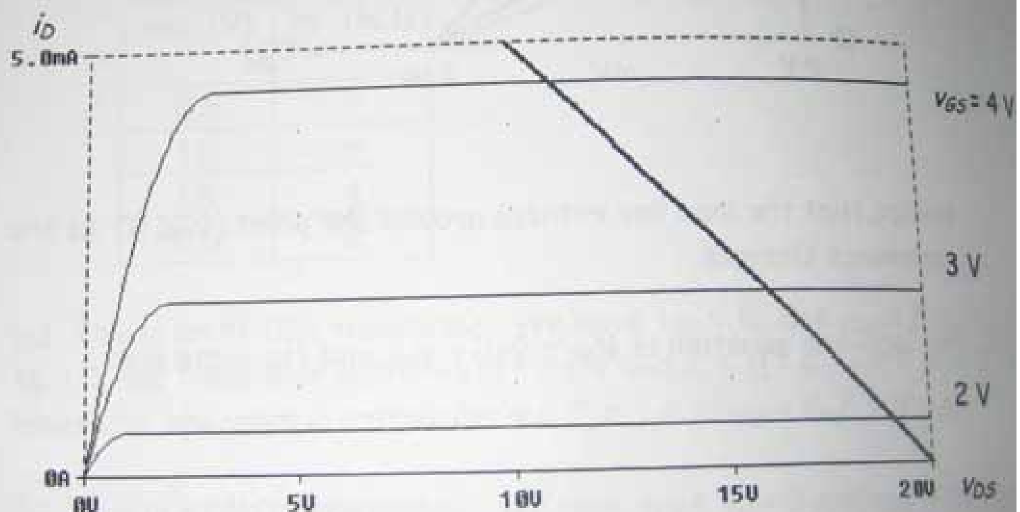
P12.20 (a) The 1.7 MΩ and 300 kΩ resistors act as a voltage divider that establishes a dc voltage $V_{GSQ} = 3$ V. Then if the capacitor is treated as a short for the ac signal, we have

$$v_{GS}(t) = 3 + \sin(2000\pi t)$$

(b), (c), and (d)



P12.26* 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 and substituting values, we have

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

P12.31 We have $V_G = V_{GSQ} = 10R_2/(R_1 + R_2) = 2.5$ V. Then we have $I_{DQ} = K(V_{GSQ} - V_{to})^2 = 0.5625$ mA. $V_{DSQ} = V_{DD} - R_DI_{DQ} = 4.375$ V.

P12.39

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{Q\text{-point}} = 9v_{GS}^2\Big|_{Q\text{-point}} = 9\text{ mS}$$

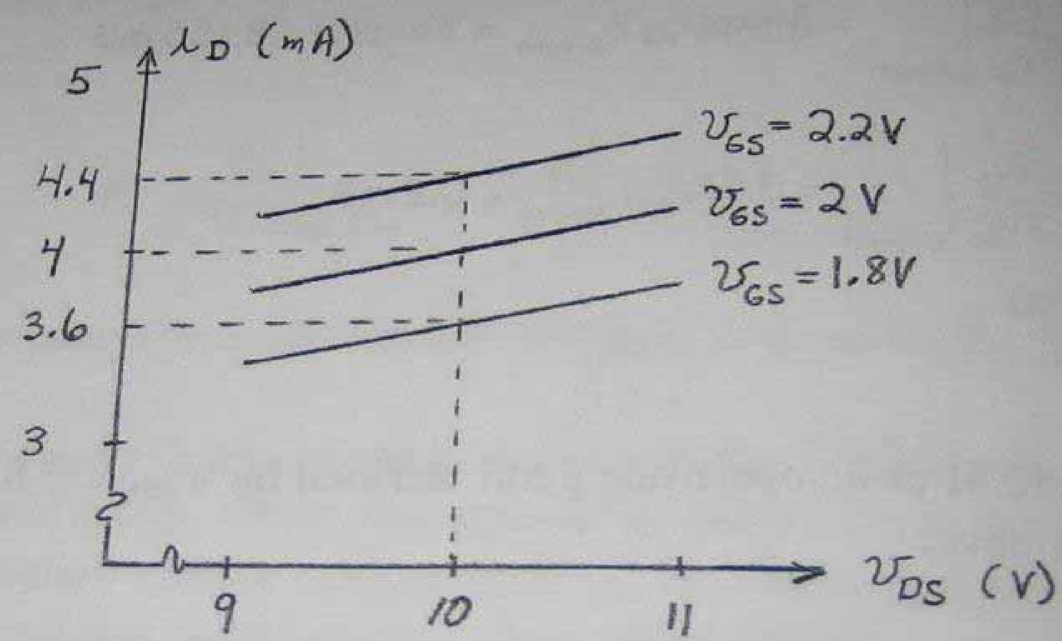
$$1/r_d = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{Q\text{-point}} = 0.1\Big|_{Q\text{-point}} = 0.1\text{ mS}$$

$$r_d = 10\text{ k}\Omega$$

P12.42 We will sketch the characteristics for v_{GS} ranging a few tenths of a volt on either side of the Q point. g_m determines the spacing between the charactersistic curves. For $g_m = 2$ mS, the curves move upward by 0.2 mA for each 0.1 V increase in v_{GS}.

Also, we will sketch the characteristics for v_{DS} ranging a few volts on either side of the Q point. r_d determines the slope of the charactersistic curves. For $r_d = 5$ kΩ, the curves slope upward by 0.2 mA for each 1 V increase in v_{DS}.

The sketch of the curves is:



P12.45* (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)

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

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

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

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

P12.50 If we need a voltage-gain magnitude greater than unity, we choose a common-source amplifier. To attain lowest output impedance usually a source follower is better.

P12.51* We have

$$K = \left(\frac{W}{L}\right)\frac{KP}{2} = 400\ \mu A/V^2$$

Assuming operation in saturation, we have

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

Solving for V_{GSQ} and evaluating we have

$$V_{GSQ} = V_{to} + \sqrt{I_{DQ}/K} = 3.236\ V$$

$$V_G = V_{DD}\frac{R_2}{R_1 + R_2} = 10\ V$$

$$V_G = V_{GSQ} + R_S I_{DQ}$$

Solving for R_S and substituting values we have

$$R_S = (V_G - V_{GSQ})/I_{DQ} = 3.382\ k\Omega$$

We have $g_m = 2\sqrt{KI_{DQ}} = 1.789\ mS$

$$R_L' = \frac{1}{1/R_L + 1/R_S + 1/r_d} = 1.257\ k\Omega$$

$$A_v = \frac{v_o}{v_{in}} = \frac{g_m R_L'}{1 + g_m R_L'} = 0.6922$$

$$R_{in} = \frac{v_{in}}{i_{in}} = R_G = R_1 \| R_2 = 666.7\ \text{k}\Omega$$

$$R_o = \frac{1}{g_m + \frac{1}{R_s} + \frac{1}{r_d}} = 386.9\ \Omega$$

P12.52 (a) We start by assuming that the MOSFET is operating in the saturation region, so we have

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

Also, we have $K = \frac{1}{2}KP(W/L) = 1.5\text{ mA/V}^2$

For a dc Q-point analysis, the capacitors behave as open circuits. Writing a voltage equation from the gate through R_s and back to ground through the V_{SS} source, we obtain

$$V_{GSQ} + R_s I_{DQ} = V_{SS}$$

Substituting for I_{DQ} we have

$$V_{GSQ} + R_s K(V_{GSQ} - V_{to})^2 = V_{SS}$$

Then substituting numerical values, we have

$$V_{GSQ} + 4.5(V_{GSQ} - 1)^2 = 15$$

Solving, we obtain V_{GSQ} = 2.656 V (The other root is extraneous.) Then we have

$$I_{DQ} = K(V_{GSQ} - V_{to})^2 = 4.114\text{ mA}$$

$$V_{DSQ} = 30 - I_{DSQ}(R_S + R_D) = 5.316\text{ V}$$

Since V_{DSQ} is higher than V_{GSQ} - V_{to} the assumption that the device operates in the saturation region is valid.

$$g_m = 2\sqrt{KI_{DQ}} = 4.968\text{ mS}$$

(b) Using the results from Exercise 12.13, we have

$$R'_L = R_D \| R_L = 2.308\text{ k}\Omega$$

$$A_v = v_o / v_{in} = R'_L g_m = 11.465$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{1}{g_m + 1/R_s} = 188.6\ \Omega$$