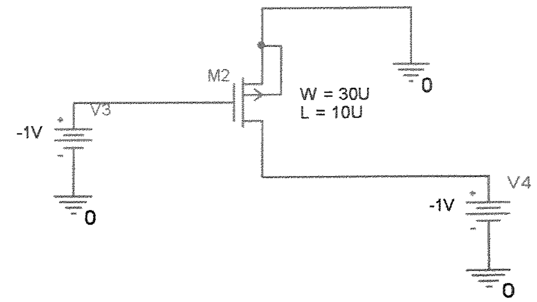
Solutions 02/14/2005 Y. Z.

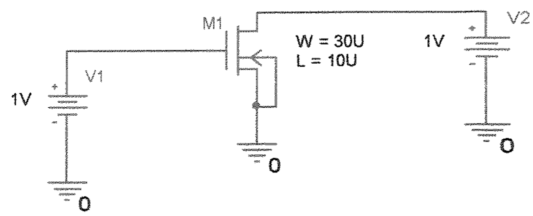
ENEE302 HW1

1.

(a)



PARAMETERS:
V1 = 1V
V3 = -1V



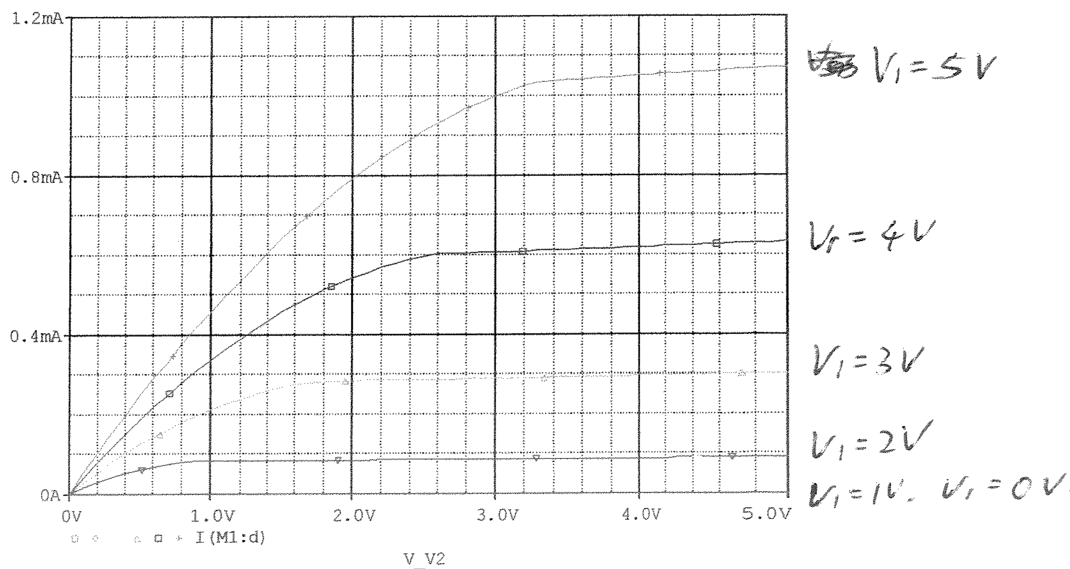
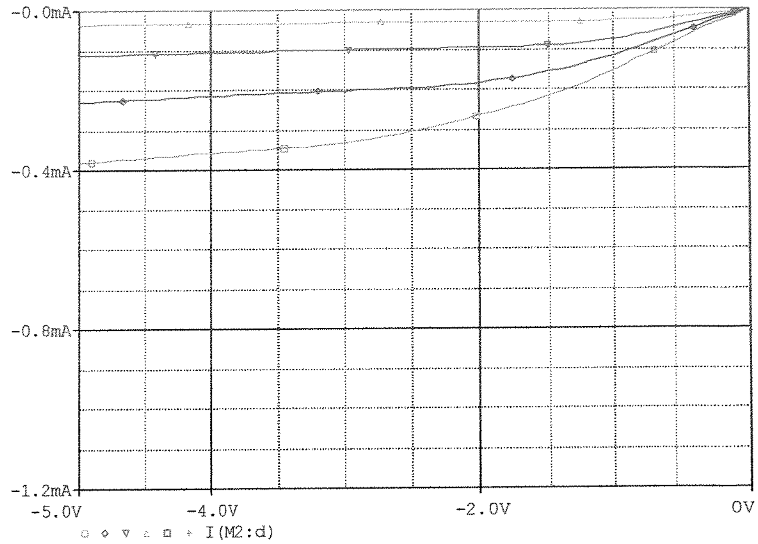


Fig. 1. I_D vs. V_{DS} for NMOS

To get these curves, do a DC primary sweep on V_2 (V_{DS} - Nmos), and parametric sweep on V_1 (V_{GS} for Nmos). V_2 is swept from 0 to 5V with 0.1V increment. V_1 is from 0V to 5V with 1V increment.

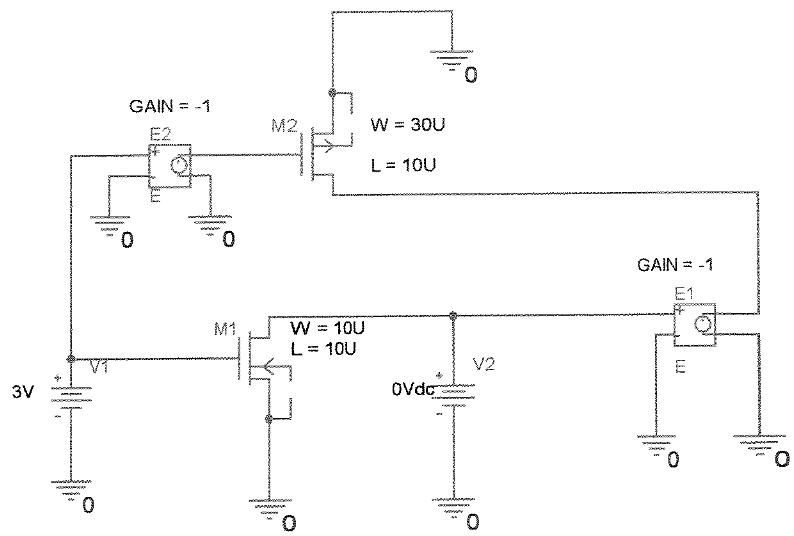


For PMOS, Drain voltage swept from −5V to 0V, 0.1V increment. Gate voltage swept from −5V to 0V, 1V increment.

Fig. 2. I_D vs. V_{DS} for PMOS

(b)

Choose Wn=10μm, Wp=30μm, we get the same magnitude I_D for the same V_G



To plot both Nmos and pmos curves on one graph, I use V_1 to control the gates of both Nmos and pmos. I use V_2 to control the drain of both transistors. I found for Wp=30um, Wn should be close to 10um to match the two drain currents. Below is the graph for Wp=30um, Wn=10um, we see the currents are almost at the same magnitude for pmos and Nmos for different V_{GS}.

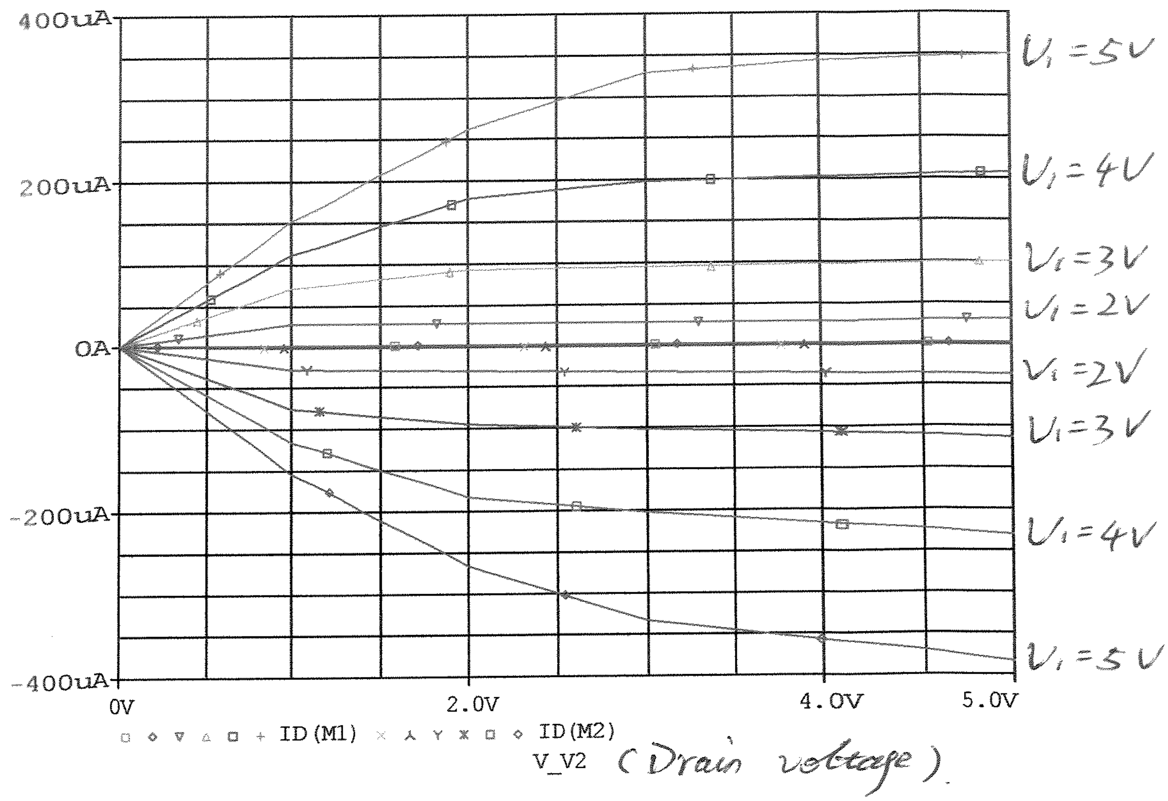


Fig. 3 Adjust the width of NMOS to achieve same magnitude of I_D for NMOS and PMOS

1(c). To calculate k_p' and V_{t0} for PMOS,
I choose two lines from the above graph,
one line for $|V_{GS}| = 3V$, the other for $|V_{GS}| = 2V$.
I selected one point from each line, and measured the I_D and V_{DS} for the point.

when $V_{GS} = -3V$, $V_{DS} = -0.575V \Rightarrow I_D = 50uA$

when $V_{GS} = -2V$, $V_{DS} = -0.41V \Rightarrow I_D = 20uA$

Use the equations for PMOS in triode region.

$$\begin{cases} 50uA = k_p' \cdot \frac{30u}{10u}\left[(-3 - V_t)\times(-0.575) - \frac{1}{2}\times 0.575^2\right] \\ 20uA = k_p' \cdot \frac{30u}{10u}\left[(-2 - V_t)\times(-0.41) - \frac{1}{2}\times 0.41^2\right] \end{cases}$$

Solve the k_p' and V_t from the two equations.
I got $V_t = -0.62V$, $k_p' = 1.39\times 10^{-5}\ A/V^2$

The same thing applies to Nmos. For Nmos

when $V_{GS} = 3V$, $V_{DS} = 0.64V$, $\Rightarrow I_D = 50uA$

when $V_{GS} = 2V$, $V_{DS} = 0.45V$, $\Rightarrow I_D = 18uA$.

$$\Rightarrow \begin{cases} 50\,uA = k_n' \cdot \frac{10u}{10u}\left[(3 - V_t) \times 0.64 - \frac{1}{2} \times 0.64^2\right] \\ 18uA = k_n' \cdot \frac{10u}{10u}\left[(2 - V_t) \times 0.45 - \frac{1}{2} \times 0.45^2\right] \end{cases}$$

$$\Rightarrow \begin{cases} V_t = 0.8257\ V \\ k_n' = 4.213 \times 10^{-5}\ A/V^2 \end{cases}$$

Check these values with the one is the library (Bicmos 12.lib).

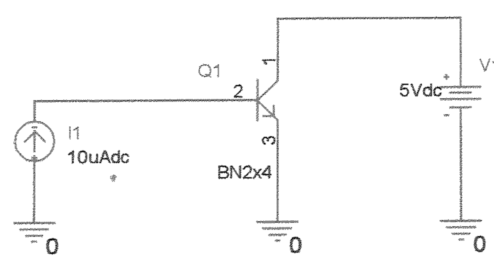
The model values are

For Pmos $\begin{cases} V_t = -0.89\ V. \\ k_p' = 1.9 \times 10^{-5}\ A/V^2 \end{cases}$

For Nmos $\begin{cases} V_t = 0.85\ V \\ k_n' = 5.04 \times 10^{-5}\ A/V^2 \end{cases}$

Calculations are close to the model values.

2. (a)



I do DC sweep on V_1 (V_{CE}) from 0V to 5V, 0.1 V increments. I do parametric sweep on I_1 (I_B) from 0 uA to 50 uA, 10uA increments.

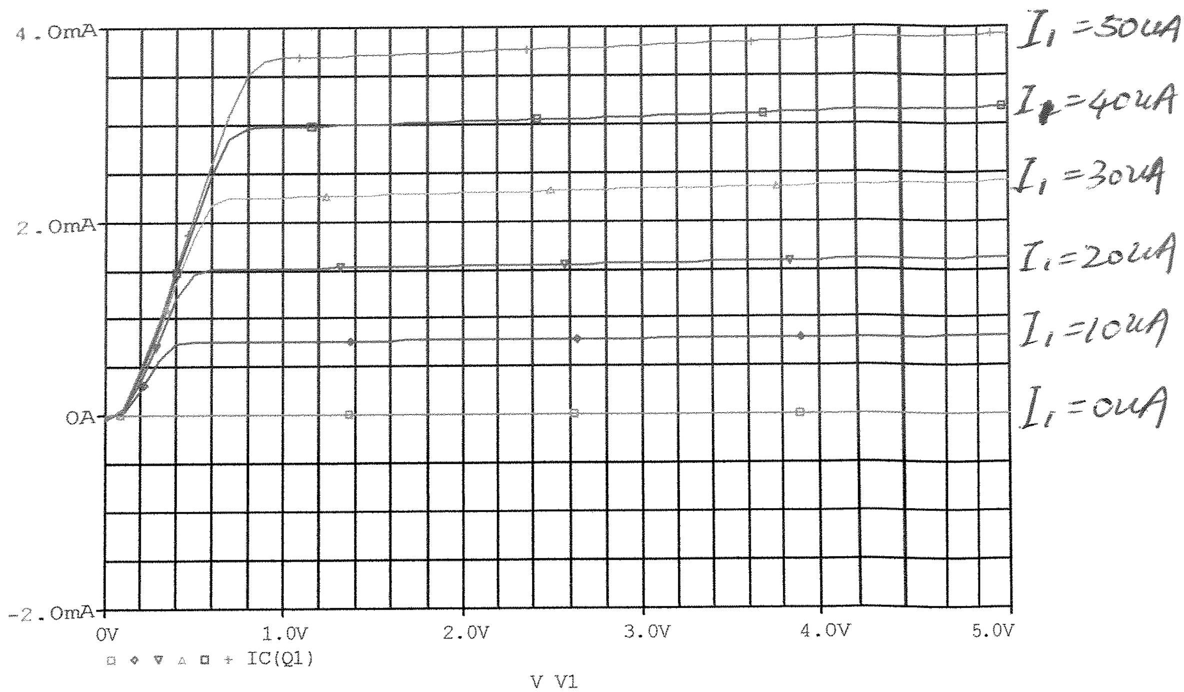
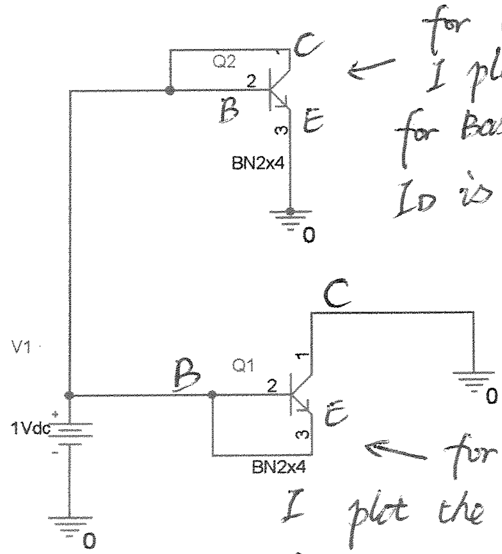


Fig. 4. Collection current vs. V_{CE} for different base current Ib

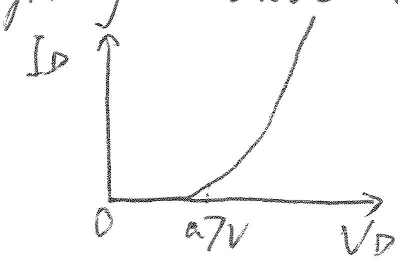
b . You can do both simulation in one page like below

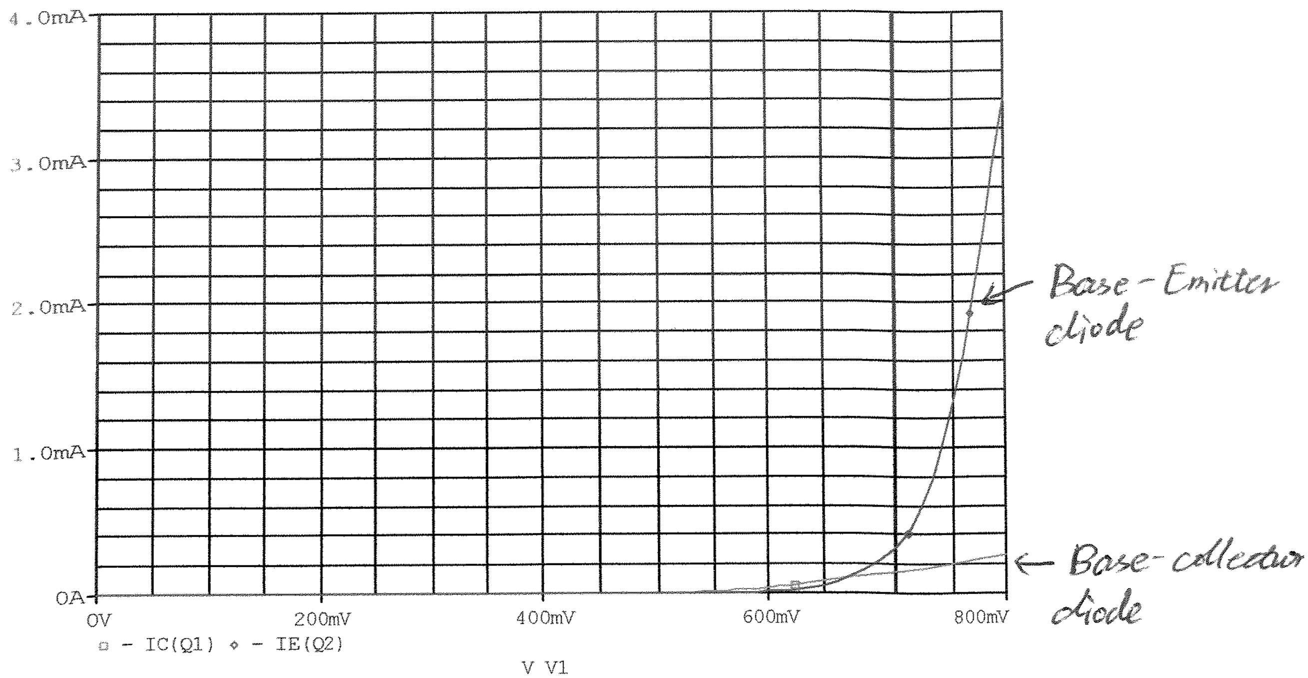


for collector tied to base, ← I plot the diode curve (I_D–V_D) for Base-emitter diode, here I_D is $-I_E$, V_D is V_{BE}.

← for Emitter tied to base I plot the diode curve (I_D–V_D) for Base-collecter diode, I_D here is $-I_C$, V_{DS} here is V_{BC}.

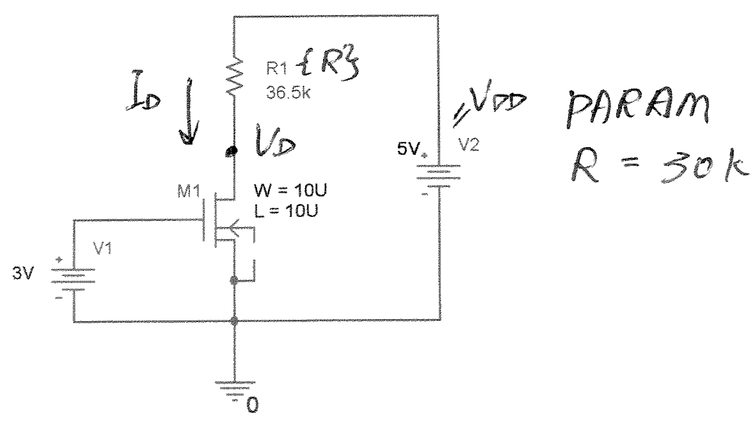
Originally a diode curve looks like below:



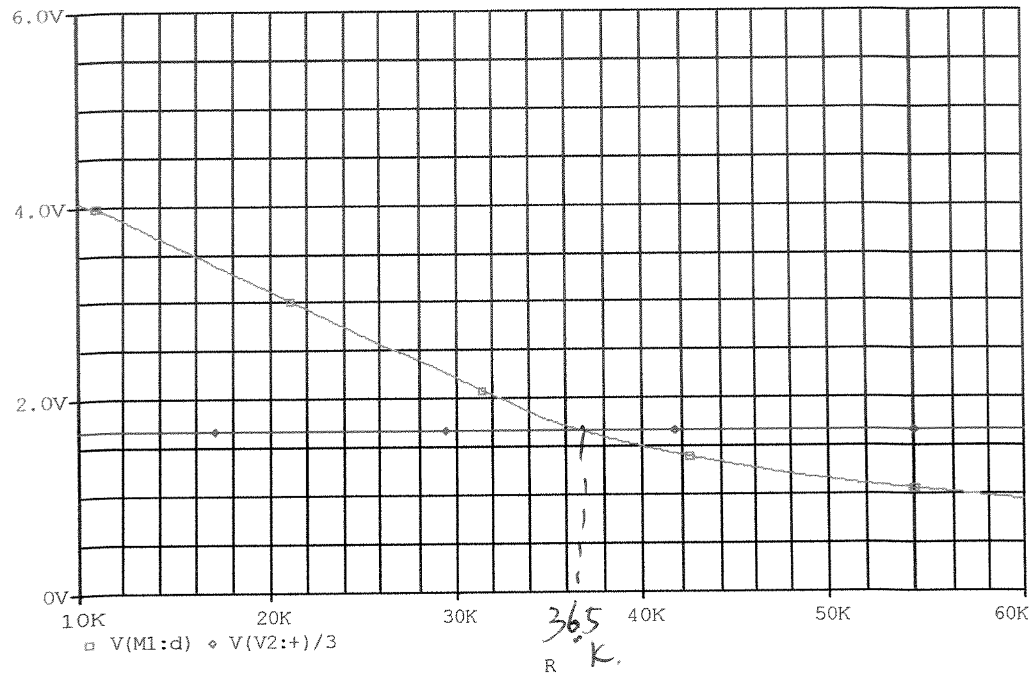


We see the B-E diode conducts much more current the B-C diode. Note even the B-C diode, I_D is around 0.2 mA at 0.8V. Definetly not on PA scale.

3.



I do a primary DC sweep on Global parameter R from 10k to 60k. 0.1k increment. I plot the V_D, and $V_D/3$ on the same graph below. The point the two curves intersects is the R I am looking for. $R \doteq 36.5k$.



To calculate by hand, first we know for $V_D = 1.67V$, NMOS is in triode region, so

$$\begin{cases} I_D = k_n' \frac{W}{L}\left[(V_{GS}-V_t)V_D - \frac{1}{2}V_D^2\right] \quad \text{(NMOS)} \\ I_D = \frac{V_{DD}-V_D}{R} \quad \text{(the same } I_D \text{ flows through R)} \end{cases}$$

We plug in $k_n' = 4.213 \times 10^{-5} A/V^2$ (from problem 1(c))

$V_t = 0.83V$ (from problem 1(c)), $V_{GS} = 3V$,

$W = 10u$, $L = 10u$. $V_{DD} = 5V$, then

We have two unknowns I_D and R in the two equations, $\Rightarrow$ $I_D \doteq 9.4 \times 10^{-5} A$

$R = 35.4\ k\Omega$.

Agrees well with PSPICE simulation.