ECE 3457 HW 1

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Due: Thursday, September 25, 2025
(i) Use this sheet as cover sheet
(ii) Turn in via Turnitin or dropbox
(iii) 10 points for each problem, total 80 points

The following questions refer to Sedra Smith **7th ed.**

$50E{-}6 = \frac{1}{2}(1.6E{-}3)(V_{GS} - 0.5)^2$
$V_{GS} = 0.25$ or $\boxed{0.75 [V]}$
$V_{DS} = V_{GS} - V_{Tn} = 0.75 - 0.5 = 0.25 [V]$

1 Sedra and Smith Text **5.18**

$200E{-}6 = \frac{1}{2}(1.6E{-}3)(V_{GS} - 0.5)^2$
$V_{GS} = 0$ or $\boxed{1 [V]}$
$V_{DS} = V_{GS} - V_{Tn} = 1 - 0.5 = 0.50 [V]$

5.18 A particular MOSFET for which $V_{tn} = 0.5$ V and $k_n'(W/L) = 1.6$ mA/V^2 is to be operated in the saturation region. If i_D is to be 50 μA, find the required v_{GS} and the minimum required v_{DS}. Repeat for $i_D = 200$ μA.

2 Sedra and Smith Text **5.27**

$V_t = 1 [V]$ $V_{OV} = V_{GS} - V_{tn}$

Case	V_S	V_G	V_D	V_{GS}	V_{OV}	V_{DS}	Region of operation
	Voltage (V)						
a	+1.0	+1.0	+2.0	0	-1	1	Cutoff
b	+1.0	+2.5	+2.0	1.5	0.5	1	Saturation
c	+1.0	+2.5	+1.5	1.5	0.5	0.5	Saturation
d	+1.0	+1.5 swap	0	1.5	0.5	1	Saturation
e	0	+2.5	+1.0	2.5	1.5	1	Triode
f	+1.0	+1.0	+1.0	0	-1	0	Cutoff
g	−1.0	0	0	1	0	1	Saturation
h	−1.5	0	0	1.5	0.5	1.5	Saturation
i	−1.0	0	+1.0	1	0	2	Saturation
j	+0.5	+2.0	+0.5	1.5	0.5	0	Triode

***5.27** The table above lists 10 different cases labeled (a) to (j) for operating an NMOS transistor with $V_t = 1$ V. In each case the voltages at the source, gate, and drain (relative to the circuit ground) are specified. You are required to complete the table entries. Note that if you encounter a case for which v_{DS} is negative, you should exchange the drain and source before solving the problem. You can do this because the MOSFET is a symmetric device.

3 Sedra and Smith Text **5.49**

D 5.49 The PMOS transistor in the circuit of Fig. P5.49 has $V_t = -0.5$ V, $\mu_p C_{ox} = 100\ \mu\text{A/V}^2$, $L = 0.18\ \mu\text{m}$, and $\lambda = 0$. Find the values required for W and R in order to establish a drain current of 180 μA and a voltage V_D of 1 V.

$$I_{SD} = \frac{1}{2} \cdot (100E-6) \frac{W}{0.18E-6} (V_{SG} - 0.5)^2$$

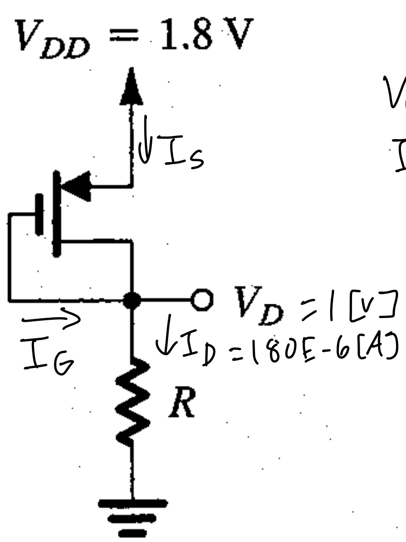


Figure P5.49

$V_G = V_D$

$I_G = 0$ [A]

$V_{GS} = 1 - 1.8 = -0.8$ [V]

$V_{GD} = 0$ [V]

Saturation Region

$$R = \frac{1\,[V]}{180E-6\,[A]} = 5555.56\,[\Omega]$$

$$V_{SG} = 1.8 - 1 = 0.8$$

$$180E-6 = \frac{1}{2} \cdot (100E-6) \frac{W}{0.18E-6} (0.8 - 0.5)^2$$

$R = 5555.56$ [Ω]

$W = 7$ [μm]

D 5.50 The NMOS transistors in the circuit of Fig. P5.50 have $V_t = 0.5$ V, $\mu_n C_{ox} = 250\ \mu\text{A/V}^2$, $\lambda = 0$, and $L_1 = L_2 = 0.25\ \mu\text{m}$. Find the required values of gate width for each of Q_1 and Q_2, and the value of R, to obtain the voltage and current values indicated. We assume current at gate is zero

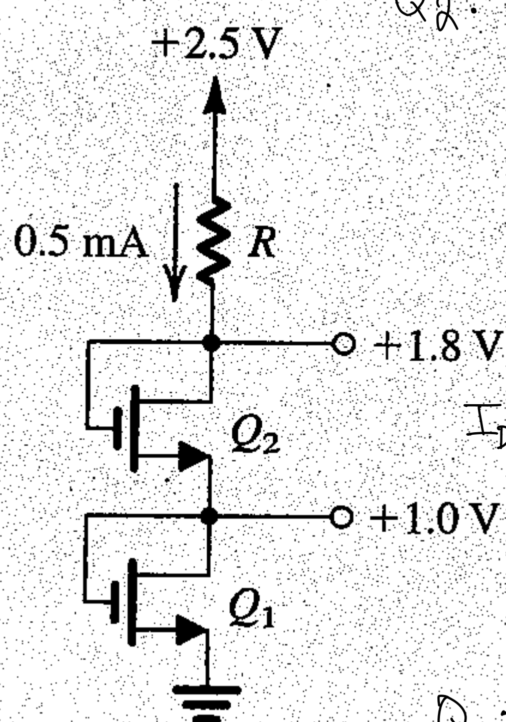


Figure P5.50

Q_2: $V_{GS} = 1.8 - 1 = 0.8\,[V]$

$$R = \frac{2.5 - 1.8}{0.5E-3} = 1400\,[\Omega]$$

$V_{DS} = 1.8 - 1 = 0.8\,[V]$ Saturation Region

$V_{GS} > V_t$, $V_{DS} > 0.8 - 0.5$

$$I_D = 0.5\,[mA] = \frac{1}{2} \cdot 250E-6 \cdot \frac{W}{0.25E-6} \cdot (0.8 - 0.5)^2$$

Q_2_W = 11.1 [μm]

Q_1: $V_{GS} = 1 - 0 = 1\,[V]$

$V_{DS} = 1 - 0 = 1\,[V]$

$V_{GS} - V_t = 1 - 0.5 = 0.5\,[V]$

$V_{DS} > V_{GS} - V_t \longrightarrow$ Saturation

$$I_D = 0.5\,[mA] = \frac{1}{2} \cdot 250E-6 \cdot \frac{W}{0.25E-6} \cdot (0.5)^2$$

Q_1_W = 4 [μm]

5 Sedra and Smith Text **5.53**

Example 5.6 *continued*

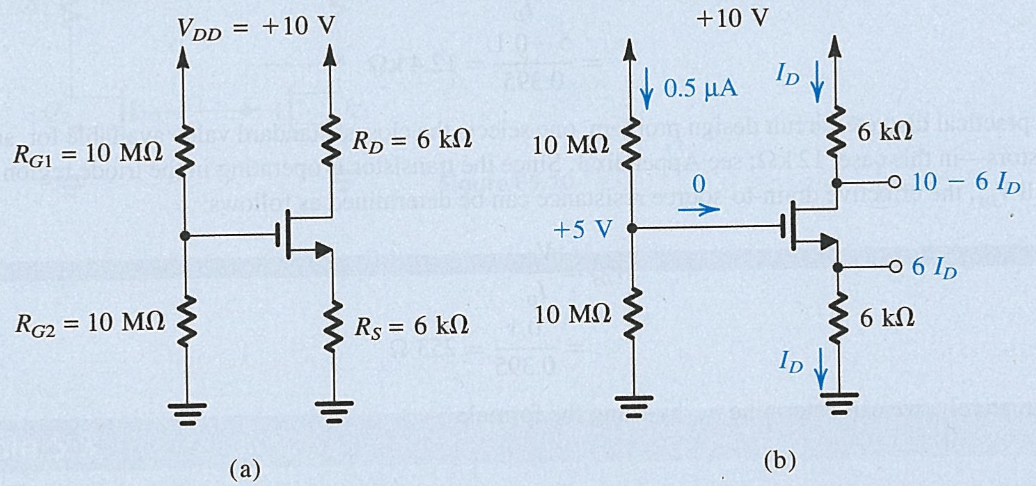
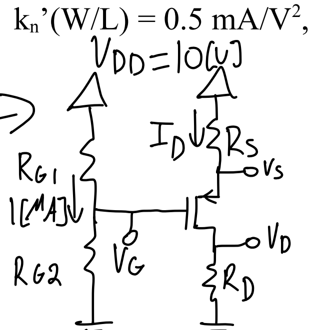


Figure 5.24 **(a)** Circuit for Example 5.6. **(b)** The circuit with some of the analysis details shown.

D 5.53 Using a PMOS transistor with $V_t = -1.5$ V, $k_p'(W/L) = 4$ mA/V^2, and $\lambda = 0$, design a circuit that resembles that in Fig. 5.24(a). Using a 10-V supply, design for a gate voltage of +6 V, a drain current of 0.5 mA, and a drain voltage of +5 V. Find the values of R_S and R_D. Also, find the values of the resistances in the voltage divider feeding the gate, assuming a 1-μA current in the divider.

6 Sedra and Smith Text **5.56**

For each of the circuits in Fig. P5.56, find the labeled node voltages. For all transistors, $k_n'(W/L) = 0.5$ mA/V^2, V_t=0.8V, and λ=0.



$R_{G2} = \dfrac{V_G}{1[MA]} = \dfrac{6}{1E\text{-}6} = 6[M\Omega]$

$R_D = \dfrac{5}{0.5E\text{-}3} = 10[k\Omega]$

$R_{G1} = \dfrac{10[V] - 6[V]}{1E\text{-}6} = 4[M\Omega]$

$-10[V] + (0.5E\text{-}3)R_S + 5[V] = 0 \rightarrow R_S = 10[k\Omega]$

Assume Saturation Region

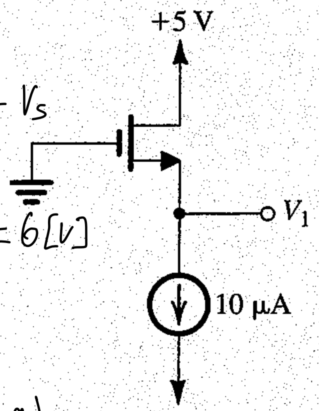
$10[\mu A] = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_{GS} - 0.8)^2 \Big\} V_{GS} = 0.6[V] \text{ or } \boxed{1[V]}$

$V_{GS} = 1[V] = 0 - V_S$

$V_S = -1[V]$

$V_{DS} = 5 - (-1) = 6[V]$

$V_{DS} > V_{ov}$



(a)

a)

Saturation Region

$V_1 = V_S = -1[V]$

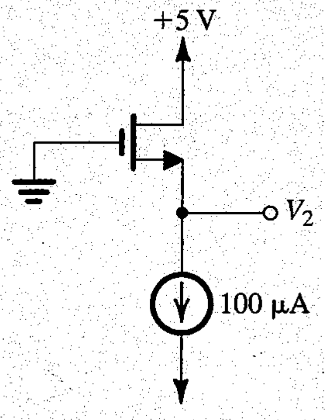
Assume Saturation Region

$100[\mu A] = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_{GS} - 0.8)^2$

$V_{GS} = 0.17[V] \text{ or } \boxed{1.43[V]}$

$V_{GS} = 1.43[V] = 0 - V_S \Big\} V_S = -1.43[V]$

$V_{DS} = 5 - (-1.43) = 6.43[V]$



(b)

b)

Saturation Region

$V_2 = V_S = -1.43[V]$

Assume Saturation Region

$1[mA] = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_{GS} - 0.8)^2$

$V_G = 0$

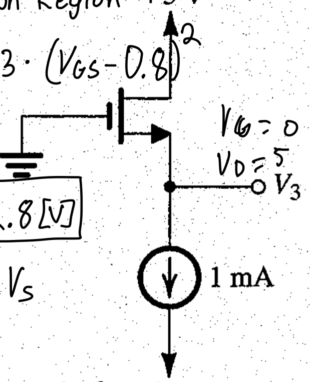
$V_D = 5$

$V_{GS} = -1.2[V] \text{ or } \boxed{2.8[V]}$

$V_{GS} = 2.8[V] = 0 - V_S$

$V_S = -2.8[V]$

$V_{DS} = 5 - (-2.8) = 7.8[V]$



(c)

c)

Saturation Region

$V_3 = V_S = -2.8[V]$

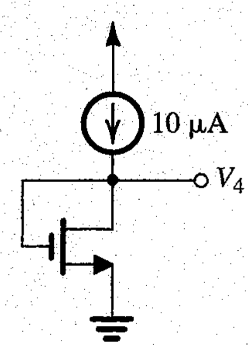
Assume Saturation Region

$10[\mu A] = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_{GS} - 0.8)^2$

$V_{GS} = 0.6[V] \text{ or } \boxed{1.0[V]}$

$V_{GS} = 1.0[V] = V_4 - 0 \Big\} V_4 = 1[V]$

$V_{DS} = V_4 - 0 = 1[V]$



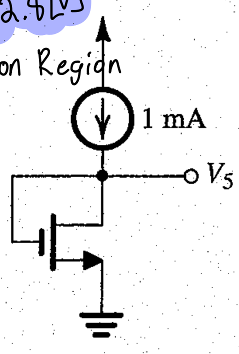
(d)

d)

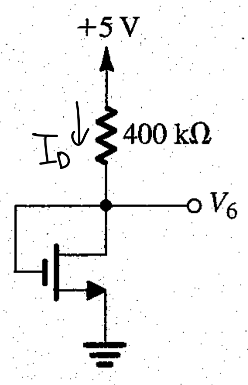
Saturation Region

$V_4 = V_S = 1[V]$

Assume Saturation Region



(e)



(f)

Figure P5.56 *continued*

$1[mA] = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_5 - 0.8)^2, \; V_{GS} = V_5 = 2.8[V] = V_{DS}$

e)

Saturation Region

$V_2 = V_S = 2.8[V]$

Assume Saturation Region

$I_D = \frac{5 - V_6}{400E3}, \; V_{GS} = V_6 - 0$

$\frac{5 - V_6}{400E3} = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_6 - 0.8)^2$

$V_{GS} = V_6 = 1[V], \; V_{DS} = 1[V]$

f)

Saturation Region

$V_2 = V_S = 1[V]$

$V_{GS} = V_7$

$I_D = \frac{5[V] - V_7}{2200[\Omega]} = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (V_7 - 0.8)$

$V_7 = 3.51[V]$

$V_{DS} = 3.51[V]$

$V_{ov} = 2.71[V]$

$V_{DS} > V_{ov}$

Saturation Region

$I_D = \frac{V_8 + 5[V]}{400[k\Omega]} = \frac{1}{2} \cdot 0.5E\text{-}3 \cdot (-V_8 + 0.8)$

$V_8 = -0.84[V]$

$V_{GS} = -V_8 = 0.84$

$V_{DS} = 5 - V_8 = 5.84$

$V_{ov} = 0.04[V]$

$V_{DS} > V_{ov}$

Saturation Region

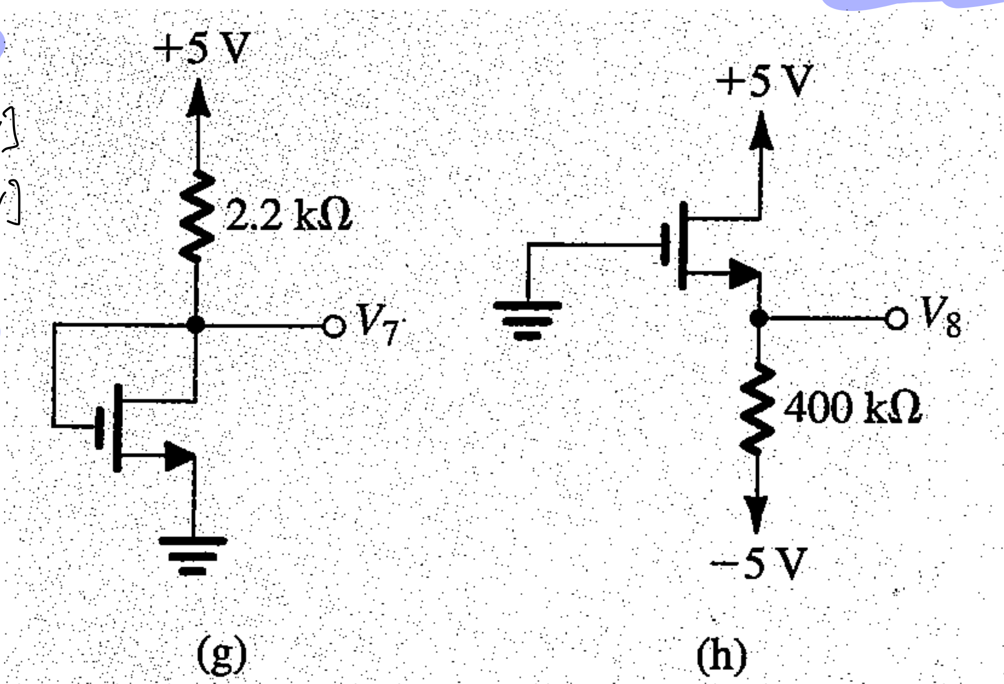


Figure P5.56 *continued*

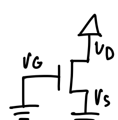
7 Sedra and Smith Text **5.65** $V_{DS} = V_D = 0.1$

$I_D = 2E\text{-}3\left[(0+3)0.1 - \frac{0.1^2}{2}\right] = 0.59[mA]$

$V_{GS} > V_t \quad V_{DS} < V_{GS} - V_t$

Triode Region

5.65 A depletion-type *n*-channel MOSFET with $k_n' W/L = 2\ \text{mA/V}^2$ and $V_t = -3$ V has its source and gate grounded. Find the region of operation and the drain current for $v_D = 0.1$ V, 1 V, 3 V, and 5 V. Neglect the channel-length-modulation effect.



$V_{DS} = V_D = 1[V]$

$I_D = 2E\text{-}3\left[(0+3)\cdot 1 - \frac{1^2}{2}\right] = 5[mA]$

$V_{GS} > V_t \quad V_{DS} < V_{GS} - V_t$

Triode Region

8 Sedra and Smith Text **5.67**

$V_{DS} = V_D = 3[V]$

$I_D = 2E\text{-}3\left[(0+3)\cdot 3 - \frac{3^2}{2}\right] = 9[mA]$

$V_{GS} > V_t \quad V_{DS} \geq V_{GS} - V_t$

Saturation Region

$V_{DS} = V_D = 5[V]$

$I_D = \frac{1}{2} \cdot 2E\text{-}3 \cdot (0+3)^2 = 9[mA]$

Saturation Region

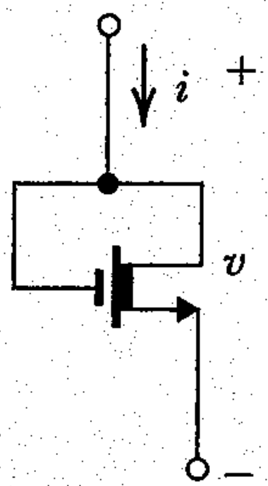
$V_{GS} > V_t \quad V_{DS} \geq V_{GS} - V_t$

***5.67** Neglecting the channel-length-modulation effect, show that for the depletion-type NMOS transistor of Fig. P5.67, the i–v relationship is given by

$$i = \frac{1}{2}k_n'(W/L)\left(v^2 - 2V_t v\right) \qquad \text{for } v \geq V_t$$

$$i = -\frac{1}{2}k_n'(W/L)V_t^2 \qquad \text{for } v \leq V_t$$

(Recall that V_t is negative.) Sketch the i–v relationship for the case: $V_t = -2$ V and $k_n'(W/L) = 2$ mA/V^2.



$V = 1\,[V] \quad i = \frac{1}{2}\cdot 2E{-}3\cdot(1^2 + (4\cdot 1)) = 5\,[mA]$

$V = 0\,[V] \quad i = \frac{1}{2}\cdot 2E{-}3\cdot(0) = 0\,[mA]$

$V = -1\,[V] \quad i = \frac{1}{2}\cdot 2E{-}3\cdot(1^2 + (4\cdot -1)) = -3\,[mA]$

$V = -4\,[V] \quad i = -\frac{1}{2}\cdot 2E{-}3\cdot 4 = -4\,[mA]$

Figure P5.67

$V_{DS} = V_{GS} = V$

$V_{ov} = V_{DS} + 4$

Always in triode when $V_{GS} > V_t$