# HOMEWORK 2

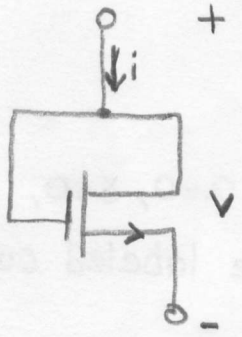
## FIELD-EFFECT TRANSISTORS (FETs)

① Neglecting the channel-length-modulation effect show that for the depletion-type NMOS transistor of figure below the i-v relationship is given by;

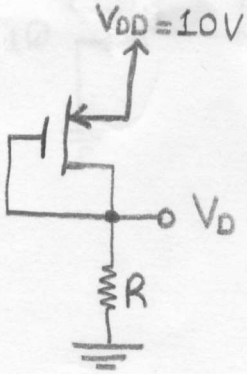
$$i = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(v^2 - 2V_t v), \quad \text{for } v \geq V_t$$

$$i = -\frac{1}{2} k_n' \left(\frac{W}{L}\right) V_t^2 \quad , \quad \text{for } v \leq V_t$$

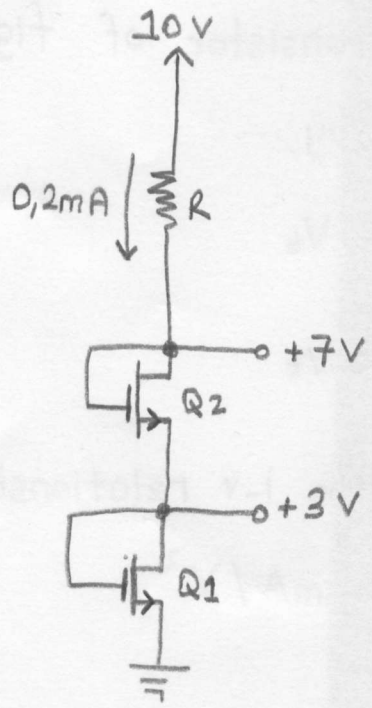
(Recall that $V_t$ is negative.) Sketch the i-v relationship for the case $V_t = -2V$ and $k_n'\left(\frac{W}{L}\right) = 2mA/V^2$




② The PMOS transistor in the circuit of figure below has $V_t = -2V$, $\mu_p C_{ox} = 8\mu A/V^2$, $L = 10\mu m$ and $\lambda = 0$. Find the values required for W and R in order to establish a drain current of 0.1mA and a voltage $V_D$ of 7V.

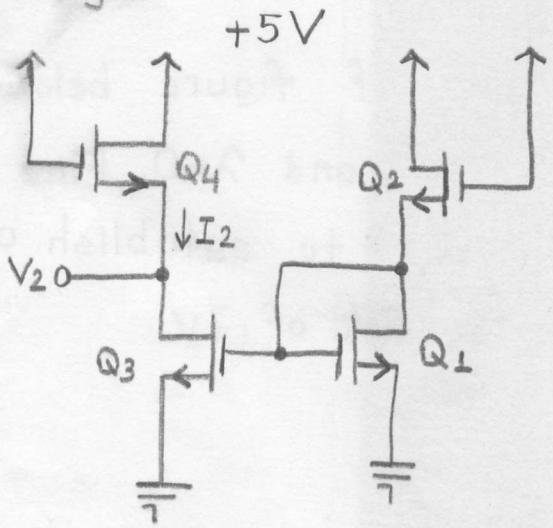


(3) The NMOS transistors in the circuit below have $V_t = 2V$, $\mu_n C_{ox} = 20\mu A/V^2$, $\lambda = 0$ and $L_1 = L_2 = 10\mu m$. Find the required values of gate width for each of $Q_1$ and $Q_2$, and the value of R, to obtain the voltage and current values indicated.

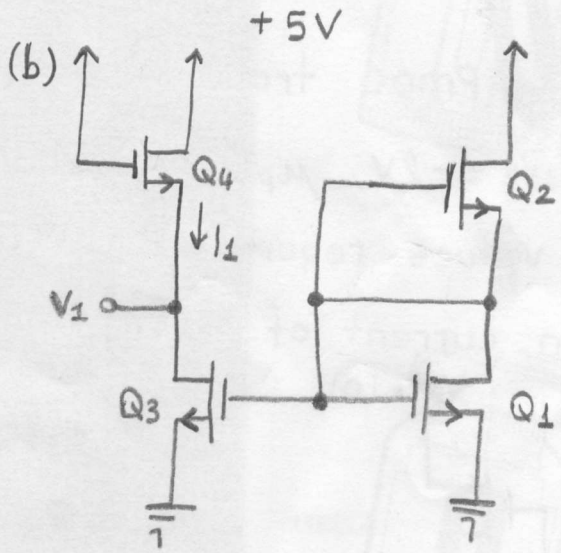



(4) For the devices in the circuits below $|V_t| = 1V$, $\lambda = 0$, $\gamma = 0$, $\mu_n C_{ox} = 20\mu A/V^2$, $L = 1\mu m$ and $W = 20\mu m$. Find the labeled currents and voltages.

(a)



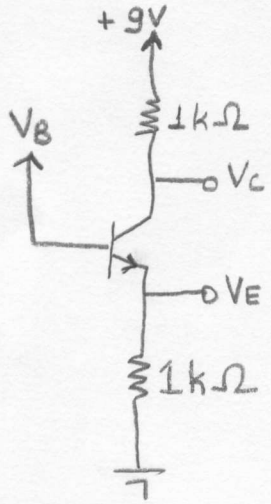

(b)



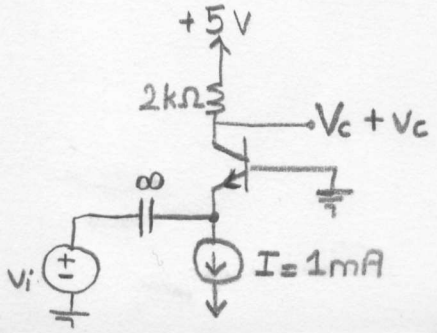
# BIPOLAR JUNCTION TRANSISTORS (BJTs)

(5) A pnp transistor has $V_{EB} = 0{,}8\,V$ at a collector current of 1A. What do you expect $V_{EB}$ to become at $i_C = 10mA$? at $i_C = 5A$?

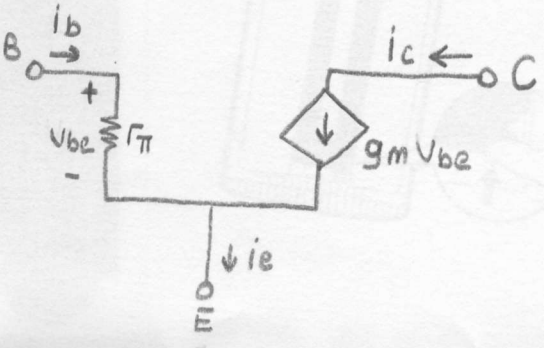
(6) Consider the circuit below with the base voltage $V_B$ obtained using a voltage divider across the 9V supply. Assuming the transistor $\beta$ to be very large (that is, ignoring the base current), design the voltage divider to obtain $V_B = 3V$. Design for a 0.2 mA current in the voltage divider. Now if the BJT $\beta = 100$, analyze the circuit to determine the collector current and collector voltage.




(7) The transistor amplifier below is biased with a current source I and has a very high $\beta$. Find the dc voltage at the collector, $V_C$. Also find the value of $g_m$. Replace the transistor with its simplified hybrid-$\pi$ model. (Note that the dc current source I should be replaced with an open circuit) Hence find the voltage gain $v_c/v_i$.




Hybrid-$\pi$ model:



(8) For the common-emitter amplifier shown below, let $V_{cc} = 9V$, $R_1 = 27k\Omega$, $R_2 = 15k\Omega$, $R_E = 1.2k\Omega$ and $R_c = 2.2k\Omega$. The transistor has $\beta = 100$ and $V_A = 100V$. Calculate the dc bias current $I_E$. If the amplifier operates between a source for which $R_s = 10k\Omega$ and a load of $2k\Omega$, replace the transistor with its hybrid-$\pi$ model, and find the values of $R_i$, the voltage gain $V_o/V_s$ and the current gain $i_o/i_i$