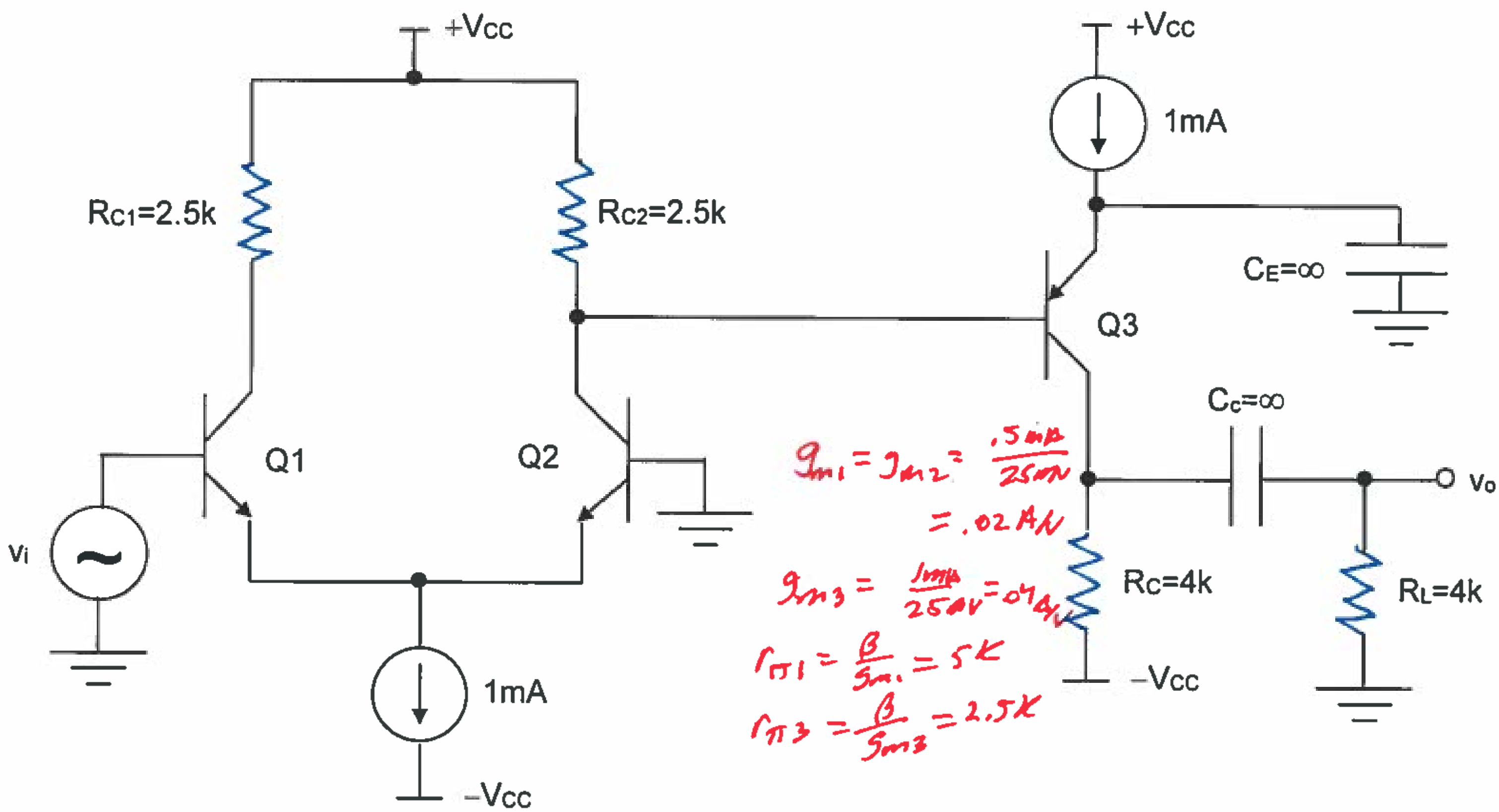
Problem 1 (40 points):

Consider the following amplifier comprised of a BJT Diff Amp in cascade with a BJT CE Amp driving an output load, R_L. Assume β=100, r_o=infinity, and V_T=25mV for all three transistors. You may make reasonable approximations in your analysis. Note that there is no *formal* DC analysis required in this problem (i.e., this is a small-signal AC midband analysis).



$g_{m1} = g_{m2} = \frac{.5mA}{25mV} = .02 A/V$

$g_{m3} = \frac{1mA}{25mV} = .04 A/V$

$r_{\pi 1} = \frac{\beta}{g_{m1}} = 5K$

$r_{\pi 3} = \frac{\beta}{g_{m3}} = 2.5K$

a) Calculate the overall midband gain, $A_m = v_o/v_i$.
(Hints: First, consider the gain of each amp separately. Then multiply them together to get the overall gain. Also, notice that the R_{in} looking into the base of Q3 acts as a load, R_L, to the Diff Amp.)

b) Calculate R_{in} (looking into the Q1 input).

c) Calculate R_{out} (looking into Rc and before R_L).

a.) $A_M = A_1 * A_2$; $A_1 = \frac{g_{m1}}{2}(R_c \| r_{\pi 3}) = \frac{.02}{2}[2.5K \| 2.5K] = 12.5$

$A_2 = -g_{m3}[R_c \| R_L] = -.04[4K \| 4K] = -80$

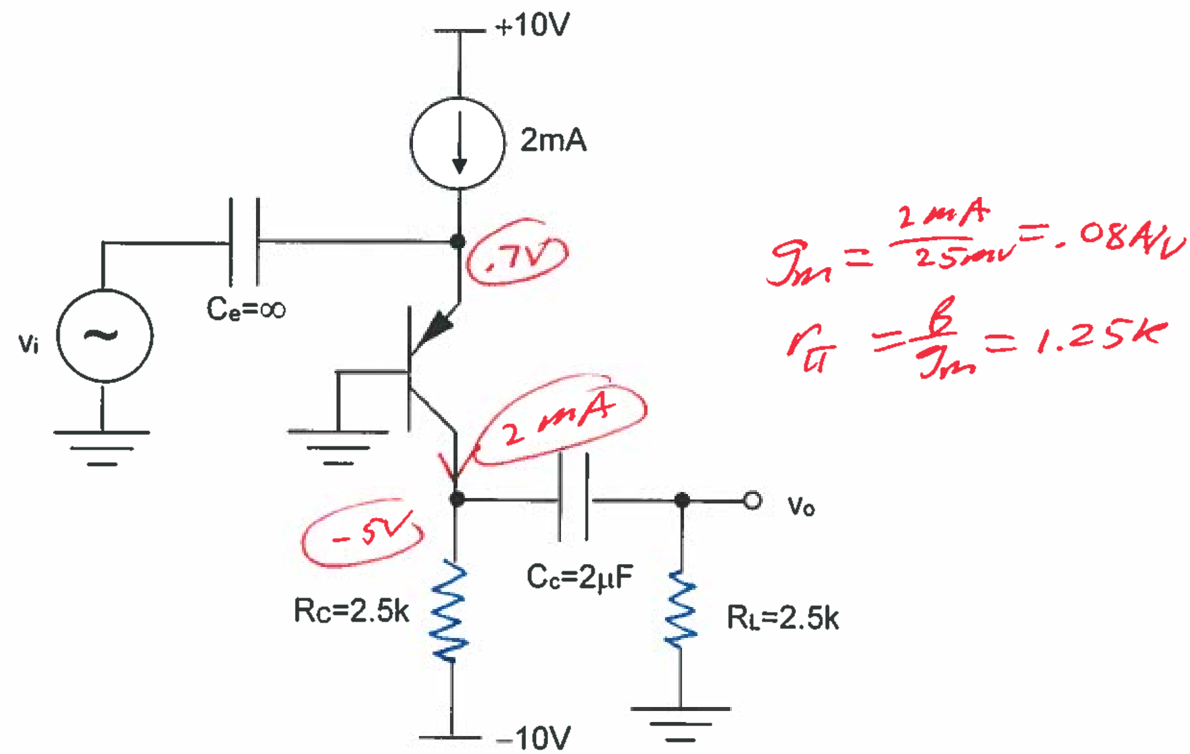
$A_m = (12.5)(-80) = -1000$ V/V

b.) $R_{in} = 2r_{\pi 1} = 10K$

c.) $R_{out} = R_C = 4K$

Problem 2 (60 points):

Consider the following simple BJT CB Amplifier. Assume β=100, $V_{BE\text{-}on}$=0.7V, C_π=200pF, C_μ=80pF, r_o=infinity, and V_T=25mV. You may make reasonable approximations in your analysis.



a) DC Analysis: Calculate I_C, V_E and V_C.

b) AC Midband Analysis: Sketch and label the midband small-signal AC model and calculate A_M, R_{in}, and R_{out} (looking into R_C and before R_L)

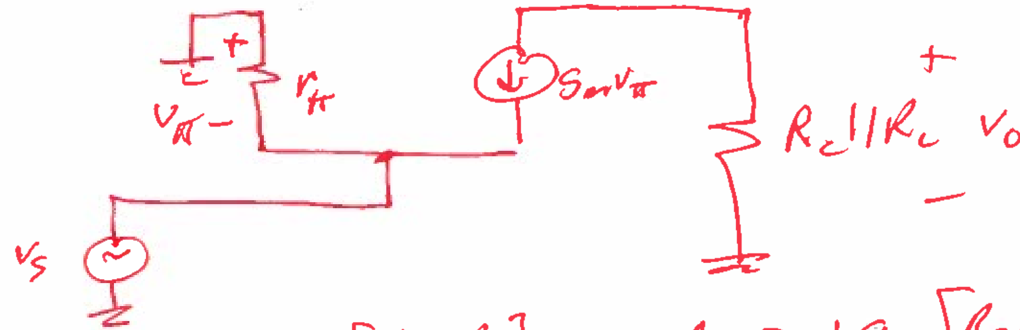
c) AC Low Frequency Analysis: Sketch and label the low frequency small-signal AC model and calculate the low frequency ω_L using SCTC's.

d) AC High Frequency Analysis: Sketch and label the high frequency small-signal AC model and calculate the high frequency ω_H using OCTC's.

e) Determine $T(s)=V_o/V_i(s)$. Then sketch the "magnitude" Bode Plot only. (Hint: The form of T(s) is $T(s)=A_M\frac{(s/\omega_L)}{(1+s/\omega_L)(1+s/\omega_H)}$)

f) Calculate the f_t of the BJT.

b.)

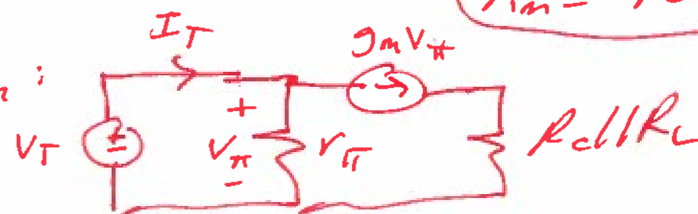


$$V_o = -g_m V_\pi [R_C \| R_L] \Rightarrow A_m = +g_m [R_C \| R_L]$$

$$= +.08[1.25K]$$

$$A_m = +100$$

R_{in} :

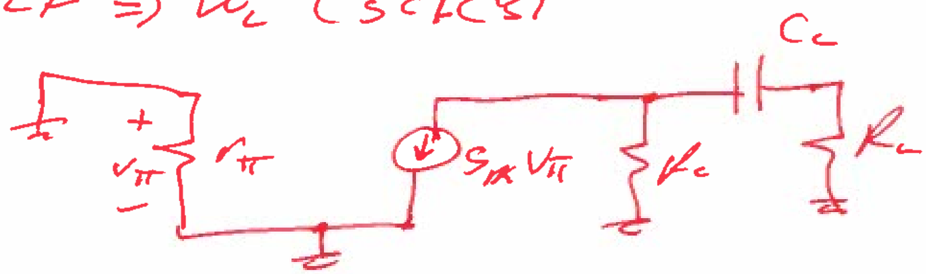


$$R_{in} = \frac{V_T}{I_T} \; ; \; I_T = \frac{V_\pi}{r_\pi} + g_m V_\pi = \frac{V_\pi}{r_\pi}[1+\beta] = \frac{V_T}{r_\pi}(1+\beta)$$

$$\therefore R_{in} = \frac{V_T}{I_T} = \frac{r_\pi}{1+\beta} = \frac{1.25K}{101} = 12.4\Omega$$

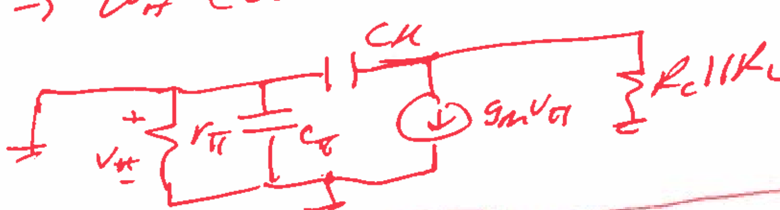
$$R_{out} = R_C = 2.5K$$

c.) LF ⇒ ω_L (SCTC's)



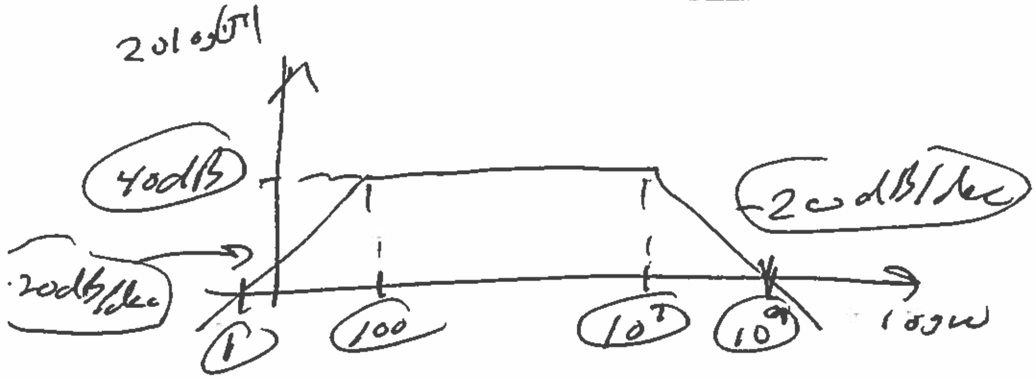
$$\omega_L = \frac{1}{\tau_{C_C}} = \frac{1}{R_{C_C} C_C} = \frac{1}{(R_C + R_L) C_C} = 100 \text{ rad/sec}$$

d.) HF ⇒ ω_H (OCTC's)



$$\omega_H = \frac{1}{\tau_{C_\pi} + \tau_{C_\mu}} \; ; \; \tau_{C_\pi} = 0 \quad \tau_{C_\mu} = (R_C \| R_L) C_\mu = 10^{-7} \Rightarrow \omega_H = \frac{1}{\tau_{C_\mu}} = 10^7 \text{ rad/sec}$$

e.) $T(s) = 100 \left(\frac{s/100}{(1+s/100)(1+s/10^7)} \right)$

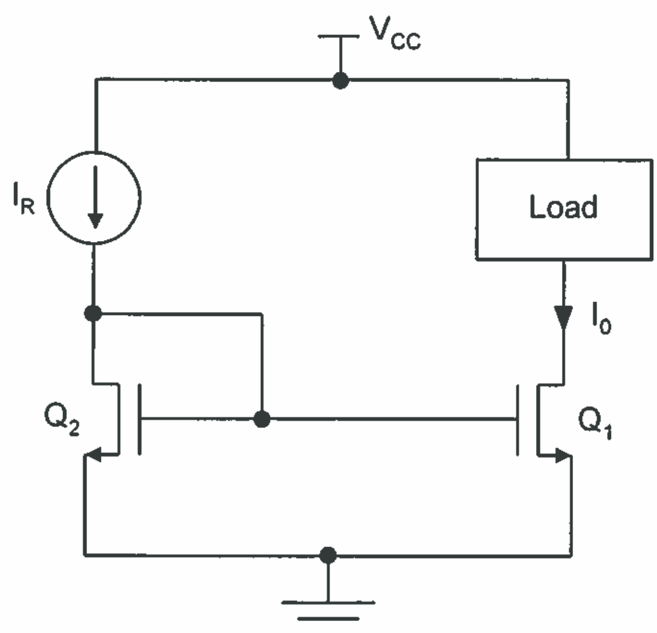


f.) $f_T = \frac{g_m}{2\pi[C_\pi + C_\mu]} = \frac{.08}{2\pi[280pF]} = 45.5\,MHz$

Optional Bonus Problem (10 points, no partial credit):

Consider the following MOS Current Source/Mirror. Assume both nFET's are matched. Assume W_1=40um, W_2=10um, L_1=L_2=1um, and I_R=100uA.

Calculate I_0.



$$I_0 = \frac{W_1}{W_2} I_R = \frac{40}{10}(100\mu A) = 400\mu A$$