The NMOS transistor shown has the parameters of $K_n = 1 \text{mA/V}^2$, $V_{TN} = 1 \text{V}$ and $\lambda_N = 0 \text{V}^{-1}$. In saturation, the large signal model is $i_D = 0.5K_n(v_{GS}-V_T)^2$.

a.) Assume the NMOS transistor is saturated and find the value of $R_S$ that gives a drain current of $0.2 \text{mA}$.

b.) What value of $R_D$ will cause the MOSFET to go from the saturation to the active region when $I_D = 0.2 \text{mA}$?

**Solution**

a.) Let us solve for the value of $V_{GS}$ that gives $I_D = 0.2 \text{mA}$ when the MOSFET is saturated.

\[
I_D = 0.5K_n(V_{GS} - V_{TN})^2 = 0.5(V_{GS} - 1)^2 = 0.2
\]

\[
0.4 = V_{GS}^2 - 2V_{GS} + 1 \quad \rightarrow \quad V_{GS}^2 - 2V_{GS} + 0.6 = 0
\]

\[
\therefore \quad V_{GS} = 1 \pm 0.5\sqrt{4-0.6(4)} = 1 \pm 0.5\sqrt{1.6} = 1 \pm 0.632 \text{V} \quad \rightarrow \quad V_{GS} = 1.632 \text{V} \quad (2)
\]

Since we know that $V_G = 5 \text{V}$ \quad (1), then $V_S = 5 - 1.632 = 3.367 \text{V}$. Therefore,

\[
R_S = \frac{V_S}{I_D} = \frac{3.367}{0.2 \text{mA}} = 16.84 \text{k}\Omega \quad (3)
\]

b.) To find the value of $R_D$ that will cause the MOSFET to leave the saturation region and enter the active region, we will use the following relationship that gives the conditions at the boundary of the two regions.

\[
V_{DS} = V_{GS} - V_{TN} \quad (1)
\]

This relationship can be rewritten as,

\[
V_D - V_S = V_G - V_S - V_{TN} \quad \rightarrow \quad V_D = V_G - V_{TN} = V_G - 1 \quad (1)
\]

Therefore, $V_D = 5 - 1 = 4 \text{V}$ is when the MOSFET will be at the boundary of the two regions. Thus, the voltage drop across $R_D$ is $6 \text{V}$ and the current through it is $0.2 \text{mA}$. From Ohm’s law, we get,

\[
R_D = \frac{(10-V_D)}{I_D} = \frac{6 \text{V}}{0.2 \text{mA}} = 30 \text{k}\Omega \quad (2)
\]