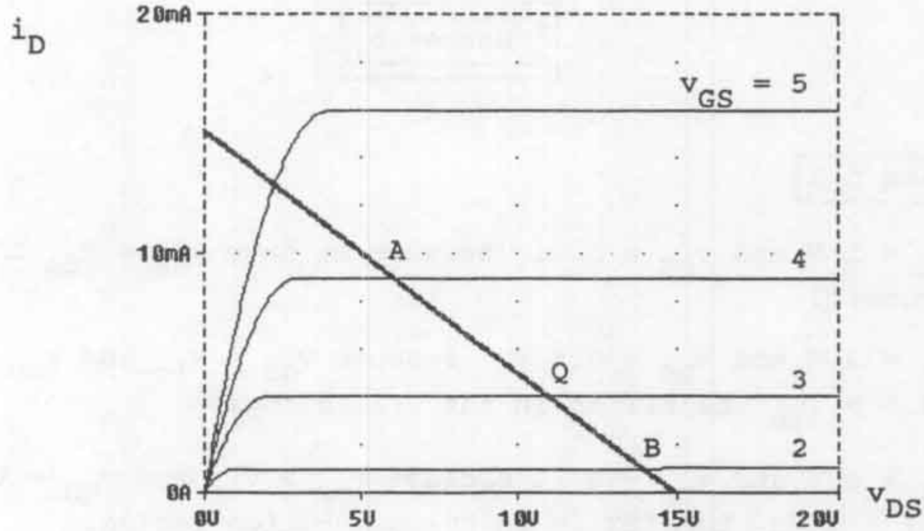
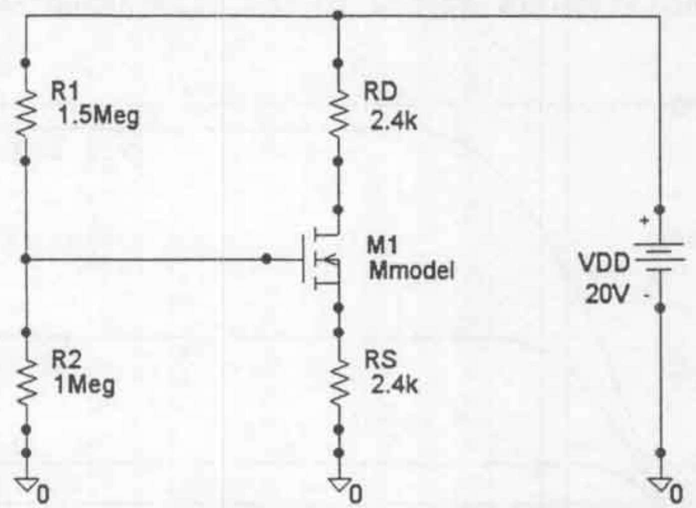
Exercise 5.3

The characteristics and the load line are shown on the next page. The simulation is stored in the file named Exer5_3.



For $v_{in} = +1$ we have $v_{GS} = 4$ and the instantaneous operating point is A. Similarly for $v_{in} = -1$ we have $v_{GS} = 2$ V and the instantaneous operating point is at B. We find $V_{DSQ} \cong 11$ V, $V_{DSmin} \cong 6$ V, $V_{DSmax} \cong 14$ V.

Exercise 5.4



The analysis is similar to Example 5.3 in the book.

$$K = \left(\frac{W}{L}\right)\frac{KP}{2} = 1 \text{ mA/V}^2$$

$$V_G = V_{DD}\frac{R_2}{R_1 + R_2} = 20\ \frac{1}{(1.5 + 1)} = 8\ \text{V}$$

$$V_{GSQ}^2 + \left(\frac{1}{R_S K} - 2V_{to}\right)V_{GSQ} + (V_{to})^2 - \frac{V_G}{R_S K} = 0$$

After values are substituted, we have

$$V_{GSQ}^2 - 3.583V_{GSQ} + 0.6667 = 0$$

Solving we find $V_{GSQ} = 3.39$ V. (The second root is extraneous and should be discarded.) Then we have

$$I_{DQ} = K(V_{GSQ} - V_{to})^2 = 1.92\ \text{mA}$$

$$V_{DSQ} = V_{DD} - (R_D + R_S)I_{DQ} = 10.8\ \text{V}$$

Exercise 5.5

We should choose $R_D = 0$ for a source follower. Many values will work for the other resistors. A reasonable set of values is $R_S = 3.9$ kΩ , $R_1 = 1$ MΩ, and $R_2 = 2$ MΩ. These values yield $I_{DQ} =$ 1.98 mA and $V_{DSQ} = 7.26$ V. Use SPICE to check that your design provides a Q-point close to the desired value.

Problem 5.3

Calculation of the drain currents was omitted. The drain currents are:

(a) $i_D = K(v_{GS} - V_{to})^2 = (W/L)(KP/2)(v_{GS} - V_{to})^2 = 2.25$ mA

(b) $i_D = K[2(v_{GS} - V_{to})v_{DS} - (v_{DS})^2]$

$= (W/L)(KP/2)[2(v_{GS} - V_{to})v_{DS} - (v_{DS})^2]$

$= 2$ mA

(c) $i_D = 0$

Problem 5.3

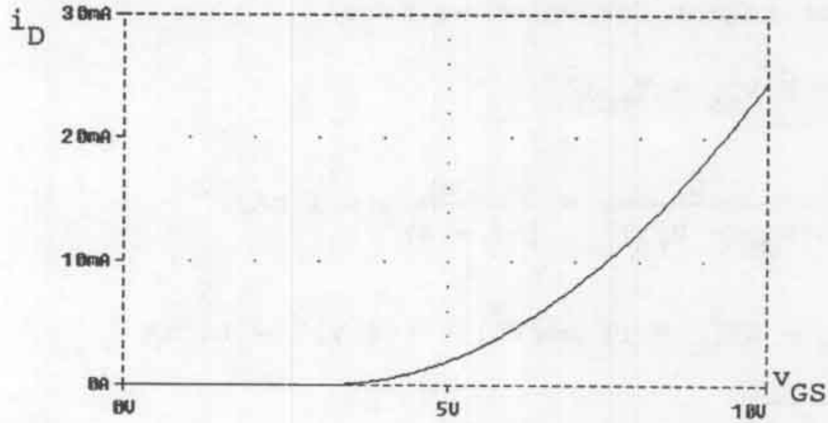
(a) Saturation because we have $v_{GS} \geq V_{to}$ and $v_{DS} \geq v_{GS} - V_{to}$.

(b) Triode because we have $v_{DS} < v_{GS} - V_{to}$ and $v_{GS} \geq V_{to}$.

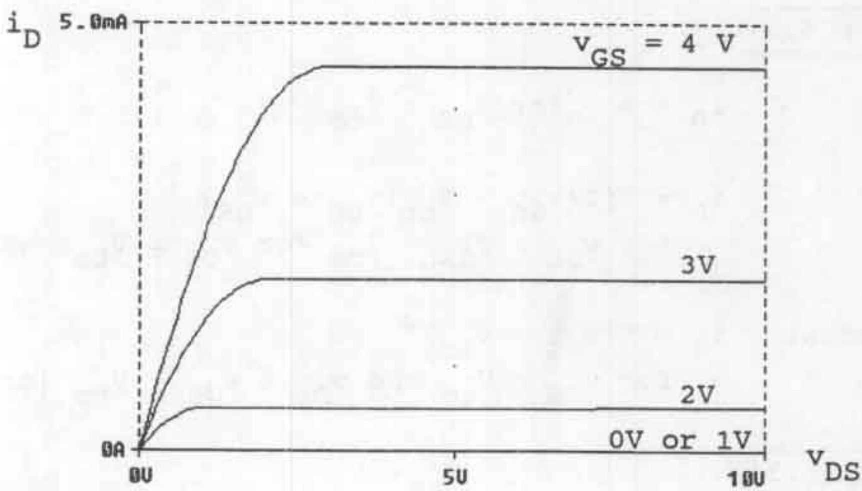
(c) Cutoff because we have $v_{GS} \leq V_{to}$.

Problem 5.4

The device is in saturation for $v_{DS} \geq v_{GS} - V_{to} = 2$ V. The device is in the triode region for $v_{DS} \leq 2$ V. The plot of i_D versus v_{GS} in the saturation region is:



Problem 5.5



Problem 5.6

(a) Cutoff because we have $v_{GS} \leq V_{to}$.

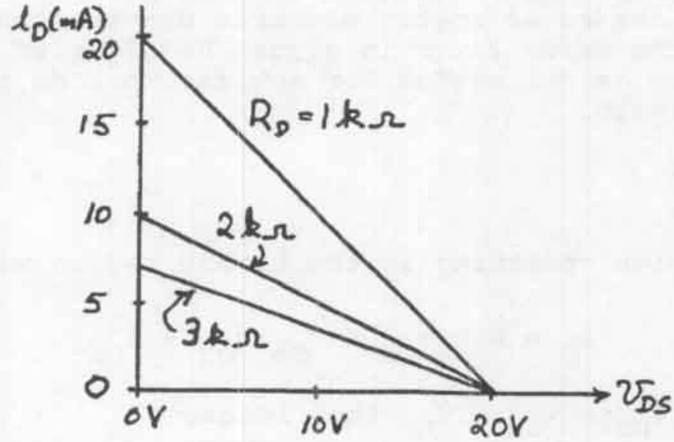
(b) Triode because we have $v_{DS} < v_{GS} - V_{to}$ and $v_{GS} \geq V_{to}$.

(c) Saturation because we have $v_{GS} \geq V_{to}$ and $v_{DS} \geq v_{GS} - V_{to}$.

(d) Saturation because we have $v_{GS} \geq V_{to}$ and $v_{DS} \geq v_{GS} - V_{to}$.

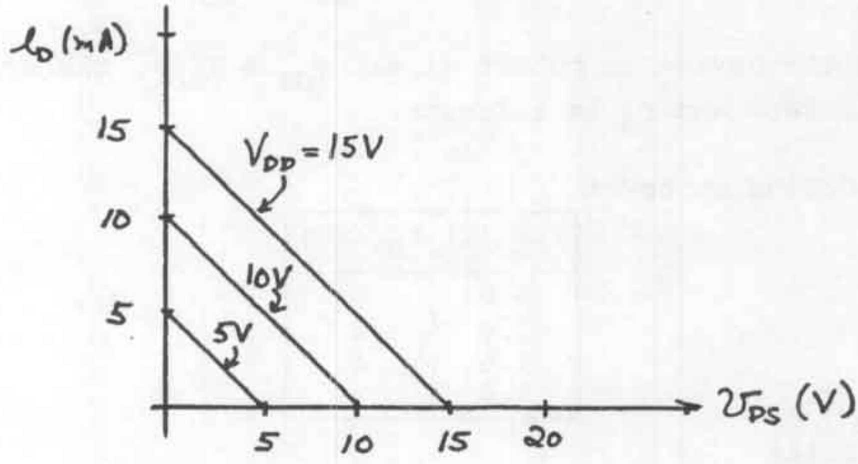
Problem 5.15

The load-line equation is $V_{DD} = R_D i_D + v_{DS}$, and the plots are shown on the next page.



Notice that the load line rotates around the point (V_{DD}, 0) as the resistance changes.

Problem 5.16



Notice that the load lines are parallel as long as R_D is constant.