

**10.36** Consider a p-channel MOSFET with the following parameters:  $k'_p = 0.12 \text{ mA/V}^2$  and  $W/L = 20$ . The drain current is  $100 \mu\text{A}$  with applied voltages of  $V_{SG} = 0$ ,  $V_{BS} = 0$ , and  $V_{SD} = 1.0 \text{ V}$ . (a) Determine the  $V_T$  value. (b) Determine the drain current  $I_D$  for  $V_{SG} = 0.4 \text{ V}$ ,  $V_{SB} = 0$ , and  $V_{SD} = 1.5 \text{ V}$ . (c) What is the value of  $I_D$  for  $V_{SG} = 0.6 \text{ V}$ ,  $V_{SB} = 0$ , and  $V_{SD} = 0.15 \text{ V}$ ?

➤ Change to  $W/L = 16$ .

**Linear Region** [ $0 \leq V_{SD} \leq V_{SD}(\text{sat})$  and  $V_{SG} > V_T$ ]

$$I_D = \frac{k'_p}{2} \frac{W}{L} \left[ 2(V_{SG} + V_T)V_{SD} - V_{SD}^2 \right] \quad (10.70).$$

**Saturation** [ $V_{SG} \geq V_T$  &  $V_{SD} \geq V_{DS}(\text{sat})$ ]

$$I_D(\text{sat}) = \frac{k'_p}{2} \frac{W}{L} (V_{SG} + V_T)^2 \quad (10.72).$$

a) Since  $V_{SD} = 1 \text{ V}$  &  $V_{SG} = 0 \text{ V}$ , assume saturation. Per (10.72),

$$100 \times 10^{-6} = \frac{0.12 \times 10^{-3}}{2} (16)(0 + V_T)^2 \Rightarrow \underline{V_T = 0.3227486 \text{ V}}.$$

b) Per (10.74),  $V_{SD}(\text{sat}) = V_{SG} + V_T = 0.4 + 0.32275 = 0.72275 \text{ V}$

Here,  $V_{SD} = 1.5 \text{ V} > V_{DS}(\text{sat}) = 0.723 \text{ V}$  &  $V_{SG} = 0.4 \text{ V} > V_T = 0.323 \text{ V}$

⇒ **saturation**

$$I_D = \frac{0.12 \text{ mA/V}^2}{2} (16)(0.4 + 0.3227486)^2 \Rightarrow \underline{I_D = 0.51478 \text{ mA} = 514.8 \mu\text{A}}.$$

c) Per (10.74),  $V_{SD}(\text{sat}) = V_{SG} + V_T = 0.6 + 0.32275 = 0.92275 \text{ V}$

Here,  $V_{SD} = 0.15 \text{ V} < V_{DS}(\text{sat}) = 0.923 \text{ V}$  &  $V_{SG} = 0.6 \text{ V} > V_T = 0.323 \text{ V}$

⇒ **linear**

$$I_D = \frac{0.12 \text{ mA/V}^2}{2} (16) \left[ 2(0.6 + 0.3227486)0.15 - 0.15^2 \right]$$

$$\Rightarrow \underline{I_D = 0.24415 \text{ mA} = 244.15 \mu\text{A}}.$$