating}} + V_{M(\Delta)} = +2\cdot\frac{d(8)}{dt} = +16 \text{ Volts}$$

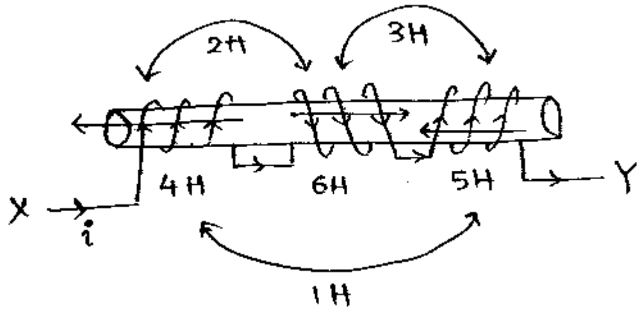
$$V_{XY} = V_s + V_{m(\bullet)} + \underbrace{0\,(V_{m(\square)})}_{\text{mutual Induce emf} = 0} = 6\frac{d(6t)}{dt} + 4\frac{d(8t)}{dt} = 68 \text{ Volts}$$

∵ Not excited to Induce flux in the other coil −

$$V_{YB} = \underbrace{0\,V_{Self}}_{\text{no current circulating}} + V_{m(\ast)} + V_{m(\square)} = -3\frac{d(8t)}{dt} - 1\cdot\frac{d(6t)}{dt} = -30V$$

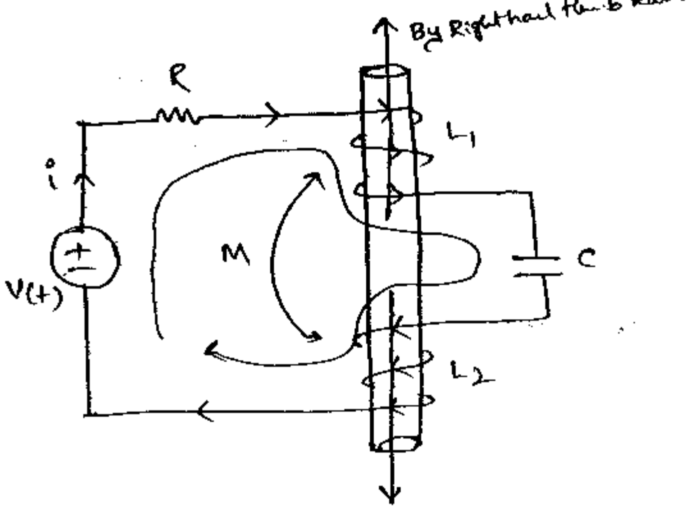
$$V_{AB} = V_{AX} + V_{XY} + V_{YB} = 16 + 68 - 30 = 54 \text{ volts}$$

$L_{XY} =$ ______



$$\left.\begin{aligned} V_1 &= 4-2+1 = 3H \\ V_2 &= 6-2-3 = 1H \\ V_3 &= 5-3+1 = 3H \end{aligned}\right\} 7H.$$

Write KVL & find 'f_0'

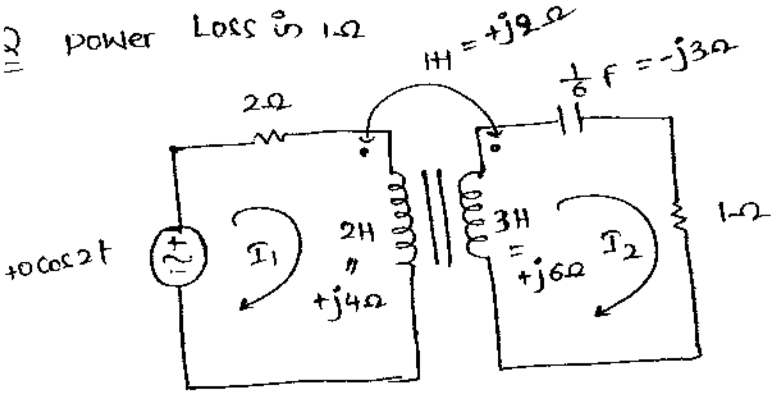


KCL

$$-V(t) + iR + (L_1 + L_2 - 2M)\frac{di}{dt} + \frac{1}{C}\int i\,dt = 0$$

$$f_0 = \frac{1}{2\pi\sqrt{(L_1+L_2-2M).C}} \text{ Hz.}$$

12 Power Loss in 1Ω



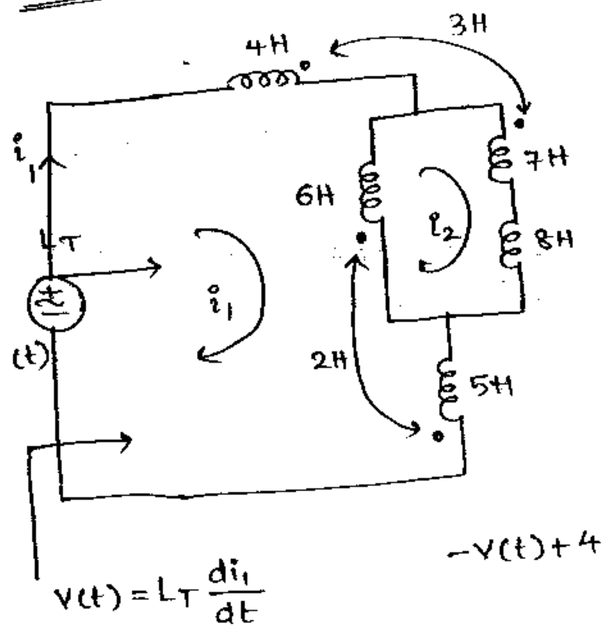
$$\Rightarrow \quad -\left[\underset{\text{rms}}{\underbrace{\frac{40}{\sqrt{2}}}}\angle 0^\circ\right] + I_1[2+j4] - 2j[I_2] = 0 \longrightarrow (1)$$

$$I_2[j6 - j3 + 1] - j2[I_1] = 0 \longrightarrow (2)$$

Solving (1) & (2) $I_2 =$ ______

$P_{1\Omega} = [I_2]^2(1) =$ ______ watts.

IES(C) What is L_{Total} = ___



$$-v(t) + 4\frac{di_1}{dt} + 6\left[\frac{di_1}{dt} - \frac{di_2}{dt}\right] + 5\frac{di_1}{dt} -$$

$$v(t) = L_T\frac{di_1}{dt}$$

$$-v(t) + 4\frac{di}{dt} + 6\left[\frac{di_1}{dt} - \frac{di_2}{dt}\right] + 5\frac{di_1}{dt} - 3\frac{di_1}{dt} + 2\frac{di_1}{dt} + 2\left[\frac{di_1}{dt} - \frac{di_2}{dt}\right] = 0$$

$$19\frac{di_1}{dt} - 11\frac{di_2}{dt} = v(t) \longrightarrow (1)$$

$$6\left[\frac{di_2}{dt} - \frac{di_1}{dt}\right] + 7\frac{di_2}{dt} + 8\frac{di_2}{dt} - 2\frac{di_1}{dt} - 3\frac{di_1}{dt} = 0$$

$$-11\frac{di_1}{dt} + 21\frac{di_2}{dt} = 0 \rightarrow 21\frac{di_2}{dt} = 11\frac{di_1}{dt} \longrightarrow (2).$$

$$V(t) = \frac{di_1}{dt}\left[19 - 11\left(\frac{11}{27}\right)\right]$$

$$V(t) = [13.23] \cdot \frac{di_1}{dt}$$

$$\downarrow$$

$$L_T = 13.23.$$

Rules to write mesh voltages.

1. Which mesh
2. Which two dots
3. aiding (+) or subtracting (−)
4. Resultant current?

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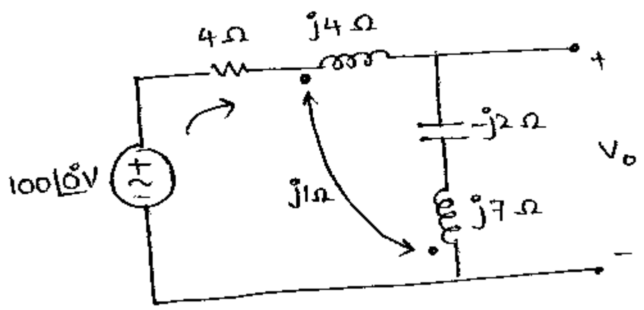
Gate $V_o =$ ______

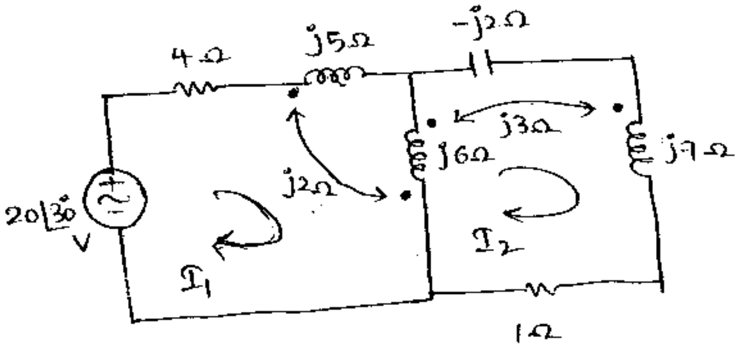


$$V_o = 100\angle 0^\circ \left[\frac{-j2 + j7 - j1}{4 + j4 - j2 + j7 - \underbrace{2(j1)}_{2m}}\right]$$

$$V_o = \frac{400\angle 90^\circ}{(4 + j7)}$$

$=$

IES Write Mesh Equation



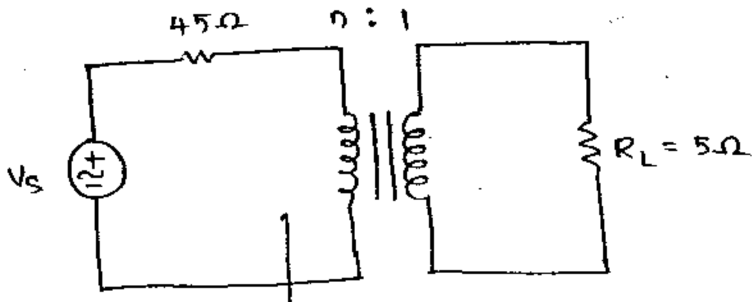
$$-[20\angle 30^\circ]+I_1[4+j5]+j6[I_1-I_2]-j2[I_1-I_2]-j2[I_1]+j3[I_2]=0$$

$$(4+j7)I_1-j1[I_2]=20\angle 30^\circ \longrightarrow (1)$$

$$j6[I_2-I_1]+I_2[-j2+j7+1]+j2[I_1]-j3[I_2]-j3[I_2-I_1]=0$$

$$-j1[I_1]+[1+j5]I_2=0 \longrightarrow (2).$$

Gate For what value of 'n', P_{max} occurs in load.



P_{max} Source R = load R in Conductively Connected ckt but not in Inductively Connected ckt

∴ make this ckt into Conductively Connected ckt by using Reflection

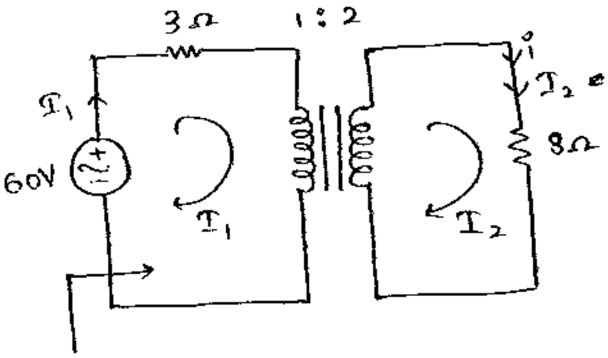
$$R_2' = \frac{R_2}{K^2} = \frac{5}{(1/n)^2} = n^2 5$$

$$\text{for } P_{max} \Rightarrow n^2 5 = 45$$

$$n^2 = 9$$

$$\underline{n = 3}$$

IES find $i =$ ______



$\therefore i = I_2$.

$$I_1 = \frac{V_s}{R_T} = \frac{V_s}{R_1 + R_2'} = \frac{60}{3 + \frac{8}{(2/1)^2}} = \frac{60}{3+2}$$

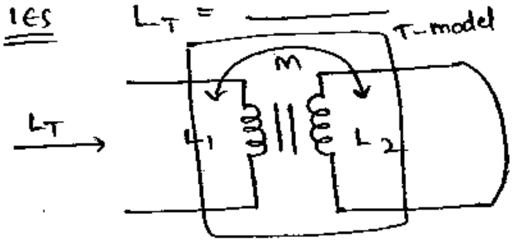
$$= \frac{60}{5}$$

$$= \underline{\underline{12A}}$$

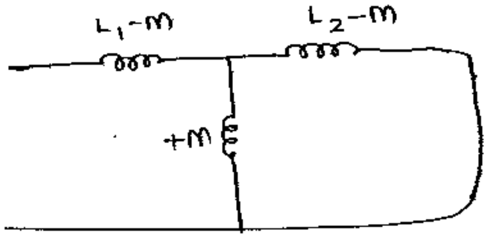
$$K = \frac{2}{1} = \frac{I_1}{I_2}$$

$$\Rightarrow \frac{2}{1} = \frac{12}{I_2} \Rightarrow I_2 = 6A \Rightarrow I_2 = \underline{\underline{i = 6A}}$$

IES $L_T =$ ______

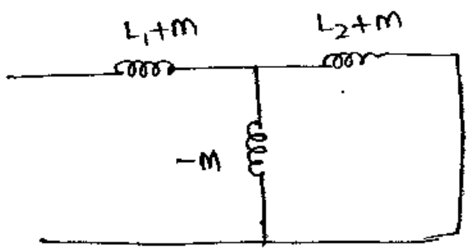


$\Rightarrow$ to find L_T convert it into T model
($\because$ it is in ckt model)



$$L_1 - m + \left[\frac{mL_2}{L_2} - \frac{m^2}{L_2}\right]$$

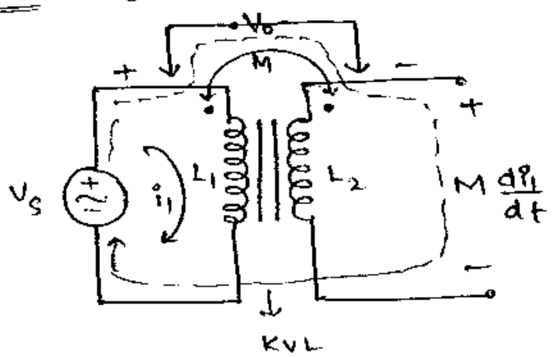
$$L_T = L_1 - \frac{m^2}{L_2}$$



$$L_1 + m + \left[\frac{-mL_2}{L_2} - \frac{m^2}{L_2}\right]$$

$$L_T = L_1 - \frac{m^2}{L_2}.$$

Gate $V_0 =$ ______



(a) $V_s\left[1-\frac{M}{L_1}\right]$

(b) $V_s\left[1-\frac{L_1}{M}\right]$

(c) $V_s\left[1-\frac{L_2}{M}\right]$

(d) $V_s\left[1-\frac{M}{L_2}\right]$

(in 1st mesh
Self Inductance Exist
mutual Ind = 0.
in 2nd mesh
self = 0 (∵ no current)
mutual Exist (due to current flowing in L_1)

$$-V_s+V_0+M\cdot\frac{di_1}{dt}=0$$

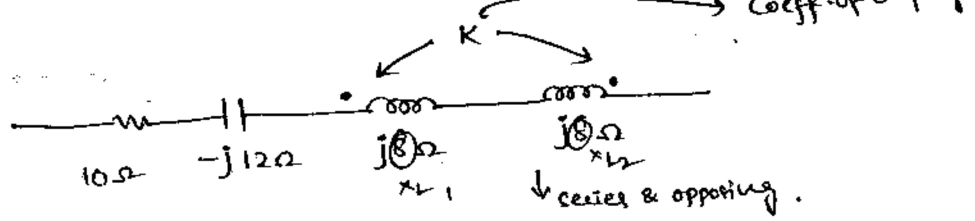
$$V_0=V_s-M\frac{di_1}{dt}$$

(ohms law in 1st Mesh) $V_s = L_1\frac{di_1}{dt}$

$$V_0=V_s-M\cdot\left[\frac{V_s}{L_1}\right]$$

$$V_0=V_s\left[1-\frac{M}{L_1}\right]$$

Gate For What Value of 'k' branch undergoes Resonance.



$$X_L=\omega L_T=\omega\left[L_1+L_2-2M\right]$$

$$=\omega L_1+\omega L_2-2\omega k\sqrt{L_1L_2}$$

$$=\omega L_1+\omega L_2-2k\sqrt{(\omega L_1)(\omega L_2)}$$

$$X_L=X_1+X_2-2k\sqrt{X_1X_2}$$

$$=8+8-2k\sqrt{8\times8}$$

$$X_L=(16-16k)$$

at resonance

$$|X_L|=|X_C|$$

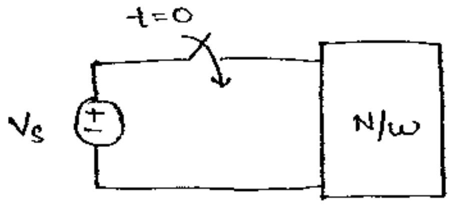
$$(16-16k)=12$$

$$16k=4$$

$$k=\frac{1}{4}=0.25.$$

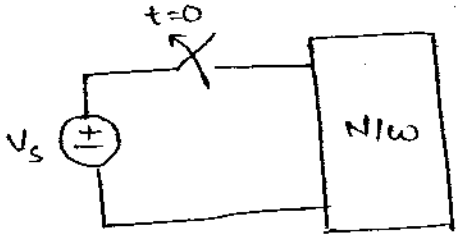
Electrical Transients

⇒ Transients are regarded as Sudden change in the state of N/w or ckt, Indicated by Switch operation or Special Input function.



⇒ Step Response

Ex: Turning-ON a motor (Excitation)



⇒ Source-free Response

Ex: Turning-OFF a motor (deenergise)

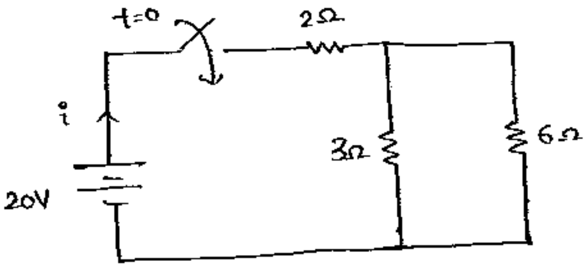
⇒ Transients Occur in Nature usual in electric ckts as Networks & Systems are not adaptable for Sudden Changes in their energy states.

⇒ allowing Sudden change in Energy in Zerotime is not possible which is Violation of law of Conservation Energy.

⇒ Note: In electric Circuits Capacitor Cannot allow Sudden change in Voltage across it & Inductor Can Never allow Sudden Change in Current through it. However Resistor has the ability to Convert & dissipate Energy in the form of Heat can allow Sudden changes.

IES(O)

What is $i(0^+)$ = ____ → Current just after the Sudden change



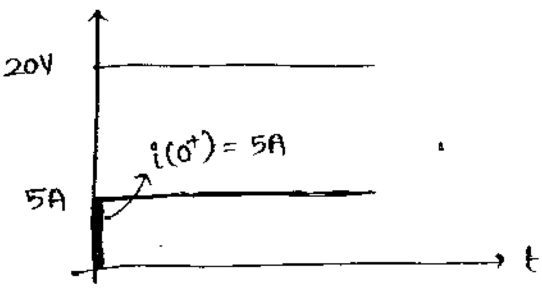
$i(0^-)$ = previous Steady state (i.e, Sw is open)

$\therefore i(0^-) = 0A$.

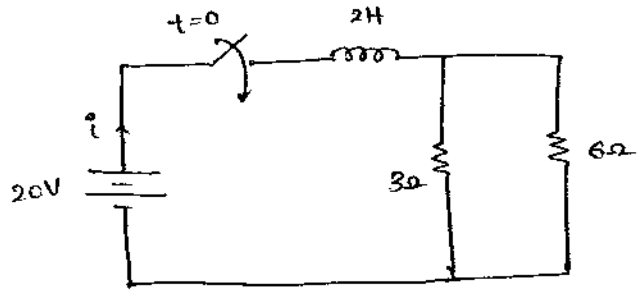
$$i(0^+) = \frac{20}{2+[3||6]} = 5A$$

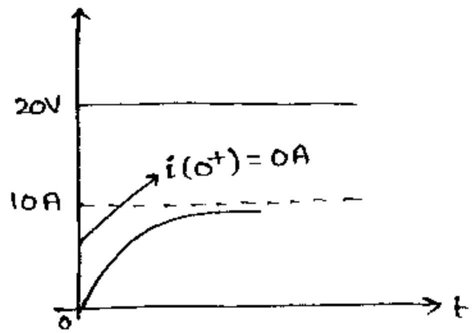
$i(\infty) = 5A$

↳ DC steady state



Q $i(0^+) =$ ___





$i(0^-) = 0A$

$i(0^+) = 0A$ [∵ Inductor is Inertia element in magnetic domain Which never allow Sudden change in Current ∴ $i(0^+) = 0A$]

$i(\infty) = \dfrac{20}{3 \| 6} = 10A$

⇒ Transient is non linear mode to linear ckt

⇒ Transients are regarded as argument b/w input Excitation & output Response

⇒ Transients are regarded as argument b/w input Excitation & output Response as Network reaches its Next Steady state from previous Steadystate.

⇒ Though Transients Occur for Very Short duration in time but their analysis is Very Critical as this state Can determine the overall Steady state Stability.

⇒ Customers of electrical N/w applications look into its steady state performance but designer is more Interested in its Transient state as this state Could determine the overall Critical Design parameter Value

State Variables :

These are the Critical parameters that should be selected in any ckt. which Can determine its Correct state at any Instant in time.

(a) In a ckt Involving Capacitor, $\because i = C\dfrac{dV}{dt}$

↓

Voltage across Capacitor is Correct State Variable

$\boxed{KCL \longrightarrow Nodal.}$ (RC)

(b) In a ckt Involving Inductor $\because V = L\frac{di}{dt}$

Current through Inductor is Correct state Variabl

$\boxed{\therefore \text{KVL} \longrightarrow \text{mesh}^{th}}$

(for RL ckts)

⇒ any ckt or N/w can have two types of Responses

I. The Responce of a ckt or N/w with Source present in it, is called as Forced Responce that leads to steady state Responce. This Response is Independent to Nature of passive elements but purely depends Upon the Type of Input. This Response Can be different for different types of Inputs.

⇒ Ex: DC & AC Steady state Responces.

⇒ The solution to this part of diff. Eqns Can be obtained by solving the perticular Integral part.

II. The Responce of a ckt or N/w without any Source in it is called as Natural Response that leads to Transients. This Response is Independent to the type of Input but purely depends upon the Nature of passive elements. This Responce is always Unique Which Can be determined from the characteristic Equation Governing the N/w.

⇒ Ex: Source free Responce of ckts.

⇒ The Solution to this part of Eqn Diff. Eqn. Can be obtained by Solving Complementary Function part.

Note: Ckts & N/ws Can Responce even without Source provided they have Some Intial Stored Energy

(a) in Capacitor : $q_0 = CV_0 \longrightarrow$ intial Voltage

Intial stored Electrostatic Energy will give rise to

(b) In a Inductor,

$$\underset{\substack{\downarrow \\ \text{internal Stored} \\ \text{Electro magnetic Energy}}}{\psi_0} = L\, i_0 \longrightarrow \text{initial Current}$$

will give rise to.

So,

[Total Response] = [Forced Response] + [Natural Response]

= [zero State Response] + [zero input Response]

= [leads to Steady state] + [leads to Transients]

[Total Solution to D.E] = [P.I] + [C.F]

Ex: $V(t) = 10 - 5 \cdot e^{-2t}$

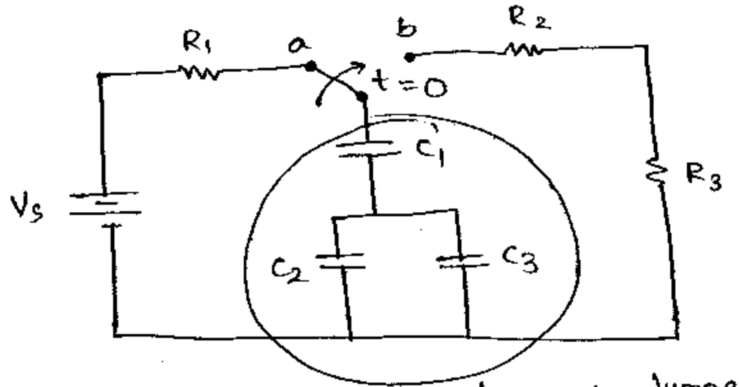
$i(t) = 2\cos 5t + \frac{5}{3} \cdot e^{-3t} - \frac{2}{3} \cdot e^{-t}$

Order of a Circuit (or) Network:

The Number of Energy storage elements available in distributed form but Interacting Represents its "order"

R-L, R-C ⟶ 1st order

R-L-C, L-R-L, C-R-C, L-C ⟶ 2nd order



↳ can be lumped

∴ 1st order only

Initial Conditions:

These are the Critical Values of Voltages across Capacitors & Current through Inductors that must be Considered from prev. Steady State so as to determine the Solution to its Next steady State, which are Specifically Indicated in time as, $t=0^-$ → instant Just before Switch Separation (S.S before Switch operation) 160

$t=0$, Exact instant of Switch operation

$t=0^+$, instant Just after Switch operation [Transient state]

$t\to\infty$, Steady state after Switch operation.

Note: $V_c(0^-) = V_c(0) = V_c(0^+)$ [∵ cap. doesn't allow sudden change in Voltage]

$i_L(0^-) = i_L(0) = i_L(0^+)$ [∵ Inductor doesn't allow sudden change in Current]

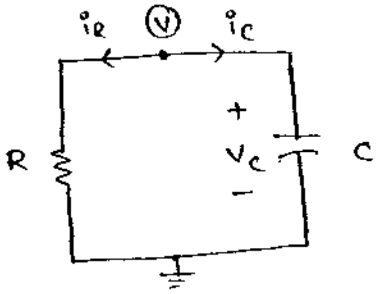
Behaviour of passive elements in Transient state:

⇒ if analysing ckts for Sudden changes in time ie, $t\to 0^+$ is Considered as Transients. then analysing the Same ckt as $S\to\infty$ Which is steady state frequency Solution will also include the Transient part in it. Hence laplace Transforms are powerfull tools to analyse ckts during Transients.

Element	D.C S.S $S=0$	A.C S.S $S=j\omega$ ↓ const	TRANSIENT State $t\to 0^+$ $S\to\infty$	$S=j\omega$ ↓ Complex Eq
R	R	R	R	$Z_R = R\,\Omega$
L	S.C	I_L lags V_L by $\phi = 90°$	O.C	$Z_L = +j\omega L = SL\,\Omega$
C	O.C	I_c leads V_c by $\phi = 90°$	S.C	$Z_C = \frac{1}{j\omega C} = \frac{1}{SC}\,\Omega$

Category-I : Source free first order Circuits.

(a) R-C Circuit.



Let $V(0) = V_0$

Nodal

$$i_C + i_R = 0$$

$$\boxed{C\frac{dV}{dt} + \frac{V}{R} = 0}$$

$$C\frac{dV}{dt} = \frac{-V}{R}$$

$$\int \frac{dV}{V} = -\int \frac{dt}{RC}$$

$$\ln[V] = \frac{-t}{RC} + \ln[A]$$

$$\ln\left[\frac{V}{A}\right] = \frac{-t}{RC}$$

$$V = A.e^{-t/RC}$$

at $t=0 \longrightarrow V = V_0$

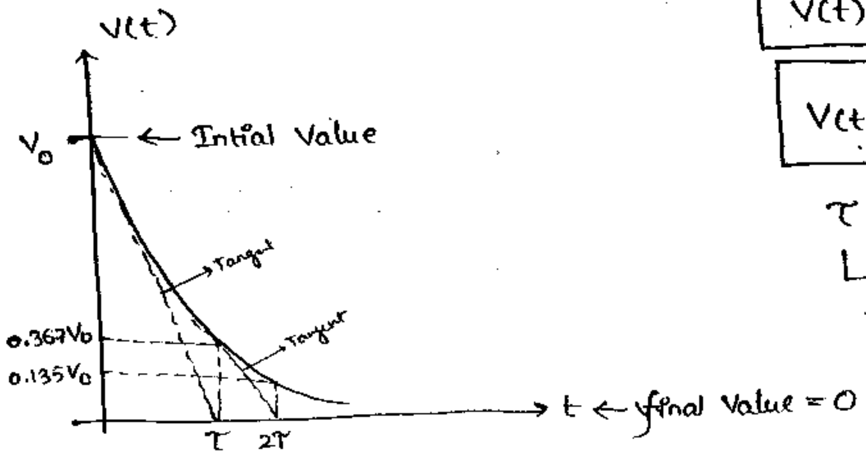
So, $A = V_0$

$$\boxed{V(t) = V_0 . e^{-t/RC} \quad t>0}$$

$$\boxed{V(t) = V_0 . e^{-t/\tau} \quad , t>0}$$

$\tau = RC$

↳ Time Constant.



$V(t=0) \longrightarrow V_0$

$$\left.\begin{aligned} V(t=\tau) &= e^{-1} V_0 = 0.367 V_0 \\ V(t=2\tau) &= e^{-2} V_0 = 0.135 V_0 \\ V(t=3\tau) &= e^{-3} V_0 = 0.049 V_0 \\ V(t=4\tau) &= e^{-4} V_0 = 0.018 V_0 \end{aligned}\right\}$$

$0 \leq t \leq 4\tau \Rightarrow$ TRANSIENT

$t \geq 5\tau \Longrightarrow$ S.S

$V(t=5\tau) = e^{-5} V_0 = 0.006 V_0$

$$i_c(t) = C\frac{d}{dt}\left\{V_0 \cdot e^{-t/\tau}\right\} = C.V_0.e^{-t/\tau} * \frac{-1}{\tau} \longrightarrow i_c(t) = \frac{-V_0}{R} e^{-t/\tau} \ \underline{A}, \ t>0$$

$$P_R(t) = \frac{[v(t)]^2}{R} = \frac{V_0^2}{R} . e^{-t/(\tau/2)} \ \underline{\underline{W}}$$

$$E_c(t) = \frac{1}{2} C [v(t)]^2 = \frac{1}{2} C V_0^2 . e^{-t/(\tau/2)} \ \underline{\underline{J}}$$

$$q(t) = CV(t) = CV_0 . e^{-t/\tau} \ \underline{\underline{C}}.$$

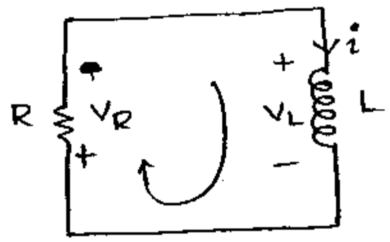
Time Constant :

it is the Time taken by Response to reach 36.7 % of its Intial value While decaying

(or)

** it is the Time taken by Response to Reach 63.2 % to its final Value

(b) R-L Circuit :



Let $i(0) = I_0$

$\underline{\underline{KVL}}$

$$V_L + V_R = 0$$

$$L\frac{di}{dt} + iR = 0$$

$$L\frac{di}{dt} = -iR$$

$$\int \frac{di}{i} = \frac{-R}{L}\int dt$$

$$\ln[i] = \frac{-R}{L}.t + \ln[A]$$

$$\ln\left[\frac{i}{A}\right] = -\frac{R}{L}.t$$

$$i = A.e^{-\frac{R}{L}t}$$

at $t=0 \longrightarrow i = I_0$

so, $A = I_0$

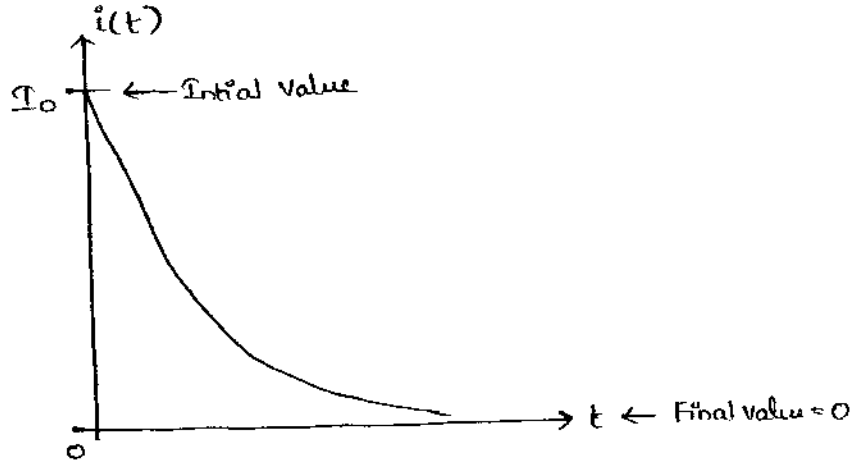
$$i(t) = I_0 e^{-t/(L/R)}, \ t>0$$

$$i(t) = I_0 \cdot e^{-t/(L/R)} \quad , \; t>0$$

$$\boxed{i(t) = I_0 \cdot e^{-t/\tau} \quad , \; t>0}$$

$$\tau = \frac{L}{R}$$

$\hookrightarrow$ Time Constant.



$$V_L(t) = L \frac{d}{dt}\left\{ I_0 \cdot e^{-t/\tau} \right\} = L I_0 \cdot e^{-t/\tau} * \frac{1}{\tau}$$

$$V_L(t) = -I_0 \cdot R \cdot e^{-t/\tau} \quad \underline{\text{Volts}}.$$

$$P_R(t) = [i(t)]^2 \cdot R = I_0^2 \cdot R \cdot e^{-t/(\tau/2)} \quad \underline{W}$$

$$E_L(t) = \frac{1}{2} L [i(t)]^2 = \frac{1}{2} L \cdot I_0^2 \cdot e^{-t/(\tau/2)} \quad \underline{J}$$

$$\psi(t) = L \cdot i(t) = L \cdot I_0 \cdot e^{-t/\tau} \quad \underline{\text{Volt-sec}}.$$

⇒ The units of 'τ' is <u>Seconds</u>

⇒ In terms of units only

$$\boxed{\tau_v = \tau_i}$$

$$\boxed{RC = \frac{L}{R}}$$

⇒ The Units of $\frac{L}{RC}$ is $\underline{\Omega}$

⇒ The Units of $\frac{L}{R^2}$ is $\underline{F}$

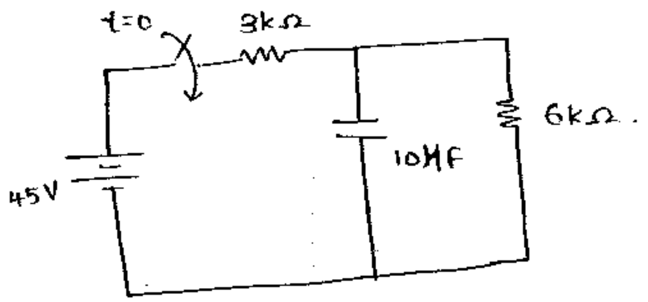
⇒ The units of R^2C is $\underline{H}$

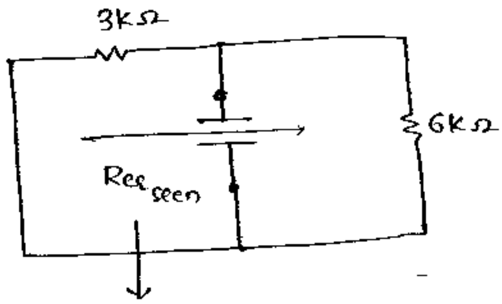
⇒ The Units of $\frac{RC}{L}$ is $\underline{\mho}$

⇒ The Units of $\sqrt{\frac{L}{C}}$ is $\underline{\Omega}$

⇒ The Units of $\frac{L}{R^2C}$ is $\underline{1}$ (unit less)

Q Determine 'τ' of circuit





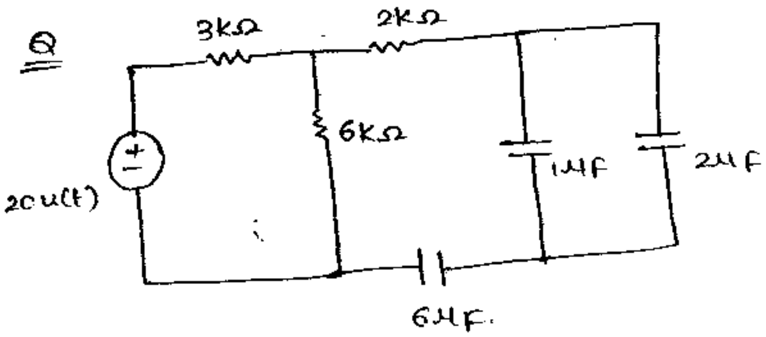
$R_{eq\,\text{seen from cap}} = 3k \| 6k$

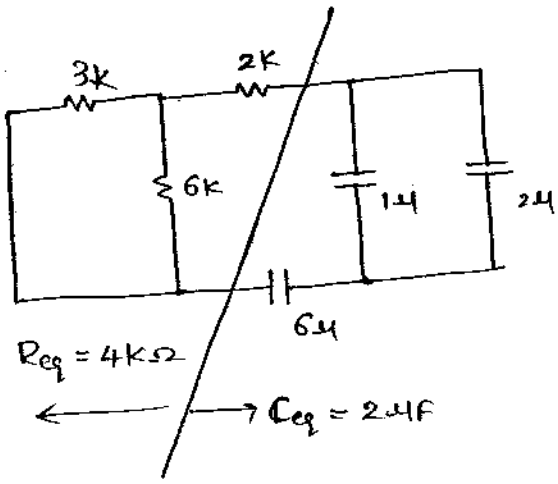
$\tau = R_{eq} \cdot C_{eq}$

$= [3k \| 6k] 10\mu$

$= 20\text{msec}$.

Q

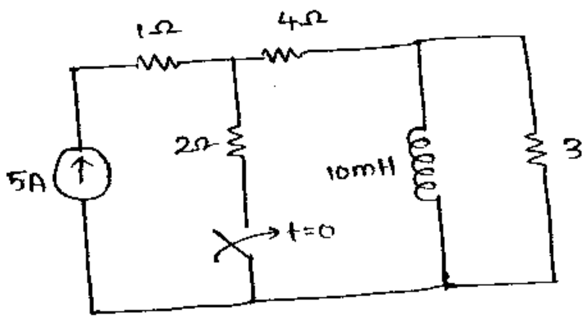


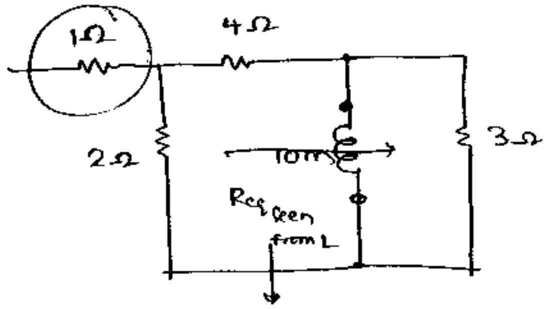


$\tau = R_{eq}C_{eq}$

$\tau = (4K)(2\mu F)$

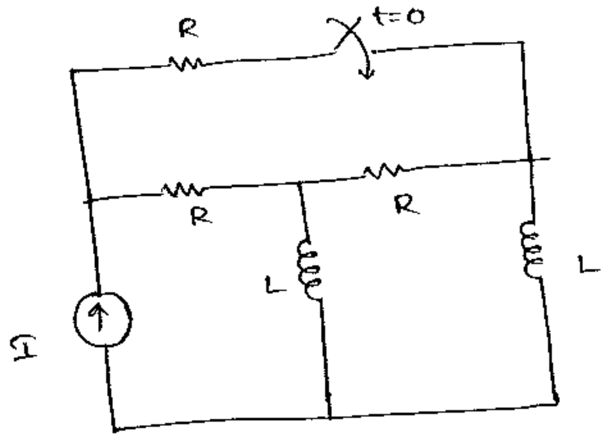
$= 8\,\text{msec}$

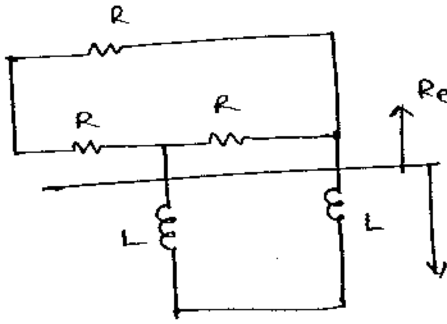




$$\tau = \frac{L_{eq}}{R_{eq}} = \frac{10m}{(6 \parallel 3)} = \frac{10m}{2} = 5\,\text{msec.}$$

$$R_{eq\,seen} = (6\Omega \parallel 3\Omega)$$



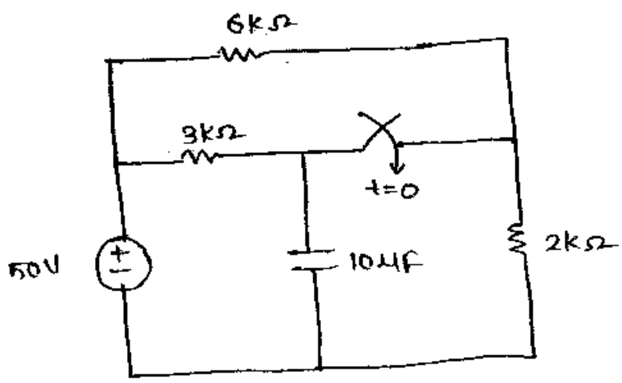


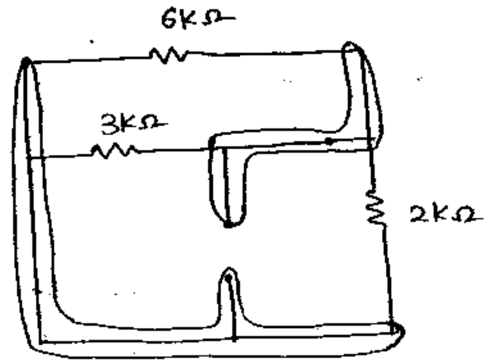
$R_{eq} = R \parallel 2R$

$L_{eq} = 2L$.

$$\tau = \frac{2L}{\frac{2}{3}R} = \frac{3L}{R}\ \text{sec.}$$

<u>Gate</u> find τ.

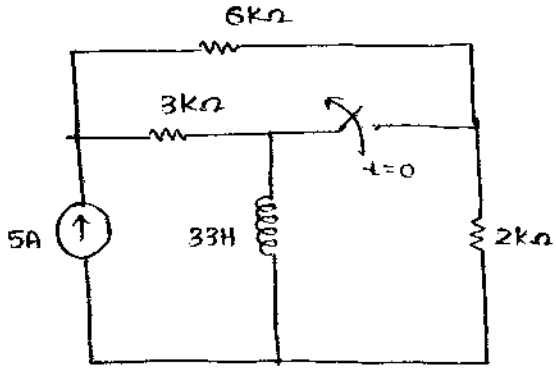


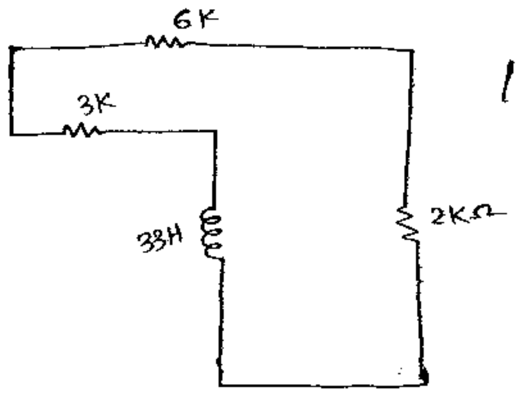


$$\tau = R_{eq} \cdot C = [6k \parallel 3k \parallel 2k] \times 10\mu$$

$$= 10\ \text{m Sec.}$$

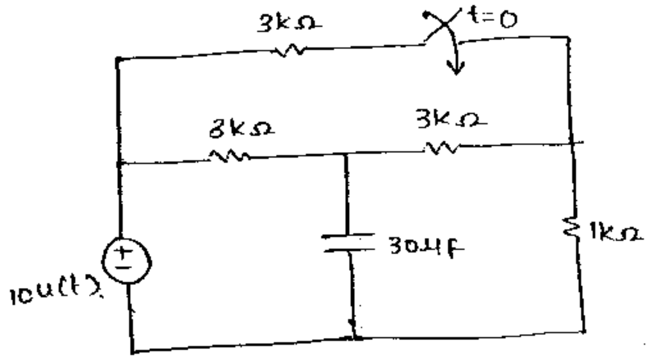
Q

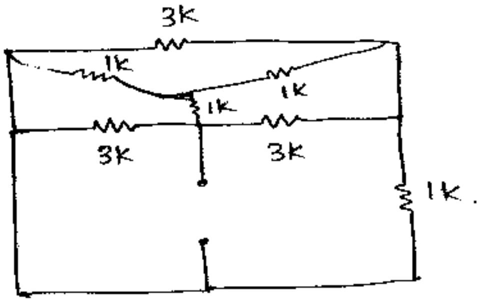




$$\tau = \frac{33}{11K} = 3\text{msec}$$

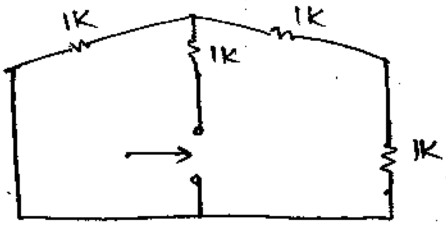
Q $\tau =$.





$$R_{eq} = 1K + [1K \,//\, 2K] = \left[1+\tfrac{2}{3}\right]K$$

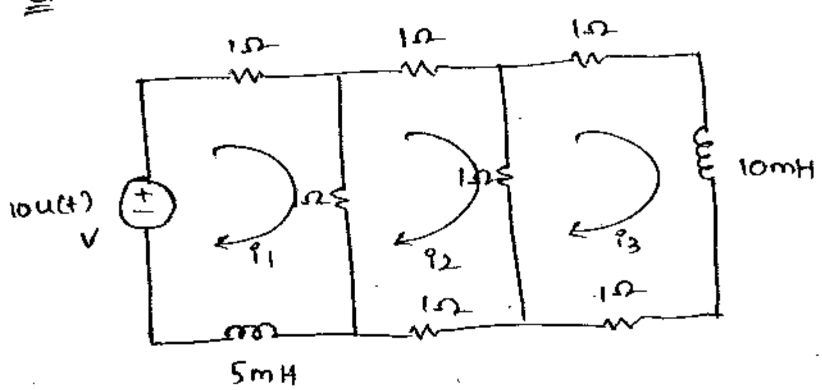
$$= \frac{5}{3}K.$$



$$\tau = R_2 C$$

$$= \frac{5}{3}K \cdot 30\mu \Rightarrow \tau = 50\,\text{msec}$$

Q $\tau =$ ________

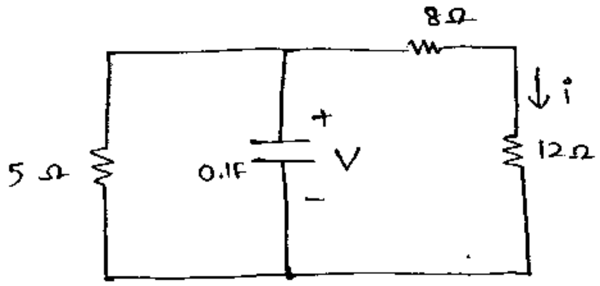


Here the two Inductors Cannot be lumped Together. So, it is a Second order circuit that to Non Canonical form.

Here, the two State Variable Inductor Currents will have different Time Constants in different Segment of ckt.

& the Solution to these diff Eqns Can be easily determined by Laplace T/F method.

if $V(0) = 120V$. determine the Complete Expression for Current $i(t)$ for all $t>0$



⇒ it is Source free Response, 1st order

⇒ State Variable (S.V) = 'V'

$$V(t) = V_0 e^{-t/\tau}$$

$$V_0 = 120V$$

$$\tau = R_2 C = [5 \| 20][0.1]$$

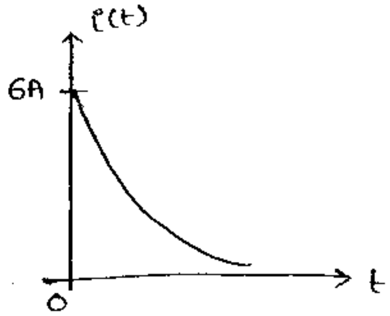
$$= 0.4\,sec.$$

$$V(t) = 120 \cdot e^{-t/0.4}$$

$$V(t) = 120 \cdot e^{-2.5t}, \quad t>0$$

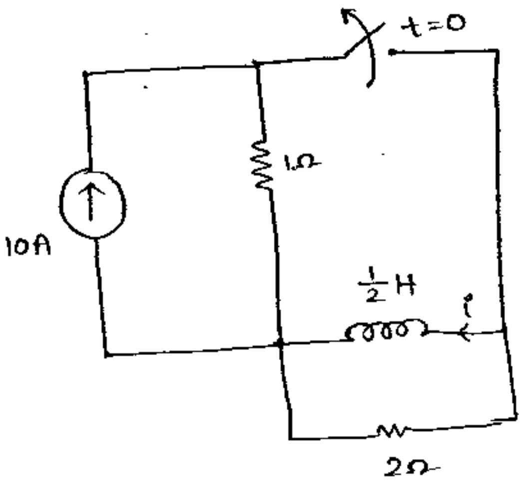
But $$i(t) = \frac{V(t)}{8+12} = \frac{120 \cdot e^{-2.5t}}{20}$$

$$i(t) = 60 \cdot e^{-2.5t}, \quad t>0$$



Gate

determine the Complete Expreccion for Current $i(t)$ for all $t>0$.

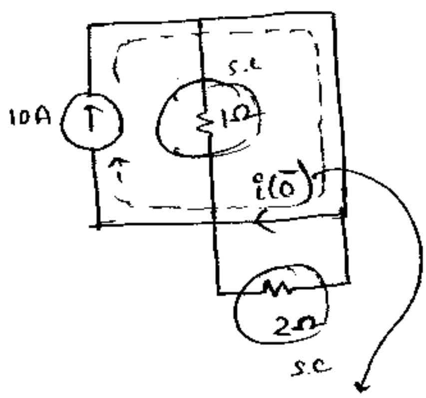


⇒ Source free, I order

⇒ S.V ⇒ "i"

Intial Condition not given

∴ find Intial Condition for D.C.S.S



$$i(0^-) \Rightarrow I_0 = 10\,A$$

$i(t) = I_0 \cdot e^{-t/\tau}$

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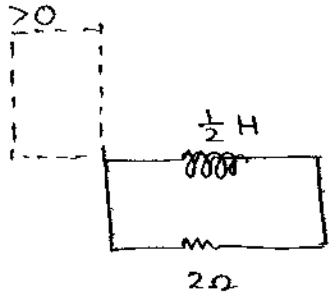
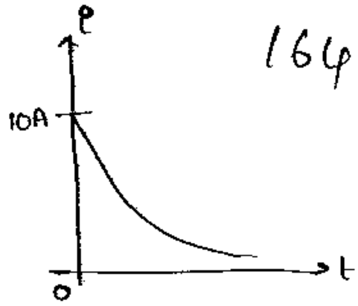
τ, $t>0$

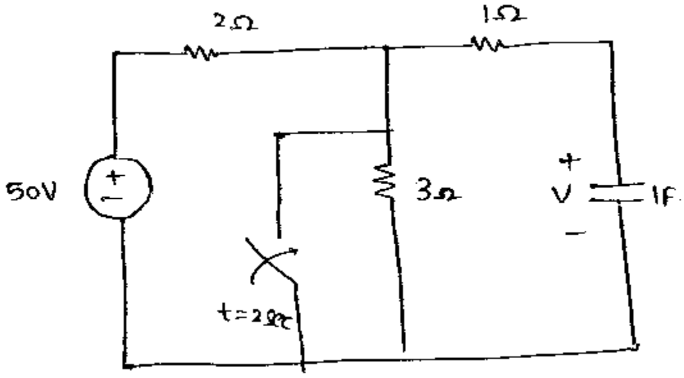


$\tau = \dfrac{\frac{1}{2}}{2} = \frac{1}{4}$ sec

$i(t) = 10\,e^{-4t}$, $t>0$



Q Determine the Energy stored by Cap. upto $t = 2.5$ Sec



⇒ When switch is closed, S.C

∴ Source is Isolating from State variable

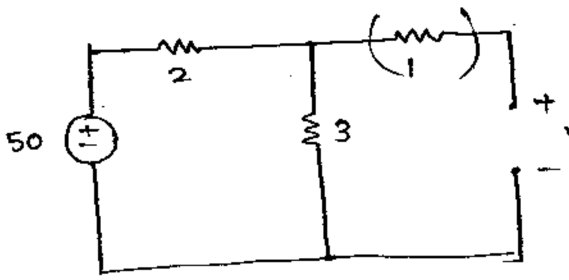
(when switch is open ⇒ it is in prev Steady state)

ie, from $0<t<2$

↳ Source free 1st order, R-C

↳ S.V ⇒ 'V'

P-I $0<t<2$ ⇒ DC.S.S



$V = 50\left[\frac{3}{5}\right]$

$= 30V.$

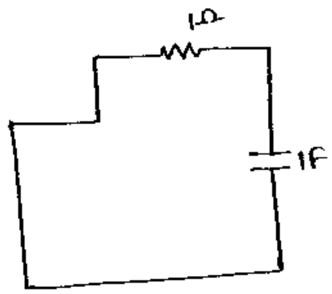
P-II $t>2$ ⇒ TRANSIENT

$V(t) = V_0 \cdot e^{-t/\tau}$

$V_0 \Rightarrow V(2^-)$, from prev. S.S.

$V(2^-) = 30V.$

$T,\ t>2$

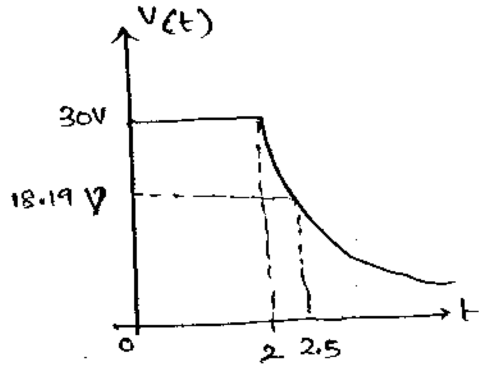


$\tau = 1$ sec.

$V(t) = 30.e^{-\frac{(t-2)}{1}}, \quad t>2$

Total Response is

$$V(t) = \begin{cases} 30V, & 0<t<2 \text{ sec} \\ 30.e^{-(t-2)} V, & t>2 \text{ sec.} \end{cases}$$



E_c (upto $t = 2.5$ sec) $= E_c$ (at $t = 2.5$ sec)

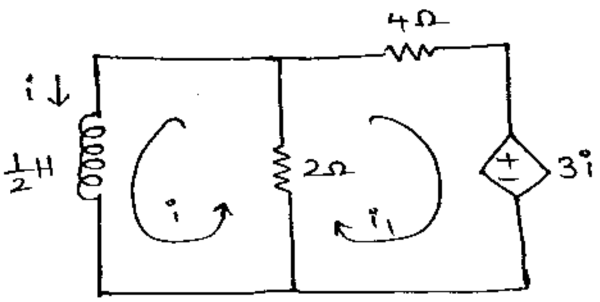
$V_c(t=2.5) = 30.e^{-1/2}$

$= 18.19$ V

$E_c = \frac{1}{2}(1)(18.19)^2$

$= 165.5$ J

Q if $i(0) = 12A$. determine the Complete Expression for all $t>0$ for current $i(t)$



⇒ Source free, Ist order

⇒ S.V = i

Method-I, Diff Eqn.

$$\frac{1}{2}\frac{di}{dt} + 2[i+i_1] = 0 \longrightarrow (1)$$

$$4i_1 + 3i + 2[i+i_1] = 0$$

$$5i = -6i_1 \longrightarrow (2)$$

$$\frac{1}{2}\frac{di}{dt} + 2i + 2\left[\frac{-5}{6}\right]i = 0$$

$$\frac{1}{2}\frac{di}{dt} + \frac{i}{3} = 0$$

$$\frac{di}{dt} = \frac{-2}{3}i$$

$$\int \frac{di}{i} = \frac{-2}{3}\int dt$$

$$\ln[i] = \frac{-2}{3}.t + \ln[A]$$

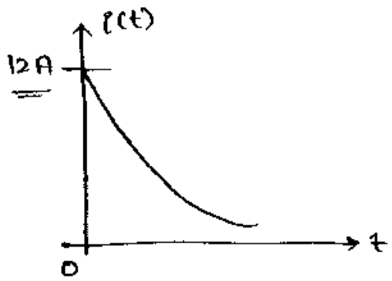
$$\ln\left[\frac{i}{A}\right] = \frac{-2}{3}t$$

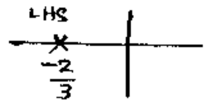
$$i = A.e^{-\frac{2}{3}t}$$

at $t=0 \longrightarrow i=12$

So, $A=12$

$i(t) = 12.e^{-\frac{2}{3}t}, t>0$ $\xrightarrow{L.T}$ $I(s) = \dfrac{12}{(s+3)}$





$\therefore$ Stable

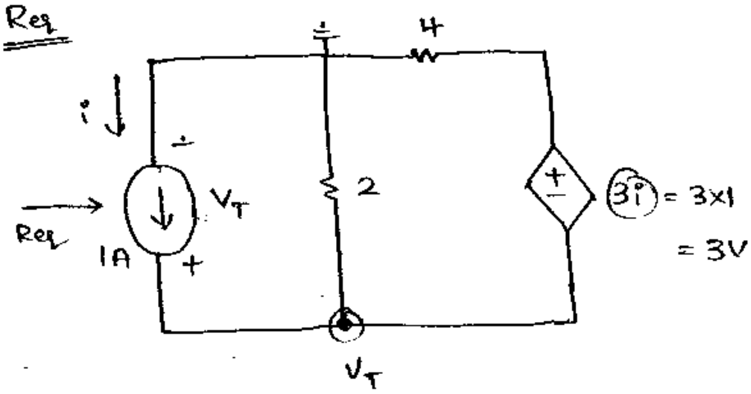
Method - II

$i(t) = I_0.e^{-t/\tau}$

$I_0 = 12\,A$

$\tau = \dfrac{L}{R_{eq}}.$

Req



Nodal

$$-1 + \frac{V_T}{2} + \frac{(V_T+3)}{4} = 0$$

$$-4 + 2V_T + V_T + 3 = 0$$

$$3V_T = 1$$

$$V_T = \frac{1}{3}\,V$$

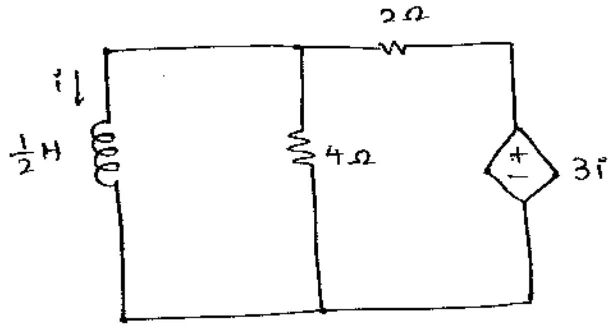
$$R_{eq} = \frac{V_T}{1A} = \frac{1/3\,V}{1A} = \frac{1}{3}\,\Omega$$

$$\tau = \frac{L}{R_{eq}} = \frac{1/2}{1/3} = \frac{3}{2}\text{ Sec.}$$

$$\therefore i(t) = 12.e^{-2/3\,t}, \; t>0$$

Q In the above problem, determine the Complete Expression for Current i, if the Values of Resistors are Interchanged.

Req. +ve feed back

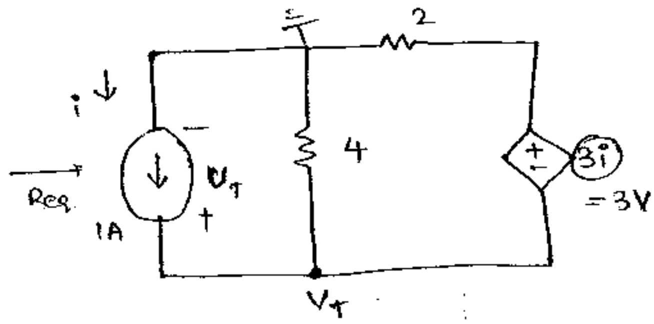


Method -2

$i(t) = I_0 \cdot e^{-t/\tau}$

$I_0 = 12\,A$

$\tau = \frac{L}{R_{eq}}$



Nodal :

$$-1 + \frac{V_T}{4} + \frac{(V_T+3)}{2} = 0$$

$$-4 + V_T + 2V_T + 6 = 0$$

$$3V_T = -2$$

$$V_T = \frac{-2}{3}\,V$$

$$R_{eq} = \frac{V_T}{1} = \frac{-2}{3}\,V.$$

– Ve Resistance

~~Req~~ ~~rate~~ Regenerative +ve feedback N/w

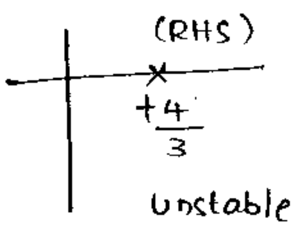
makes System Unstable

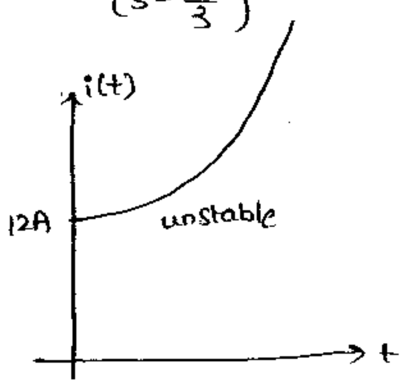
$$\therefore \tau = \frac{L}{R_{eq}} = \frac{1/2}{-2/3} = \frac{-3}{4}$$

$$i(t) = 12 \cdot e^{+\frac{4}{3}t}, \quad t > 0$$

$\downarrow$

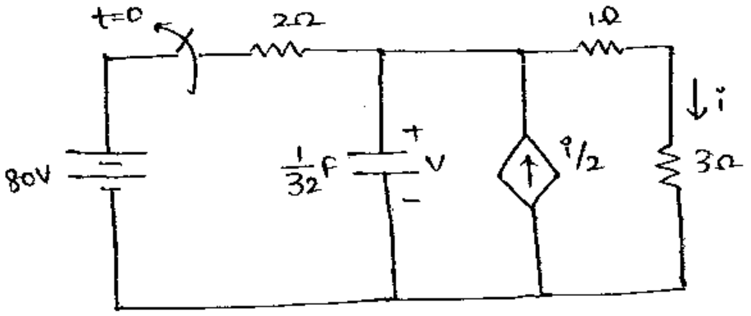
$$I(s) = \frac{12}{\left(s - \frac{4}{3}\right)}$$





IES

Determine the Complete Expression for Current $i(t)$, for all $t>0$.



$\Rightarrow$ Source Free, Ist order

$\Rightarrow$ S.V $\rightarrow$ 'V_c'

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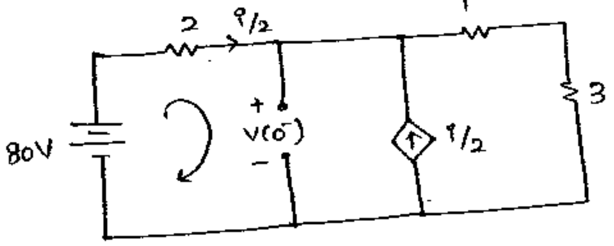
Direct Method : $V(t) = V_0 . e^{-t/\tau}$

$t = 0^-$, (DC S.S)

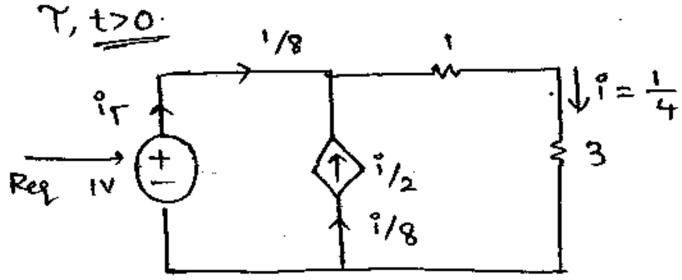


$-80V + \frac{i}{2}(2) + 4i = 0 \Rightarrow i = 16A.$

$-80 + \frac{i}{2}(2) + V(0^-) = 0 \Rightarrow V(0^-) = 80 - i$

$= 80 - 16 = 64V.$

τ, $t>0$.



$\downarrow i = \frac{1}{4} \quad \left(= \frac{1V}{1+3}\right)$

$$\left.\begin{array}{l} i_T = \frac{1}{8} \\ R_2 = \frac{1V}{i_T} = \frac{1}{1/8} = 8\Omega \end{array}\right\} \quad \tau = R_{eq}.C = 8 \times \left[\frac{1}{32}\right] = \frac{1}{4} \text{ Sec.}$$

$V(t) = 64. e^{-4t}, \quad t>0.$

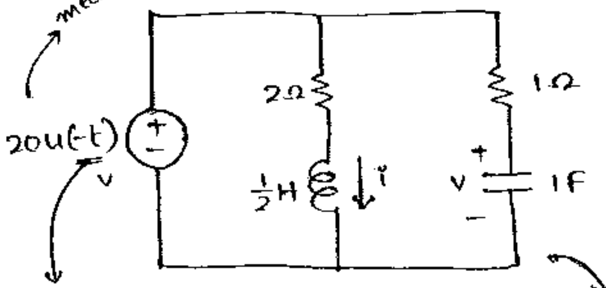
$i(t) = \frac{V(t)}{R} = \frac{V(t)}{1+3} = \frac{64. e^{-4t}}{4}$

$i(t) = 16. e^{-4t}, \quad t>0$

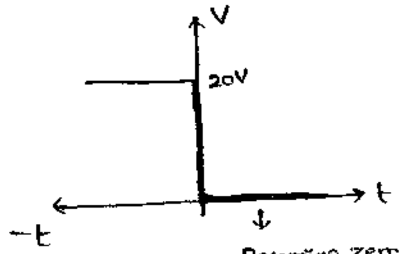
Q find (a) Ratio τ_v to τ_i $\left(\frac{\tau_v}{\tau_i}\right)$

(b) Complete Expression for $v(t), i(t)$ for all $t>0$,

means 20 becoming '0' at $t=0$

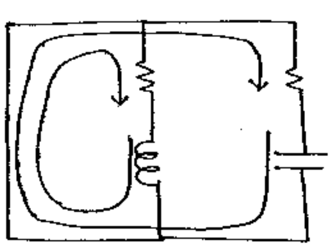


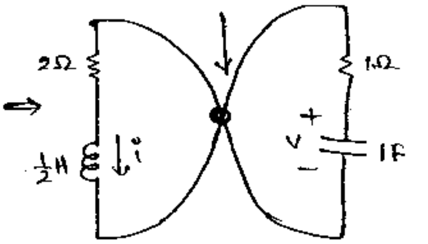
represent



Becoming zero
∴ Source free

t>0





Here Short circuit not allowing Interaction b/w L & C

$\underbrace{\hspace{3em}}$ L&C are not Interacting with each other
∴ it is not a 2nd order
⇓
it become two Independent first orders.

$\tau_i = \frac{1/2}{2} = \frac{1}{4}$ sec (very less)

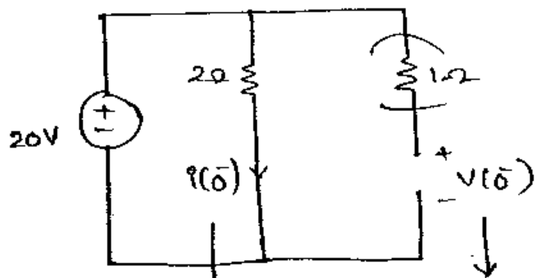
$\tau_v = 1(1) = 1$ sec. (more)

(a) $\frac{\tau_v}{\tau_i} = \frac{1}{1/4} = 4$

(b) $v(t) = V_0 \cdot e^{-t/\tau_v}$

$i(t) = I_0 \cdot e^{-t/\tau_i}$

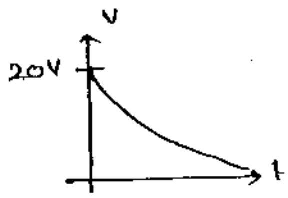
$t = 0^-$



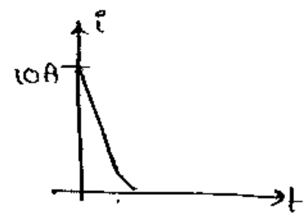
10A

20V

$v(t) = 20 \cdot e^{-t}, \; t>0$

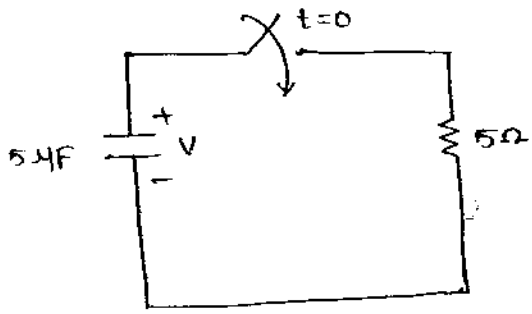


$i(t) = 10 \cdot e^{-4t}, \; t>0$



Gate.

Q if $V(0) = 4V$, determine the charge Transferred by Capacitor from $25\mu sec$ to $100\mu sec$.



$\Rightarrow$ Source free, first order R-C

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$\Rightarrow$ S.V $\rightarrow$ 'V'

$\tau = RC$

$\tau = 5\mu \times 5$

$= 25\mu$

$V(t) = V_0 . e^{-t/RC}$

$V(t) = 4 . e^{-t/25\mu}$

$q(t) = CV(t)$

$q(t) = 20 . e^{-t/25\mu}\ \mu C$

$q(t = 25\mu) = 20 . e^{-1}\ \mu C = 7.35\ \mu C$

$q(t = 100\mu) = 20 . e^{-4}\ \mu C = 0.35\ \mu C$

$q_{transferred} = (7.35 - 0.35)\mu C$

$= 7\mu C.$

Category - II.

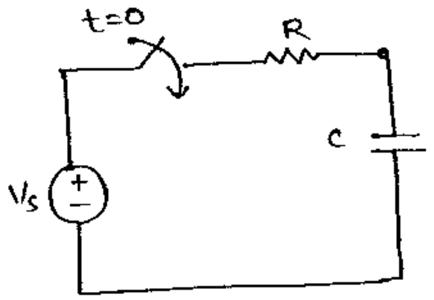
Step Response of first order.

(a) R-C ckt:

Where $V(0)$ = Voltage across Cap. before Switch operation in prev. S.S

$V(\infty)$ = Voltage across Cap after Switch operation in Next S.S

$\tau = RC$ Time Const. of ckt.



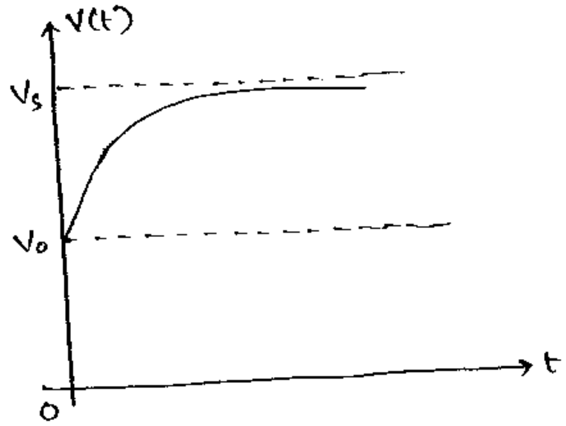
$V(t) = V_{ss}(t) + V_{tr}(t)$

$$\boxed{V(t) = V(\infty) + [V(0) - V(\infty)]\, e^{-t/\tau}}$$

Case (i) With Initial Condition.

$$V(0) = V_0$$

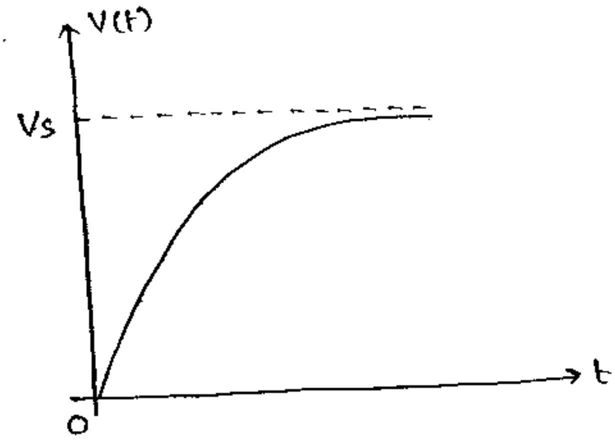
$$V(t) = V_S + [V_0 - V_S]\, e^{-t/\tau}$$



Case (ii) Without Initial Condition.

$$V(0) = 0$$

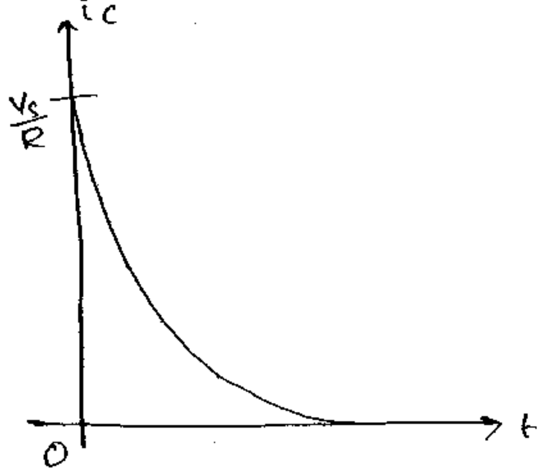
$$V(t) = V_S\left[1 - e^{-t/\tau}\right]$$



$$i_c(t) = C\frac{d}{dt}\left[V_S(1 - e^{-t/\tau})\right]$$

$$= CV_S \cdot \left[0 - e^{-t/\tau} \times \frac{-1}{\tau}\right]$$

$$i_c(t) = \frac{V_S}{R}\, e^{-t/\tau}$$



$P_c(t) = V_c(t) \cdot i_c(t)$

$$P_c(t) = \frac{V_s^2}{R}\left[e^{-t/\tau} - e^{-2t/\tau}\right] \quad \underline{\underline{\omega}}$$

$$E_c(t) = \int_0^\infty P_c(t)\,dt$$

$$= \frac{1}{2}CV_s^2 \quad \underline{\underline{J}}$$

$$i_R(t) = \frac{V_s}{R} \cdot e^{-t/\tau} \quad \underline{\underline{A}}$$

$$V_R(t) = V_s \cdot e^{-t/\tau} \quad \underline{\underline{V}}$$

$$P_R(t) = \frac{V_s^2}{R} e^{-2t/\tau} \quad \underline{\underline{\omega}}$$

$$E_R(t) = \int_0^\infty P_R(t) = \frac{1}{2}CV_s^2 \quad \underline{\underline{J}}$$

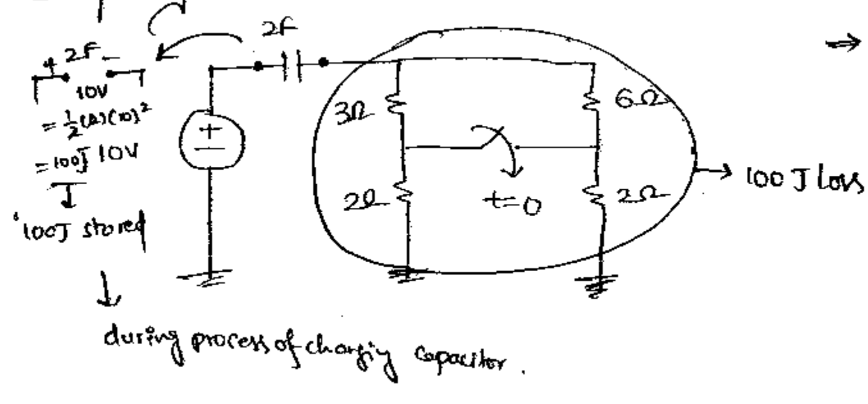
$$\%\eta_{RC} = \frac{E_o}{E_{in}} * 100\% = \frac{E_o}{\underbrace{E_o + \text{losses}}_{\text{energy loss in 'R'}}} \times 100\%$$

$$\%\eta_{RC} = \frac{\frac{1}{2}CV_s^2}{\frac{1}{2}CV_s^2 + \frac{1}{2}CV_s^2} \times 100\%$$

$$\%\eta_{RC} = \underline{\underline{50\%}}$$

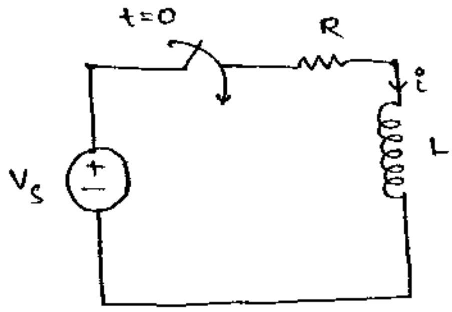
Note: In the above ckt total Energy Supplied by the Source in charging the Capacitor Completely is $\frac{1}{2}CV_s^2 + \frac{1}{2}CV_s^2 = \underline{\underline{CV_s^2}}$

Q The total Energy Supplied by the Source in charging the Capacitor Completely is ______



$$\rightarrow CV_s^2 = 2F(10V)^2$$
$$= \underline{\underline{200\text{ J}}}$$

(b) R-L Circuit.



$$i(t) = I_{ss}(t) + I_{tr}(t)$$

$$\boxed{i(t) = I(\infty) + \left[I(0) - I(\infty)\right] \cdot e^{-t/\tau}}$$

Where,

$I(0)$ = Current through Inductor before switch operation in prev. S.S

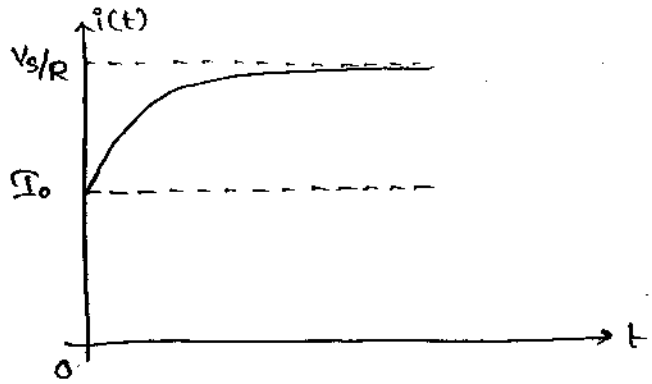
$I(\infty)$ = Current through Inductor after switch operation in next S.S

τ = time const. of ckt $= \frac{L}{R}$

Case(i): With Initial Condition:

let $I(0) = I_0$

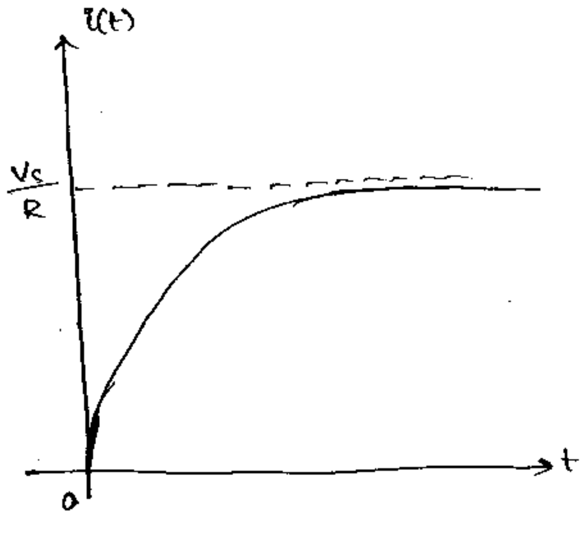
$$\boxed{i(t) = \frac{V_s}{R} + \left[I_0 - \frac{V_s}{R}\right] e^{-t/\tau} \text{ A}}$$



Case (ii): Without Initial Condition:

$I(0) = 0$

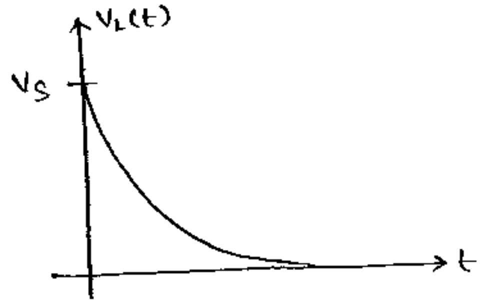
$$i(t) = \frac{V_s}{R}\left[1 - e^{-t/\tau}\right] \text{ A}$$



$$V_L(t) = L\frac{d}{dt}\left\{\frac{V_S}{R}\left(1-e^{-t/\tau}\right)\right\}$$

$$= L\cdot\frac{V_S}{R}\left\{0-e^{-t/\tau} * \frac{-1}{\tau}\right\}$$

$$V_L(t) = V_S \cdot e^{-t/\tau}, \quad t>0.$$



$$P_L(t) = V_L(t)\cdot i_L(t)$$

$$P_L(t) = \frac{V_S^2}{R}\left[e^{-t/\tau} - e^{-2t/\tau}\right] \ \underline{\underline{W}}$$

$$E_L(t) = \int_0^{\infty} P_L(t)\,dt$$

$$= \frac{1}{2}L\left[\frac{V_S}{R}\right]^2 \ \underline{\underline{J}}$$

$$i_R(t) = \frac{V_S}{R}\left[1-e^{-t/\tau}\right] \ \underline{\underline{A}}$$

$$V_R(t) = V_S\left[1-e^{-t/\tau}\right] \ \underline{\underline{V}}$$

$$P_R(t) = \frac{V_S^2}{R}\left[1-e^{-t/\tau}\right]^2 \ \underline{\underline{W}}$$

$$E_R(t) = \int_0^{\infty} P_R(t) = \infty \ \underline{\underline{J}}$$

$$\%\eta_{RL} = \frac{E_o}{E_{in}}\times 100 = \frac{E_o}{E_o + \text{losses}}\times 100\%$$

$$\%\eta_{RL} = \frac{\frac{1}{2}L\left[\frac{V_S}{R}\right]^2}{\frac{1}{2}L\left[\frac{V_S}{R}\right]^2 + \infty}\times 100\%$$

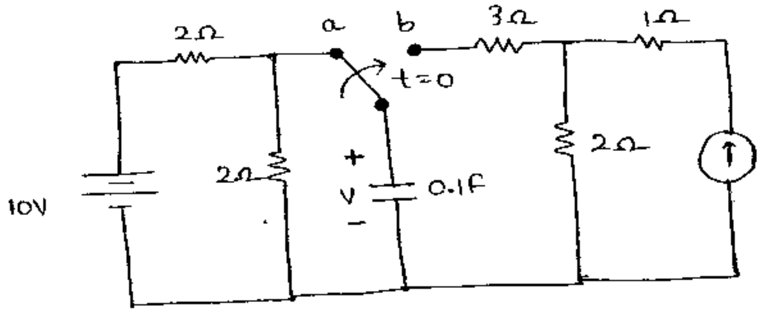
$\infty \longrightarrow t\to\infty$

current has to flow in Inductor upto ∞ time
the R produces '∞' losses
$\therefore$ R-L η is very less.
$\therefore$ most of switching ckts use R-C only.

$$\%\eta_{RL} = 0\%$$

'L' is most inefficient Passive element.

determine Complete Expression for Voltage $V(t)$ for all $t>0$.

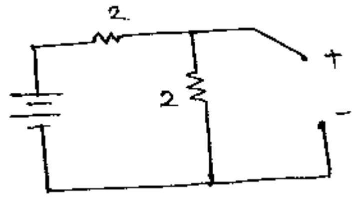


⇒ Step Response, First order

⇒ SV ⟶ 'V'

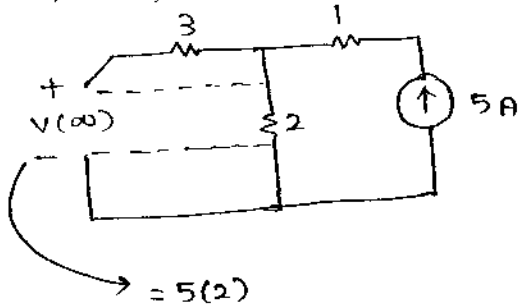
$$V(t) = V(\infty) + [V(0) - V(\infty)] \cdot e^{-t/\tau}$$

⇒ V(0)



$V(0) = 5V$

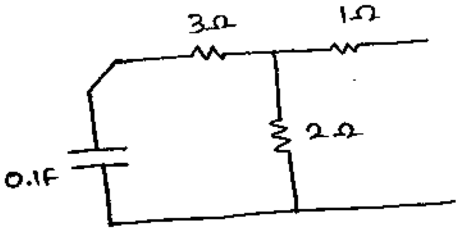
⇒ V(∞)



$= 5(2)$

$= 10V$

τ, t>0

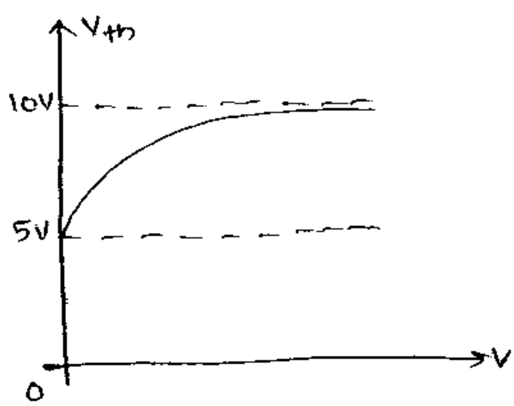


$$\tau = R_{eq} \cdot C = 5(0.1)$$

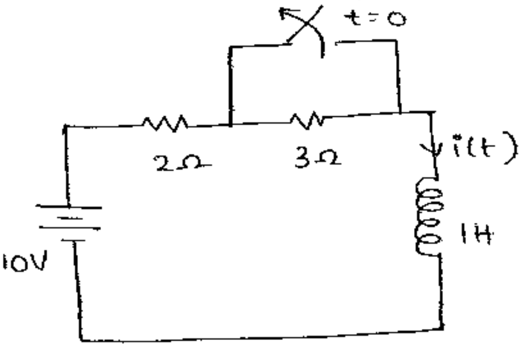
$$= \frac{1}{2} \text{ sec.}$$

$$V(t) = 10 + [5 - 10]\, e^{-t/\frac{1}{2}}$$

$$V(t) = 10 - 5e^{-2t}, \; t>0$$



determine the Complete Expression for current 'i' for all $t>0$.



$\Rightarrow$ step. Resp, I^{st} order

$\Rightarrow$ S.V $\Rightarrow$ 'i'

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$$i(t) = I(\infty) + \left[I(0) - I(\infty)\right] \cdot e^{-t/\tau}$$

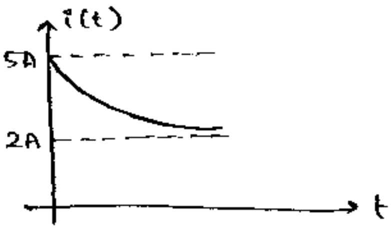
$$I(0) = \frac{10}{2} = 5A$$

$$I(\infty) = \frac{10}{5} = 2A$$

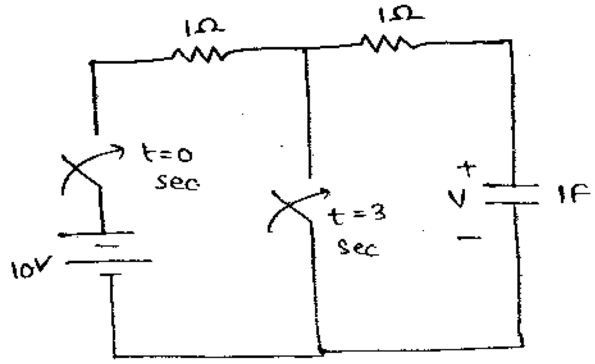
$$\tau = \frac{L}{R} = \frac{1}{5} \text{ sec.}$$

$$i(t) = 2 + [5-2] \cdot e^{-t/1/5}$$

$$i(t) = 2 + 3 \cdot e^{-5t} \; ; t>0$$



Q plot Voltage $V(t)$ for all $t>0$.

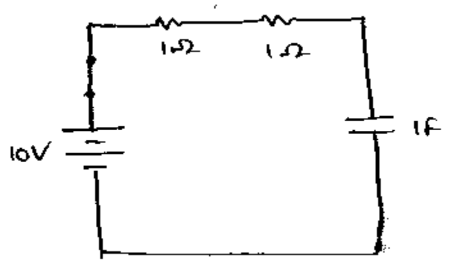


part: I:

$0 < t \leq 3$ sec.

$\Rightarrow$ step-Resp, I^{st} order

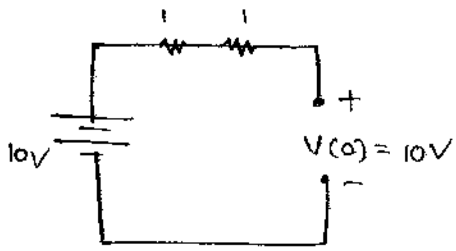
$\Rightarrow$ S.V $\longrightarrow$ V



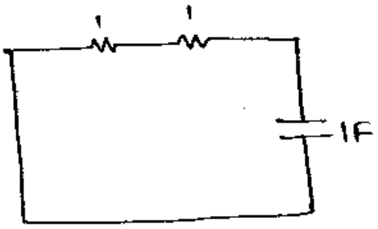
$$V(t) = V(\infty) + \left[V(0) - V(\infty)\right] e^{-t/\tau}$$

$V(0) = 0$

$V(\infty) = 10V$



τ, $t>0$



$\tau = 2\,\text{sec}.$

$$V(t) = 10\left[1 - e^{-t/2}\right]_{0<t\leq 3\,\text{sec}.}$$

P-II $t>3$

Source free 1st order

S.V $\longrightarrow$ V

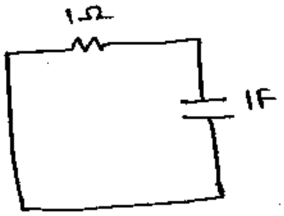
$V(t) = V_0 \cdot e^{-t/\tau}$

$V_0 \longrightarrow V(3^-)$ from previous state

$$V(3^-) = 10\left[1 - e^{-3/2}\right]$$

$$= 7.76\,\underline{\underline{V}}$$

τ, $t>3$

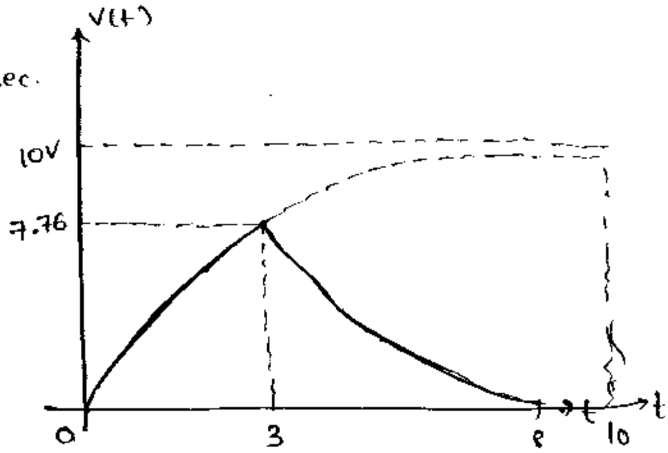


$T = 1\,\text{sec}$

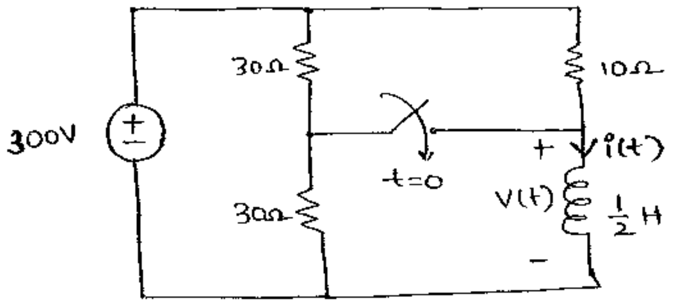
$$V(t) = 7.76 \cdot e^{-\frac{(t-3)}{1}}, \; t>3.$$

Total Response is

$$V(t) = \begin{cases} 10(1 - e^{-t/2})\,\underline{\underline{V}}, & 0<t\leq 3\,\text{sec}. \\ 7.76\,e^{-(t-3)}\,\underline{\underline{V}}, & t>3\,\text{sec}. \end{cases}$$



Determine the Voltage Exp. for all $t>0$.



$$i(t) = I(\infty) + [I(0) - I(\infty)].e^{-t/\tau}$$

$$I(0) = \frac{300}{10} = 30A.$$

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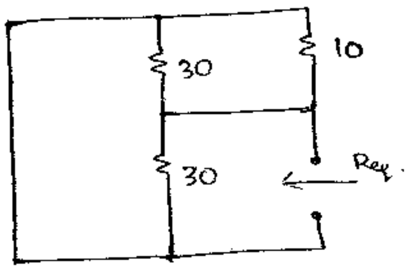
$$I(\infty) = \frac{300}{(30 // 10)} = 40A$$

$$\tau = \frac{L}{R_{eq}} = \frac{1/2}{(30 // 30 // 10)} = \frac{1}{12} \text{ sec.}$$

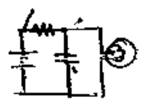


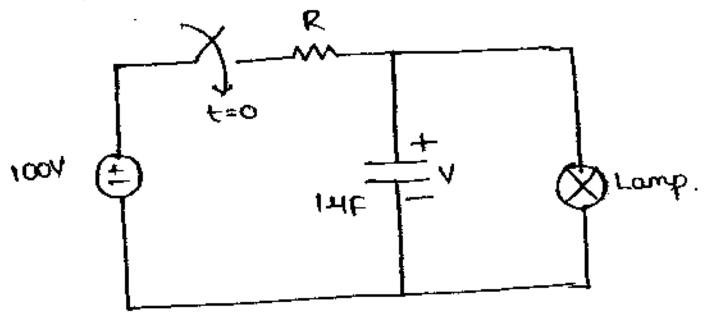
$$i(t) = 40 - 10.e^{-12t}$$

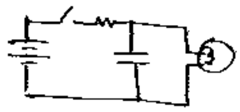
$$V(t) = L\frac{di(t)}{dt} = \frac{1}{2}\left[0 - 10.e^{-12t}(-12)\right]$$

$$V(t) = 60.e^{-12t}, \ t>0$$

Q a Neon Lamp Ionises at 75 Volts, is Connected across 1 μF capacitor, determine the Value of Resistance 'R' that should be Connected in Series to this Combination In order to Trigger the lamp Exactly after 20 sec from an Instant DC 100V is applied to the entire circuit.







$$V(t) = 100 + [0 - 100].e^{-t/R\mu}$$

$$V(t) = 100\left[1 - e^{-t/R\mu}\right]$$

$$\downarrow$$

$$75V = 100\left[1 - e^{-20/R\mu}\right]$$

$$1 - e^{-20/R\mu} = \frac{3}{4}$$

$$e^{-20/R\mu} = \frac{1}{4}$$

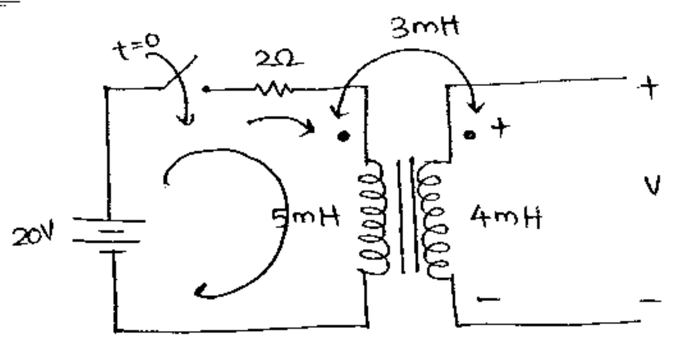
$$\frac{-20}{R4} = \ln\left[\frac{1}{4}\right]$$

$$-\frac{20}{R4} = -1.38$$

$$R = \frac{20}{1.384}$$

$$\underline{R = 14.4\,M\Omega}$$

Gate Determine the max. Value of Voltage 'V'



$$i(t) = I(\infty) + \left[I(0) - I(\infty)\right] \cdot e^{-t/\tau}$$

$$I(0) = 0\,A$$

$$I(\infty) = \frac{20}{2} = 10\,A$$

$$\tau = \frac{L}{R} = \frac{5m}{2}$$

$$i(t) = 10\left\{1 - e^{-400t}\right\}, \quad t>0$$

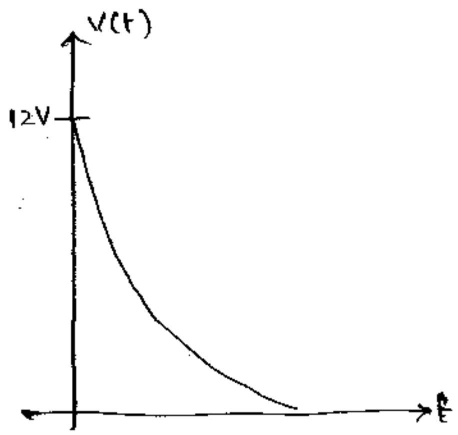
$$e_2 = +M\frac{di}{dt}$$

$$V(t) = +3m \cdot \frac{d}{dt}\left\{10\left(1 - e^{-400t}\right)\right\}$$

$$= 30m \cdot \left[0 - e^{-400t}(-400)\right]$$

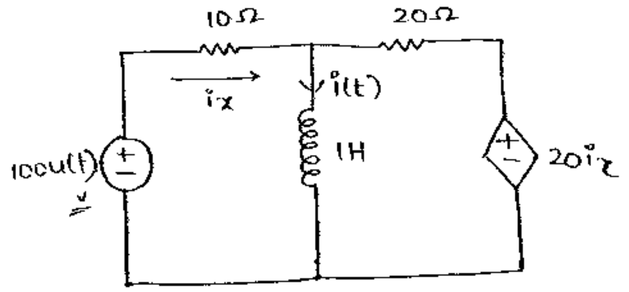
$$V(t) = 12e^{-400t}$$

$$\therefore V_{max} = 12\,\text{Volts}$$



gate

Determin the Complete Exp. for $i(t)$ for all $t>0$



$$i(t) = I(\infty) + \left[I(0) - I(\infty)\right] e^{-t/\tau}$$

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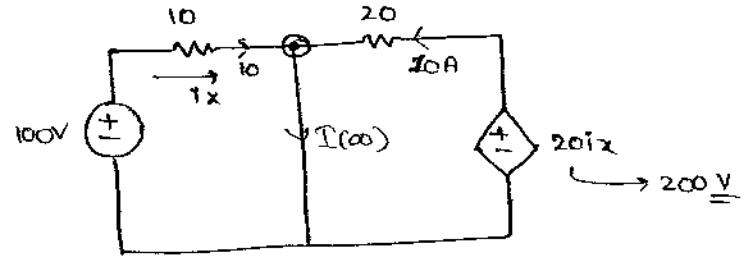
$I(0) = 0A$

$I(\infty)$

DC. S.S

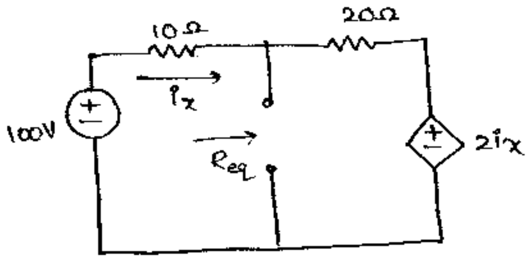


KCL

$10 + 10 = I(\infty)$

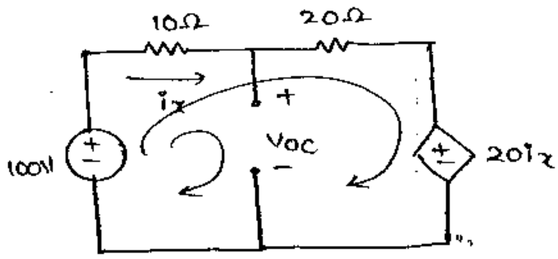
$I(\infty) = 20A$

$\Rightarrow \tau = \frac{L}{R_2}$



$R_{eq} = \frac{V_{oc}}{R_{eq}}$

S.I] Voc



$-100 + 30i_x + 20i_x = 0 \Rightarrow i_x = 2A$

KVL,

$-100 + 10i_x + V_{oc} = 0 \longrightarrow V_{oc} = 100 - 20$

$= 80V$

S-II] I_{sc}

↳ But Here

$I_{sc} = I(\infty)$

$I_{sc} = 20A.$

$R_{eq} = \frac{V_{oc}}{I_{sc}} = \frac{80}{20} = 4\Omega.$

$$\tau = \frac{L}{R_{eq}} = \frac{1}{4}\,\text{Sec}$$

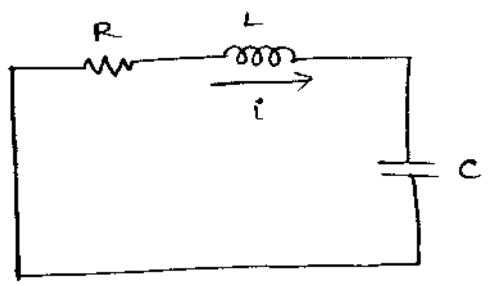
$$i(t) = 20 + [0-20]\cdot e^{-t/1/4}$$

$$i(t) = 20\left[1 - e^{-4t}\right],\ t>0.$$

Category - III

Source free Second order circuits [Canonical forms]

(a) Series R-L-C:



preferable S.V ⟶ 'i'

Mesh

$$iR + L\frac{di}{dt} + \frac{1}{C}\int i\,dt = 0$$

$$\boxed{L\frac{d^2 i}{dt^2} + R\frac{di}{dt} + \frac{i}{C} = 0}$$

Use L.T [Homogeneous]

$$L\cdot s^2 I(s) + R\cdot s\,I(s) + \frac{I(s)}{C} = 0$$

$$I(s)\left[s^2 + \frac{R}{L}s + \frac{1}{LC}\right] = 0$$

$$\because I(s) \neq 0$$

$$\boxed{s^2 + \frac{R}{L}s + \frac{1}{LC} = 0}$$

The two roots,

$$s_1, s_2 = \frac{-R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \left(\frac{1}{\sqrt{LC}}\right)^2}$$

Let $\alpha = \frac{R}{2L}$ → Damping factor

(or)

Damping Coefficient

$\omega_0 = \frac{1}{\sqrt{LC}}$ ⇒ Undamped Natural freq.

The two roots are

$$s_1, s_2 = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

Case (i) : If $\alpha > \omega_0$ ⇒ over damped (sluggish & slow)

$$\frac{R}{2L} > \frac{1}{\sqrt{LC}}$$

Then two roots s_1, s_2 are −ve Real & unequal.

Then

$$\boxed{i(t) = A_1 e^{+s_1 t} + A_2 e^{+s_2 t}, \quad t > 0}$$

$$\tau = \frac{-1}{\text{Dominant pole}} \text{ sec}$$

A_1 & A_2 are Constants than can be determined from initial Condition.

Case (ii) : If $\alpha = \omega_0$ ⇒ Critically damped.

$$\frac{R}{2L} = \frac{1}{\sqrt{LC}}$$

Then two roots s_1, s_2 are −ve Real & equal.

Then

$$\boxed{i(t) = e^{-\alpha t}\left[A_1 + A_2 t\right], \quad t > 0}$$

$$\tau = \frac{1}{\alpha} = \frac{2L}{R} \text{ sec}$$

Case (iii): If $\underline{\alpha < \omega_0}$ $\Rightarrow$ Underdamped.

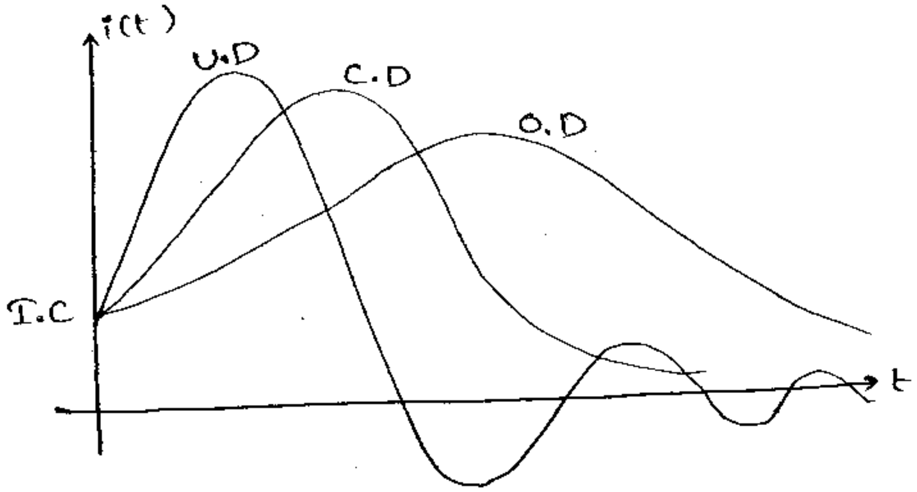
$$\frac{R}{2L} < \frac{1}{\sqrt{LC}}$$

Then the two roots S_1, S_2 are Complex Conjugate with (-ve) Real part

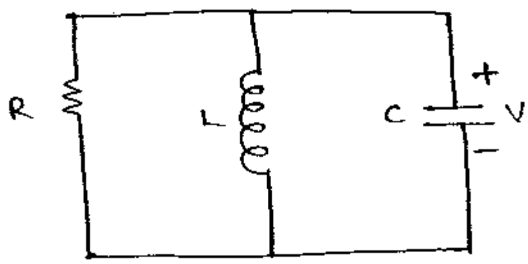
Then $\boxed{i(t) = e^{-\alpha t}\left[A_1 \cos\omega_d t + A_2 \sin\omega_d t\right], \; t>0}$ $\quad \tau = \frac{1}{\alpha} = \frac{2L}{R}$ sec.

$$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

$\rightarrow$ damped / forced / Ringing freq.



(b) parallel R-L-C:



pref. S.V $\longrightarrow$ 'V'

KCL

$$\frac{V}{R} + \frac{1}{L}\int V dt + C\frac{dV}{dt} = 0$$

$$\boxed{C\frac{d^2V}{dt^2} + \frac{1}{R}\frac{dV}{dt} + \frac{V}{L} = 0}$$

Use L.T [Homogeneous]

$$C.s^2 V(s) + \frac{s}{R} V(s) + \frac{V(s)}{L} = 0$$

$$V(s)\left[s^2 + \frac{s}{RC} + \frac{1}{LC}\right] = 0$$

$$\because V(s) \neq 0$$

$$\boxed{s^2 + \frac{s}{RC} + \frac{1}{LC} = 0}$$

The two roots are,

$$s_1, s_2 = \frac{-1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 - \left(\frac{1}{\sqrt{LC}}\right)^2}$$

Let $\alpha = \frac{1}{2RC}$ $\Rightarrow$ damping factor (or) Damping Coefficient.

$\omega_0 = \frac{1}{\sqrt{LC}}$ $\Rightarrow$ Undamped Natural Freq.

The two roots,

$$s_1 s_2 = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

Case(1): If $\underline{\alpha > \omega_0}$ $\Rightarrow$ overdamped

$$\frac{1}{2RC} > \frac{1}{\sqrt{LC}}$$

Then Two roots $s_1 s_2$ are -Ve Real & Unequal.

Then, $\boxed{v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}, \; t > 0}$ $\quad \tau = \frac{-1}{\text{Dominant pole}}$

A_1, A_2 are Constants that Can be determined from I.C.

Case (ii): If $\alpha = \omega_0 \Rightarrow$ Critically damped

$$\frac{1}{2RC} = \frac{1}{\sqrt{LC}}$$

The two roots are $S_1, S_2 \rightarrow$ -ve, Real & equal.

Then $\boxed{V(t) = e^{-\alpha t}(A_1 + A_2 t), t>0.}$ $\tau = \frac{1}{\alpha} = 2RC$ sec.

Case (iii): If $\alpha < \omega_0 \Rightarrow$ Underdamped.

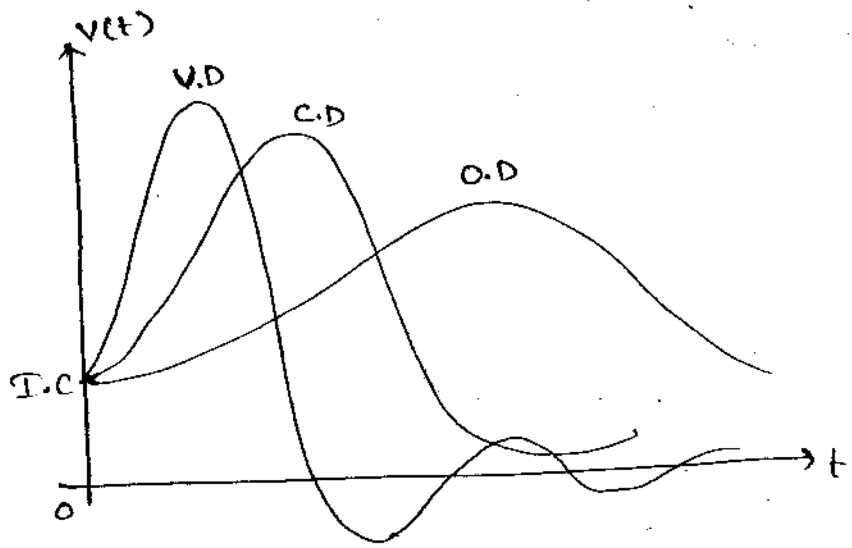
$$\frac{1}{2RC} < \frac{1}{\sqrt{LC}}$$

The two roots S_1, S_2 are Complex Conjugate with (-ve) Real part.

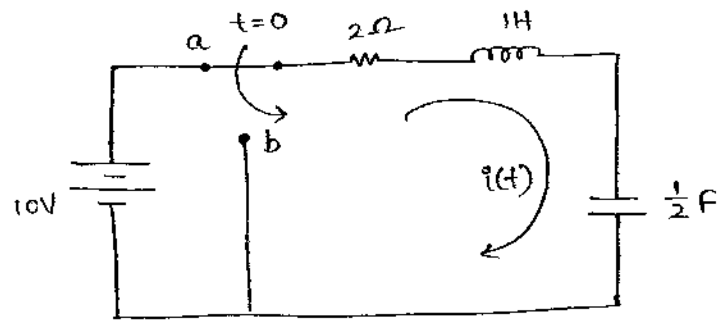
Then $\boxed{V(t) = e^{-\alpha t}\left[A_1 \cos\omega_d t + A_2 \sin\omega_d t\right], t>0}$ $\tau = \frac{1}{\alpha} = 2RC$ sec

$$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

$\rightarrow$ damped / Forced / Ringing freq.



Q The Response of Current $i(t)$ is of the form.



(a) O.D

(b) C.D

~~(c)~~ U.D

(d) Sinusoidal

$$\alpha = \frac{R}{2L} = \frac{2}{2(1)} = 1$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1 \cdot \frac{1}{2}}} = \sqrt{2}$$

$\alpha < \omega_0$ U.D

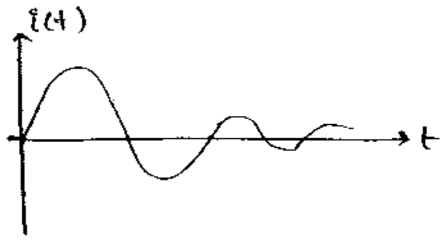
$i(0^-)$ = Current in prev. S.S = 0 A

$E(0^-)$ = ~~L~~, C, ~~Both~~

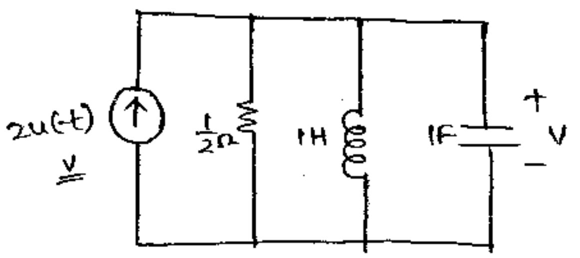
↳ energy stored in prev. S.S

$(\because i = 0 \Rightarrow \frac{1}{2}Li^2 = 0)$

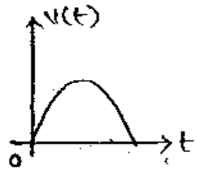
$i(\infty) = 0\,A$



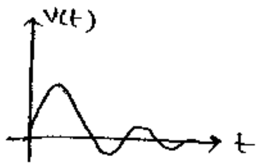
Q The Response for Voltage $v(t)$ ___



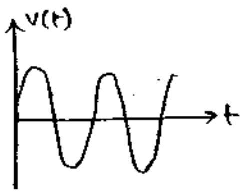
(a)



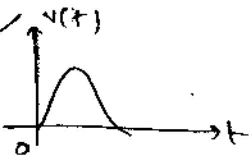
(b)



(c)



~~(d)~~



$$\alpha = \frac{1}{2 \cdot \frac{1}{2} \cdot 1} = 1$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = 1$$

$\alpha = \omega_0$ C.D.

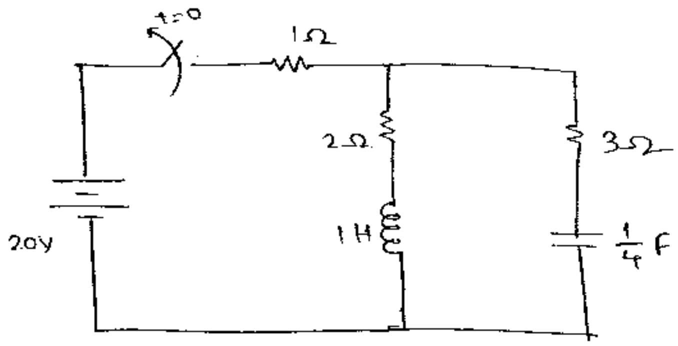
$V(0^-) = 0V$

$E(0^-) \rightarrow$ L ~~C~~, ~~Both~~

$(\frac{1}{2}CV^2 = 0)$

$V(\infty) = 0V$

The time Constant of ckt given below.



$$\alpha = \frac{2+3}{2(1)} = 2.5$$

$$\omega_0 = \frac{1}{\sqrt{1 \cdot \frac{1}{4}}} = 2$$

$\alpha > \omega_0 \Rightarrow$ O.D.

$$S_1 S_2 = -2.5 \pm \sqrt{(2.5)^2 - 2^2}$$

$$= -1, -4$$

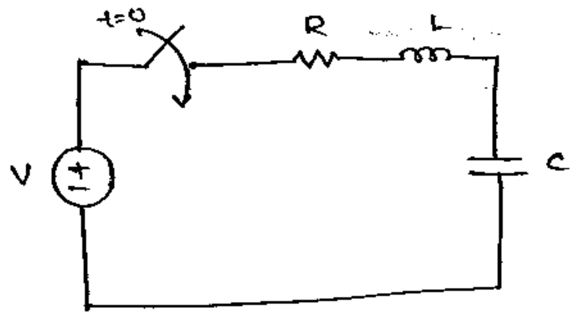
↑ Dom. pole

$$T = \frac{-1}{D.P} = \frac{-1}{(-1)} = 1 \text{ sec}$$

Category - IV

Step Responce of Second order ckts [canonical form]

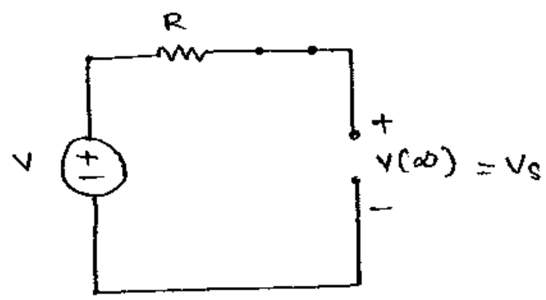
(a) Series R-L-C



Dominat S.V ⟶ 'v' only

$$v(t) = V_{ss}(t) + V_{tr}(t)$$

$V_{ss}(t)$ at $t \longrightarrow \infty$

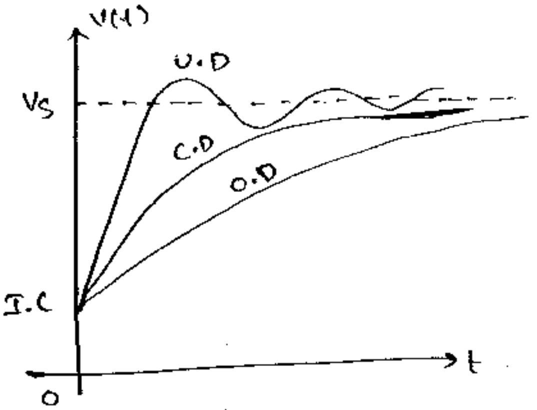


But $V_{tr}(t)$ depends Upon R, L, C

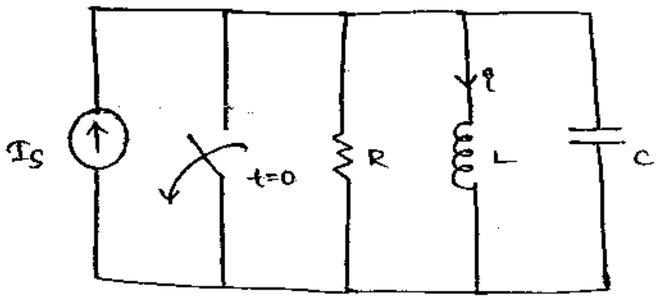
$$\alpha = \frac{R}{2L} \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$

Total Response

$$V(t) = \begin{cases} V_S + A_1 e^{S_1 t} + A_2 e^{S_2 t}, \; t>0 \quad \text{if } \alpha > \omega_0 \Rightarrow \text{overdamped} \\ \text{(or)} \\ V_S + e^{-\alpha t}\left[A_1 + A_2 t\right], \; t>0 \quad \text{if } \alpha = \omega_0 \Rightarrow \text{critically damped} \\ \text{(or)} \\ V_S + e^{-\alpha t}\left[A_1 \cos\omega_d t + A_2 \sin\omega_d t\right], \; t>0, \; \text{if } \alpha < \omega_0 \Rightarrow \text{Underdamped} \end{cases}$$



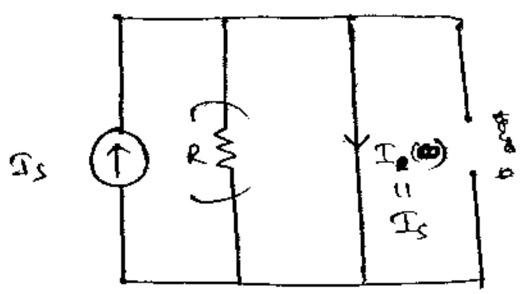
(b) parallel R-L-C



Dominant S.V $\longrightarrow$ 'i' only.

$i(t) = I_{ss}(t) + I_{tr}(t)$.

$I_{ss}(t)$, at $t \longrightarrow \infty$



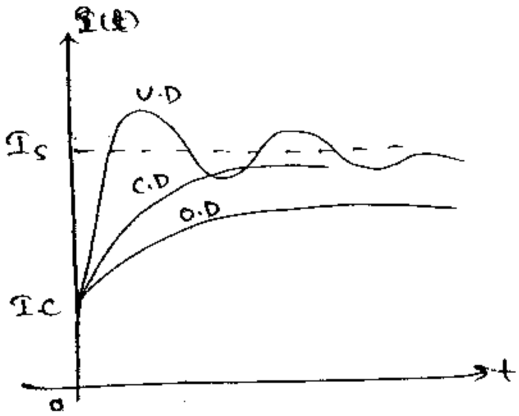
But $I_{tr}(t)$ depends upon R, L, C

$$\alpha = \frac{1}{2RC}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

total Response,

$$i(t) = \begin{cases} I_S + A_1 e^{S_1 t} + A_2 e^{S_2 t}, t>0 & \text{if } \alpha > \omega_0 \rightarrow \text{over damped} \\ \text{(or)} & \\ I_S + e^{-\alpha t}\{A_1 + A_2 t\}, t>0 & \text{if } \alpha = \omega_0 \longrightarrow \text{Critically damped} \\ \text{(or)} & \\ I_S + e^{-\alpha t}\left[A_1 \cos\omega_d t + A_2 \sin\omega_d t\right], t>0 & \text{if } \alpha < \omega_0 \longrightarrow \text{underdamped} \end{cases}$$



Note: 1. Never we should represent sudden change in voltage across capacitor (∵ Results in high $\frac{di}{dt}$)

2. Never we should represent a sudden change in current through Inductor (∵ Results in high $\frac{dv}{dt}$)

3. Never we should a switch across Ideal voltage source & switch in series to Ideal current source

Category V

Intial Condition problems (or) Trancient State problem i.e., problems at $t=0^+$.

Equivalent ckt representation of passive elements in Transient state:

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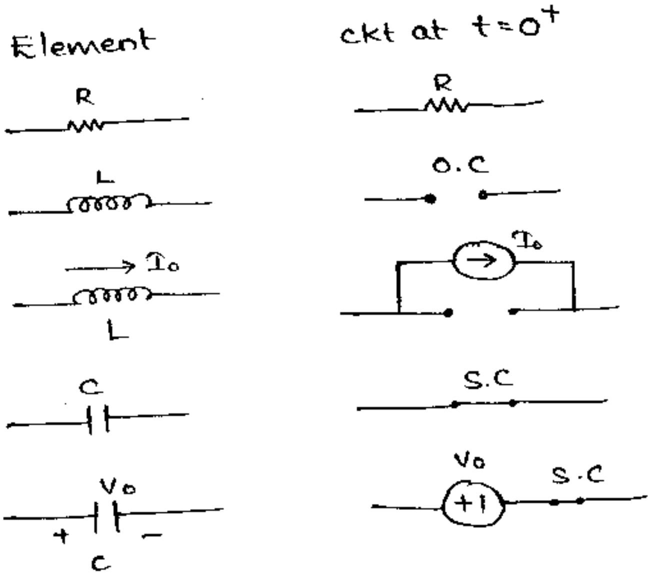
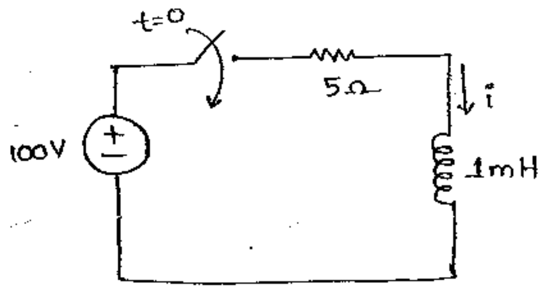


Q find $i(0^+)$, $\frac{di(0^+)}{dt}$, $\frac{d^2i(0^+)}{dt^2}$



at $t=0^-$, Switch was open,

$$i(0^-) = 0A = i(0^+)$$

∵ Inductor never allow sudden change in current

KVL, $t>0$

$$-100 + 5i + 1m\frac{di}{dt} = 0 \longrightarrow (1)$$

$\longrightarrow t=0^+$

$$-100 + 5\,i(0^+) + 1m.\frac{di(0^+)}{dt} = 0$$

$$\frac{di(0^+)}{dt} = \frac{+100}{1m} = 100\,kA/sec.$$

diff. Eq(1) again

$$5 \cdot \frac{di}{dt} + 1m \cdot \frac{d^2 i}{dt^2} = 0$$

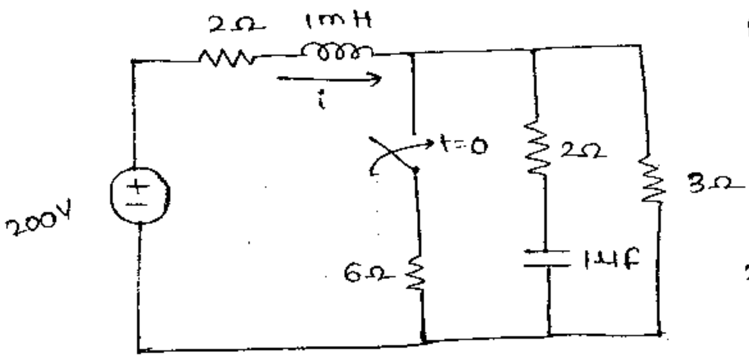
$\rightarrow t = 0^+$

$$5 \cdot \frac{di(0^+)}{dt} + 1m \cdot \frac{d^2 i(0^+)}{dt^2} = 0$$

$$\frac{d^2 i(0^+)}{dt^2} = \frac{-500k}{1m} = \underline{-500\ MA/sec^2}$$

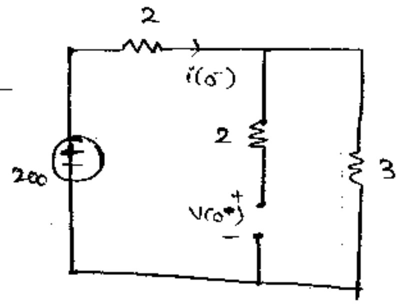
to determine stability

Q find $i(0^+)$, $V(0^+)$, $\frac{di(0^+)}{dt}$, $\frac{dv(0^+)}{dt}$, $i(\infty)$, $V(\infty)$



part - I [$t = 0^-$]

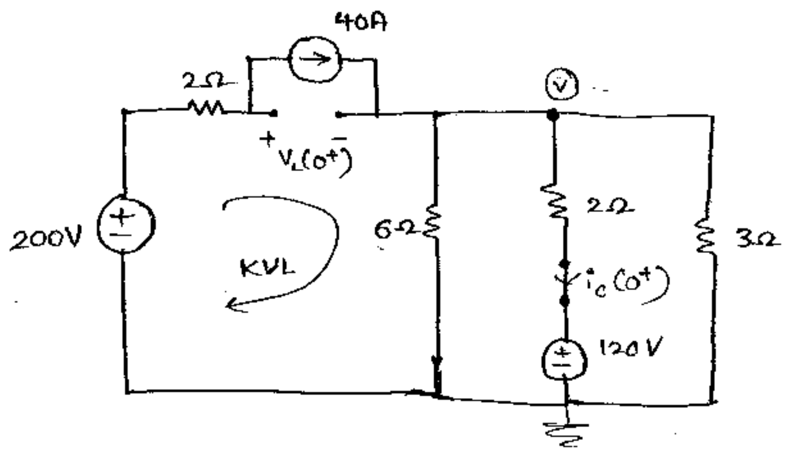
$i(0^-) = \frac{200}{}$



$$i(0^-) = \frac{200}{5} = 40A = i(0^+)$$

$$V(0^-) = 40(3) = 120V = V(0^+)$$

P-II] Transient state [$t = 0^+$]



$$\frac{di(0^+)}{dt} = \frac{V_L(0^+)}{L}$$

$$\frac{dV(0^+)}{dt} = \frac{i_c(0^+)}{C}$$

Nodal ,, $[t = 0^+]$

$$-40 + \frac{V}{6} + \frac{(V-120)}{2} + \frac{V}{3} = 0$$

$$-240 + V + 3V - 360 + 2V = 0$$

$$6V = 600$$

$$V = 100V$$

$$-200 + 40(2) + V_L(0^+) + 100 = 0$$

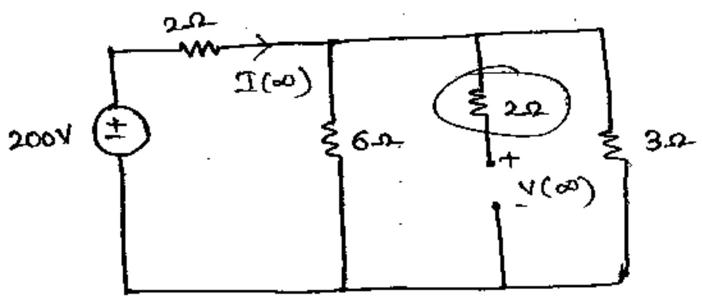
$$V_L(0^+) = 20$$

$$\frac{di(0^+)}{dt} = \frac{V_L(0^+)}{L} = \frac{20}{1m} = 20\,kA/sec.$$

$$i_c(0^+) = \frac{V-120}{2} = \frac{100-120}{2} = -10\,A.$$

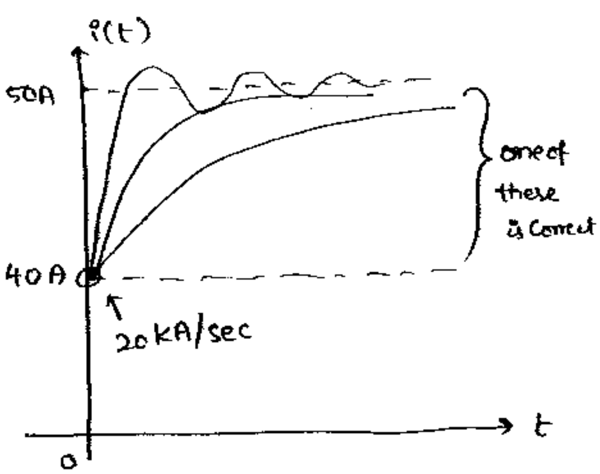
$$\frac{dV(0^+)}{dt} = \frac{i_c(0^+)}{C} = \frac{-10}{1\mu} = -10\,MV/sec.$$

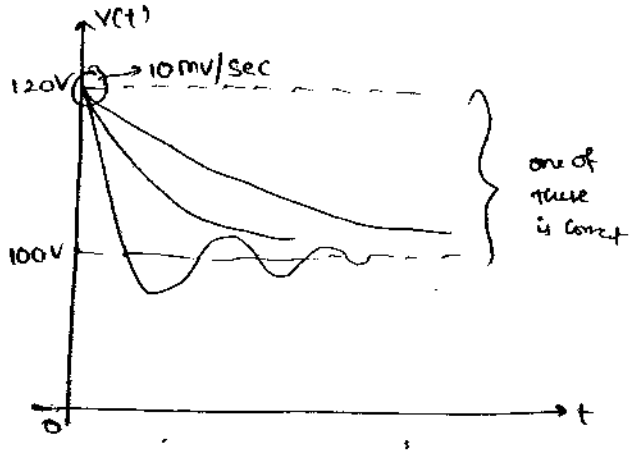
P-III] future $[t \to \infty]$



$$I(\infty) = \frac{200}{2 + [6//3]} = 50A$$

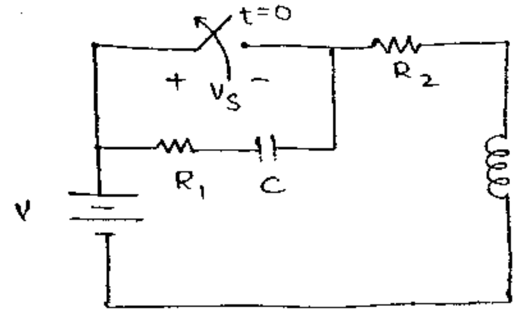
$$V(\infty) = 200\left[\frac{2}{2+2}\right] = 100\,V.$$



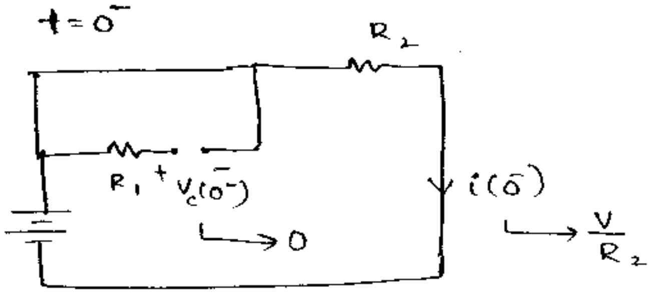


Q $V_S(0^+) =$ ____

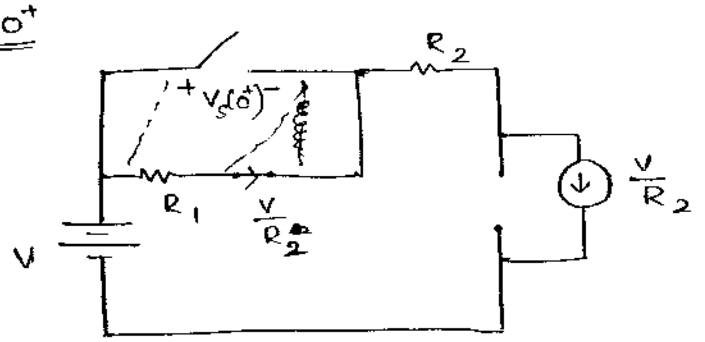
~~(a)~~ $V\left[\frac{R_1}{R_2}\right]$ (b) $V\left[\frac{R_2}{R_1}\right]$ (c) $V\left[\frac{R_1}{R_1+R_2}\right]$ (d) $V\left[\frac{R_2}{R_1+R_2}\right]$



$t=0^-$



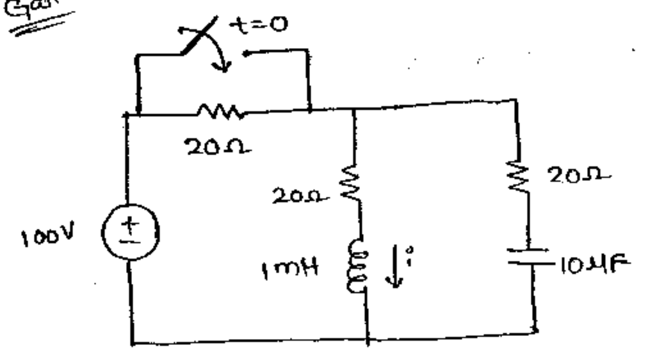
$t=0^+$



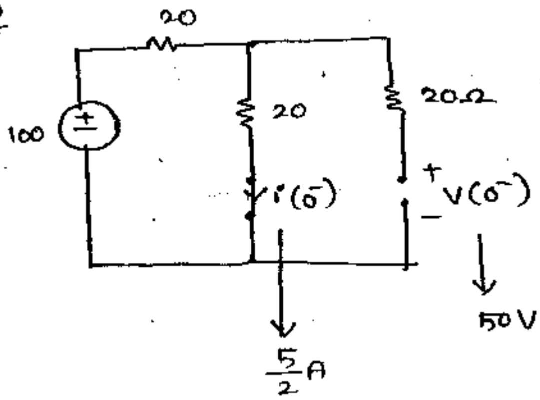
$$V_S(0^+) = \frac{V}{R_2}[R_1]$$

Gate

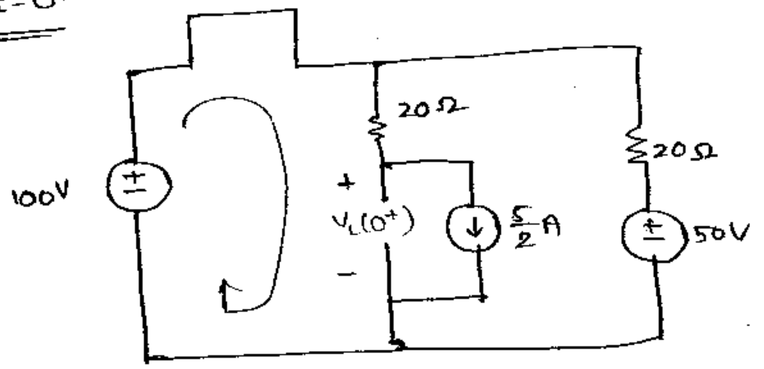
$$\frac{di(0^+)}{dt} = \text{\_\_\_\_}$$



$t=0^-$



$t=0^+$



KVL

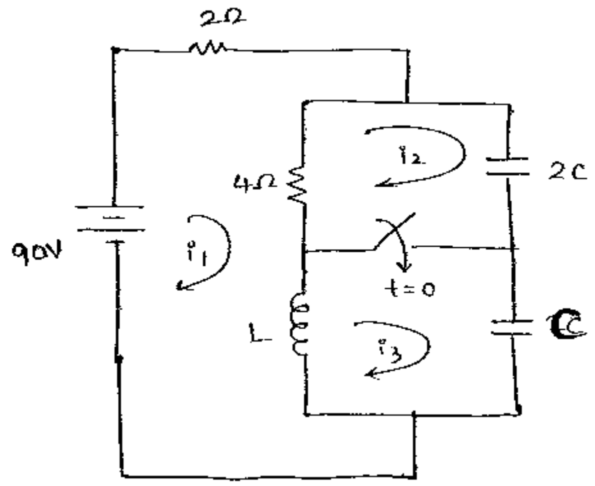
$$-100+\frac{5}{2}(20)+V_L(0^+)=0 \rightarrow$$

$$V_L(0^+)=50$$

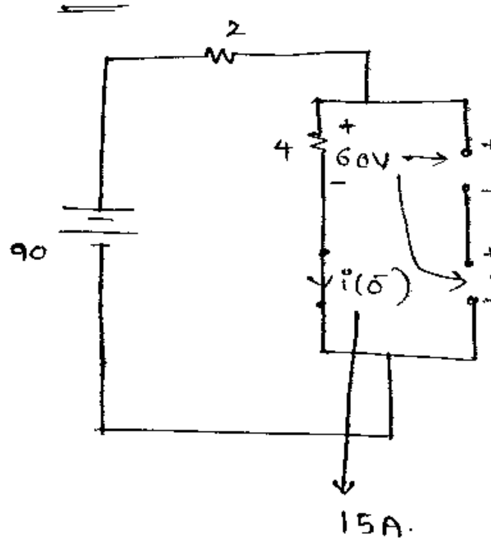
$$\frac{di(0^+)}{dt} = \frac{V_L(0^+)}{L} = \frac{50}{1m}$$

$$= 50\,KA/sec$$

Q find $i_1(0^+)$, $i_2(0^+)$, $i_3(0^+)$



$t=0^-$

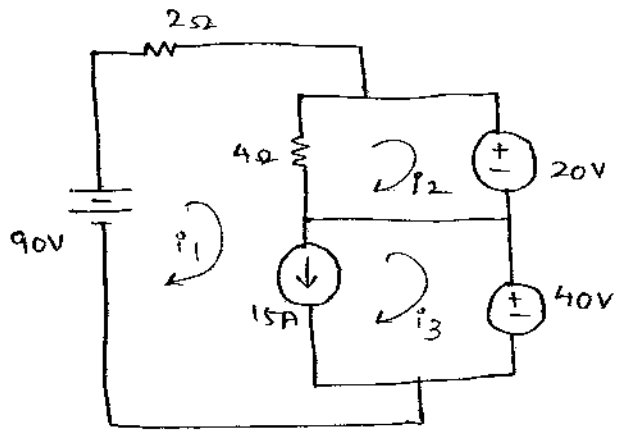


$V(0^-) = 60\left[\frac{C}{2C}\right]$

$= 20V$

$V(0^-) = 60\left[\frac{2C}{3C}\right]$

$= 40V$



mesh

$-90+2i_1+4[i_1-i_2]+40=0 \longrightarrow (1)$

$4[i_2-i_1]+20=0 \longrightarrow (2)$

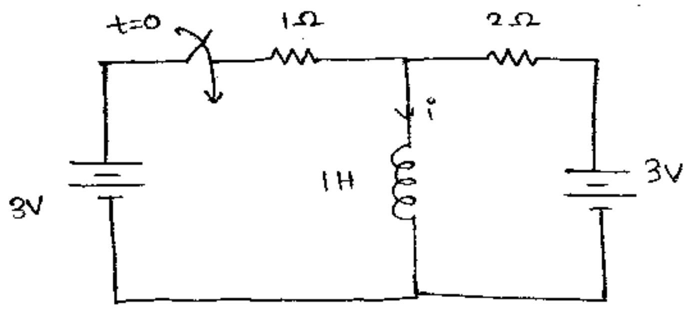
$(i_1-i_3)=15 \longrightarrow (3)$

$i_1(0^+) = 15A$

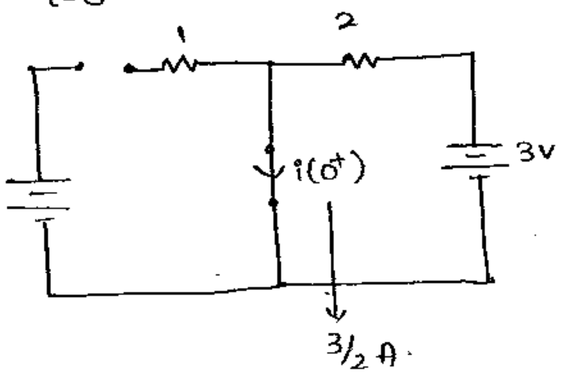
$i_2(0^+) = 10A$

$i_3(0^+) = 0A$

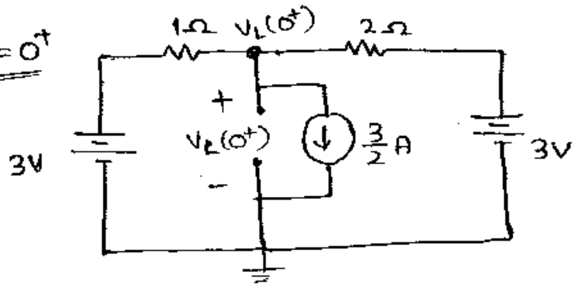
Gate $\frac{di(0^+)}{dt} =$ ____



$t=0^-$



$t=0^+$



Nodal

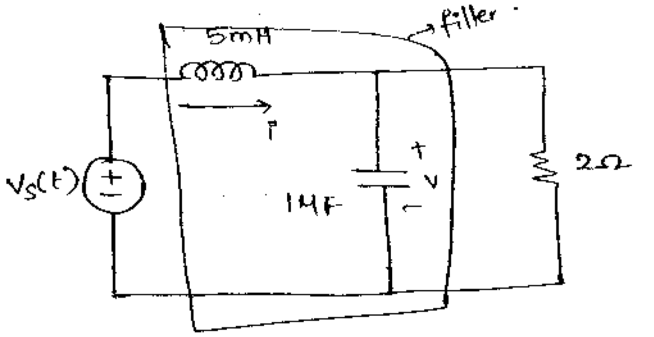
$$\frac{[V_L(0^+)-3]}{1}+\frac{3}{2}+\frac{[V_L(0^+)-3]}{2}=0$$

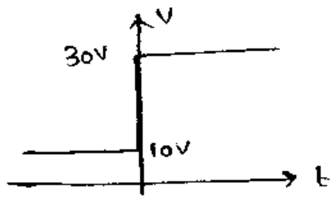
$$3V_L(0^+)=6 \longrightarrow V_L(0^+)=2$$

$$\frac{di(0^+)}{dt}=\frac{V_L(0^+)}{L}=2\,A/sec.$$

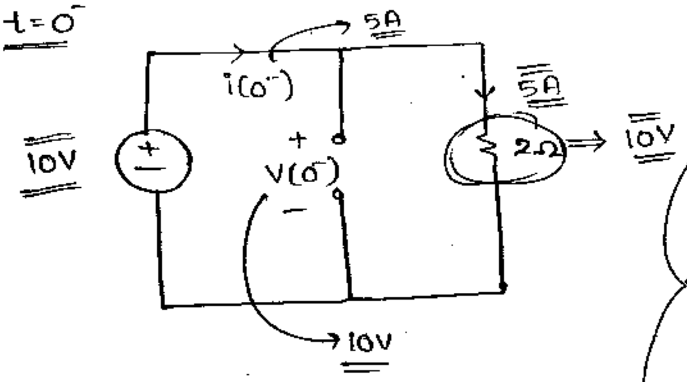
pb: If $V_s(t)=10+20u(t)$

find $\frac{di(0^+)}{dt}=$ ____ , $\frac{dv(0^+)}{dt}=$ ____





$t=0^-$



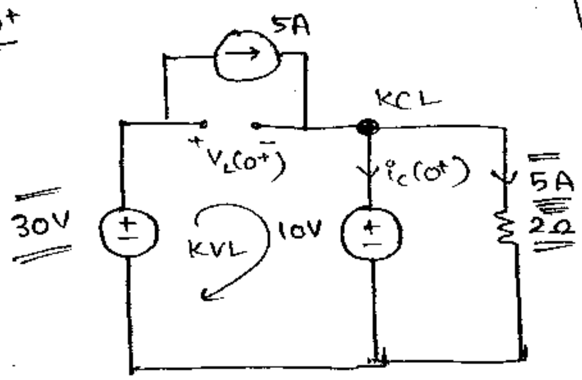
even the Supply suddenly changed but load side v, I are sam

it is appl. of shock absorber, filter

KVL

$$-30+V_L(0^+)+10=0 \rightarrow V_L(0^+)=20V$$

$t=0^+$



$$\frac{di(0^+)}{dt}=\frac{V_L(0^+)}{L}=\frac{20}{5m}$$

$$=4\,kA/sec$$

KCL

$$5=i_c(0^+)+5$$

$$\therefore i_c(0^+)=0\,A$$

$$\frac{dv(0^+)}{dt}=\frac{i_c(0^+)}{C}=0\,V/sec$$

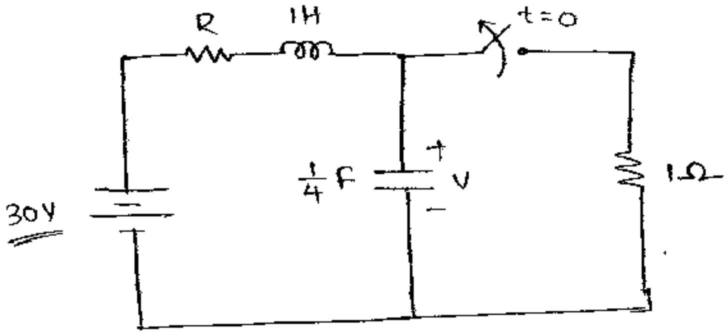
Complete Solution to Second order ckt :

Q Determine the Complete Exp. for Voltage $V(t)$ for all $t>0$ if

(a) $R = 5\Omega$

(b) $R = 4\Omega$

(c) $R = 1\Omega$

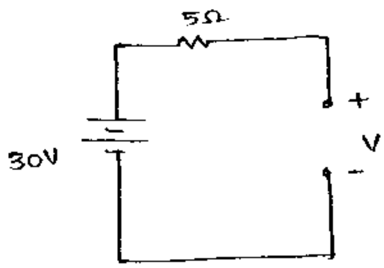


⇒ Step. Resp. 2nd order

⇒ Series R-L-C

$V(t) = V_{ss}(t) + V_{tr}(t)$

$V_{ss}(t)$, at $t \to \infty$



$V(\infty) \to 30V$

⇒ But $V_{tr}(t)$ depends upon R, L, C

$$\alpha = \frac{5}{2(1)} = 2.5$$

$$\omega_0 = \frac{1}{\sqrt{1\left(\frac{1}{4}\right)}} = 2$$

$\alpha > \omega_0 \to$ O.D

$$V_{tr}(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

$$s_1, s_2 = -2.5 \pm \sqrt{(2.5)^2 - 2^2}$$

$$= -4, -1$$

Total Response is

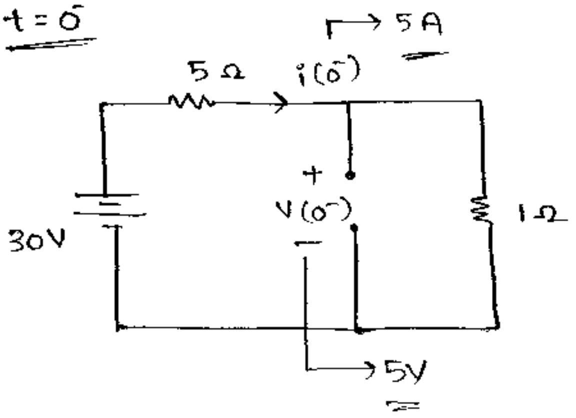
$$V(t) = 30 + A_1 e^{-4t} + A_2 e^{-t}, \quad t>0$$

1. $V(0) =$ ______

2. $\frac{dV(0)}{dt} =$ ______

cat - V

$t = 0^-$

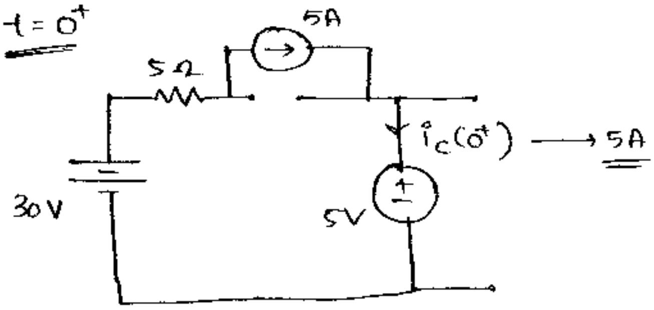


$V(0^-) = V(0) = 5V$

$5 = 30 + A_1 + A_2$

$A_1 + A_2 = -25 \longrightarrow (1)$

$t = 0^+$



$$\frac{dV(0^+)}{dt} = \frac{i_c(0^+)}{C} = \frac{5}{1/4}$$

$= 20\ V/sec.$

$$\frac{dV(t)}{dt} = -4A_1 e^{-4t} - A_2 e^{-t}$$

$\llcorner\!\!\longrightarrow t = 0$

$20 = -4A_1 - A_2 \longrightarrow (2)$

(1) & (2)

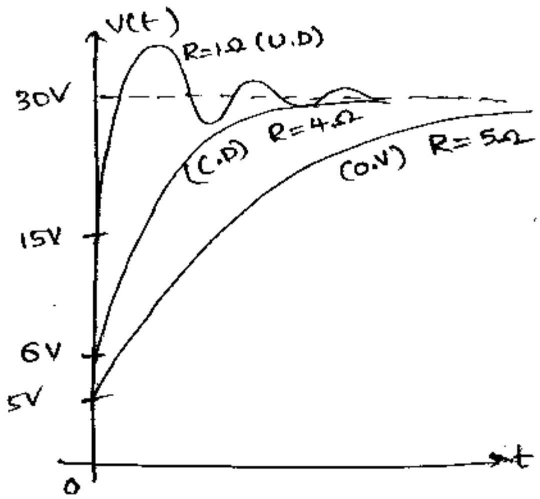
$A_1 = \frac{5}{3}$

$A_2 = \frac{-80}{3}$

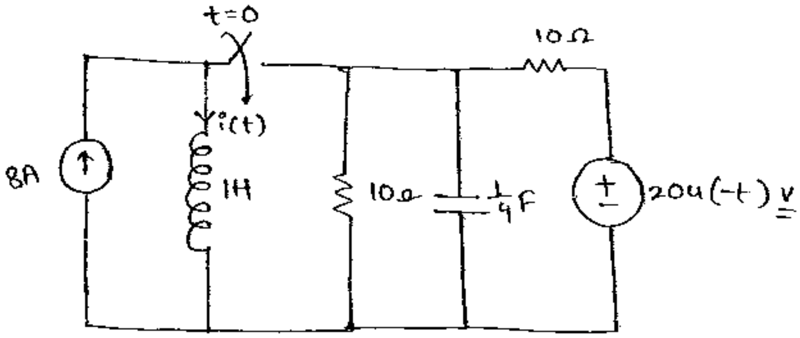
Total Response is

$$V(t) = 30 + \frac{5}{3}e^{-4t} - \frac{80}{3}e^{-t}, \quad t > 0$$

Resistor → dampers



Q determine the Complete Exp for Current $i(t)$ for all $t>0$

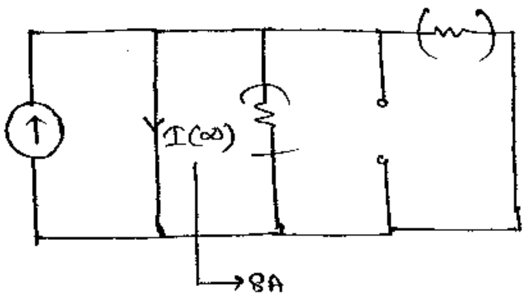


→ step Response, II order

→ parallel R-L-C

$i(t) = I_{ss}(t) + I_{tr}(t)$

I_{ss}, at $t \to \infty$



But $I_{tr}(t)$ depends upon, R, L, C

$$\alpha = \frac{1}{2\{10//10\}\frac{1}{4}} = \frac{2}{5}$$

$$\omega_0 = \frac{1}{\sqrt{1\left(\frac{1}{4}\right)}} = 2$$

$\alpha < \omega_0$

↓

U.D

$$I_{tr}(t) = e^{-\alpha t}\left[A_1 \cos\omega_d t + A_2 \sin\omega_d t\right]$$

$$\omega_d = \sqrt{\left(4 - \frac{4}{25}\right)} = \sqrt{\frac{96}{25}} = 1.96 \text{ rad/sec}$$

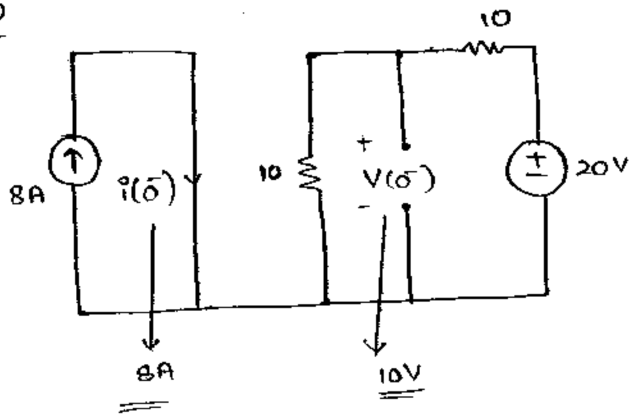
⇒ Total Responce is

$$i(t) = 8 + e^{-\frac{2t}{5}}\left[A_1 \cos 1.96t + A_2 \sin 1.96t\right], \quad t>0$$

Idea, (i) $i(0) =$ ______

(ii) $\frac{di(0)}{dt} =$ ______

$t=0^-$

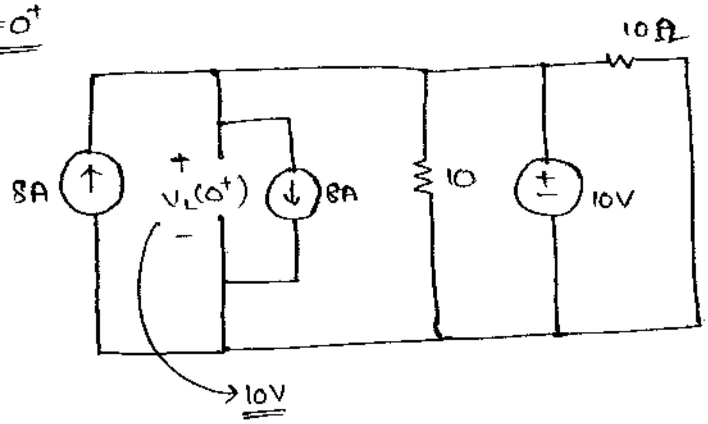


$i(0^-) = i(0) = 8A$ [use]

$8 = 8 + A_1$

$A_1 = 0 \longrightarrow (1)$

$t=0^+$



$$\frac{di(0^+)}{dt} = \frac{V_L(0^+)}{L} = \frac{10}{1} = 10\,A/sec \quad (use)$$

$$\frac{di(t)}{dt} = e^{-\frac{2t}{5}}\left[-1.96.A_1 \sin 1.96t + 1.96A_2 \cos 1.96t\right] + \left[A_1 \cos 1.96t + A_2 \sin 1.96t\right]\left[\frac{-2}{5}.e^{-\frac{2t}{5}}\right]$$

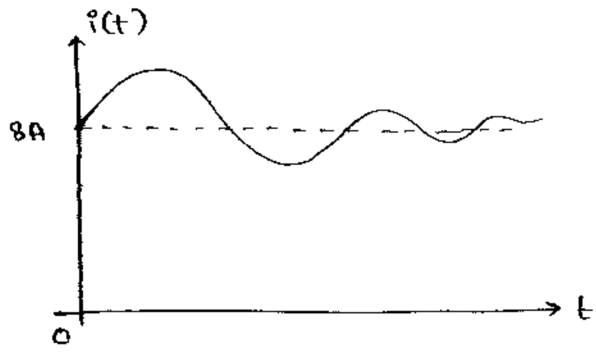
$t=0$

$$10 = 1.96A_2 - \frac{2A_1}{5} \longrightarrow (2)$$

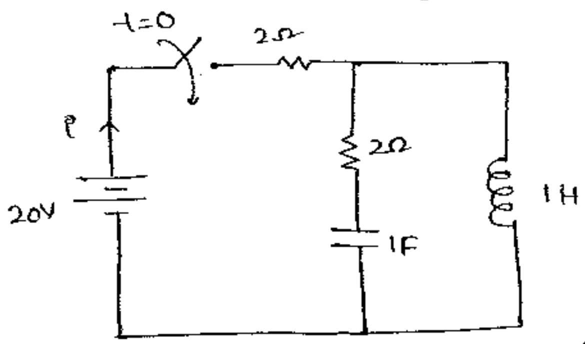
So, $A_2 = \frac{10}{1.96} = 5.1$

total Response is

$$i(t) = 8 + 5.1\,e^{-\frac{2t}{5}} \sin 1.96t \quad , t > 0.$$

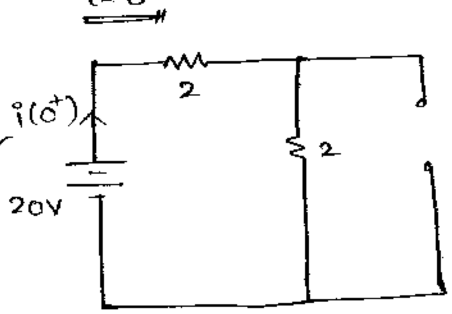


Q determine Current through Battery at $t=0^+$ & $t \to \infty$.



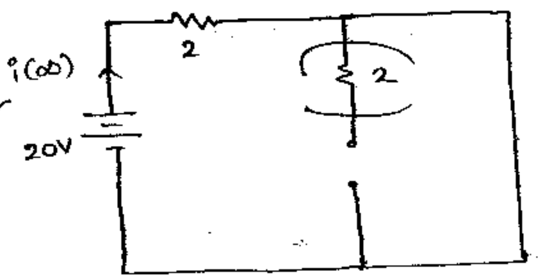
at $t=0^-$ { Intially relaxed Quescent state (ie. quite) } no initial condition

$t=0^+$



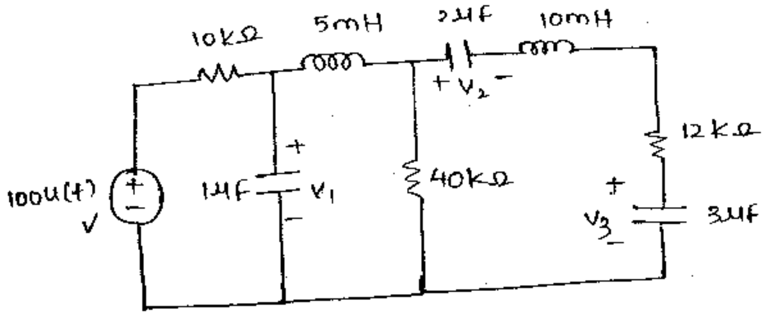
$i(0^+) = \frac{20}{4} = 5A.$

$t \to \infty$

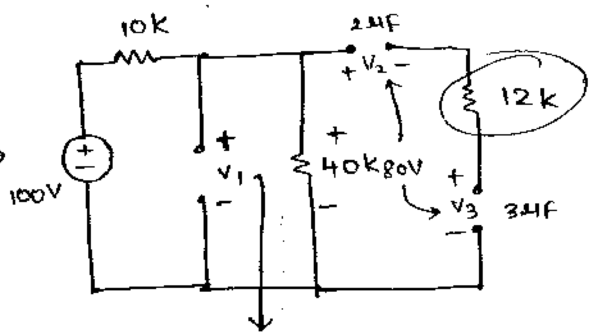


$i(\infty) = \frac{20}{2} = 10A$

Q) determine S.S Voltages across Capacitor



→



$$V_1 = 100\left[\frac{40}{40+10}\right]$$

$$V_1 = 80V,$$

$$V_2 = 80\left[\frac{3\mu}{5\mu}\right] = 48V$$

$$V_3 = 80\left[\frac{2\mu}{5\mu}\right] = 32V.$$

H.W-1

Determine Current through Batter at $t=0^+$ & $t\rightarrow\infty$

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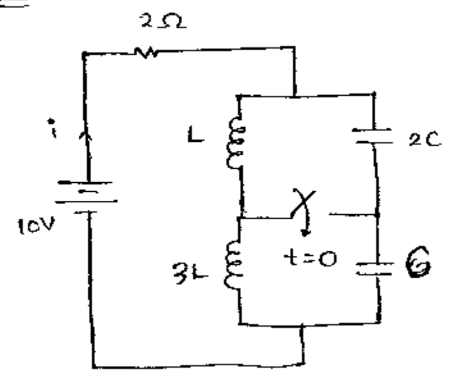
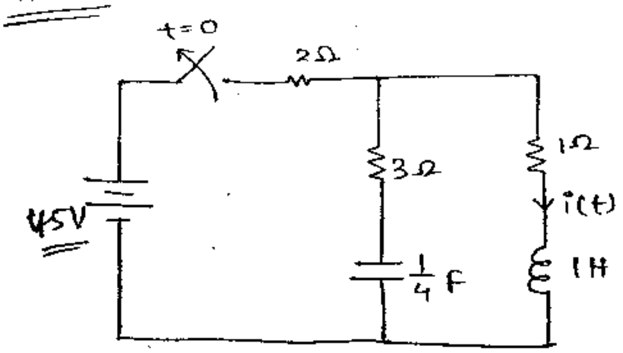


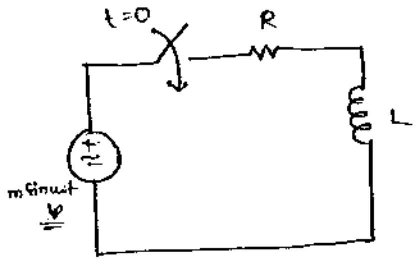
Hw-2

Determine the Complete Solution for Current $i(t)$ for all $t>0$



Category : VI : AC Trancients.

(a) R-L ckt:



$$i(t) = I_{ss}(t) + I_{tr}(t)$$

The solution is of the form

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t - \phi) + A.e^{-t/\gamma}$$

When

$$|Z| = \sqrt{R^2 + (\omega L)^2}$$

$$\phi = \tan^{-1}\left[\frac{\omega L}{R}\right]$$

$$\gamma = \frac{L}{R}$$

at $t = 0 \longrightarrow i = 0$

$$0 = \frac{V_m}{|Z|}\sin(-\phi) + A$$

$$A = +\frac{V_m}{|Z|}\sin\phi$$

Total Responce is ;

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t - \phi) + \overbrace{\frac{V_m}{|Z|}\sin\phi}^{\text{DC off set value}}.e^{-t/\gamma}, \quad t > 0.$$

Note: 1) If Input Supply is phase shifted to $V(t) = V_m \sin(\omega t + \theta)$ then output Responce is also phase shifted.

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t + \theta - \phi) + A.e^{-t/\gamma}, \quad t > 0.$$

at $t = 0 \longrightarrow i = 0$

$$0 = \frac{V_m}{|Z|}\sin(\theta - \phi) + A$$

So, total Responce is,

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t + \theta - \phi) - \frac{V_m}{|Z|}\sin(\theta - \phi)\, e^{-t/\gamma}, \quad t > 0.$$

In the above Current Expression for what circuit Condition the Current in ckt is free from Transient.

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t + \theta - \phi) - \underbrace{\frac{V_m}{|Z|}\sin(\theta-\phi)e^{-t/\tau}}_{=0}$$

$$\sin(\theta-\phi) = 0 \implies \sin(\theta-\phi) = \sin 0$$

$$\theta - \phi = 0 \Rightarrow \underline{\underline{\theta = \phi}}$$

In the above Current Expression for what circuit Condition the dc offset value is +ve maximum

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t + \theta - \phi) - \underbrace{\frac{V_m}{|Z|}\sin(\theta-\phi)e^{-t/\tau}}_{\text{positive max}}$$

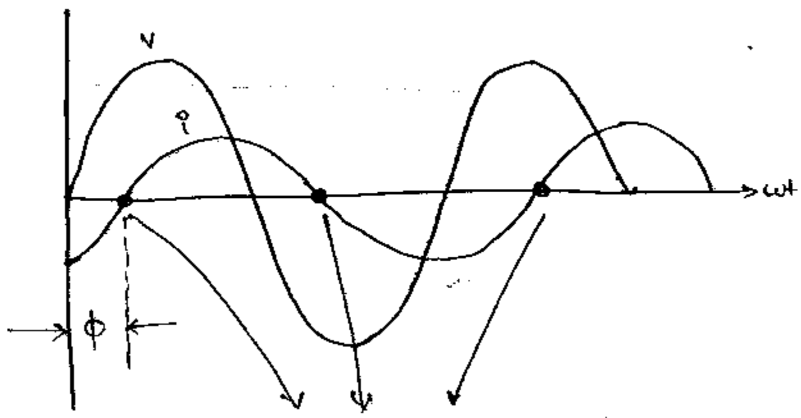
$$\sin(\theta-\phi) = -1 = \sin(-90^\circ)$$

$$\theta - \phi = -90^\circ$$

$$\theta = -90^\circ + \phi$$

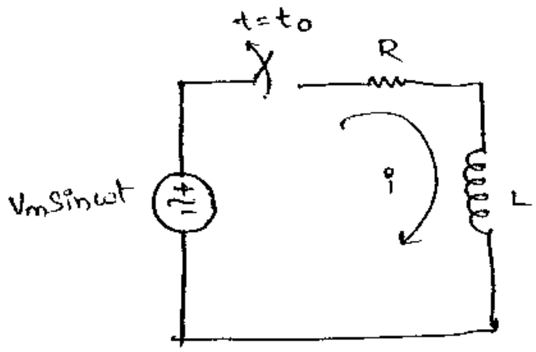
Note:2: If input Excitation is in Cosine terms then also Express the Response in Cosine terms.

Note 3: In general A.C S.S R-L circuit



Natural zero Current instances in time.

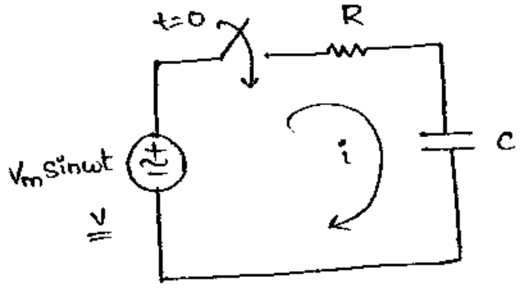
⇒ say if we can interrupt the circuit Exactly at these instances when Current is zero, we can Completely avoid Transients



at $\boxed{\omega t_0 = \phi}$ → open the Switch to avoid TRANSIENT Current

↓ Calculate t_0

(b) R-C Circuit:



$i(t) = I_{ss}(t) + I_{tr}(t)$

Theis solution of the form

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t+\phi) + A.e^{-t/\tau}$$

When $|Z| = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$

$$\phi = \tan^{-1}\left[\frac{1}{\omega RC}\right]$$

$$\tau = RC$$

at $t=0 \longrightarrow i=0$

$$0 = \frac{V_m}{|Z|}\sin(+\phi) + A$$

$$A = \frac{-V_m}{|Z|}\sin\phi$$

Total Responce is,

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t+\phi) - \frac{V_m}{|Z|}\sin\phi . e^{-t/\tau}$$

Note 1: If Input Supply is phase shifted to $V(t) = V_m \sin(\omega t + \theta)$, then Output Responce is also phase shifted

$$i(t) = \frac{V_m}{|Z|}\sin(\omega t+\theta+\phi) + A.e^{-t/\tau}, \quad t>0$$

at $t=0 \longrightarrow i=0$

$$0=\frac{V_m}{|Z|}\sin(\theta+\phi)+A$$

So, Total Response is,

$$i(t)=\frac{V_m}{|Z|}\sin(\omega t+\theta+\phi)-\frac{V_m}{|Z|}\sin(\theta+\phi)\cdot e^{-t/\tau}$$

Q In the above Current Expression for what circuit Condition the Current in the ckt is free from Transient.

$$i(t)=\frac{V_m}{|Z|}\sin(\omega t+\theta+\phi)-\underbrace{\frac{V_m}{|Z|}\sin(\theta+\phi)\cdot e^{-t/\tau}}_{=0}$$

$$\sin(\theta+\phi)=0=\sin 0^\circ \Rightarrow \theta+\phi=0^\circ$$

$$\underline{\theta=-\phi.}$$

Q In the above Current Expression for what circuit Condition the Current dc offset value of Current is +ve maximum.

$$i(t)=\frac{V_m}{|Z|}\sin(\omega t+\theta+\phi)-\frac{V_m}{|Z|}\sin(\theta+\phi)\cdot e^{-t/\tau}$$

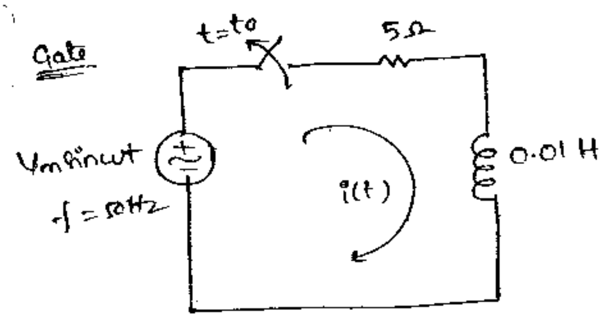
$$\sin(\theta+\phi)=-1$$
$$=\sin(-90^\circ)$$

$$\theta+\phi=-90^\circ$$

$$\boxed{\theta=-90^\circ-\phi} \qquad \phi=\tan^{-1}\left[\frac{1}{\omega RC}\right]$$

Note:2:, If Input Excitation is in Cosine terms then also Express the Response in Cosine terms

Gate



at what Switching Instant $t=t_0$ the Current in the circuit is free from Transients ?

$$\omega t_0=\phi$$

$$2\pi f t_0=\tan^{-1}\left[\frac{2\pi f L}{R}\right]$$

$$100\pi t_0=\underbrace{\tan^{-1}\left[\frac{100\pi(0.01)}{5}\right]}_{\text{Radian}}$$

$$100\pi t_0=0.56$$

$$t_0=\frac{0.56}{100\pi}=1.78$$

we can completely avoid Transients

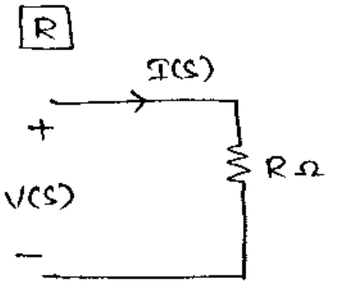
if we can open the switch Exactly after 1.78 msec, from instant of Zero crossover in Voltage

Category-VII Laplace Transforms & its applications to elec. ckt analysis and the title is Circuit Analysis in S-domain (or) Advance Circuit Analysis.

Higher order, non conventional, Special function } S-domain ✓, time domain ✗

Equivalent ckt Representation of passive elements in Laplace domain for any type of Input Excitation:

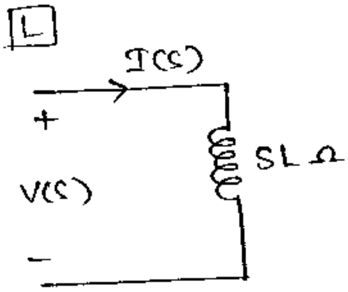
R



$$V(S) = I(S).R$$

$$\boxed{I(S) = \frac{V(S)}{R}}$$

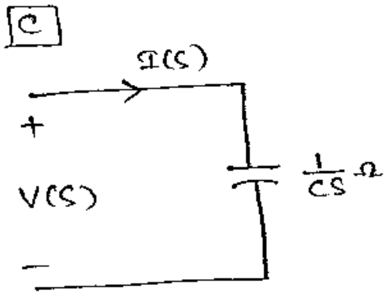
L



$$V(S) = S.L\,I(S)$$

$$\boxed{I(S) = \frac{V(S)}{S.L}}$$

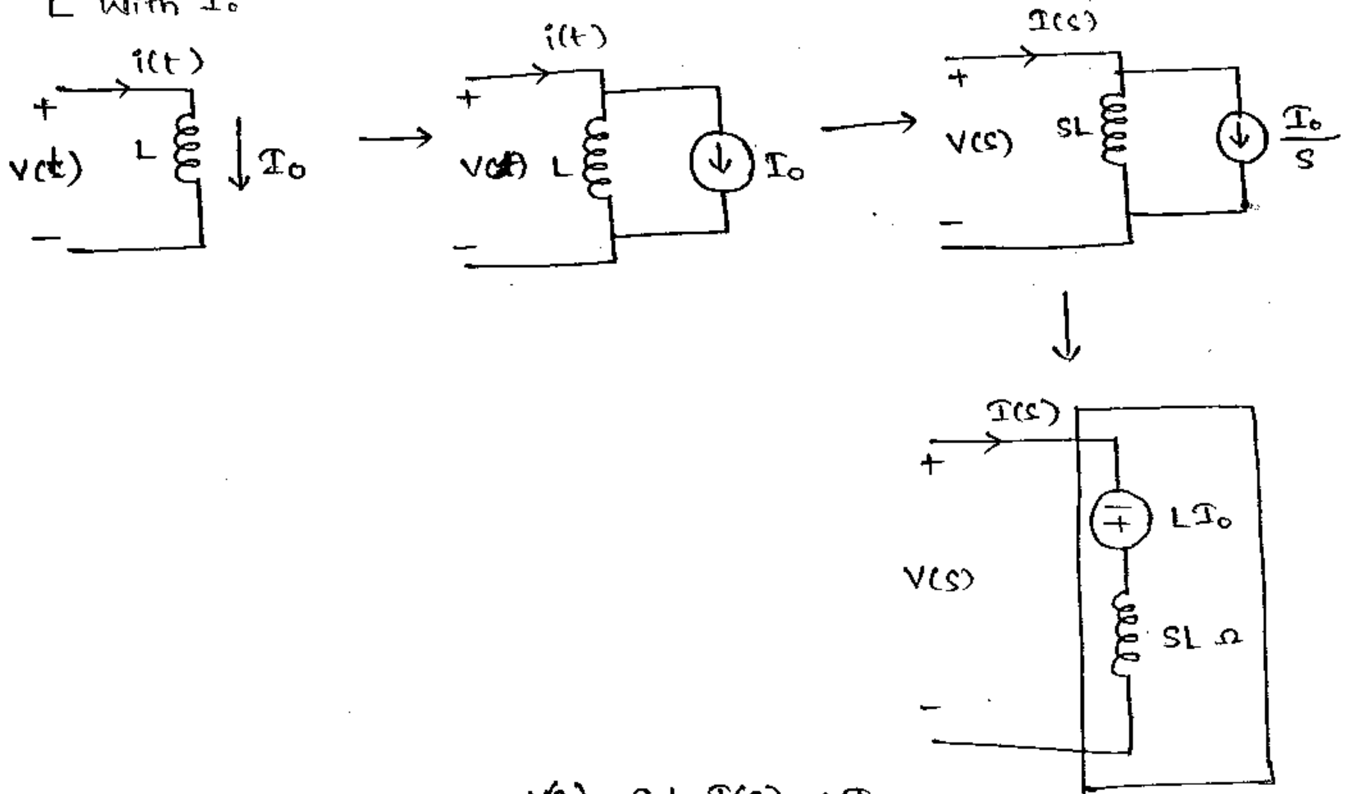
C



$$V(S) = \frac{I(S)}{CS}$$

$$\boxed{I(S) = C.S.V(S)}$$

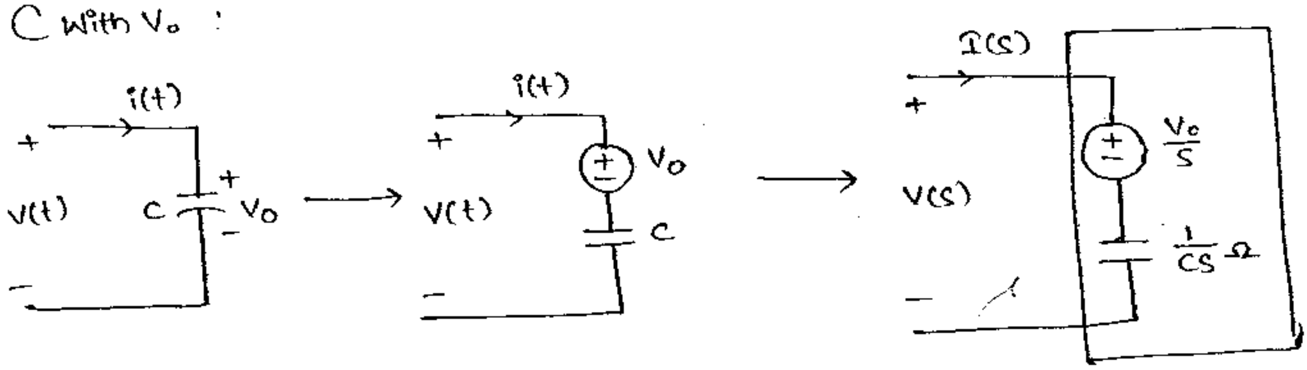
L with 'I_0'



$$V(S) = S.L.I(S) - LI_0$$

$$\boxed{I(S) = \frac{V(S)}{SL} + \frac{I_0}{S}}$$

C with V_o :



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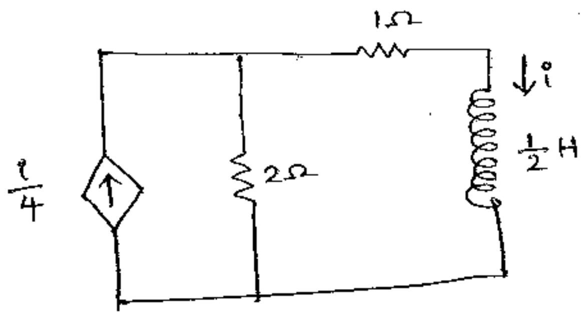
$$V(s) = \frac{I(s)}{Cs} + \frac{V_o}{s}$$

$$\boxed{I(s) = C.sV(s) - CV_o}$$

Q If $i(0) = 10A$, determine the Complete Expression for current $i(t)$, for all $t>0$. (a) in time domain analysis (b) Using Laplace Transform Analysis

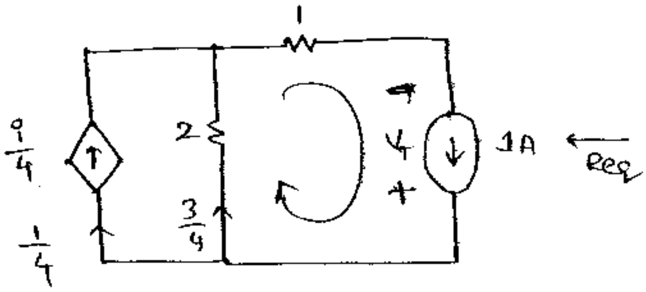


(a) time domain

→ Source free, 1^{st} order

→ S.V → 'i'

$i(t) = I_o . e^{-t/\tau}$ $\tau = \frac{L}{R_{eq}}$ $I_o = 10A$



KVL: $\frac{3}{2} + 1 - V_T = 0$

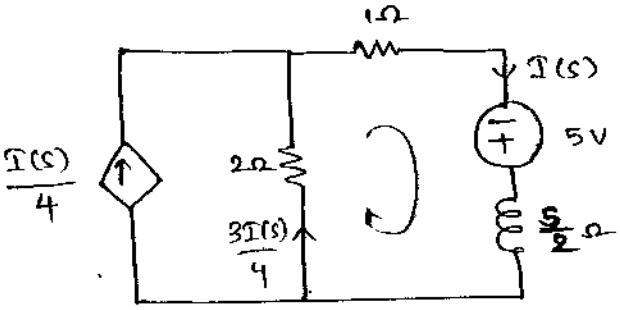
$V_T = \frac{5}{2} V$

$R_{eq} = \frac{V_T}{1A} = \frac{5/2}{1} = \frac{5}{2} \Omega$

$\tau = \frac{L}{R_{eq}} = \frac{1/2}{5/2} = \frac{1}{5}$ sec.

$i(t) = 10 . e^{-5t}, \ t>0$

(b) S-domain



KCL + KVL

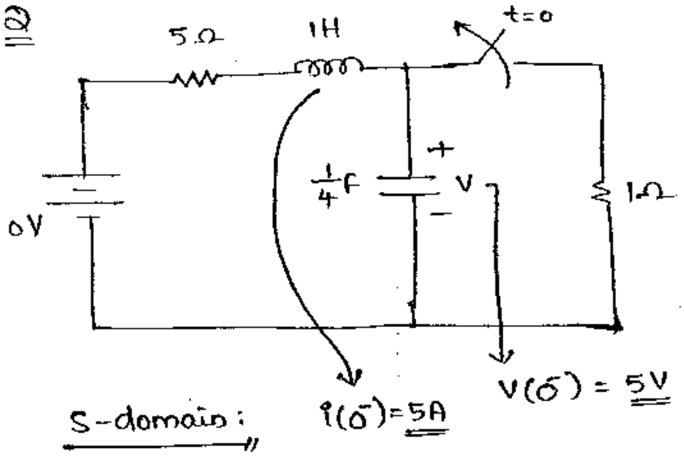
$$\frac{3}{2}I(s) + I(s) - 5 + I(s)\cdot\frac{s}{2} = 0$$

$$I(s)\left[\frac{s}{2} + \frac{5}{2}\right] = 5$$

$$I(s) = \frac{10}{s+5}$$

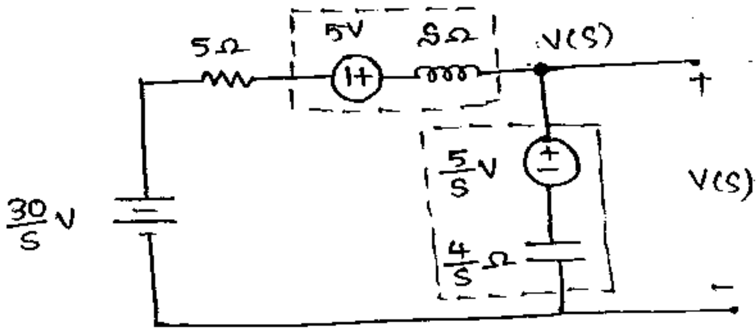
$$i(t) = L^{-1}[I(s)] = \underline{\underline{10.e^{-5t}}},\ t>0$$

12)



Determine the Complete Expression for Voltage $V(t)$ for all $t>0$ using Laplace Transform method.

S-domain:



Nodal

$$\frac{\left[V(s) - \frac{30}{s} - 5\right]}{(s+5)} + \frac{\left[V(s) - \frac{5}{s}\right]}{\frac{4}{s}} = 0$$

$$V(s)\left[\frac{1}{s+5} + \frac{s}{4}\right] = \frac{30}{s(s+5)} + \frac{5}{(s+5)} + \frac{5}{4}$$

$$V(s)\left[\frac{4+s^2+5s}{\cancel{4}(\cancel{s+5})}\right] = \frac{120+20s+5s^2+25s}{\cancel{4}\,s\,(\cancel{s+5})}$$

$$V(s) = \underbrace{\frac{5s^2+45s+120}{s(s+4)(s+1)} = \frac{A}{s} + \frac{B}{s+4} + \frac{C}{s+1}}_{\text{Partial fraction}}$$

$$A = V(s)\cdot s\Big|_{s=0} = 30$$

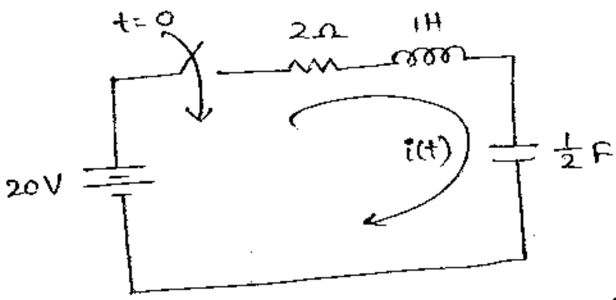
$$B = V(s)(s+4)\Big|_{s=-4} = \frac{20}{12} = \frac{5}{3}$$

$$C = V(s)(s+1)\Big|_{s=-1} = \frac{80}{(-1)(3)} = \frac{-80}{3}$$

$$V(s) = \frac{30}{s} + \frac{5}{3(s+4)} - \frac{80}{3(s+1)}$$

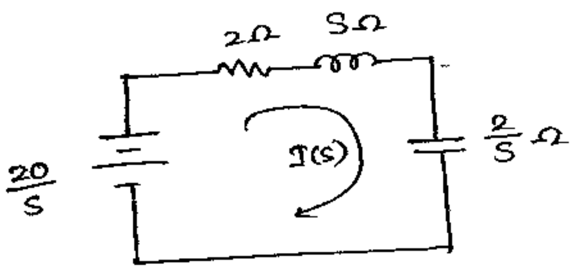
$$V(t) = L^{-1}(V(s)) = 30 + \frac{5}{3}e^{-4t} - \frac{80}{3}e^{-t}, \ t>0.$$

Gate



Determine the Complete Expression for Current $i(t)$ for all $t>0$.

↳ Intially Relaxed i.e, no Intial Conditions



KVL

$$-\frac{20}{s} + I(s)\left[2 + s + \frac{2}{s}\right] = 0$$

$$I(s)\left[\frac{s^2+2s+2}{s}\right] = \frac{20}{s}$$

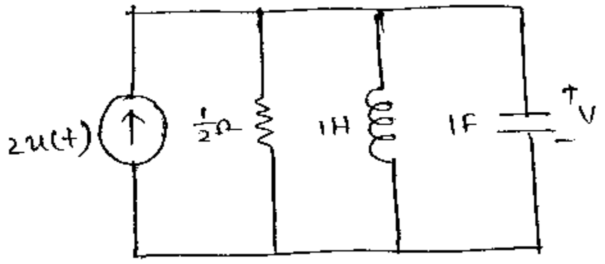
$$I(s) = \frac{20}{s^2+2s+2}$$

$$I(s) = \frac{20}{(s+1)^2+(1)^2}.$$

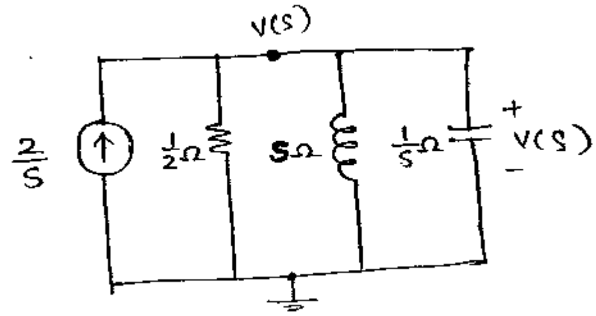
$$i(t) = L^{-1}(I(s))$$

$$= 20.e^{-t}\sin t, \ t>0.$$

determine the Complete Expression for Voltage $V(t)$ for all $t>0$.



→ Initially relaxed i.e., no Int. Cond.



$$-\frac{2}{s}+\frac{V(s)}{1/2}+\frac{V(s)}{s}+\frac{V(s)}{1/s}=0$$

$$V(s)\left[s+2+\frac{1}{s}\right]=\frac{2}{s}$$

$$V(s)\left[\frac{s^2+2s+1}{s}\right]=\frac{2}{s}$$

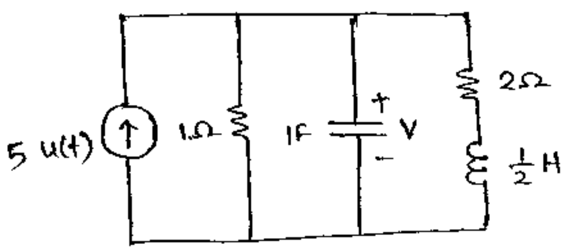
$$V(s)=\frac{2}{(s+1)^2}$$

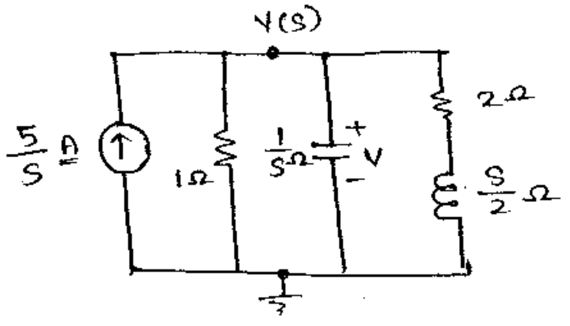
$$V(t)=L^{-1}[V(s)]=2t.e^{-t},\ t>0$$

determine the Complete Expression for voltage $V(t)$ for all $t>0$.

→ Second order; Non Canonical

→ Initially relaxed





Nodal,,

$$-\frac{5}{S}+\frac{V(s)}{1}+\frac{V(s)}{1/s}+\frac{V(s)}{(2+\frac{s}{2})}=0$$

$$V(s)\left[1+s+\frac{2}{s+4}\right]=\frac{5}{s}$$

$$V(s)\left[\frac{s+4+s^2+4s+2}{s+4}\right]=\frac{5}{s}$$

$$V(S) = \frac{5(S+4)}{S(S+3)(S+2)} = \frac{A}{S} + \frac{B}{S+3} + \frac{C}{S+2}$$

→ over damped

$A = V(S).S \Big|_{S=0} = \frac{10}{3}$

$B = V(S)(S+3) \Big|_{S=-3} = \frac{5}{3}$

$C = V(S).(S+2) \Big|_{S=-2} = -5$

$$V(S) = \frac{10}{3S} + \frac{5}{3(S+3)} - \frac{5}{(S+2)}$$

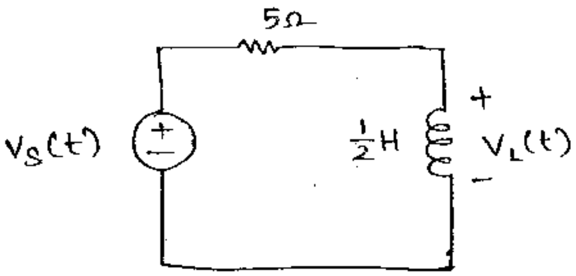
$$V(t) = L^{-1}[V(S)]$$

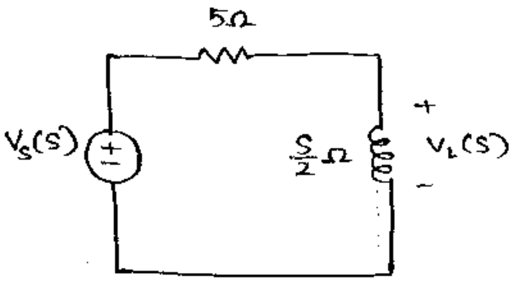
$$= \frac{10}{3} + \frac{5}{3}.e^{-3t} - 5.e^{-2t}, \; t>0.$$

Q find $V_L(t)$, $t>0$

if (a) $V_S(t) = 10.e^{-t}u(t)$

(b) $V_S(t) = 3\delta(t)$





$$V_L(S) = V_S(S)\left[\frac{S/2}{5+S/2}\right]$$

$$V_L(S) = V_S(S)\left[\frac{S}{S+10}\right]$$

(a) $V_S(t) = 10.e^{-t}u(t)$

$$V_S(S) = \frac{10}{S+1}$$

$$V_L(S) = \frac{10S}{(S+1)(S+10)} = \frac{A}{S+10} + \frac{B}{S+1}$$

$A = \frac{100}{9}$, $B = \frac{-10}{9}$

$$V_L(S) = \frac{100}{9(S+10)} - \frac{10}{9(S+1)}$$

$$V_L(t) = L^{-1}[V_L(S)] = \frac{100}{9}e^{-10t} - \frac{10}{9}e^{-t}, \; t>0$$

(b). $V_s(t) \longrightarrow 3\delta(t)$

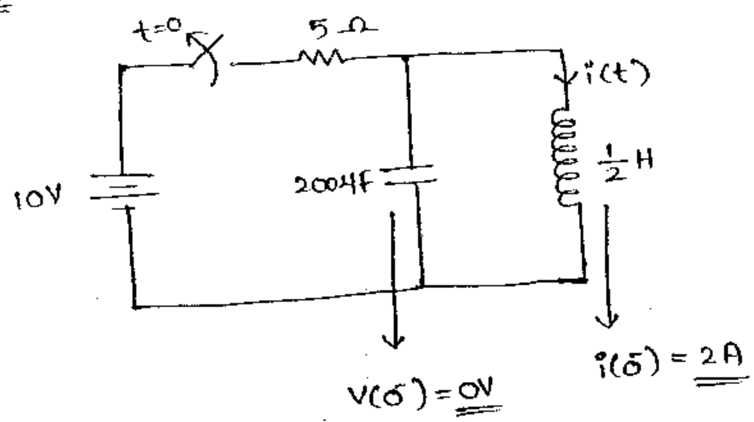
$V_s(S) \longrightarrow 3$

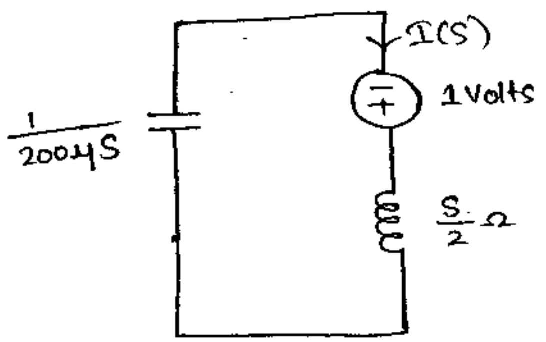
$$V_L(S) = \frac{3S}{S+10} = 3\left[\frac{S+10-10}{S+10}\right]$$

$$V_L(S) = 3\left[1 - \frac{10}{S+10}\right]$$

$$V_L(t) = L^{-1}\left[V_L(S)\right] = 3\left[\delta(t) - 10.e^{-10t}\right], \underline{t>0}$$

Q determine the Complete Expression for current i(t) for all $t>0$.





KVL,

$$I(S)\left[\frac{S}{2} + \frac{1}{200\mu S}\right] = 1.$$

$$I(S)\left[S + \frac{10^6}{100S}\right] = 2$$

$$I(S)\left[\frac{S^2+10^4}{S}\right] = 2$$

$$I(S) = \frac{2S}{S^2+10^4}$$

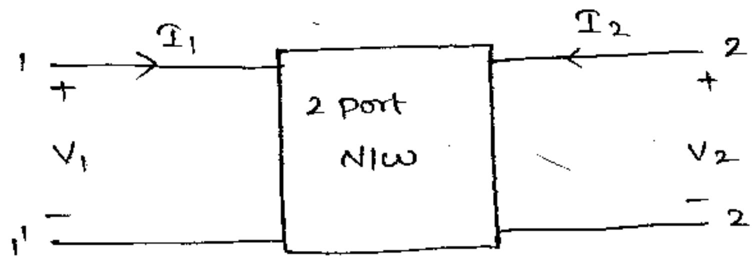
$$I(S) = \frac{2S}{S^2+(100)^2}$$

$$i(t) = L^{-1}\left[I(S)\right]$$

$$= 2\cos 100t, \underline{t>0}$$

TWO PORT NETWORKS

⇒ It Consists of two pairs of terminals describing the N/w where the +ve reference ~~Curren~~' Voltage polarities & Current directions are shown as below.



⇒ Here, out of 4 parameters, V_1 V_2 I_1 & I_2 two of them are Considered as dependent & other two as Independent. So we have $^4C_2$ i.e., = 6 types of parameters With Which we can model this two port N/ws.

they are $[Z]$, $[Y]$, $[h]$, $\begin{bmatrix} A & B \\ C & D \end{bmatrix}$, $\underbrace{[g], \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix}}_{\times}$

Z BUS, Y BUS, Transistor, Power System

⇒ The N/ws inside the ports ~~as~~ Considered as Block Box where it should Consist of linear, passive, Bilateral elements.

⇒ The N/w inside may also have Energy storage elements L & C but their Intial Conditions must be Zero.

⇒ The N/w inside may also have dependent sources but never an Inedependent Source in it.

Concept of Symmetry in 2-port N/w:

if the ratio of Excitation to Responce at Both the ports are Independently Equal w.r.t the given N/w Conditions such as open circuit (or) Short circuit etc. is Said to be Symmetrical.

fig (a)

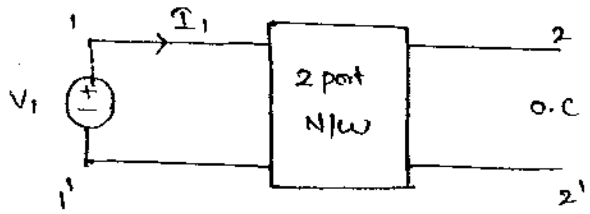
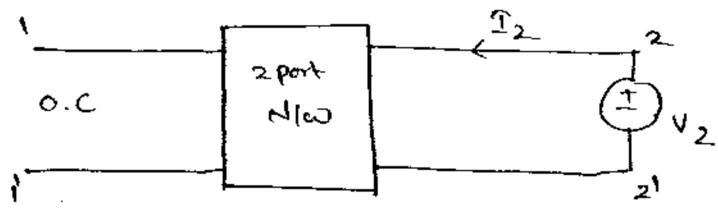


fig (b)



If N/w is symmetrical, then

$$\boxed{\frac{V_1}{I_1} = \frac{V_2}{I_2}}$$

Note: In the case of small Independent passive N/ws symmetry can be Identified as mirror Image property w.r.t ports.

Concept of Reciprocity in 2-port N/ws:

If the 2-port N/w obey's Reciprocity theorem, However any Linear, passive, Bilateral N/w is always Reciprocal. Since, Reciprocity means passivity.

) Z-parameters (Open Circuit Impedence parameters):

Here $V_1\ V_2 \longrightarrow$ dependent

$I_1\ I_2 \longrightarrow$ Independent

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

Condition for Symmetry : $Z_{11} = Z_{22}$

Reciprocity : $Z_{12} = Z_{21}$

II. $[Y]$ → Short circuit admittance parameters.

$I_1\ I_2 \longrightarrow$ dependent

$V_1 V_2 \longrightarrow$ Independent.

$$I_1 = Y_{11}V_1 + Y_{12}V_2$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

Symmetry : $Y_{11} = Y_{22}$

Reciprocity : $Y_{12} = Y_{21}$

III. $[h] \longrightarrow$ hybrid circuit parameters.

$V_1 I_2 \longrightarrow$ dependent

$I_1\ V_2 \longrightarrow$ Independent.

$$V_1 = h_{11}I_1 + h_{12}V_2$$

$$I_2 = h_{21}I_1 + h_{22}V_2$$

Symmetry : $(h_{11}h_{22} - h_{12}h_{21}) = 1$

Reciprocity : $h_{12} = -h_{21}$

Note: $[g] \longrightarrow$ Inverse Hybrid circuit parameters.

$$I_1 = g_{11}V_1 + g_{12}I_2$$

$$V_2 = g_{21}V_1 + g_{22}I_2$$

Symmetry : $(g_{11}g_{22} - g_{12}g_{21}) = 1.$

Reciprocity : $g_{12} = -g_{21}$

Q

IV. $\begin{bmatrix} A & B \\ C & D \end{bmatrix}$ / $[T]$ $\longrightarrow$ Transmission circuit parameters.

$V_1\ I_1 \longrightarrow$ dependent

$V_2\ I_2 \longrightarrow$ Independent

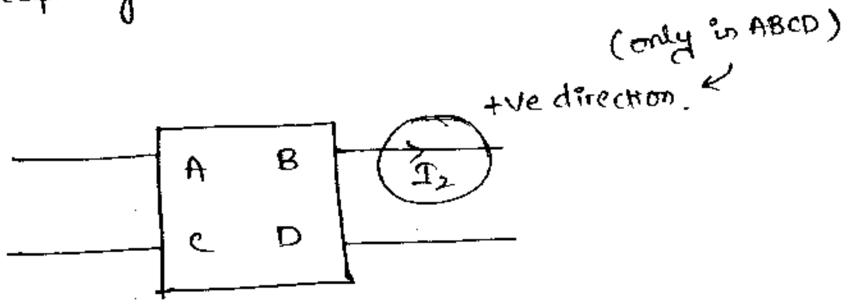
$$V_1 = AV_2 + BI_2$$

$$I_1 = CV_2 + D\,I_2$$

Symmetry : $A = D$

Reciprocity : $(AD - BC) = 1$

Note :



Note: $\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix}$ $\longrightarrow$ Inverse Transmission Circuit parameters.

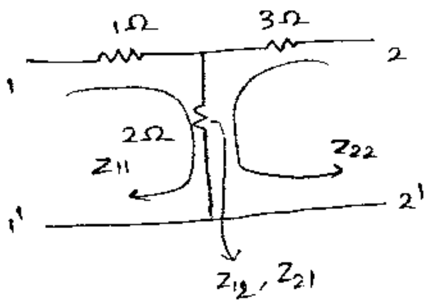
$$V_2 = A'V_1 + B'I_1$$

$$I_2 = C'V_1 + D'I_1$$

Symmetry : $A' = D'$

Reciprocity : $(A'D' - B'C') = 1$.

Q. Determine the Z-parameters



$$[Z] = \begin{bmatrix} 1+2 & 2 \\ 2 & 2+3 \end{bmatrix}$$

$$= \begin{bmatrix} 3 & 2 \\ 2 & 5 \end{bmatrix} \Omega$$

(or) procedure

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

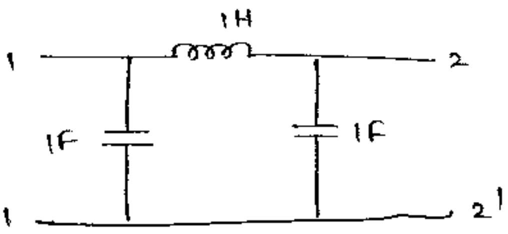
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$Z_{11} \ \& \ Z_{21} \longrightarrow I_2 = 0 = \text{O.C}$$

$$V_1 = 3 I_1 \longrightarrow Z_{11} = 3\Omega$$

$$V_2 = 2 I_1 \longrightarrow Z_{21} = 2\Omega$$

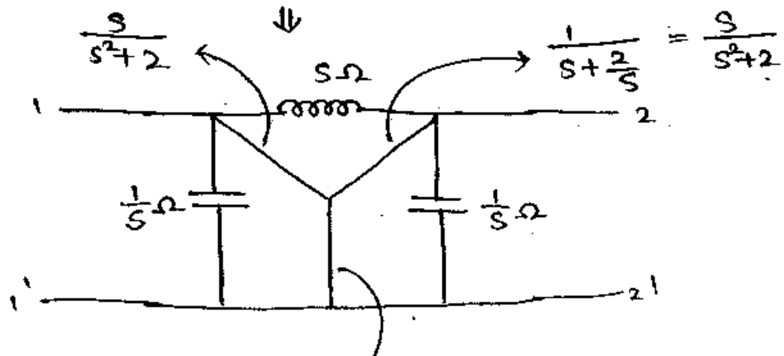
<u>1Q</u> $[Z] =$



$\Rightarrow$ Convert to s-domain

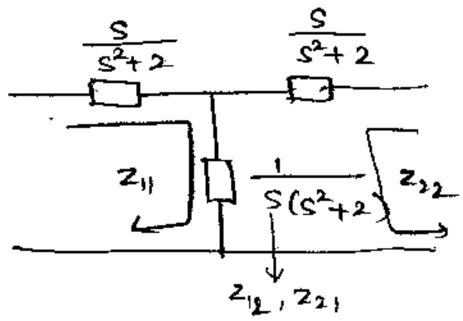
∵ We want to convert into parameter of any freq.

$\Downarrow$



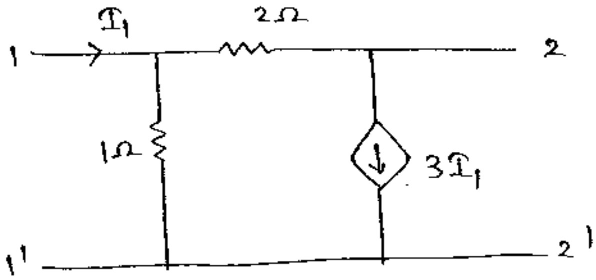
$$\frac{\frac{1}{s^2}}{s+\frac{2}{s}} = \frac{1}{s(s^2+2)}$$

$\Rightarrow$

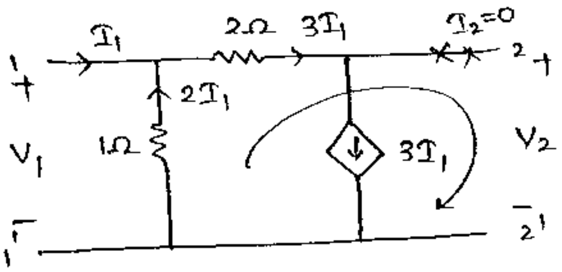


$$[Z] = \begin{bmatrix} \frac{s^2+1}{s(s^2+2)} & \frac{1}{s(s^2+2)} \\ \frac{1}{s(s^2+2)} & \frac{s^2+1}{s(s^2+2)} \end{bmatrix}$$

Gate. $[z] =$ ____



Z_{11} & $Z_{21} \longrightarrow I_2 = 0$

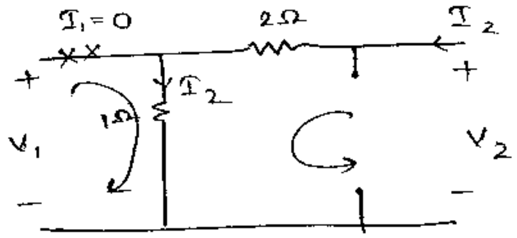


$V_1 = -2I_1 \longrightarrow Z_{11} = -2\Omega$

$2I_1 + 6I_1 + V_2 = 0 \longrightarrow V_2 = -8I_1$

$Z_{21} = -8\Omega$

Z_{22} & $Z_{12} \longrightarrow I_1 = 0$

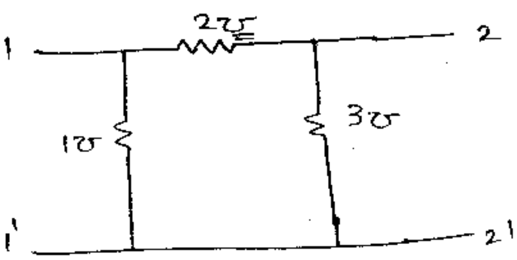


$V_2 = 3I_2 \longrightarrow Z_{22} = 3\Omega$

$V_1 = I_1 \longrightarrow Z_{12} = 1\Omega$

$$[z] = \begin{bmatrix} -2 & 1 \\ -8 & 3 \end{bmatrix} \Omega$$

* $[Y] =$ ____



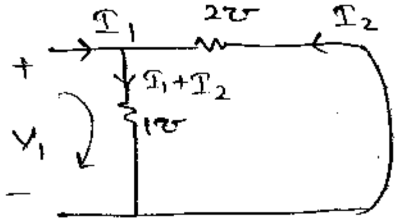
Y in admittan & π network, then apply short cut

$$[Y] = \begin{bmatrix} 3 & -2 \\ -2 & 5 \end{bmatrix}$$

procedure -

$$I_1 = Y_{11}V_1 + Y_{12}V_2$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2$$



Y_{11} & Y_{21} $\longrightarrow V_2 = 0$

$$V_1 = \frac{I_1+I_2}{1} \longrightarrow ①$$

$$\frac{I_2}{2} + \frac{I_1+I_2}{1} = 0$$

$$I_1 = -\frac{3}{2}I_2 \longrightarrow ②$$

$\underline{\underline{Y_{11}}}$

$$V_1 = I_1 + \left[\frac{-2}{3}\right]I_1$$

$$V_1 = \frac{I_1}{3} \longrightarrow \underline{\underline{Y_{11} = 3℧}}$$

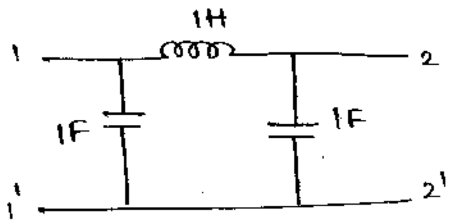
$\underline{\underline{Y_{21}}}$

$$V_1 = -\frac{3}{2}I_2 + I_2$$

$$V_1 = \frac{-I_2}{2}$$

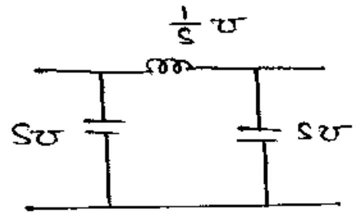
$$Y_{21} = \underline{\underline{-2℧}}$$

$\underline{\underline{Q}}$



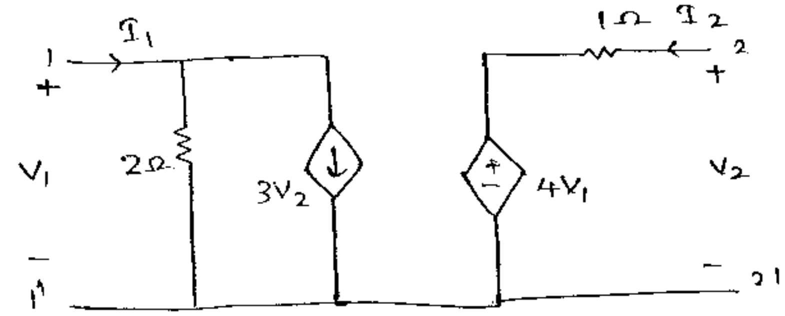
$[Y] =$

$\longrightarrow$ convert to s-domain admitance

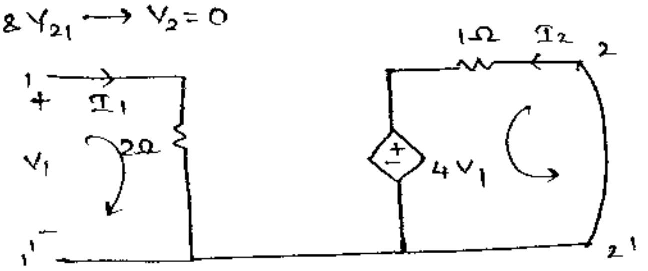


$$\begin{bmatrix} s+\frac{1}{s} & \frac{-1}{s} \\ \frac{-1}{s} & s+\frac{1}{s} \end{bmatrix} = \begin{bmatrix} \frac{s^2+1}{s} & \frac{-1}{s} \\ \frac{-1}{s} & \frac{s^2+1}{s} \end{bmatrix} \underline{\underline{℧}}$$

Gate $[Y] = \_\_\_\_$



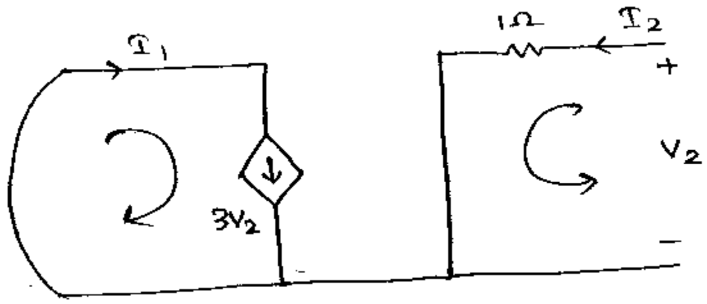
Y_{11} & $Y_{21} \longrightarrow V_2 = 0$



$$V_1 = 2I_1 \longrightarrow Y_{11} = \frac{1}{2}\,\mho$$

$$I_2 = -4V_1 \longrightarrow Y_{21} = -4\,\mho$$

Y_{22} & $Y_{12} \longrightarrow V_1 = 0$

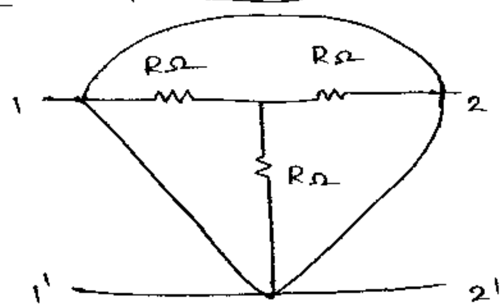


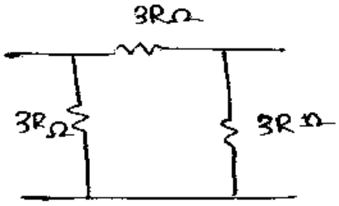
$$V_2 = I_2 \longrightarrow Y_{22} = 1\,\mho$$

$$I_1 = 3V_2 \longrightarrow Y_{12} = 3\,\mho$$

$$[Y] = \begin{bmatrix} 1/2 & 3 \\ -4 & 1 \end{bmatrix} \mho$$

Gate $Y_{21} =$ ______





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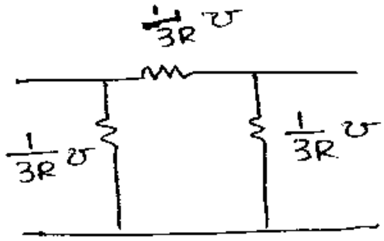
$\Downarrow$



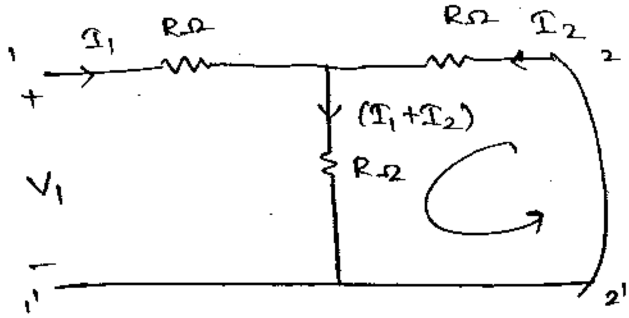
$$\Rightarrow Y = \begin{bmatrix} \frac{1}{3R}+\frac{1}{3R} & -\frac{1}{3R} \\ \frac{-1}{3R} & \frac{1}{3R}+\frac{1}{3R} \end{bmatrix}$$

$\downarrow$

$$Y_{21} = \frac{-1}{3R}$$

for the above N/w find h_{21}

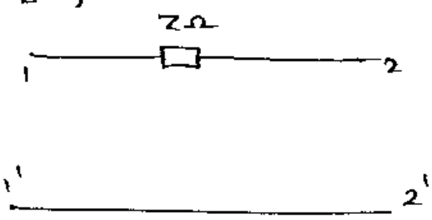
$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$$



$$R I_2 + R\,(I_1+I_2) = 0$$

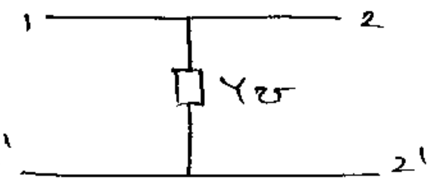
$$I_1 = -2I_2 \longrightarrow h_{21} = \frac{I_2}{I_1} = \frac{-1}{2}$$

$[T] =$



$$[T] = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

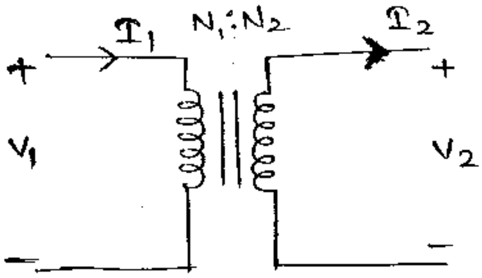
$[T] =$ ______



$$[T] = \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

Gate $[T] =$ ______

Ideal T/F is Reciprocal



$$K = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_1}$$

$$V_1 = \left[\frac{N_1}{N_2}\right] V_2 + [0] I_2$$

$$I_1 = [0] V_2 + \left[\frac{N_2}{N_1}\right] I_2 .$$

$$[T] = \begin{bmatrix} (N_1/N_2) & 0 \\ 0 & (N_2/N_1) \end{bmatrix}$$

$\Downarrow$

$AD - BC = 1.$

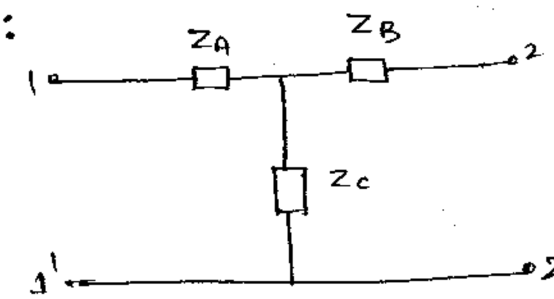
$\Downarrow$

Ideal Transformer is Reciprocal

Note: two port N/ws allows us to model our Complex practical N/ws & Systems into their Simple mathematical Subcircuit models. Such as T, TT, Lattice, T-T, Bridged-T, Ladder N/ws ... etc. Using such Simplified mathematical Equivalents of Original N/w we can still determine the performance of original Network in terms of these two port N/w parameters.

Ex: Modelling our medium distance Tr. line N/ws as T (or) TT model. using A.BCD parameters from which we can determine the Regulation, power factor, Efficiency of original Tr. line N/w

$\Rightarrow$ 1. T Eq. Representation of a Two port Reciprocal N/w in terms of z-parameters:

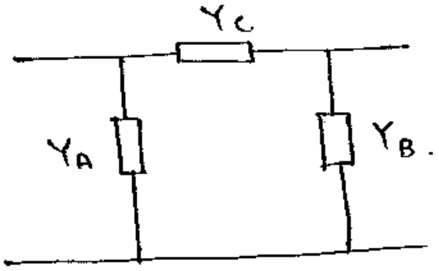


$$Z_A = (Z_{11} - Z_{12})$$

$$Z_B = (Z_{22} - Z_{21})$$

$$Z_C = Z_{12} = Z_{21}$$

2. π Eq. Representation of a two port Reciprocal N/w interms of Y-parameters

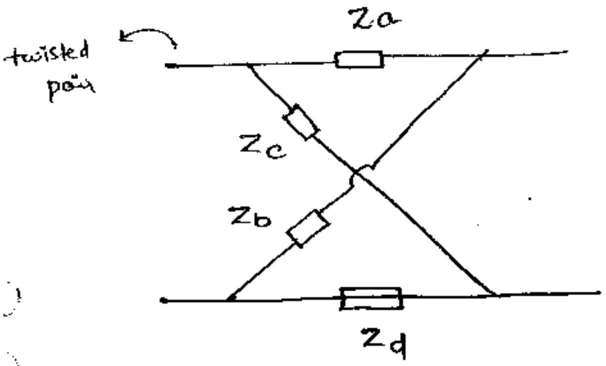


$$Y_A = Y_{11} + Y_{12}$$

$$Y_B = Y_{22} + Y_{21}$$

$$Y_C = -Y_{12} = -Y_{21}$$

3. Lattice N/w :



if

$(Z_a = Z_d)$ & $(Z_b = Z_c)$ } Symmetrical & Balanced Lattices

if

$(Z_a \neq Z_d)$ or $(Z_b \neq Z_c)$ } Assymmetrical & unbalanced lattice

Representation of lattice N/w in terms of Z-parameters provided it is Symmetrical & Balanced :

$$Z_{11} = Z_{22} = \frac{Z_b + Z_a}{2}$$

$$Z_{12} = Z_{21} = \frac{Z_b - Z_a}{2}$$

$$\boxed{Z_{11} + Z_{12} = Z_b}$$

$$\boxed{Z_{11} - Z_{12} = Z_a}$$

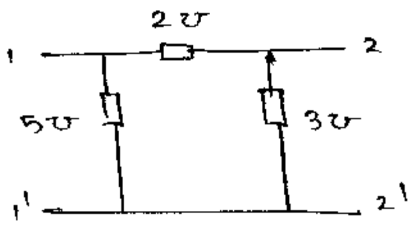
Gate

The port Currents of a 2 port N/w are given by $I_1 = 7V_1 - 2V_2$
$I_2 = -2V_1 + 5V_2$

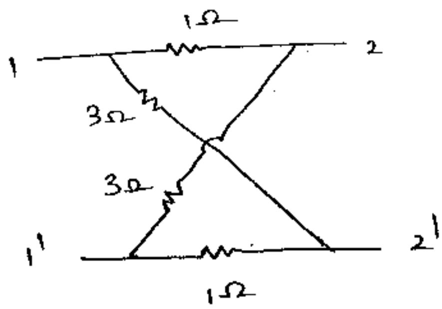
then its Eq. π model is ____

$$[Y] = \begin{bmatrix} 7 & -2 \\ -2 & 5 \end{bmatrix} \mho$$

$\because Y_{12} = Y_{21} \Rightarrow$ N/w is Reciprocal
so, π model is possible



ies $[Z]$ = ____



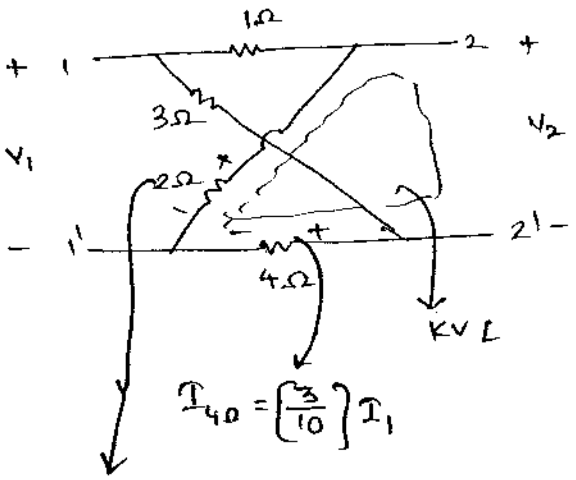
$\because$ it is symmetrical & balanced lattice. so we can determine $[Z]$ parameters directly

$$Z_{11} = Z_{22} = \frac{3+1}{2} = 2\Omega$$

$$Z_{12} = Z_{21} = \frac{3-1}{2} = 1\Omega$$

$$[Z] = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \Omega$$

Gate find $[Z]$ = ____



$I_{4\Omega} = \left[\frac{3}{10}\right] I_1$

$I_{2\Omega} = I_1 \left[\frac{7}{10}\right]$

$Z_{11} = 3 // 7 = 2.1\Omega$

$Z_{22} = 6 // 4 = 2.4\Omega$

$Z_{11} = Z_{21} \Rightarrow$ [$\because$ passive N/w is, Reciprocal] find $Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$

$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0}$

$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0.}$

KVL + C. Div. Rule

$$+V_2 + 4\cdot\frac{6}{10}I_1 - \frac{7}{10}I_1\cdot 2 = 0$$

$$V_2 = \frac{1}{5}I_1$$

$$Z_{21} = 0.2\Omega = Z_{12}$$

$$[z] = \begin{bmatrix} 2.1 & 0.2 \\ 0.2 & 2.4 \end{bmatrix}\Omega$$

Note:

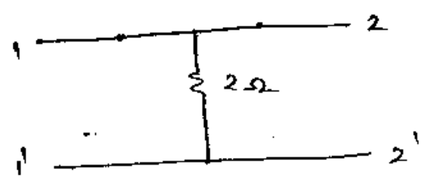
$$[z] = [Y]^{-1} \quad \& \quad [Y] = [z]^{-1}$$

$$[h] = [g]^{-1} \quad \& \quad [g] = [h]^{-1}$$

$$\boxed{[T] = [T']^{-1} \quad \& \quad [T'] = [T]^{-1}}$$

↳ Invertable only is N/w is Reciprocal.

Gate find $[Y] =$

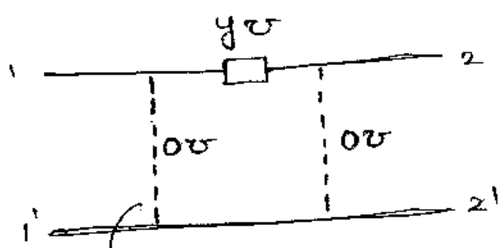


$$[z] = \begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$$

$\det|z| = 0 \longrightarrow$ singular Matrix

so, $[Y]$ doesnot Exists.

IES find $[Y]$ & then $[Z]$



o.c ckt Impedence = ∞

o.c ckt admitance = 0

$$[Y] = \begin{bmatrix} y & -y \\ -y & y \end{bmatrix}$$

$\det|Y| = 0$

↳ singular Matrix

so, $[Z]$ does n't Exists.

Inter Conversion b/w two port N/w parameters:

Ex: determine h-parameters in terms of Y-parameters.

$\boxed{Y}$

$$\begin{cases} I_1 = Y_{11}V_1 + Y_{12}V_2 \\ I_2 = Y_{21}V_1 + Y_{22}V_2 \end{cases}$$

$\boxed{h}$

$$V_1 = h_{11}I_1 + h_{12}V_2$$

$$I_2 = h_{21}I_1 + h_{22}V_2$$

h_{11} & $h_{21} \longrightarrow V_2 = 0$

$$V_2 = 0 \quad \begin{cases} I_1 = Y_{11}V_1 \\ I_2 = Y_{21}V_1 \end{cases}$$

$$h_{11} = \frac{V_1}{I_1} = \frac{1}{Y_{11}}$$

$$h_{21} = \frac{I_2}{I_1} = \frac{Y_{21}}{Y_{11}}$$

h_{22} & $h_{12} \longrightarrow I_1 = 0$

$$I_1 = 0 \quad \begin{cases} Y_{11}V_1 = -Y_{12}V_2 \\ I_2 = Y_{21}V_1 + Y_{22}V_2. \end{cases}$$

$$h_{22} = \frac{I_2}{V_2} = \frac{\Delta Y}{Y_{11}}$$

$$I_2 = Y_{21}\left[\frac{-Y_{12}}{Y_{11}}\right]V_2 + Y_{22}V_2$$

$$I_2 = V_2\left[\frac{Y_{11}Y_{22} - Y_{21}Y_{12}}{Y_{11}}\right]$$

$$I_2 = \left[\frac{\Delta Y}{Y_{11}}\right] \cdot V_2$$

$$h_{12} = \frac{V_1}{V_2} = \frac{-Y_{12}}{Y_{11}}$$

$$[h] = \begin{bmatrix} \frac{1}{Y_{11}} & \frac{-Y_{12}}{Y_{11}} \\ \frac{Y_{21}}{Y_{11}} & \frac{\Delta Y}{Y_{11}} \end{bmatrix}$$

IES find Z_{12} & Z_{21} in terms of $\begin{bmatrix} A & B \\ C & D \end{bmatrix}$

In ABCD I_2 direction is opposite to the other parameter

∴ take +ve direction of I_2 by −ve sign

$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$$

$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$

$$V_1 = AV_2 - BI_2$$

$$I_1 = CV_2 - DI_2$$

$Z_{12} \Longrightarrow I_1 = 0$

$$CV_2 = DI_2$$

$$V_1 = A\left[\frac{D}{C}\right]I_2 - BI_2$$

$$V_1 = \left[\frac{\Delta T}{C}\right] \cdot I_2$$

$$Z_{12} = \frac{\Delta T}{C}$$

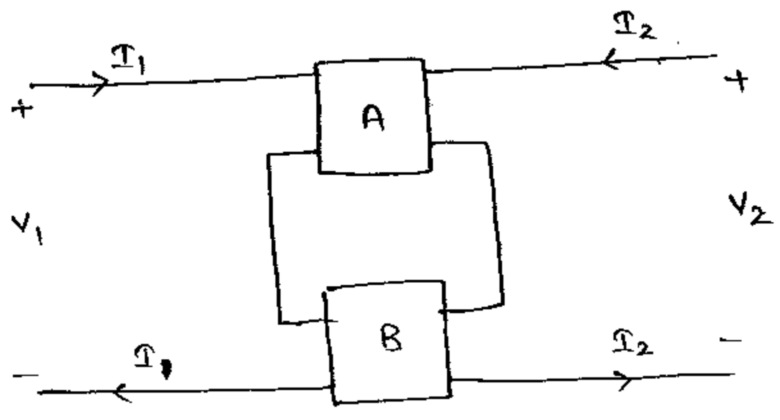
$Z_{21} \Longrightarrow I_2 = 0$

$$I_1 = CV_2$$

$$Z_{21} = \frac{V_2}{I_1} = \frac{1}{C}$$

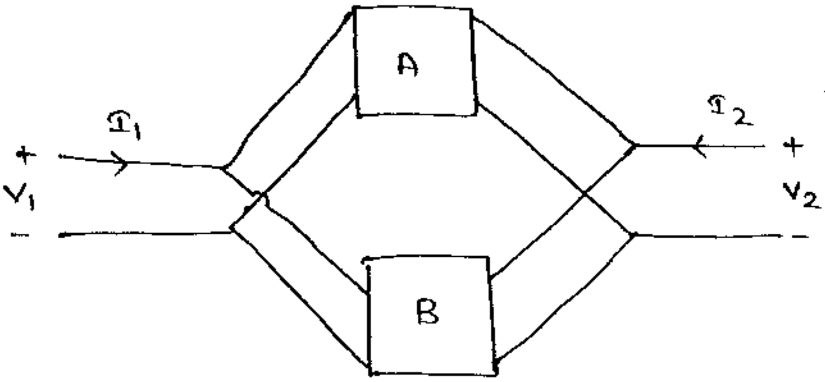
Inter Connection b/w two-twoport N/ws:

I. Series - Series



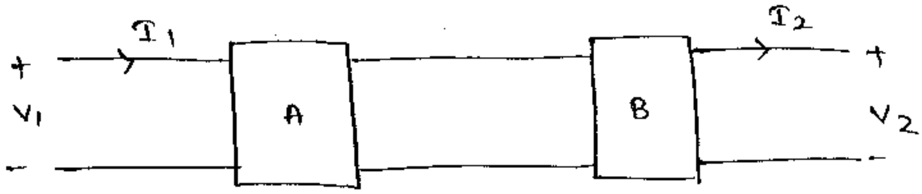
$$[Z_T] = [Z_A] + [Z_B]$$

II. parallel-parallel.



$$[Y_T] = [Y_A] + [Y_B]$$

III. cascaded / chain / Tandem :



∵ it is a P.S N/w

P.S N/w is a cascaded sys.

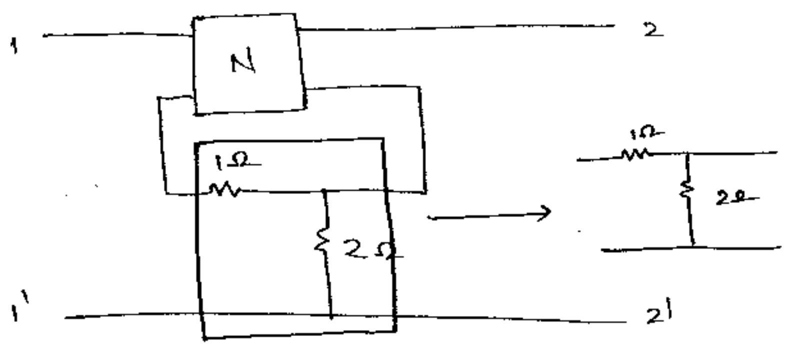
Distribution sys is a parallel system

$$[T_T] = [T_A] \cdot [T_B]$$

↑ multiply.

Gate

If $[Z_n] = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \Omega$ total $[Z]$ of entire N/w is ______



$$\Rightarrow [Z] = \begin{bmatrix} 3 & 2 \\ 2 & 2 \end{bmatrix}$$

$$[Z]_{Total} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} + \begin{bmatrix} 3 & 2 \\ 2 & 2 \end{bmatrix}$$

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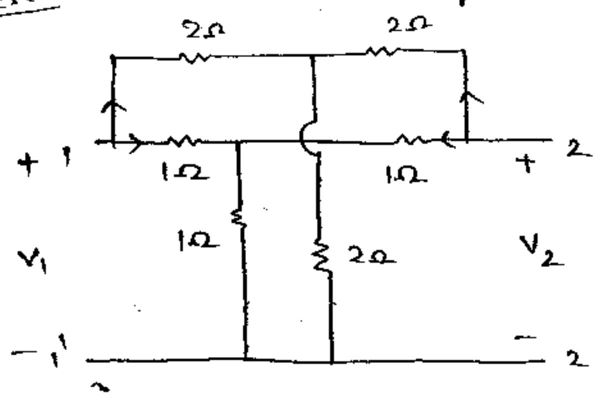
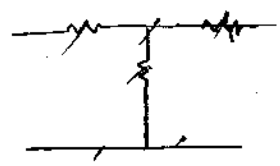
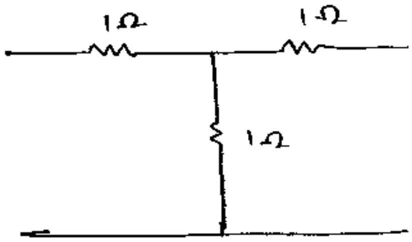
$$= \begin{bmatrix} 4 & 4 \\ 5 & 6 \end{bmatrix} \Omega$$

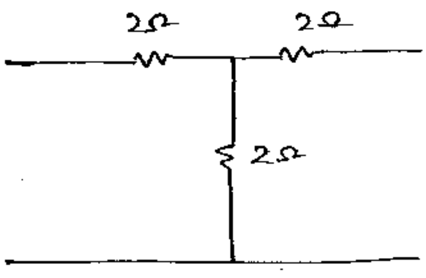
IES(c) $[Y] =$ ___ → two T N/Ws Connected in parallel.







$$\longrightarrow [Z_A] = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \longrightarrow [Y_A] = [Z_A]^{-1} = \begin{bmatrix} \frac{2}{3} & \frac{-1}{3} \\ \frac{-1}{3} & \frac{2}{3} \end{bmatrix} \mho$$

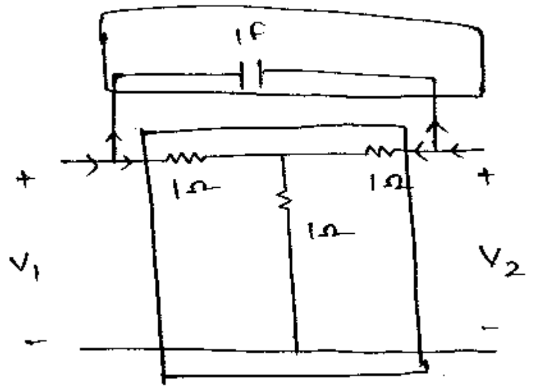


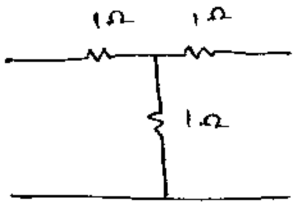
$$\longrightarrow [Z_B] = \begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix} = [Y_B] = [Z_B]^{-1} = \begin{bmatrix} \frac{1}{3} & \frac{-1}{6} \\ \frac{-1}{6} & \frac{1}{3} \end{bmatrix} \mho$$

$$[Y_T] = [Y_A] + [Y_B] = \begin{bmatrix} 1 & -\frac{1}{2} \\ -\frac{1}{2} & 1 \end{bmatrix} \mho$$

<u>Gate</u>

$[Y] =$ ______

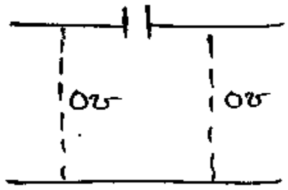




$\downarrow$

$$[Y_A] = \begin{bmatrix} 2/3 & -1/3 \\ -1/3 & 2/3 \end{bmatrix} \mho$$

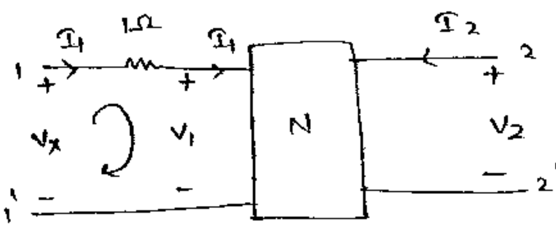
$1F = S\mho$



$$\Rightarrow [Y_B] = \begin{bmatrix} S & -S \\ -S & S \end{bmatrix} \mho$$

$$[Y]_{total} = [Y_A] + [Y_B] = \begin{bmatrix} S+\frac{2}{3} & -(S+\frac{1}{3}) \\ -(S+\frac{1}{3}) & S+\frac{2}{3} \end{bmatrix}$$

Gate If $[Z_N] = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$, then total $[z]$ of entire N/w is



$V_1 = Z_{11}I_1 + Z_{12}I_2 \longrightarrow (1)$

$V_2 = Z_{21}I_1 + Z_{22}I_2 \longrightarrow (2)$

KVL

$-V_x + I_1(1) + V_1 = 0$

$V_x = V_1 + I_1$

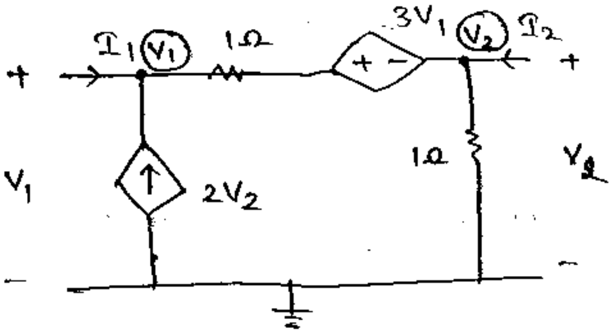
$V_x = Z_{11}I_1 + Z_{12}I_2 + I_1$

$V_x = (Z_{11}+1)I_1 + Z_{12}I_2 \longrightarrow (3)$

from (3) & (2)

$$[z] = \begin{bmatrix} (Z_{11}+1) & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

Gate $[Y] =$ ______



KCL ⟶ Nodal

$$-I_1 - 2V_2 + \frac{(V_1 - V_2 - 3V_1)}{1} = 0$$

$I_1 = -2V_1 - 3V_2 \longrightarrow (1)$

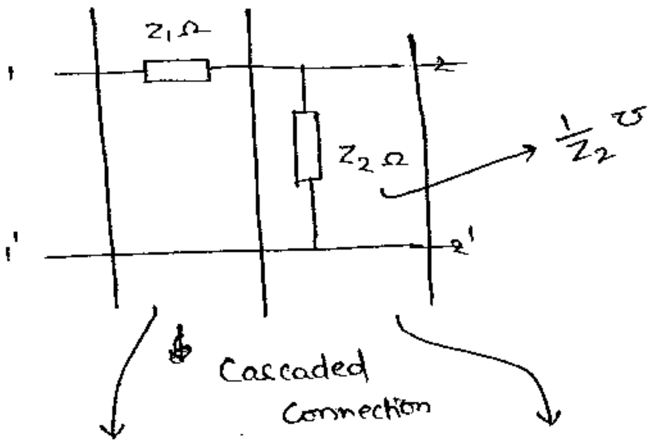
$$-I_2 + \frac{V_2}{1} + \frac{(V_2 - V_1 + 3V_1)}{1} = 0$$

$I_2 = 2V_1 + 2V_2 \longrightarrow (2)$

from (1) & (2)

$$[Y] = \begin{bmatrix} -2 & -3 \\ 2 & 2 \end{bmatrix} \mho$$

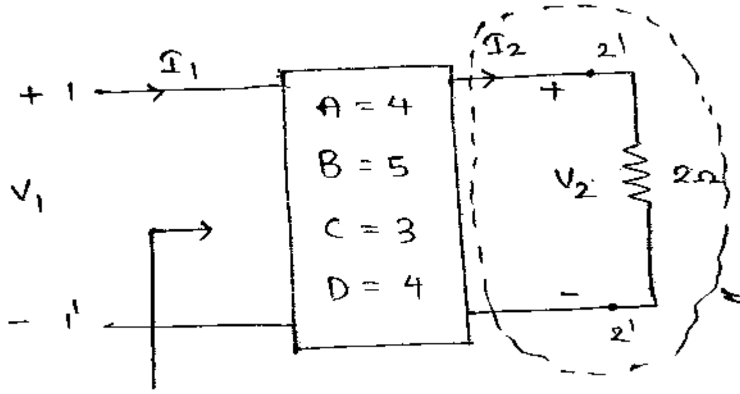
Gate $[T] =$ ____



$$\begin{bmatrix} 1 & Z_1 \\ 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_2} & 1 \end{bmatrix}$$

$$[T]_{Total} = \begin{bmatrix} 1 & Z_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_2} & 1 \end{bmatrix} = \begin{bmatrix} 1+\frac{Z_1}{Z_2} & Z_1 \\ \frac{1}{Z_2} & 1 \end{bmatrix}$$

Gate Find total input Impedence of N/ω.



$V_1 = 4V_2 + 5I_2$

$I_1 = 3V_2 + 4I_2$.

$\Rightarrow V_2 = 2I_2$.

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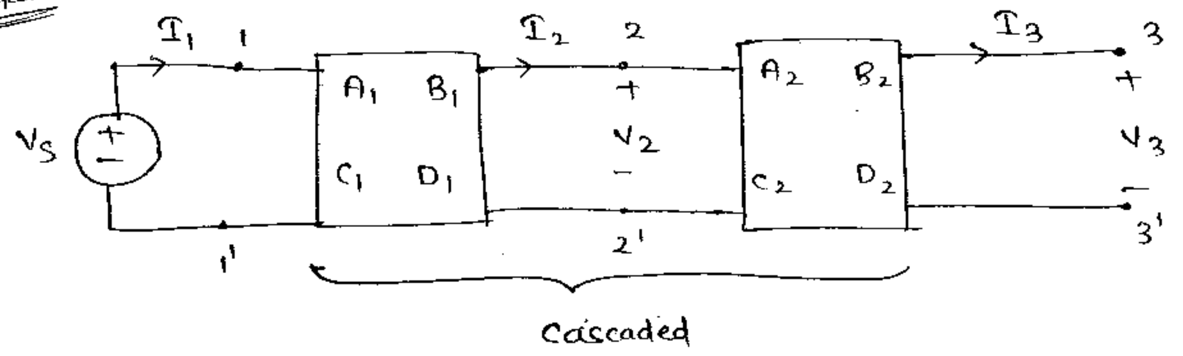
$$Z_{in} = \frac{V_1}{I_1} = \frac{4V_2 + 5I_2}{3V_2 + 4I_2} = \frac{4(2I_2) + 5I_2}{3(2I_2) + 4I_2} = \frac{13 I_2}{10 I_2}$$

$$= \frac{13}{10}\,\Omega$$

Gate Determine the Thevenins Eq. of N/w at port 3



$$[T_1][T_2] = \begin{pmatrix} A_1 & B_1 \\ C_1 & D_1 \end{pmatrix}\begin{pmatrix} A_2 & B_2 \\ C_2 & D_2 \end{pmatrix}$$

$$[T]_{total} = \begin{bmatrix} A_1A_2+B_1C_2 & A_1B_2+B_1D_2 \\ C_1A_2+D_1C_2 & C_1B_2+D_1D_2 \end{bmatrix}$$

$$\therefore\ V_s = (A_1A_2+B_1C_2)V_3 + (A_1B_2+B_1D_2)I_3 \longrightarrow (1)$$

$$I_1 = (C_1A_2+D_1C_2)V_3 + (C_1B_2+D_1D_2)I_3 \longrightarrow (2)$$

S-I V_{th} of port 3

$\longrightarrow I_3 = 0$
& let $V_3 = V_{th}$ $\longrightarrow$ in Eq(1)

So.

$$V_{Th} = \left[\frac{V_s}{A_1A_2+B_1C_2}\right] \underline{\underline{V}}$$

S-II $Z_{th} \Rightarrow$ (by ohms law)

$\longrightarrow V_s = 0$ (o.c Voltage source)

$$Z_{th} = \frac{V_s}{I_3} \Rightarrow \text{But } I_3 = -Ve$$

$\because$ if we give Excitation at port 3 the current enters according to passive notation but we are considering as leaving $\therefore$ apply −ve sign.

put $V_s = 0$ & $I_3 = (-ve)$ in Eq ①

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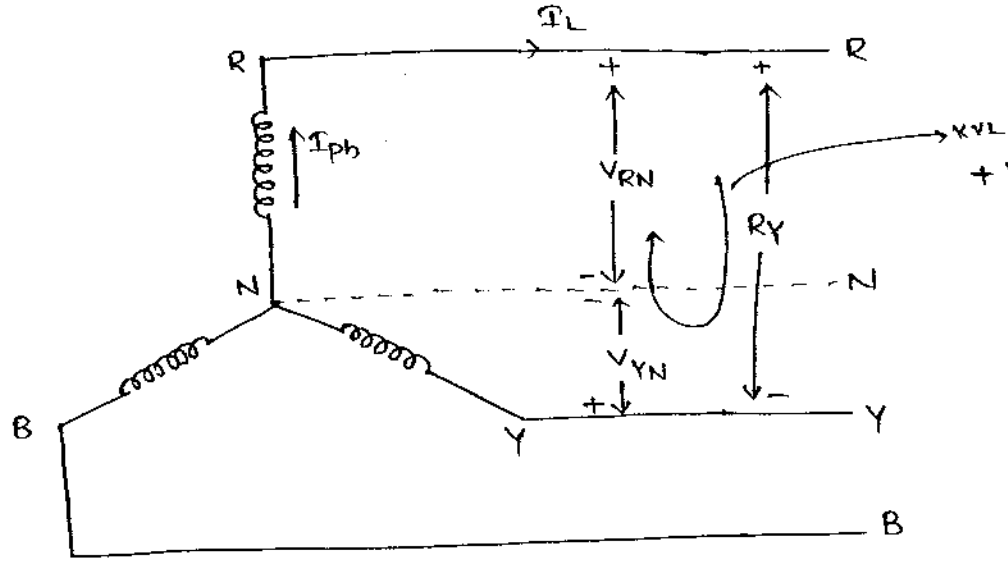
$$(A_1 B_2 + B_1 D_2) I_3 = (A_1 A_2 + B_1 C_2) V_3$$

$$Z_{th} = \frac{V_3}{I_3} = \left[\frac{A_1 B_2 + B_1 D_2}{A_1 A_2 + B_1 C_2}\right] \Omega$$

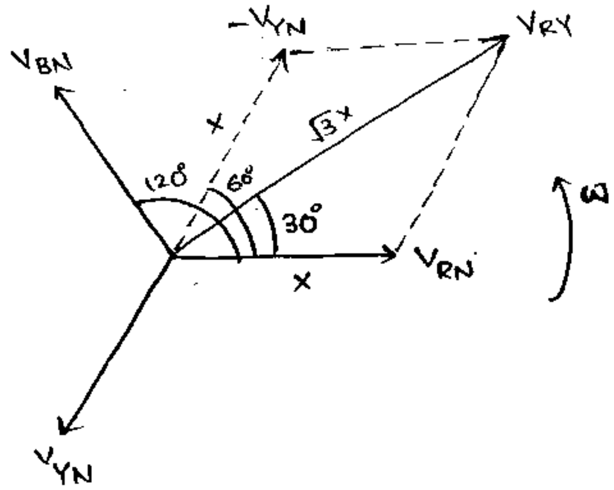
3-ϕ Circuits

(a) Star Connection.



$$+V_{RY} + V_{YN} - V_{RN} = 0$$

$$V_{RY} = V_{RN} - V_{YN}$$



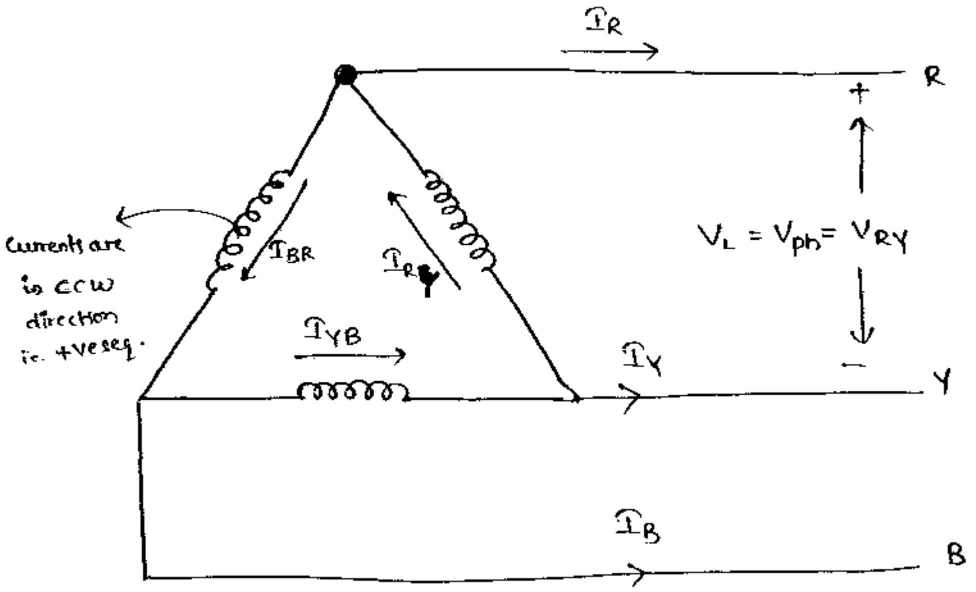
$$|V_{RY}| = \sqrt{x^2 + x^2 + 2x^2 \cos 60^\circ}$$

$$= \sqrt{x^2 + x^2 + x^2}$$

$$|V_{RY}| = \sqrt{3}\,x$$

In a Balanced 3ϕ Star Connected Supply line Voltage is $\sqrt{3}$ times phase Voltage in Magnitude & line Voltage leads phase Voltage by 30° in a positive R-Y-B phase sequence system

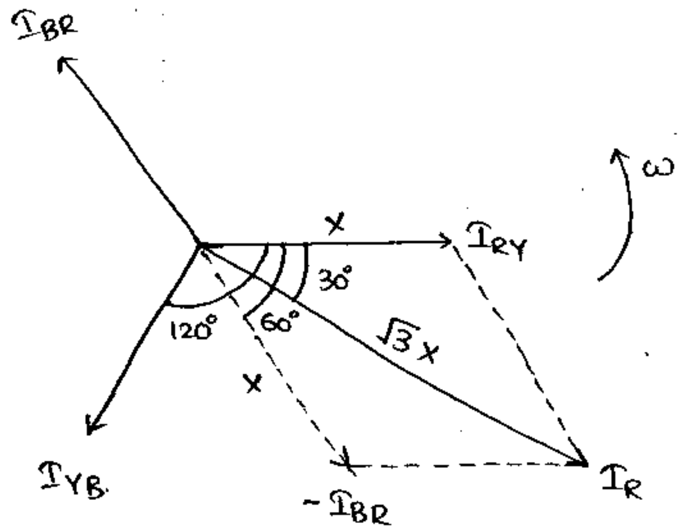
(b) Delta Connection :



KCL

$$\bar{I}_{RY} = \bar{I}_R + \bar{I}_{BR}$$

$$\bar{I}_R = \bar{I}_{RY} - \bar{I}_{BR}$$



$$|I_R| = \sqrt{x^2 + x^2 + 2x^2\cos 60^\circ}$$

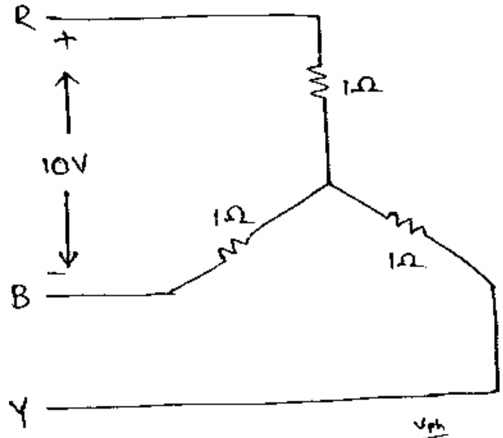
$$= \sqrt{x^2 + x^2 + x^2}$$

$$|I_R| = \sqrt{3}\,x$$

In a balanced 3φ delta Connected Supply, line Current is $\sqrt{3}$ times phase Current in Magnitude. and line Current lags phase Current by 30° in a positive R-Y-B Sequence.

Q1 Calculate the Total power absorbed in the 3ϕ N/w shown

(1)

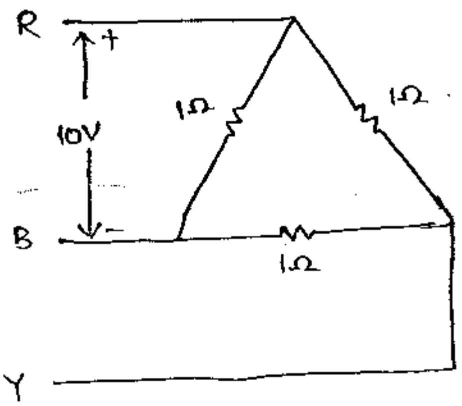


$$P_T = 3 . V_{ph} . \underset{\frac{V_{ph}}{R}}{I_{ph}} \cos\phi$$

$$= 3\left[\frac{10}{\sqrt{3}}\right] . \left[\frac{10}{\sqrt{3} \times 1}\right] \times 1$$

$$= 100W$$

(2)



$$P_T = 3[10]\left[\frac{10}{1}\right] . (1)$$

$$= 300W$$

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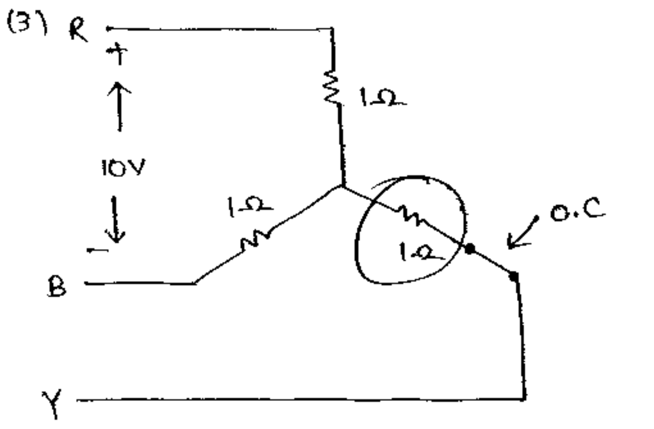
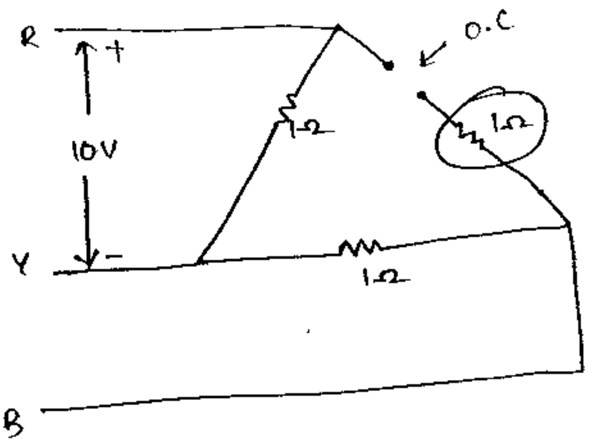
(3)



$$P_T = \frac{V^2}{R} = \frac{10^2}{1+1} = 50\omega$$

(4)



$$P_T = \frac{10^2}{1} + \frac{10^2}{1} = 200\omega$$

Note: two Incandescent bulbs of rating 230V, 100W ; 230V, 200W are Connected to a balanced 3ϕ 400V supply in R-N-Y phases Respectively. If Neutral wire Breaks Suddenly

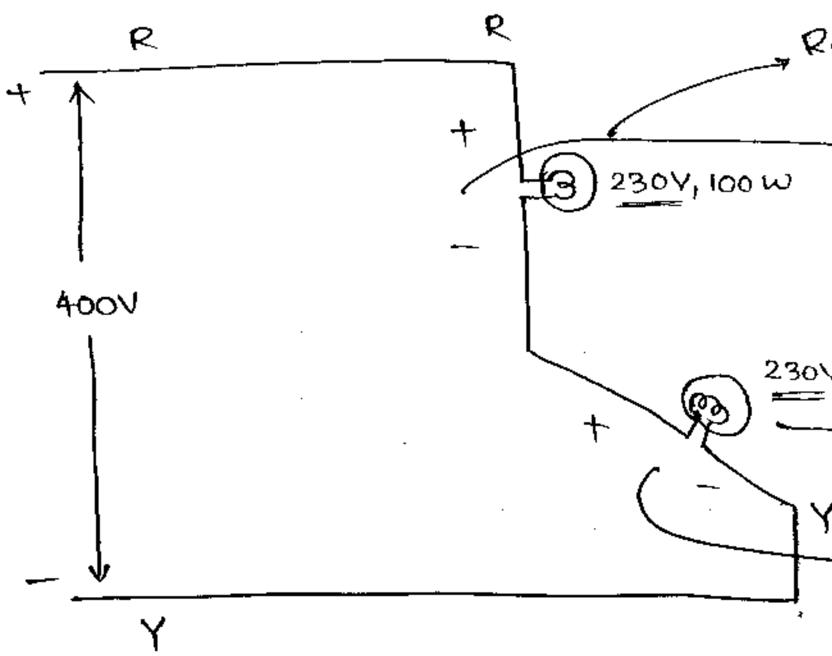
Line-Line Voltage.

(a) Bulb in R-ph will fuse off

(b) Bulb in Y-ph Will fuse off

(c) Both Bulbs Will fuse off

(d) Both Bulbs are safe.



$R_R = \frac{(230)^2}{100} = 529\,\Omega$

$400\left[\frac{529}{529+264.5}\right] = 266.6V$

$R_Y = \frac{(230)^2}{200} = 264.5\,\Omega$

$400\left[\frac{264.5}{264.5+529}\right] = 133.32V$

once Neutral Wire Breaks Over Voltage appears in R-ph & under Voltage appears in Y-ph. therefore R-ph Bulb will Blow off.

In a balanced 3ϕ 400V supply lines 2 Equal Resistors are Connected in Series between Line-B & Line-C. determine the magnitude of Voltage B/w Line-A & Junction of these two Resistors.

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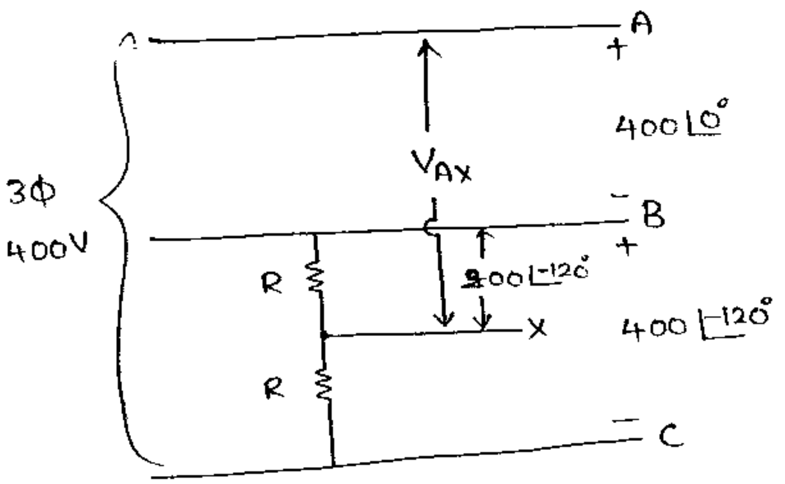


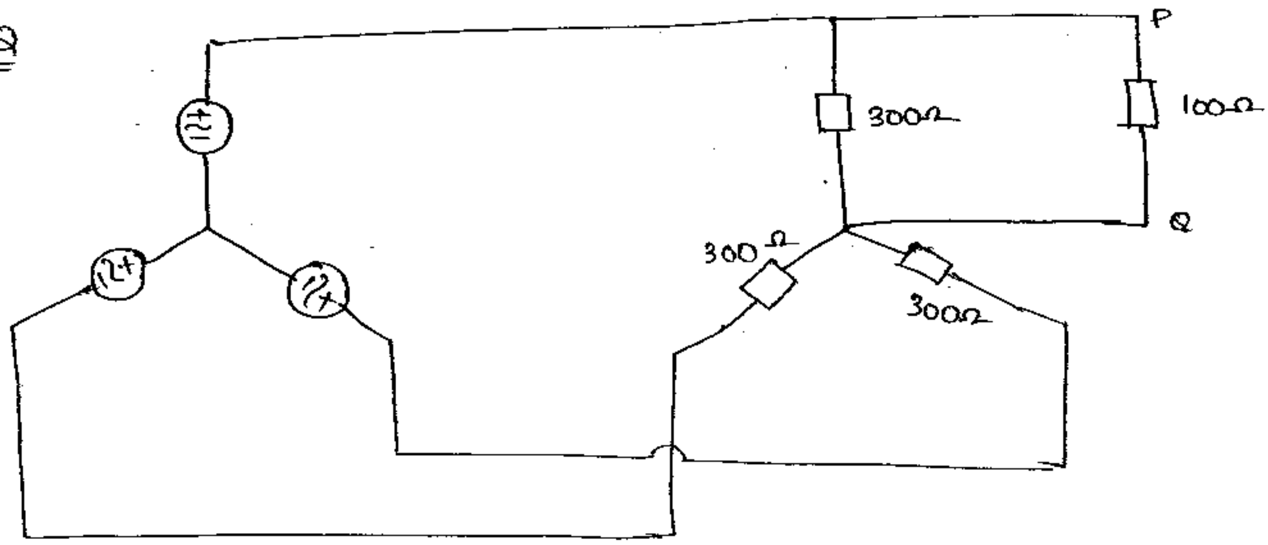
$$|V_{AX}| = 400\angle 0° + 200\angle -120°$$

$$|V_{AX}| = \underline{200\sqrt{3}}\ V$$

$$= 346.4\ V$$

Determine the Voltage across 100Ω Resistor by using Thevenin theorem

Q

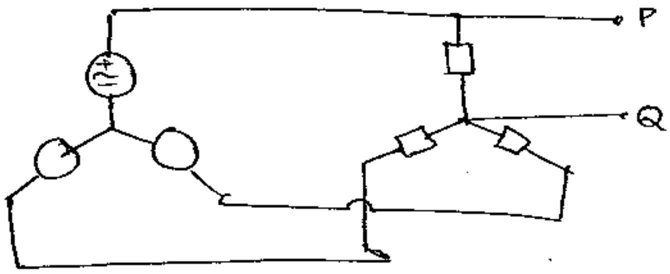


3ϕ balanced 400V supply

↳ ∴ No Neutral Current i.e. $I_N = 0$

∴ Voltage across PQ ⇒ $V_{Th} = V_{ph}$

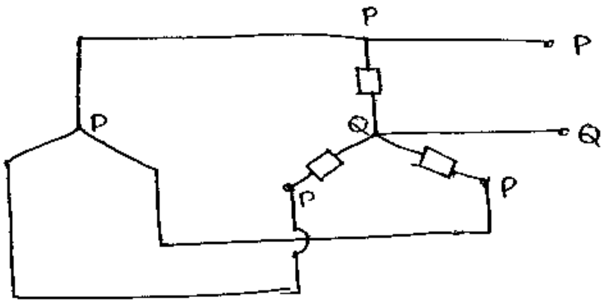
Step-I



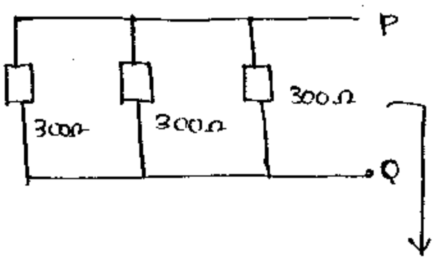
$$V_{Th} = V_{ph}$$

$$V_{Th} = \frac{400}{\sqrt{3}} \angle 0^\circ$$

Step-II

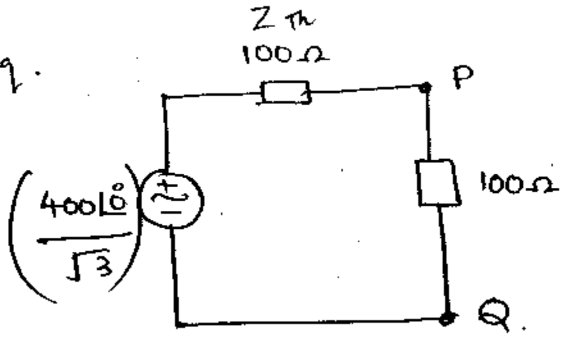


$\Rightarrow$



$$Z_{Th} = 100\,\Omega$$

Thev. eq.



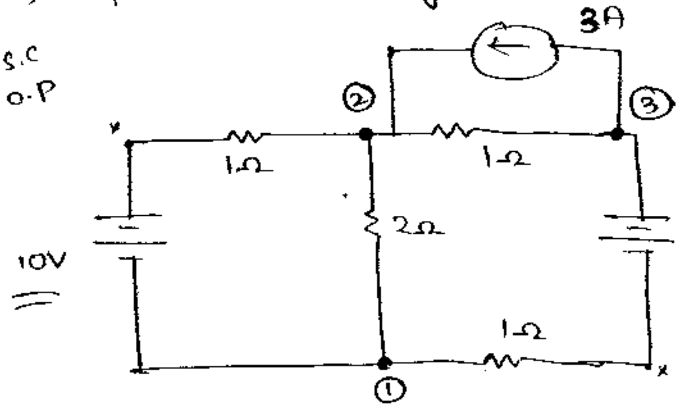
$$V_{PQ} = \frac{400\angle 0^\circ}{\sqrt{3}} \left[\frac{100}{200}\right]$$

$$= \frac{200}{\sqrt{3}} \angle 0^\circ = \_\_\_\_\_\_\_\_ V$$

Topology

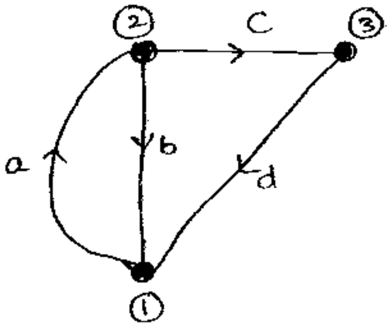
determine all branch Currents for N/w shown by writing N/w Eqns in standard KVL form Using Tieset matrix

V – S.C
I – O.P

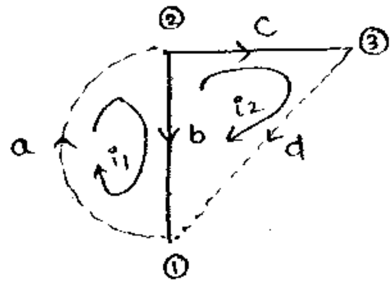


⇒

Graph



Tree



$$[B] = \begin{array}{c} \\ i_1 \\ i_2 \end{array}\begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{bmatrix} +1 & +1 & 0 & 0 \\ 0 & -1 & +1 & +1 \end{bmatrix}_{2\times4} \end{array}$$

b, c twigs
a, d links

one link & rem. twigs forms fund. loop

—— ⇒ Tree
- - - ⇒ CoTree

dir. of Current in direction of link.

$$[Z_b] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}_{4\times4}.$$

$$[I_{link}] = \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}_{2\times1} \qquad [V_s] = \begin{bmatrix} +10 \\ 0 \\ 0 \\ -5 \end{bmatrix} \qquad [I_s] = \begin{bmatrix} 0 \\ 0 \\ +3 \\ 0 \end{bmatrix}_{4\times1}$$

$$[B][Z_b][B]^T[I_{link}] = [B][V_s] - [B][Z_b][I_s]$$

LHS

$[B][Z_b]$

$$= \begin{bmatrix} 1 & 2 & 0 & 0 \\ 0 & -2 & 1 & 1 \end{bmatrix}_{2\times4} \begin{bmatrix} 1 & 0 \\ 1 & -1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}_{4\times2} = \begin{bmatrix} 3 & -2 \\ -2 & 4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

LHS RHS

$$= \begin{bmatrix} 3i - 2i_2 \\ -2i_1 + 4i_2 \end{bmatrix} = \begin{bmatrix} +10 \\ -8 \end{bmatrix}$$

RHS

$[B][V_s] - [B][Z_b][I_s]$

$$\begin{bmatrix} +10 \\ -5 \end{bmatrix}_{2\times1} - \begin{bmatrix} 0 \\ 3 \end{bmatrix}_{2\times1}$$