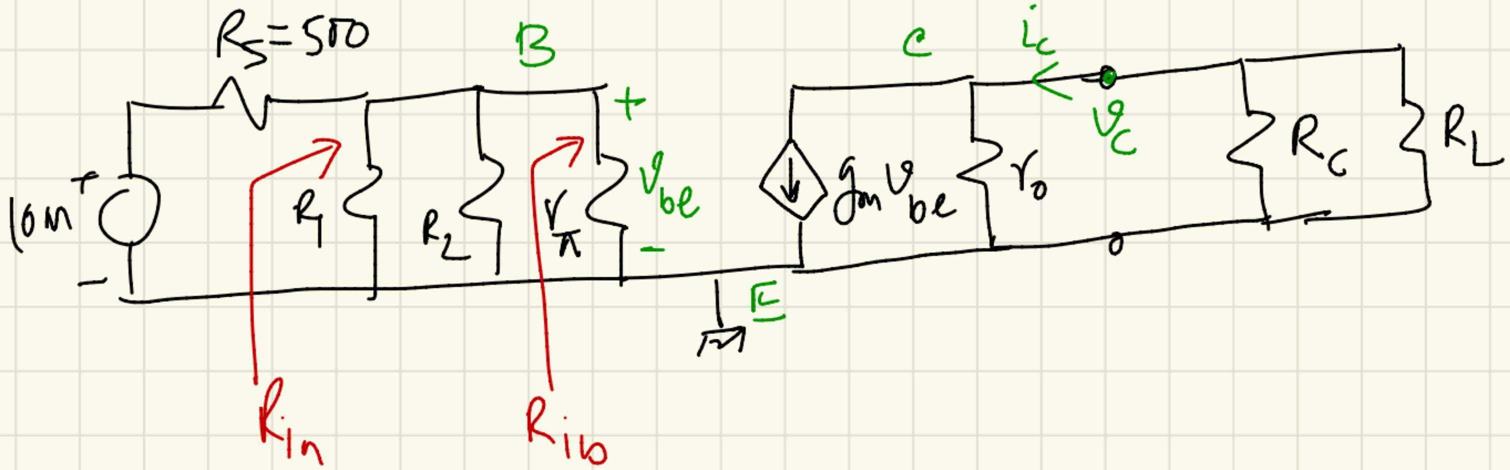
Problem 1

DC analysis will be same as problem 5.

Small Signal Model:



Now, $R_{ib} = r_\pi = 563.1\,\Omega$

$r_o = \dfrac{V_A}{I_C} = 32.15\,k\Omega$

$g_m = I_C/V_T = 124.4\ mA/V$

$R_{in} = R_1 \| R_2 \| r_\pi$

$= 481.6\,\Omega$

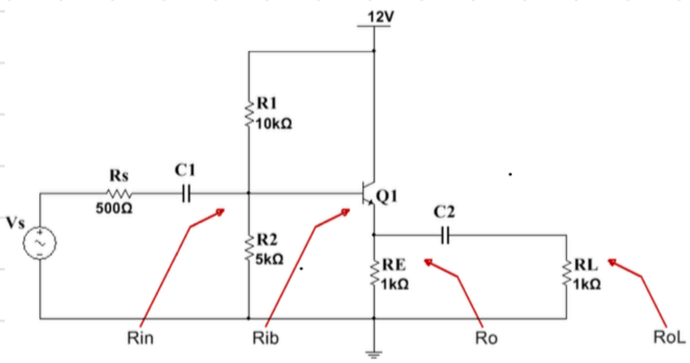
$\therefore\ v_{be} = V_s R_{in}/(R_S + R_{in}) = 4.91\ mV$

$\therefore\ v_c = -g_m v_{be}(r_o \| R_C \| R_L)$

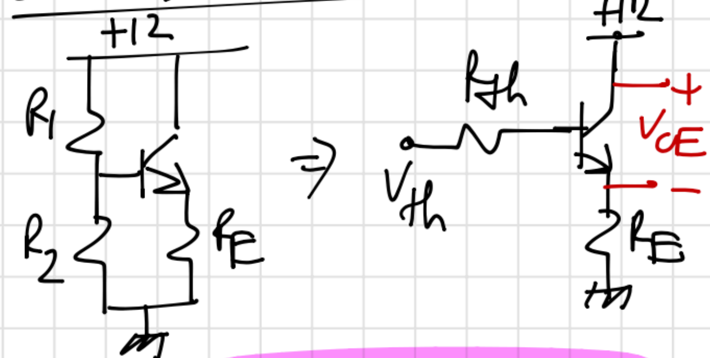
$= -124.4\times10^{-3} \times 4.91\times10^{-3} \times 492.34$

$$\boxed{\begin{aligned} v_c &= -300.7\ mV \\ i_c &= v_c/(R_C \| R_L) = 601.4\ \mu A \end{aligned}}$$

Problem 2



DC Equivalent Circuit:



$$R_{th} = R_1 \| R_2 = 3.33k$$

$$V_{th} = \frac{R_2}{R_1+R_2} 12 = 4V$$

$$V_{th} = I_B R_{th} + V_{BE} + I_E R_E$$

$$\Rightarrow I_E = 3.1522\ mA$$

$$\boxed{\therefore I_C = \frac{\beta}{\beta+1} I_E = 3.1078\ mA}$$

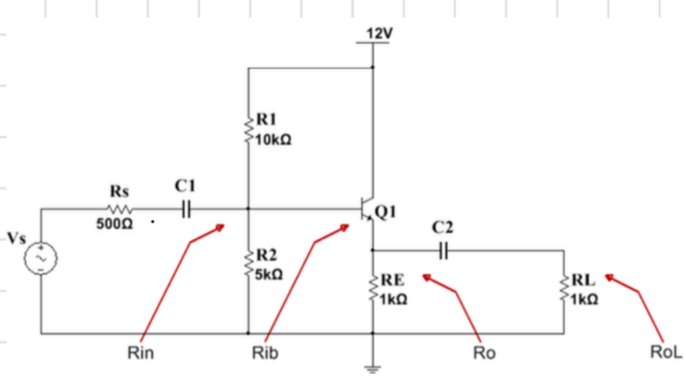
$$\boxed{\begin{aligned} V_{CE} &= 12 - I_E R_E \\ &= 8.8478V \end{aligned}}$$

$$g_m = \frac{I_C}{V_T} = 124.312\ mA/V$$

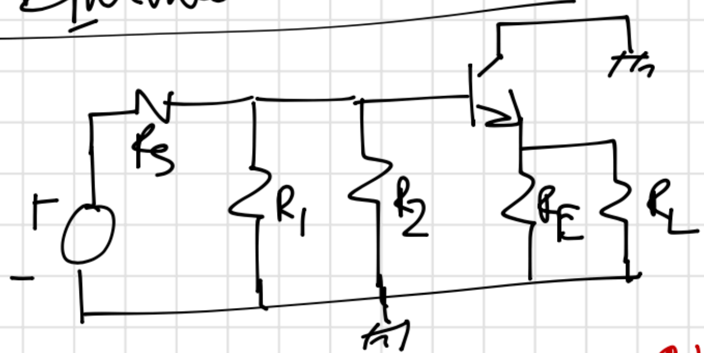
$$r_e = \frac{V_T}{I_E} = 7.931\ \Omega$$

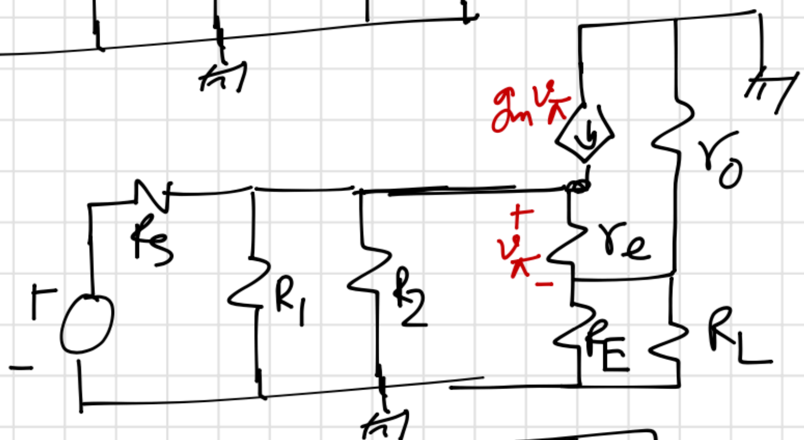
$$r_\pi = \frac{V_T}{I_B} = 563\ \Omega$$

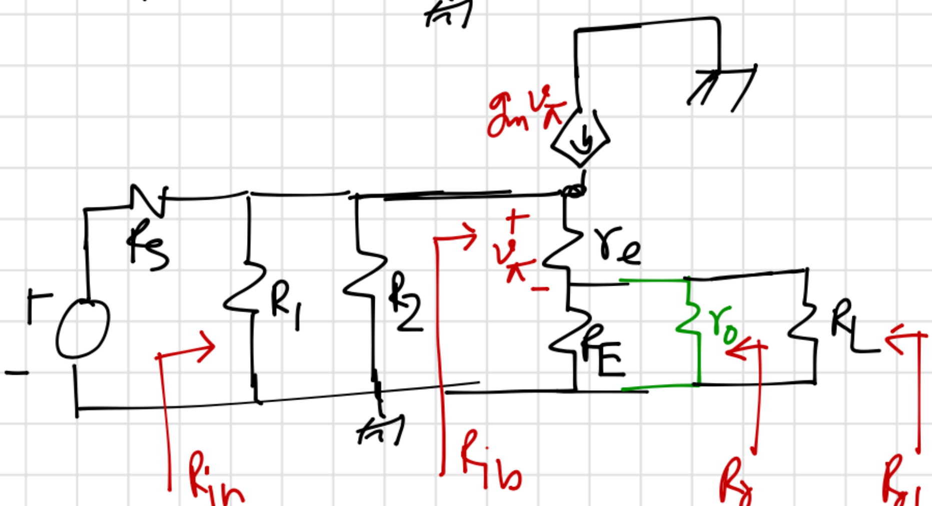
$$r_o = \frac{V_A}{I_C} = 32.18\ \Omega$$



AC Equivalent circuit:



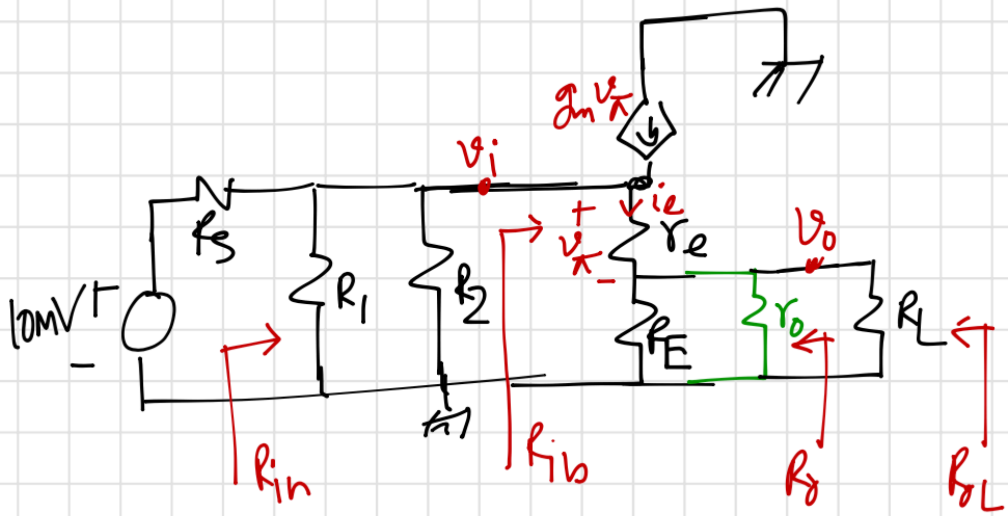




$$R_{ib} = (\beta+1)\left[r_e + (R_E \,\|\, r_o \,\|\, R_L)\right]$$

$$\approx 36\ k\Omega$$

$$R_{in} = R_1 \,\|\, R_2 \,\|\, R_{ib} = 3.0738\ k\Omega$$



$$R_o = r_o \,\|\, R_E \,\|\, \left[r_e + (R_1 \| R_2 \| R_s)/(\beta+1)\right]$$

$$\simeq r_e + (R_1 \| R_2 \| R_s)/(\beta+1)$$

$$= 14\,\Omega$$

$$R_{oL} = R_o \,\|\, R_L = 13.8\,\Omega$$

$$v_i = v_{sig} \frac{R_{in}}{R_{sig}+R_{in}} = 8.6945\,\text{mV}$$

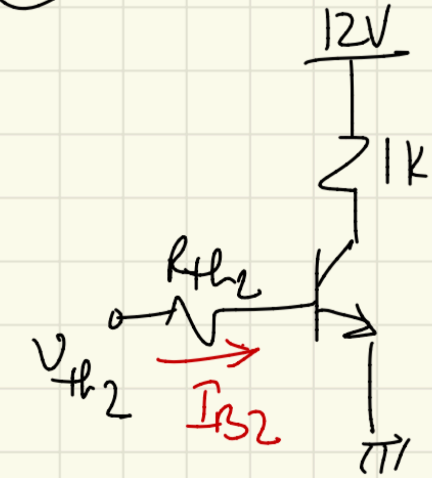
$$i_e = \frac{v_i}{r_e + R_E \| r_o \| R_L} = 17.38\,\mu\text{A}$$

$$v_o = i_e \left(R_E \| r_o \| R_L\right) = 8.55\,\text{mV}$$

Problem 3

For the first stage, DC analysis and small signal parameters are same as before.

For the second stage:



$$R_{th_2} = R_5 \| R_6 = 2.775\,k\Omega$$

$$V_{th_2} = \frac{R_6}{R_5+R_6} 12 = 0.9V$$

$$\therefore I_{B2} = \frac{0.9-0.7}{R_{th2}} = 72.1\,\mu A$$

$$I_{C_2} = 5.047\,mA$$

$$I_{E_2} = 5.12\,mA$$

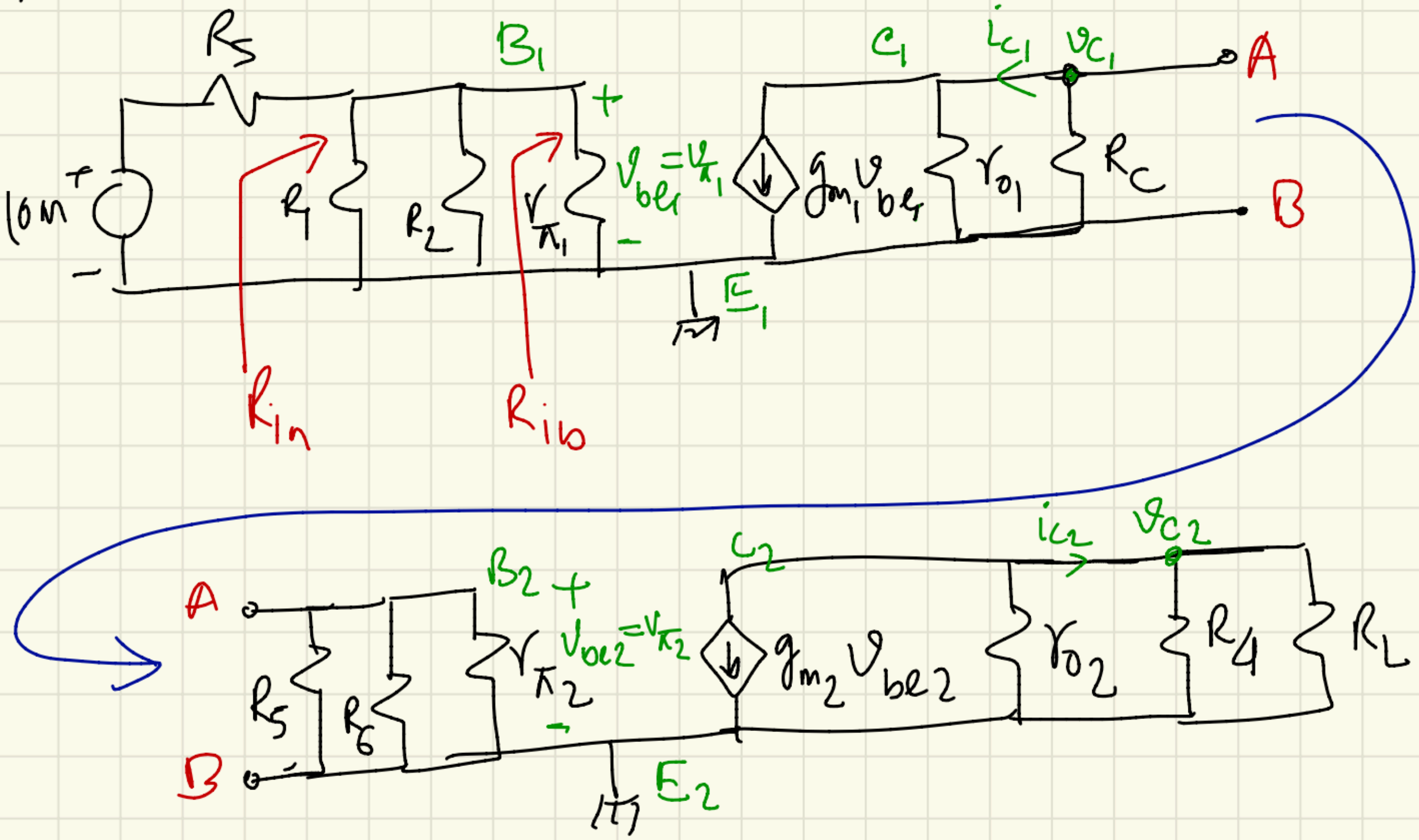
$$g_{m_2} = \frac{I_{C_2}}{V_T} = 201.88\,mA/V$$

$$r_{e_2} = \frac{V_T}{I_{E_2}} = 4.88\,\Omega$$

$$r_{\pi_2} = \frac{V_T}{I_{B2}} = 346.741\,\Omega$$

$$r_{o_2} = V_A / I_C = 19.81\,k\Omega$$

Small signal Model:



$$\therefore \; v_{c_1} = -g_{m_1} v_{be_1} \left(r_{o_1} \| R_C \| R_5 \| R_6 \| r_{\pi_2} \right)$$

$$r_{o_1} \| R_C \| R_5 \| R_6 \| r_{\pi_2} = 269.76\,\Omega$$

$$v_{c_1} = -41.1 \times 10^{-3} \times 8.5 \times 10^{-3} \times 269.76$$

$$= -94.2\,mV$$

$$R_C \| R_5 \| R_6 \| r_{\pi_2} = 270.51$$

$$\therefore \; i_{c_1} = v_{c_1} / \left(R_C \| R_5 \| R_6 \| r_{\pi_2} \right)$$

$$= 348.2\,\mu A$$

Now, $v_{be_2} = v_{c_1} = -94.2\,mV$

$r_{o_2} \| R_4 \| R_L = 487.7\,\Omega$

$\therefore v_{c_2} = g_{m_2} v_{be2} (r_{o_2} \| R_4 \| R_L)$

$= 201.88 \times 10^{-3} \times 94.2 \times 10^{-3} \times 487.7$

$= 9.275\,V$ → see that it is a positive value.

$i_{c_2} = v_{c2} / (R_4 \| R_L)$

$= 9.275/500$

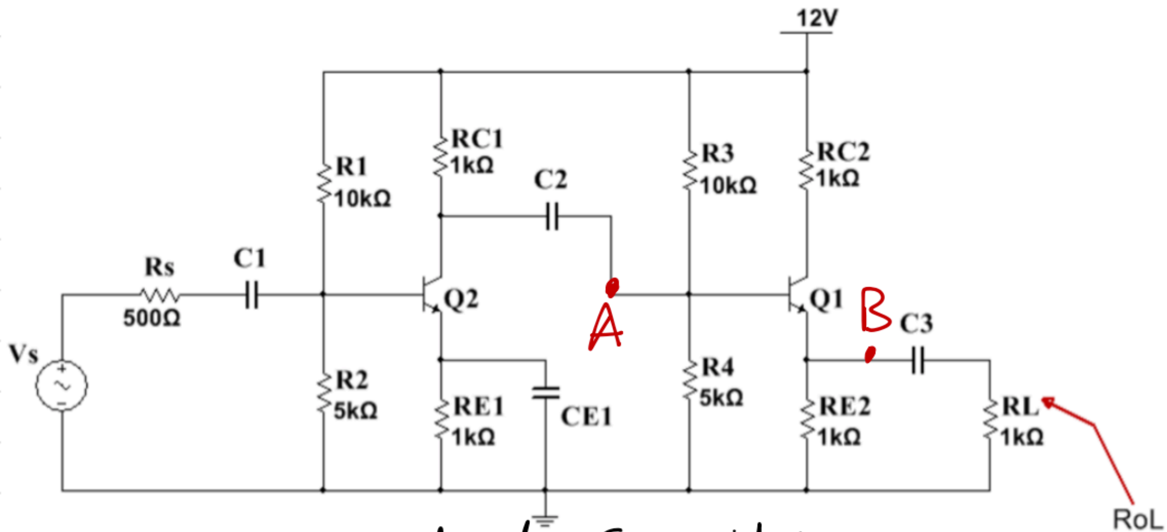
$= 18.6\,mA$

→ look at the considered direction of i_{c_2} in the circuit.

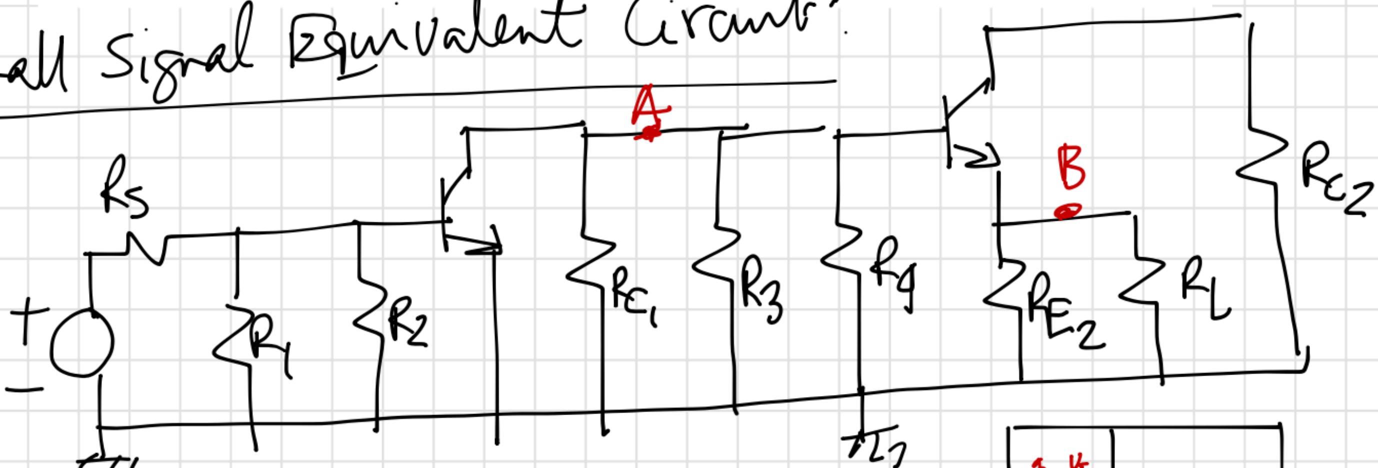
→ If opposite direction is considered, i_{c_2} will be negative.

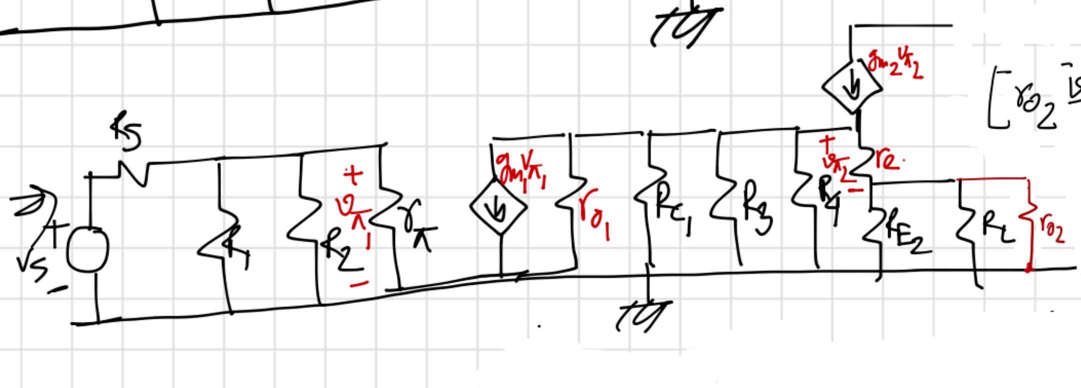
Problem 4

Biasing and small signal parameters are as same as Problem 5 for both first and second stages.

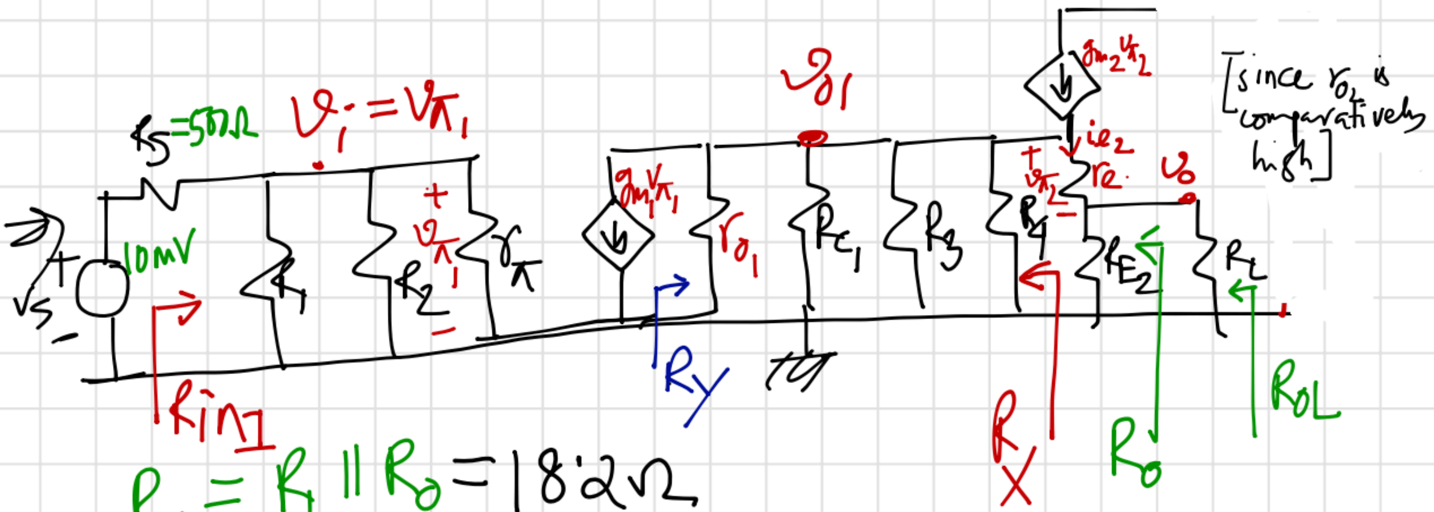


Small Signal Equivalent Circuit:





[r_{o_2} is comparatively high]



$$R_{oL} = R_L \| R_o = 18.2\Omega$$

$$R_o = R_{E_2} \| \left[r_e + R_X/(\beta+1)\right] = 18.5\Omega$$

$$R_X = R_4 \| R_3 \| R_{C_1} \| r_{o_1} = 750\Omega$$

$$v_i = v_S \frac{R_{in1}}{R_S + R_{in1}} \quad \text{where } R_{in1} = R_1 \| R_2 \| r_\pi$$

$$R_y = r_{o_1} \| R_{C_1} \| R_3 \| R_4 \| \left[(r_e + R_{E_2} \| R_L)\cdot(\beta+1)\right]$$

$$v_{o1} = -g_{m_1} v_i R_y$$

$$v_o = i_{e_2}(R_{E_2} \| R_L)$$

$$i_{e_2} = \frac{v_{o1}}{r_e + R_{E_2} \| R_L}$$

$$\therefore v_o = \frac{v_{o1}}{r_e + R_{E_2} \| R_L}(R_{E_2} \| R_L) \approx v_{o1} \quad \left[\because R_{E_2} \| R_L >> r_e\right]$$