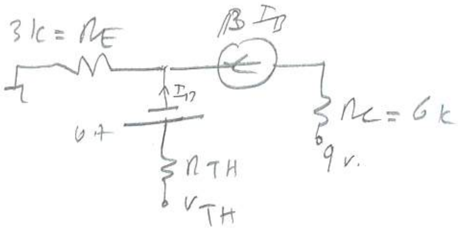
EEE313 MT2 solution 24-4-2021



Q1. a) $R_{TH} = R_1 // R_2 = 150//50 = 37.5\ k\Omega$.

$V_{TH} = \frac{R_2}{R_1+R_2}\times 9 = \frac{50}{200}\times 9 = 2.25V$.

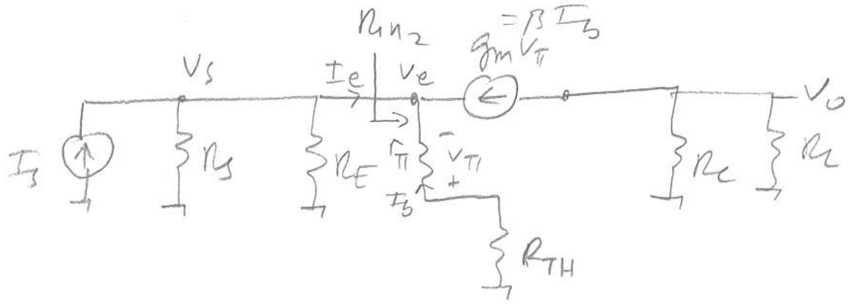
Assume F.A. $I_B = \frac{2.25-0.7}{37.5+126\times 3} = \frac{1.55}{415.5} = 3.73\mu A$ (2p)

$\Rightarrow I_{CQ} = 125\times I_B = 0.466\ mA$. (1p)

(2p) $V_{CEQ} = 9 - 0.466\times 6 - \frac{126}{125}\times 0.466\times 3 = 4.79V > 0.2$ ✓ (1p)

b) $g_m = \frac{0.466}{0.026} = 17.92\ mA/V$ $r_\pi = \frac{125}{g_m} = 6.97\ k\Omega$. (1p+1p)

↑ If gm is not used the 2p.



$I_e = -(\beta+1) I_b$ $I_b = \frac{-V_e}{r_\pi+R_{TH}}$ $\Rightarrow R_{in_2} = \frac{V_e}{I_e} = \frac{r_\pi+R_{TH}}{\beta+1} = \frac{6.97+37.5}{126}$

$= 0.353\ k\Omega$.

$\frac{V_e}{I_s} = R_s // R_E // R_{in_2}$

$\frac{V_o}{V_e} = \frac{-\beta I_b\ R_C//R_L}{-I_b\ (r_\pi + R_{TH})}$

$\frac{V_o}{I_s} = \frac{V_e}{I_s}\cdot\frac{V_{out}}{V_e} = R_s//R_E//R_{in_2}\times\frac{\beta\ R_C//R_L}{r_\pi+R_{TH}}$

$R_s//R_E = 100//3 = 2.913\ k\Omega$. $= \frac{(R_s//R_E)\cancel{R_{in_2}}}{R_s//R_E + R_{in_2}}\times\frac{\beta\ R_C//R_L}{(\beta+1)\cancel{R_{in_2}}}$

$R_C//R_L = 4//6 = 2.4\ k\Omega$. $= \frac{2.913}{2.913+0.353}\times\frac{125}{126}\times 2.4 = 2.124\ \Omega$. (8p) →

c) $A_v = \frac{V_o}{V_s} = \frac{V_o}{I_s}\cdot\frac{I_s}{V_s}$ $\frac{V_s}{I_s} = R_s//R_E//R_{in_2}$

$= 100//2//0.353 = 2.913//0.353$

$= 0.3148\ \Omega$.

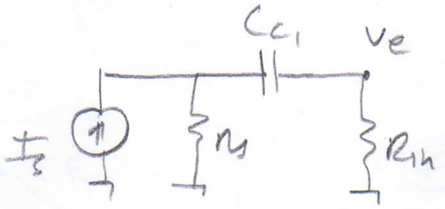
$\Rightarrow A_v = 2.124\times\frac{1}{0.3148}$

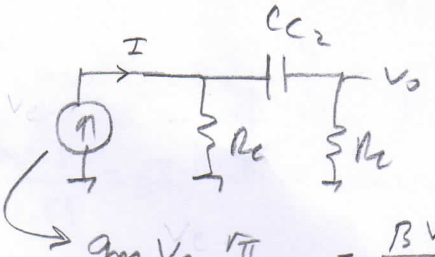
$= 6.747\ V/V$ (6p) *

← *

d) $R_{in} = R_E // R_{in_2} = 3 // 0.353 = 0.316\ k\Omega.$ (6p)

e)





$$g_m V_e \frac{r_\pi}{r_\pi + R_{TH}} = \frac{\beta V_e}{r_\pi + R_{TH}}$$

$$\frac{V_e}{I_s} = \frac{R_s}{R_{in} + \frac{1}{j\omega C_{c_1}} + R_s} \times R_{in}$$

$$= \frac{R_s R_{in} j\omega C_{c_1}}{1 + j\omega C_{c_1}(R_{in} + R_s)} = \frac{R_s R_{in}}{R_{in} + R_s} \frac{j f/f_1}{1 + j f/f_1}$$

where $f_1 = \frac{1}{2\pi \times C_{c_1} \times (R_{in} + R_s)} = \frac{1}{2\pi \times 10^{-6} \times 100.316 \times 10^3}$

$= 1.586\ Hz.$ (2p)

$$\frac{V_o}{I} = \frac{R_c}{R_c + \frac{1}{j\omega C_{c_2}} + R_L} \times R_L = \frac{R_c R_L j\omega C_{c_2}}{1 + j\omega C_{c_2}(R_c + R_L)} = \frac{R_c R_L}{R_c + R_L} \cdot \frac{j f/f_2}{1 + j f/f_2}$$

Where $f_2 = \frac{1}{2\pi \times C_{c_2} \times (R_L + R_c)} = \frac{1}{2\pi \times 10^{-6} \times 10 \times 10^3}$

$= 15.92\ Hz.$ (2p)

$\therefore f_L = 15.92\ Hz.$ (3p)

→ b) formula correct no merical result −3
" " wrong " " −2
formula wrong − basically wrong 0
smaller mistake −4 (or −2 each)

not in compact form −2
and no result −2

Q2. a) Assume SAT.

$$I_D = K_p (V_{SG} + V_{TP})^2 \quad \text{Also} \quad 9 = I_D R_S + V_{SG}$$

$$\therefore 2(V_{SG} - 2)^2 = \frac{9 - V_{SG}}{1.2}$$

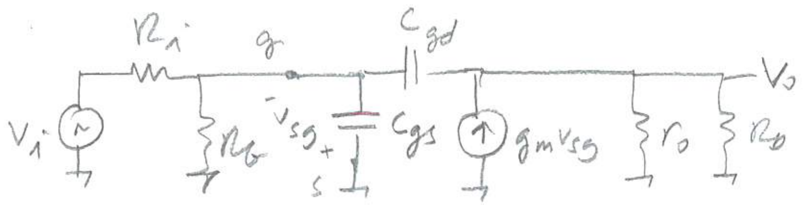
$$V_{SG}^2 - 4V_{SG} + 4 = \frac{9}{2.4} - \frac{V_{SG}}{2.4} \qquad V_{SG}^2 - 3.58\overline{33}\, V_{SG} + 0.25 = 0$$

(4p) $\Rightarrow V_{SG} = \begin{cases} 3.512\text{ V} > 2 \ \checkmark \\ 0.07 < 2 \ \times \end{cases} \Rightarrow I_{DQ} = \frac{9 - 3.512}{1.2} = 4.573\text{ mA}.$ (2p)

$$V_{SDQ} = 9 - 4.573 \times (1.2 + 1) - (-9) = 18 - 4.573 \times 2.2$$

(2p) $= 7.94\text{ V} > 3.51 - 2 \ \checkmark$ (2p)

b) $g_m = 2\sqrt{2 \times 4.573}$ (1p) $= 6.05\text{ mA/V}$ $\quad r_0 = \frac{1}{0.01 \times 4.573} = 21.87\text{ k}\Omega$. (1p)



$r_o // R_D = 21.87 \times 1 = 0.956\text{ k}\Omega$.

$$A_{MB} = \frac{-R_G}{R_1 + R_G} \times g_m \times r_o // R_D$$

$$= \frac{-100}{100 + 2} \times 6.05 \times 0.956 = -5.67 \text{ V/V} \quad \text{(7p)}$$

③ ④

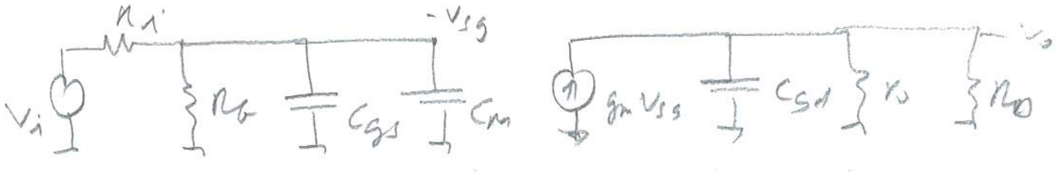
−2p for no (−)

−2, 3, for each numerical mistake

c) $C_M = C_{gd}(1 + g_m r_o // R_D) = 1(1 + 6.05 \times 0.956)$

$= (1 + 5.78) = 6.78\text{ pF}$ (4p)

$C_T = C_{gs} + C_M = 16.78\text{ pF}$



$$\frac{v_{sg}}{v_i} = -\frac{R_G // \frac{1}{j\omega C_T}}{R_G // \frac{1}{j\omega C_T} + R_1} = \frac{\frac{R_G}{1 + j\omega C_T R_G}}{\frac{R_G}{1 + j\omega C_T R_G} + R_1} = \frac{R_G}{R_G + R_1 + j\omega C_T R_G R_1}$$

$$= -\frac{R_G}{R_G + R_1} \frac{1}{1 + j f/f_1}, \quad \text{where } f_1 = \frac{1}{2\pi \times C_T \times R_G // R_1}$$

$R_G // R_1 = 100 // 2 = 1.96\text{ k}\Omega$.

$$= \frac{1}{2\pi \times 16.78 \times 10^{-12} \times 1.96 \times 10^3} = 4.84\text{ MHz}. \quad \text{(4p)}$$

$$\frac{v_o}{v_{sg}} = g_m \frac{1}{j\omega C_{gd}} // r_o // R_D = g_m (r_o // R_D) \frac{1}{1 + j f/f_2} \quad \text{where } f_2 = \frac{1}{2\pi \times C_{gd} \times r_o // R_D}$$

$$f_2 = \frac{1}{2\pi \times 1 \times 10^{-12} \times 0.956 \times 10^3} = 166.5\text{ MHz} \quad \text{(4p)} \quad \therefore f_H = 4.84\text{ MHz}. \quad \text{(4p)}$$

Q3.

a) $I_{REF} = I_{S_1} e^{\frac{V_{BE}}{V_T}} \Rightarrow V_{BE} = V_T \ln \frac{I_{REF}}{I_{S_1}} = 0.026 \ln \frac{0.5 \times 10^{-3}}{10^{-12}}$

$\Rightarrow V_{BE} = 0.5208$ v. 6p

b) $R_1 = \frac{5 - 0.5208}{0.5} = 8.96$ kΩ. (4p)

not solving part a) and taking app. $0.7 = V_{BE}$ for part b) 3p.

c) $V_{EC_0} = V_{CE_2} \Rightarrow V_{EC_0} + V_{CE_2} = 5 \Rightarrow V_{EC_0} = V_{CE_2} = 2.5$ v.

$$I_{S_0} e^{\frac{V_{EB_0}}{V_T}} \left(1 + \frac{V_{EC_0}}{V_{AP}}\right) = I_{S_2} e^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE_2}}{V_{AN}}\right)$$

$$5 \times 10^{-13} \times e^{\frac{V_{EB_0}}{0.026}} \left(1 + \frac{2.5}{80}\right) = 10^{-12} \times e^{\frac{0.5208}{0.026}} \left(1 + \frac{2.5}{120}\right)$$

$$e^{\frac{V_{EB_0} - 0.5208}{0.026}} = \frac{10^{-12}\left(1 + \frac{2.5}{120}\right)}{5 \times 10^{-13} \times \left(1 + \frac{2.5}{80}\right)} = 1.9797 \rightarrow$$

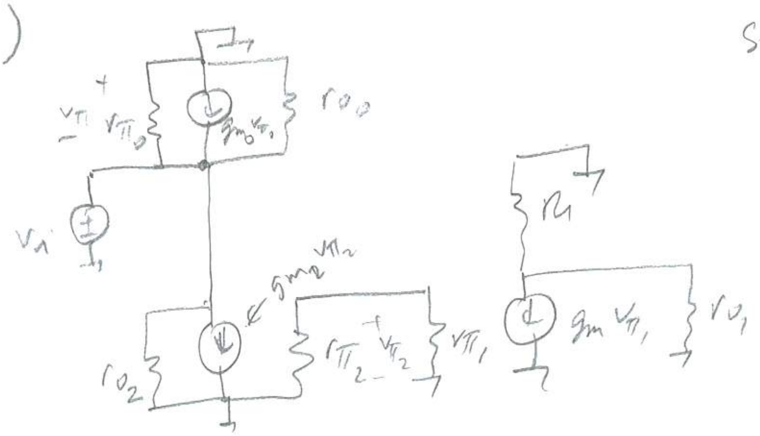
$V_{EB_0} - 0.5208 = 0.026 \times \ln 1.9797 = 0.0178$

$V_{EB_0} = 0.0178 + 0.5208 = 0.5386$

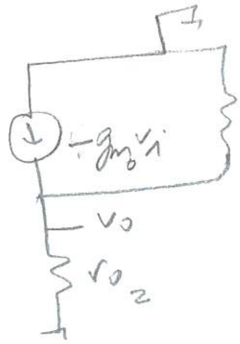
$\Rightarrow V_I = 5 - 0.5386 = 4.461$ v. (10p)

$I_0 = 0.5$

d)



Since $v_{\pi_2} = v_{\pi_1} = 0$ we have



$$\frac{v_o}{v_1} = -g_{m_0}(r_{o_0} // r_{o_2}) \qquad r_{o_0} // r_{o_2} = \frac{\frac{V_{AP}}{I_{C0}} \times \frac{V_{AN}}{I_{C0}}}{\frac{V_{AP}}{I_{C0}} + \frac{V_{AN}}{I_{C0}}}$$

$g_{m_0} \cong I_{C0}/V_T \quad r_{o_0} \cong \frac{V_{AP}}{I_{C0}} \quad r_{o_2} \cong \frac{V_{AN}}{I_{C0}}$

$$= \frac{1}{I_{C0}} \times \frac{1}{\frac{1}{V_{AN}} + \frac{1}{V_{AP}}}$$

$$\therefore \frac{v_o}{v_1} = \frac{-I_{C0}}{V_T} \times \frac{1}{I_{C0}} \frac{1}{\frac{1}{V_{AN}} + \frac{1}{V_{AP}}} = \frac{-\frac{1}{V_T}}{\frac{1}{V_{AN}} + \frac{1}{V_{AP}}}$$

$$= \frac{-1/0.026}{1/80 + 1/120} = -1846 \text{ V/V} \quad (10p)$$

or; $\frac{v_1}{v_o} = -5.42 \times 10^{-4}$

just writing $\frac{v_o}{v_1} = g_m(r_{o_0} // r_{o_2})$ 4p.

$\frac{0.5}{0.026} \times 240 // 160$