CIRCUITS LAB SUMMARY

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FALL - 2013

POWER UNIT
ELECTRICAL ENGINEERING

Electric Circuit Lab

EE 219

Summary & Review

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Electrical Engineering

Note :

1- This summary for final exam so you need to solve problems after studying it

2- Review the Summary at the End of Manual.

3- This is just personal effort...
Good Luck :)

Experiment 1 :-

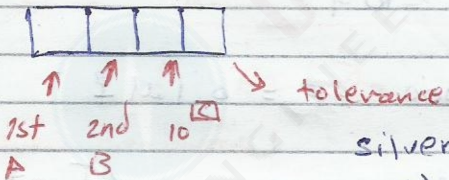
PERFORMANCE OF DC circuits

Part 1 : identification of R and C using color coding :

① Resistors :- Two Types :-

* Four color code

$AB \times 10^{C} \pm T$



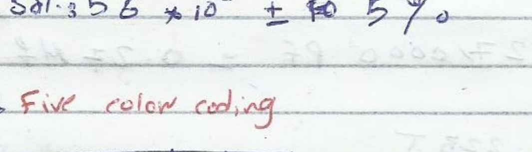
silver ±10%
gold ±5%

Example:- green, blue, orange, gold

green 5
Blue 6
orange 3

Sol. : $56 \times 10^{3} \pm 5\%$

* Five color coding



Brown ± 1%
Red ± 2%

Example : blue grey brown red Brown

Sol. $681 \times 10^{2} \pm 1\%$

② capacitors :-

A	B	Z	S

A: 1st number
B: 2nd number
Z: # of zeros
S: Symbol of Tolerance (B: ± 0.1%, C: ± 0.25%)

* Example: 104

10,0000 PF = 0.1 μf

* Example 103 J (J: ± 5%)

10,000 PF ± 5%
= 0.01 μf

* Ex: 274 M (M: 20%)

= 27,0000 PF = 0.27 μf ± 20%

223 J
22,000 PF = 22 nf = 0.022 μf ± 5%

151 K (K: 10%)
15,0 PF = 150 PF ± 10%

Sometimes directly
4.7 PF , 4P7 (4.7 PF) , 4μ7 (4.7 μf), 4n7 (4.7 nf)

$$\%e = \frac{\text{measured} - \text{nominal}}{\text{nominal}} * 100\%$$

Part 2: Voltage & current division.

$$V_{R_1} = V_S * \frac{R_1}{R_1 + R_2 + \dots R_n} \quad (R_1 - R_n) \text{ Series}$$

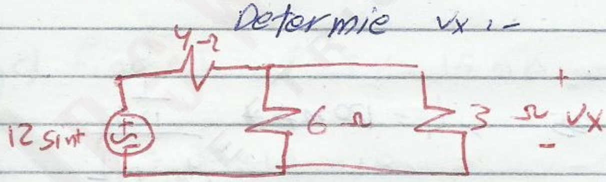
$$I_{R_1} = I * \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \frac{1}{R_n}} \quad (R_1 - R_n) \text{ Parallel}$$

* Note: solve problems!

Part 3: Nodal & Mesh Analysis.

Example 3.12

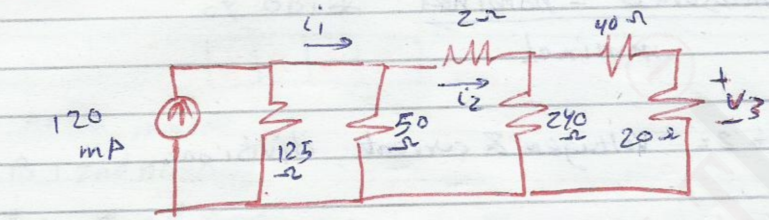
Determie vx :-



$$\frac{6*3}{9} = \frac{18}{9} = 2\ \Omega$$

$$v_x = 12\sin(t) * \frac{2}{4+2} = 4\sin t$$

practice 3.13 find i_1, i_2, V_3



$40+20 = 60$, $\frac{60 * 240}{60+240} = 48$, $48+2 = 50$

$i_2 = 120\,mA * \dfrac{\frac{1}{50}}{\frac{1}{50} + \frac{1}{50} + \frac{1}{125}}$ = ~~52.45 mA~~ 50 mA

$V(50) = 50 * 50 = 2.5\,V = V(60) = i_3 * 60 = 2.5$

$i_3 = 0.042\,mA$

$V_3 = i_3 * 20 = 0.83\,V$

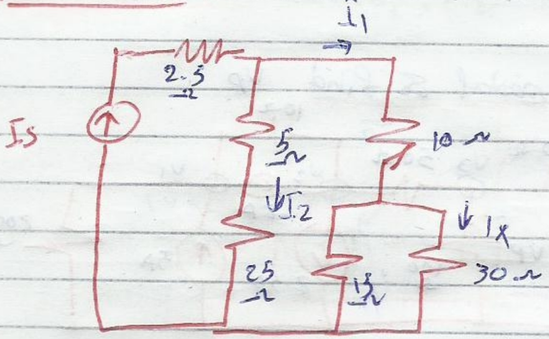
~~$i_1 = 120$~~

$\frac{50 * 50}{100} = 25$, $i_1 = 120\,mA * \dfrac{\frac{1}{125}}{\frac{1}{125} + \frac{1}{25}}$

$= 100\,mA$

Problem

problem 70 :-



a) find I_x if $I_1 = 12\,mA$

$\frac{30 * 15}{45} = 10$, $I_1 * 10 = 0.12$ $V = 30 * I_x$

$\Rightarrow I_x = 4\,mA$

b) find I_1 if $I_x = 12\,mA$

$V = 30 * I_x = 0.36 = I_1 \times 10 \Rightarrow I_1 = 36\,mA$

c) find I_x if $I_2 = 15\,mA$

$R_1 = \frac{30 \times 15}{30 + 15} = 10$

$V_1 = I_2(5 + 25) = I_1 * (10 + R_1)$
$= 0.45 = I_1 * 20 \Rightarrow I_1 = 22.5\,mA$

$V_{R_1} = I_1 * R_1 = 0.225$, $I_x = \frac{0.225}{30} = 7.5\,mA$

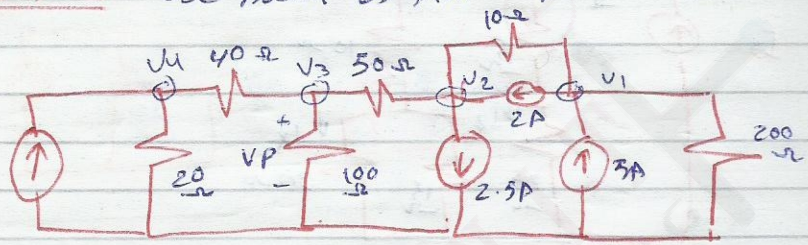
d) I_x if $I_s = 60$

$I_1 = 60 * \frac{\frac{1}{20}}{\frac{1}{20} + \frac{1}{30}} = 36\,mA$

$I_x = 12\,mA$

CH 4

Problem 3 Use nodal & find V_P



Sol.

Node 1 :- $\frac{V_1}{200} + \frac{V_1 - V_2}{10} = 3$ ①

Node 2 :- $\frac{V_2 - V_1}{10} + \frac{V_2 - V_3}{50} = -0.5$ ②

Node 3 :- $\frac{V_3 - V_2}{50} + \frac{V_3}{100} + \frac{V_3 - V_4}{40} = 0$ ③

Node 4 :- $\frac{V_4}{20} + \frac{V_4 - V_3}{40} = 10$ ④

$\Rightarrow 0.105\,V_1 - 0.1\,V_2 + 0\,V_3 + 0\,V_4 = 3$ --[1]

$-0.1\,V_1 + 0.12\,V_2 - 0.02\,V_3 + 0\,V_4 = -0.5$ [2]

$0\,V_1 - 0.02\,V_2 + 0.055\,V_3 - 0.025\,V_4 = 0$ [3]

$0\,V_1 + 0\,V_2 - 0.025\,V_3 + 0.075\,V_4 = 10$ [4]

$\Rightarrow$ multibly (3) by 0.075 and ④ by -0.025

(3) -(4) = $-1.5 \times 10^{-3}\,V_2 + 3.5 \times 10^{-3}\,V_3 = 0.25$ --[5]

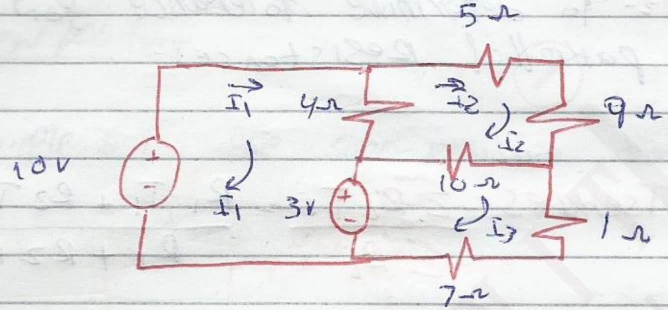
Solve ① ② ⑤

$V_1 = 251.26$

$V_2 = 273.824$

$V_3 = \underline{\underline{V_P}} = 171.64$

Practice 4.6 Find i_1, i_2

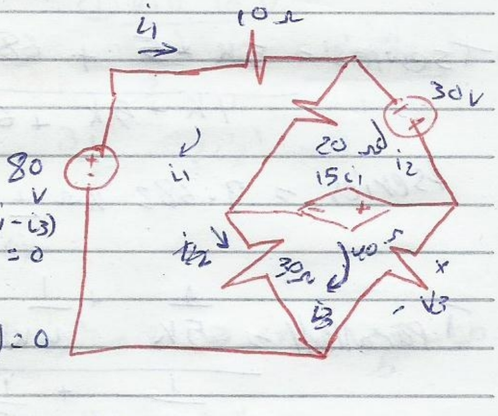


mesh 1: $-10 + 4(I_1 - I_2) + 3 = 0$
mesh 2: $14 I_2 + 10(I_2 - I_3) + 4(I_2 - I_1) = 0$
mesh 3: $8 I_3 - 3 + 10(I_3 - I_2) = 0$

$4I_1 \quad -4I_2 = 7 \qquad (1)$
$-4I_1 + 28 I_2 - 10 I_3 = 0 \qquad (2)$
$0 I_1 - 10 I_2 + 18 I_3 = 3$

$I_1 = 2.22\ A, \quad i_2 = 0.47\ A, \quad I_3 = 0.43\ mA$

Practice 4.8 Find V_3



mesh 1: $-80 + 10 i_1 + 20(i_1 - i_2) + 30(i_1 - i_3) = 0$

mesh 2: $-30 + 15 i_1 + 20(i_2 - i_1) = 0$

mesh 3: $-15 i_1 + 40 i_3 + 30(i_3 - i_1) = 0$

$i_1 = 3.08, \quad i_2 = 2.27, \quad i_3 = 1.98$

$V_3 = 40 \times 1.98 = 79.2$

*Note:- To determine tolerance for series or parallel Resistance:-

$$T_{series} = \frac{\sum R_i T_i}{\sum R_i} = \frac{R_1 T_1 + R_2 T_2 + \cdots}{R_1 + R_2 + R_3 \cdots}$$

$$T_{parallel} = \frac{\sum \frac{1}{R_i}}{\sum \frac{1}{R_i T_i}} = \frac{\frac{1}{R_1} + \frac{1}{R_2} + \cdots}{\frac{1}{R_1 T_1} + \frac{1}{R_2 T_2} + \frac{1}{R_3 T_3} \cdots}$$

Example :-

$R_1 = 5\,K\Omega \pm 5\%$

$R_2 = 682\,\Omega \pm 10\%$

$R_3 = 4\,K\Omega \pm 1\%$

$$T_{series} = \frac{5k * 5 + 682 * 10 + 4k}{4k + 5k + 682} = 3.7\%$$

$R_{series} = 9.682\,K\Omega \pm 3.7\%$

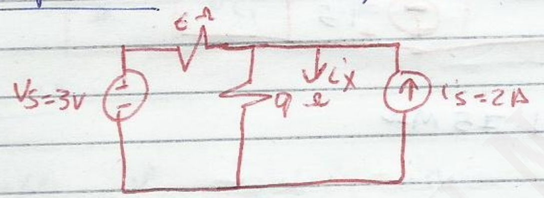
$$T_{parallell} = \frac{\frac{1}{5K} + \frac{1}{4K} + \frac{1}{682}}{\frac{1}{5K * 5} + \frac{1}{682 * 10} + \frac{1}{4K * 1}} = 4.4\%$$

$R_{parallel} = 521.85 \pm 4.4\%$

Experiment 2: Network Theorm

① Super position

Example 5.1 use super position to find i_x

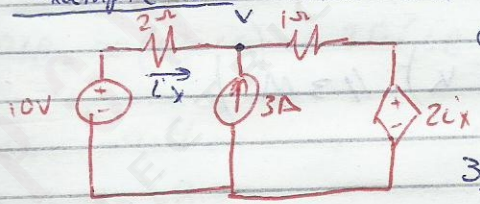


① kill 3V $\Rightarrow i_x' = 2 * \frac{6}{9+6} = 0.8\ A$

② kill 2A $\Rightarrow i_x'' = 3 * \frac{9}{(9+6)\,9} = \frac{3}{15} = 0.2$

$i_x = i_x' + i_x'' = 1\ A$

Example 5.3 find i_x



① kill 10 V

$\frac{v'}{2} - 3 + \frac{v' - 2i_x'}{1} = 0$

$\frac{3v'}{2} - 2i_x' = 3$

$\frac{0 - v'}{2} = i_x' \Rightarrow v' = -2i_x'$

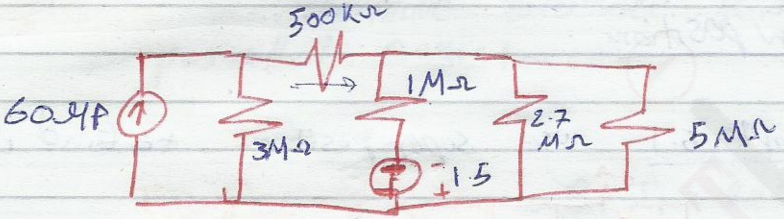
$\frac{-6i_x'}{2} - 2i_x' = 3 \Rightarrow -5i_x' = 3 \Rightarrow i_x' = \frac{-3}{5} = -0.6\ A$

② kill 3A $\Rightarrow -10 + 2i_x'' + i_x'' + 2i_x'' = 0$

$i_x'' = 10/5 = 2A$

$i_x = 2 - 0.6 = 1.4\ A$

Problem 9 find power across 500 kΩ



① $\frac{2.7 * 5}{2.7 + 5} = 1.75\ M\Omega$

② Kill 60 μA

$\underbrace{3M + 500K}_{A} \parallel 1.75M = \underbrace{1.17\ M\Omega}_{B}$

$V_B = -1.5 * \frac{1.17\ M}{1.17M + 1M} = -0.81\ v$

$= V_A$, $I_A = \frac{V_A}{A} = 0.23\ \mu A$

③ Kill 1.5

$\left(\left(1.75M \parallel 1M + 500\ k \right) \parallel 3\ M \right)$

A 0.64 M

1.136 MΩ
B

0.824 MΩ
C

$I_C = 60\ \mu A$

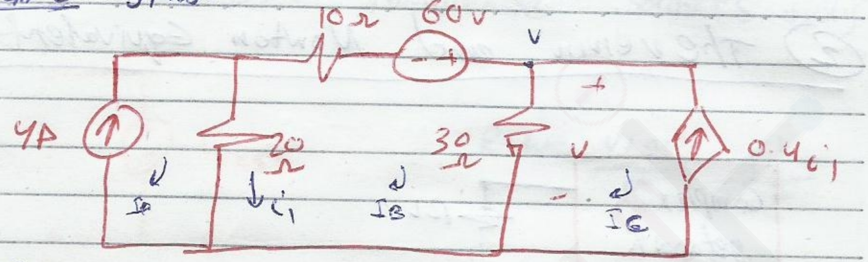
$V_C = 49.5 = V_B$, $I_B = \frac{V_B}{B} = 43.6\ \mu A$

$V_{500k} = 21.78$, $I'' = 43.6\ \mu A$

$I = 43.83$

$P = 0.96\ mW$ ✓

problem 8 find V



① Kill 4A

$$\frac{v' - 60}{30} + \frac{v'}{30} - 0.4 i_1 = 0$$

$$i_1 = \frac{v' - 60}{30}$$

$v' = 22.5$ $\quad i_1' = -1.25$

② Kill 60 V

$i_A = 4$

$10 i_B + 30(i_B - i_C) + 20(i_B - 4) = 0$ (1)

$i_C = -0.4 i_1 = -0.4(4 - i_B) = 0.4 i_B - 1.6$

$i_1 = 4 - i_B$

$0.4 i_B - i_C = 1.6$ —(2)

$i_B = 0.67$, $v'' =$

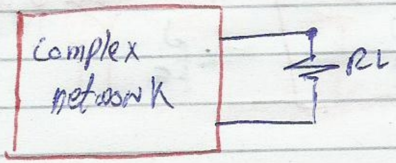
$i_C = -1.33$

$i(30) = i_B - i_C = 2$

$v'' = 2 \times 30 = 60$

$V = 60 + 22.5 = 82.5V$

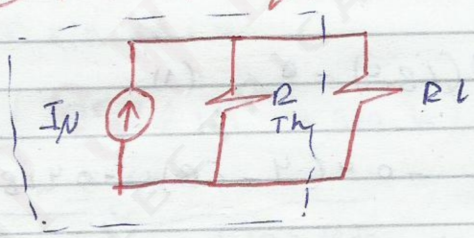
② Thevenin and Norton Equivalent cct



① Thevenin equivalent circuit

$V_{Th} = V_{oc}$

② Norton equivalent circuit



$I_N = I_{sc}$

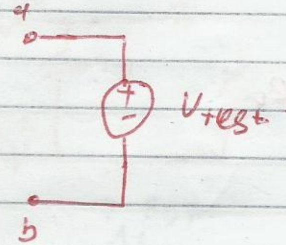
R_{Th} :- ① If there are no dependent source.

⇒ Kill all sources, $R_{th} = R_{eq}$.

② If there are dependent & independent:

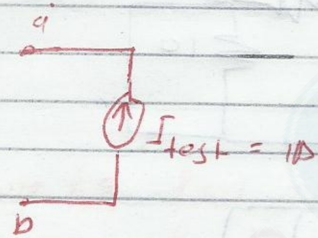
$$R_{th} = \frac{V_{oc}}{I_{sc}}$$

③ If there are independent sources only



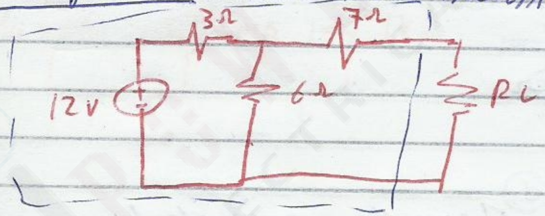
$R_{th} = \frac{V_{test}}{I} = \frac{1}{I}$

OR



$R_{th} = \frac{V}{I_{test}} = V$

Example 5.6 Determine Thevenin & Norton for left side



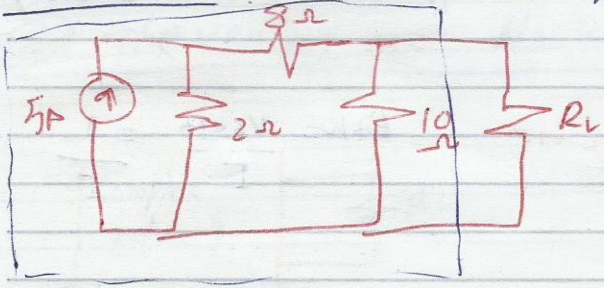
← thevenin

① $V_{th} = V_{oc} = \frac{12 * 6}{9} = 8V$

② $I_N = I_{SC} = \frac{12}{3} * \frac{\frac{1}{7}}{\frac{1}{3} + \frac{1}{6} + \frac{1}{7}} = \frac{8}{9} A$

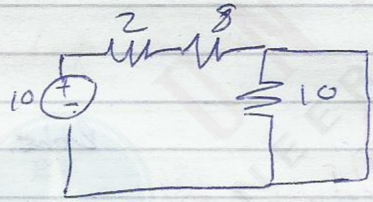
$R_{th} = \frac{3 \times 6}{9} + 7 = 2 + 7 = 9 \Omega$

Practice 5.5 Find Norton equivalent

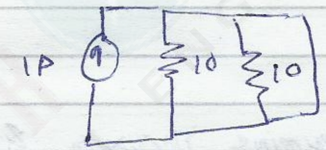


$I_{SC} = 1A$

$V_1 = 5 * 2 = 10$



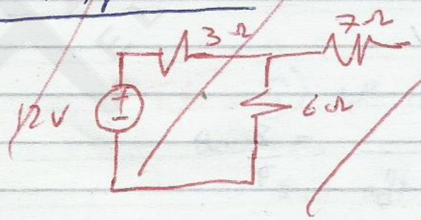
$I_1 = \frac{10}{10} = 1A$



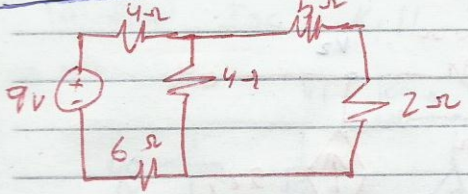
$I_{SC} = 1A$

$R_{th} = \frac{10 * 10}{20} = 5\Omega$

Example 5.7 Find thevenin equivalent



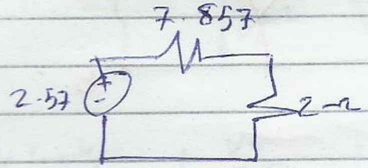
Practice 5.6 Find I through 2Ω by thevinin



① $V_{th} = V_{oc} = 9 \times \frac{4}{4+4+6}$

$= 2.571\ V$

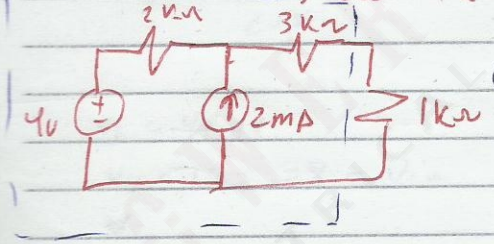
② $R_{th} = \frac{10 \times 4}{14} + 5 = 7.857$



$I_{2\Omega} = \frac{2.571 \times 2}{(2+7.857) \times 2}$

$= 260.8\ mA$

Example 5.8 find Theven & Norton for the network faced 1kΩ



① $V_{th} = V_{oc}$

~~Voc~~

ⓐ Kill 4V

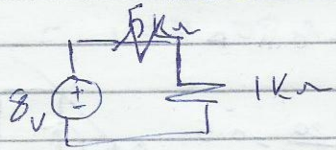
$V_{oc}' = 4\ V$

ⓑ Kill 2mA

$V_{oc}'' = 4V$

$V_{th} = 4 + 4 = 8V$

$R_{th} = 5k\Omega$



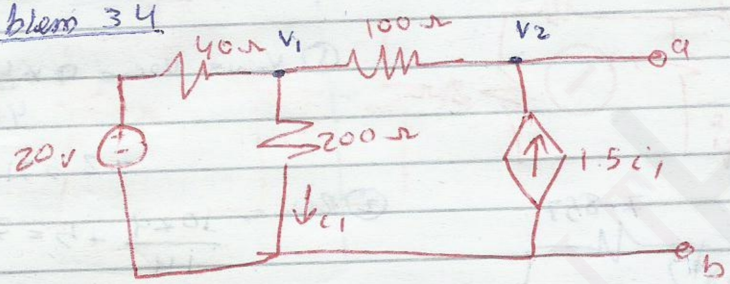
② $I_N = I_{sc}$ ⓐ Kill 4V $\Rightarrow I_{sc}' = 2 \times \frac{2}{5} = 0.8mA$

ⓑ Kill 2mA $I_{sc}'' = \frac{4}{5} = = 0.8\ mA$

$I_{sc} = 1.6\ mA$

~~Example 5.8~~

Problem 34



① $V_{th} = V_{OC}$

$$\frac{V_1 - 20}{40} + \frac{V_1 - V_2}{100} + \frac{V_1}{200} = 0$$

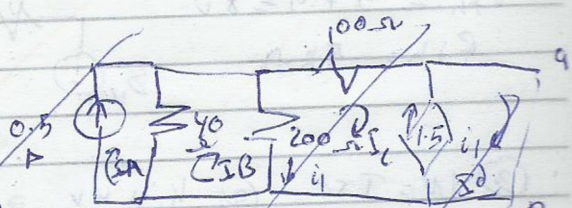
$$\frac{V_2 - V_1}{100} - 1.5\, i_1 = 0$$

$$i_1 = \frac{V_1}{200}$$

$V_1 = 22.22$ V , $V_2 = V_{OC} = 38.89$ V

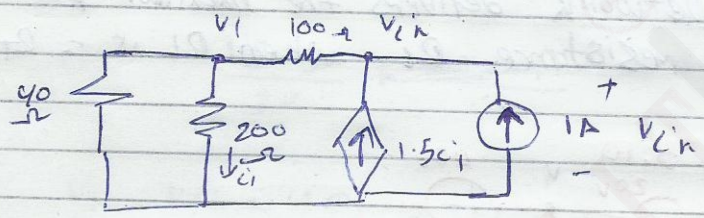
$i_1 = 0.11$ A

Isc $\frac{20}{40} = 0.5$



$$\frac{40 \times 200}{240} = 33.33$$ $\times 0.5 = 16.67$

To find Isc kill 20V and test 1A



$$\frac{V1 - V_{in}}{100} + \frac{V_1}{40} + \frac{V_1}{200} = 0$$

$$-1 - 1.5i_1 + \frac{V_{in} - V_1}{100} = 0$$

$$i_1 = \frac{V_1}{200}$$

$V_1 = 44.44$

$V_2 = 177.78 = V_{in}$

~~V~~

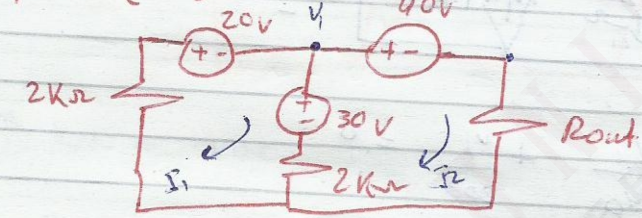
$i_1 = 0.222$ A

$$\therefore R_{th} = \frac{V_{in}}{1A} = 177.78\ \Omega$$

Maximum Power transfer

A Network delivers the maximum power to a load resistance R_L when R_L is = R_{Th}.

practice 5.10



a) ~~If Rout = 3 k Ω~~

find the maximum power that can deliver to any Rout?

⇒ max. at Rout = Rth

$R_{th} = \frac{2 \times 2}{2} = 2\ k\Omega$

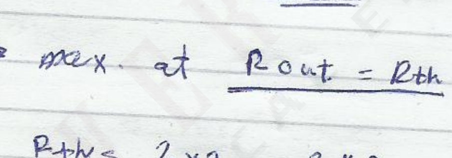
$V_{th} = V_{oc}$

① kill 20, 40 ⇒ $V_{oc} = 15\ V$

kill 20, 30 ⇒ $-V_{oc} - 40 = 0$, $V_{oc} = -40\ V$

kill 40, 30 ⇒ $V_{oc} = -20 \times \frac{2}{4} = -10\ V$

$V_{th} = -35\ V$



at Rout = 2kΩ

$V = -35 \times \frac{2}{4} = -17.5$

$V_{Th} = V_{OC}$

$$\frac{V_1 + 20}{2k} + \frac{V_1 - 30}{2K} = 0$$

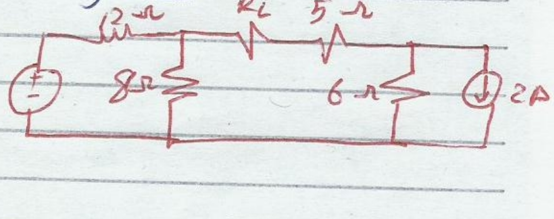
$V_1 - V_{Th} = 40$

$\Rightarrow 1 \times 10^{-3} V_1 = 5 \times 10^{-3} \Rightarrow V_1 = 5$

$5 - V_{Th} = 40 \Rightarrow \boxed{V_{Th} = -35\ V}$

$$P_{RL}\Big|_{max} = \frac{V_{Th}^2}{4R_L} = \frac{(-35)^2}{4(2k)} = 153.13\ mW$$

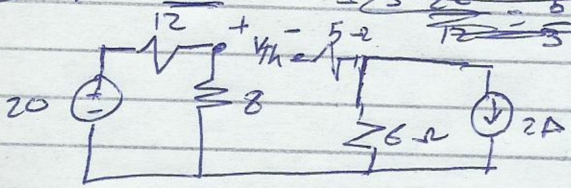
Problem 47 Find Maximum power can be dissipated by any R_L



① $R_{th} = \frac{12 \times 8}{20} + 6 + 5$

$= 15.8\ \Omega$

② $V_{th} = V_{OC}$ ⇒ ~~$I = \frac{20}{12} = \frac{5}{3}$~~, ~~$R = 4.8$~~



① Kill 2A

$V_8 = 8V$

② Kill 20 V,

$-8 + V_{th} = 0$

$\boxed{V_{th} = 8}$

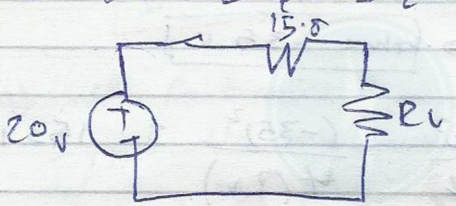
② Kill 20 V

$\frac{12 * 8}{20} = \frac{4}{3}$ 4.8 kΩ

$V_6 = -2 * 6 = -12$

$\Rightarrow 12 - V_{th} = 0$ $\Rightarrow$ $V_{th}'' = 12 \ V$

$V_{Th} = -12 + 8 = 20 \ V$

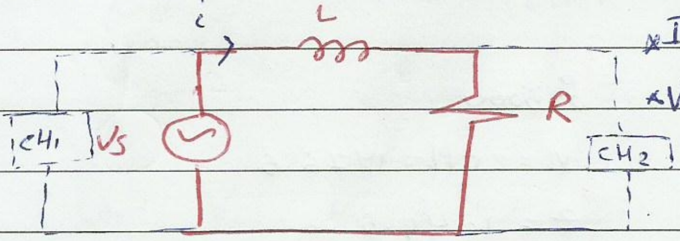


$P_{RL}|_{max} = \frac{20^2}{4 * 15.8} = 6.33 \ W$

Experiment 3

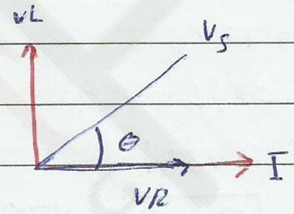
Series RL & RC under AC excitation

① series RL circuit



$* I = I_R = I_L$ --(1)

$* V^2 = V_L^2 + V_R^2$ --(2)



I lag VL by 90° and lag V by θ

$* \theta = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{V_L}{V_R}\right)$ ...(3)

(θ is -ve goes from 0 to -90)

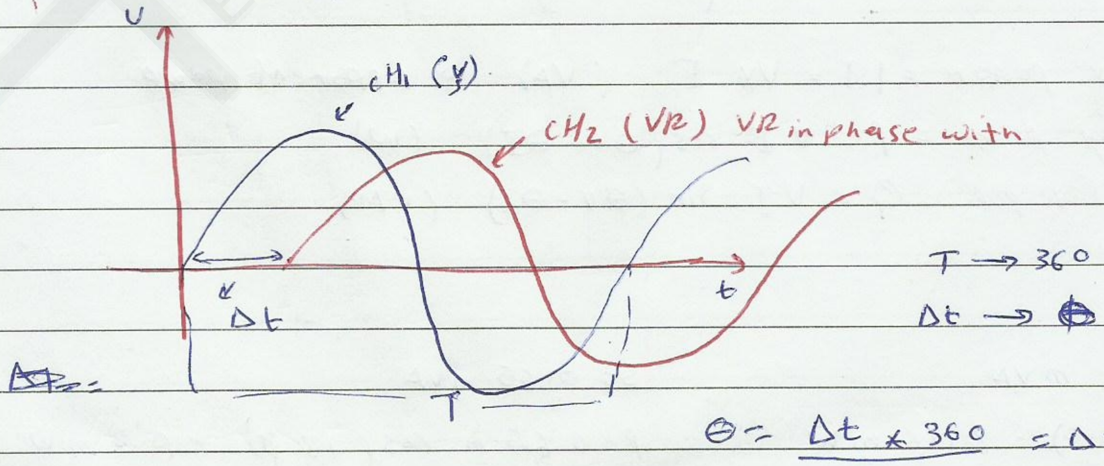
$* X_L = 2\pi f L$ --(4) $\quad * I = \frac{V\angle 0}{Z} \angle\theta$, $Z = \frac{V_S}{I}$, $X_L = \frac{V_L}{I}$

f↑ → XL↑ (2πfL) → VL↑ (I × jXL) → VR↓ (Vs const) → I↓, $\left(\frac{V_R}{R}\right)$

$* P = V_L I$ (Power in inductor)

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

$* P = I^2 R + L I \frac{di}{dt}$ (total power)



T → 360

Δt → θ

$\theta = \frac{\Delta t * 360}{T} = \Delta t * 360 * f * \text{Scale}$

Example: Let $V_S = 1\angle 0$, $L = 47$ mH, $R = 470\ \Omega$.
determine ~~I, VR, VL~~ Z, θ, I, V_R, V_L for
$f = 100, 2000, 5000$

Sol.

$f = 100$

$X_L = 2\pi f L = 29.53$

$Z = |R + jX_L|$

$= \sqrt{R^2 + X_L^2} = 470.93\ \Omega$

$\theta = \tan^{-1}\left(\frac{X_L}{R}\right) = -3.6^\circ$

$I = \frac{V_S}{Z} = \frac{1}{470.93} = 2.13\angle -3.6$ mA

$V_R = I * R = 2.13\angle -3.6 * 470 * 10^{-3}$

$= 1.001\angle -3.6^\circ$

$V_L = I * jX_L = 2.13\angle -3.6 * j29.53 * 10^{-3}$

$= 0.063\angle 86.4$

Check: ~~$\tan^{-1}\left(\frac{V_L^2}{V_R^2}\right)$~~ =

$-\tan^{-1}\left(\frac{V_L}{V_R}\right) = -3.6$ ✓

$f = 5000$

$X_L = 2\pi f L = 1476.5$

$Z = 1549.5\ \Omega$

$\theta = \tan^{-1}\left(\frac{X_L}{R}\right) = -72.34$

$I = 0.65\angle -72.34$ mA

$V_R = I * R = 0.31\angle -72.34$

$V_L = I * jX_L = 0.96\angle 17.66$

$-\tan^{-1}\left(\frac{V_L}{V_R}\right) = \tan^{-1}\left(\frac{0.96}{0.31}\right) = -72.1$ ✓

Note: ① complex power $= |S| = V \times I$ (VA) → Apparent powe

② Average power $= P = V I \cos(\theta_V - \theta_I)$ (W)

③ Reactive powe $= Q = V I \sin(\theta_V - \theta_I)$ (VAR)

$S = V \times I = 2.13$ mVA

$P = V \times I \times \cos(0 + 3.6) = 2.126$ mW

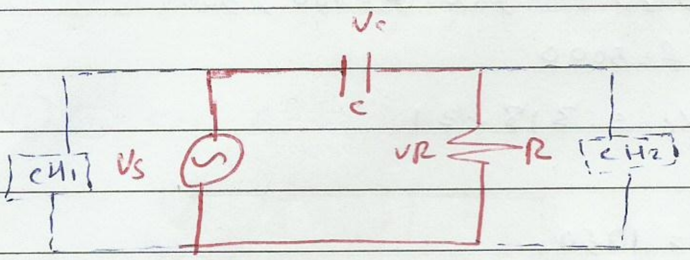
$Q = V \times I * \sin(3.6) = 0.134$ mVAR

$S = 0.65$ mVA

$P = 0.65\text{m} \cos(72.3) = 0.2$ mW

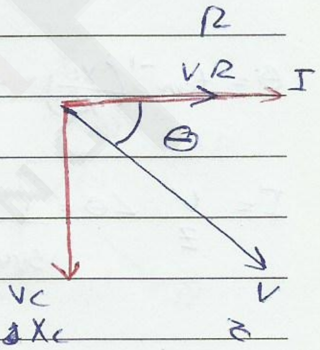
$Q = 0.65 \sin(72.3) = 0.62$ mVAR

② Series RC circuit



$I = I_C = I_R$

$V^2 = V_C^2 + V_R^2$



I lead V_c by $90°$ and lead V by θ

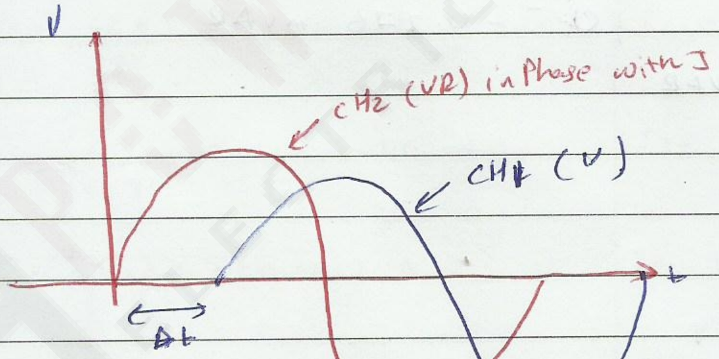
$\angle I \quad \theta = +\tan^{-1}\left(\frac{X_C}{R}\right) = \tan^{-1}\left(\frac{V_C}{V_R}\right)$

(θ goes from 90 to zero) (+ve)

$X_C = \frac{1}{2\pi f c}$, $I = \frac{V}{Z}\angle\theta$, $Z = \frac{V_S}{I}$, $X_C = \frac{V_C}{I}$

$f\uparrow \longrightarrow X_C\downarrow \left(\frac{1}{2\pi f c}\right) \longrightarrow V_C\downarrow \left(I * jX_C\right) \longrightarrow V_R\uparrow$ (Vconst)

$\uparrow I \left(\frac{V_R}{R}\right)$



Example: Let $V_s = 1\angle 0$, $C = 0.1\ \mu F$, $R = 1000\ \Omega$

determine, Z, θ, I, V_C, V_L, P, Q, S for $f = 100, 5000$

$f = 100$ Hz

$X_C = \frac{1}{2\pi f C} = 15915.5\ \Omega$

$Z = \sqrt{X_C^2 + R^2} = 15947\ \Omega$

$\theta = \tan^{-1}\left(\frac{X_C}{R}\right) = +86.4^\circ$

$I = \frac{V}{Z}\angle\theta = \frac{1}{15947}\angle 86.4 = 0.063\ mA\angle 86.4$

$V_C = I * -jX_C = 0.998\angle -3.6^\circ$

$V_R = I * R = 0.063\angle 86.4\ mA$

$|S| = V * I = 0.063\ mVA$

$P = VI\cos(\theta_V - \theta_I) =$ ~~3.96 m~~ $0.00395\ mW$

$Q = VI\sin(\theta_V - \theta_I) = -0.063\ mVAR$

$f = 5000$

$X_C = 318.31$

$Z = 1050$

$\theta = 16.86^\circ$

$I = 0.952\angle 16.86\ mA$

$V_C = 0.3\angle -73.14$

$V_R = 0.952\ V$

$|S| =$ ~~0.91 mVA~~ $0.952\ mVA$

$P = 0.91\ mW$

$Q = -0.276\ mVAR$

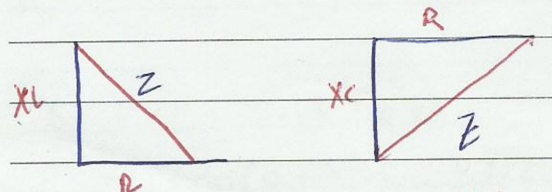
check: $\tan^{-1}\left(\frac{V_C}{V_R}\right) = 86.4$

$Z = \frac{V_s}{I} = \frac{1\angle 0}{I} = 15873\angle -86.4$

$X_C = \frac{V_C}{I} = 15841$

---

*Note:- Impedence triangle



Q- Why the f.G output voltage level change with f?

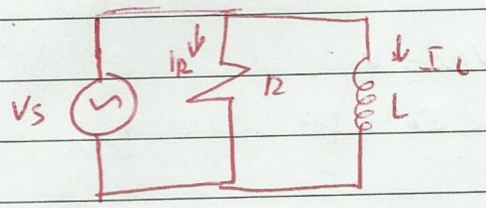
because it has internal impedence change with f.

$i = \frac{V\left(1 - e^{-\frac{R t}{L}}\right)}{R}$, $\frac{L}{R}$, Time constant

Experiment 4

Parallel RC and RL circuits Under AC Excitation

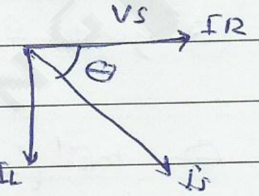
① Parallel RL circuit:



$V_S = V_R = V_L$

$I_S^2 = I_L^2 + I_R^2$

(θ goes from -90 to zero) (-ve) (0 → pure R, -90 → pure L)



$\theta = -\tan^{-1}\left(\frac{I_L}{I_R}\right)$, $I_R = \frac{V_s}{R}$, $I_L = \frac{V_s}{X_L}$, $Y = \frac{I}{V_s}$, $B_L = \frac{I_L}{V_S}$

$f\uparrow \rightarrow X_L\uparrow (2\pi f L) \rightarrow I_L\downarrow \rightarrow I_R$ const $\rightarrow \uparrow I_S = \sqrt{I_L^2 + I_R^2}$ ~~θ~~ -ve)

Example: let $V_s = 1\angle 0$, $L = 100$ mH , $R = 680\ \Omega$
determine I_R , I_L, I , θ ($\angle I$ with V_s) , Y , B_L . For $f = 100, 5000$

$f = 100$

$X_L = 2\pi f L = 62.8\ \Omega$

$I_R = \frac{1\angle 0}{680} = 1.471$ mA

$I_L = \frac{1\angle 0}{j62.8} = 0.016\angle -90$ A

$I = \sqrt{I_L^2 + I_R^2} = 0.0161$ A

$= 0.$

$\theta = -\tan^{-1}\left(\frac{I_L}{I_R}\right) = -\tan^{-1}\left(\frac{0.016}{0.00147}\right)$

$= -84.75^{\circ}$

$Y = \frac{I}{V_s} = \frac{0.0161\angle -84.75}{1\angle 0}$

$= 0.0161\angle -84.75\ \Omega^{-1}$

$B_L = \frac{I_L}{V_s} = 0.016\angle -90\ \Omega^{-1}$

$f = 5000$

$X_L = 3141.6$

$I_R = 1.471$ mA

$I_L =$ ~~3.18~~ $0.318\angle -90$ mA

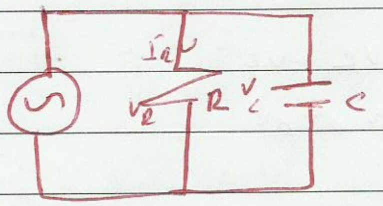
$I = 1.505$ mA

~~$\angle$ -12.2~~ $\theta = -12.2^{\circ}$

$Y = 1.505\angle -12.2$ mΩ^{-1}

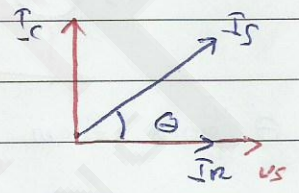
$B_L = 0.318\angle -90^{\circ}$ mΩ^{-1}

② Parallel RC circuit



$V_S = V_R = V_C$

$I_S^2 = I_R^2 + I_C^2$



(θ goes from 0 to 90) (+ve)

$\theta = \tan^{-1}\left(\frac{I_C}{I_R}\right)$, $I_R = \frac{V_S}{R}$, $I_C = \frac{V_S}{X_C}$, $Y = \frac{I}{V_S}$, $B_C = \frac{I_C}{V_S}$

$f\uparrow \rightarrow X_C\downarrow \rightarrow I_C\uparrow \rightarrow I_R$ const $\rightarrow I_S\uparrow$

Example: Let $R = 680\,\Omega$, $C = 0.1\,\mu f$, $V_S = 1\angle 0$

determine, I_R, I_C, I, θ, Y, B_C for f=100, 5000, S, P, Q

f = 100

$f = 100$, $X_C = \frac{1}{2\pi f c} = 15915.5\,\Omega$

$I_R = \frac{1}{680} = 1.471$ mA

$I_C = \frac{1}{-jX_C} =$ ~~6.~~ $62.8\angle 90\,\mu A$

$I = 1.472$ mA

$\theta = \tan^{-1}\left(\frac{I_C}{I_R}\right) = 2.44°$

$Y = \frac{I}{V_S} = 1.472\angle 2.44$ m℧

$B_C = \frac{I_C}{V_S} = 62.8\angle 90\,\mu\Omega^{-1}$

S = 1.472 mVA

P = 1.47 mW

Q = -0.063 VAR

f = 5000

$f = 5000$, $X_C = 318.31$

$I_R = 1.471$ mA

$I_C = 3.14\angle 90$ mA

I = ~~12 mA~~ 3.47 mA

θ = 64.9°

$Y = 3.47\angle 64.9°$

$B_C = 3.14\angle 90\ m\Omega^{-1}$

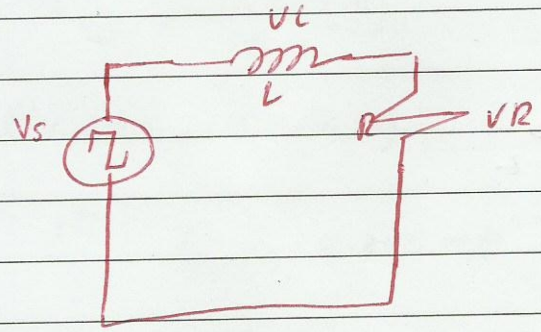
S = 3.47 mVA

P = 1.472

Q = -3.14

Experiment 5:
TRANSIENT ANALYSIS

① RL circuit



$\tau = \frac{L}{R}$

~~$V_R = V_s$~~

*** Resistors**

$V_R = V_s(1 - e^{-t/\tau})$

at $t = 0 \rightarrow V_R = 0$

at $t = 1\tau \rightarrow V_R = 0.64\, V_s$

at $t = 5\tau$ (large τ) $\rightarrow V_R \simeq V_s$

*** Inductors**

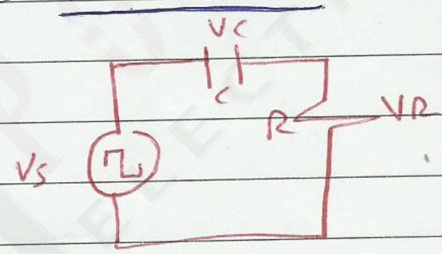
$V_L = V_s\, e^{-t/\tau}$

at $t = 0 \rightarrow V_L = V_s$

at $t = 1\tau \rightarrow V_L = 0.36\, V_s$

at $t = 5\tau$ (large τ) $\rightarrow V_L \simeq 0$

② RC circuit



$\tau = RC$

*** Resistor:-**

$V_R = V_s\, e^{-t/\tau}$

at $t = 0 \rightarrow V_R = V_s$

at $t = \tau \rightarrow V_R = 0.36\, V_s$

at $t = 5\tau \rightarrow V_R = 0$

*** Capacitor**

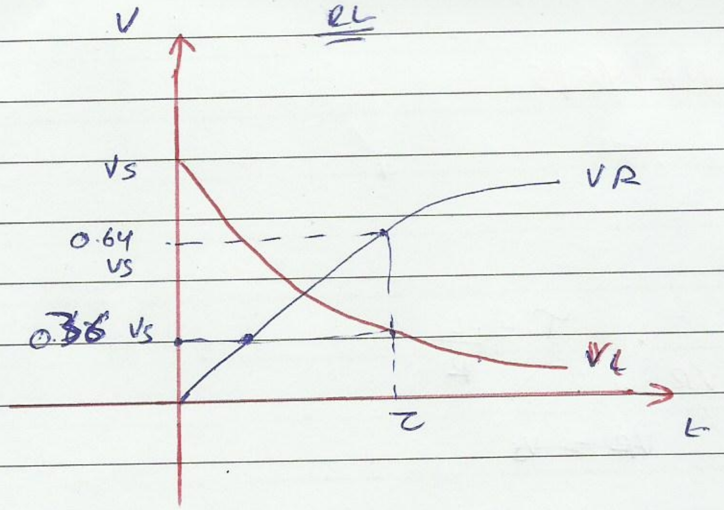
$V_C = V_s(1 - e^{-t/\tau})$

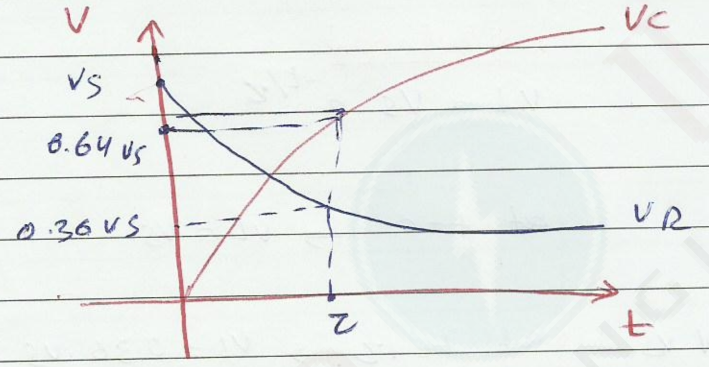
at $t = 0 \rightarrow V_C = 0$

at $t = \tau \rightarrow V_C = 0.64\, V_s$

at $t = 5\tau \rightarrow V_C = V_s$

RL





Example: in RL part, let $V_s = 4\,p\text{-}p$, $L = 100\ mH$
$R = 470\ \Omega$, find $i_L(t)$, $i(t)$, $V_R(t)$, $V_L(t)$

① $\tau = \frac{L}{R} = \frac{1}{4700}$

② $i_L(t) = i_f(t) + i_n(t)$

$i_f(t) = \frac{2}{470} = 4.255\ mA$

$i_n(t) = C\, e^{-t/\tau}$

$= C e^{-4700t}$

$\therefore i(t) = 4.255\ mA + C e^{-4700t}$

$i(0) = 4.255\ mA + C = 0$

$C = -4.255\ m$

$\therefore i_L(t) = 4.255 - 4.255\, e^{-4700t}\ mA$

$= i(t)$

$V_R(t) = R * i(t)$

$= 2 - 2e^{-4700t}\ V$

$V_L(t) = L\frac{di(t)}{dt} = 2e^{-4700t}$

* Now consider :-

at $t=0$, $V_L = 2 = V_S$

$V_R = 0$

at $t = \frac{1}{4700} = \tau$, $V_L = 0.74 = 0.36\, V_S$

at $t = 10\tau$, $V_L \simeq 0$

$V_R = V_S$

Example: in RC part, let $V_S = 4\,V\ p\text{-}p$, $C = 0.1\ \mu f$.
$R = 1000\ \Omega$, find ~~i(t)~~ $V_C(t)$, $V_R(t)$, $i_C(t)$

① $\tau = RC = \frac{1}{10000}$

② $V_C(t) = V_f(t) + V_n(t)$

$V_f(t)$ at $t=0$ $= 2\,V$

$V_n(t) = C e^{-10000t}$

$V_c(t) = 2 + C e^{-1000t}$

$V_c(0) = 2 + C = 0$, $C = -2$

$V_C(t) = 2 - 2e^{-10000t}$

$V_R(t) = V_S(t) - V_c = 2e^{-1000t}$

$i_C(t) = \frac{1}{C}\int V_C(t)\,dt$

Now consider :-

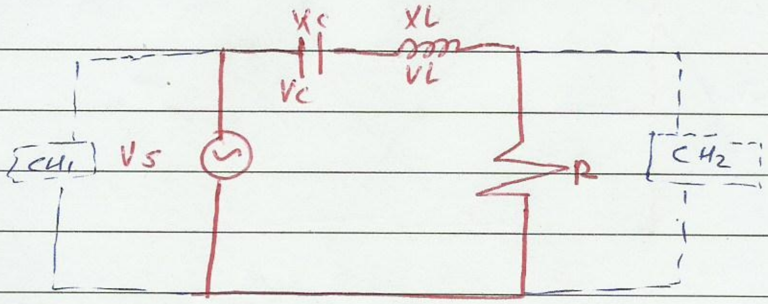
at $t=0 \rightarrow V_C = 0$

at $t = \tau \rightarrow V_C = 0.64\, V_S$

Experiment 6:

SERIES AND PARALLEL RESONANCES

① Series Resonance :-



There are 3 cases :-

① $f < f_r$

f↑ → Xc↓ → XL↑ →

Vc↓ ($I * jX_c$) → VL↑ ($I * jX_L$)

→ VR↑ (I↑ since $X_c > X_L$)

Before f_r, ckt is capacitive $X_c > X_L$

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

↑ $I = \frac{V_s \angle 0}{Z \angle \theta}$

↓ $Z = \sqrt{(X_L - X_C)^2 + R^2}$

$X_c > X_L$ (capacitive)

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

θ goes from +90 to zero

② $f = f_r$

f↑ → Xc↓ → XL↑ →

$V_C = V_L$ → VR↑ (max)

at f_r, ckt is Resistive, $X_L = X_C$

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

$I↑ = \frac{V_S \angle 0}{R}$

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

$X_C = X_L$ (Resistive

$\theta = \tan^{-1}(0) = 0$

$X_C = X_L$

$\frac{1}{2\pi f_r C} = 2\pi f_r L$

$f_r = \frac{1}{2\pi\sqrt{LC}}$

③ $f > f_r$

f↑ → Xc↓ → XL↑

→ Vc↓ → VL↑

→ VR↓ (I↓ since ~~XL > Xc~~)

$X_C < X_L$

after f_r, ckt is inductive $X_C < X_L$

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

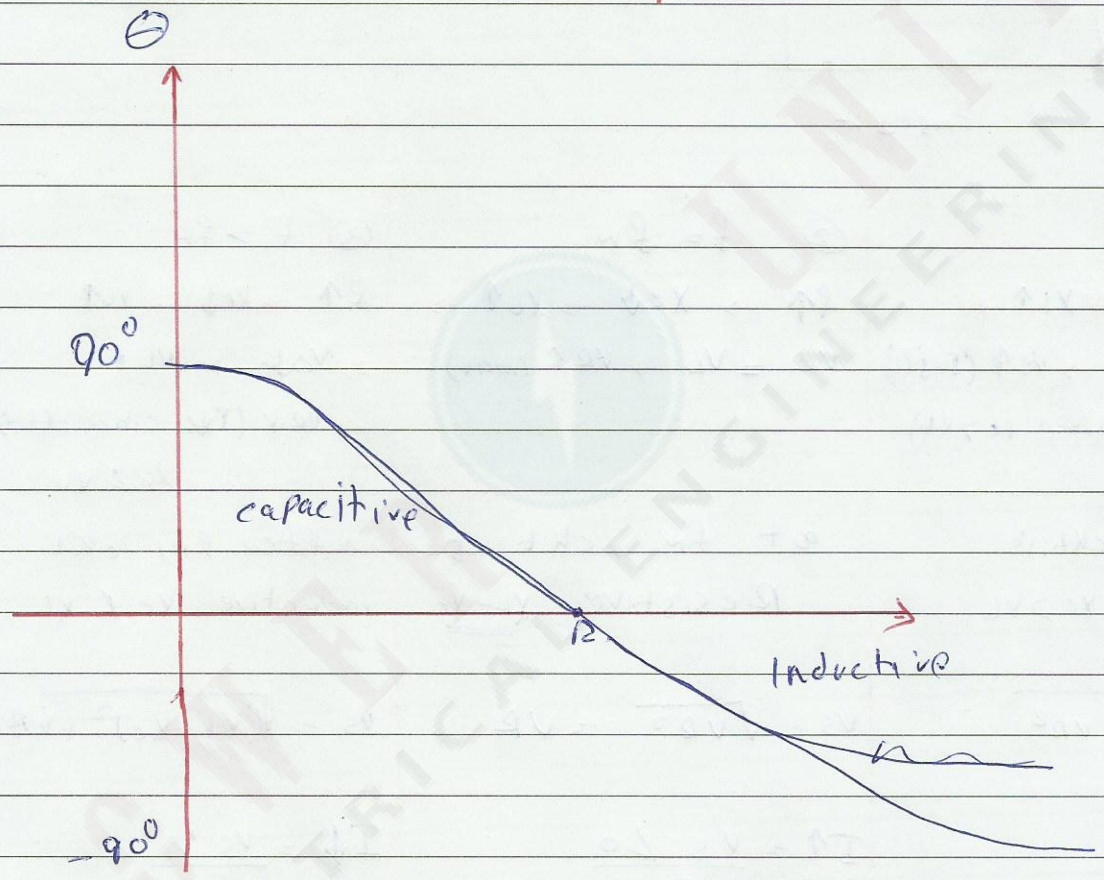
$I↓ = \frac{V_S}{Z \angle \theta}$

↑ $Z = \sqrt{(X_L - X_C)^2 + R^2}$

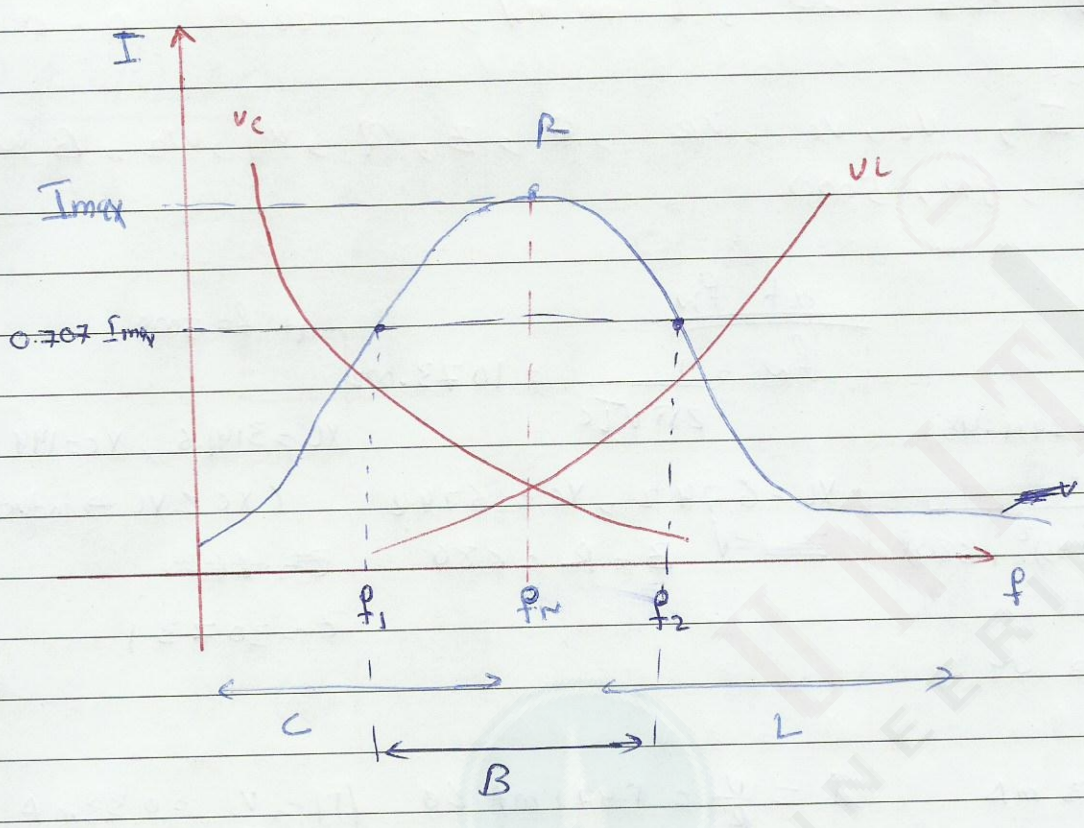
$X_C < X_L$ (inductive)

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

θ goes from 0 to -90



θ
90°
capacitive
R
inductive
-90°



$B = f = \frac{\omega}{2\pi}$, $\omega = 2\pi f$

~~$B = f_2 - f_1 = \omega_2 - \omega_1$~~

* → f_1: lower cut off freq (f_L)

→ At half power = $\frac{P_m}{2}$, $I = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$

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

(capacitive)

* f_2: upper cutoff freq (f_u)

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

* Band width (B)

$B = \frac{f_r}{Q} = f_2 - f_1$ ✓

~~$= \frac{R}{L} = \frac{R}{2\pi L}$~~

* Quality factow (Q)

~~$Q = \frac{X_L}{R}$~~ $= \frac{1}{R X_C} = \frac{1}{R}\sqrt{\frac{L}{C}}$ ✓

$Q = \frac{X_L}{R}$ at f_r $= \frac{\omega_0}{B}$

$= \frac{\omega_0}{\omega_2 - \omega_1} = \frac{f_0}{f_2 - f_1}$

Example 3: let $V_s = 1\angle 0$, $L = 100\ mH$, $C = 0.22\ \mu F$, $R = 680\ \Omega$

determine:

f_r, I, V_L, V_C, V_R, θ, Z, Q, ω_1, ω_2, B.W

at $f = 300$, f_r, 5000

Sol.

$f = 300\ Hz$

$X_L = 188.5$, $X_C = 2411.45$

$Z = \sqrt{(188.5 - 2411.45)^2 + (680)^2}$

$= 2324.63\ \Omega$

$|I| = \frac{V}{Z} = 0.43\ mA$

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

$\theta = 73^\circ$

$V_L = I * X_L = 0.0811\ V$

$V_C = I * X_C = 1.04\ V$

$V_R = I * R = 0.29\ V$

~~$Q = \frac{X_L}{R} = 0.277$~~

$= \frac{1}{R X_C}$ $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = 0.991$

$\omega_1 = \frac{-680}{200 \times 10^{-3}} + \sqrt{\left(\frac{680}{200 \times 10^{-3}}\right)^2 + \frac{1}{100 \times 0.22 \times 10^{-9}}}$

~~$= 22919395.32$~~

$\omega_1 = 4150.8$

$\omega_2 = 10950.8$

$f_1 = \frac{\omega_1}{2\pi} = 660.6$

~~$B = 6800$~~

$f_2 = \frac{\omega_2}{2\pi} = 1742.8$

$B = 1082.2$

at f_r

$f_r = \frac{1}{2\pi\sqrt{LC}} = 1073.022$

$X_L = 674.2$, $X_C = 674.2$

$Z = R = 680$

$I = \frac{V}{R} = 1.471\ mA\ \angle 0$

$\theta = 0$

$V_L = 0.99$, $V_C = 0.99\ V$

$V_R = I * R = 1\ V$

$Q = \frac{X_L}{R} = 0.991$

$B = \frac{f_r}{Q} = \frac{1073.022}{0.991}$

$= 1082.2$

at $f = 5000$

$X_L = 3141.6$, $X_C = 144.7$

($X_C < X_L \rightarrow$ inductive)

~~$Z = 666$~~

$Z = 3073.1$

$|I| = \frac{V}{Z} = 0.33\ mA$

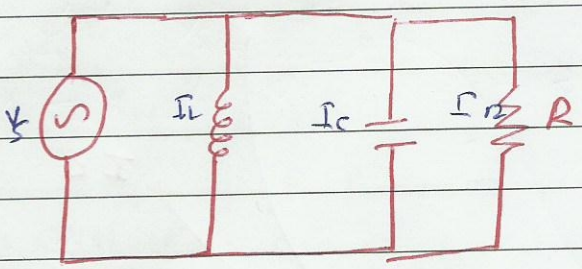
$\theta = -77.22^\circ$

$V_L = 1.04\ V$

$V_C = 0.05\ V$

$V_R = 0.2244$

(2) Parallel Resonance



There are 3 cases :-

(1) $f < f_r$

$f\uparrow \rightarrow X_L\uparrow \rightarrow X_C\downarrow \rightarrow$

$I_C\uparrow \left(\frac{V_s}{X_C}\right) \rightarrow I_L\downarrow \left(\frac{V_s}{X_L}\right) \rightarrow$

I_R const $\left(\frac{V}{R}\right)$

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

$X_C > X_L$ ($B_C < B_L$)

inductive parallel

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

θ goes from -90 to zero.

(2) $f = f_r$

$f_r = \frac{1}{2\pi\sqrt{LC}}$

$f\uparrow \rightarrow X_L\uparrow \rightarrow X_C\downarrow \rightarrow$

$I_C = I_L \rightarrow I_R$ const

$I_S = \sqrt{I_R^2} = I_R$ (min)

$X_C = X_L$ ($B_C = B_L$)

Resistive

$\theta = 0$

(3) $f > f_r$

$f\uparrow, \rightarrow X_L\uparrow \rightarrow X_C\downarrow \rightarrow$

$I_C\uparrow \rightarrow I_L\downarrow$

I_R const

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

$X_C < X_L$ ($B_C > B_L$)

capacitive parallel

$\theta = \tan^{-1}(I_L - I_C)$ (+ve)

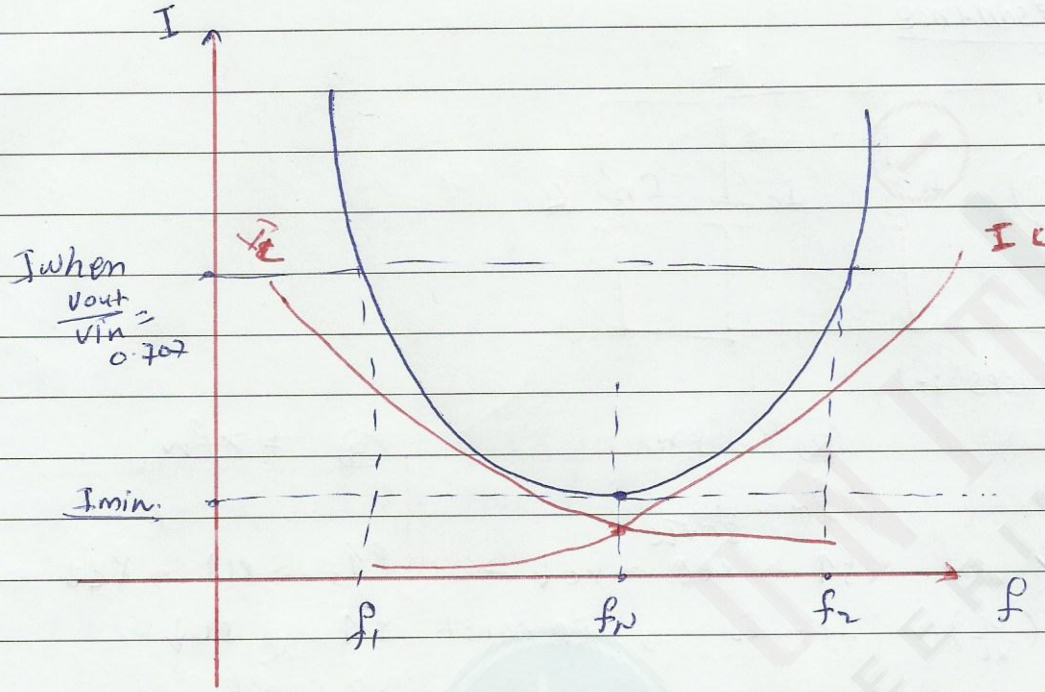
θ goes from 0 to 90.

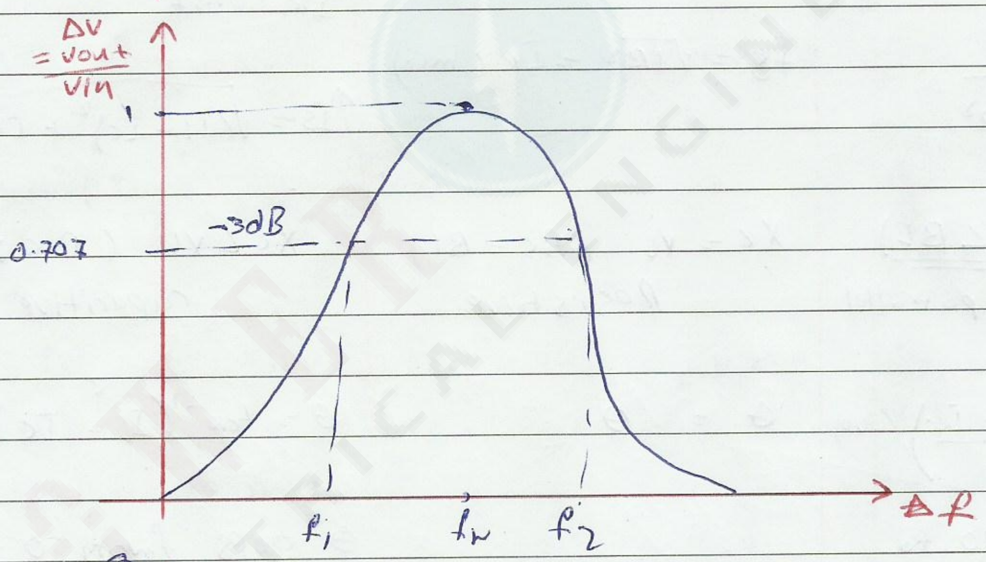
---

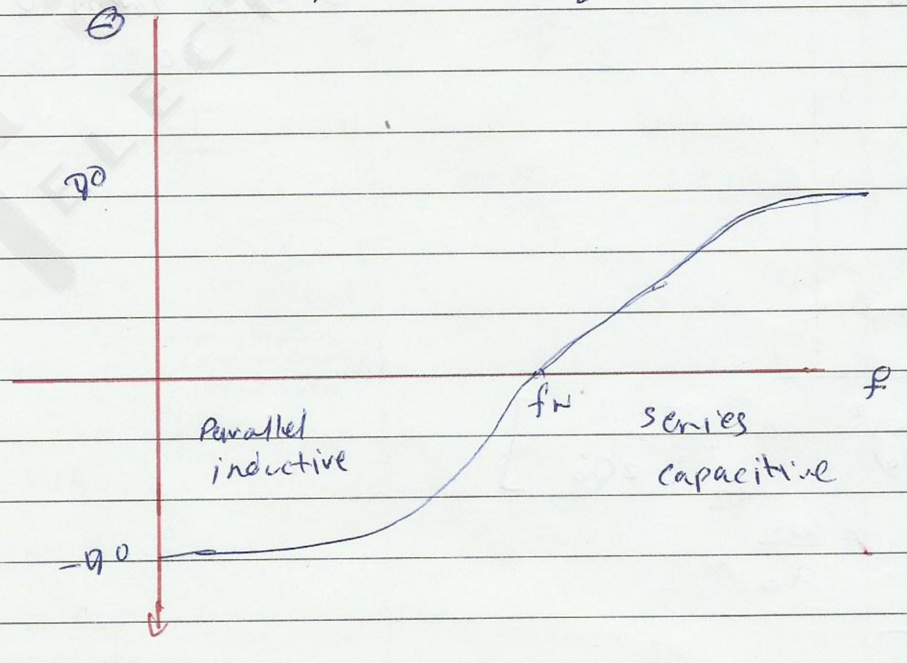
* $$\omega_{1,2} = \omega_0\left[\sqrt{1 + \left(\frac{1}{2Q_0}\right)^2} \mp \frac{1}{2Q_0}\right]$$

$$B = \omega_2 - \omega_1 = \frac{\omega_0}{Q_0}$$

$$Q_0 = R\sqrt{\frac{C}{L}}$$


I
I when
Vout/Vin = 0.707
Imin
IL
IC
f1
fr
f2
f


AV = Vout/Vin
1
0.707
-3dB
f1
fr
f2
Δf


θ
90
-90
fr
f
Parallel inductive
series capacitive

Example :- Let $R = 680$, $L = 400\,mH$, $C = 0.22\,\mu F$, $V_s = 1\angle 0$

find f_r, I, I_L, I_C, I_R, θ, Y, Q, ω_1, ω_2, BW

at $f = 300$, f_r, 5000

$f = 300$

$X_L = 188.5$, $X_C = 2411.45$

$B_L = -j5.31\,m\Omega^{-1}$, $B_C = j0.415\,m\Omega^{-1}$

$Y_s = -j5.31m + j0.415m + 1/680$

$= 5.11 \angle -73.3$

$I_R = \frac{V}{R} = 1.471\,mA$

$I_C = \frac{V}{X_C} = 0.414\,mA$

$I_L = \frac{V}{X_L} = 5.31\,mA$

$I_S = \sqrt{(5.31m - 0.414m)^2 + 1.471m^2}$

$= 5.11\,mA$

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

$= -73.3$

$Q = R\sqrt{\frac{C}{L}} = 1.009$

~~ω_1~~

$f = f_r$

$f_r = \frac{1}{2\pi\sqrt{LC}} = 1073.022$

$X_L = 674.2$ $X_C = 674.2$

$Y = \frac{1}{R} = 1.471\,m\Omega^{-1}\angle 0$

$I_R = 1.471$

$I_C = I_L = 1.48\,mA$

$I_S = \sqrt{I_R^2} = I_R = 1.471\,mA$

$\theta = 0$

$\omega_{1,2} = \omega_0 \left[\sqrt{1 + \left(\frac{1}{2Q_0}\right)^2} \mp \frac{1}{2Q_0}\right]$

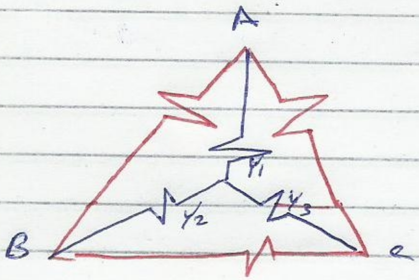
$\omega_1 = 4183.6$

$\omega_2 = 10865.3$

$\omega_2 - \omega_1 = 6681.7 = \frac{\omega_0}{Q_0}$

Experiment 7

Δ-Y TRANSFORMATION

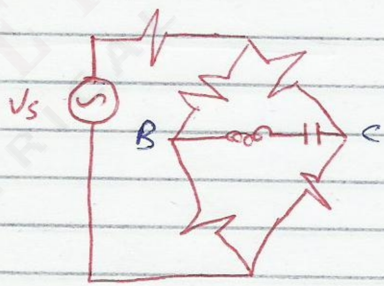


$$Y_1 = \frac{\Delta_{AC}\ \Delta_{AB}}{\Delta_{AC} + \Delta_{AB} + \Delta_{BC}}$$

$$\Delta_{AB} = \frac{Y_1 Y_2 + Y_2 Y_3 + Y_3 Y_1}{Y_3}$$

* Resonance

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



① at $f < f_r \Rightarrow$
$V_{BC} \downarrow$

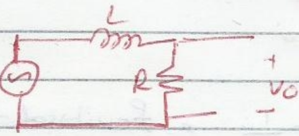
② at $f = f_r$, $V_C = X_L$, $V_{BC} = 0$

③ at $f > f_r$, $V_{BC} \uparrow$

Transfer function of A Two Port Network

① RL series:

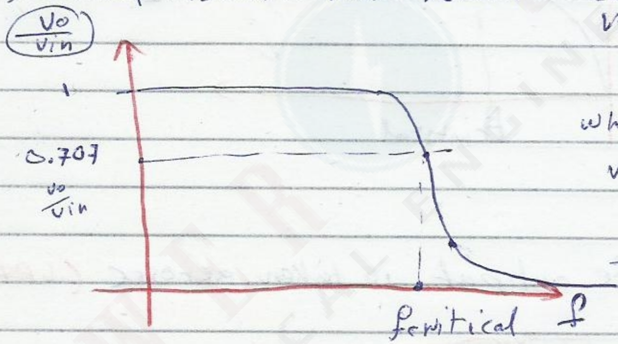
ⓐ The output across R (LPF)



f↑, XL↑, VL↑, VR↓

$\tau = \frac{L}{R}$, $\omega_o = \frac{1}{\tau}$, $f_{critical} = \frac{R}{2\pi L}$

$f_{critical}$ is at half power $\frac{V}{\sqrt{2}}$

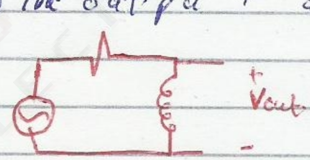


when f↓, XL → S/C

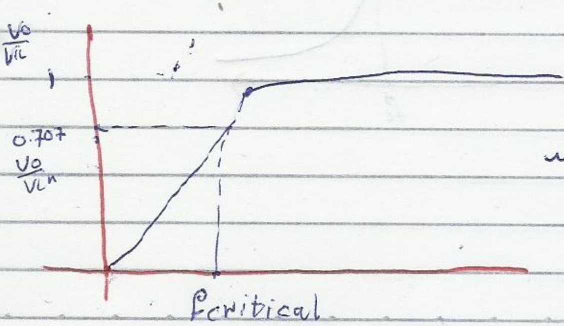
$V_o = V_{in}\left(\frac{R}{R + j\omega L}\right)$

$\frac{V_o}{V_{in}} = \frac{R}{R + j\omega L}$

ⓑ The output across L (HPF)



f↑, XL↑, VL↑, VR↓



when f is High

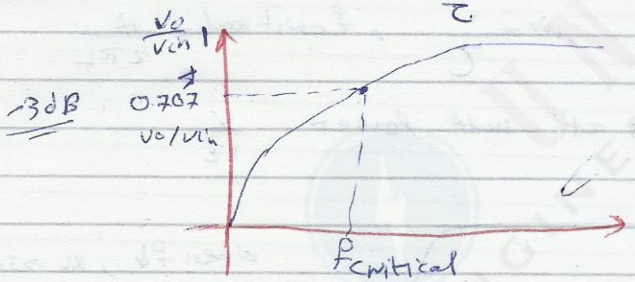
XL = O.C

$V_{in} = V_o$

② RC series , f↑, X_C↓ (LPF) , V_C↓ , V_R↑ (HPF)

ⓐ The output is taken across R (HPF)

$\tau = RC$, $\omega_0 = \frac{1}{\tau}$, $f_{critical} = \frac{1}{2\pi RC}$



~~Xc↓~~ → s/c

V_o =

ⓑ The output is taken across C (LPF)