P12.9 (a) This NMOS transistor is operating in saturation because we have $v_{GS} \geq V_{to}$ and $v_{DS} \geq v_{GS} - V_{to}$. Thus, $I_a = K(v_{GS} - V_{to})^2 = 1.8$ mA.

(b) This PMOS transistor is operating in saturation because we have $v_{GS} \leq V_{to}$ and $v_{DS} = -4 \leq v_{GS} - V_{to} = -3 - (-1) = -2$. Thus, $I_b = K(v_{GS} - V_{to})^2 = 0.8$ mA.

(c) This PMOS transistor is operating in the triode region because we have $v_{GS} \leq V_{to}$ and $v_{DS} = -1 \geq v_{GS} - V_{to} = -5 - (-1) = -4$. Thus, $I_c = K[2(v_{GS} - V_{to})v_{DS} - v_{DS}^2] = 1.4$ mA.

(d) This NMOS transistor is operating in the triode region because we have $v_{GS} \geq V_{to}$ and $v_{DS} = 1 \leq v_{GS} - V_{to} = 3 - 1 = 2$. Thus, $I_d = K[2(v_{GS} - V_{to})v_{DS} - v_{DS}^2] = 0.6$ mA.

P12.13

$i_D = k(V_{GS} - V_{t0})^2$

$0.8 = 0.2(V_{GS} + 1)^2$

$V_{GS} = 1$ V

P12.31* We can write $V_{DD} = V_{DSQ} + R_S I_{DQ}$. Substituting values and solving, we obtain $R_S = 3\ \text{k}\Omega$. Next we have $K = \frac{1}{2}KP(W/L) = 2\ \text{mA/V}^2$. Assuming that the NMOS operates in saturation, we have

Substituting values and solving, we find $V_{GSQ} = 0$ V and $V_{GSQ} = 2$ V. The correct root is $V_{GSQ} = 2$ V. (As a check we see that the device does operate in saturation because we have greater than) Then we have $V_G = V_{GSQ} + R_S I_{DQ} = 8$ V. However we also have

Substituting values and solving, we obtain $R_2 = 2\ \text{M}\Omega$.

P12.33 We have $V_G = V_{GSQ} = 5R_2/(R_1 + R_2) = 2.5$ V. Then we have $I_{DQ} = K(V_{GSQ} - V_{to})^2 = 1.28$ mA. $V_{DSQ} = V_{DD} - R_D I_{DQ} = -0.12$ V. For the MOSFET to operate in saturation R_D cannot exceed 2.65 kΩ

P12.53* (a)

$$V_G = V_{DD}\frac{R_2}{R_1+R_2} = 20\frac{0.3}{1.7+0.3} = 3\text{ V}$$

$$V_{GSQ} = V_G = 3\text{ V}$$

$$K = \tfrac{1}{2}KP(W/L) = 2.5\text{ mA/V}^2$$

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

$$V_{DSQ} = V_{DD} - R_D I_{DSQ} = 10\text{ V}$$

$$g_m = 2\sqrt{KI_{DQ}} = 0.01\text{ S}$$

(b)

$$R_L' = \frac{1}{1/R_D + 1/R_L} = 500\ \Omega$$

$$A_v = -g_m R_L' = -5$$

$$R_{in} = \frac{1}{1/R_1 + 1/R_2} = 255\text{ k}\Omega$$

$$R_o = R_D = 1\text{ k}\Omega$$

P12.62