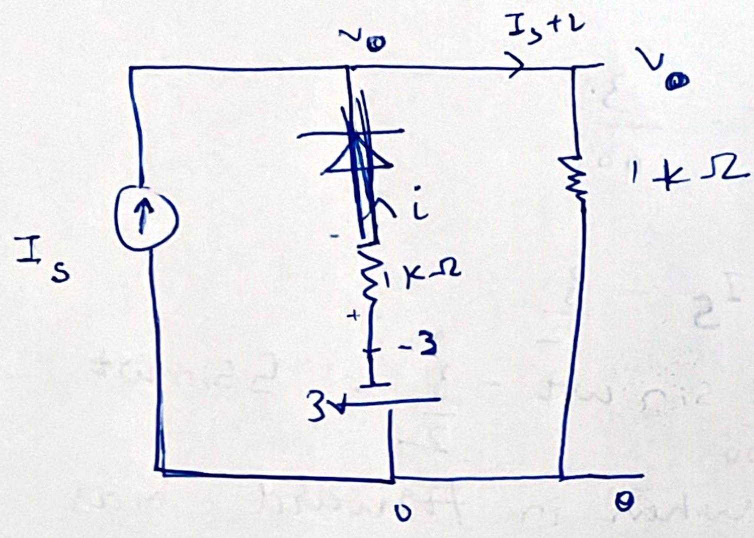
Q1) Case 1:- D in forward bias :-



$i > 0$

$V_0 < -3$

$v_0 = (I_s + i) \cdot 1000$

$i = \dfrac{-3 - v_0}{1000}$

$\left[I_s - \dfrac{(v_0 + 3)}{1000}\right] \cdot 1000 < -3$

$I_s - \dfrac{v_0}{1000} - \cancel{\dfrac{3}{1000}} < \cancel{\dfrac{-3}{1000}}$

$I_s < \dfrac{v_0}{1000}$

$I_s < \dfrac{-3}{1000}$

So for $10 \sin \omega t < -3$, diode in forward bias & $10 \sin \omega t > -3$, diode in reverse bias.

$$\frac{V_0}{1000} = I_S - \frac{V_0 + 3}{1000}$$

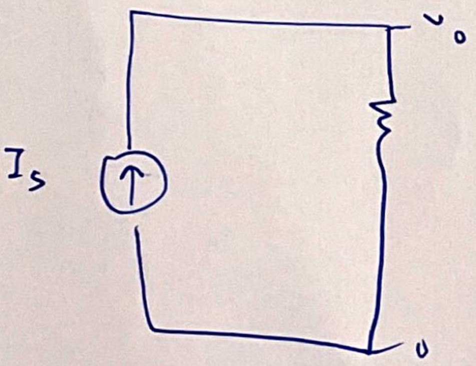
$$\frac{2V_0}{1000} = I_S - \frac{3}{1000}$$

$$V_0 = 500\, I_S - \frac{3}{2}$$

$$V_0 = \frac{5000 \sin \omega t}{1000} - \frac{3}{2} = 5 \sin \omega t - \frac{3}{2}$$

when in forward bias

case 2:- D in reverse bias

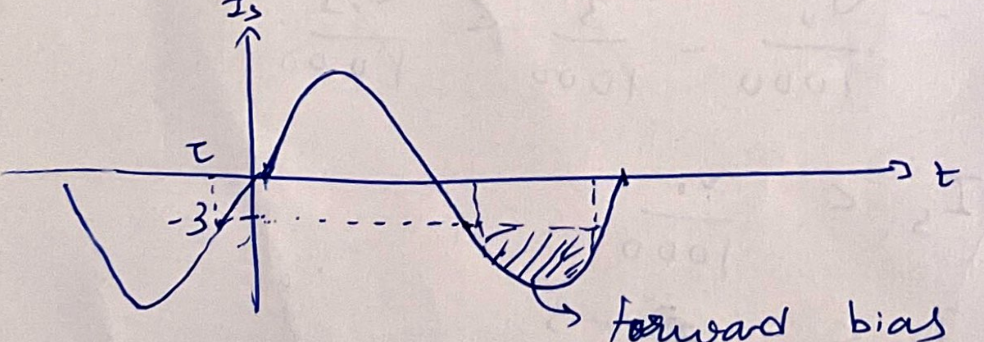


$$V_0 = 1000\, I_S$$

$$= \frac{10000 \sin \omega t}{1000}$$

$$= 10 \sin \omega t$$

$\therefore$ Let $\tau = \frac{1}{\omega} \sin^{-1} \frac{-3}{10} = \frac{-1}{\omega} \sin^{-1} \frac{3}{10}$



$$\cancel{V = \begin{cases} 10000 \sin \omega t, & \frac{2n\pi + \pi + \tau}{\omega} \leq t \leq \frac{2(n+1)\pi}{\omega} - \tau \\ 5000 \sin \omega t - 3, & t \end{cases}}$$

$$v = \begin{cases} 10\sin n\omega t & \frac{2n\pi}{\omega} - \tau \le t \le \frac{(2n+1)\pi}{\omega} + \tau \\ 5\sin n\omega t - \frac{3}{2} & \frac{(2n+1)\pi}{\omega} + \tau \le t \le \frac{(2n+2)\pi}{\omega} - \tau \end{cases}$$

Q2)

$$\frac{v_R}{v_i} = \frac{R \parallel X_L}{Z}$$

$$= \frac{\frac{R \cdot \omega L i}{R + \omega L i}}{\frac{R \cdot \omega L i}{R + \omega L i} - \frac{i}{\omega C}}$$

$$\cancel{= \frac{\omega^2 R L C i}{\quad}}$$

$$= \frac{\frac{R\omega L}{R + \omega L i}}{\frac{R\omega L}{R + \omega L i} - \frac{1}{\omega C}}$$

$$= \frac{R\omega^2 LC}{R\omega^2 LC - R - \omega L i}$$

$$= \frac{R\omega^2 LC}{R[\omega^2 LC - 1] - \omega L i}$$

$$H(\omega) = \frac{R^2 \omega^2 LC[\omega^2 LC - 1] + R\omega^3 L^2 C i}{R^2 [\omega^2 LC - 1]^2 + \omega^2 L^2}$$

$$Re(H(\omega)) = \frac{R^2 LC \omega^2 [\omega^2 LC - 1]}{R^2 [\omega^2 LC - 1]^2 + \omega^2 L^2}$$

For $Re(H(\omega)) = 0$,

$$\omega^2 [\omega^2 LC - 1] = 0$$

$$\boxed{\omega = 0 \text{ or } \frac{1}{\sqrt{LC}}}$$

$$H(\omega) = \frac{R^2 \omega^2 LC[\omega^2 LC - 1] + R\omega^3 L^2 C i}{\omega^2 L^2 \left[R^2 \left[\frac{\omega^2 LC - 1}{\omega L}\right]^2 + 1\right]}$$

$$= \frac{R^2 \omega^2 LC[\omega^2 LC - 1] + R\omega^3 L^2 C i}{\omega^2 L^2 \left[R^2 \left[\omega C - \frac{1}{\omega L}\right]^2 + 1\right]}$$

$$= \frac{R^2 \frac{C}{L} [\omega^2 LC - 1] + R\omega C i}{R^2 \left(\omega C - \frac{1}{\omega L}\right)^2 + 1}$$

$$H(\omega) = \frac{R^2 \frac{C}{L}\left[\omega^2 LC - 1\right] + R\omega C i}{-2R^2\frac{C}{L} + R^2\omega^2 C^2 + \frac{R^2}{\omega^2 L^2} + 1}$$

$$\approx \frac{R^2 \frac{C}{L}\left[\omega^2 LC - 1\right] + R\omega C i}{R^2\left[\omega C - \frac{1}{\omega L}\right]^2}$$

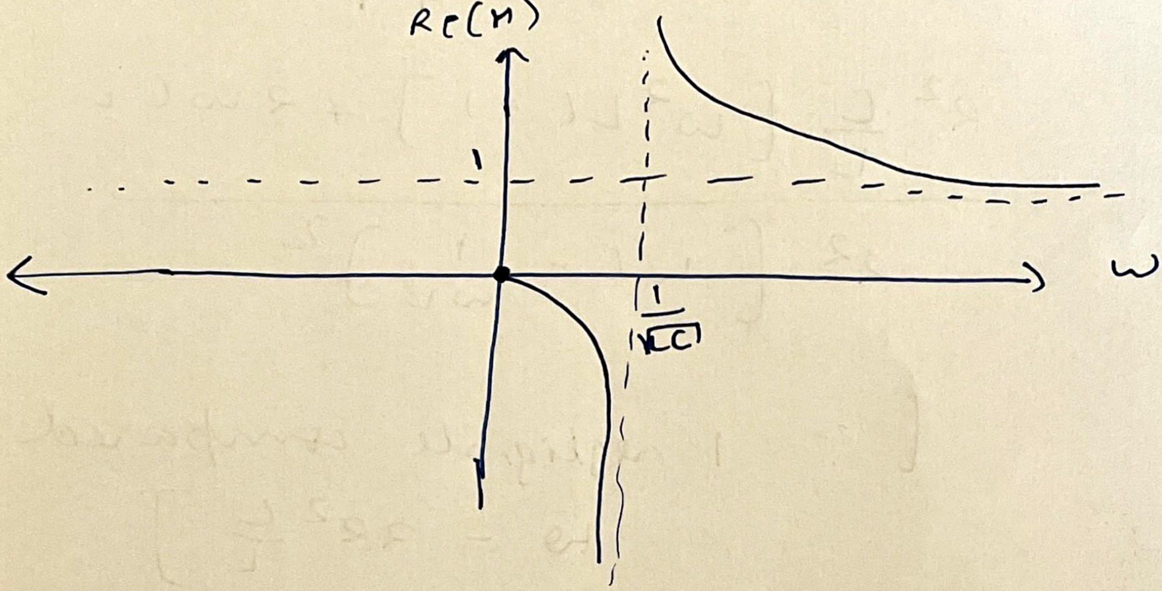
$\left[\because 1 \text{ negligible compared to } -2R^2\frac{C}{L}\right]$

$$\cancel{H(\omega) = \frac{\omega R^2 \frac{C^2}{L}\left[\omega L - \frac{1}{\omega C}\right] + Ri}{R^2\left[\omega C - \right.}}$$

$$H(\omega) = \frac{R^2\omega C\left[\omega C - \frac{1}{\omega L}\right] + R\omega C i}{R^2\left[\omega C - \frac{1}{\omega L}\right]^2}$$

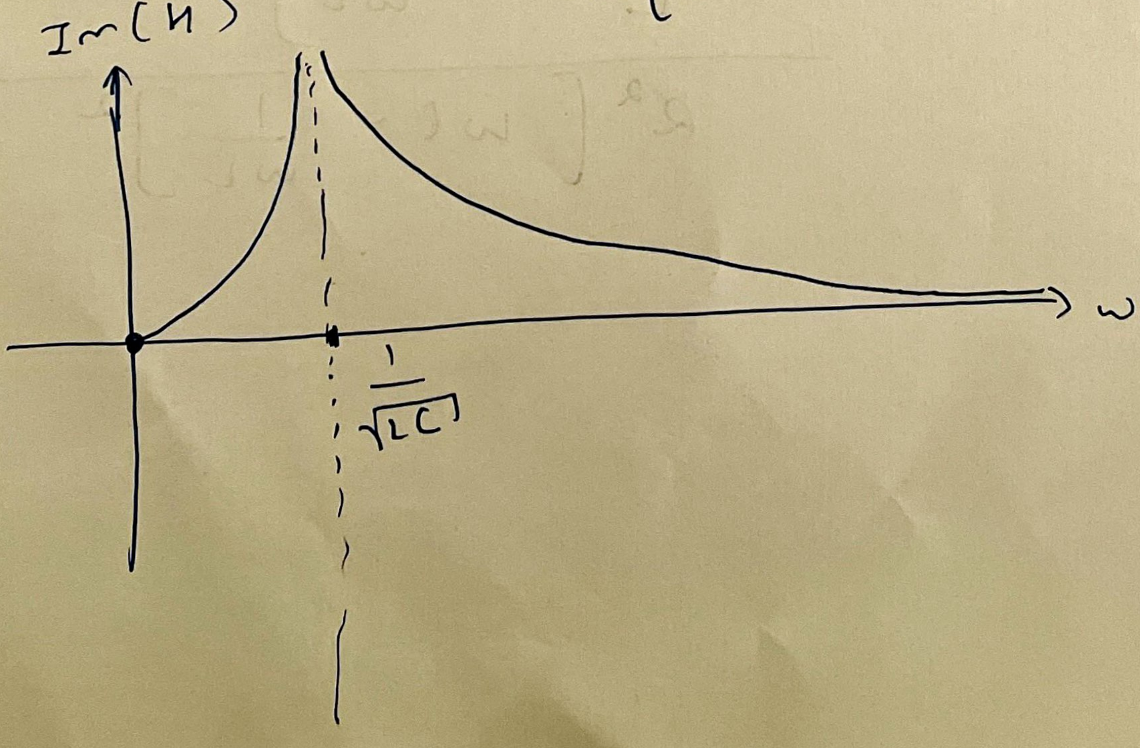
$$\text{Re}(H) = \frac{\omega C}{\omega C - \frac{1}{\omega L}}$$

$$= \frac{\omega^2 L C}{\omega^2 L C - 1}$$



$$\text{Im}(H) = \frac{\omega C}{R\left[\omega C - \frac{1}{\omega L}\right]^2}$$

$$= \frac{\omega^3 L^2 C}{R\left[\omega^2 L C - 1\right]^2}$$



$$\text{abs}(H) = \frac{R\omega C \sqrt{R^2\left(\omega C - \frac{1}{\omega L}\right) + 1}}{R^2\left[\omega C - \frac{1}{\omega L}\right]^2}$$

$$\approx \frac{R\omega C \cdot R\left(\omega C - \frac{1}{\omega L}\right)}{R^2\left[\omega C - \frac{1}{\omega L}\right]^2}$$

$$\because \left[R^2 \frac{C}{L} \gg 1\right]$$

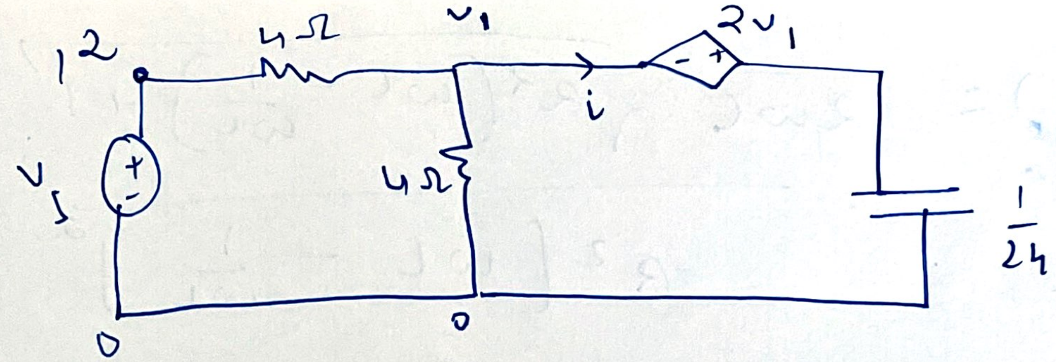
$$= \frac{\omega C}{\omega C - \frac{1}{\omega L}}$$

$$= \frac{\omega^2 C L}{\omega^2 C L - 1}$$

$$\text{Max}(\text{abs}(H)) \to \infty$$

as $\omega \to \frac{1}{\sqrt{LC}}$

93)



For $t < 0$,

$v(t) = 0$, $i(t) = 0$

For $t > 0$,

q : charge on capacitor

$$\frac{q}{c} = 3v_1 = 3i_1R_1$$

$$\frac{12 - v_1}{4} = \frac{v_1}{4} + \dot{i}$$

$$\dot{i} + i_1 = 3 - i_1$$

$$\dot{i} = 3 - 2i_1$$

$$i_1 = \frac{q}{3R_1C} = \frac{q}{3 \cdot 4 \cdot \frac{1}{24}}$$

$$i_1 = 2q$$

$$\frac{dq}{dt} + 4q = 3$$

$$\frac{d}{dt}\left[e^{4t} \cdot q\right] = 3e^{4t}$$

$$\cancel{q e^{4t} \Big| = \frac{3}{4} e^{4t} \Big|}$$

$$q e^{4t} = \frac{3}{4} e^{4t} + c$$

At $t = 0$, $q = 0$

$$0 = \frac{3}{4} + c , \quad c = -\frac{3}{4}$$

$$\therefore \quad q = \frac{3}{4}\left[1 - e^{-4t}\right]$$

$$\therefore \quad i = -\frac{3}{4} e^{-4t} (-4)$$

$$i = 3 e^{-4t}$$

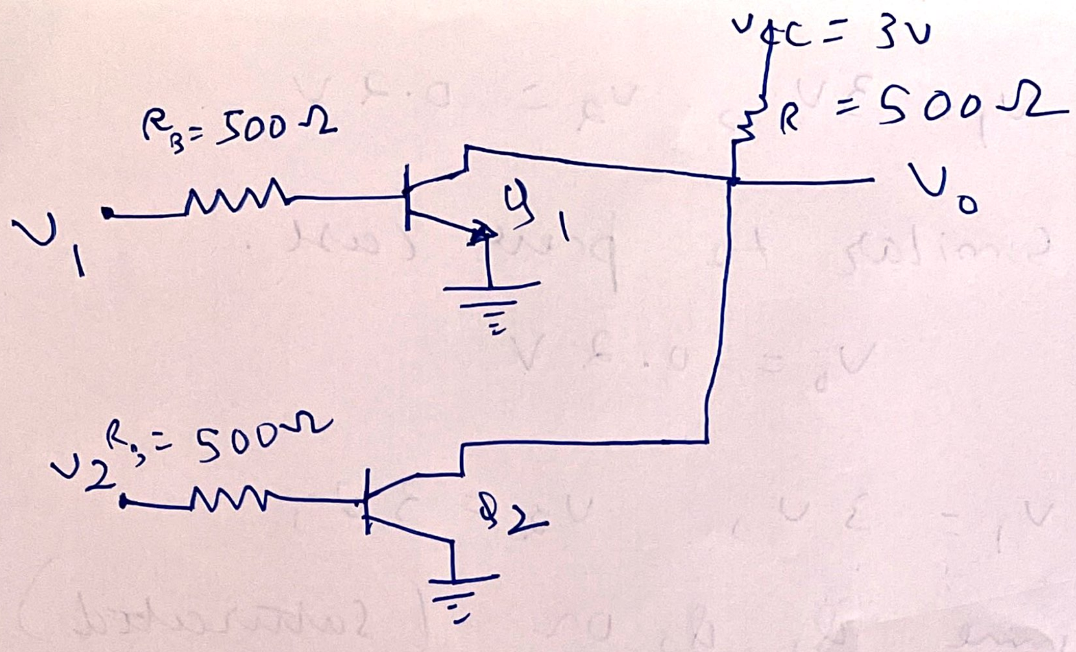
$$\therefore \quad i(t) = \begin{cases} 0 & t < 0 \\ 3e^{-4t} & t \geq 0 \end{cases}$$

$$v = \frac{q}{c} = 24 q$$

$$= 18\left[1 - e^{-4t}\right]$$

$$v(t) = \begin{cases} 0 & t < 0 \\ 18\left(1 - e^{-4t}\right] & t \geq 0 \end{cases}$$

Q4)



If $v_1 = V_2 = 0.2\,V$

If Q_1, Q_2 off,

$V_o = 3V$

If $v_1 = 0.2V$, $V_2 = 3V$

Assume Q_1 off Q_2 on (saturated)

$$V_o = 0.2\,V$$

$$iB_2 = \frac{3-0.8}{500} = 4.4\,mA$$

$$iE_2 = \frac{3-0.2}{500} = 5.6\,mA$$

$$\frac{iE_2}{iB_2} = \frac{4.4}{5.6} = 1.27 < \beta$$

Assumption correct.

If $v_1 = 3V$, $v_2 = 0.2V$

Similar to prev. case.

$$v_0 = 0.2\,V$$

If $v_1 = 3V$, $v_2 = 3V$;

Assume Q_1, Q_2 on (saturated)

$$v_0 = v_{E_1} = v_{E_2} = 0.2\,V$$

$$i_{E_1} = i_{E_2} = \frac{1}{2} \cdot \frac{3 - 0.2}{500} = 2.8\,mA$$

$$i_{B_1} = i_{B_2} = 4.4\,mA$$

$$\frac{i_{E_1}}{i_{B_1}} = \frac{i_{E_2}}{i_{B_2}} = 0.67 < \beta$$

Assumption correct.

v_1	v_2	v_0
0	0	1
0	1	0
1	0	0
1	1	0

NOR Gate

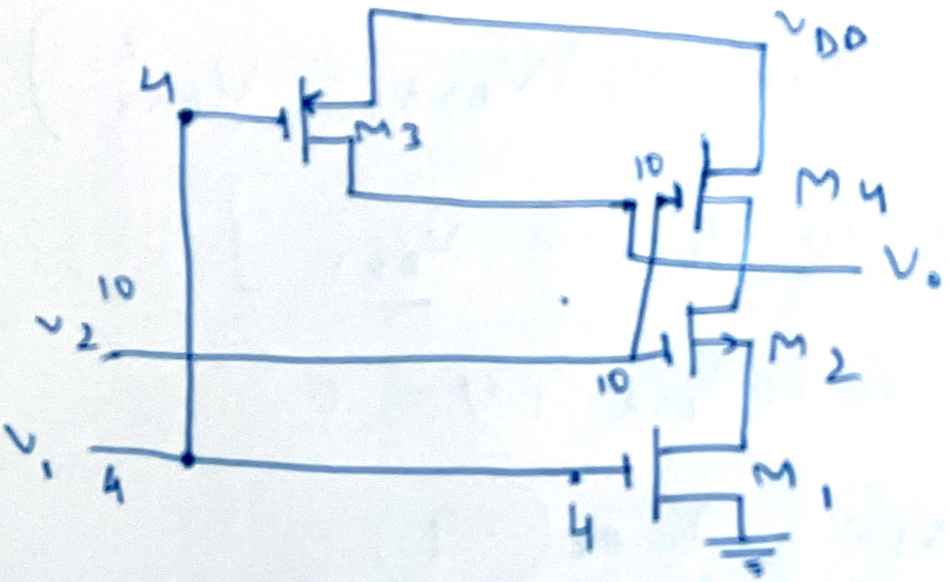
1	2	3	4	5	6	7	8
0.2	3	0.2	3	0.2			
0.2	3	0.2	3	0.2			
= 3	= 0.2	= 3	= 0.2	= 3			

9	10	1 original
	3	0.2
	3	0.2
	$= \boxed{0.2}$	$= \boxed{3}$

∴ The output voltage of the gate is 3 V.

1 → 3
2 → 5
3 → 2
4 → 3
5 → 2
6 → 1

Q5)



$v_1 = 4V$, $v_2 = 10V$, $V_{DD} = 10V$

$K = 0.25 \; mA/V^2$

$v_T(M_1, M_2) = 1V$

$v_T(M_3, M_4) = -1V$

when M_4 is off,

$V_{GS4} = 0 > V_{T4}$

$V_{GS3} = -6V < V_{T3}$

$\therefore$ Assume M_1, M_2 active & M_3 ohmic

$i_3 = i_2 = i_1$

$i_1 = K(V_{GS1} - v_T)^2 = (4-1)^2 K$
$= 9K$

$i_2 = K(v_{GS2} - v_T)^2 = (9 - v_{DS1})^2 K$

$i_1 = i_2 \Rightarrow \quad 9 - v_{DS1} = 3$

$v_{DS1} = 6$

$$i_3 = k\left[2(V_{GS3} - V_T)V_{DS3} - V_{DS3}^2\right]$$

$$= k\left[-10\, V_{DS3} - V_{DS3}^2\right]$$

$$V_{DS3}^2 + 10V_{DS3} + 9 = 0$$

$$V_{DS3} = -1 \text{ or } -9$$

Rejected as for active region, $V_{DS} > V_{GS} - V_T = -5$

$\therefore V_{DS3} = -1$

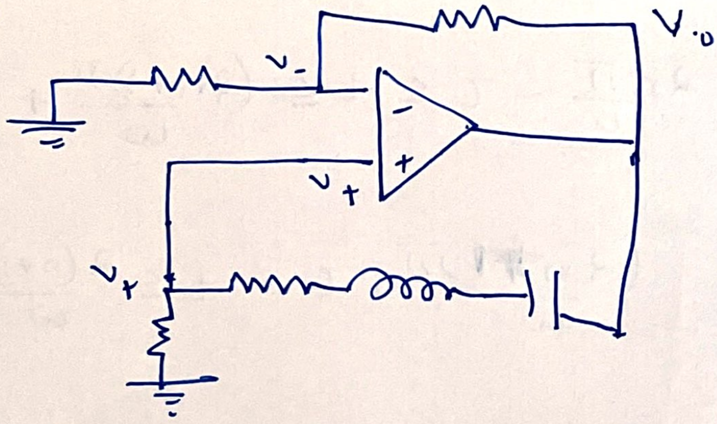
$\therefore V_{DS3} \geq V_{GS3} - V_T = -5\,V$

$\therefore M_3$ in ohmic region.

$V_{DS2} = V_0 - V_{DS1} = 3V \geq V_{GS2} - V_T = 3V$

$V_{DS1} = 6V \geq V_{GS1} - V_T = 3V$

Q6)



Assuming virtual short, $v_+ = v_-$

$$\frac{v_o - v_-}{100} = \frac{v_-}{10}$$

$$v_o = 11 v_-$$

$$\frac{v_+}{R} = \frac{v_o - v_+}{|Z|}$$

$$\frac{v}{R} = \frac{11v - v}{|Z|} \qquad [V = v_- = v_+]$$

$$|Z| = 10R$$

$$100R^2 = 5^2 + \left(\omega L - \frac{1}{\omega C}\right)^2 \times 10^{-6}$$

$$10R \geq 5$$

$$R \geq 0.5\ k\Omega$$

$$\boxed{R \geq 500\ \Omega}$$

For $R = 500$, $\omega = \frac{1}{\sqrt{LC}}$

$$= \frac{1}{\sqrt{2\times10^{-9} \times 5\times10^{-3}}} \times 10^{-6} = \boxed{10^6\ rad/s}$$