PROBLEM SET #6

Issued: Friday, September 28, 2018

Due: Friday, October 12, 2018 at 12:00 noon via **Gradescope**.

1. Sedra & Smith, Problem 5.44

2. Figure PS6.1 presents an NMOS transistor cross-section and its top-view. The length of the channel is $5\mu m$. The width of the channel changes linearly from $1\mu m$ at the source to $0.3\mu m$ at the drain. Derive the expression for the device current when operating in the saturation region as a function of μ_n, C_{ox}, V_{GS}, V_{DS} and V_{th}. Assume $\lambda = 0$.

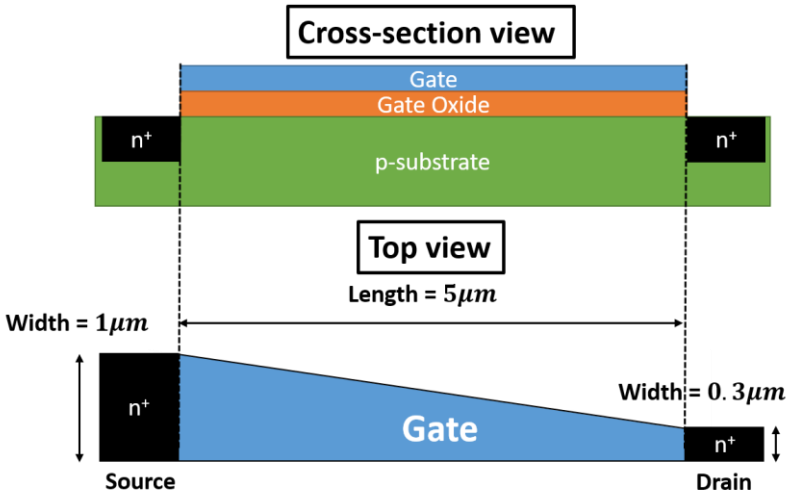

Figure PS6.1

For problems 3~5 below, use the parameters in Table PS6.1 as needed.

PARAMETER	*NMOS VALUE*	*PMOS VALUE*	*UNIT*
V_{TO}	0.75	-0.75	V
γ	0.75	0.5	$\sqrt{\text{V}}$
$2\phi_f$	0.6	0.6	V
K'	25	10	$\mu\text{A/V}^2$

Table PS6.1

3. (a) Calculate the on-resistance for an NMOS transistor having $\frac{W}{L} = 100/1$ and operating with $V_{GS} = 5V$ and $V_{TN} = 0.75V$. (b) Repeat for a similar PMOS transistor with $V_{GS} = -5V$ and $V_{TP} = -0.75V$. (c) What $\frac{W}{L}$ is required for the PMOS transistor to have the same R_{on} as the NMOS transistor in (a)?

4. (a) Calculate the drain current in an NMOS transistor if $K_n = 250\frac{\mu A}{V^2}$, $V_{TN} = 1V$, $\lambda = 0.025V^{-1}$, $V_{GS} = 5V$, and $V_{DS} = 6V$. (b) Repeat assuming $\lambda = 0$.

For problem 5 below, use the parameters in Table PS6.2 as needed

$V_{SB}(V)$	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
$V_{TN}(V)$	0.75	0.91	1.09	1.23	1.38	1.51	1.60	1.72	1.82	1.90	2.01

Table PS6.2

5. (a) What is the on-resistance and voltage V_o for the parallel combination of the NMOS ($\frac{W}{L} = 10/1$) and PMOS ($\frac{W}{L} = 25/1$) transistors in Figure PS6.2 for $V_{in} = 0$? (b) For $V_{in} = 5V$? This circuit is called a transmission gate.

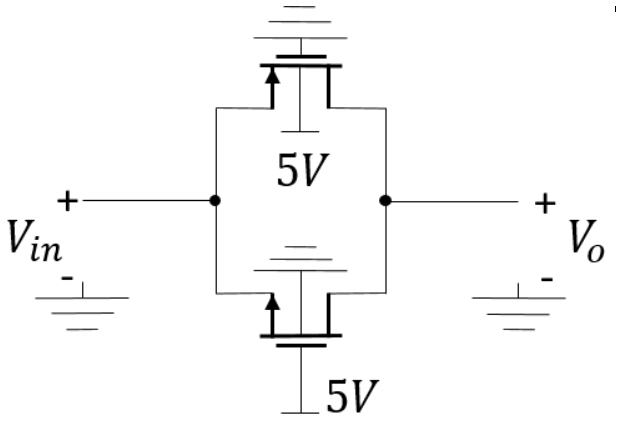

Figure PS6.2

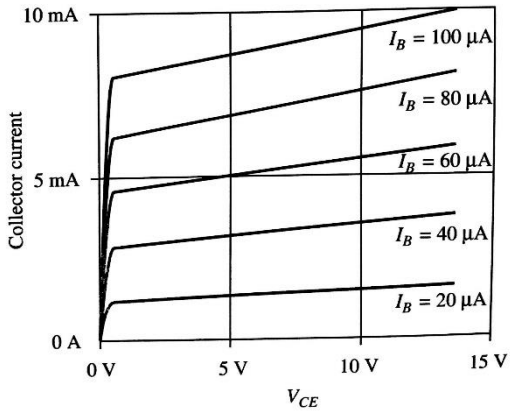

Figure PS6.3

6. Indicate the region of operation for an *npn* transistor biased as follows:

(a) $V_{BE} = -5.0V, V_{BC} = 0.7V$.

(b) $V_{BE} = -5.0V, V_{BC} = -5.0V$.

(c) $V_{BE} = 0.7V, V_{BC} = 0.7V$.

(d) $V_{BE} = 0.7V, V_{BC} = -5.0V$.

7. Indicate the region of operation for an *pnp* transistor biased as follows:

(a) $V_{EB} = 0.7V, V_{CB} = 0.7V$.

(b) $V_{EB} = 0.7V, V_{CB} = -0.65$.

(c) $V_{EB} = -0.65V, V_{CB} = 0.7V$.

(d) $V_{EB} = -0.65V, V_{CB} = -0.65V$.

8. The common-emitter output characteristics for an *npn* transistor are given in Figure PS6.3. What are the values of β_F at (a) $I_C = 5mA$ and $V_{CE} = 5V$? (b) $I_C = 7mA$ and $V_{CE} = 7.5V$? (c) $I_C = 10mA$ and $V_{CE} = 14V$?

9. (a) Find the *Q*-point, i.e., operating point, for the circuit in Figure PS6.4. Assume that $\beta_F = 50$ and $V_{BE} = 0.7V$. (b) Repeat the calculation if all the resistor values are decreased by a factor of 5. (c) Repeat (a) for Figure PS6.5. (d) Repeat (b) for Figure PS6.5.

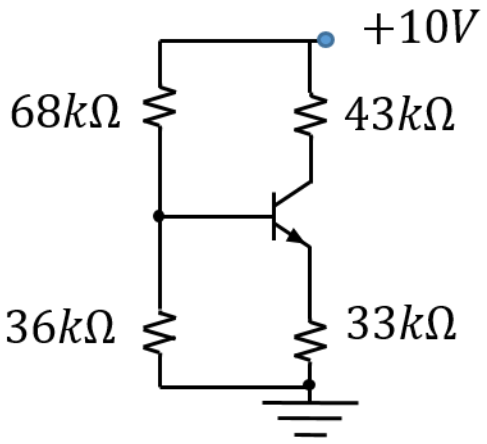

Figure PS6.4

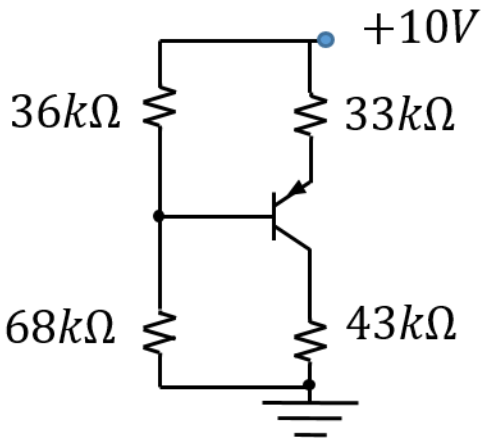

Figure PS6.5

10. (a) Find the *Q*-point for the circuit in Figure PS6.4 if the $33k\Omega$ resistor is replaced with a $22k\Omega$ one. Assume that $\beta_F = 75$. (b) Repeat (a) for the circuit in Figure PS6.5.

11. Design a four-resistor bias network for an *npn* transistor using the resistor values in Figure PS6.6 to give $I_C = 10\mu A$ and $V_{CE} = 6V$ if $V_{CC} = 18V$ and $\beta_F = 75$. I_C and V_{CE} must meet the specified values within a tolerance of $\pm 10\%$.

12. Design a four-resistor bias network for an *pnp* transistor using the resistor values in Figure PS6.6 to give $I_C = 13mA$ and $V_{CE} = 5V$ if $V_{CC} = -15V$ and $\beta_F = 50$. I_C and V_{CE} must meet the specified values within a tolerance of $\pm 10\%$.

Standard resistor values: All values available with a 5 percent tolerance. Bold values are available with 10 percent tolerance.

Ohms							
1.0	**5.6**	**33**	**180**	**1000**	**5600**	**33000**	**180000**
1.1	6.2	36	200	1100	6200	36000	200000
1.2	**6.8**	**39**	**220**	**1200**	**6800**	**39000**	**220000**
1.3	7.5	43	240	1300	7500	43000	240000
1.5	**8.2**	**47**	**270**	**1500**	**8200**	**47000**	**270000**
1.6	9.1	51	300	1600	9100	51000	300000
1.8	**10**	**56**	**330**	**1800**	**10000**	**56000**	**330000**
2.0	11	62	360	2000	11000	62000	360000
2.2	**12**	**68**	**390**	**2200**	**12000**	**68000**	**390000**
2.4	13	75	430	2400	13000	75000	430000
2.7	**15**	**82**	**470**	**2700**	**15000**	**82000**	**470000**
3.0	16	91	510	3000	16000	91000	510000
3.3	**18**	**100**	**560**	**3300**	**18000**	**100000**	**560000**
3.6	20	110	620	3600	20000	110000	620000
3.9	**22**	**120**	**680**	**3900**	**22000**	**120000**	**680000**
4.3	24	130	750	4300	24000	130000	750000
4.7	**27**	**150**	**820**	**4700**	**27000**	**150000**	**820000**
5.1	30	160	910	5100	30000	160000	910000

Megohms						
1.0	1.6	**2.7**	4.3	**6.8**	11.0	**18.0**
1.1	**1.8**	3.0	**4.7**	7.5	**12.0**	20.0
1.2	2.0	**3.3**	5.1	**8.2**	13.0	**22.0**
1.3	**2.2**	3.6	**5.6**	9.1	**15.0**	
1.5	2.4	**3.9**	6.2	**10.0**	16.0	

Figure PS6.6