10.33 Consider an n-channel MOSFET with the following parameters: $k_n' = 0.18$ mA/V^2, $W/L = 8$, and $V_T = 0.4$ V. Determine the drain current I_D for (*a*) $V_{GS} = 0.8$ V, $V_{DS} = 0.2$ V; (*b*) $V_{GS} = 0.8$ V, $V_{DS} = 1.2$ V; (*c*) $V_{GS} = 0.8$ V, $V_{DS} = 2.5$ V; and (*d*) $V_{GS} = 1.2$ V, $V_{DS} = 2.5$ V.

➢ Change to $W/L = 6$.

Linear Region ($0 \le V_{DS} \le V_{DS}(\text{sat})$ and $V_{GS} \ge V_T$)

$$I_D = \frac{k_n'}{2}\frac{W}{L}\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] = K_n\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] \quad (10.63)$$

Saturation ($V_{DS} \ge V_{DS}(\text{sat}) = V_{GS} - V_T$ (10.64) and $V_{GS} \ge V_T$)

$$I_D(\text{sat}) = \frac{k_n'}{2}\frac{W}{L}(V_{GS} - V_T)^2 = K_n(V_{GS} - V_T)^2 \quad (10.67).$$

a) Per (10.64), $V_{DS}(\text{sat}) = V_{GS} - V_T = 0.8 - 0.4 = 0.4$ V

Here, $0 < V_{DS} = 0.2\text{ V} < V_{DS}(\text{sat}) = 0.4\text{ V}$ & $V_{GS} = 0.8\text{ V} > V_T = 0.4\text{ V} \Rightarrow$ **linear**

$$I_D = \frac{0.18\,\text{mA/V}^2}{2}(6)\left[2(0.8 - 0.4)0.2 - 0.2^2\right] \quad \Rightarrow \underline{\boldsymbol{I_D = 0.0648\text{ mA} = 64.8\ \mu\text{A}}}.$$

b) Per (10.64), $V_{DS}(\text{sat}) = V_{GS} - V_T = 0.8 - 0.4 = 0.4$ V

Here, $V_{DS} = 1.2\text{ V} > V_{DS}(\text{sat}) = 0.4\text{ V}$ & $V_{GS} = 0.8\text{ V} > V_T = 0.4\text{ V} \Rightarrow$ **saturation**

$$I_D = \frac{0.18\,\text{mA/V}^2}{2}(6)(0.8 - 0.4)^2 \quad \Rightarrow \underline{\boldsymbol{I_D = 0.0864\text{ mA} = 86.4\ \mu\text{A}}}.$$

c) Per (10.64), $V_{DS}(\text{sat}) = V_{GS} - V_T = 0.8 - 0.4 = 0.4$ V

Here, $V_{DS} = 2.5\text{ V} > V_{DS}(\text{sat}) = 0.4\text{ V}$ & $V_{GS} = 0.8\text{ V} > V_T = 0.4\text{ V} \Rightarrow$ **saturation**

$$I_D = \frac{0.18\,\text{mA/V}^2}{2}(6)(0.8 - 0.4)^2 \quad \Rightarrow \underline{\boldsymbol{I_D = 0.0864\text{ mA} = 86.4\ \mu\text{A}}}.$$

d) Per (10.64), $V_{DS}(\text{sat}) = V_{GS} - V_T = 1.2 - 0.4 = 0.8$ V

Here, $V_{DS} = 2.5\text{ V} > V_{DS}(\text{sat}) = 0.8\text{ V}$ & $V_{GS} = 1.2\text{ V} > V_T = 0.4\text{ V} \Rightarrow$ **saturation**

$$I_D = \frac{0.18\,\text{mA/V}^2}{2}(6)(1.2 - 0.4)^2 \quad \Rightarrow \underline{\boldsymbol{I_D = 0.3456\text{ mA} = 345.6\ \mu\text{A}}}.$$