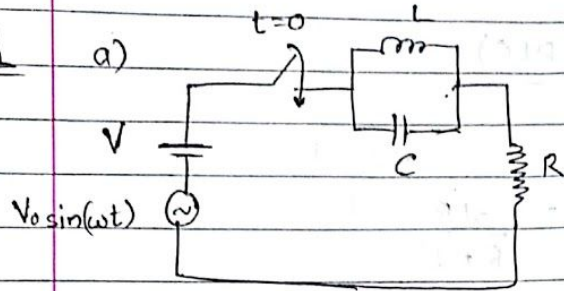
Assignment 7 solution

Q.1 a)



For AC,

$$Z_s = R + sL \,||\, \tfrac{1}{sC}$$

$$= R + \frac{L/C}{\frac{s^2LC+1}{sC}}$$

$$\therefore Z_s = \frac{R + sL + s^2RLC}{1 + s^2LC}$$

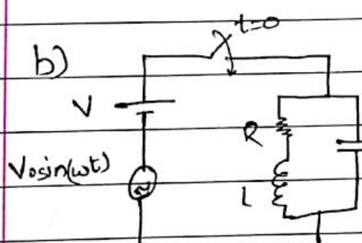
$$s = j\omega, \quad \therefore Z_s = \frac{R + j\omega L - \omega^2 RLC}{1 - \omega^2 LC}$$

$$i_{ac} = \cancel{\frac{V_0 \sin(\omega t)}{Z_s}} \; \frac{V_0 \sin(\omega t)}{Z_s} \Rightarrow i_{ac} = \frac{V_0(1-\omega^2LC)\sin\omega t}{R(1-\omega^2LC) + j\omega L}$$

for DC, $$I_{dc} = \frac{V_0}{R}\left(1 - e^{-Rt/L} + \cancel{V_0}\, e^{-t/RC}\right)$$

$$\underline{i = i_{ac} + I_{dc}}$$

b)



For AC,

$$Z_s = (R + j\omega L) \,||\, \frac{1}{j\omega C}$$

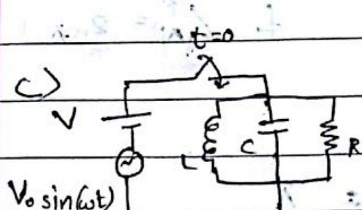
$$= \frac{(R + j\omega L)/j\omega C}{\frac{j\omega RC - \omega^2 LC + 1}{j\omega C}}$$

$$\therefore Z_s = \frac{R + j\omega L}{1 + j\omega RC - \omega^2 LC}$$

$$i_{ac} = \frac{V_0 \sin(\omega t)}{Z_s} = \frac{V_0(1 + j\omega RC - \omega^2 LC)\sin(\omega t)}{R + j\omega L}$$

for DC, $$I_{dc} = \frac{V}{R}\left(1 - e^{-Rt/L}\right)$$

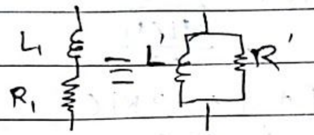
c)



$$Z_s = R \,||\, j\omega L \,||\, \frac{1}{j\omega C}$$

$$Z_s = \frac{j\omega LR}{R + j\omega L - \omega^2 RLC}$$

$$i_{ac} = \frac{V\sin(\omega t)(R + j\omega L - \omega^2 RLC)}{j\omega RL}$$



$$sL_1 + R_1 = \frac{sL'R'}{R' + sL'}$$

$$j\omega R'L_1 \cancel{A} - \omega^2 L'L_1 + R'R_1 + j\omega L'R_1 = j\omega L'R'$$

$$\therefore \quad R'R_1 = \omega^2 L'L_1 \quad \& \quad \omega(R'L_1 + L'R_1) = L'R'$$

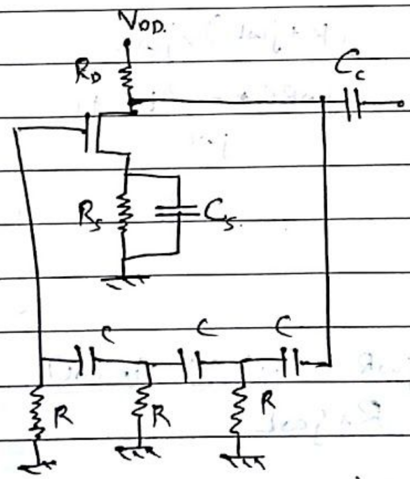
$$\therefore L' = L_1\left[1 + \frac{R_1^2}{\omega^2 L_1^2}\right] \qquad Q = \frac{\omega L_1}{R_1}$$

$$\therefore \quad L' = L_1\left[1 + \frac{1}{Q^2}\right] \Rightarrow R' = R_1 Q^2\left[1 + \frac{1}{Q^2}\right]$$

Near resonance, Q is large. $\therefore$ $L' \to L_1$ & $R' \to R_1 Q^2$

at $\omega_0 = \frac{1}{\sqrt{L_1 C_1}}$, $\underline{Z_s = R_1 Q^2}$

Q.2.



~~without feedback~~, the source resistor will be shorted by the bypass capacitor.

$\therefore$ open-loop-gain $= -g_m R_D = A$

$$\beta = \left(\frac{R}{R + \frac{1}{j\omega C}}\right)^3 = \left(\frac{j\omega CR}{1 + j\omega CR}\right)^3$$

~~for~~ from Barkhausen ~~cri~~ criterion, $|A\beta| = 1$ & $\angle A\beta = 2n\pi$

phase shift by ~~op~~-A is 180°

$\therefore$ phase shift by β should be 180°

phase shift by $\beta = 3\tan^{-1}\left(\frac{1}{\omega RC}\right) = \pi$

$\therefore \quad \frac{1}{\omega RC} = \sqrt{3} \Rightarrow C = \frac{1}{\omega R\sqrt{3}}$

~~$\omega = 2k$~~ $f = 2\,kHz$ & $R = 10\,k\Omega$

$\therefore \quad \underline{\underline{C = 4.6\,nF}}$

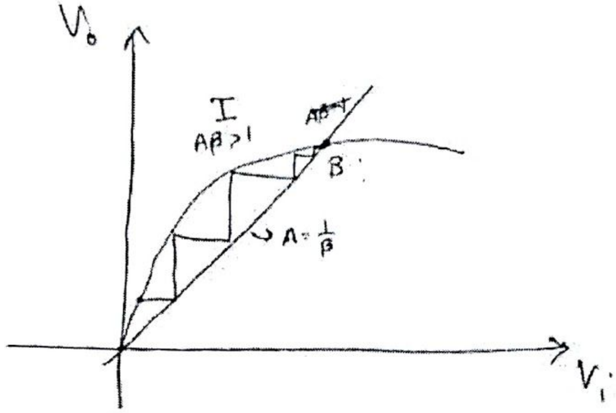
Also, as $|A\beta| = 1$ ~~$\Rightarrow g_m R_D$~~

$\therefore \quad \frac{g_m R_D\, \omega^3 R^3 C^3}{(1+\omega^2 R^2 C^2)^{3/2}} = 1 \Rightarrow \frac{g_m R_D}{\left(\left(\frac{1}{\omega RC}\right)^2 + 1\right)^{3/2}} = 1$

$\therefore \quad g_m R_D = 8 \Rightarrow \underline{\underline{R_D = 800\,\Omega}} \quad (\because g_m = 10\,mS)$

Q3.

$$V_o = 10\left(1 - e^{-V_i}\right)$$

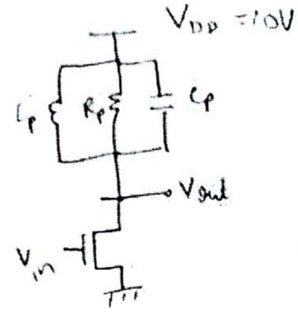


If a point is taken in Region I, because of +ve feedback the i/p will increase and so gain will decrease (clear from the graph)

Hence at B, the oscillation will become stable as Barkhausen criteria is satisfied. $\{|A\beta| = 1\}$

Hence B is a stable point (where $A = \frac{1}{\beta}$)

Q4.



$(V_{in})_{DC} = 4V$ (assumed)

Also assume $V_T = 1V$

$\Rightarrow \quad V_{GS} - V_T = 3V$

Clearly max amplitude of V_{in} can be 7V as above that the saturation region does not exist

Minimum amplitude is $\frac{V_{DD}}{2} = 5V$

Gain $= -g_m R_D$.

$$\Rightarrow \quad 5 \leq (V_{in}) g_m R_D \leq 7$$

We take std. i/p of 5mV sin ωt and $g_m = 10m\,S$

$$\Rightarrow \quad 5 \leq (5m)\, g_m R_p \leq 7$$

$$\Rightarrow \quad 1K \leq g_m R_p \leq 1.4K$$

$$\boxed{100k\Omega \leq R_p \leq 140k\Omega}$$