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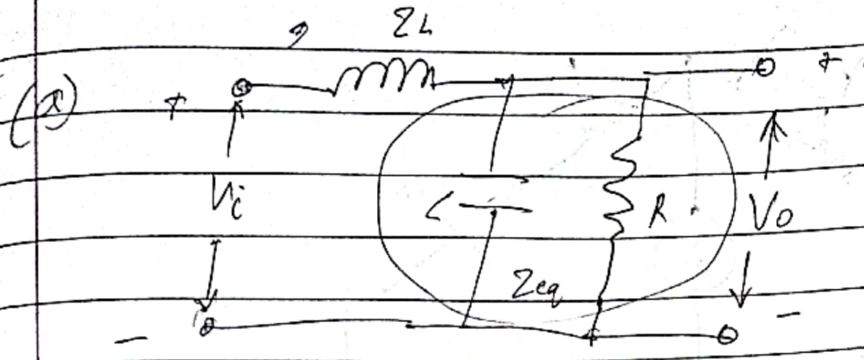
PAGE NO.:
DATE / /

Q1

(a)



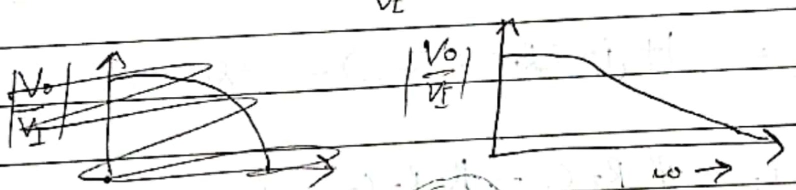
$$\frac{V_o}{V_I} = \frac{Z_{eq}}{Z_{eq}+Z_L} = \frac{1}{1+\frac{j\omega L}{\left(\frac{R}{1+j\omega RC}\right)}}$$

$$Z_{eq} = \frac{1}{\frac{1}{R}+j\omega C} = \frac{R}{1+j\omega RC}$$

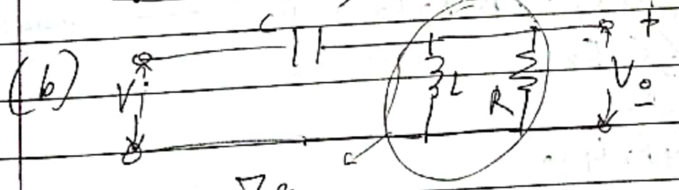
$$\frac{V_o}{V_I} = \frac{1}{1-\omega^2 LC + j\frac{\omega L}{R}}$$

when $\omega \to \infty$, $\frac{V_o}{V_I} \to 0$, This is a low pass filter.

$\omega \to 0$, $\frac{V_o}{V_I} \to 1$



(b)



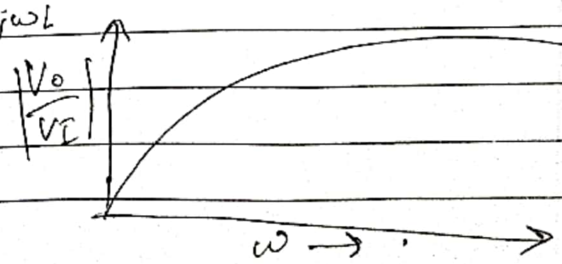
High pass filter.

$$Z_{eq} = \frac{1}{\frac{1}{R}+\frac{1}{j\omega L}} = \frac{j\omega RL}{R+j\omega L}$$

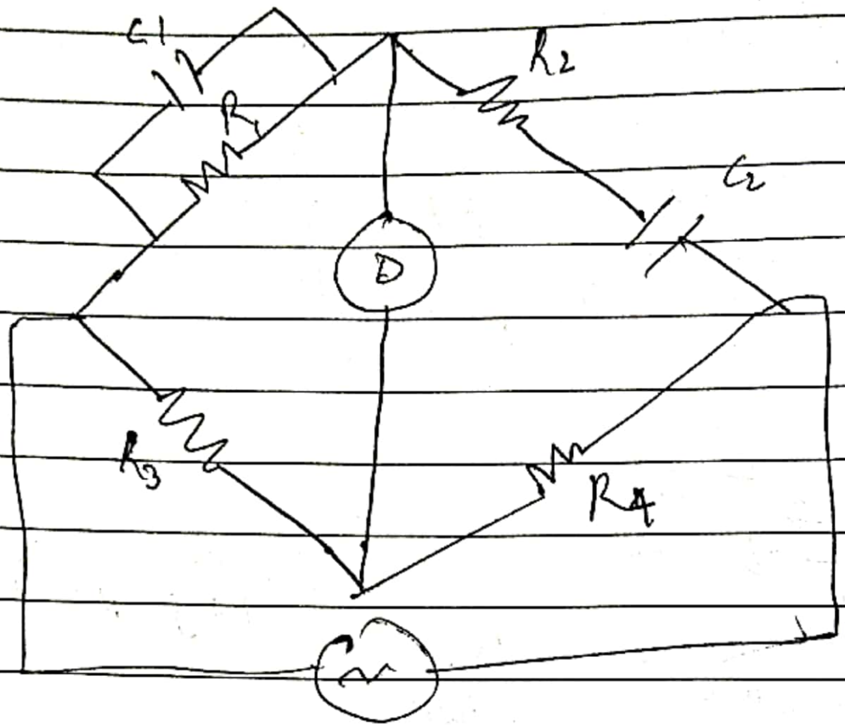
$$\frac{V_o}{V_I} = \frac{1}{1+\frac{\frac{1}{j\omega C}}{\frac{j\omega RL}{R+j\omega L}}} = \frac{\omega^2 LCR}{\omega^2 LCR - R - j\omega L} = \frac{1}{\left(1-\frac{1}{\omega^2 LC}\right)-\frac{j}{\omega RC}}$$

$\omega \to \infty$, $\frac{V_o}{V_I} \to 1$,

$\omega \to 0$, $\frac{V_o}{V_I} \to 0$



2)



Balancing condition $|Z_1||Z_4| = |Z_2||Z_3|$.

$$\frac{1}{\frac{1}{R_1}+j\omega C_1}\cdot R_4 = R_3\left(R_2+\frac{1}{j\omega C_2}\right).$$

$$\frac{R_1R_4}{1+j\omega R_1C_1} = R_3\left(\frac{1+j\omega R_2C_2}{j\omega C_2}\right)$$

$$\frac{R_1R_4}{R_3}\cdot j\omega C_2 = 1+j\omega(R_1C_1+R_2C_2)-\omega^2R_1C_1C_2R_2.$$

$\Rightarrow$ $R_1R_4C_2 - R_1R_3C_1 - R_2R_3C_2 = 0$ --- imagin

$\cancel{R_3} = \omega^2R_1R_2\cancel{R_3}C_1C_2$ --- real

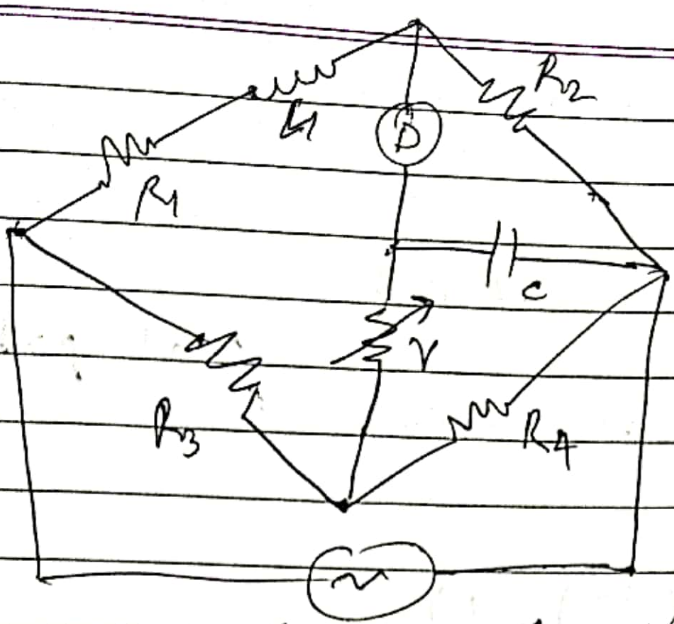
$\Rightarrow$ $\omega^2 = \dfrac{1}{R_1R_2C_1C_2}$

$\Rightarrow$ $\omega = \dfrac{1}{\sqrt{R_1R_2C_1C_2}}$

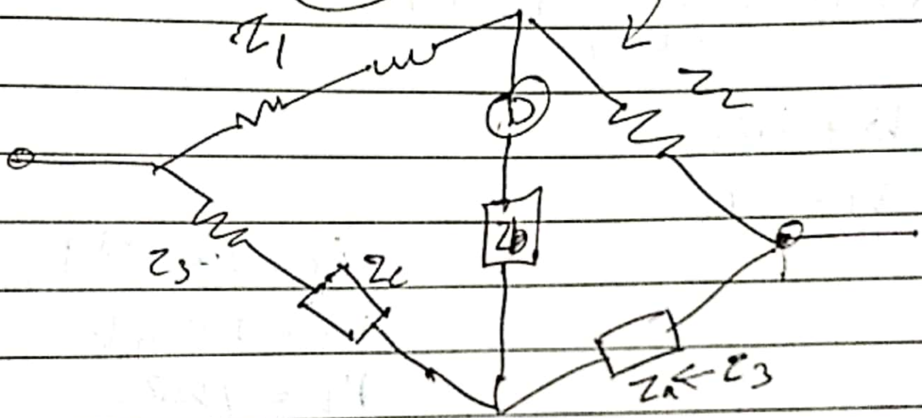
PAGE NO.:

DATE / /

3)



Do Delta star



$$Z_a = \frac{R_4 / j\omega C}{r + R_4 + \frac{1}{j\omega C}} = Z_3$$

$$Z_4 = \frac{r R_4}{r + R_4 + \frac{1}{j\omega C}}$$

$$\Rightarrow \frac{Z_1}{Z_2} = \frac{Z_4}{Z_3}$$

$$\Rightarrow \frac{(R_1 + j\omega L_1) R_4}{r + R_4 + \frac{1}{j\omega C}} = R_2 \left(R_3 + \frac{r R_4}{r + R_4 + \frac{1}{j\omega C}} \right)$$

$$\Rightarrow \frac{R_1 R_4 + j\omega L_1 R_4}{j\omega C} = r R_4 R_2 + r R_2 R_3 + R_2 R_3 R_4 - j \frac{R_2 R_3}{\omega C}$$

$$\Rightarrow -j \frac{R_1 R_4}{\omega C} + \frac{L_1 R_4}{C} = r R_4 R_2 + r R_3 R_2 + R_2 R_3 R_4 - j \frac{R_2 R_3}{\omega C}$$

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$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad \text{-- imaginary part}$$

$$\frac{R_4 L}{c} = R_2 (rR_4 + rR_3 + R_3 R_4) \quad \text{real part}$$

$$\Rightarrow \frac{L}{c} = \frac{R_2}{R_4}(rR_4 + rR_3 + R_3 R_4).$$

4) $$i_D = i_S \left(\exp\left(\frac{V_D}{V_T}\right) - 1 \right)$$

$$V_S = V_D + i_D R_L$$

$$V_D = V_S - i_D R_L$$

$i_S = 1 \times 10^{-8} A$,
$V_T = 26\,mV$.
$R_L = 1\,k\Omega$

$$V_D = V_S - I_D R_L$$

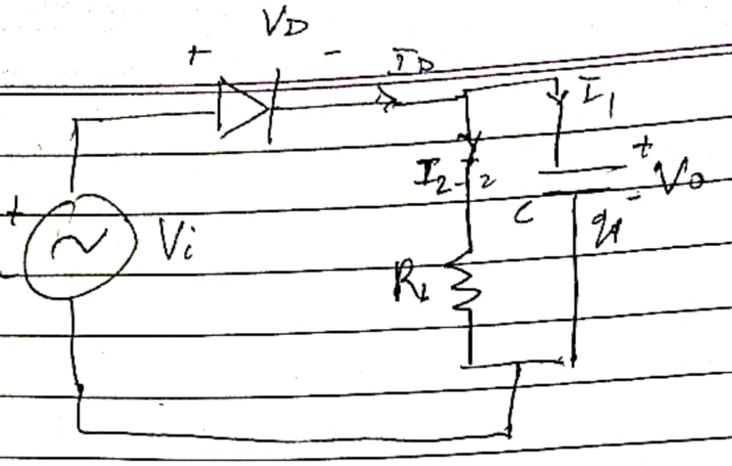
$$\frac{I_D}{I_S} + 1 = \exp\left(\frac{V_S - I_D R_L}{V_T}\right)$$

$$\frac{I_D}{10^{-8}} + 1 = \exp\left(\frac{V_D - 1000 I_D}{26 \times 10^{-3}}\right)$$

$$f(x) = 10^8 x + 1 - \exp\left(\frac{V_S - 1000x}{26 \times 10^{-3}}\right)$$

Code & figure in zip

5-



$i_D = i_1 + i_2$

$q_1 = CV_0 \Rightarrow i_1 = C\frac{dV_0}{dt}$

$R_L i_2 = V_0 \Rightarrow i_2 = \frac{V_0}{R_L}$

$i_D = C\frac{dV_0}{dt} + \frac{V_0}{R_L}$

$i_D = i_s\left(\exp\left(\frac{V_D}{V_T}\right) - 1\right)$

$V_D = V_i - V_0$

$\Rightarrow$ ~~$i_D = i_s(\exp$~~ $i_D = i_s\left(\exp\left(\frac{V_i - V_0}{V_T}\right) - 1\right)$

$\Rightarrow i_s\left(\exp\left(\frac{V_i - V_0}{V_T}\right) - 1\right) = C\frac{dV_0}{dt} + \frac{V_0}{R_L}$

$i_s = 10^{-8}$

$V_i = 10\sqrt{2}\sin(100\pi t)$ $R_L = 1\ kV$

$V_T = 26\ mV$

(All figures & code in zip file)