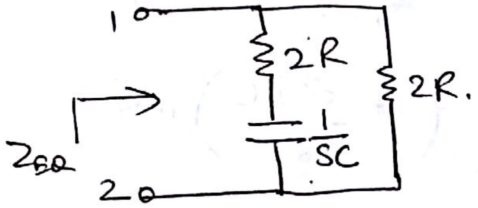
10.3)

a) observing the circuit in s domain



$$\therefore Z_{EQ} = \left(2R + \frac{1}{sC}\right) \| 2R. = \left(\frac{2RCs+1}{sC}\right) \| 2R.$$

$$= \frac{\frac{2RCs+1}{sC} \times 2R}{\frac{2RCs+1}{sC} + 2R.} = \frac{(2RCs+1)2R.}{2RCs+1+2RCs}$$

$$= \frac{(2RCs+1)2R}{4RCs+1}$$

zeros! $2RCs+1=0 \Rightarrow s = \frac{-1}{2RC}$ (zero)

poles: $4RCs+1=0 \Rightarrow s = \frac{-1}{4RC}$ (pole)

b) select R & C so that pole at -640 rad/s.

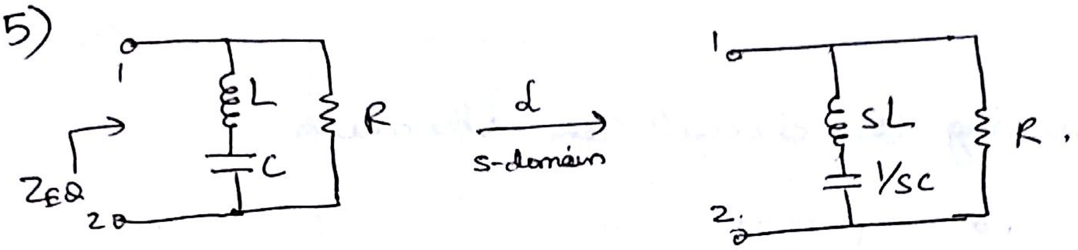
$$\therefore \frac{-1}{4RC} = -640 \Rightarrow RC = \frac{1}{4 \times 640}$$

let $R = 1k\Omega$. $\therefore C = \frac{1}{4 \times 640 \times 10^3} = 0.391\mu F$

$$\therefore \text{zero} = \frac{-1}{2RC} = \frac{-1}{\cancel{2 \times RC}} = \cancel{}\, 2 \times \left(\frac{-1}{4RC}\right)$$

$$= 2 \times (-640) = -1280 \text{ rad/s.}$$

10.5)



a) $Z_{EQ} = \left(sL + \frac{1}{sC}\right) \| R = \left(\frac{1+s^2LC}{sC}\right) \| R.$

$$= \frac{\left(\frac{1+s^2LC}{sC}\right) \times R}{\frac{1+s^2LC}{sC} + R} = \frac{R + s^2LCR}{1 + sRC + s^2LC}$$

zeros: $R + s^2LCR = 0 \Rightarrow s = \pm j\sqrt{\frac{1}{LC}}$ (zeros)

poles: $1 + sRC + s^2LC = 0$

$$\Rightarrow s^2 + s\frac{R}{L} + \frac{1}{LC} = 0 \Rightarrow s = -\frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

$$= \frac{-RC \pm \sqrt{R^2C^2 - 4LC}}{2LC.} \text{ (poles)}$$

b) $R = 2k\Omega$, $C = 0.1\mu F$.

zeros at $\pm j5000$ rad/s.

$$\Rightarrow 5000 = \sqrt{\frac{1}{LC}} \Rightarrow L = \frac{1}{C \times (5000)^2} = \frac{1}{0.1\times10^{-6} \times 25\times10^{6}}$$

$$= 0.4H. \quad \therefore \boxed{L = 0.4H}$$

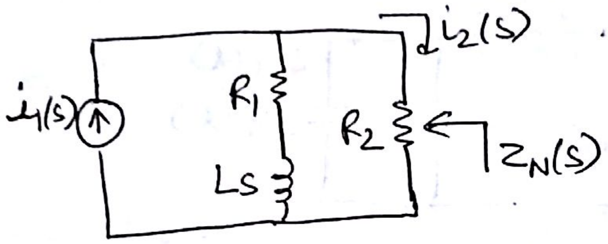
c) $$s = -\frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

$$= -\frac{2\times10^3}{2\times0.4} \pm \sqrt{\frac{4\times10^6}{4\times0.16} - (5000)^2}$$

$\therefore s = -2.5\times10^3 \pm j4330.1$

$$\boxed{s \simeq -2500 \pm j4330 \text{ rad/s.}}$$

10.15)



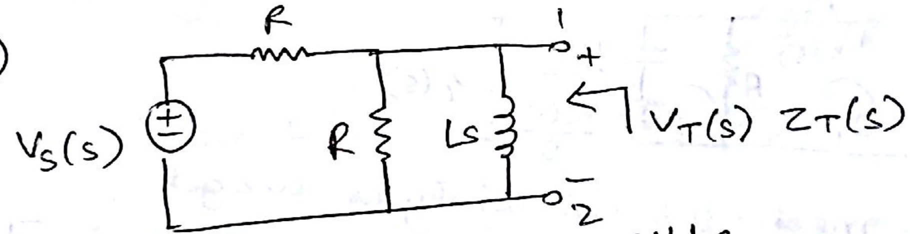
a) $$\frac{i_2(s)}{i_1(s)} = \frac{1/R_2}{1/R_2 + 1/(R_1+sL)} = \frac{1/R_2}{\frac{R_1+sL+R_2}{R_2(R_1+sL)}}$$

$$= \frac{sL+R_1}{R_1+R_2+sL}$$

$$\therefore \boxed{i_2(s) = \frac{sL+R_1}{R_1+R_2+sL} \times i_1(s)}$$

b) $$Z_n(s) = R_2 \,||\, (R_1+sL) = \frac{R_2(R_1+sL)}{sL+R_1+R_2}$$

10.17)



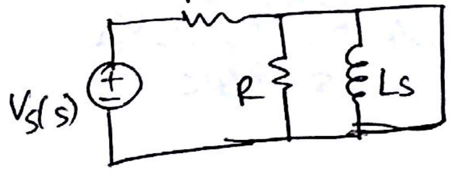
$V_T(s) =$ voltage across $R||Ls$

$$\therefore V_T(s) = \frac{(R||Ls)}{(R+R||Ls)} \times V_s(s) = \frac{\frac{RLs}{R+Ls}}{\frac{RLs}{R+Ls}+R} \times V_s(s)$$

$$= \frac{Ls}{R+2Ls} V_s(s).$$

~~Z_T voltage turning of sources~~

By short circuiting 1 & 2, we get :



$$I_{sc}(s) = \frac{V_s(s)}{R}.$$

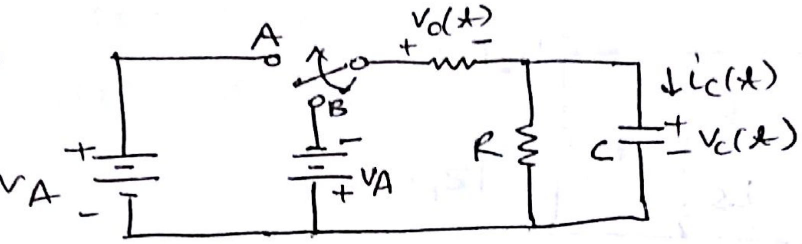
$$\therefore Z_T(s) = \frac{V_T(s)}{I_{sc}(s)} = \frac{RLs}{R+2Ls}$$

pole at $s = -\frac{R}{2L}$

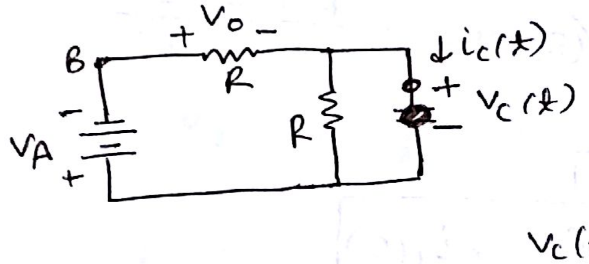
if pole at $s = -12k$ rad/s choose $\boxed{R = 3k\,\Omega}$.

$\therefore \boxed{L = 125\,mH}$.

10·22)



initial condition. (switch at B)



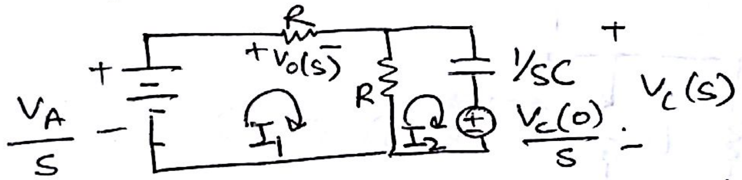
For $t<0$, circuit is DC steady state condition & capacitor acts as open circuit.

$\therefore i_c(0) = 0$

$$V_c(0) = V_R(t) = \frac{R}{R+R}(-V_A) = -\frac{1}{2}V_A$$

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

Transform the circuit in s-domain for $t>0$ & (switch at A)



Using mesh-current analysis, we get.

$$\underbrace{\begin{bmatrix} R+R & -R \\ -R & R+\frac{1}{sC} \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} I_1 \\ I_2 \end{bmatrix}}_{x} = \begin{bmatrix} V_A/s \\ -\frac{V_c(0)}{s} \end{bmatrix} = \underbrace{\begin{bmatrix} V_A/s \\ V_A/2s \end{bmatrix}}_{b}$$

$$x = A^{-1}b = \frac{sC}{R(2+sRC)} \begin{bmatrix} \frac{V_A}{s}\left(\frac{1+sRC}{sC} + \frac{R}{2}\right) \\ \frac{V_A}{s}(R+R) \end{bmatrix}$$

$$\Rightarrow I_1(s) = \frac{sC}{R(2+sRC)} \times \frac{V_A}{s} \times \frac{1+1.5sRC}{sC} = \frac{1+1.5sRC}{sR(2+sRC)} V_A$$

$$I_2(s) = \frac{sC}{R(2+sRC)} \times \frac{V_A \times 2R}{s} = \frac{2C}{2+sRC} V_A = \frac{2/R}{s+2/RC} V_A.$$

$$= \frac{2}{R}\left(\frac{1}{s+\frac{2}{RC}}\right) V_A$$

10:22) continued

$$\therefore V_o(s) = R I_1(s) = \boxed{\frac{1+1.5sRC}{s(2+sRC)} V_A}$$

$$v_o(t) = \mathcal{L}^{-1}\{V_o(s)\} = \mathcal{L}^{-1}\left\{\left(\frac{k_1}{s} + \frac{k_2}{\left(s+\frac{2}{RC}\right)}\right) V_A\right\}$$

$$k_1 = sV_o(s)\Big|_{s=0} = \frac{1}{2}$$

$$k_2 = \left(s+\frac{2}{RC}\right) V_o(s)\Big|_{s=-\frac{2}{RC}} = 1$$

$$\therefore v_o(t) = \mathcal{L}^{-1}\left\{\left(\frac{1}{2s} + \frac{1}{s+\frac{2}{RC}}\right) V_A\right\}$$

$$\Rightarrow \boxed{v_o(t) = \left(\frac{1}{2} + e^{-2t/RC}\right) V_A\, u(t)}$$

$$V_c(s) = \frac{1}{sC} I_2(s) + \frac{v_c(0)}{s} = \frac{2}{RC}\left(\frac{1}{s\left(s+\frac{2}{RC}\right)}\right) V_A - \frac{1}{2s} V_A$$

$$= \frac{2}{RC}\Big[\underbrace{\frac{k_1}{s} + \frac{k_2}{s+\frac{2}{RC}}}\Big] V_A - \frac{1}{2s} V_A$$

$$k_1 = \frac{1}{s+\frac{2}{RC}}\Big|_{s=0} = \frac{RC}{2}$$

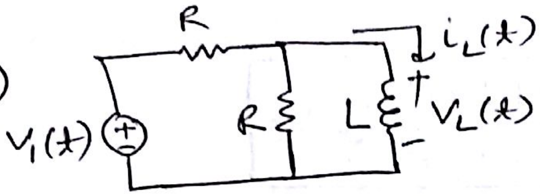
$$k_2 = \frac{1}{s}\Big|_{s=-\frac{2}{RC}} = -\frac{RC}{2}.$$

$$\therefore V_c(s) = \left[\frac{1}{s} - \frac{1}{s+2/RC}\right] V_A - \frac{1}{2s} V_A = \left(\frac{1}{2s} - \frac{1}{s+\frac{2}{RC}}\right) V_A$$

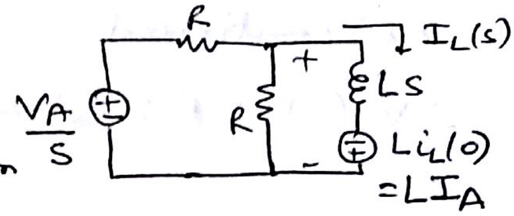
$$\therefore v_c(t) = \mathcal{L}^{-1}\{V_c(s)\}$$

$$\Rightarrow \boxed{v_c(t) = \frac{V_A}{2}\left(1 - 2e^{-2t/RC}\right) u(t)}.$$

10.23)



$\Longrightarrow$ s domain

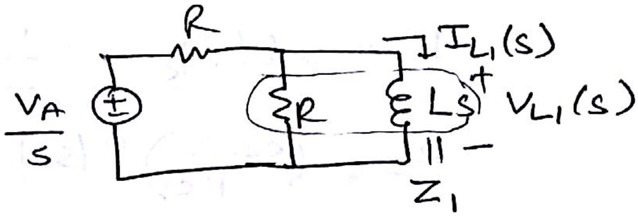


$v_1(t) = V_A u(t)$

$i_L(0) = I_A$

Using superposition.

(i) turn LI_A off.



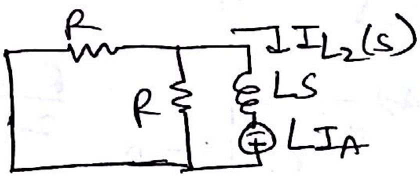
$$I_{L_1}(s) = \frac{V_{L_1}(s)}{Ls}.$$

voltage division: $V_{L_1}(s) = \dfrac{Z_1 \times \frac{V_A}{s}}{R+Z_1}$

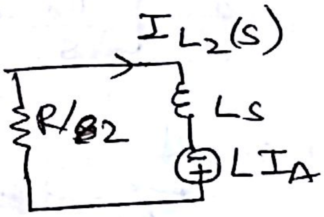
$Z_1 = \dfrac{LRs}{R+Ls}$

$$\Rightarrow I_{L_1}(s) = \frac{V_A}{s(R+2Ls)} = \frac{V_A}{2L}\left(\frac{1}{s\left(s+\frac{R}{2L}\right)}\right)$$

(ii) turn $\frac{V_A}{s}$ off.



$\Rightarrow$



$$I_{L_2}(s) = \frac{LI_A}{\frac{R}{2}+Ls} = \frac{I_A}{s+\frac{R}{2L}}$$

$$\therefore I_L(s) = I_{L_1}(s) + I_{L_2}(s) = \frac{V_A}{2L}\left(\frac{1}{s\left(s+\frac{R}{2L}\right)}\right) + \frac{I_A}{s+\frac{R}{2L}}$$

$$= \frac{\frac{V_A}{R}}{s} + \frac{I_A - \frac{V_A}{R}}{s+R/2L}.$$

$$\therefore i_2(t) = \mathcal{L}^{-1}\{I_L(s)\} = \left[\frac{V_A}{R} + \left(I_A - \frac{V_A}{R}\right)e^{-\frac{R}{2L}t}\right]u(t)$$

10·23) Continued.

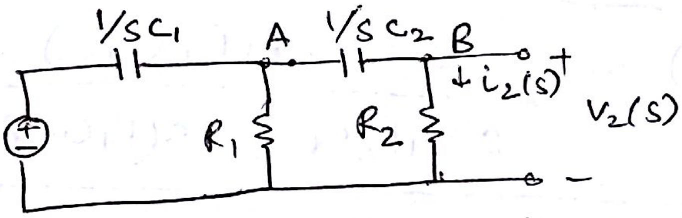
$$V_L(s) = (Ls) I_L(s) - L I_A$$

$$= Ls\left[\frac{\frac{V_A}{R}}{s} + \frac{I_A - \frac{V_A}{R}}{s + R/2L}\right] - L I_A$$

$$= \frac{\frac{1}{2}(V_A - R I_A)}{s + \frac{R}{2L}}$$

$$\therefore\ V_L(t) = \mathcal{L}^{-1}\{V_L(s)\} = \frac{1}{2}(V_A - R I_A)\, e^{-\frac{R}{2L}t}\, u(t)$$

10·43) a) Circuit in s-domain.



By observation, node voltage equations at A & B are.

A :
$$\left(\frac{1}{1/sC_1} + \frac{1}{1/sC_2} + \frac{1}{R_1}\right)V_A - \left(\frac{1}{1/sC_2}\right)V_B = \frac{1}{1/sC_1} \times V_1(s)$$

$$\Rightarrow \left(sC_1 + sC_2 + \frac{1}{R_1}\right)V_A - sC_2 V_B = sC_1 V_1(s) \quad -(i)$$

B :
$$\left(-\frac{1}{1/sC_2}\right)V_A + \left(\frac{1}{1/sC_2} + \frac{1}{R_2}\right)V_B = 0.$$

$$\Rightarrow -sC_2 V_A + \left(sC_2 + \frac{1}{R_2}\right)V_B = 0 \quad -(ii)$$

b) Solving for $V_2(s)$. $(V_2(s) = V_B)$

in eq^n (i) ~~$V_2(s) = V_B =$~~ ~~sC_2V_A~~

$$V_A = \frac{sC_1 V_1(s) + sC_2 V_2(s)}{sC_1 + sC_2 + \frac{1}{R_1}}$$

Substituting this in (ii), we get.

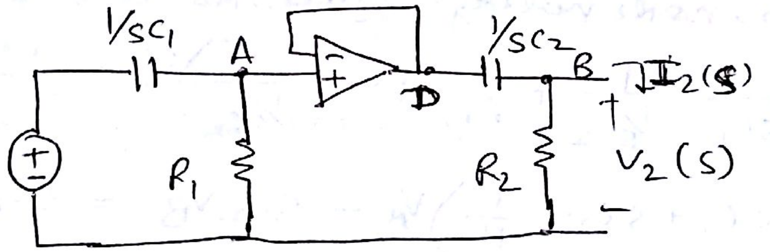
$$-sC_2 \times \frac{sC_1V_1(s)+sC_2V_2(s)}{sC_1+sC_2+\frac{1}{R_1}} + \left(sC_2+\frac{1}{R_2}\right)V_2(s) = 0.$$

$$\Rightarrow \frac{-s^2C_1C_2R_1R_2V_1(s) - s^2C_2^2R_1R_2V_2(s) + (sR_2C_2+1)(sR_1C_1+sR_1C_2+1)V_2(s)}{(R_1C_1s+R_1C_2s+1)R_2} = 0$$

$$\Rightarrow -s^2C_1C_2R_1R_2V_1(s) - s^2C_2^2R_1R_2V_2(s) + \{s^2R_1R_2C_1C_2 + s^2R_1R_2C_2^2 + sR_2C_2 + sR_1C_1 + sR_1C_2 + 1\} \times V_2(s) = 0.$$

$$\Rightarrow \boxed{V_2(s) = \frac{s^2C_1C_2R_1R_2V_1(s)}{s^2R_1R_2C_1C_2 + s(R_1C_1+R_2C_2+R_1C_2)+1}}$$

c)



as the output impedence of opamp is very low.

$V_A = V_D$

at Node A: $\left(\frac{1}{R_1}+sC_1\right)V_A = V_1(s)\times sC_1$

at Node B: $(-sC_2)V_A + \left(sC_2+\frac{1}{R_2}\right)V_2(s) = 0.$

Solving them we get.

$$(-sC_2)\left(\frac{V_1(s)\,sC_1}{sC_1+\frac{1}{R_1}}\right) + \left(sC_2+\frac{1}{R_2}\right)V_2(s) = 0$$

$$\Rightarrow V_2(s) = \frac{s^2C_1C_2R_1R_2V_1(s)}{(sC_1R_1+1)(sC_2R_2+1)} = \frac{s^2V_1(s)}{\left(s+\frac{1}{C_1R_1}\right)\left(s+\frac{1}{C_2R_2}\right)}$$

The buffer changes the denominator as. now at Node A, current through the op-amp would be zero & hence the current from source doesn't pass through op-amp & routes through R_1

d) we need first poles at 10 krad/s & second at 100 krad/s.

In case with op-amp buffer.

poles are $s = \frac{-1}{C_1 R_1}, \frac{-1}{C_2 R_2}$

$\therefore$ for first pole $\frac{1}{C_1 R_1} = 10 \times 10^3$

$\Rightarrow C_1 R_1 = 10^{-4}$

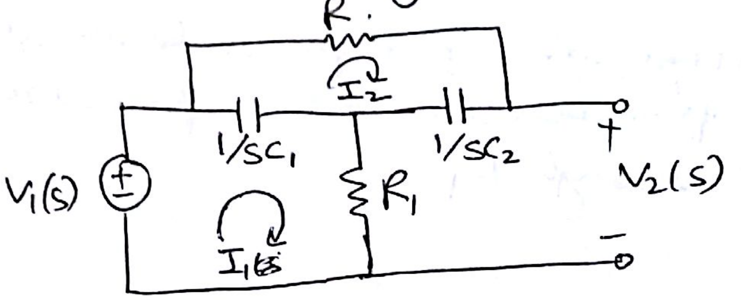
$\boxed{R_1 = 1k\Omega \Rightarrow C_1 = 0.01 \mu F}$

for second pole $\frac{1}{C_2 R_2} = 100 \times 10^3$

$\Rightarrow C_2 R_2 = 10^{-5}$

$\boxed{R_2 = 1k\Omega \Rightarrow C_2 = 0.1 \mu F}$

10.45) a) Transforming the circuit in s domain.



in mesh 1: $-V_1(s) + \frac{I_1}{sC_1} - \frac{I_2}{sC_1} + I_1 R_1 = 0$

mesh 2 : $I_2 R + \frac{I_2}{sC_2} + \frac{I_2 - I_1}{sC_1} = 0$

$\therefore$ the equations are:

$$\left(R_1 + \frac{1}{sC_1}\right) I_1 - \left(\frac{1}{sC_1}\right) I_2 = V_1(s)$$

$$-\left(\frac{1}{sC_1}\right) I_1 + \left(R_2 + \frac{1}{sC_1} + \frac{1}{sC_2}\right) I_2 = 0.$$

b) Solving for I_1 & I_2. using matlab we get.

$$\cancel{\left(R_1 + \frac{1}{sC_1}\right) \times \left(R_2 + \frac{1}{sC_1} + \frac{1}{sC_2}\right) \times sC_1 I_2 - \left(\frac{1}{sC_1}\right) I_2 = V_1(s)}.$$

$$\Rightarrow R_1 I_1 + \left(R_2 + \frac{1}{sC_1} + \frac{1}{sC_2}\right) I_2 - \frac{1}{sC_1} I_2 = V_1(s)$$

$$\Rightarrow R_1 I_1 + R_2 I_2 + \frac{1}{sC_2} I_2 = V_1(s)$$

$$\Rightarrow R_1 I_1 + \left(R_2 + \frac{1}{sC_2}\right) I_2 = V_1(s)$$

$$I_1 = \frac{V_1(s) - \left(R_2 + \frac{1}{sC_2}\right) I_2}{R_1}$$

using in second equation.

$$\left(-\frac{1}{sC_1}\right) \times \frac{V_1(s) - \left(R_2 + \frac{1}{sC_2}\right) I_2}{R_1}$$

$$I_1 = \frac{s(C_1 + C_2 + C_1C_2R_2s)\,V_1(s)}{C_1R_1s + C_2R_1s + C_2R_2s + C_1C_2R_1R_2s^2 + 1}$$

$$I_2 = \frac{sC_2V_1(s)}{C_1R_1s + C_2R_1s + C_2R_2s + C_1C_2R_1R_2s^2 + 1}$$

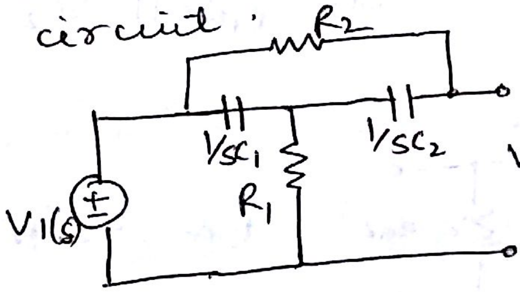
Now

$$-I_1R_1 - I_2 \times \frac{1}{sC_2} + V_2(s) = 0$$

$$\Rightarrow V_2(s) = I_1R_1 + I_2 \times \frac{1}{sC_2}$$

$$= \frac{[s(C_1 + C_2 + C_1C_2R_2s)R_1 + 1]\,V_1(s)}{C_1R_1s + C_2R_1s + C_2R_2s + C_1C_2R_1R_2s^2 + 1}$$

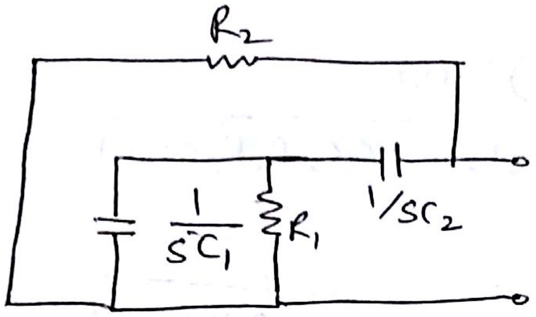
10.47) We need to find the Thevenin equivalent of the circuit:



as calculated in 10.45)

$$V_{oc}(s) = V_2(s) = \frac{[s(C_1 + C_2 + C_1C_2R_2s)R_1 + 1]\,V_1(s)}{C_1R_1s + C_2R_1s + C_2R_2s + C_1C_2R_1R_2s^2 + 1}$$

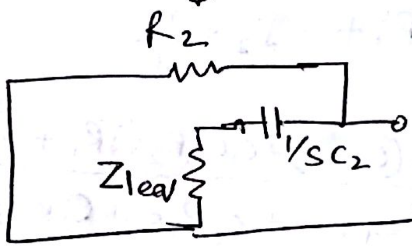
to find Z_T, we switch off the circuit & redraw it as:



$\frac{1}{sC_1}$ & R_1 are in parallel.

$$Z_{eq} = \frac{R_1 \cancel{sC_1} \times \frac{1}{sC_1}}{R_1 + \frac{1}{sC_1}} = \frac{R_1}{C_1R_1s+1}$$

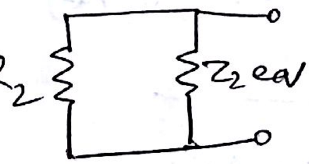
↓



$Z_1 eq$ & $\frac{1}{sC_2}$ are in series.

$$Z_2 eq = Z_1 + \frac{1}{sC_2} = \frac{R_1}{C_1R_1s+1} + \frac{1}{sC_2} = \frac{sR_1C_2 + C_1R_1s+1}{(C_1R_1s+1)sC_2}$$

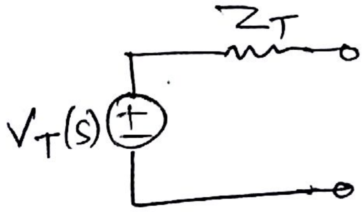
↓



R & $Z_2 eq$ in parallel

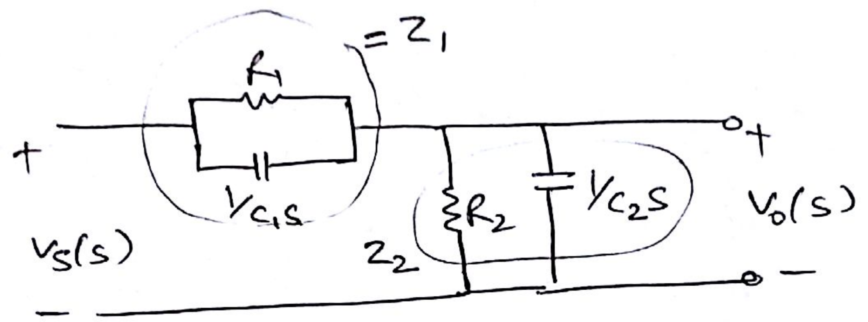
$$\therefore Z_T = R_2 \,\|\, Z_{eq} = \frac{R_2 \times \frac{sR_1C_2 + C_1R_1s+1}{(C_1R_1s+1)sC_2}}{R_2 + \frac{sR_1C_2 + C_1R_1s+1}{(C_1R_1s+1)sC_2}}$$

$$= \frac{R_2\left((R_1C_1 + R_1C_2)s+1\right)}{sR_1C_2 + sC_1R_1 + sC_2R_2 + s^2C_1C_2R_1R_2 + 1}$$



10.67)

a)



$$Z_1 = R_1 \parallel \frac{1}{C_1 s} = \frac{R_1}{R_1 C_1 s + 1}$$

$$Z_2 = R_2 \parallel \frac{1}{C_2 s} = \frac{R_2}{R_2 C_2 s + 1}$$

Using voltage division.

$$V_o(s) = \frac{Z_2}{Z_1 + Z_2} V_s(s) = \frac{R_2(R_1 C_1 s + 1) V_s(s)}{R_1(C_2 R_2 s + 1) + R_2(C_1 R_1 s + 1)}$$

$$\Rightarrow \frac{V_o(s)}{V_s(s)} = \frac{R_1 R_2 C_1 s + R_2}{s(R_1 R_2 C_2 + R_1 R_2 C_1) + R_1 + R_2}$$

b) $R_2 = 15\,M\Omega \quad C_2 = 3\,pF$

$$\frac{V_o(s)}{V_s(s)} = \frac{1}{2} \Rightarrow \frac{R_1 R_2 C_1 s + R_2}{s R_1 R_2 (C_1 + C_2) + R_1 + R_2} = \frac{1}{2}.$$

$$\Rightarrow 2R_1 R_2 C_1 s + 2R_2 = sR_1 R_2 C_1 + sR_1 R_2 C_2 + R_1 + R_2$$

$$\Rightarrow sR_1 R_2 C_1 + R_2 = sR_1 R_2 C_2 + R_1$$

For $R_1 = R_2$ & $C_1 = C_2$, the eq^n is true.

we get $R_1 = 15\,M\Omega$ & $C_2 = 3\,pF$.