

**Learning Objective: MOSFET Concepts**

**Problem 1.** Consider an p-channel MOSFET with a gate oxide thickness of 10 nm, threshold voltage  $V_{TH} = -0.6$  V, gate width of  $25\text{ }\mu\text{m}$  and gate length of  $1\text{ }\mu\text{m}$ . Assume the hole channel mobility is  $\mu_p = 100\text{ cm}^2/\text{V/s}$  at  $T = 300$  K. Use  $\epsilon_{ox} = 3.9\epsilon_0$ ,  $n_i = 1.5 \times 10^{10}\text{ cm}^{-3}$  if needed.

- Suppose  $V_{GS} = -0.1$  V,  $V_{DS} = -3$  V, determine the **operating region** and **drain-to-source current  $I_{DS}$** .
- Suppose  $V_{GS} = -3$  V,  $V_{DS} = -5$  V, determine the **operating region** and **drain-to-source current  $I_{DS}$** .
- Suppose  $V_{GS} = -5$  V,  $V_{DS} = -0.1$  V, determine the **operating region** and **drain-to-source current  $I_{DS}$** .

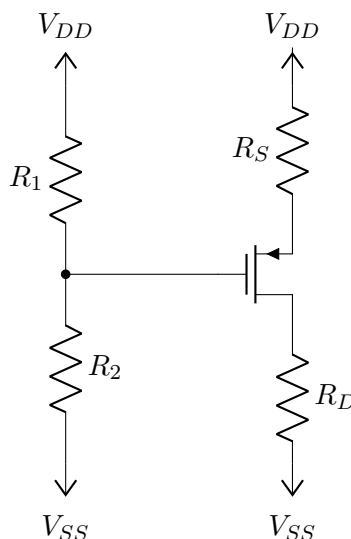
**Problem 2.** An n-channel MOSFET has parameters:  $W = 15\text{ }\mu\text{m}$ ,  $L = 2\text{ }\mu\text{m}$ ,  $C_{ox} = 6.9 \times 10^{-8}\text{ F/cm}^2$ . Use  $\epsilon_{ox} = 3.9\epsilon_0$ ,  $n_i = 1.5 \times 10^{10}\text{ cm}^{-3}$  if needed at 300 K.

- Calculate the **oxide thickness** of the MOSFET.
- Assume the drain current in the saturation region for high  $V_{DS}$  is  $I_{DS} = 35\text{ }\mu\text{A}$  at  $V_{GS} = 2.3$  V and  $I_{DS} = 75\text{ }\mu\text{A}$  at  $V_{GS} = 2.5$  V. Calculate the **electron channel mobility** and **threshold voltage**.
- Assume the drain current in the linear region for low  $V_{DS} = 0.10$  V is  $I_{DS} = 35\text{ }\mu\text{A}$  at  $V_{GS} = 1.5$  V and  $I_{DS} = 75\text{ }\mu\text{A}$  at  $V_{GS} = 2.5$  V. Calculate the **electron channel mobility** and **threshold voltage**.

**Learning Objective: MOSFET DC Biasing**

**Problem 3.** Consider the circuit shown below. The transistor parameters are  $V_{TH} = -0.8$  V and  $K_p = 0.5\text{ mA/V}^2$ . The component values are  $V_{DD} = 3$  V,  $V_{SS} = -3$  V,  $R_1 = 8\text{ k}\Omega$ ,  $R_2 = 22\text{ k}\Omega$ , and  $R_D = 5\text{ k}\Omega$ .

- Calculate  $V_{SG}$ ,  $I_{SD}$ , and  $V_{SD}$  for  $R_S = 0\text{ }\Omega$ .
- Calculate  $V_{SG}$ ,  $I_{SD}$ , and  $V_{SD}$  for  $R_S = 0.5\text{ k}\Omega$ .



**Problem 4.** Consider the circuit shown below. The transistor parameters are  $V_{TH} = 0.4$  V and  $K_n = 0.5$  mA/V<sup>2</sup>. The component values are  $V_{DD} = 5$  V,  $R_1 = 20$  k $\Omega$ ,  $R_2 = 5$  k $\Omega$ ,  $R_D = 2$  k $\Omega$ .

- (a) Calculate  $V_{GS}$ ,  $I_{DS}$ , and  $V_{DS}$  for  $R_S = 0$   $\Omega$ .
- (b) Calculate  $V_{GS}$ ,  $I_{DS}$ , and  $V_{DS}$  for  $R_S = 1$  k $\Omega$ .

