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

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

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

---

For this circuit, we can write

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

Assuming operation in saturation, we have

$$I_{DQ} = K(V_{GSO} - V_N)^2$$

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

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

where we have assumed that $I_{DQ}$ is in mA. Rearranging and substituting values, we have

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

P12.31 We have $V_C = V_{GSO} = 10R_2/(R_1 + R_2) = 2.5$ V. Then we have $I_{DQ} = K(V_{GSO} - V_N)^2 = 0.5625$ mA. $V_{DQ} = V_{DO} - R_D I_{DQ} = 4.375$ V.
P12.39

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

\[ \frac{1}{r_d} = \left. \frac{\partial i_D}{\partial v_{DS}} \right|_{Q\text{-point}} = 0.1 \mid_{Q\text{-point}} = 0.1 \text{ mS} \]

\[ r_d = 10 \text{ k}\Omega \]

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 characteristic curves. For \( g_m = 2 \text{ mS} \), 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 characteristic curves. For \( r_d = 5 \text{ k}\Omega \), the curves slope upward by 0.2 mA for each 1 V increase in \( v_{DS} \).

The sketch of the curves is:

![Graph showing characteristic curves with \( v_{GS} \) ranging from 1.8V to 2.2V and \( v_{DS} \) ranging from 9V to 11V.]
\( V_{\text{g}} = V_{\text{DD}} \frac{R_2}{R_1 + R_2} = 20 \frac{0.3}{1.7 + 0.3} = 3 \text{ V} \)

\( V_{\text{gsq}} = V_{\text{g}} = 3 \text{ V} \)

\( K = \frac{1}{2} K_P (W/L) = 2.5 \text{ mA/V}^2 \)

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

\( V_{\text{dsq}} = V_{\text{DD}} - R_D I_{\text{Dsq}} = 10 \text{ V} \)

\( g_m = 2\sqrt{K I_{\text{DQ}}} = 0.01 \text{ S} \)

\( R'_{\text{L}} = \frac{1}{1/R_D + 1/R_L} = 500 \Omega \)

\( A_i = -g_m R'_{\text{L}} = -5 \)

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

\( R_o = R_D = 1 \text{ k\Omega} \)

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
tsourcet follower is better.
*P12.51* We have

\[ K = \left( \frac{W}{L} \right) \frac{K^p}{2} = 400 \, \mu A/V^2 \]

Assuming operation in saturation, we have

\[ I_{DQ} = K(V_{GSQ} - V_{to})^2 \]

Solving for \( V_{GSQ} \) and evaluating we have

\[ V_{GSQ} = V_{to} + \sqrt{I_{DQ}/K} = 3.236 \, V \]

\[ V_{G} = V_{DD} \frac{R_2}{R_1 + R_2} = 10 \, V \]

\[ V_{G} = V_{GSQ} + R_3I_{DQ} \]

Solving for \( R_3 \) and substituting values we have

\[ R_3 = (V_{G} - V_{GSQ})/I_{DQ} = 3.382 \, \text{k}\Omega \]

We have \( g_m = 2 \sqrt{K I_{DQ}} = 1.789 \, \text{mS} \)

\[ R'_{L} = \frac{1}{1/R_L + 1/R_3 + 1/r_d} = 1.257 \, \text{k}\Omega \]

\[ A = \frac{V_o}{V_{in}} = \frac{g_m R'_L}{1 + g_m R'_L} = 0.6922 \]
\[ R_{in} = \frac{V_{in}}{i_{in}} = R_6 = R_1 \parallel R_2 = 666.7 \text{ k}\Omega \]

\[ R_o = \frac{1}{g_m + \frac{1}{R_s} + \frac{1}{r_d}} = 386.9 \text{ \Omega} \]
(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 \( V_{GSQ} = 2.656 \text{ V} \) (The other root is extraneous.) Then we have
\[ I_{DQ} = K(V_{GSQ} - V_{to})^2 = 4.114 \text{ mA} \]
\[ V_{DSQ} = 30 - I_{DQ} (R_s + R_D) = 5.316 \text{ V} \]
Since \( V_{DSQ} \) is higher than \( V_{GSQ} - V_{to} \) the assumption that the device operates in the saturation region is valid.
\[ g_m = 2\sqrt{K I_{DQ}} = 4.968 \text{ mS} \]

(b) Using the results from Exercise 12.13, we have
\[ R'_L = R_D || R_L = 2.308 \text{ k}\Omega \]
\[ A_v = \frac{v_o}{v_{in}} = R'_L g_m = 11.465 \]
\[ R_{in} = \frac{v_{in}}{i_{in}} = \frac{1}{g_m + 1/R_s} = 188.6 \text{ \Omega} \]