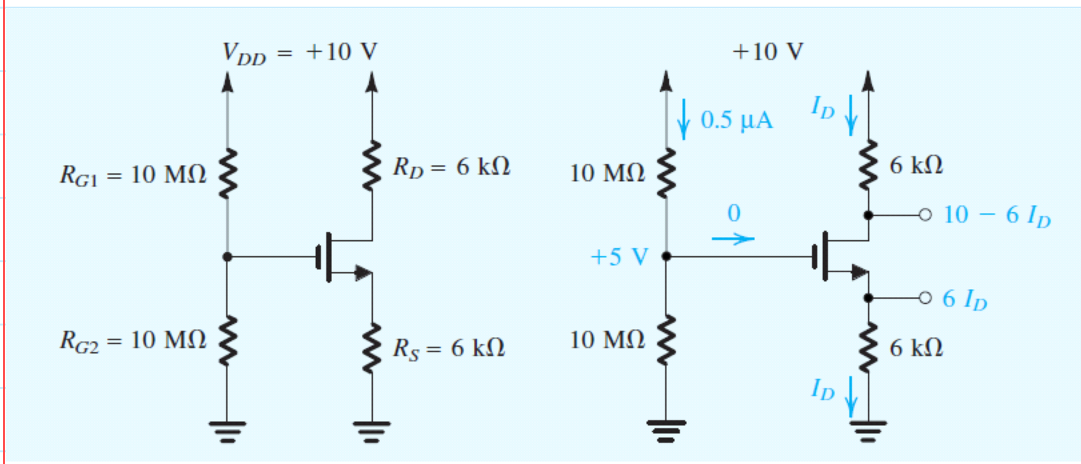
Q1

5.12 For the circuit of Fig. 5.24, what is the largest value that R_D can have while the transistor remains in the saturation mode?

Ans. 12 kΩ

Let $V_{tn} = 1$ V and $k_n'(W/L) = 1$ mA/V^2.



Hint: See the similar example, solved in the class.

In saturation $V_{DS} > V_{ov} = V_{GS} - V_T$ & $I_D = \frac{1}{2} k_n V_{ov}^2$

$V_G = \frac{10}{20M} \cdot 10M = 5V$ and $V_S = 0 + I_D \cdot 6k$

$$I_D = \frac{1}{2} k_n V_{ov}^2 = \frac{1}{2} \cdot 1m \cdot (V_G - V_S - V_T)$$

$$= \frac{1}{2} 1m (5 - I_D \cdot 6k - 1) = I_D \Rightarrow 2m = 4 I_D \Rightarrow I_D = \frac{1}{2} mA$$

For saturation

$$V_{DS} > V_{ov} \Rightarrow V_{DS} > V_G - V_S - V_T = 5 - \overbrace{6k \cdot \frac{1m}{2}}^{V_S = 3V} - 1 = 1V$$

$$V_D - V_S > 1V \Rightarrow V_D - 3V > 1V \Rightarrow V_D > 4V$$

$$V_D = 10 - R_D \cdot I_D > 4 \Rightarrow 6 > R_D \cdot \frac{1}{2} m \Rightarrow \boxed{12k\Omega > R_D}$$

Q2

D5.9 For the circuit in Fig. E5.9, find the value of R that results in $V_D = 0.7$ V. The MOSFET has $V_{tn} = 0.5$ V, $\mu_n C_{ox} = 0.4$ mA/V^2, $W/L = \frac{0.72\ \mu m}{0.18\ \mu m}$, and $\lambda = 0$.

Ans. 34.4 kΩ

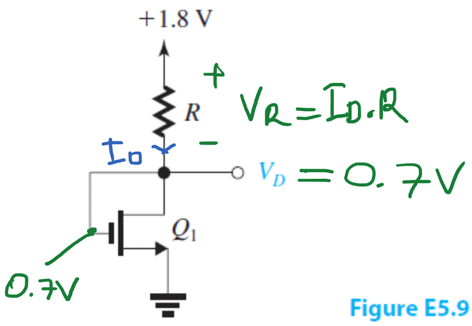


Figure E5.9

$$k_n = \mu_n C_{ox} \frac{W}{L} = 0.4m \cdot 4 = 1.6 \frac{mA}{V^2}$$

$$V_{DS} = 0.7V > V_{OV} = V_{GS} - V_T = 0.7 - 0.5 = 0.2$$

NMOS operates in saturation

$$I_D = \frac{1}{2} k_n V_{OV}^2 = \frac{1}{2} \cdot (1.6m) \cdot (0.2)^2 = 0.032 mA = 32 \mu A$$

$$V_D = 1.8 - I_D \cdot R \Rightarrow 0.7 = 1.8 - 32\mu R$$

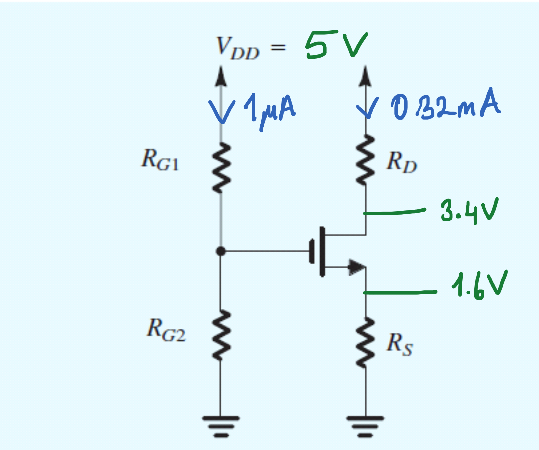
$$\boxed{R = \frac{1.1}{32\mu} \cong 34 k\Omega}$$

Q3

D5.13 Redesign the circuit of Fig. 5.24 for the following requirements: $V_{DD} = +5$ V, $I_D = 0.32$ mA, $V_S = 1.6$ V, $V_D = 3.4$ V, with a 1-μA current through the voltage divider R_{G1}, R_{G2}. Assume the same MOSFET as in Example 5.6.

Ans. $R_{G1} = 1.6\ \text{M}\Omega$; $R_{G2} = 3.4\ \text{M}\Omega$, $R_S = R_D = 5\ \text{k}\Omega$

Let $V_{tn} = 1$ V and $k_n'(W/L) = 1\ \text{mA/V}^2$.



Assume saturation $I_D = \frac{1}{2} k_n V_{ov}^2$ & $V_{DS} > V_{ov} > 0$

$0.32m = \frac{1}{2} \cdot 1m \cdot V_{ov}^2 \Rightarrow V_{ov} = \pm 0.8 \Rightarrow V_{ov} = 0.8$

$V_{DS} = V_D - V_S = 3.4 - 1.6 = 1.8V > V_{ov} = 0.8V$ ✓

saturation

$V_{ov} = 0.8 = V_{GS} - V_T = V_G - 1.6 - 1 \Rightarrow \boxed{V_G = 3.4V}$

$$\boxed{R_D = \frac{5 - 3.4}{0.32m} = \frac{1.6}{0.32m} = 5k\Omega}$$

$$\boxed{R_S = \frac{1.6 - 0}{0.32m} = \frac{1.6}{0.32m} = 5k\Omega}$$

$$V_G = 3.4 = \frac{5}{R_{G1} + R_{G2}} \cdot R_{G2}$$

$\boxed{10^6 = \text{Mega}}$

Given that $\frac{5}{R_{G1} + R_{G2}} = 1\mu A \Rightarrow 3.4 = 1\mu \cdot R_{G2} \Rightarrow \boxed{R_{G2} = 3.4M\Omega}$

$5M = R_{G1} + R_{G2} = R_{G1} + 3.4M \Rightarrow \boxed{R_{G1} = 1.6M\Omega}$