Exercise 5.6

From Figure 5.24 at an operating point defined by $V_{GSQ} = 2.5$ V and $V_{DSQ} = 6$ V, we have

$$g_m = \frac{\Delta i_D}{\Delta v_{GS}} = \frac{(4.4 - 1.1)\ \text{mA}}{1\ \text{V}} = 3.3\ \text{mS}$$

$$1/r_d = \frac{\Delta i_D}{\Delta v_{DS}} \cong \frac{(2.9 - 2.3)\ \text{mA}}{(14 - 2)\ \text{V}} = 0.05 \times 10^{-3}$$

Taking the reciprocal, we find $r_d = 20\ \text{k}\Omega$

Exercise 5.7

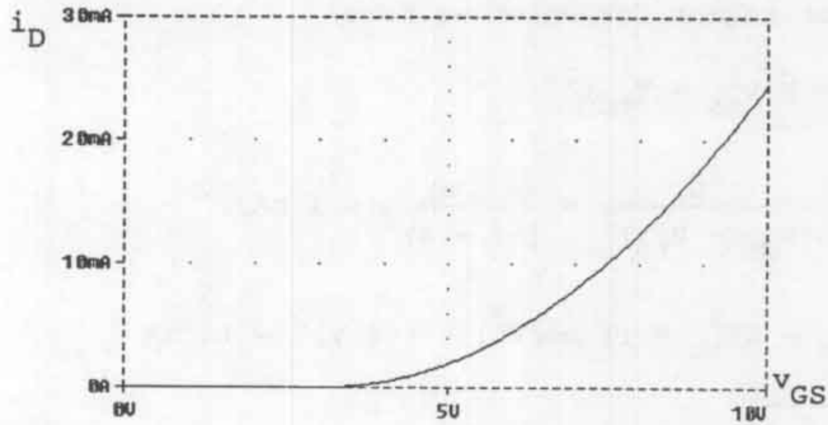
$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{Q\text{-point}}$$

$$= \left.\frac{\partial}{\partial v_{GS}} K(v_{GS} - V_{to})^2\right|_{Q\text{-point}}$$

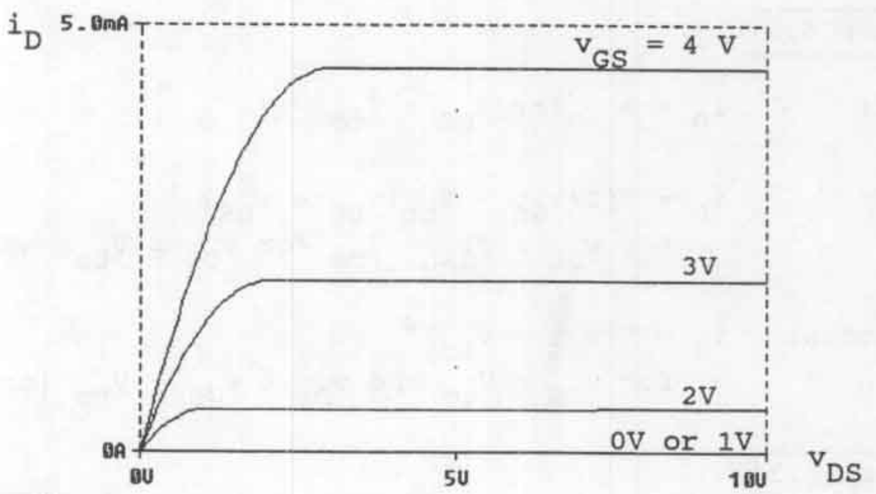
$$= 2K(V_{GSQ} - V_{to})$$

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 $v_{GS} \leq V_{to}$.

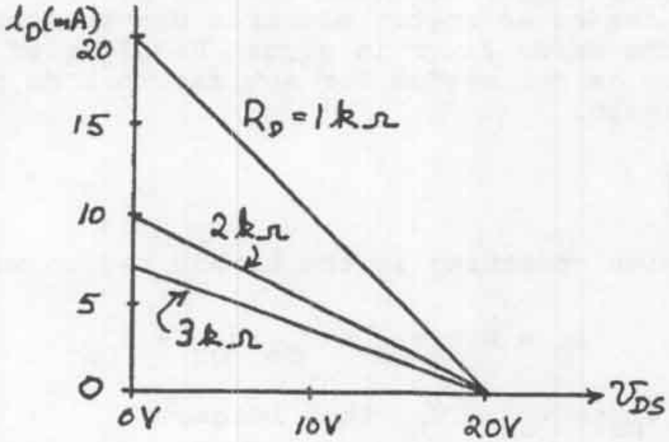
(b) Triode because we have $v_{DS} < v_{GS} - V_{to}$ and $v_{GS} \geq V_{to}$.

(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 $v_{DS} \geq v_{GS} - V_{to}$.

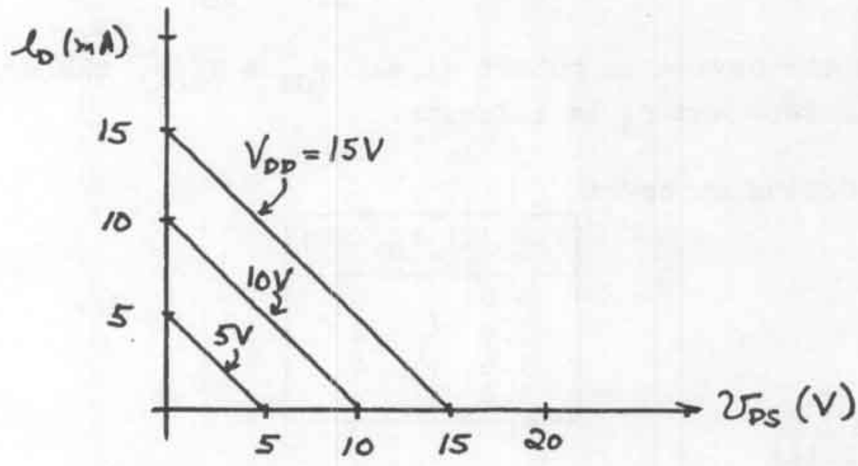
Problem 5.15

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.

Problem 5.22

For this circuit we can write

$$V_{GSQ} = 15 - I_{DQ}R_S$$

Assuming operation in saturation, we have

$$I_{DQ} = K(V_{GSQ} - V_{to})^2$$

using the first equation to substitute into the second equation we have

$$I_{DQ} = K(15 - I_{DQ}R_S - V_{to})^2 = 0.25(14 - 3I_{DQ})^2$$

where we have assumed that I_{DQ} is in mA. Rearranging we have

$$I_{DQ}^2 - 9.777 I_{DQ} + 21.777 = 0$$

The correct root is the smaller one which is $I_{DQ} = 3.432$ mA. Then we have $V_{DSQ} = 30 - R_D I_{DQ} - R_S I_{DQ} = 16.27$ V.

Problem 5.23

Assuming that the MOSFET is in saturation, we have

$$V_{GSQ} = 10 - I_{DQ}$$
$$I_{DQ} = K(V_{GSQ} - V_{to})^2$$

where we have assumed that I_{DQ} and K are in mA and mA/V^2 respectively.

(a) Using the second equation to substitute in the first, substituting values and rearranging, we have

$$V_{GSQ}^2 - 7V_{GSQ} + 6 = 0$$

which yields

$$V_{GSQ} = 6 \text{ V}$$

(The other root, $V_{GSQ} = 1$ V, is extraneous.)

$$I_{DQ} = 4 \text{ mA}$$

$$V_{DSQ} = 10 - 2I_{DQ} = 12 \text{ V}$$

(b) Similarly we have

$$V_{GSQ}^2 - 3.5V_{GSQ} - 1 = 0$$

$$V_{GSQ} = 3.765 \text{ V}$$

$$I_{DQ} = 6.234 \text{ mA}$$
$$V_{DSQ} = 20 - 2I_{DQ} = 7.53$$

Problem 5.27

We have $V_{GSQ} = V_{DSQ} = V_{DD} - R_D I_{DQ}$. Then substituting $I_{DQ} = K(V_{GSQ} - V_{to})^2$, we have

$$V_{GSQ} = V_{DD} - R_D K(V_{GSQ} - V_{to})^2$$

Substituting values and rearranging,we have

$$V_{GSQ}^2 + 2V_{GSQ} - 39 = 0$$

Solving we determine that $V_{GSQ} = 5.325$ V and then we have $I_{DQ} = K(V_{GSQ} - V_{to})^2 = 4.675$ mA.