Q4) NMOS inverter.

a) V_{OH} ⇒ Since $V_{IN} = 0V$

⇒ No major current ⇒ ~~Major drop~~ across R_L

⇒ $\boxed{V_{out} = 2.5V}$ ⇒ V_{OH}

* V_{OL} :- $V_{IN} = 2.5V$ (V_{DD})

* Here NMOS in linear region.

$$\frac{K'W}{L}\left((V_{GS}-V_T)V_{OL} - \frac{V_{OL}^2}{2}\right) = \frac{V_{DD}-V_{OL}}{R_L}$$

⇒ $K' = 345 \times 10^{-6}$

$$\Rightarrow (345\times10^{-6})(75\times10^{3})\left(2.07V_{OL} - \frac{V_{OL}^2}{2}\right) = \frac{2.5 - V_{OL}}{R_L}$$

$$\Rightarrow (25.87)\left(2.07V_{OL} - \frac{V_{OL}^2}{2}\right) = 2.5 - V_{OL}$$

$$\rightarrow \boxed{V_{OL} = 46.33\,mV}$$

2

* V_M :- $V_{IN} = V_{out}$

$\Rightarrow \frac{k' W}{L}$ (NMOS in saturation)

$$\Rightarrow \frac{k' W}{2L} (V_M - V_T)^2 = \frac{V_{DD} - V_M}{R_L}$$

$$\Rightarrow 172.5 \times 10^{-6} (V_M - 0.43)^2 = \frac{2.5 - V_m}{75 \times 10^3}$$

$$\Rightarrow 12.9 (V_M - 0.43)^2 = 2.5 - V_M$$

Solving the Quad equ.

$$\Rightarrow \boxed{V_m = 0.79 \text{ V}}$$

(b) * V_{IL}, V_{IH} = ?

For $V_{IL}, V_{IH} \Rightarrow \frac{dV_{out}}{dV_{IN}} = -1$

⊙ V_{IL} (NMOS is saturation rgn).

$$\frac{V_{DD} - V_{out}}{R_L} = \frac{k'W}{2L}(V_{IN} - V_T)^2$$

→ Derivating wrt. V_{in}

$$\Rightarrow \frac{-1}{R_L}\left(\underbrace{\frac{dV_{out}}{dV_{IN}}}_{-1}\right) = \frac{k'W}{2L}(2)(V_{IN} - V_T)$$

$$\Rightarrow \frac{1}{R_L} = \frac{k'W}{L}(V_{IN} - V_T)$$

$$\Rightarrow V_{IL} = V_{IN} = \frac{L}{k'WR_L} + V_T$$

$$= \frac{10^6}{(1035)\times(75\times10^3)} + 0.43$$

$$\boxed{V_{IL} = 0.468\ V}$$

$$\boxed{V_{IL} = 0.468V}$$

* V_{IH} (NMOS in linear regn)

$$\frac{V_{DD} - V_{out}}{R_L} = \frac{k'W}{L}\left[(V_{IN} - V_T)V_{out} - \frac{V_{out}^2}{2}\right] \rightarrow (1)$$

$$\frac{-1}{R_L}\frac{dV_{out}}{dV_{in}} = \frac{k'W}{2}\left[(V_{IN} - V_T)\frac{dV_{out}}{dV_{IN}} + V_{out} - \frac{2V_{out}}{2}\frac{dV_{out}}{dV_{in}}\right]$$

$$\Rightarrow \frac{1}{R_L} = \frac{k'W}{L}\left[V_T - V_{in} + 2.V_{out}\right]$$

$$\Rightarrow \frac{L}{R_L k'W} = V_T - V_{IN} + 2V_{out}$$

$$\Rightarrow V_{in} = V_T + 2.V_{out} - \frac{L}{R_L k'W} \rightarrow (2)$$

$\Rightarrow$ Solving (2), (1) =

$$\Rightarrow 2.5 - V_{out} = \frac{R_L k'W}{L}\left[\left(2V_{out} - \frac{L}{R_L k'W}\right)V_{out} - \frac{V_{out}^2}{2}\right]$$

on Solving this;

$$\boxed{V_{out} = 0.253\ V}$$

0.012

$$\Rightarrow V_{IH} = V_{in} = 2V_{out} + V_T$$

$$\Rightarrow \boxed{V_{IH} = V_{in} = 0.899\ V}$$

B) contd. Noise margin

$N_{MH} = V_{OH} - V_{IH} = 2.5 - 0.9$

$= 1.6V$

$N_{ML} = V_{IL} - V_{OL}$

$= 0.468 - 0.046$

$= 0.42V$

(e) Peak gain $\Rightarrow$ happens at V_m

($V_{IN} = V_{out}$) $\Rightarrow$ saturation rgn

$$\frac{k'W}{2L}(V_M - V_T)^2 = \frac{V_{DD} - V_{out}}{R_L}$$

$$\Rightarrow \left.\frac{\partial V_{out}}{\partial V_{in}}\right|_{V_{in} = V_m} \Rightarrow \text{gain}$$

$$\Rightarrow \frac{k'W}{2L}\left(2(V_m - V_T)\right) = \frac{-1}{R_L}\left(\frac{\partial V_{out}}{\partial V_{in}}\right)$$

$$\Rightarrow \frac{-R_L k'W (V_m - V_T)}{L} = \text{gain (peak)}$$

Solving

Peakgain : $\Rightarrow 25.875(0.793-0.43)$

$\Rightarrow 9.38V$

$$\boxed{\text{Peakgain} = -9.38V}$$