1. The parameters of the circuit shown in Figure Q1 are $V_{DD} = 5$ V, $R_1 = 520$ kΩ, $R_2 = 320$ kΩ, $R_D = 10$ kΩ, and $R_{Si} = 0$. Assume transistor parameters of $V_{TN} = 0.8$ V, $K_n = 0.20$ mA/V^2, and $\lambda = 0$.
   (a) Determine the small-signal parameters g_m and r_o.
   (b) Find the small-signal voltage gain v_o/v_i.
   (c) Calculate the input and output resistances R_i and R_o.

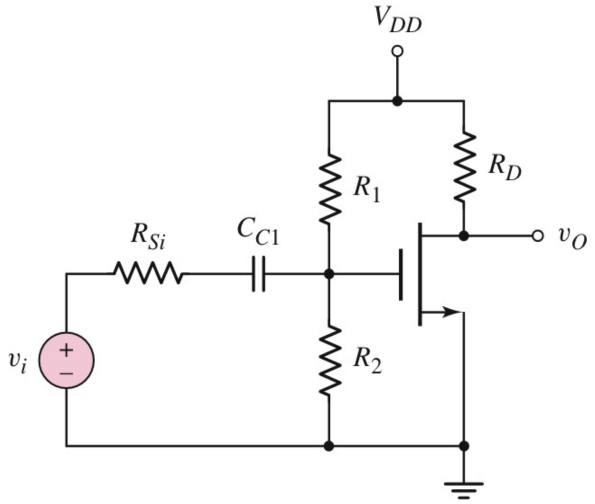

Figure Q1

Solution:

(a) $$V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right) V_{DD} = \left(\frac{320}{520 + 320}\right)(5) = 1.905 \text{ V}$$

$$I_{DQ} = 0.20(1.905 - 0.8)^2 = 0.244 \text{ mA}$$

$$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(0.2)(0.244)} = 0.442 \text{ mA/V}$$

$$r_o = \infty$$

(b) $$A_v = -g_m R_D = -(0.422)(10) = -4.22$$

(c) $$R_i = R_1 \,||\, R_2 = 520 \,||\, 320 = 198 \text{ K}$$

(d) $$R_O = R_D = 10 \text{ K}$$

2. Consider the circuit shown in Figure Q1. Assume transistor parameters of $V_{TN} = 0.8$ V, $K_n = 0.20$ mA/V^2, and $\lambda = 0$. Let $V_{DD} = 5$ V, $R_i = R_1 \,||\, R_2 = 200$ kΩ, and $R_{Si} = 0$. Determine R_D, R_1, and R_2 such that $I_{DQ} = 0.5$ mA and the Q-point is in the center of the saturation region. Find the small-signal gain v_o/v_i.

Solution:

At transition point, $I_D = 1$ mA

$$I_D = K_n(V_{GSt} - V_{TN})^2 = K_n(V_{DS}(\text{sat}))^2$$

$$1 = 0.2(V_{DS}(\text{sat}))^2 \Rightarrow V_{DS}(\text{sat}) = 2.236 \text{ V}$$

Want $V_{DSQ} = \dfrac{5-2.236}{2} + 2.236 = 3.62$ V

$$R_D = \frac{5-3.62}{0.5} = 2.76 \text{ K}$$

$$0.5 = 0.2(V_{GSQ} - 0.8)^2 \Rightarrow V_{GSQ} = 2.38 \text{ V}$$

$$V_{GSQ} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} = \frac{1}{R_1}(R_1 \parallel R_2)V_{DD}$$

So $2.38 = \dfrac{1}{R_1}(200)(5) \Rightarrow R_1 = 420$ K and $R_2 = 382$ K

$$A_v = -g_m R_D$$

$$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(0.2)(0.5)} = 0.6325 \text{ mA/V}$$

$$A_v = -(0.6325)(2.76)$$

$$= -1.75$$

3. The parameters for the transistor in the circuit shown in Figure Q3 are $V_{TN} = 0.6$ V, $K_n = 0.5$ mA/V^2, and $\lambda = 0$. (a) Determine the quiescent values of I_{DQ} and V_{DSQ} ,(b) Find the small-signal voltage gain v_o/v_i.

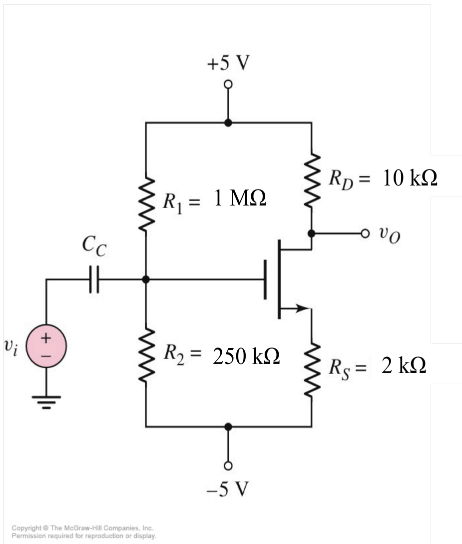

Figure Q3

Solution:

(a)

$$V_G = \left(\frac{R_2}{R_1 + R_2}\right)(10) - 5 = \left(\frac{250}{250 + 1000}\right)(10) - 5 = -3 \text{ V}$$

$$I_D = \frac{(V_G - V_{GS}) - (-5)}{2} = K_n (V_{GS} - V_{TN})^2$$

$$-3 - V_{GS} + 5 = 2(0.5)(V_{GS} - 0.6)^2$$

$$2 - V_{GS} = V_{GS}^2 - 1.2V_{GS} + 0.36$$

$$V_{GS}^2 - 0.2V_{GS} - 1.64 = 0$$

$$V_{GS} = \frac{0.2 \pm \sqrt{(0.04) + 4(1.64)}}{2} = 1.385 \text{ V}$$

$$I_{DQ} = (0.5)(1.385 - 0.6)^2 \Rightarrow I_{DQ} = 0.308 \text{ mA}$$

$$V_{DSQ} = 10 - (0.308)(10 + 2) \Rightarrow V_{DSQ} = 6.30 \text{ V}$$

(b)

$$A_v = \frac{-g_m R_D}{1 + g_m R_S} \qquad g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{(0.5)(0.308)}$$

$$g_m = 0.7849 \text{ mA/V}$$

$$A_v = \frac{-(0.7849)(10)}{1 + (0.7849)(2)} \Rightarrow \underline{A_v = -3.05}$$