Consider a resistive-load inverter circuit with $V_{DD} = 5V$, $k_n' = 20\mu A/V^2$, $V_{TO} = 0.8V$, $R_L = 200k\Omega$, and $W/L = 2$. Calculate the critical voltages (V_{OL}, V_{OH}, V_{IL}, V_{IH}) on the VTC and the find the noise margins of the circuit.

⇒ when the i/p voltage is low ie. when the driver n-MOS transistor is cut-off, the o/p high voltage can be found as,

$$V_{OH} = V_{DD} = 5V$$

In Resistive load inverter, the transconductance of the driver transistor is $k_n = k_n'(W/L)$ and hence,

$$= 40\mu A/V^2$$

$$k_n R_L = 8V^{-1}$$

The output low voltage V_{OL} is calculated by

$$V_{OL} = V_{DD} - V_{TO} + \frac{1}{k_n \cdot R_L} - \sqrt{\left(V_{DD} - V_{TO} + \frac{1}{k_n \cdot R_L}\right)^2 - \frac{2V_{DD}}{k_n \cdot R_L}}$$

$$= 5 - 0.8 + \frac{1}{8} - \sqrt{\left(5 - 0.8 + \frac{1}{8}\right)^2 - \frac{2 \cdot 5}{8}}$$

$$\boxed{V_{OL} = 0.147V}$$

The critical voltage V_{IL} is given by

$$V_{IL} = V_{TO} + \frac{1}{k_n \cdot R_L} = 0.8 + \frac{1}{8} = 0.925V$$

Finally, the critical voltage V_{IH} is given by,

$$V_{IH} = V_{TO} + \sqrt{\frac{8}{3}\frac{V_{DD}}{k_n \cdot R_L}} - \frac{1}{k_n R_L} = 0.8 + \sqrt{\frac{8}{3} \cdot \frac{5}{8}} - \frac{1}{8} = 1.97V$$

Low noise margin $NM_L = V_{IL} - V_{OL} = 0.93 - 0.15 = 0.78V$

High Noise margin $NM_H = V_{OH} - V_{IH} = 5.0 - 1.97 = 3.03V$

Consider the following inverter design problem: $V_{DD} = 5V$, $k_n' = 30\,\mu A/V^2$ and $V_{T0} = 1V$, design a resistive-load inverter circuit with $V_{OL} = 0.2V$. Specifically, determine the (W/L) ratio of the driver transistor. ~~and~~ the value of the load resistor R_L that achieve the required V_{OL} is $34\,k\Omega$.

⇒ The driver transistor is operating in the linear region when the output voltage is equal to V_{OL}, and the i/p voltage is equal to $V_{OH} = V_{DD}$

$$\frac{V_{DD} - V_{OL}}{R_L} = \frac{k_n'}{2}(W/L)\cdot\left[2\cdot(V_{OH} - V_{T0})\cdot V_{OL} - V_{OL}^2\right]$$

Assuming $V_{OL} = 0.2V$ & using the given values for the power supply voltage, the driver threshold voltage and the driver transconductance k_n', we obtain the following equation,

$$\therefore \frac{5 - 0.20}{R_L} = \frac{30\times10^{-6}}{2}\cdot\frac{W}{L}\left[(2\times4\times0.20) - (0.20)^2\right]$$

$$\therefore \frac{W}{L}\cdot R_L = 2.05\times10^5\,\Omega$$

$$\boxed{\therefore \frac{W}{L} = 6}$$