* R, L & C

* Ohm's law in field theory form — $\bar{J} = \sigma \bar{E}$
  - $\bar{J}$ → current density
  - σ → conductivity
  - $\bar{E}$ → electric field

* temp. ↑ses from room temp. conductivity ↓ses.

* In presence of active sources → R, L, C absorbs energy. current through them will be from +ve to −ve.
  In the absence of Active sources → stored energy in the memory element (L & C) will be deliver to memoryless Resistance. current through them −ve to +ve.

* $J = \sigma E$ $\quad J = \frac{i}{S}$, $\quad E = \frac{V}{l}$ $\quad \left(\sigma = n\mu_n q_n + p\mu_p q_p\right)$

$$\therefore V = \frac{l}{\sigma S} i \Rightarrow V = \frac{\rho l}{S} i \Rightarrow \boxed{V = Ri}$$ — ohm's law in circuit theory.

$$R = \frac{\rho l}{S} = \frac{l}{\sigma S}. \qquad i = \frac{dq}{dt}$$

$$\rho - \text{resistivity} = \frac{1}{\sigma} = \frac{RS}{l} \qquad \boxed{i = GV}$$ — 3rd form of ohm's law.

instantaneous power.

$$P = Vi \qquad V = \frac{dw}{dq} \qquad i = \frac{dq}{dt}$$

$$\therefore P = \frac{dw}{dt} \Rightarrow \underset{\text{electrical energy.}}{w} = \int P\,dt \qquad \boxed{P = i^2 R = \frac{V^2}{R}}$$

* Resistor is a linear, passive, bilateral and time invarient in V-I characteristic (if l, S, σ → constant) i.e R constant.

* $\Psi = N\phi$ when conductor wound like spring i.e. coil
  - Ψ → flux.
  - N → Number of turns.
  - ϕ → flux per turn.

  ~~Always~~ coil will exhibit ideal inductance.

$$\Psi \propto i \qquad \Psi = Li$$

$$V = \frac{d\Psi}{dt} \qquad V = L\frac{di}{dt} \Rightarrow i = \frac{1}{L}\int_{-\infty}^{t} V\,dt$$

$$P = Vi \qquad \boxed{W = \frac{1}{2}Li^2}$$ — Instantaneous Energy

* Inductor is a linear, passive, bilateral and time invariant in $\psi - i$ plane (L is constant)

* $i = \frac{dq}{dt}$ $\quad q \propto v \quad q = Cv$

$i = C\frac{dv}{dt}$ $\quad v = \frac{1}{C}\int_{-\infty}^{t} i\,dt$ $\quad p = vi$

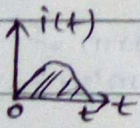
$W = \frac{1}{2}Cv^2$

instantanious energy.

* capacitor is linear, passive, bilateral and time-variant in q-v plane (c kept constant)

* $Z_L = j\omega L$ $\qquad Z_C = j\omega C$

* Power



* i(t) Vs t graph charge applied

$q =$ area under $i(t) = \int_0^t i(t)\,dt$.

* for a periodic signal.

$$P_{avg} = \frac{\text{The Energy Observed Over one period}}{\text{Time period.}}$$

$$P_{avg} = \frac{\int_0^T i^2(t) R\,dt}{T} = \frac{\int_0^T \frac{v^2(t)}{R}\,dt}{T}$$

$$= I_{rms}^2 \cdot R \qquad = \frac{V_{rms}^2}{R}$$

* find f^n i(t) or v(t) by $y = mx$ line equation.

* ① The average ~~po~~ true power or Real power or Active power delivered by the source

= absorbed by the load impedance (R)

$= P_{avg} = I^2_{rms} \cdot R$ (watt)

② The average reactive power or imagnary power Delivered by the source

= absorbed by the load impedance (X)

$= Q_{avg} = I^2_{rms} \cdot X$ (VAR)

③ The average complex power or apparent power.

= absorbed by the load impedance (Z) ($Z = R \pm Xj$)

$= S_{avg} = I^2_{rms} \cdot Z$ (VA)

$|S_{avg}| = I^2_{rms} \cdot |Z|$

① + ② = ③

$\int v \cdot i$

* energy aborbed by Resistance $= \int_0^t i^2(t) \cdot R \, dt$ $(v = iR)$

energy absorbed by inductor $= \int_0^t L i \frac{di(t)}{dt} dt$ $\left(v = L\frac{di}{dt}\right)$

energy absorbed by capacitor $= \int_0^t \frac{1}{C}\left(\int_{-\infty}^{t} i(t)\,dt\right) i \, dt$

$v = \frac{1}{C}\int_{-\infty}^{t} i(t)\,dt$

when i(t) is given convert v interms of i

||ly for v(t)

* If current through an Ideal inductor is constant then energy absorbed is 0. $\because \underbrace{\frac{d\,i(t)}{dt}}_{\text{constant}} = 0$

||ly constant capacitor voltage energy absorbed is 0 $\left(\because \frac{dv}{dt}\right.$

* energy absorbed = energy stored + energy Dessipated.

(by R, L, C) (by L, C) (by R)

* Types of Element

1) Active & passive — I OR III quadrant – passive → +ve $P = VI$; II or IV quadrant – Active → −ve $P = -(VI)$

2) Linear & Non linear. (straight line through origin, V & I linear) else non linear

3) Bilateral & Unilateral — Bilateral → symmetry about origin O, else Unilateral

4) Distributed & lumped — lumped – size is very small compared to wavelength of applied signal. Distributed – electrically unseperable

5) time invarient & time varient

* All linear elements are always bilateral, converse cant say

* Sources.

sources
- independent
  - V
  - I
    - Ideal
    - practical
- dependent
  - VCVS
  - VCCS
  - CCVS
  - CCCS

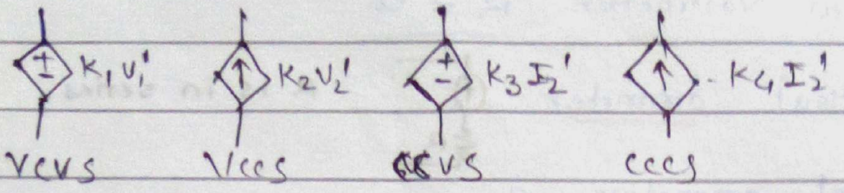
* in ideal voltage source, the load voltage is independent of the load current.

* All the Ideal sources are non-linear, since the voltage & current relation are non linear, they are active & unilateral

* Practical voltage source load voltage is a function of load current drawn.

lly for Ideal & practical current sources.

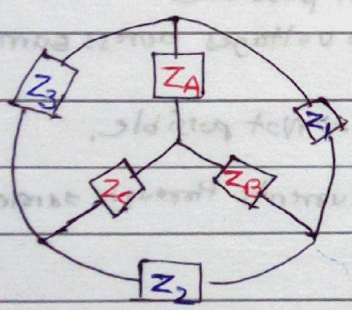
* w.r.t. to controlled variables the dependent source are said to be linear, active, bilateral



* KCL (Node) — Σ current $= 0$ OR incoming I = outgoing I.
  KCL + Ohm's law — Nodal Analysis
* KVL (mesh) — Net voltage is 0.
  KVL + ohm's law — Mesh analysis

* Voltage devider Rule — $V_1 = V \cdot \dfrac{Z_1}{Z_1 + Z_2}$

* current division Rule — $I_1 = I \cdot \dfrac{Z_2}{Z_1 + Z_2}$

* 

$$Z_A = \frac{Z_1 \cdot Z_3}{Z_1 + Z_2 + Z_3}$$

$$Z_B = \frac{Z_1 \cdot Z_2}{Z_1 + Z_2 + Z_3}$$

$$Z_C = \frac{Z_2 \cdot Z_3}{Z_1 + Z_2 + Z_3}$$

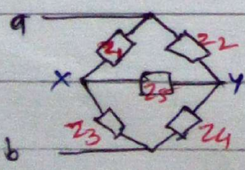
$$Z_1 = Z_A + Z_B + \frac{Z_A Z_B}{Z_C}$$

TR $= \dfrac{Z_A Z_C + Z_B Z_C + Z_A Z_B}{Z_C}$

$$Z_2 = Z_B + Z_C + \frac{Z_B Z_C}{Z_A}$$

$$Z_3 = Z_A + Z_C + \frac{Z_C Z_A}{Z_B}$$

* KVL & KCL are independent to each other.
* Ohm's law applicable only for linear passive elements (or devices) not for active & Non-linear.

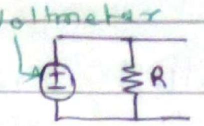
* 

if $\dfrac{Z_1}{Z_3} = \dfrac{Z_2}{Z_4}$ or $Z_1 Z_2 = Z_3 Z_4$ then bridge is balance

no current flows through Z_5

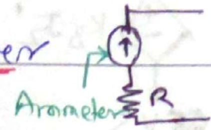
? Z_5 branch is redundant & can ~~remove~~ ~~remove~~ short x & y

$\therefore Z_1 \parallel Z_2$ & $Z_3 \parallel Z_4$

* Practical voltmeter 

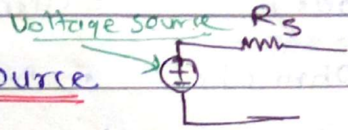
R is in paraller
↳ internal Resistance of voltmeter

Ideal voltmeter $R = \infty$

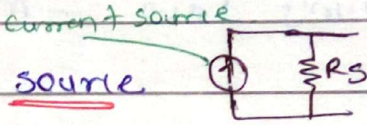
Practical ammeter 

R is in series.

Ideal ammeter $R = 0$

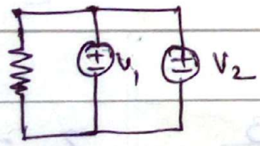
* Practical voltage source 

for Ideal voltage source $R_s = 0$

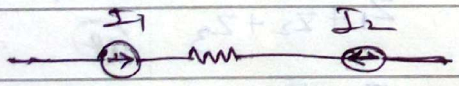
Practical current source 

for Ideal current source $R_s = \infty$

* dont violate KVL & KCL Rule in circuit.

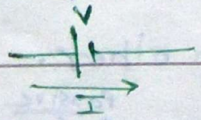


$V_1 \neq V_2$ ⇒ Not possible
two voltages across same resistor ✗

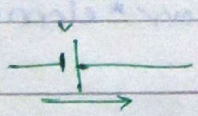


$I_1 \neq I_2$ ⇒ Not possible.
two currents through same resistor ✗

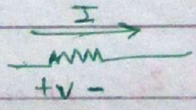
* Tellegen's theorem.
* power absorbed = power delivered.
* find branch current & voltages through each element then find power by $P = VI$



VI ⇒ Power absorbed



VI ⇒ Power delivered.



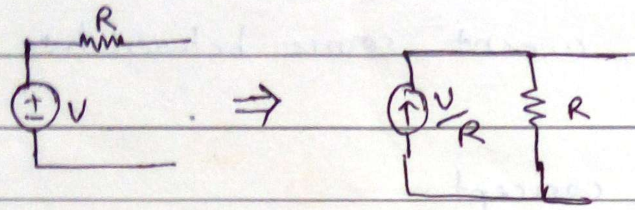
VI ⇒ Power absorbed

* Nodal analysis

* Mesh analysis.

$i_R = \frac{V_2 - V_1}{R}$	$i_C = C\frac{d(V_2 - V_1)}{dt}$	$i_L = \frac{1}{L}\int_{-\infty}^{t}(V_2 - V_1)\,dt$
$V_R = (I_2 - I_1)R$	$V_C = \frac{1}{C}\int_{-\infty}^{t}(I_2 - I_1)\,dt$	$V_L = L\frac{d(I_2 - I_3)}{dt}$

* Source Transformation.



& viceversa

Voltage series with R → current parallel with R.

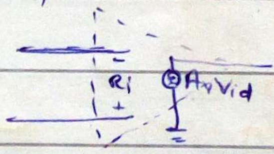
* OP-AMP.

$V_{id} = V_1 - V_2$ $\qquad$ $V_0 = A_V \cdot V_{id}$

* for ideal OP-amp $A_V = \infty$ $\quad V_{id} = 0$ $\quad$ i.e. $V_1 = V_2$
* So for Ideal OPamp voltage at Non-inverting is equal to voltage at inverting terminal.
* for ideal OPAMP $R_i = \infty$, $R_o = 0$.

input Resistance $R_i = \infty$

∴ possible to write Nodal eqⁿ at i/p side



O/P Resistance $R_o = 0$

exhibit voltage source

not possible to write Nodal at O/P.

* for Practical OPAmp:-

* in stardelta for a problem like cube if Ntwork is symmetrical and if connection also symmetrical use KVL for the ans.
*see problem for detail

* Supernode (if Voltage source between two node.)
* Supermesh (if current source between two loop).

* Balance bridge concept.

23, 31, 33, 60, 138, 141, 150, 152*, 210, 238

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* Superposition theorem :- (SPT)

Properties
- → applicable only for linear Network.
- → ideal voltage source short & current source open.
- → SPT applicable for both active & passive Ntworks.

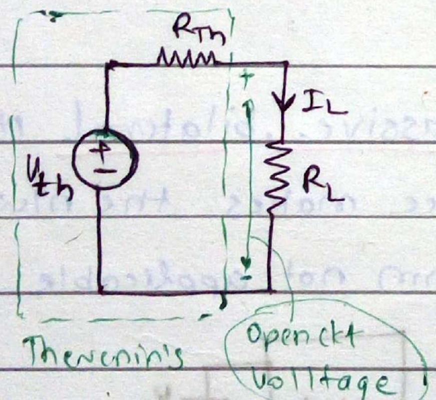
Homogenity principal :- if excitation is multiply by 'K' then response of all other Network are also multiply by K. (homogenity obeyed by all the linear networks)

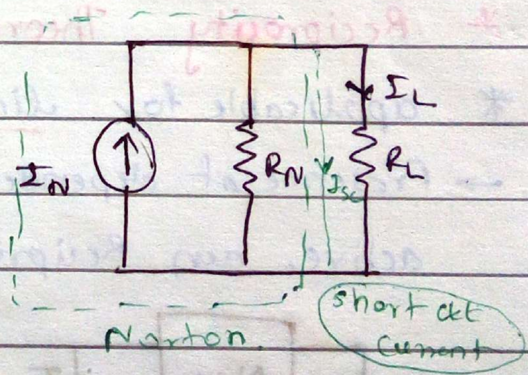
→ When multiple sources are present then superposition theorem apply first then homogenity

Before homogenity always ensure one independant source in the Network.

* maximum or minimum power dissipated when two sources with a resistor R is $(\sqrt{P_1} \pm \sqrt{P_2})^2$ W.

* Thevenins & Norton theorem.





* if ideal voltage & current source
  connected in parallel → Norton equivalent Not possible
  connected in Series → Thevinin's equivalent Not possible.

* properties simillar to SPT.

* Maximum Power Transfer Thm.

* This theorem applicable only when load is variable. otherwise choose minimum internal impedance so that maximum current flows through load & max power dessipatn

max. power transfer when $R_L = R_S$.

$$P_{max} = \frac{V_S^2}{4R_L} \quad \text{at } R_L = R_S.$$

$$\text{total power} = \frac{V_S^2}{2R_L} \qquad \%\eta\ (\text{effeciency}) = 50\%$$

∴ max. effeciency is 50%

* Properties simillar to SPT.

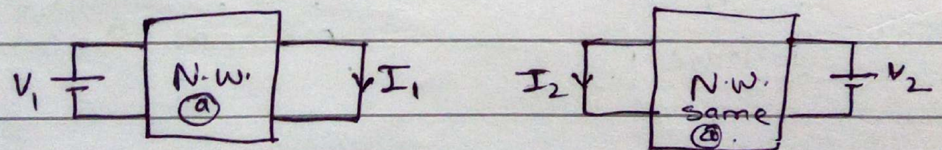
* if load is variable then theorm calculate V_{Th}, R_{Th} $\frac{V_{Th}^2}{4R_{Th}}$ = max power.

if load is fixc try to get max. current through load

* Reciprocity Theorem.

* applicable for linear, passive, bilateral N/w.

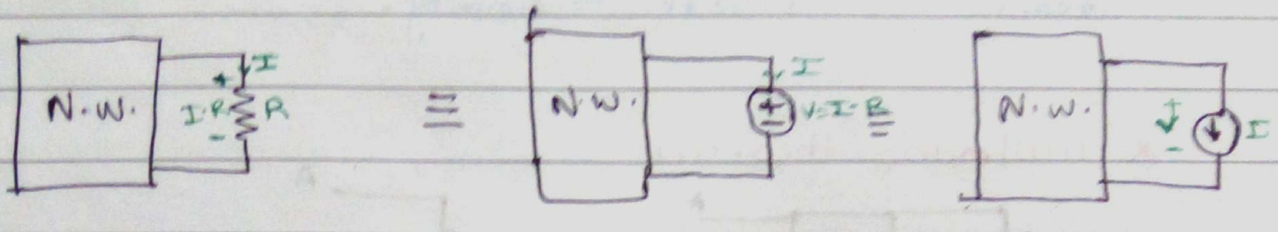
→ Presence of dependent source makes the n/w an active, hen Reciprocity thm not applicable.



$$\boxed{\frac{I_1}{V_1} = \frac{I_2}{V_2} = \text{constant.}}$$

* for complex Ntwork. use superposition thm first in that after use Reciprocity &/OR homoginity.

* The Substitution theorem, or compensation thm



$P_R = P_V = P_I = V \cdot I = R I \cdot I = I^2 R$ (abs).

* whenever two different frequencies are operating on the network simultaneously always the SPT is used to evaluate the responce. since reactive elements are frequency sensitive $Z_L = j\omega L$, $Z_C = \frac{1}{j\omega C}$.
* properties same as SPT

* Duality Principal.
* The N/w & its dual are only equal with respect to performance but the connection & elements point of view they are not equal.
* No. of mesh eq^ns = No. of Nodal eq^ns (N eq^ns)
  (N loops) (N eq^ns)   (N+1) principal nodes

$i(t) \leftrightarrow v(t)$ $I \leftrightarrow V$ $R \leftrightarrow G$ $L \leftrightarrow C$

$Z \leftrightarrow Y$ OC $\leftrightarrow$ S.C. series $\leftrightarrow$ Parallel.

Star $\leftrightarrow \Delta$ $R \cdot i(t) \leftrightarrow G \cdot V(t)$ KCL $\leftrightarrow$ KVL

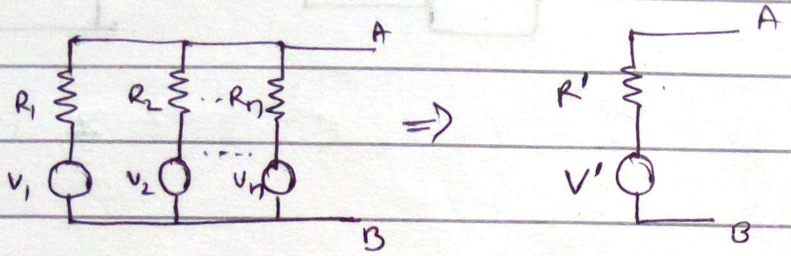
$L \frac{di(t)}{dt} \longleftrightarrow C \frac{dV(t)}{dt}$ $\frac{1}{C}\int i(t)\,dt \longleftrightarrow \frac{1}{L}\int v(t)\,dt$

Nodal $\longleftrightarrow$ mesh Thevinins $\longleftrightarrow$ Norton.

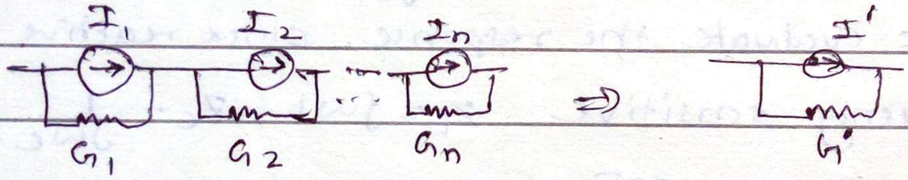
Twig $\longleftrightarrow$ link floop $\longleftrightarrow$ f-cutset.

* whenever network is complex name nodes separately redraw the network to simpify.

* Millman's theorem



$$V' = \frac{V_1G_1 + V_2G_2 + \cdots + V_nG_n}{G_1 + G_2 + \cdots + G_n} \qquad R' = \frac{1}{G_1 + G_2 + \cdots + G_n}$$



$$I' = \frac{I_1R_1 + I_2R_2 + \cdots I_nR_n}{R_1 + R_2 + \cdots + R_n} \qquad G' = \frac{1}{R_1 + R_2 + \cdots + R_n}$$

* Property same as SPT

* for a complex impedances maximum power transfer condition is $Z_L = Z_S^*$ (i.e. load impedance should be complex conjugate of source Impedance

* for complex impedance ($Z_S = x + jy$) max power tranfer by Z_L which is purely Resistive. then

$$Z_L = \sqrt{x^2 + y^2}$$

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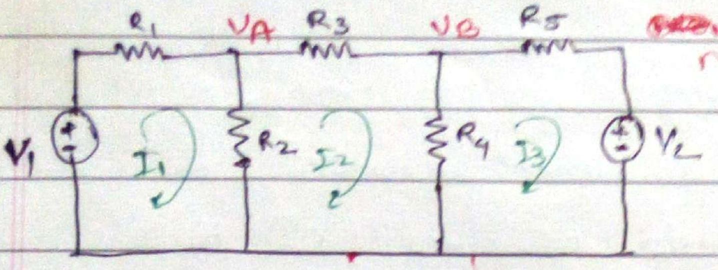
mesh



assume at 0V Ref-node

mesh

① $(R_1+R_2)I_1 - R_2 I_2 = V_1$

② $-R_2 I_1 + (R_2+R_3+R_4)I_2 - R_4 I_3 = 0$

③ $- R_4 I_2 + (R_4+R_5) I_3 = -V_2$

solve by eq^n 3 Unknown

(give polarity accordingly (here V_1 +ve V_2 -ve))

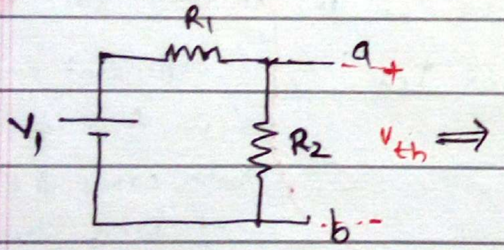
Nodal ①

$$V_A\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right) - V_B\left(\frac{1}{R_3}\right) = V_1\left(\frac{1}{R_1}\right)$$

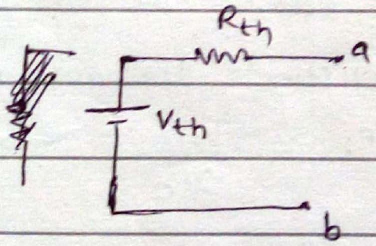
$$-V_A\left(\frac{1}{R_3}\right) + V_B\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right) = V_2\left(\frac{1}{R_5}\right)$$

(give polarity accordingly here V_1 & V_2 +ve)

Thevenins



⟹

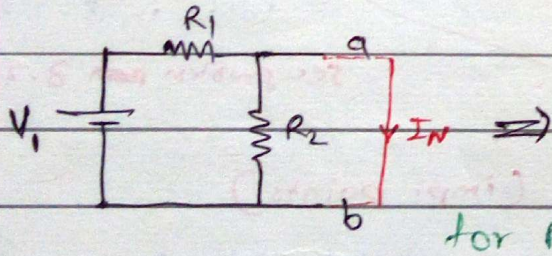


$V_{th} = \frac{V_1 R_2}{R_1+R_2}$

$R_{th} = R_1 \,||\, R_2$

equal

Norton



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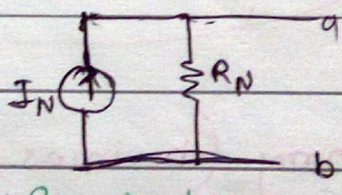
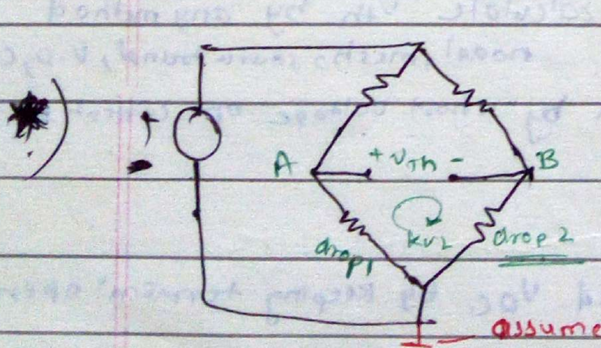


$I_N = \frac{V_1}{R_1}$

$R_N = R_1 \,||\, R_2$

for R_{th} or R_N short voltage source open current source & calculate R_{th}

*)



assume at 0V reff node Gnd

by KVL $V_{Th} = \overset{\text{drop 1}}{V_A} - \overset{\text{drop 2}}{V_B}$

1) soure transformat^n

* 2) Voltage division or current division. , series & ||el connect^n

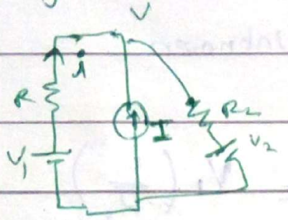
* 3) Star-delta for resist. or simplify n/w by separating nodes

(4) Nodal or mesh

5) Thevinins or norton.

6) SPT.

* during nodal be carefull about current signs.



$$i = \frac{V - V_1}{R}$$ → i → value

Nodal

$$\frac{V - V_1}{R} - I + \frac{V - V_2}{R_2} = 0$$

** to find thevenins equivalen.

(1) first open the terminal find V_{th}

(2) then short the terminal find I_{sc}

(3) $R_{th} = \frac{V_{th}}{I_{sc}}$

in both case (1) & (2) if dependent source is there then find its value in both cases (1) & (2) dont take dependent source value in (1) into (2).

see problem 3.23 pg 151

Summry (thevinins) (imp. points)

case (1) All are independent source.: calculate V_{th} by any method nodal, mesh, source transf, V.D, C.D etc

Normal method :⇒ & R_{th} by short voltage ope current source.

case (2) if both dependent & independent sources are there.

→ case 2 method ⇒ find V_{oc} by keeping terminal open then find I_{sc} by keeping terminal short then $V_{th}/I_{sc} = R_{th}$.

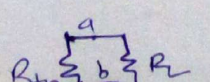
*** [or connect I_o, V_o at o/p terminal & find $\frac{V_o}{I_o} = R_{th}$] [V source SC, I source OC] Independent

case (3) only dependent source no independent source

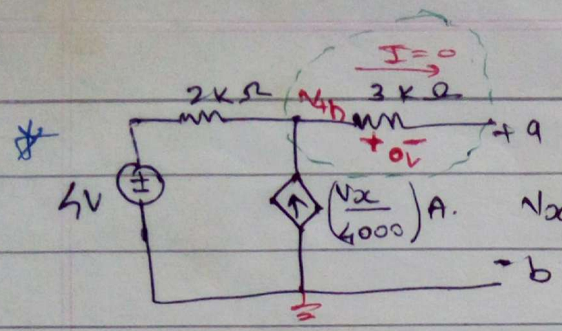
In this case $V_{th} = 0$, $I_{sc} = 0$ but $R_{th} \neq 0$

find R_{th} in this case Thevinins = Norton = Resistor behaviour

*** (in this case consider or assume voltage or current at terminal)



⑧

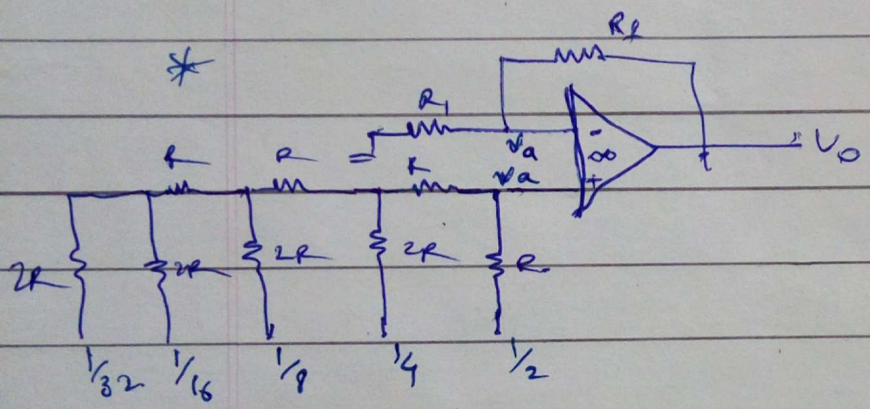


$V_x = V_{th}$

∴ Nodal

$$\frac{V_{th}-4}{2k} - \frac{V_x}{4000} + 0 = 0$$

current in O.C. is 0



$$V_o = \frac{R_f + R_1}{R_1} V_a$$

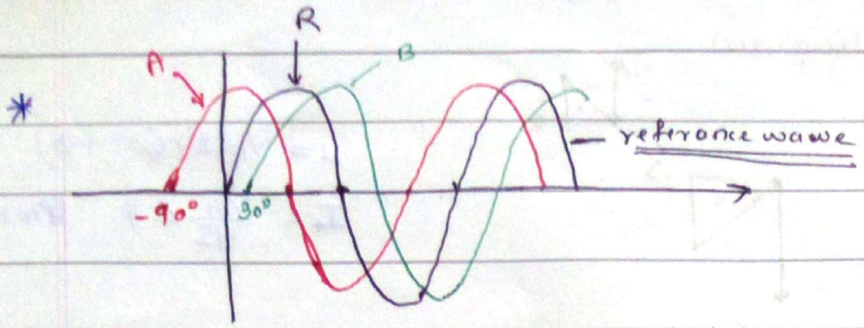
16V

$V_o = 16(V_{a_1}) + 16(V_{a_2}) + \ldots$

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

If not connected to ⏚

*



wave A → leads the referance wave by 90°.

wave B → lags the referance wave by 30°.

phase differance between A & B is 120.

R is Referance wave we can say that it is inphase ~~(...wave~~ itself as sinwave

A & B both are out of phase ∵ ref is sine wave

$v(t) = V_m \sin wt$. $\quad V_m \to$ Peak voltage.

$v(t) = V_m \sin(wt + 90°)$ — A wave.

$v(t) = V_m \sin(wt - 30°)$ — B wave

V_m = peak voltage

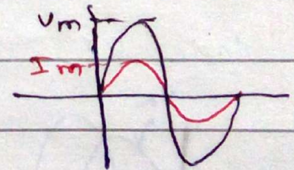
$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt.$

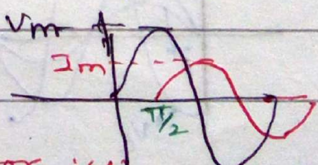
Peak factor $= \frac{V_m}{V_{rms}} = 1.414 \Rightarrow \frac{V_m}{\sqrt{2}}$

$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707\,V_m.$
$= \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}$

Form factor $= \frac{V_{rms}}{V_{avg}}$

(1) $v(t) = R\,i(t) \Rightarrow V_m = I_m R.$



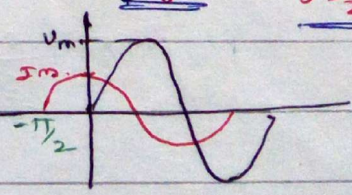


(2) $v(t) = L\frac{di}{dt} \Rightarrow V_m = wLI_m$
$= X_L I_m$

$\boxed{X_L = WL = 2\pi f L}$ $\quad Z = jwL = jX_L$

in pure inductor $i(t)$ lags $v(t)$ by $\frac{\pi}{2}$

(3) $v(t) = \frac{1}{C}\int i(t)\,dt \Rightarrow v_m = \frac{I_m}{wC} = I_m X_C$



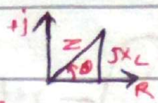
$\boxed{X_C = \frac{1}{2\pi f C}}$ $\quad Z = -\frac{j}{wC} = -jX_C$

in pure capacitor $i(t)$ leads $v(t)$ by $\frac{\pi}{2}$

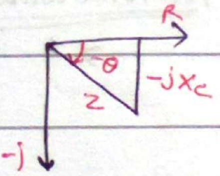
Scanned by CamScanner

* impedance diagram

RL series —



RC Series -

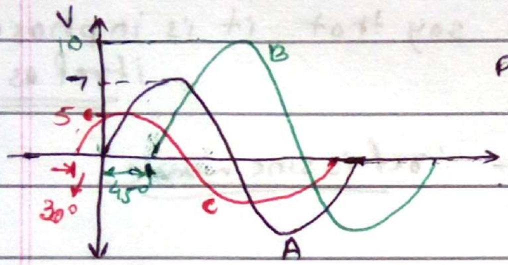


$i = V_m \sin(\omega t + \phi)$

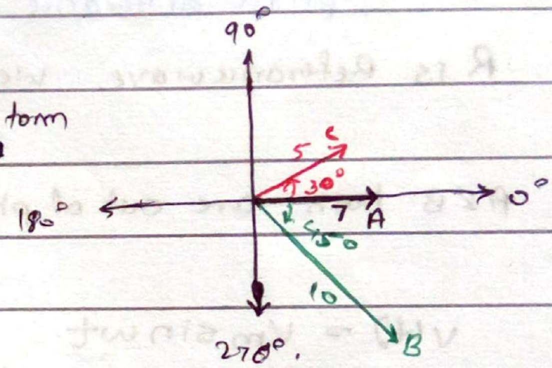
$I = \frac{V_m}{\sqrt{2}} \angle \phi$ (Phasor form)

* Phasor diagram.

it is used to represent sine wave in terms of magnitude and angular position.

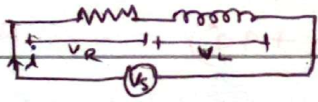


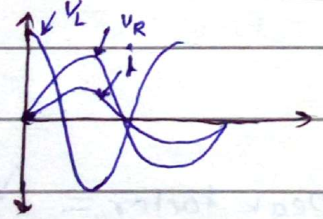
Phasor form ⇛



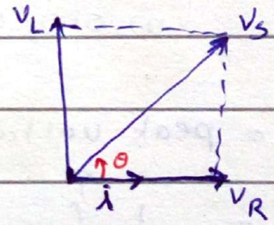
* series ckt phasors

* Series RL





Phasor form ⇒



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

$X_L = \omega L = 2\pi f L$

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

$i = \frac{V_S}{Z}$

$V_R = IR$

$V_L = IX_L$

$V_S = IR + jIX_L$

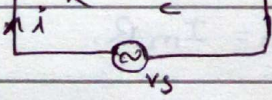
(pf) $\cos\theta = \left(\frac{V_R}{V_S}\right)$ leads

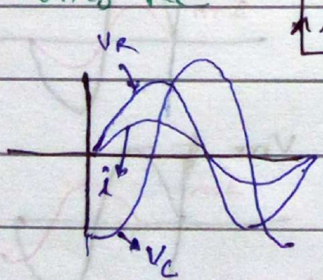
$\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$

OR

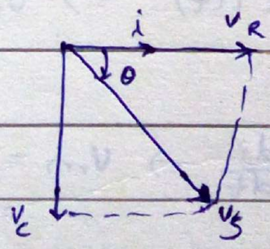
$\theta = \tan^{-1}\left(\frac{V_L}{V_R}\right)$

* series RC





Phasor form ⇒



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

$X_C = \frac{1}{2\pi f C}$

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

$i = \frac{V_S}{Z}$

$V_R = IR$

$V_C = IX_C$

$V_S = IR - jX_C$

(pf) $\cos\theta = \left(\frac{V_R}{V_S}\right)$ lags

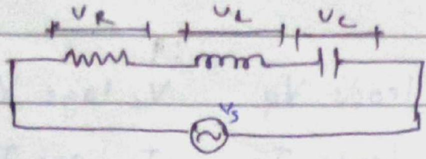
$\theta = \tan^{-1}\left(\frac{-X_C}{R}\right)$

OR

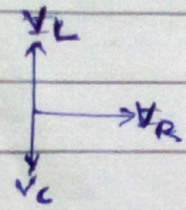
$\theta = \tan^{-1}\left(\frac{-V_C}{V_R}\right)$

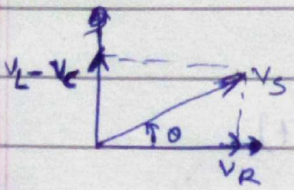
for pure L or C $\theta = \pm 90°$.

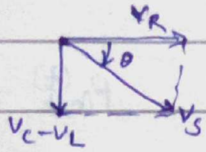
series RLC

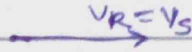


① $V_L > V_C$ ② $V_C > V_L$ ③ $V_L = V_C$.









$V_R = IR$

$V_L = IX_L\angle 90^\circ$

$V_C = IX_C\angle -90^\circ$

① $V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$

$\theta = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$

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

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

$\theta = \tan^{-1}\left(\frac{V_C - V_L}{V_R}\right)$

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

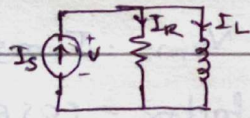
③ $V_S = V_R$

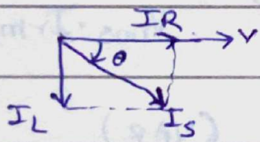
$\theta = 0$

$Z = R$

* Mel ckt phasors.

parallel RL



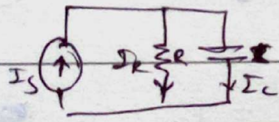


$I_S = \sqrt{I_R^2 + I_L^2}$ $\theta = \tan^{-1}\left[\frac{I_L}{I_R}\right]$

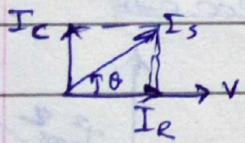
(pf) $\cos\theta = \frac{I_R}{I_S}$ lag

$I_R = \frac{V}{R}$ $I_L = \frac{V}{Z_L}$ $I_L = \frac{V}{X_L}\angle -90^\circ$ $Z = \frac{V}{I_S}$

Parallel RC



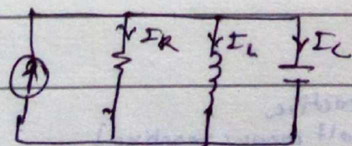
$I_R = \frac{V}{R}$ $I_C = \frac{V}{Z_C}$ $I_C = \frac{V}{X_C}\angle 90^\circ$.



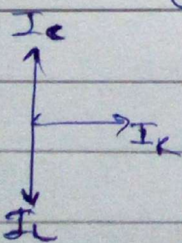
$I_S = \sqrt{I_R^2 + I_C^2}$ $\theta = \tan^{-1}\left(\frac{I_C}{I_R}\right)$

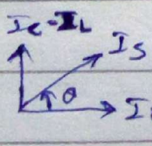
pf $\cos\theta = \frac{I_R}{I_S}$ lead $Z = \frac{V}{I_S}$

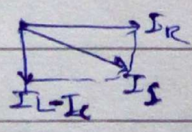
Parallel RLC

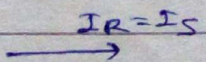


① $I_C > I_L$ ② $I_L > I_C$ ③ $I_L = I_C$









① $I_S = \sqrt{I_R^2 + (I_C - I_L)^2}$

$\theta = \tan^{-1}\left(\frac{I_C - I_L}{I_R}\right)$

$\cos\theta = \frac{I_R}{I_S}$

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

$\theta = \tan^{-1}\left(\frac{I_L - I_C}{I_R}\right)$

$\cos\theta = \frac{I_R}{I_S}$

③ $I_S = I_R$

$\theta = 0$

⇒ UPF

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* in series V_L leads V_R V_C lags V_R I constant as V_R
in parallel I_C leads I_R I_L Lags I_R V constant as I_R

instantaneous power :- $P_{inst}(t) = v(t)\, i(t)$

average power :- $P_{avg} = \frac{1}{T}\int_0^T P_{inst}(t)\, dt = \frac{1}{T}\int_0^T v(t)\, i(t)\, dt$

$P_{avg} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cos\theta$. (W)

$= V_{rms} \cdot I_{rms} \cos\theta$

($\cos\theta = 1$ when $v(t)$ & $i(t)$ are in phase)

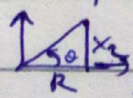
apperent power :- $= V_{rms} \cdot I_{rms}$ (W)

$\text{power factor} = \cos\theta = \frac{P_{avg}}{V_{rms} \cdot I_{rms}}$

Reactive power :- $= V_{rms} \cdot I_{rms} \sin\theta$ (VAR)

$= I_{rms}^2 Z \sin\theta$

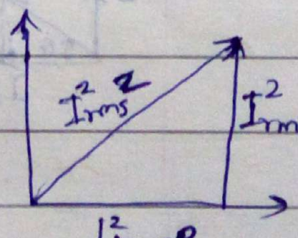
$= I_{rms}^2 X_L$ ($X_L = Z\sin\theta$ from impedance triangle see the impedance triangle)



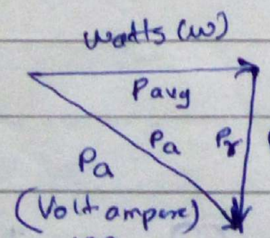
$P_a = I_{rms}^2 Z$ $\Rightarrow$ $P_{true} = P_a \cos\theta$.
apperent

$P_{avg} = P_a \cos\theta$.

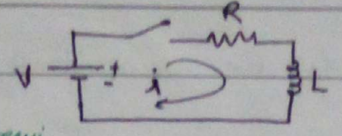
$P_{reactive} = P_a \sin\theta$.



*



* DC Responce for RL circuit.



by KVL

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

$i = \frac{V}{R} - \frac{V}{R}e^{-t/\tau}$ $\left(\tau = \frac{L}{R}\text{ sec}\right)$ ($\because$ by solving diff. eq^{ns})

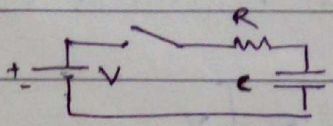
L_{equi}, $R_{eq.}$

$V_R = V\left[1 - e^{-t/\tau}\right]$ ($R \cdot i$) $\quad V_L = Ve^{-t/\tau}$

$P_R = V_R \cdot i \quad P_L = V_L \cdot i$

* after 5τ transient part reaches more than 99% of its final value.

* DC Responce for RC circuit



by KVL

$V = Ri + \frac{1}{C}\int i\,dt$

differentiating.

$\frac{di}{dt} + \frac{1}{RC}i = 0.$

solving diff. eq, to get i

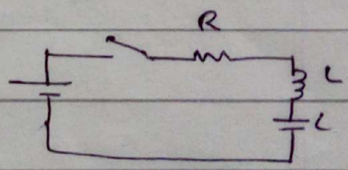
$i = \frac{V}{R}e^{-t/RC}$

$i = \frac{V}{R}e^{-t/\tau}$ $\quad \tau = RC$ — Time constant.

$V_R = Ve^{-t/\tau} \quad V_C = V(1 - e^{-t/\tau})$

$P_R = V_R \cdot i \quad P_C = V_C\, i$

* DC Responce for RLC series circuit.



By KVL $\quad V = Ri + L\frac{di}{dt} + \frac{1}{C}\int i\,dt$

to get i diffe w.r.t. i. $\Rightarrow \frac{d^2i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC}i = 0$

$\Rightarrow D^2 + \frac{R}{L}D + \frac{1}{LC} = 0$ $\quad$ solving diff. eq^n & get roots.

$$D_1, D_2 = \underbrace{-\frac{R}{2L}}_{K_1} \pm \underbrace{\sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}}_{K_2}$$

① if K_2 is +ve

$\left(\frac{R^2}{2L}\right)^2 > \frac{1}{LC}$

$[D - (K_1 + K_2)][D - (K_1 - K_2)]i = 0$

$i = c_1e^{(K_1+K_2)t} + c_2e^{(K_1-K_2)t}$

② if K_2 is -ve

$\left(\frac{R^2}{2L}\right)^2 < \frac{1}{LC}$

$[D - (K_1 + jK_2)][D - (K_1 - jK_2)]i = 0$

$i = e^{K_1t}[c_1\cos K_2t + c_2\sin K_2t]$

③ if K_2 is zero.

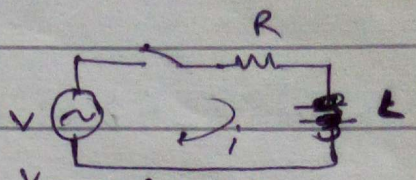
$\frac{R^2}{2L} = LC$

$(D - K_1)(D - K_2)i = 0.$

$i = e^{K_1t}(c_1 + c_2t)$

eg. 497

* Sinusoidal Responce of RL ckt

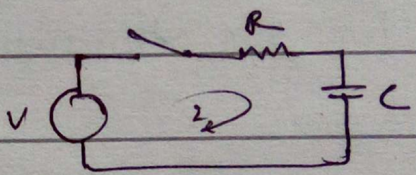


$V = \cos(\omega t + \theta)$

$$i = e^{-t/\tau}\left[\frac{-V}{\sqrt{R^2+(\omega L)^2}}\cos\left(\theta - \tan^{-1}\frac{\omega L}{R}\right)\right]$$

$$+ \frac{V}{\sqrt{R^2+(\omega L)^2}}\cos\left(\omega t + \theta - \tan^{-1}\frac{\omega L}{R}\right)$$

* sinusoidal Responce of RC ckt



$V = \cos(\omega t + \theta)$

$$i = e^{-t/\tau}\left[\frac{V}{R}\cos\theta - \frac{V}{\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}}\cos\left(\theta + \tan^{-1}\frac{1}{\omega CR}\right)\right]$$

$$+ \frac{V}{\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}}\cos\left(\omega t + \theta + \tan^{-1}\frac{1}{\omega CR}\right)$$

* sinusoidal Responce of RLC ckt

* Behaviour of L & C elements at $t=0^+$ and $t\to\infty$ instants.

we know $Z_L = sL$ $Z_C = \frac{1}{sC}$

$t=0^+ \Rightarrow s=\infty \Rightarrow Z_L=\infty \Rightarrow L \to OC$

$Z_C = 0 \Rightarrow C \to SC.$

$t\to\infty \Rightarrow s\to 0 \Rightarrow Z_L = 0 \Rightarrow L \to SC$

$Z_C = \infty \Rightarrow C \to OC.$

* In steady state energy stored in the memory element is maximum and constant.

$\frac{1}{2}Li_L^2 \Rightarrow$ max & const. $\Rightarrow i_L =$ max & const.

$\therefore$ Inductor act as constant current source in steady state.

$\therefore V_L = L\frac{di}{dt} \Rightarrow i_L \to 0$ $L \to SC.$

Illy

$\frac{1}{2}CV_C^2 =$ max & const $\Rightarrow V_C =$ max & const.

$\therefore$ capacitor act as a constant voltage source in steady state

$\therefore i_C = C\frac{dV_C}{dt} \Rightarrow i_C \to 0 \Rightarrow C \to O.C.$

* Inductor current cannot change instanteneously ($V_L(t)$ = practical i/ps)

i.e. $i_L(0^+) = i_L(0^-)$ Illy $E_L(0^+) = E_L(0^-)$

but $V_L(t) = \delta(t)$

$i_L(0^+) = i_L(0^-) + \frac{1}{L}$ Illy $E_L(0^+) > E_L(0^-)$

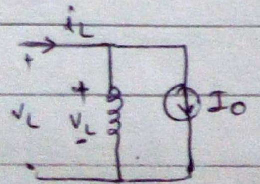
$i_L(0^-) = 0$ $\therefore i_L(0^+) = \frac{1}{L} \Rightarrow E_L(0^+) = \frac{1}{2L}(J)$

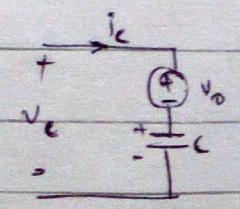
* Illy $V_C(0^+) = V_C(0^-)$ for practical i/ps.

but for $i_C = \delta(t)$

$V_C(0^+) = \frac{1}{C}$ $E_C(0^+) = \frac{1}{2C}(J)$

$i_L = I_0 + \frac{1}{L}\int_0^t V_L dt$ $V_C = V_0 + \frac{1}{C}\int_0^t i_C dt$ (Pge 86 Ace Notes)





* DC Transient (According to Ace Notes)

① Source free circuits (i.e. without independent sources)

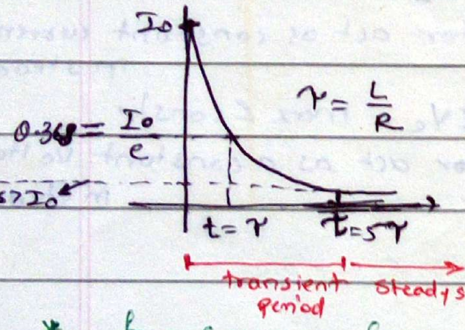
→ in all source free ckt. stored energy in memory elements at $t=0$ is maximum.

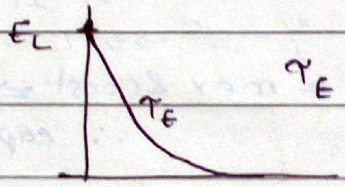
→ As a f^n of time this stored energy is given to the memory less Resistance in an exponential decaying manner

→ Hence Energy ~~also~~ present in the network at steady state (i.e. $t \to \infty$) is zero

* ~~i(t)~~ ⇒ for source free RL ckt.

$$i(t) = I_0 e^{-t/\tau} \qquad I_0 = i(0^+) \text{ (initially stored energy due to.)}$$

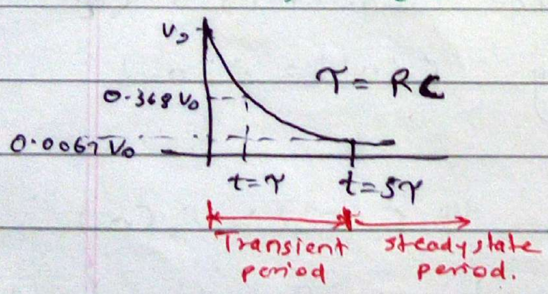


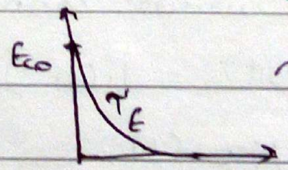


$$\tau_E = \frac{L}{2R} \text{ sec.}$$

* for source free RC ckt.

$$V(t) = V_0 e^{-t/\tau} \qquad V_0 = V(0^+)$$





$$\tau_E = \frac{RC}{2} \text{ sec}$$

comparing τ we get $\boxed{\frac{L}{R} = RC}$

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* Resonance.

ckt is said to be in resonance if current is in phase whith the applied voltage.

** $\boxed{\text{* for series RLC ckt:-}}$ series Resonance — for resonance $X_L = X_C$ is must condit^n.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ f_r - frequency of resonance.

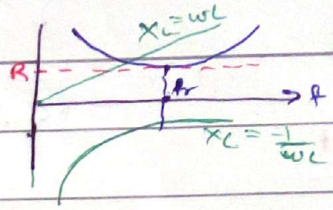
***

(at $f=0$ circuit is capacitive)

current leads source voltage ⇐ $f < f_r$ — $X_L < X_C$ (at $f=0$ $X_L=0$ $X_C=\infty$ inductor short cap. open)

In phase ⇐ $f = f_r$ — $X_L = X_C$ ($\Rightarrow \underline{Z=R}$)

current lags behind applied voltage ⇐ $f > f_r$ — $X_L > X_C$

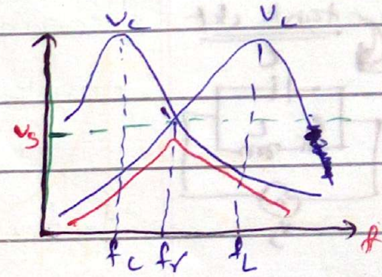


($\because$ impedance varies as frequency varies)

drop across R is maximum at $f = f_r$

$\boxed{V_L + V_C = 0}$ maximum voltage across capacitor at $f = f_C$

LC like short combination — max voltage across inductor is at $f = f_L$



$$f_L = \frac{1}{2\pi\sqrt{LC}}\sqrt{\frac{1}{1-\frac{R^2C}{2L}}} \qquad f_C = \frac{1}{2\pi}\sqrt{\frac{1}{LC}-\frac{R^2}{2L}}$$

Bandwidth of system is the range of frequency for wich the current or o/p voltage is equal to 70.7% of its value at the resonant frequency. $(BW = f_L - f_C)$

→ $\omega_r^2 = \omega_L \omega_C$ $\quad \because \omega_r^2 = \frac{1}{LC}$ $\quad \omega_L - \omega_C = \frac{R}{L}$

$\boxed{f_r^2 = f_L \cdot f_C}$

$f_L - f_C = BW = \frac{R}{2\pi L} \Rightarrow f_C = f_r - \frac{R}{4\pi L} \quad f_L = f_r + \frac{R}{2\pi L}$

Q factor, figr. of minity i.e quality factor = ~~$Q = 2\pi f_r L / R$~~

$$\frac{f_L - f_C}{f_r} = \frac{1}{Q} \Rightarrow Q = \frac{f_r}{B.W.}$$

$$\boxed{Q = \frac{\omega_r L}{R} = \frac{1}{\omega_r C R}}$$

$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

→ At resonance frequency power is $P_{max} = I^2_{max} R$.

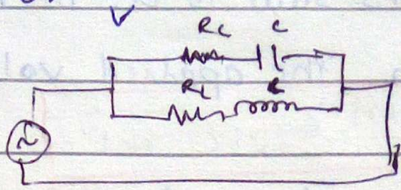
→ power at f_C & f_L (lower & higher cutt of frequencies) $P_L = P_C = \frac{I^2_{max} R}{2}$

Q factor is ratio of reactive power of inductor or capacitor to the true power $\quad Q = 2\pi \times \frac{\text{max energy stored}}{\text{energy dessipated per cycle.}}$

$$\boxed{Q = \frac{\omega_r L}{R} = \frac{1}{\omega_r C R} = \frac{f_r}{BW}}$$ here $\omega_r = \underline{2\pi f_r}$ *

* Magnification :- $Q = \frac{V_L}{V}$ or $\frac{V_C}{V}$

for series resonance



* Parallel Resonance :

→ in parallel resonance also $X_L = X_C$ must condition.

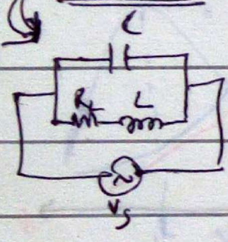
→ current in each branch is same in magnitude but 180° phase shift so overall current & voltage are in phase at resonance.

$\boxed{I_C + I_L = 0}$

LC like open ckt

$$\omega_r = \frac{1}{\sqrt{LC}} \sqrt{\frac{R_L^2 - (L/C)}{R_C^2 - (L/C)}}$$ ∴ for $R_L = R_C$ $f_r = \frac{1}{2\pi\sqrt{LC}}$

tank ckt



Resonant frequency for tank ckt. (parallel resonant ckt)

tanck ckt ⇒ the stored energy transfered back & forth between capacitor & inductor.

$$f_r \text{ for tank ckt} = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R_L^2}{L^2}}$$

Q factor for parallel Resonance = $\boxed{Q_r = \omega_r RC = \frac{R}{\omega_r L}} = R\sqrt{\frac{C}{L}}$

* magnification for $\parallel^{lel}$ resonance $Q_r = \frac{I_L}{I}$ or $\frac{I_C}{I}$

$$I_L = Q I \angle -90° = -jQI$$
$$I_C = Q I \angle 90° = jQI$$

$I_R = I$ $I_L + I_C = 0$

* minimum R for physical existance calle critical resistance in series RLC when ξ(damping factor) = 1

$$\xi = \frac{1}{2Q} = 1 \Rightarrow Q = \frac{1}{2}$$

$$R_{critical}\text{ (for series RLC)} = 2\sqrt{\frac{L}{C}}$$

* lly for parallel Resonance R max. called critical Resistance

$$R_{critical}\text{ (ll resonance)} = \frac{1}{2}\sqrt{\frac{L}{C}}$$

* for a Resonant frequency find impendance Z. & equate j term with zero ∵ at Resonance total impedance is pure Resistive.

* in parallel resonance ckt will Resonate for all frequencies if $R^2 = \frac{L}{C}$ out of infinite resonate frequencies we select $\omega_0 = \frac{1}{\sqrt{LC}}$

* Average power in series resonance $= \frac{V_{Lrms}^2}{R} + \frac{V_{crms}^2}{R}$

$$= \frac{V_{rms}^2}{R_{eq}}$$

Average power in llel resonance $= I_L^2 rms \cdot R + I_c^2 rms \cdot R$

$$= I_{rms}^2 \cdot R_{eq}$$

* for llel resonance. $i(t) = \frac{v_i(t)}{Z} = i_R$.

$$V = V_C = V_L = V_R \quad V_R = i_R \cdot R.$$

$$i_c = C\frac{dv_c}{dt} = C\frac{dv_R}{dt}$$

$$i_L = \frac{1}{L}\int v_L\, dt = \frac{1}{L}\int v_R\, dt.$$

* for half wave rectifier average value $= \frac{\text{Peak Value}}{\pi}$

* Locus Diagram.

* phasor diagram expanded to develop a curv known as locus.
* locus diagram useful in determining the behaviour or response. of an RLC circuit when one of its parameter is varied while frequency and voltage kept constant.
* circle diagrams identifies locus plots that are either circular or semicircular.

* based on leading of current in capacitor & lagging the current by the inductor concept. ~~dr~~ mudify the phasor diagram by varying the component and get locus of current this is the locus diagram for clarity see problem pg 323, 324 319, 320 etc.

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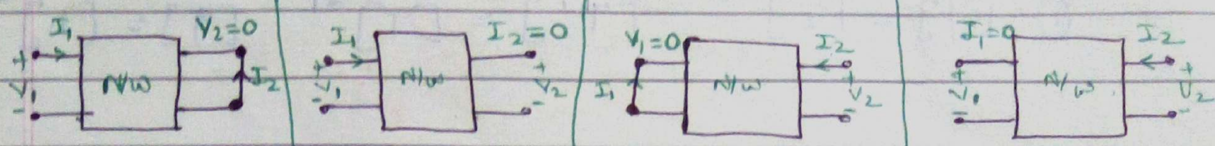
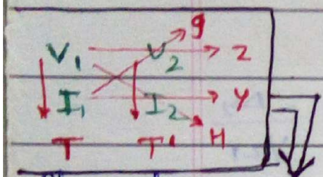
* Two port Network.



	SC Port 2	OC Port 2	SC Port 1	OC Port 1
calculating →	y_{11}, y_{21}	z_{11}, z_{21}	y_{12}, y_{22}	z_{12}, z_{22}
	h_{11}, h_{21}	g_{11}, g_{21}	g_{12}, g_{22}	h_{12}, h_{22}
	B, D	A, C	B', D'	A', C'



Name of Parameters	Express	In terms of	equations	matrix Assoiated	condition of reciprosity, symmetry.
open ckt Impedance (Z)	V_1 V_2	I_1 & I_2 I_1 & I_2	$V_1 = z_{11}I_1 + z_{12}I_2$ $V_2 = z_{21}I_1 + z_{22}I_2$	$[z] = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix}$	$z_{12} = z_{21}$ $z_{11} = z_{22}$
Short ckt Admitance (Y)	I_1 I_2	V_1 & V_2 V_1 & V_2	$I_1 = y_{11}V_1 + y_{12}V_2$ $I_2 = y_{21}V_1 + y_{22}V_2$	$[y] = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$	Passive $y_{12} = y_{21}$ $y_{11} = y_{22}$
transmission (T) (ABCD)	V_1 I_1	V_2 & I_2 V_2 & I_2	$V_1 = AV_2 - BI_2$ $I_1 = CV_2 - DI_2$	$[T] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$	$AD - BC = 1$ $A = D$.
Inverse Transmisn (T') (A'B'C'D')	V_2 I_2	V_1 & I_1 V_1 & I_1	$V_2 = A'V_1 - B'I_1$ $I_2 = C'V_1 - D'I_1$	$[T'] = \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix}$	$A'D' - B'C' = 1$ $A' = D'$
Hybrid (H)	V_1 I_2	I_1 & V_2 I_1 & V_2	$V_1 = h_{11}I_1 + h_{12}V_2$ $I_2 = h_{21}I_1 + h_{22}V_2$	$[h] = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$	$h_{12} = -h_{21}$ $\Delta h = 1$ ↳ determinant $[h]$
Inverse hybrid (g)	I_1 V_2	V_1 & I_2 V_1 & I_2	$I_1 = g_{11}V_1 + g_{12}I_2$ $V_2 = g_{21}V_1 + g_{22}I_2$	$[g] = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$	$g_{12} = -g_{21}$ $\Delta g = 1$

* interconnection betⁿ parameters.

① $[y] = [z]^{-1}$ $[T'] = [T]^{-1}$ $[g] = [h]^{-1}$

② $\Delta y \, \Delta z = 1$, $z_{11} y_{11} = z_{22} y_{22}$, $A = z_{11}/z_{21}$

$h_{11} = B/D = 1/y_{11}$ etc.

$\Delta \rightarrow$ determinant of matrix

we obtained

y to z $\Rightarrow$ $z_{11} = \frac{y_{22}}{\Delta y}$, $z_{12} = \frac{-y_{12}}{\Delta y}$, $z_{21} = \frac{-y_{21}}{\Delta y}$, $z_{22} = \frac{y_{11}}{\Delta y}$

1|y for rest T' to T & g to h

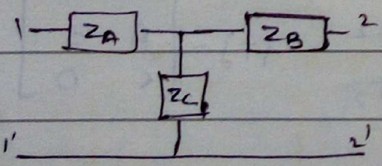
$A = \frac{z_{11}}{z_{21}} = \frac{-y_{22}}{y_{21}}$ $B = \frac{\Delta z}{z_{21}} = -\frac{1}{y_{21}}$ $C = \frac{1}{z_{21}} = \frac{-\Delta y}{y_{21}}$

$D = \frac{z_{22}}{z_{21}} = \frac{-y_{11}}{y_{21}}$

* to get relation between parametter write equations of both parameter take conditions & apply to both equations & obtain relation (pg 752)

* Typical Ntworks & parameters

* T N/w :-



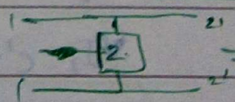
$$z = \begin{bmatrix} z_A + z_C & z_C \\ z_C & z_B + z_C \end{bmatrix}$$

Reciprocal $z_{12} = z_{21}$

Symmetry if $z_A = z_B$

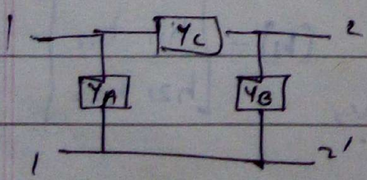
if $z_A = z_B = 0$ $z_C = z$ T becomes shunt element

$(\because) \Rightarrow$



$\Rightarrow$ Y not defined for N/w. $\det[z] = 0$

* π N/w.



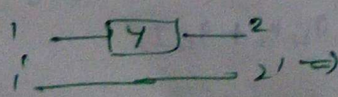
$$y = \begin{bmatrix} y_A + y_C & -y_C \\ -y_C & y_B + y_C \end{bmatrix}$$

Reciprocal $\because y_{12} = y_{21}$

symmetry if $y_A = y_B$

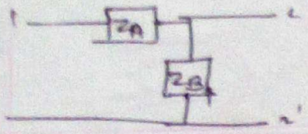
if $y_A = y_B = 0$ & $y_C = y$ π becomes series element

$\therefore \Rightarrow$



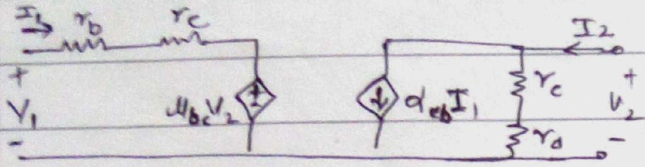
$\Rightarrow$ z no defined for such N/w $\Delta[y] = 0$.

* T network



$$T = \begin{bmatrix} 1+\frac{Z_A}{Z_B} & Z_A \\ \frac{1}{Z_B} & 1 \end{bmatrix}$$

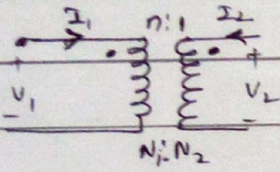
* model of CE connector transistor.



$$[h] = \begin{bmatrix} r_b + r_c & \mu_{bc} \\ \alpha_{cb} & 1/(r_c + r_d) \end{bmatrix}$$

Niether reciprocal nor symetrical.

* Ideal Transformer



$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{1}{n} = \frac{I_1}{-I_2}$$

Reciprocal, symmetric if $n=1$

$$h = \begin{bmatrix} n & 0 \\ 0 & 1/n \end{bmatrix} \quad h = \begin{bmatrix} 0 & n \\ -n & 0 \end{bmatrix}$$

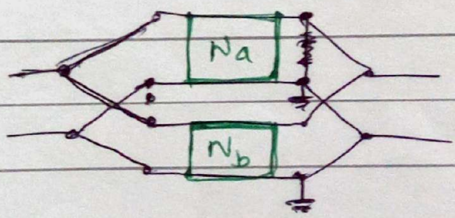
(Neither Z nor Y parameter defined)

* Interconnection of 2 port N/ws.

* Parallel connections

individual y parameters get added to get ~~new~~ y parameter of overall N/w.

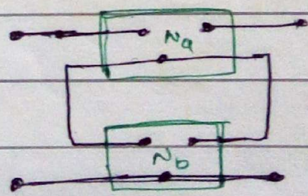
$$[Y] = [Y_a] + [Y_b]$$



* Series connection

Individual Z parameter get added to get Z parameters of overall N/w

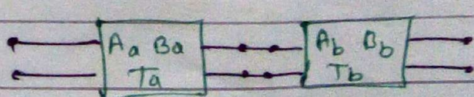
$$[Z] = [Z_a] + [Z_b]$$



* Casecade connection

Here individual T-matrices are multiplied to get overall T parameter of N/w

$$[T] = \underbrace{[T_a] \times [T_b]}_{\text{matrix multiplicat}^n}$$

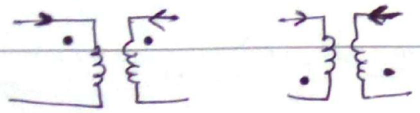


A = (first row first column)

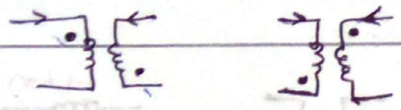
$$A = A_a A_b + B_a C_b$$

* Coupled circuits.

* if the current enters the dots or leaves the dot in both the coils simultaneously, then the mutual flux will aid to self flux else oppose the self flux.



$$\Rightarrow L_1 \frac{di}{dt} + M \frac{di}{dt}.$$



$$\Rightarrow L_1 \frac{di}{dt} - M \frac{di}{dt}.$$

coeff of coupling

$K = M / \sqrt{L_1 L_2}$ — self inductances; M — mutual inductance

maximum possible inductance

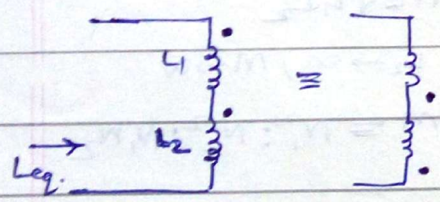
$\underline{\underline{M = \sqrt{L_1 L_2}}}$ $\underline{\underline{\because K = 1}}$

$$V = L\frac{di}{dt} \;\&\; V = N\frac{d\phi}{dt} \Rightarrow L = N\frac{d\phi}{dt}.$$

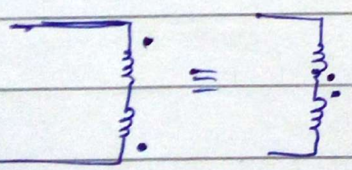
$$L \propto N^2 \Rightarrow \frac{L_1}{L_2} = \frac{N_1^2}{N_2^2} = \frac{I_2^2}{I_1^2} \qquad \frac{N_2^2}{N_1^2} = \frac{L_2}{L_1} = a^2$$

a — turn ratio

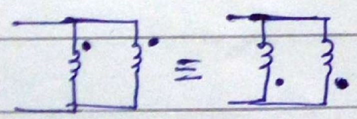
* coupled inductors in series :-



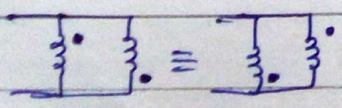
$$\Rightarrow L_{eq} = L_1 + L_2 + 2M$$



$$\Rightarrow L_{eq} = L_1 + L_2 - 2M,$$

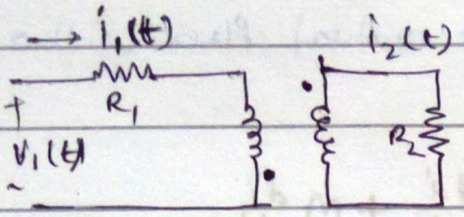


$$\Rightarrow L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$$



$$\Rightarrow L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$$

* Transform coupling.

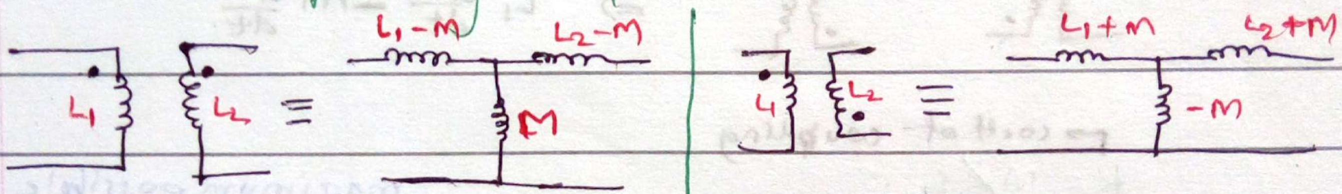


KVL:

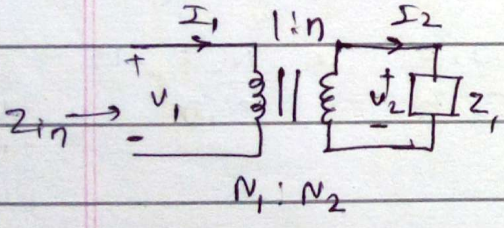
$$V_1(t) = L_1 \frac{di_1(t)}{dt} + M\frac{di_2(t)}{dt} + R_1 i_1(t)$$

$$0 = L_2 \frac{di_2(t)}{dt} + M\frac{di_1(t)}{dt} + R_2 i_2(t)$$

* Tranformer replaced by T-equivalent



* Transformer as a impedance matching properties.



$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = n = \frac{I_1}{I_2}$$

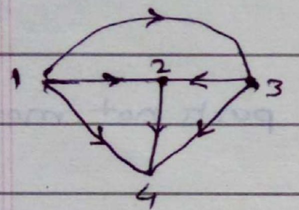
$$\boxed{Z_{in} = \frac{Z_L}{n^2}}$$

$$\frac{Z_L}{Z_{in}} = n^2 = \left(\frac{n_2}{n_1}\right)^2$$

for Ideal transformer
- $k = 1$, $M = \sqrt{L_1 L_2}$
- $L_1 \to \infty$, $L_2 \to \infty$, $M \to \infty$
- $L_1 : L_2 : M = N_1^2 : N_2^2 : N_1 N_2$

* Graph theory

* No. of Nodes in graph = No. of Nodes in tree.
→ if tree has n node ⇒ $(n-1)$ branches
→ branches of tree are called twigs. twigs $(n-1)$ ⇒ tree value or rank of the tree
→ complementary set of branches are co-tree
→ branches of co-tree are links. or chords.
→ N/w with b branches & n nodes have $(n-1)$ twigs and $(b-n+1)$ links. i.e. $b-(n-1)$ links.
→ incident matrix. $(A)_{n \times b}$ (n ↓ node, b ↓ branch)



$$\begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ 2 & -1 & -1 & 0 & 1 & 0 & 0 \\ 3 & 0 & 1 & 0 & 0 & 1 & -1 \\ 4 & 0 & 0 & -1 & -1 & -1 & 0 \end{array}$$

* Properties
→ incident matrix is unique having order $n \times b$.
→ rank of incident matrix. is equal to rank of graph $= (n-1)$
→ det. of complete incident matrix of close loop is always 0.

→* The numbe of edges (or branch) of complete graph with n nodes is
$= \frac{n(n-1)}{2}$
→ Number of possible trees of complete graph with n nodes
$= n^{n-2}$
→ Tree + co-tree = original graph.

* fundamental loop matrix or F. ckt matrix or tie-set matrix.
→ f-loops or f-ckts or tie sets are minimum number of loop or mesh equations required to solve the corresponding N/w of a given graph.
adding 1 link at a time get f-link equations.

* Properties →

→ Rank of Tie set matrix = $(b-n+1)$ i.e. $b-(n-1)$

→ No. of f loops always equal to no. of links = $(b-n+1)$

→ every fundamental loop consists of only one link in its representation.

→ One f loop matrix for one tree & for one graph n^{n-2} trees possible ∴ n^{n-2} f loop matrices are possible.

→ Cut set is a minimal set of branches of a graph, removal of which divides the graph in to two parts, i.e. the cutset always comprises minimum number of removed branches from the original graph

*→ cut set must devide graph in two parts not more than two.

* f-cutset matrix

gives minimum no. of nodal eq^n s required to solve corresponding N/W.

① select tree ② removing one tree branch at a time result one f cut set

Properties

→ rank of f-cutset matrix is $n-1$

→ no. of f-cutset are always equal to the number of tree branches i.e. twigs = $(n-1)$

→ Every f-cut set consist of only one tree branch in its representat^n.

→ every tree will result one f-cut set matrix ∴ for any graph no. of cutset matrixes = no. of trees = n^{n-2}

* Filters

$D = 10\log_{10}\frac{P_1}{P_2}$ $\frac{P_1}{P_2} \Rightarrow$ i/p power/o/p power

$D = 20\log_{10}\frac{V_1}{V_2}$ $\frac{V_1}{V_2} \Rightarrow$ i/p voltg/o/p voltag

$1D = 0.115N$ N – Neper D – Decibal.

$Z_R = R\,\Omega$ $Z_L = j\omega L\,\Omega$ $Z_C = \frac{1}{j\omega C}\,\Omega$

* $\omega = 0 \Rightarrow Z_L = 0 \Rightarrow L \to SC$ & $Z_C = \infty \Rightarrow C \to OC$
* $\omega = \infty \Rightarrow Z_L = \infty \Rightarrow L \to OC$ & $Z_C = 0 \Rightarrow C \to SC$

** To identify the filter put $\omega = 0$ & $\omega = \infty$ & find V_o at 0 & V_o at ∞ and conclude about filter.

* All pass Filter add min 0 & max ± 180 phase shift.
∴ APF is basically a phase shifter ckt.

2nd order Filters

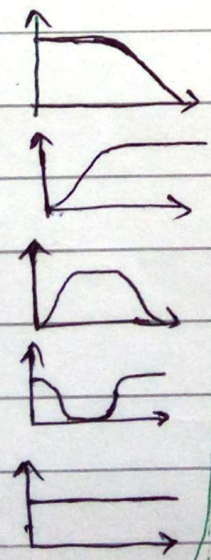
$LPF = \frac{1}{s^2+s+1}$

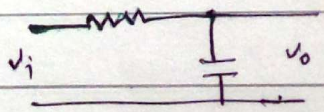
$HPF = \frac{s^2}{s^2+s+1}$

$BPF = \frac{s}{s^2+s+1}$

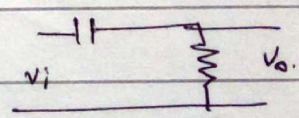
$BSF = \frac{s^2+1}{s^2+s+1}$

$APF = \frac{1-s}{1+s}$



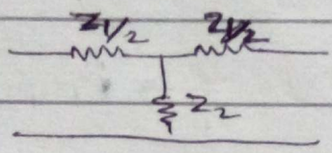


$\Rightarrow$ 1st order LPF



$\Rightarrow$ 1st order HPF.

* for T N/w.

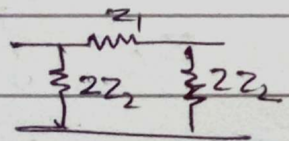


$$Z_{0T} = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2} \qquad Z_{0T} = \sqrt{Z_{oc} Z_{sc}}$$

$$\tanh \gamma = \sqrt{\frac{Z_{sc}}{Z_{oc}}} \qquad \cosh \gamma = 1 + \left(\frac{Z_1}{2Z_2}\right) = \sqrt{\frac{Z_1}{4Z_2}}$$

↓ Propagatⁿ constant for T N/w.

* for π N/w

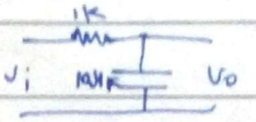


$$Z_{0\pi} = \sqrt{\frac{Z_1 Z_2}{1 + Z_1/4Z_2}} = \frac{Z_1 Z_2}{Z_{0T}} \qquad Z_{0\pi} = \sqrt{Z_{oc} Z_{sc}}$$

$$\cosh \gamma = 1 + \frac{Z_1}{2Z_2}$$

↳ Propagatⁿ constant for π N/w.

* $V_i = 3 + 4\sin 100t$ V. (w=0) (w=100)



$H(s) = \frac{1}{1+sCR} \Rightarrow H(j\omega) = \frac{1}{1+j\omega CR}$ find $H(j\omega)$ for $\omega = 0$ & $\omega = 100$ then i.e. $H(s)$

$V_o(s) = H(s) \cdot V_i(s)$

$\frac{I(s)}{V(s)} = H(s) = Y(s) = \frac{1}{Z(s)}$

* if asked steady state current or voltage go by laplace transform of ckt & find T.F. & ans. eg. as above.

* C is SC in DC & Depends on freq. in AC. (mostly OC)

C is SC $t=0^+$ & OC at $t \to \infty$ (s.s.)

L is OC $t=0^+$ & SC at $t \to \infty$. (s.s)

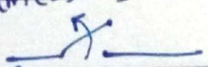
(T.S.)

* $\frac{di}{dt} + \frac{R}{L} i = 0 \Rightarrow i(t) = I_0 e^{-R/L\, t} = I_0 e^{-t/\tau}$ $\tau = \frac{L}{R}$

My $v(t) = V_0 e^{-t/RC} = V_0 e^{-t/\tau}$ $\tau = RC$

*for particular sum (eg. 1st)

*



(switching off) $\Rightarrow$ 3 states

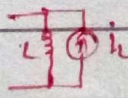
① S is ON $t \to \infty$
this is steady state $L = SC$, $C = O.C$
find i_L for L &/or V_C for C.
i_L through L as L is SC $\Rightarrow 0^-$

② Now S is just off 0^+
Now this is transient state or $V_C(0^+) = V_C(0^-)$
$L = OC$, $C = SC$, & $i_L(0^+) = i_L(0^-)$
but L have ||el current source of i_L
& Hy C have V_C source in series.

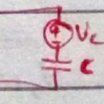
in this state ckt becomes Resistive.

*(if $i_L(0^+) = i_L(0^-)$ for L
then $V_L(0^+) \neq V_L(0^-)$
find $V_L(0^+)$
My for V_C also)

③ Now $t \geq 0$ L is replaced by



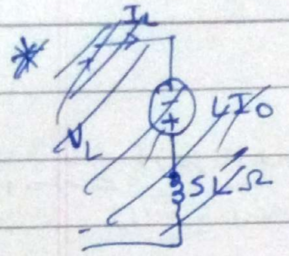
Hy C is



* find τ for L or C N/w.
to have $i(t)$ & $v(t)$ eqn.

* for all source free ckt of transient current will flow from -ve to +ve terminal. Energy is decaying $\because$ memory elements are discharging.

*



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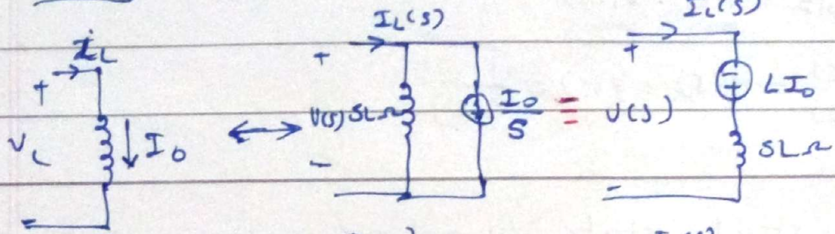
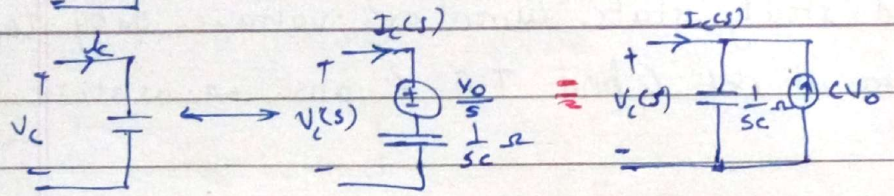




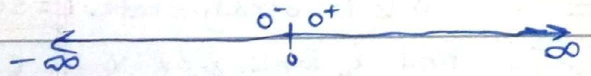
* $i_L(t) = i_L(\infty) + [i_L(0) - i_L(\infty)]\, e^{-t/\tau}$

My for source free $i_L = i_L(0)\, e^{-t/\tau}$ $\because i_L(\infty) = 0A$

$V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

for source free $V_c(t) = V_c(0)\, e^{-t/\tau}$ $\because V_c(\infty) = 0$.

* main concept

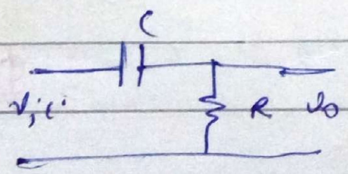


① for s.s. cap. is o.c. & Inductor is s.c. find V_c & i_L

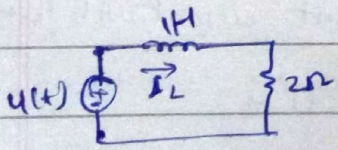
② at transient cap is sc. Inductor is oc with replacement of appropriate V_c^+ & I_L sources.

③ at $t \to \infty$ again cap. o.c. & Inductor s.c.

*



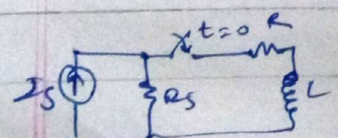
RC diff. ckt.



2 method

① Laplace method & $\frac{V(s)}{I(s)} = Z(s) = 2 + sL$, $V(s) = \frac{1}{s}$, $I(s) = ?$ & $i_L(t)$

② find $i_L(0)$, $i_L(\infty)$ & then $i_L(t)$



$\frac{di(0^+)}{dt} = ?$

$i_L(0) = 0$

Ans = $\frac{I_s R_s}{L}$

at $t \geq 0$ $I_s R_s = i_L(R_s + R) + L\frac{di}{dt}$