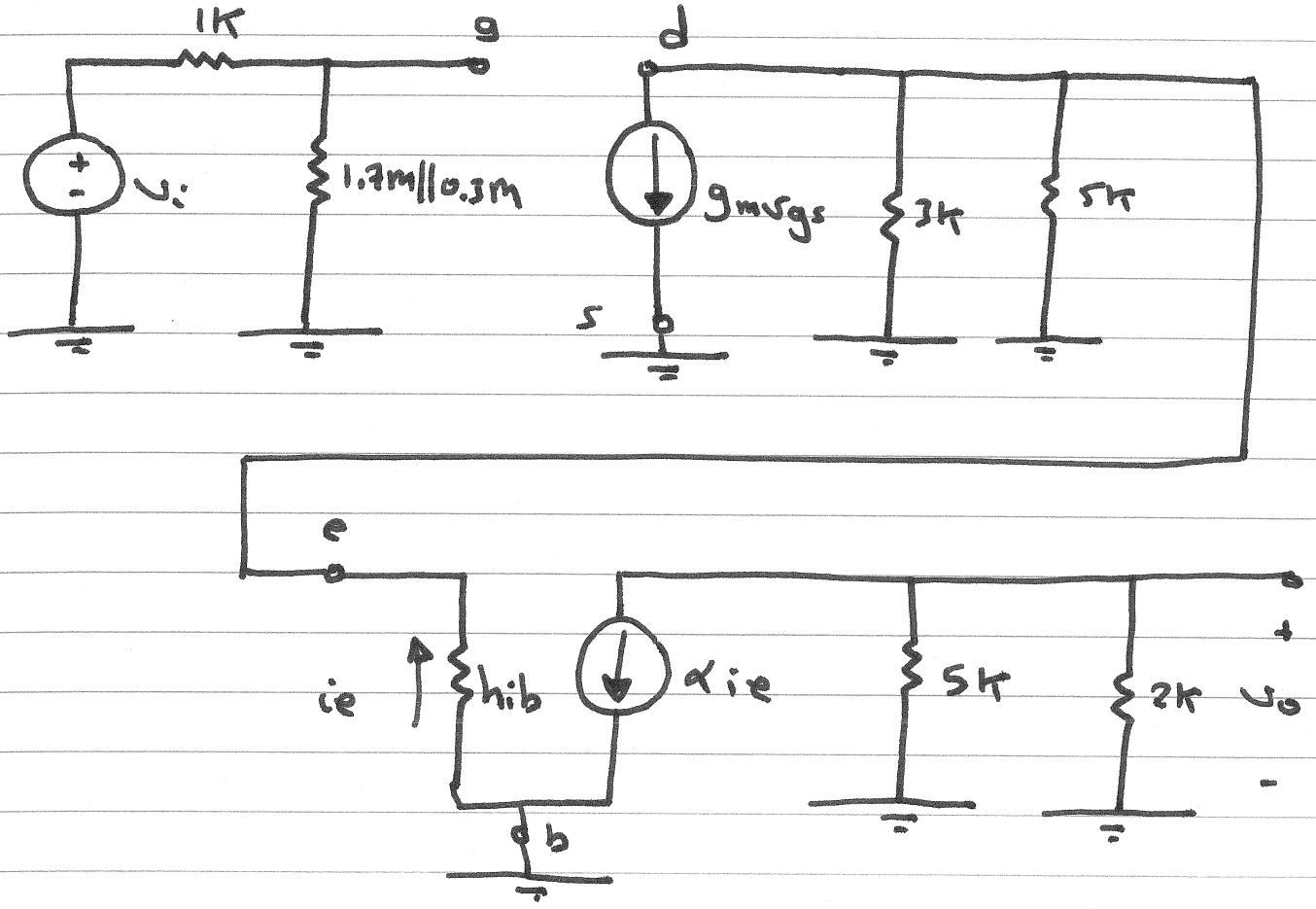
Solutions of Multistage Amplifiers

Q1 : $h_{ib} = \frac{h_{ie}}{1+h_{fe}} \approx 30\,\Omega$



$$v_o = -(5K \| 2K)\,\alpha\, i_e$$

$$i_e = +g_m v_{gs} \frac{3K \| 5K}{3K \| 5K + h_{ib}}$$

$$v_{gs} = v_g - v_s = v_g = \frac{0.3M \| 1.7M}{0.3M \| 1.7M + 1K} v_i$$

$\therefore A_v = -5.62$

Q_2

$$V_{TH} = \frac{10K}{10K+47K} \cdot 15V = 2.6V$$

$$R_{TH} = 10K \| 47K = 8.25K$$

$$I_{E_1} = \frac{V_{TH} - 0.7}{\frac{R_{TH}}{\beta_1+1} + R_{E_1}} = 1.825mA$$

$$h_{ie_1} = \frac{(\beta_1+1)\, V_T}{I_{E_1}} = 2.85K$$

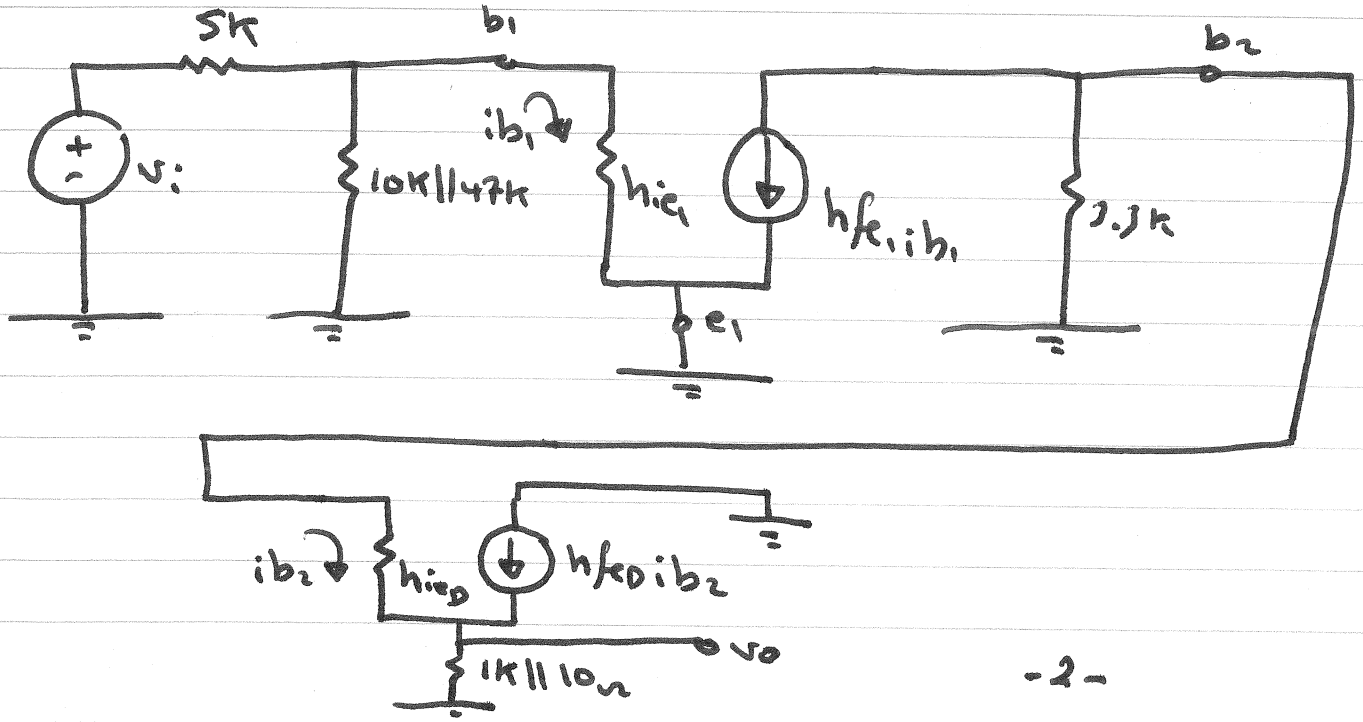
$$V_{CC} = 3.3K\,(I_{C_1} + I_{B_2}) + 0.7 + 0.7 + 1K\, I_{E_3}$$

$$I_{E_3} = (\beta_3+1)(\beta_2+1)\, I_{B_2}$$

$$\therefore I_{E_2} = 0.075\ mA \quad ; \quad I_{E_3} = 7.575\ mA$$

$$h_{ie_2} = 34.67K\Omega \quad \therefore h_{ieD} \cong 70K$$

$$h_{feD} \cong h_{fe_2} \cdot h_{fe_3} = 10000$$



$$v_o = (1k \| 10\Omega)(1 + h_{fe_2}) i_{b_2}$$

$$i_{b_2} = -h_{fe} i_{b_1} \frac{3.3k}{3.3k + h_{ie_2} + (1k \| 10\Omega)(1 + h_{fe_2})}$$

$$i_{b_1} = \frac{8.25k}{8.25k + h_{ie_1}} i_i$$

$$i_i = \frac{v_i}{5k + Z_i}$$

$$Z_i = 8.25k \| 2.85k \approx 2.1k$$

$$\therefore v_o \approx -40 v_i$$

b) $v_o = -h_{fe} i_{b_1} (3.3k \| 10\Omega)$

$i_{b_1} = 0.74 i_i$

$i_i = 0.14 v_i$

$\therefore v_o = -0.207 v_i$

Q3

$$V_{G_1} = \frac{1M}{1M+1.5M} \cdot 20 = 8V$$

$$V_{S_1} = 4.7k\, I_{DS_1}$$

$$I_{DS_1} = I_{DSS}\left(1 - \frac{V_{GS_1}}{V_P}\right)^2$$

$$\therefore I_{DS_1} = \begin{cases} 1.92mA & \checkmark \\ 2.36mA & \times \end{cases}$$

KVL : $4.1k\, I_{DS_2} + V_{GS_2} - 4.7k\, I_{DS_2} = 0$

$$\therefore V_{GS_2} = -7.9 + 4.7k\, I_{DS_2}$$

$$I_{DS_2} = I_{DSS}\left(1 - \frac{V_{GS_2}}{V_P}\right)^2$$

$$\therefore I_{DS_2} = \begin{cases} 2.33mA & \times \\ 1.89mA & \checkmark \end{cases}$$

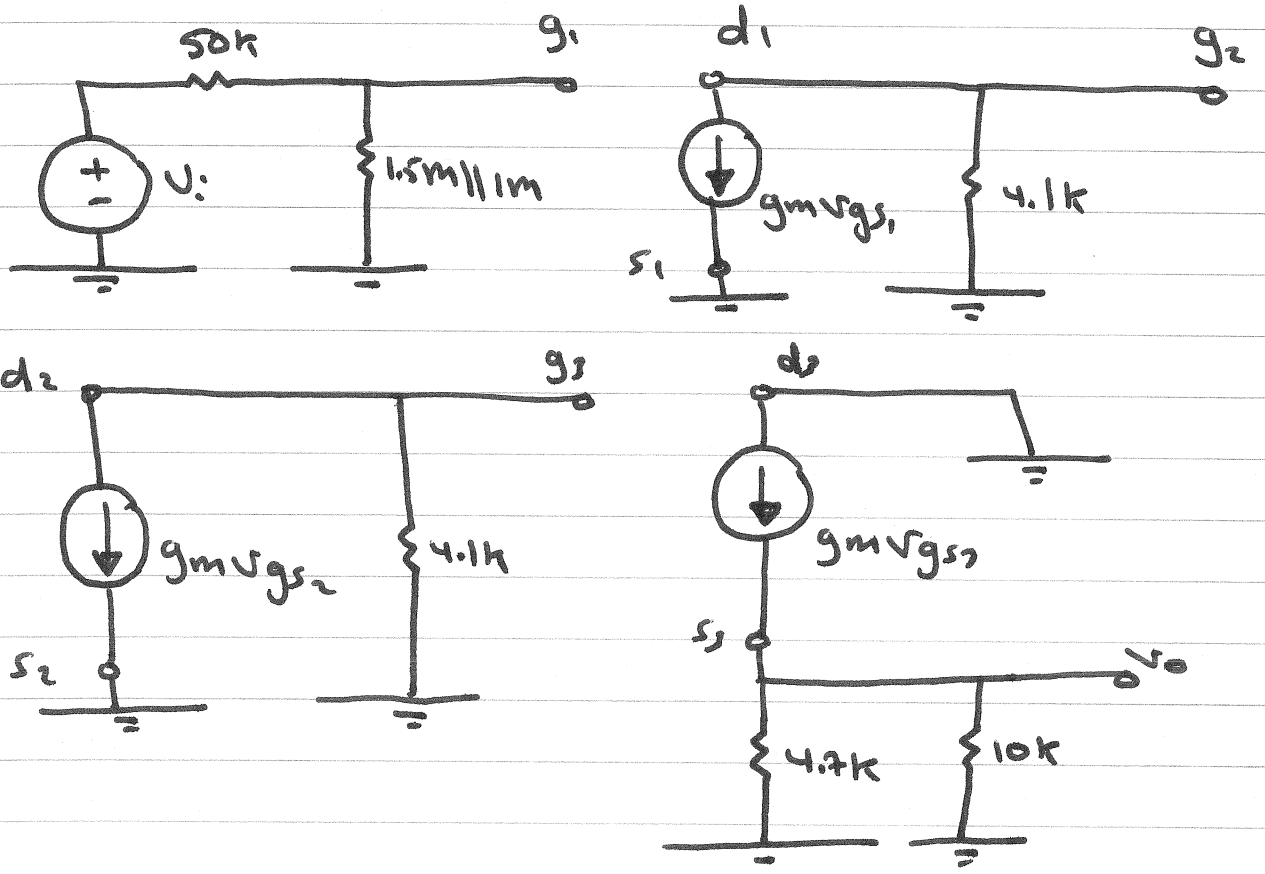
KVL : $V_{GS_3} + 4.7k\, I_{DS_3} - 4.1k\, I_{DS_2} = 0$

$$\therefore V_{GS_3} = 7.8 - 4.7k\,(I_{DS_3})$$

$$I_{DS_3} = I_{DSS}\left(1 - \frac{V_{GS_3}}{V_P}\right)^2$$

$\therefore I_{DS_3} = \begin{cases} 1.88\ mA & \checkmark \\ 2.3\ mA & \times \end{cases}$

$g_{m_1} \approx g_{m_2} \approx g_{m_3} = 3.9\ mS$



$V_o = (4.7k \| 10k)\ g_m v_{gs_3}$

$v_{gs_3} = v_{g_3} - v_{s_3}$

$v_{s_3} = v_o$

$v_{g_3} = -g_m v_{gs_2}(4.1k)$

$v_{gs_2} = v_{g_2} - v_{s_2} = v_{g_2} = -g_m v_{gs_1}(4.1k)$

$v_{gs_1} = v_{g_1} - v_{s_1} = v_{g_1} = \dfrac{1.5m \| 1m}{1.5m \| 1m + 50k} v_i$

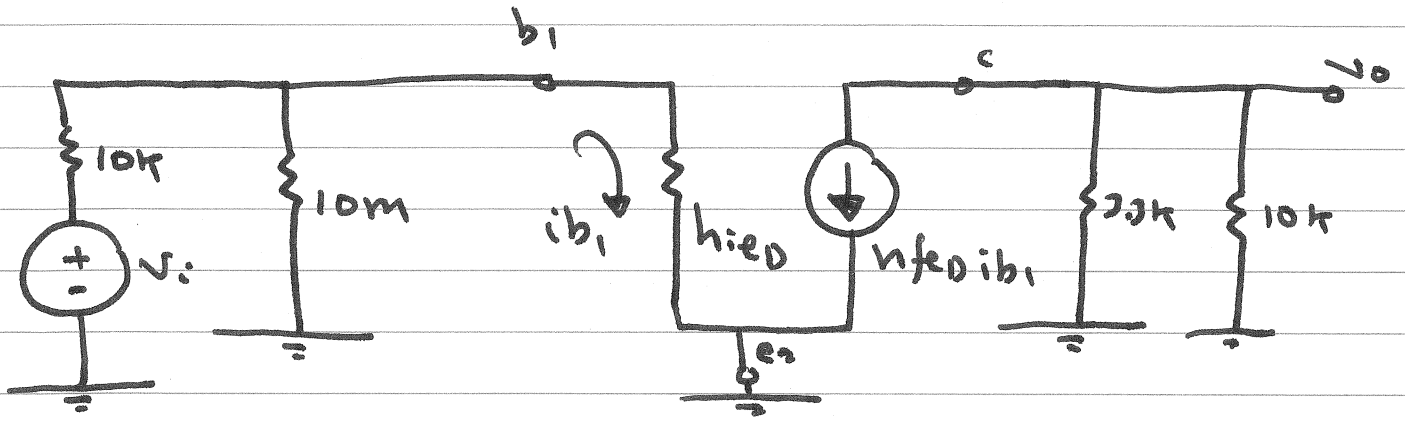
$\therefore A_V \cong 218$

Q4

$$5 = 10M I_{B1} + 0.7 + 0.7$$

$$\therefore I_{B1} = 0.36\,MA$$

$$\therefore h_{ie1} \cong 72K \longrightarrow h_{ieD} = 144K$$



$$V_o = -h_{feD}\, i_{b1} (3.3K \| 10K)$$

$$i_{b1} = \frac{10M}{10M + h_{ieD}}\, i_i$$

$$i_i = \frac{V_i}{10K + 10M \| h_{ieD}}$$

$$\therefore A_V \cong -40$$