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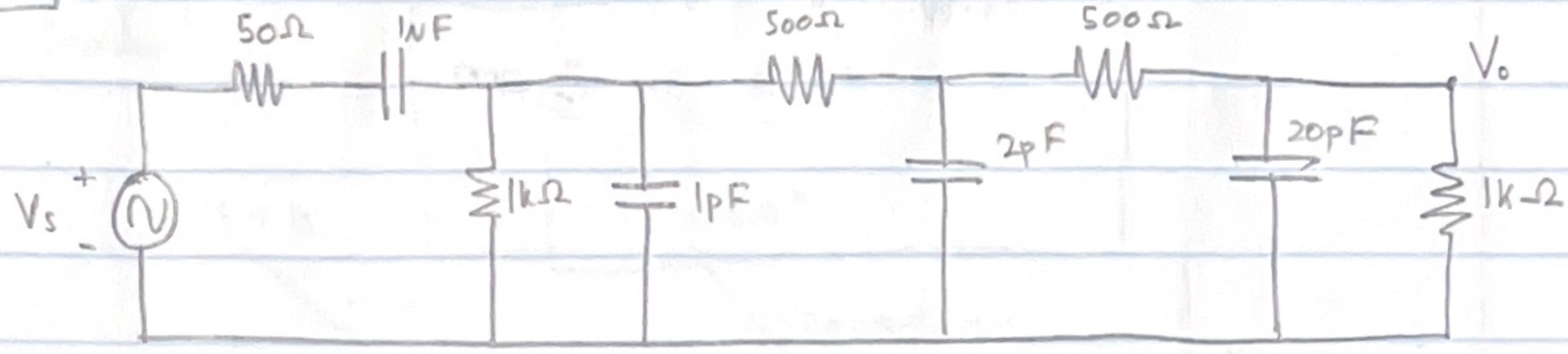
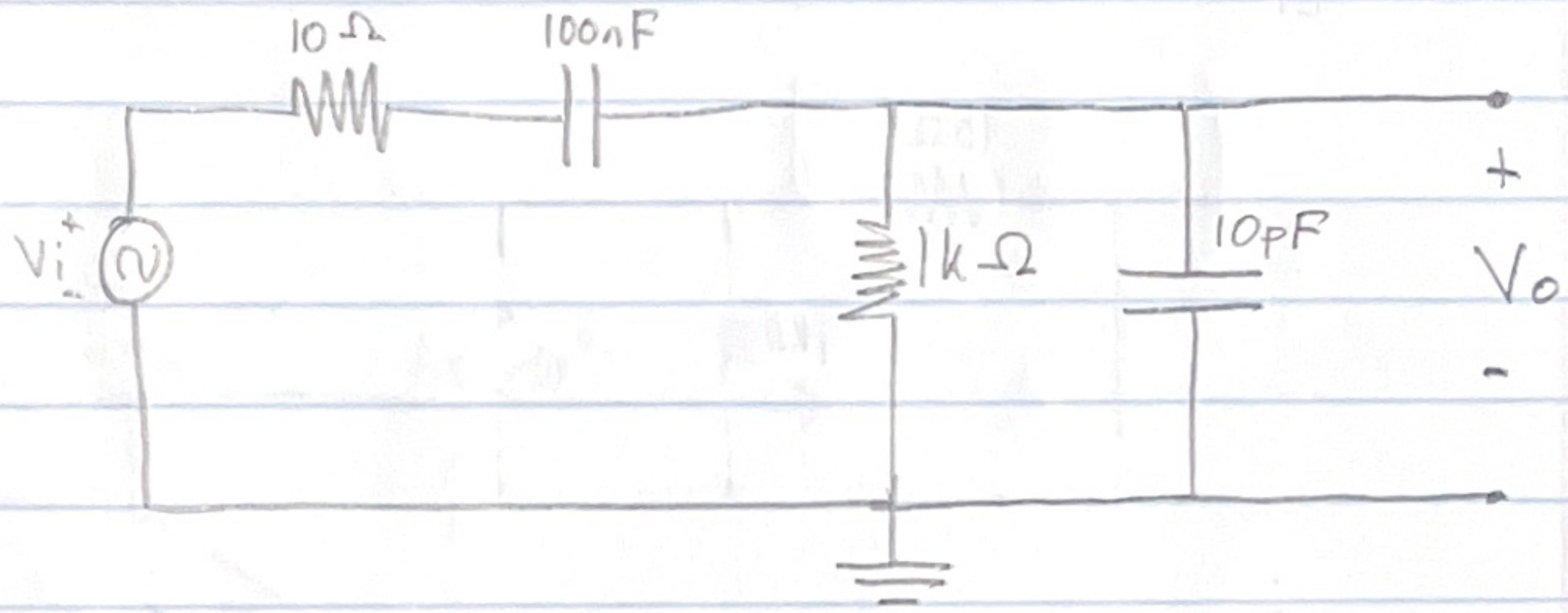
Problem Set 2

Q3

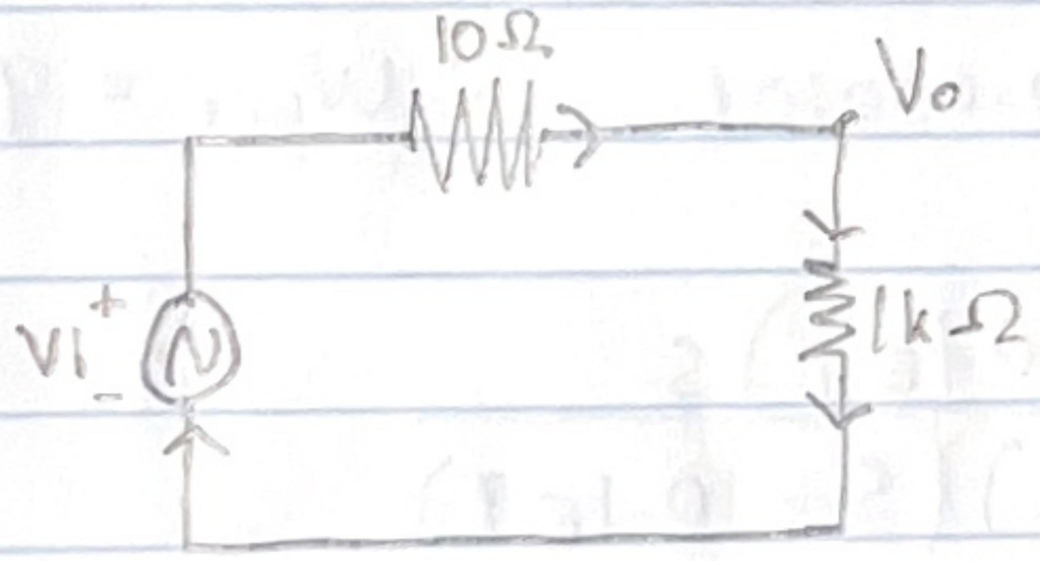


Q2



$T(s) = A_M F_L(s) F_H(s)$

Solving for A_M:



KCl: $\frac{V_i - V_o}{10} = \frac{V_o}{1000}$

$\frac{V_i}{10} - \frac{V_o}{10} = \frac{V_o}{1000}$

$\frac{V_i}{10} = \frac{V_o}{1000} + \frac{V_o}{10}$

$V_i = \frac{V_o}{100} + V_o$

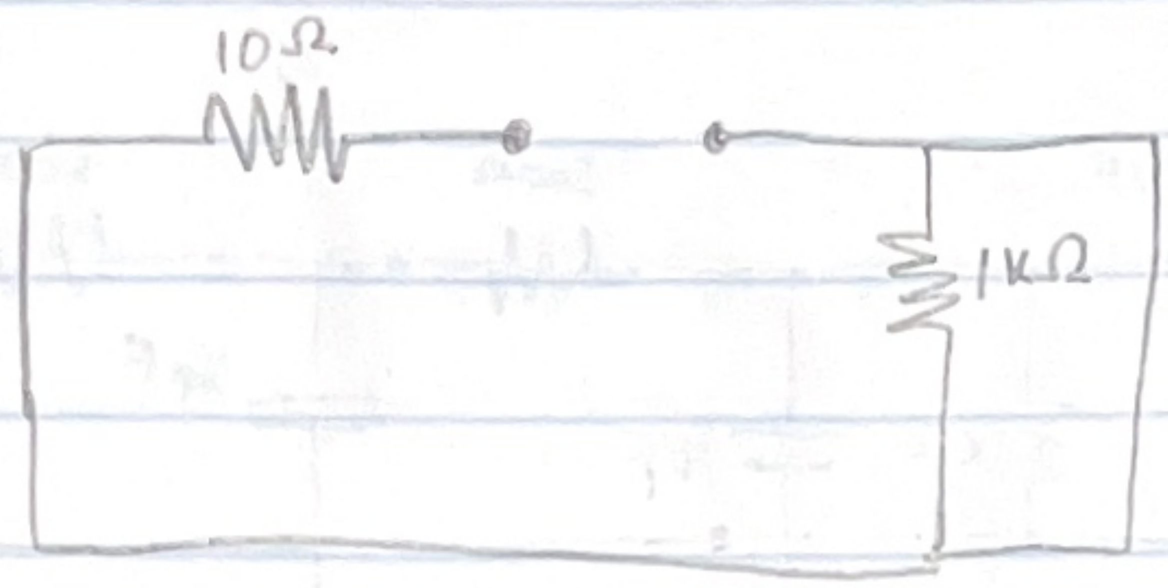
$V_o\left(\frac{1}{100} + 1\right) = V_i$

$\frac{V_o}{V_i} = \left(\frac{1}{100} + \frac{100}{100}\right)^{-1}$

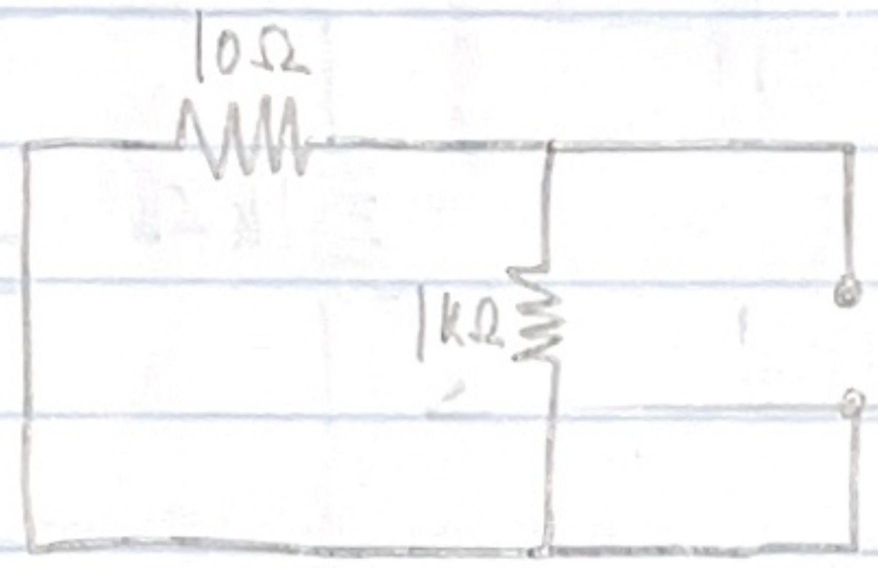
$\frac{V_o}{V_i} = \left(\frac{101}{100}\right)^{-1}$

$\frac{V_o}{V_i} = \frac{100}{101} = \boxed{0.99}$

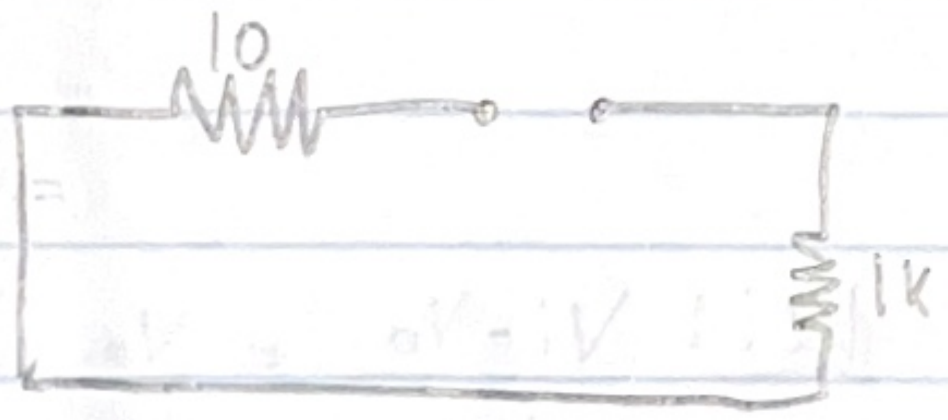
$F_L(s)$:



$T_{C1}^{sc} = 100nF(10) = 10^{-6}$



$T_{C2}^{sc} = 10pF(10 \| 1k) = 9.9E(-11)$ ✓ $\therefore W_{HP1} \approx 1.01 \times 10^{10}$

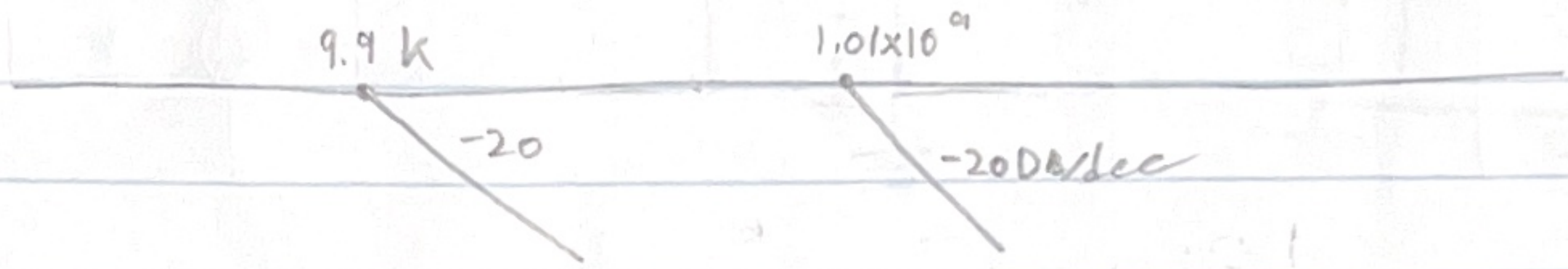


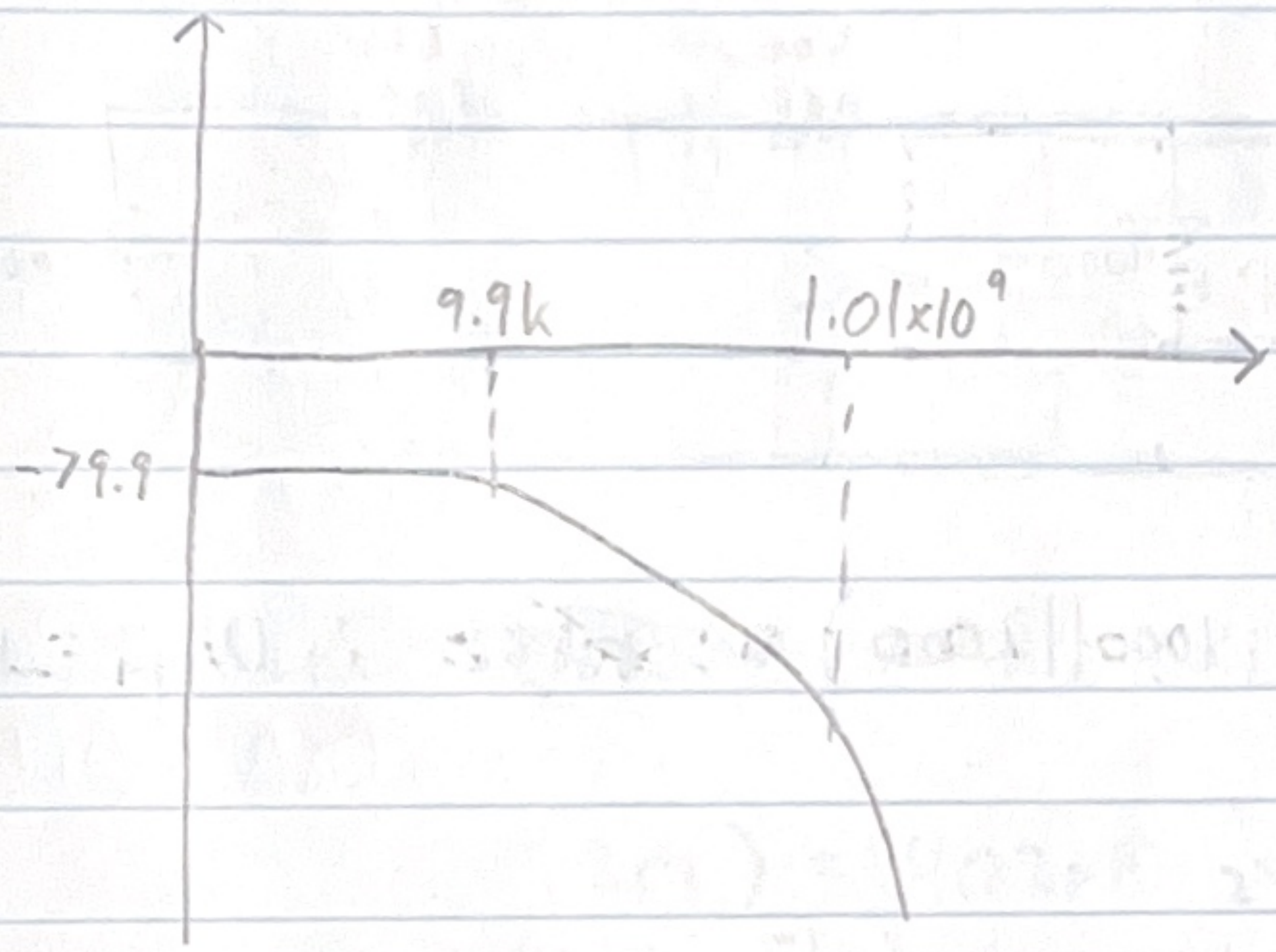
$T_{C1}^{oc} = 100nF(1010) = 0.000101$ $\therefore W_{LP1} \approx 9.9k$ rad/s

$$T(s) = (0.99) \cdot \frac{(10.1E9)s}{(s+9.9E3)(s+10.1E9)}$$

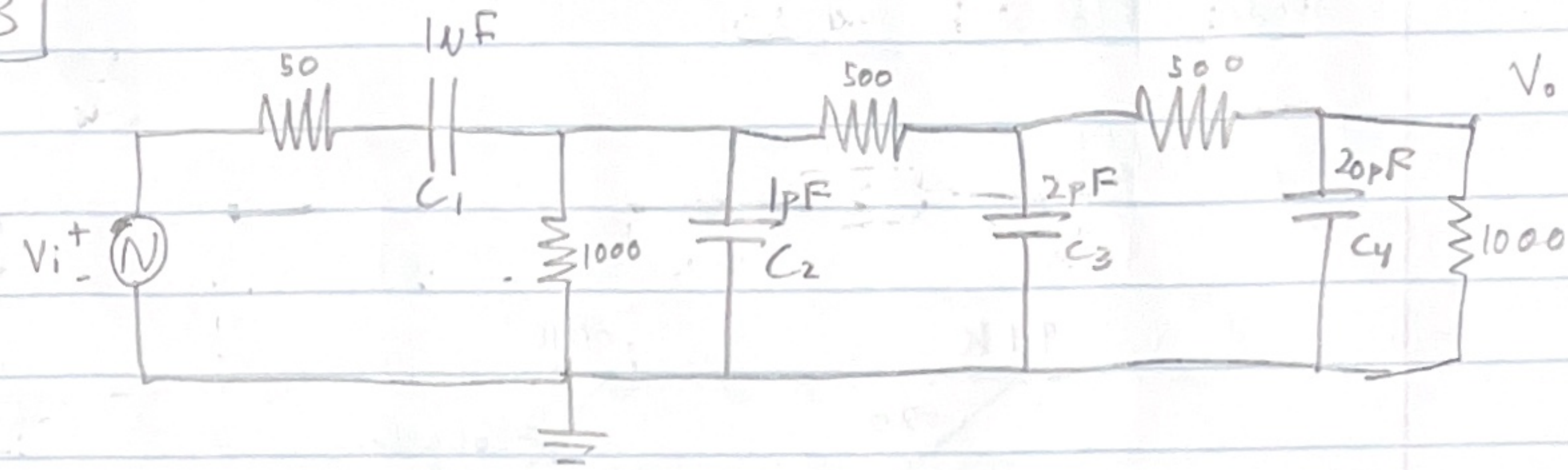
Bode Plots :

Magnitude

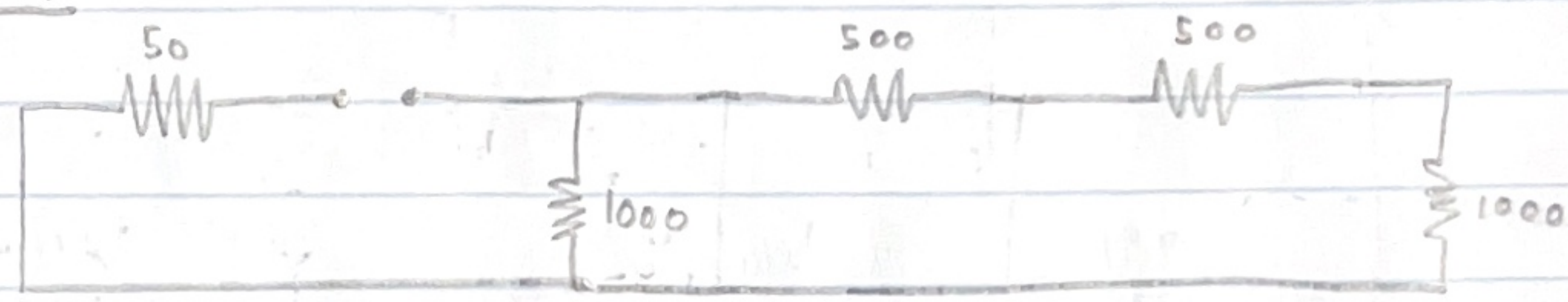




Q3



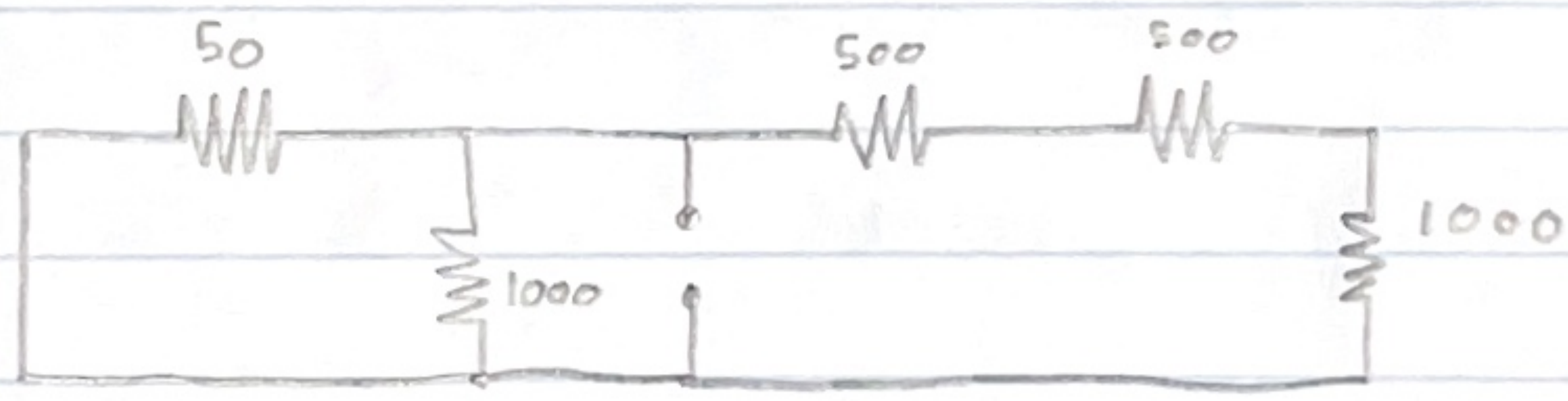
$F_L(s)$:



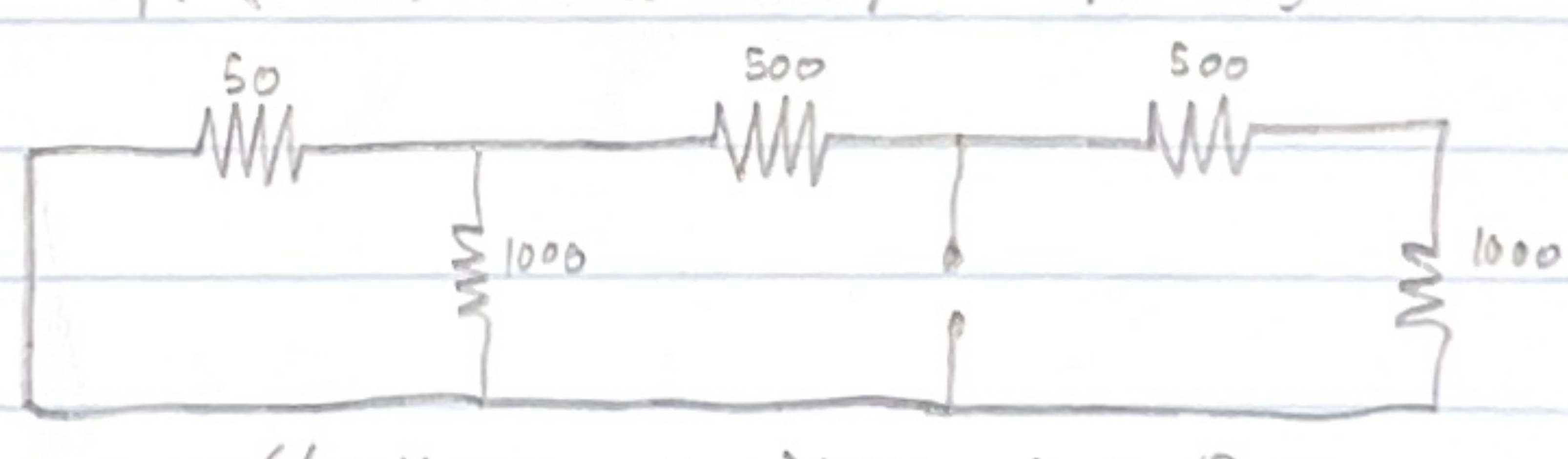
$T_{C1}^{sc} = 1nF(50 + 1000||2000)$ $\therefore W_{Lp1} =$

$W_{L3dB} = 1400$ rad/s

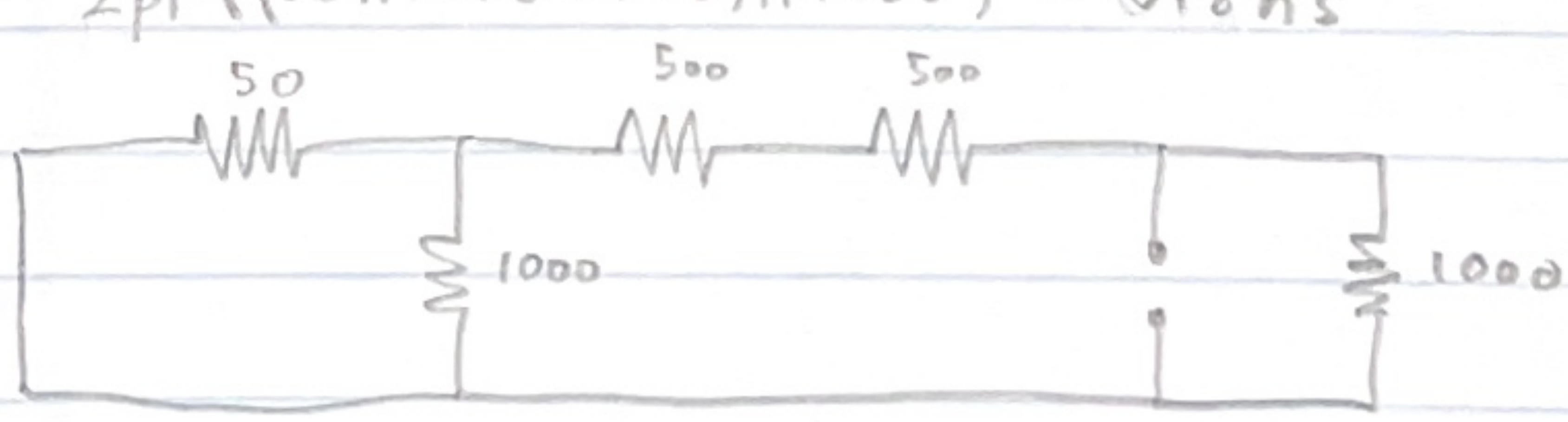
$F_H(s)$:



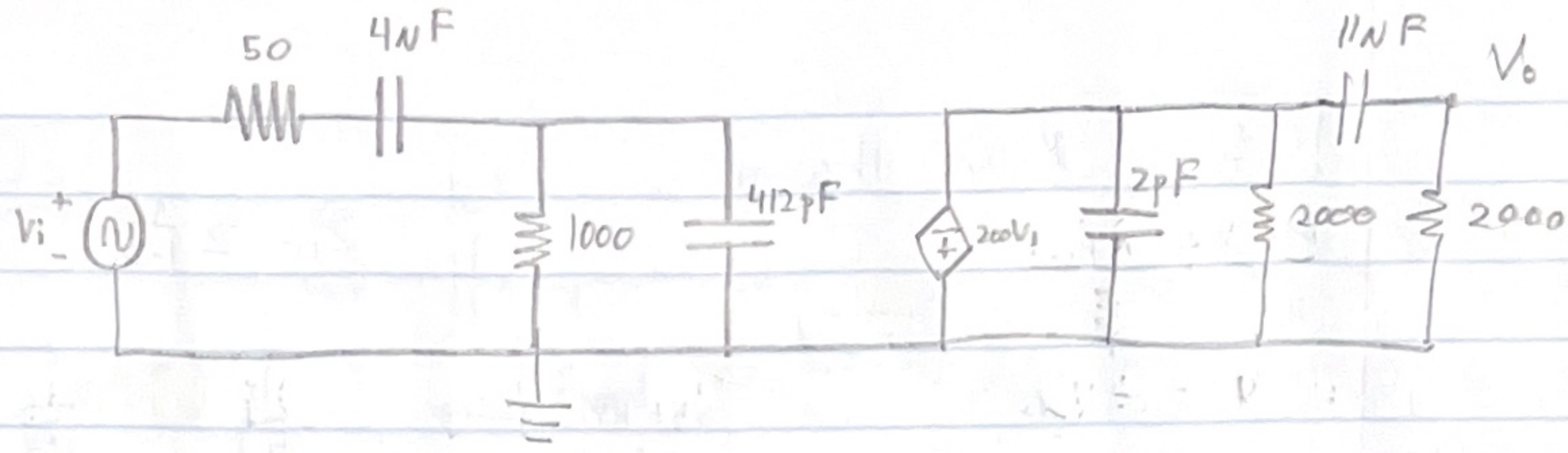
$T_{C2}^{oc} = 1pF(50||1000||2000) = 4.65 \times 10^{-11}$



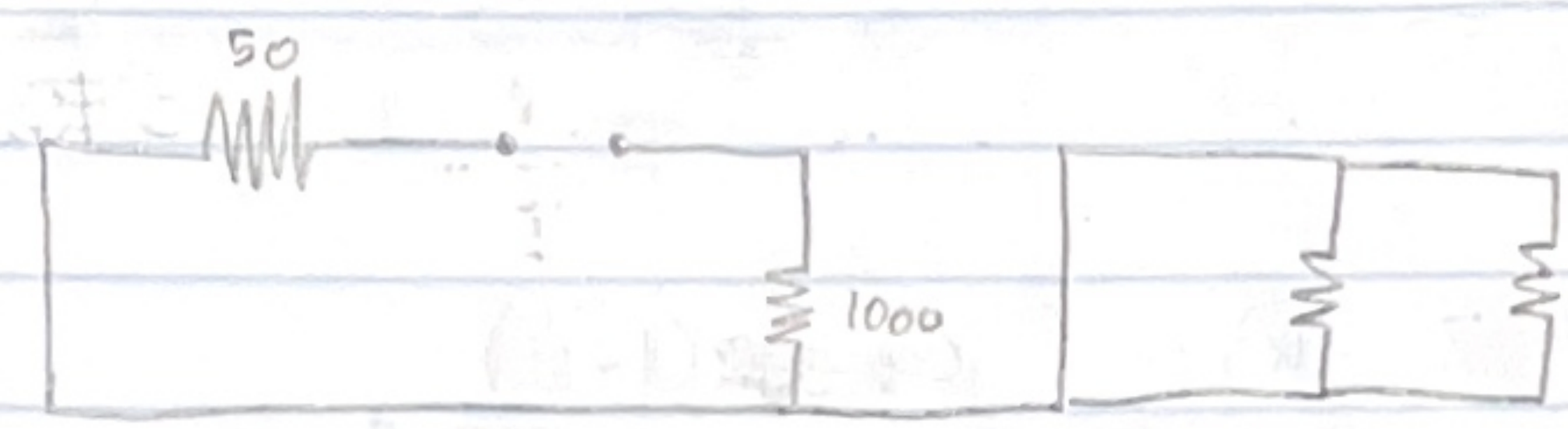
$T_{C3}^{oc} = 2pF((50||1000 + 500)||1500) = 0.8ns$



$T_{C4}^{oc} = 20pF((50||1000 + 1000)||1000) = 10.23ns$



$F_L(s)$



$\tau_{C1}^{sc} = 4NF(1050) \rightarrow \omega_{LP1} = 166.67$ rad/s

Problem Set 3

① 1/3 Rule:

① $V_B = \frac{1}{3}V_{cc}$
② $V_C = \frac{2}{3}V_{cc}$ $\longrightarrow$
③ $I_1 = {}^{I_E}/\sqrt{\beta}$

① $R_{B1} = \dfrac{\frac{2}{3}V_{cc}}{I_E/\sqrt{\beta}}$ ② $R_{B2} = \dfrac{R_{B1}}{2} \dfrac{1}{1 - 1/\sqrt{\beta}}$

③ $R_C = \dfrac{\frac{1}{3}V_{cc}}{I_C}$ ④ $R_E = \dfrac{1/3 V_{cc} - V_{BE}}{I_E}$

② 1/3 Rule:

① $V_C = \frac{2}{3}V_{cc}$
② $V_E = \frac{1}{3}V_{cc}$ $\longrightarrow$
③ $I_1 = {}^{I_E}/\sqrt{\beta}$

① $R_{B1} = \dfrac{\frac{2}{3}V_{cc} - V_{BE}}{I_E/\sqrt{\beta}}$ ② $R_{B2} = \dfrac{\frac{1}{3}V_{cc} + V_{BE}}{I_E/\sqrt{\beta} - I_B}$

$\boxed{Q1}$ ① 1/3 Rule:

① $V_C = \frac{2}{3}V_{cc}$
② $V_B = \frac{1}{3}V_{cc}$ $\longrightarrow$
③ $I_1 = \dfrac{I_E}{\sqrt{\beta}}$

① $R_{B1} = \dfrac{V_C}{I_1}$ ② $R_{B2} = \dfrac{R_{B1}}{2} \dfrac{1}{1 - 1/\sqrt{\beta}}$

③ $R_C = \dfrac{V_B}{I_C}$ ④ $R_E = \dfrac{V_B - V_{BE}}{I_E}$

$V_{cc} = 15\,V$
$I_C = 2mA$

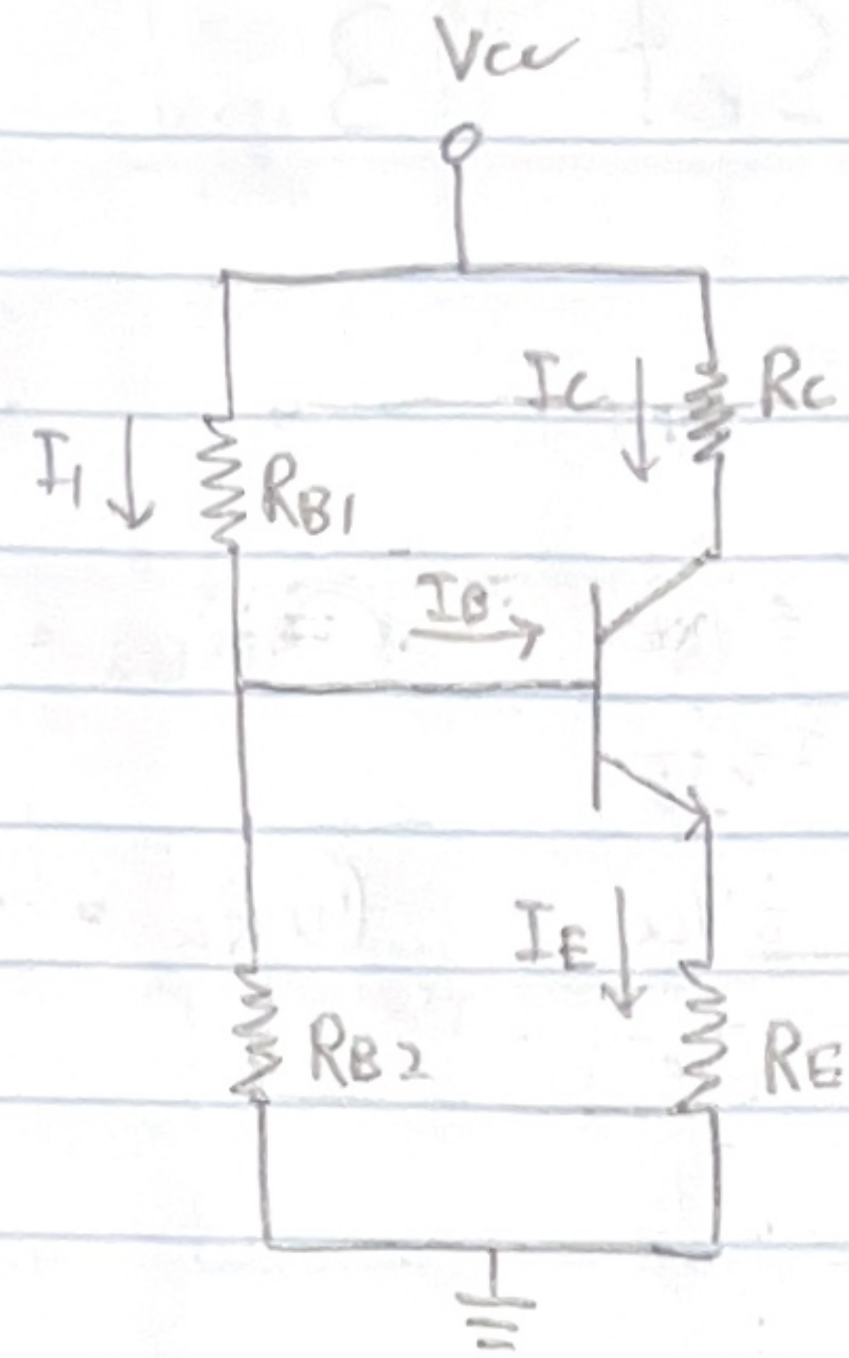
$\boxed{\begin{array}{l} ①\ V_C = 10V \\ ②\ V_B = 5V \end{array}}$

$I_E = \frac{1}{\alpha} I_C$
$= \frac{101}{100} \cdot 2mA = 2.02mA$

$I_1 = \dfrac{2.02mA}{10} = 0.202mA$

$\boxed{\begin{array}{l} R_{B1} = 49.5\,k\Omega \\ R_{B2} = 27.5\,k\Omega \\ R_C = 2.6\,k\Omega \\ R_E = 2.128\,k\Omega \end{array}}$

Q2



② 1/3 Rule:

① $V_C = \frac{2}{3} V_{CC}$
② $V_E = \frac{1}{3} V_{CC}$ →
③ $I_1 = \frac{I_E}{\beta}$

① $R_{B1} = \frac{V_C - V_{BE}}{I_1}$ ② $R_{B2} = \frac{V_E + V_{BE}}{I_1 - I_B}$

③ $R_C = R_E = \frac{V_E}{I_C}$

$V_{CC} = 12V$

$R_E = 8k\Omega$

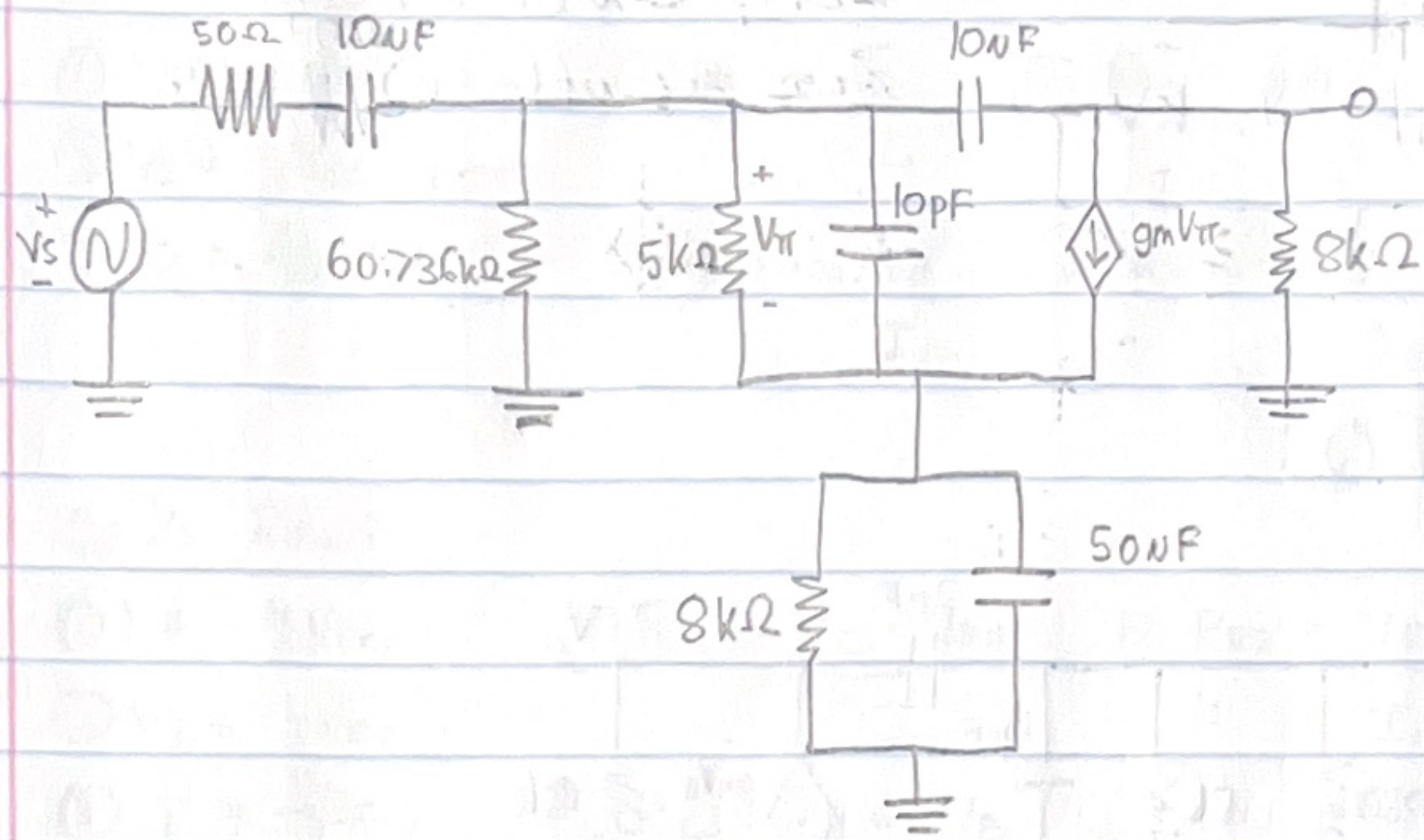
① $\boxed{V_C = 8V}$ $\boxed{V_E = 4V}$

$\boxed{R_C = 8k\Omega} = \frac{4V}{I_C}$

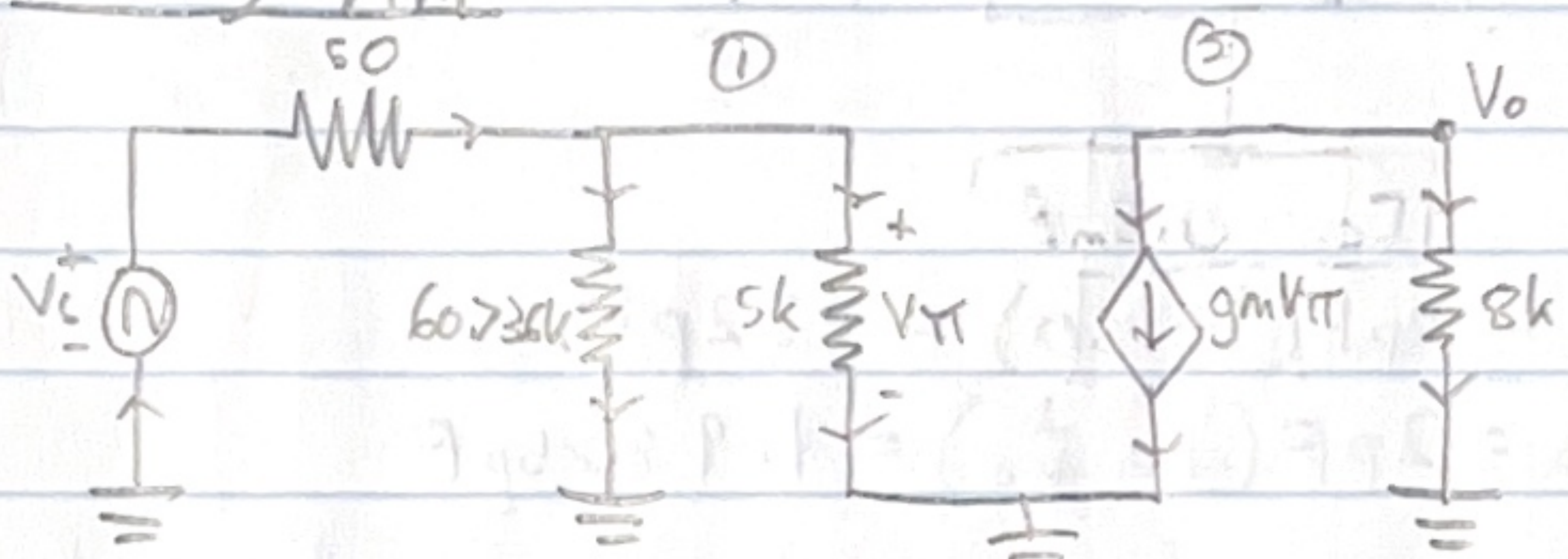
$\therefore \boxed{I_C = 0.5mA}$

$I_B = 5\mu A$
$I_E = 0.505mA$

$R_{B1} = 144.6k\Omega$
$R_{B2} = 103.3k\Omega$



Finding A_M:



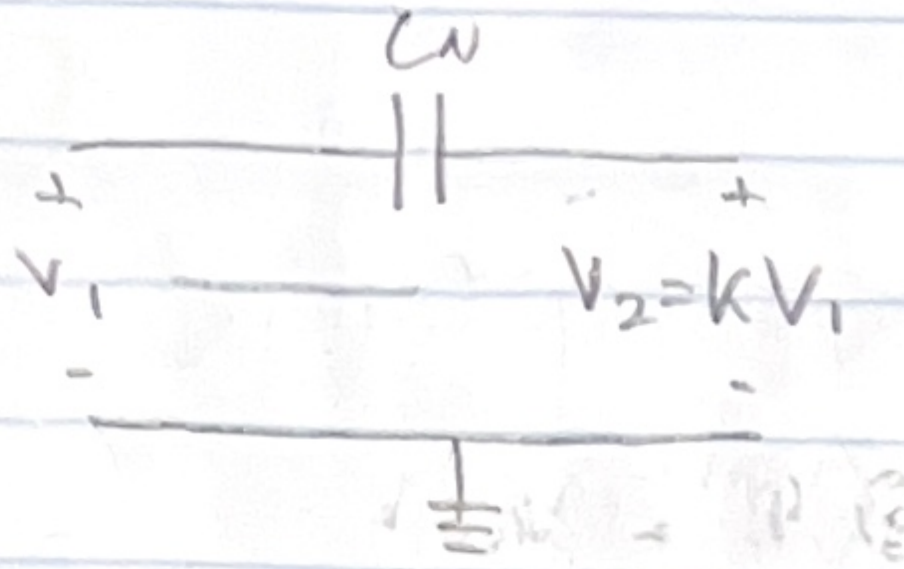
KCl_1: $\frac{V_s - V_1}{50} = \frac{V_1}{60.73kk} + \frac{V_1}{5k}$ | KCl_2: $0 = \frac{V_o}{8k} + g_m V_\pi$

$\frac{V_s}{50} - \frac{V_1}{50} = \frac{V_1}{60.7k} + \frac{V_1}{5k}$ | $\frac{V_o}{8k} = -20m℧ \cdot V_1$

$\frac{V_s}{50} = V_1\left[\frac{1}{50} + \frac{1}{60.7k} + \frac{1}{5k}\right]$ | $\cancel{\frac{V_o}{V_1} = 2.5M}$

$\frac{V_1}{V_s} = 0.989$ | $\frac{V_o}{V_1} = -160$

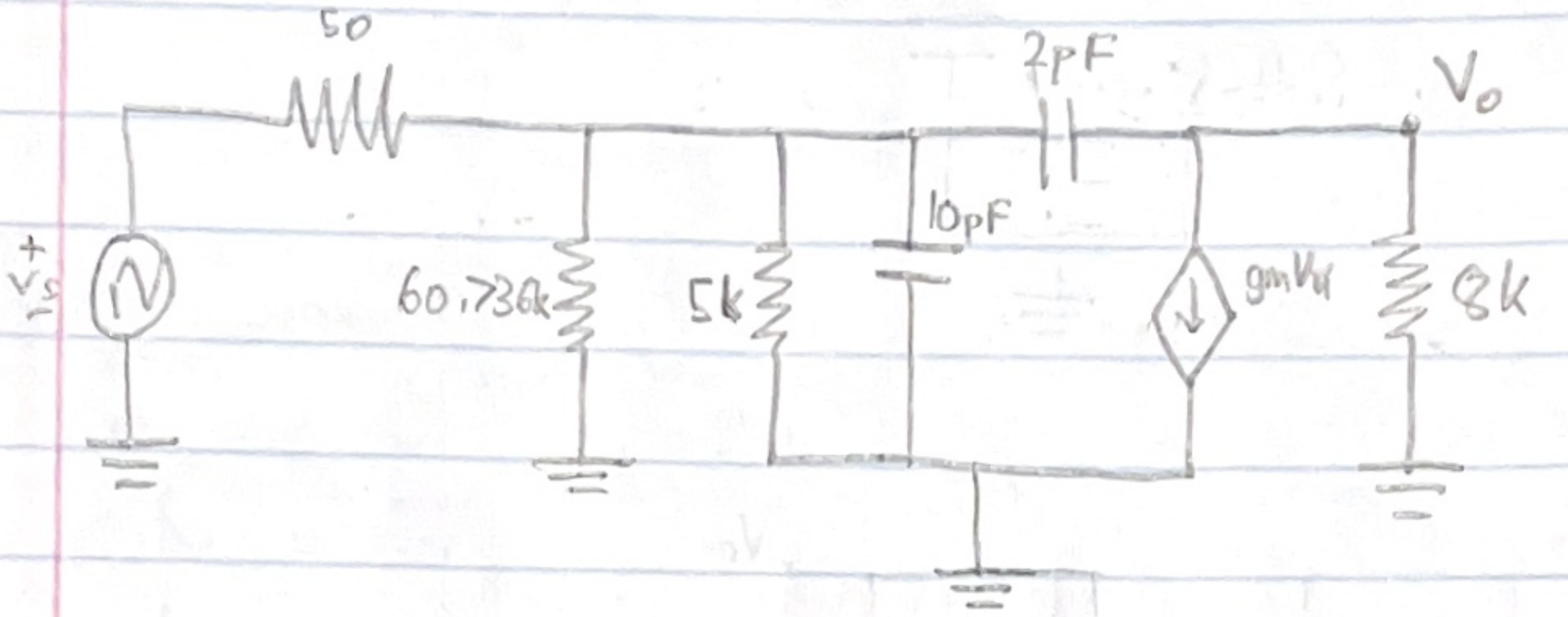
$\boxed{\therefore A_M = -158.3 \ \frac{V}{V}}$



$Z_{C1} = C_N(1-k)$

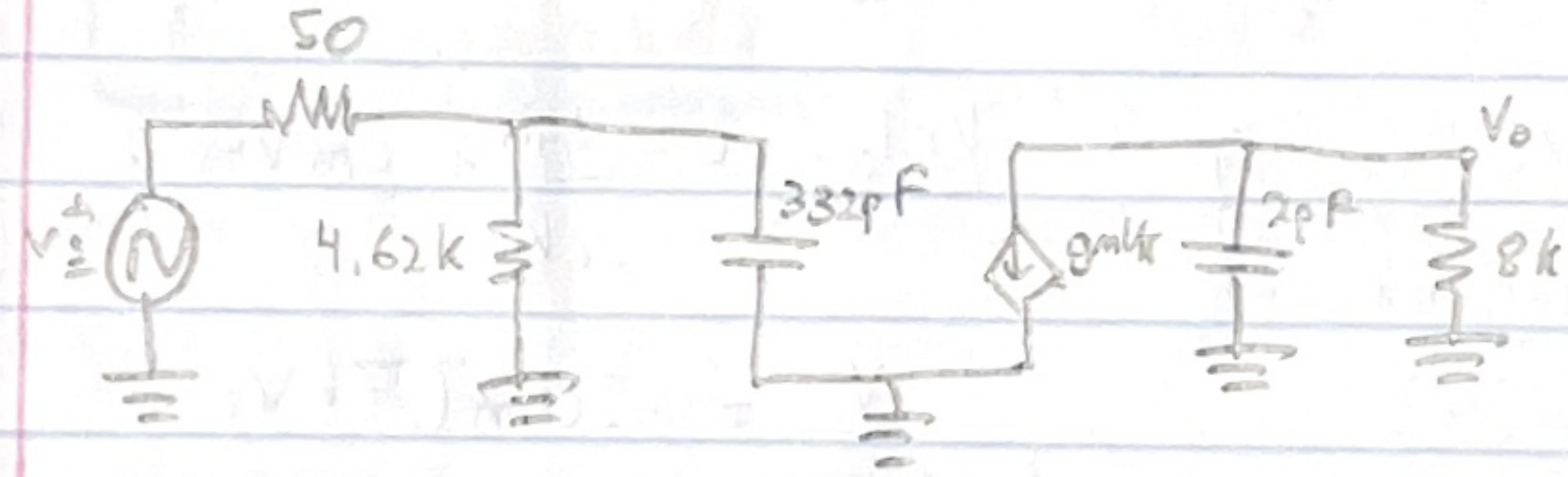
$Z_{C2} = C_N(1-1/k)$

High FREQ:



$k=-160$ $\quad Z_{C1} = 2pF(1+160) = 322pF$

$Z_{C2} = 2pF(1-\frac{1}{160}) = 1.9875pF$



$\tau_{C1}^{oc} = 332pF(50||4.62k) \rightarrow \omega_{HP1} = 60.89M/s$

① 1/3 Rule:

① $V_C = \frac{2}{3}V_{CC}$

② $V_B = \frac{1}{3}V_{CC}$ →

③ $I_1 = \frac{I_E}{\sqrt{\beta}}$

① $R_{B1} = \frac{V_C}{I_1}$ ② $R_{B2} = \frac{R_{B1}}{2} \frac{1}{1 - 1/\sqrt{\beta}}$

③ $R_C = \frac{V_B}{I_C}$ ③ $R_E = \frac{V_B - V_{BE}}{I_E}$

② 1/3 Rule:

① $V_C = \frac{2}{3}V_{CC}$

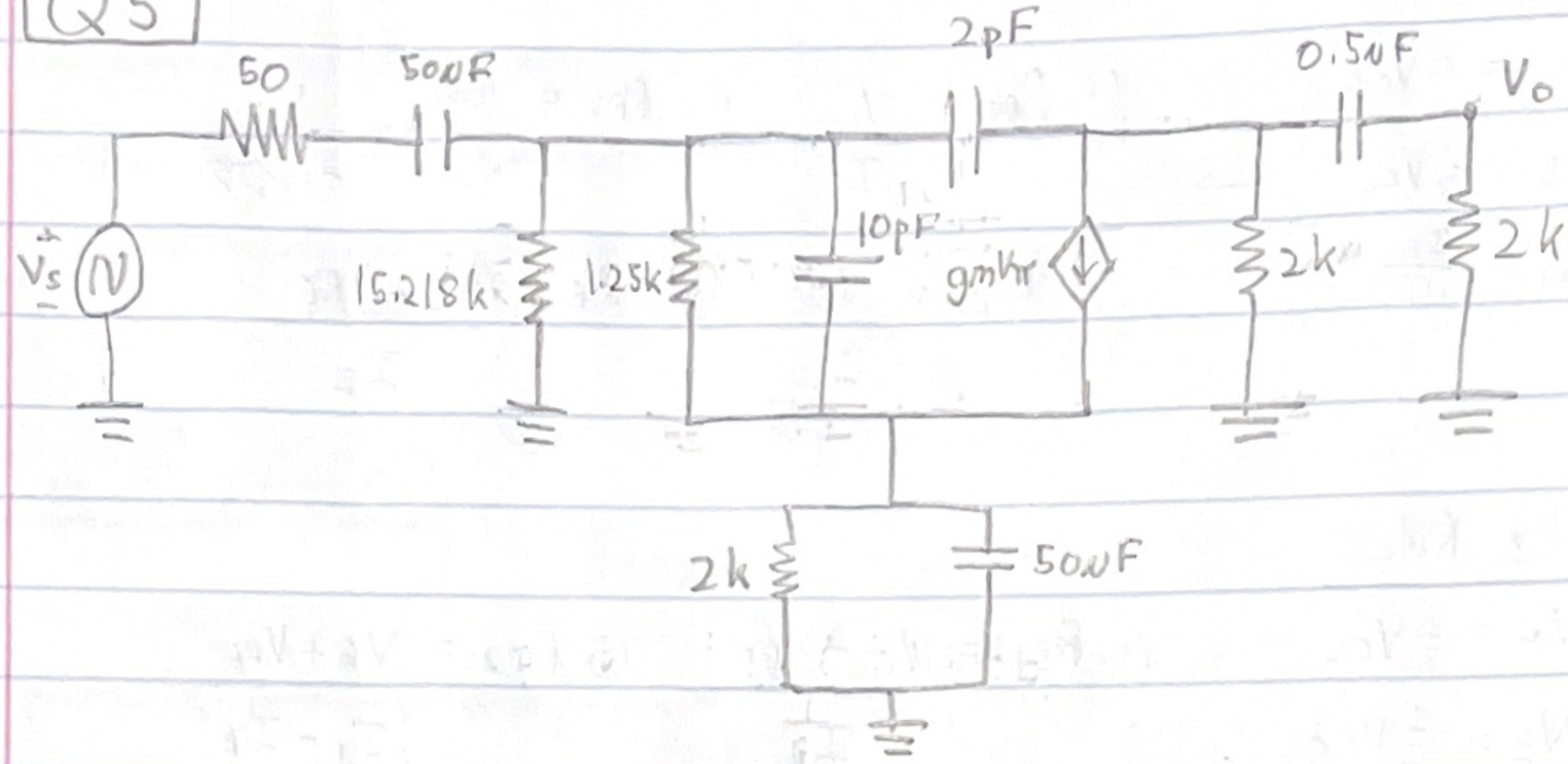
② $V_E = \frac{1}{3}V_{CC}$

③ $I_1 = \frac{I_E}{\sqrt{\beta}}$

① $R_{B1} = \frac{V_C - V_{BE}}{I_1}$ ② $R_{B2} = \frac{V_E + V_{BE}}{I_1 - I_B}$

③ $R_C = R_E = \frac{V_E}{I_C}$

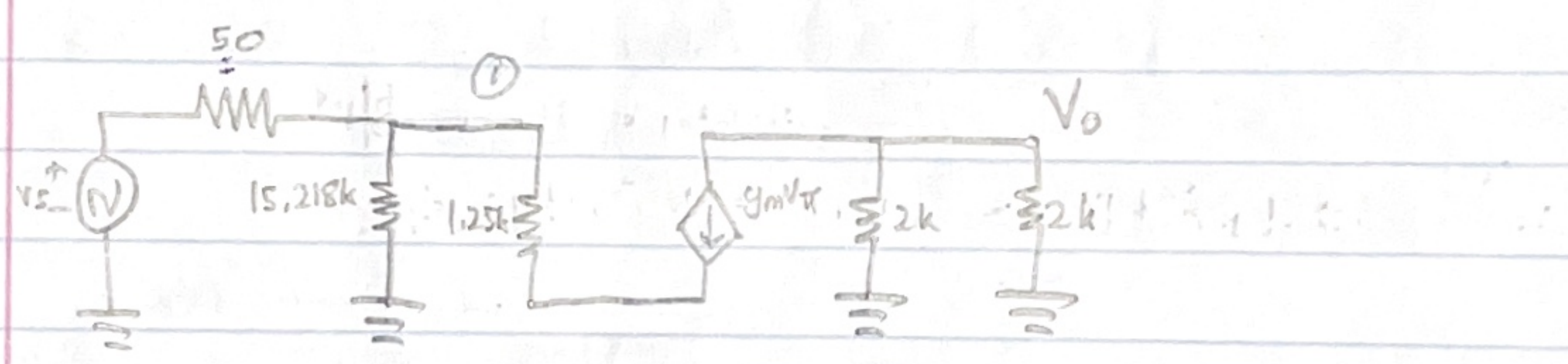
Q5



$g_m = 80m℧$

$r_\pi = 1.25k\Omega$

Finding A_M:



KCL_1: $\frac{V_s - V_1}{50} = \frac{V_1}{15.218k} + \frac{V_1}{1.25k}$

$\frac{V_s}{50} = V_1\left[\frac{1}{50} + \frac{1}{15.218k} + \frac{1}{1.25k}\right]$

$\frac{V_1}{V_s} = 0.956 \frac{V}{V}$

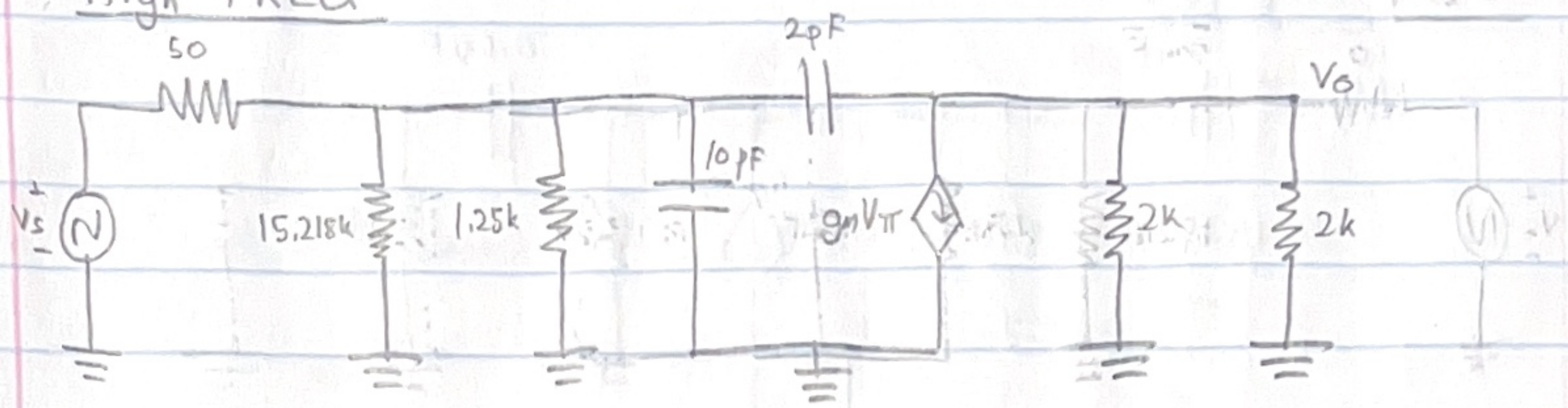
$0 = g_m V_\pi + \frac{V_o}{2k} + \frac{V_o}{2k}$

$V_o\left[\frac{1}{2k} + \frac{1}{2k}\right] = -80m℧ \cdot V_\pi$

$\frac{V_o}{V_\pi} = -80 \frac{V}{V}$

$\boxed{A_M = -76.69 \frac{V}{V}}$

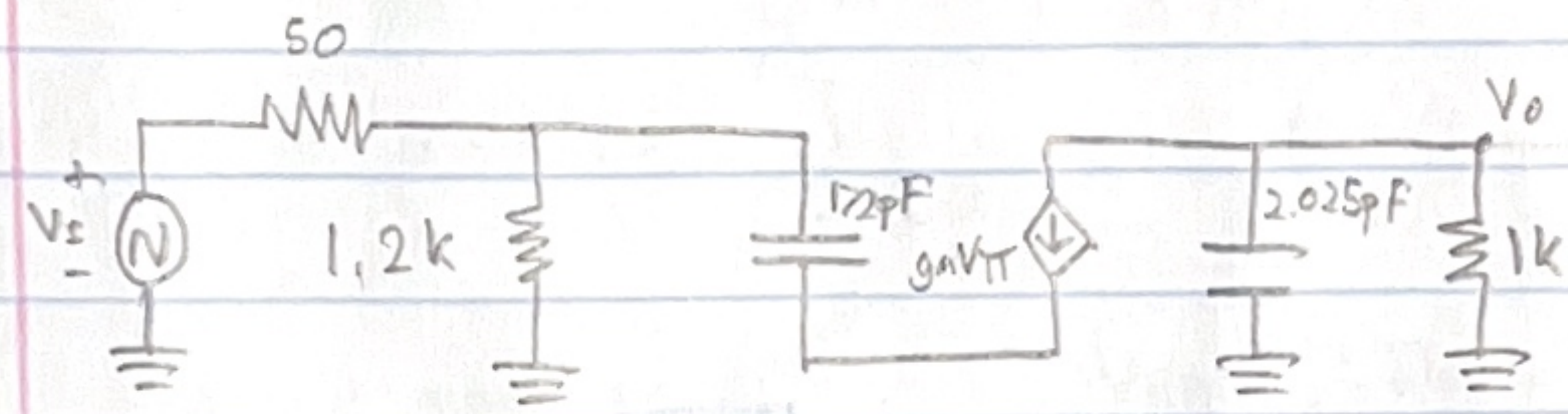
High FREQ :



millers :

$Z_{C1} = 2pF(1+80) = 162pF$

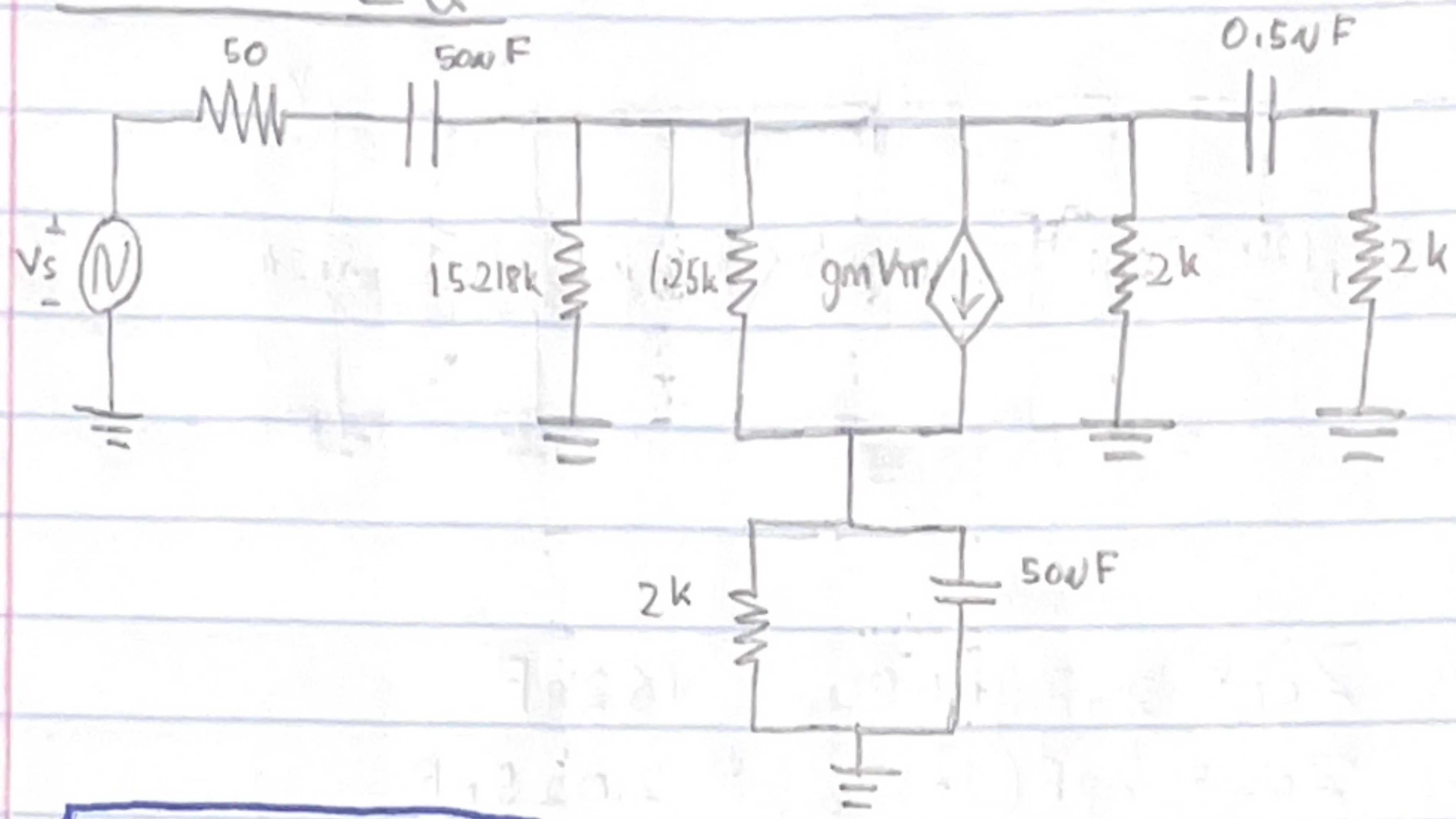
$Z_{C2} = 2pF\left(1 - \frac{1}{-80}\right) = 2.025pF$



$T^{oc}_{C1} = 172pF(50 \| 1.2k) \rightarrow \boxed{W_{HP1} = 121.3M/s}$

$T^{sc}_{C2} = 2.025pF(1k) \rightarrow \boxed{W_{HP2} = 493.827M/s}$

Low FREQ:



$$\boxed{\begin{aligned} \omega_{LZ1} &= 0 \\ \omega_{LZ2} &= 0 \\ \omega_{LZ3} &= 10 \text{ rad/s} \end{aligned}}$$

$$\tau^{sc}_{CC2} = 0.5nF(4k) \rightarrow \omega_{LP3} = \boxed{500 \text{ rad/s}}$$

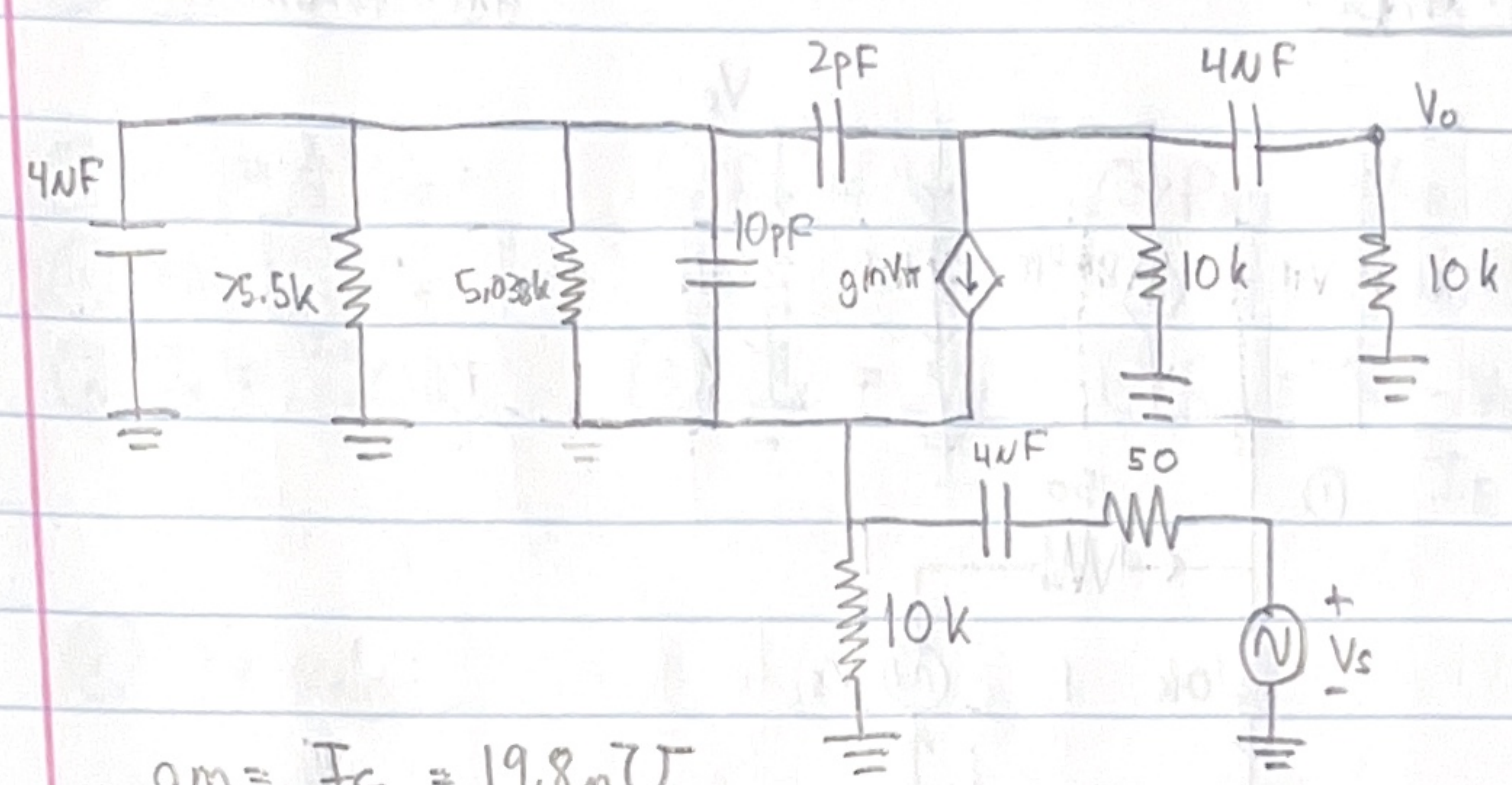
$$\tau^{sc}_{CE} = 50nF\left(2k \| (1+\beta)^{-1}(r_\pi + R_{BB} \| R_S)\right) \rightarrow \boxed{\omega_{LP2} = 1.56k \text{ rad/s}}$$

$$\cancel{\tau^{sc}_{CC1} = 50nF(50 \| 15.218k \| (1+\beta)(1.25k+2k)) \rightarrow \omega_{LP1} =}$$

$$\tau^{sc}_{CC1} = 50nF(50 + 15.218k \| 1.25k + (1+\beta)2k) \quad \omega_{LP1} = \boxed{1.4 \text{ rad/s}}$$

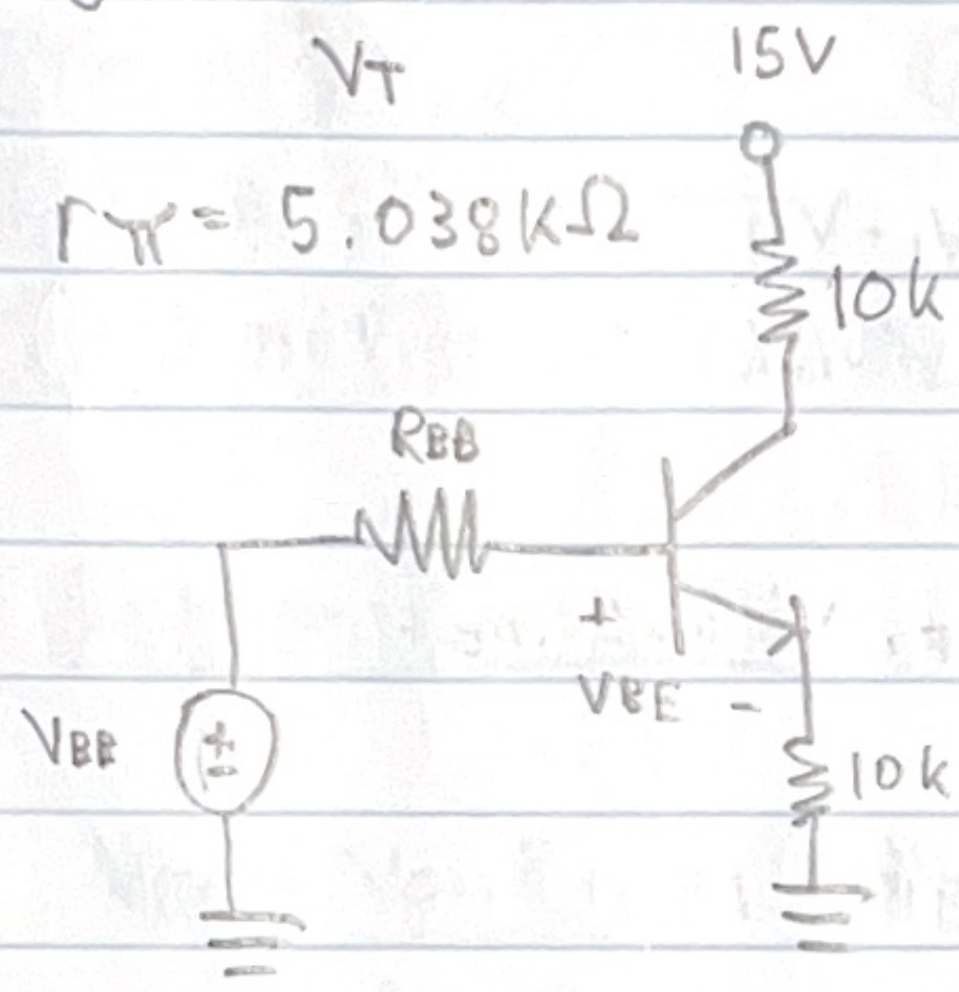
$$\omega_{LP1} = C_{C1}[R_S + R_{BB} \| (r_\pi + (1+\beta)R_E)]$$
$$\omega_{LP3} = C_E\left[R_E \| \frac{r_\pi + R_{BB} \| R_S}{1+\beta}\right]$$

Problem Set 4



$g_m = \frac{I_C}{V_T} = 19.8\,m℧$

$r_\pi = 5.038\,k\Omega$



$V_{BB} - I_b R_{BB} - V_{BE} - I_E \cdot 10k = 0$

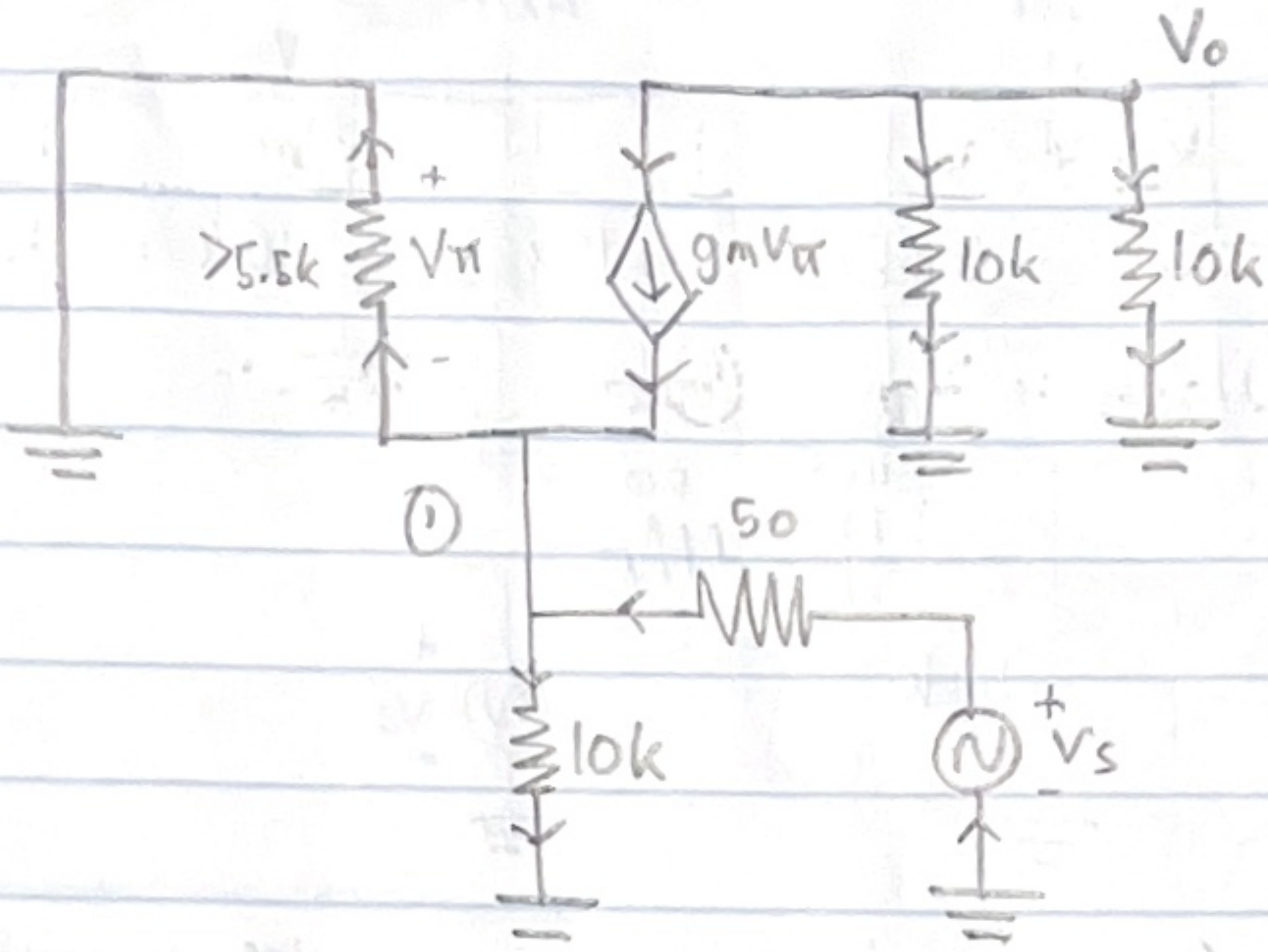
$I_E = I_B + I_C$

$I_E = I_B + \beta I_B$

$I_E = (1+\beta) I_B$

Finding A_M:

$g_m = 19.8 m \mho$



KCL: $g_m V_\pi + \frac{V_s}{50} - \frac{V_1}{50} = \frac{V_1}{10k} + \frac{V_1 - V_\pi}{75.5k}$

$$V_\pi = \frac{((1+\beta)^{-1} r_\pi \| 10k))}{((1+\beta)^{-1} r_\pi \| 10k + 50)} V_s$$

① 1/3 Rule:

① $V_C = \frac{2}{3}V_{CC}$
② $V_B = \frac{1}{3}V_{CC}$ →
③ $I_1 = I_E/\sqrt{\beta}$

① $R_{B1} = \frac{V_C}{I_1}$
② $R_{B2} = \frac{R_{B1}}{2} \cdot \frac{1}{1 - 1/\sqrt{\beta}}$
③ $R_C = \frac{V_B}{I_C}$
④ $R_E = \frac{V_B - V_{BE}}{I_E}$

② 1/3 Rule:

① $V_C = \frac{2}{3}V_{CC}$
② $V_E = \frac{1}{3}V_{CC}$ →
③ $I_1 = \frac{I_E}{\sqrt{\beta}}$

① $R_{B1} = \frac{V_C - V_{BE}}{I_1}$
② $\frac{V_E + V_{BE}}{I_1 - I_B}$
③ $R_C = R_E = \frac{V_E}{I_C}$

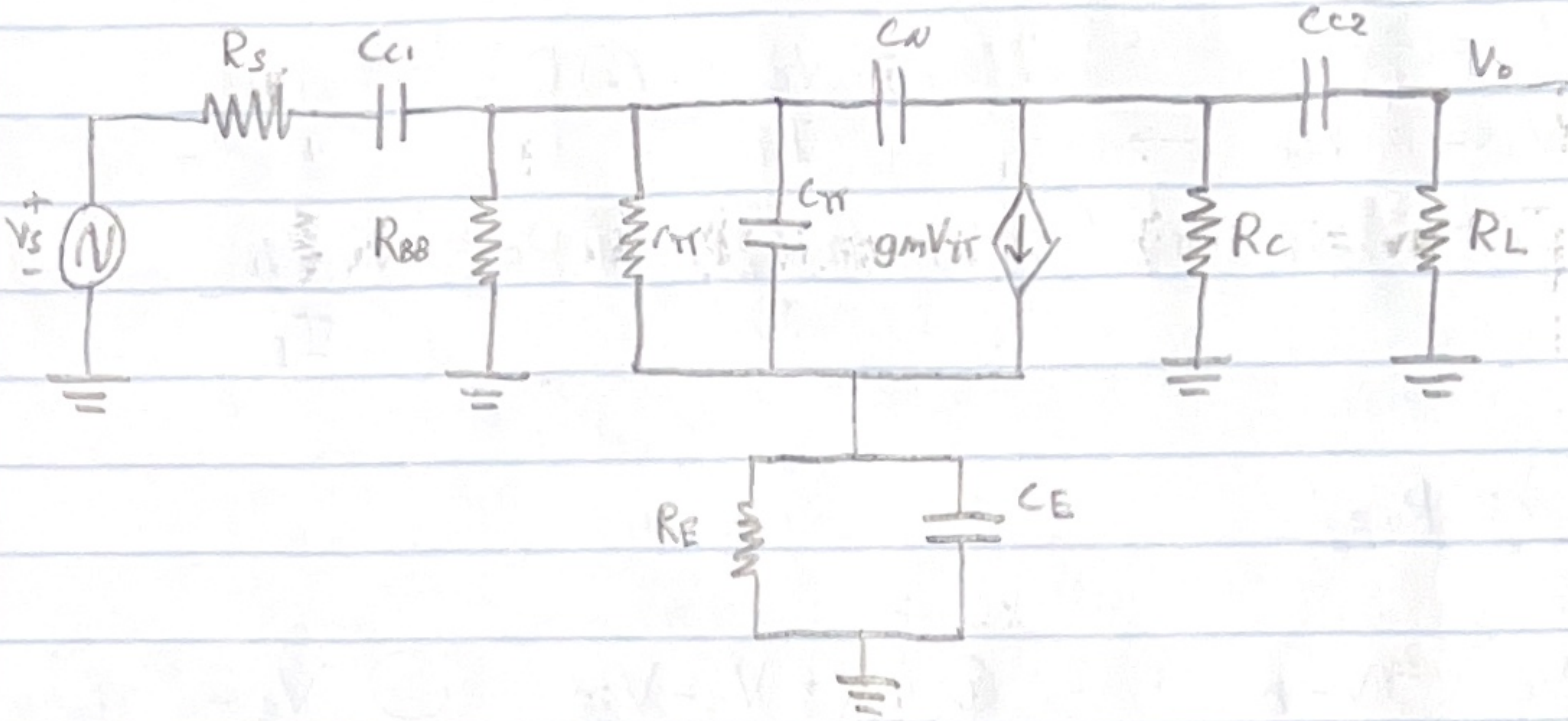
Solving for gm:

$V_{BB} = \frac{V_{CC}R_{B2}}{R_{B1}+R_{B2}}$ $R_{BB} = R_{B1} \| R_{B2}$

KVL: $V_{BB} - I_B R_{BB} - 0.7V - (1+\beta)I_B \cdot R_E = 0$

millers: $Z_{C1} = C_N(1-k)$
$Z_{C2} = C_N(1-1/k)$

Common emmitter:

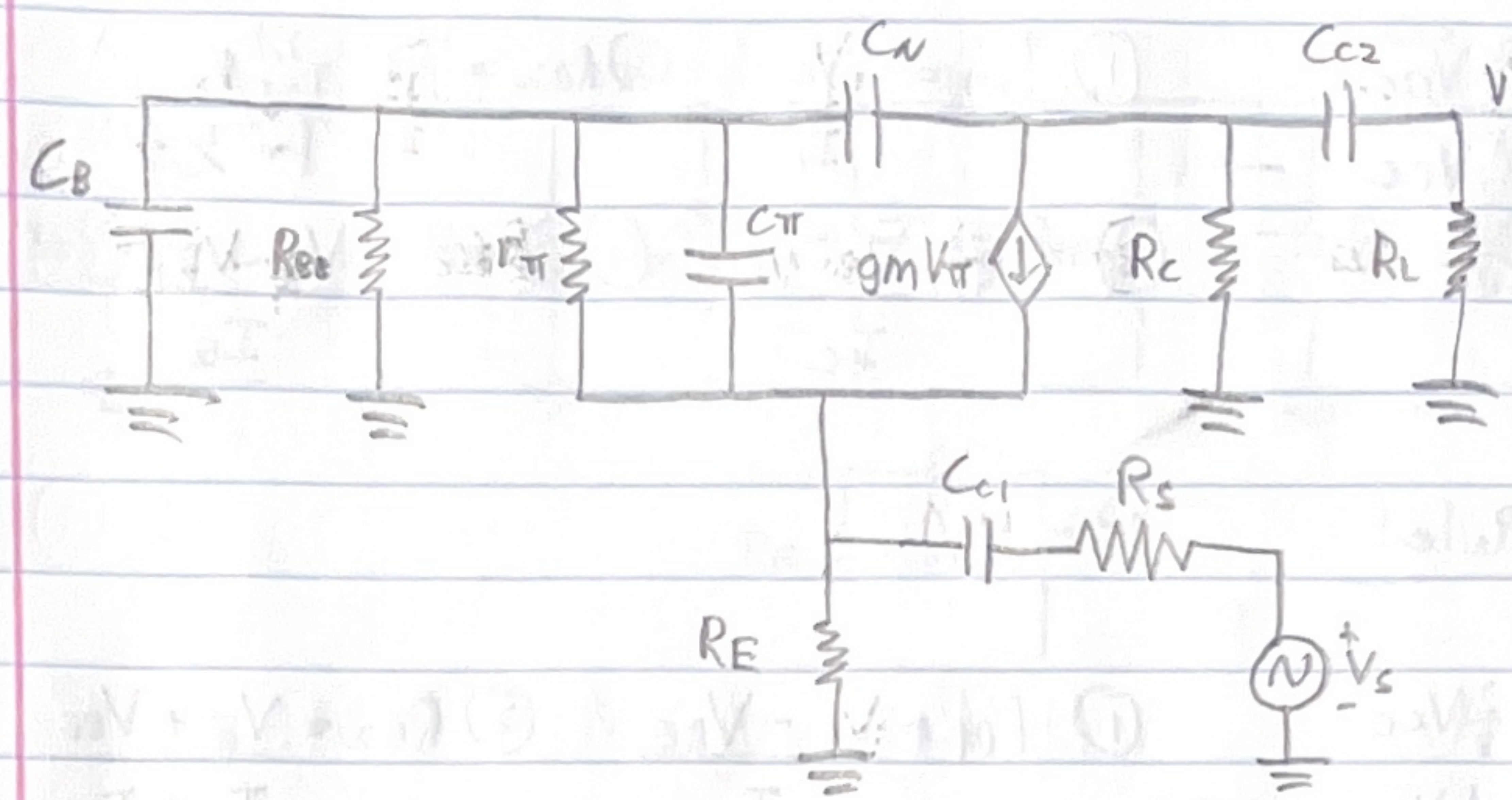


$$W_{LZ1} = 0 \qquad W_{LP1}^{CC1} = C_{C1}\left[R_S + R_{BB} \,||\, (r_\pi + (1+\beta)R_E)\right]$$

$$W_{LZ2} = 0 \qquad W_{LP2}^{CC2} = C_{C2}(R_C + R_L)$$

$$W_{LZ3} = \frac{1}{R_E C_E} \qquad W_{LP3}^{CE} = C_E\left[(1+\beta)^{-1}(R_S \,||\, R_{BB} + r_\pi) \,||\, R_E\right]$$

Common-Base:



$\omega_{LZ1} = 0$

$\omega_{LZ2} = 0$

$\omega_{LZ3} = \dfrac{1}{R_{BB} C_B}$

$\omega_{LP1} = C_{C1}[R_S + R_E \,||\, \frac{r_\pi}{(1+\beta)}]$

$\omega_{LP2} = C_{C2}[R_C + R_L]$

$\omega_{LP3} = C_B[R_{BB} \,||\, (r_\pi + (1+\beta)R_E)]$

① $\frac{1}{3}$ Rule:

① $V_C = \frac{2}{3}V_{CC}$

② $V_B = \frac{1}{3}V_{CC}$ $\rightarrow$

③ $I_1 = \frac{I_E}{\sqrt{\beta}}$

① $R_{B1} = \frac{V_C}{I_1}$ ② $R_{B2} = \frac{R_{B1}}{2} \cdot \frac{1}{1 - 1/\sqrt{\beta}}$

③ $R_C = \frac{V_B}{I_C}$ ④ $R_E = \frac{V_B - V_{BE}}{I_E}$

② $\frac{1}{3}$ Rule:

① $V_C = \frac{2}{3}V_{CC}$

② $V_E = \frac{1}{3}V_{CC}$ $\rightarrow$

③ $I_1 = I_E/\sqrt{\beta}$

① $R_{B1} = \frac{V_C - V_{BE}}{I_1}$ ② $R_{B2} = \frac{V_E + V_{BE}}{I_1 - I_B}$

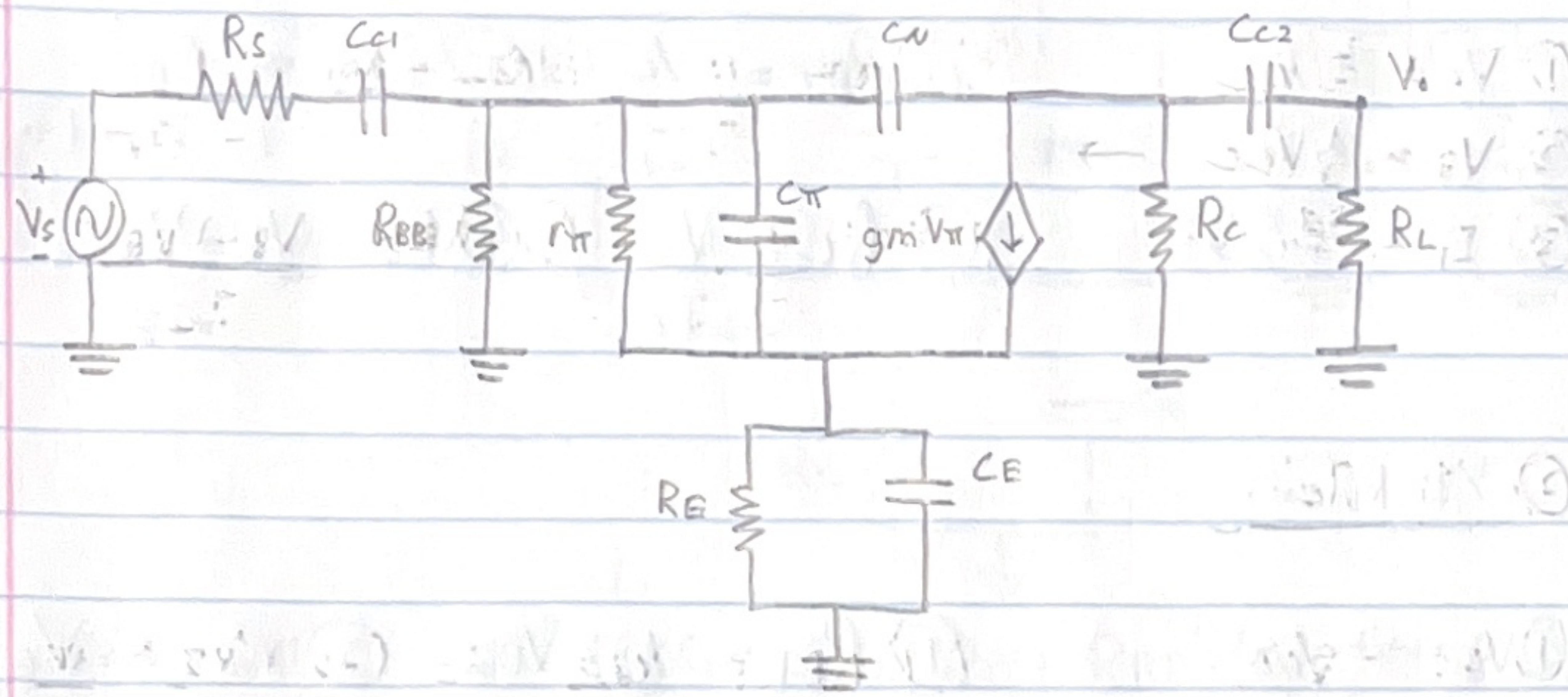
③ $R_C = R_E = \frac{V_E}{I_C}$

Finding gm:

$V_{BB} = \frac{V_{CC} R_{B2}}{R_{B1} + R_{B2}}$, $R_{BB} = R_{B1} \| R_{B2}$

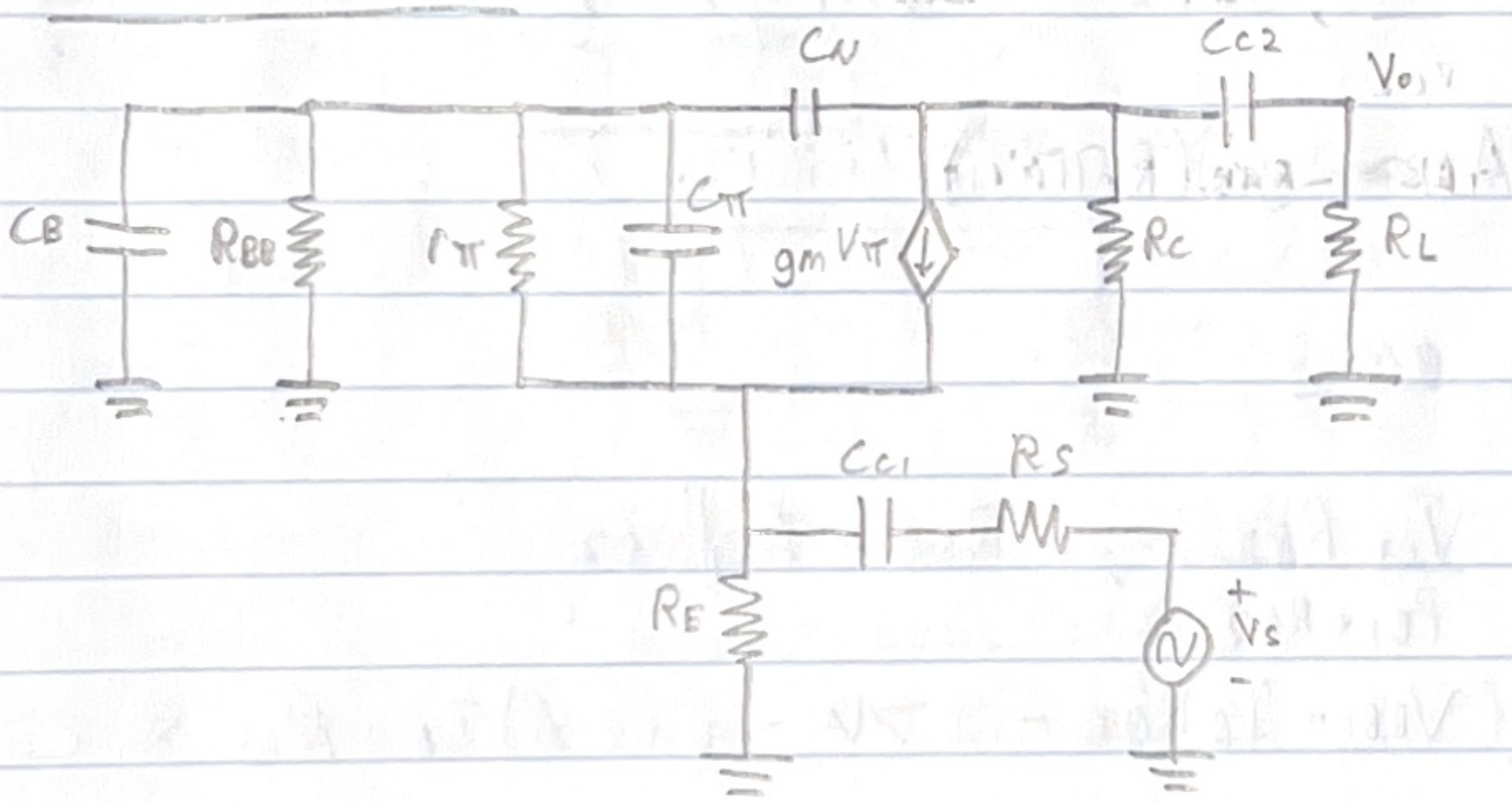
KVL: $V_{BB} - I_B R_{BB} - 0.7V - (1+\beta) I_B \cdot R_E = 0$

Common Emmitter :



$W_{LZ1} = 0$	$W_{LP1} = C_{C1}[R_S + R_{BB} \| (r_\pi + (1+\beta) R_E)]$
$W_{LZ2} = 0$	$W_{LP2} = C_{C2}[R_C + R_L]$
$W_{LZ3} = 1/R_E C_E$	$W_{LP3} = C_E\left[R_E \| \frac{r_\pi + R_S \| R_{BB}}{1+\beta}\right]$

Common Base :



$W_{LZ1} = 0$	$W_{LP1} = C_{C1}\left[R_S + R_E \| \frac{r_\pi + \cancel{R_{BB}}}{1+\beta}\right]$
$W_{LZ2} = 0$	$W_{LP2} = C_{C2}[R_C + R_L]$
$W_{LZ3} = 1/R_{BB} C_B$	$W_{LP3} = C_B[R_{BB} \| (r_\pi + (\beta+1) R_E)]$

① 1/3 Rule:

① $V_C = \frac{2}{3}V_{CC}$
② $V_B = \frac{1}{3}V_{CC}$ $\longrightarrow$
③ $I_1 = I_B/\sqrt{\beta}$

① $R_{B1} = \frac{V_C}{I_1}$ ② $R_{B2} = \frac{R_{B1}}{2} \frac{1}{1 - 1/\sqrt{\beta}}$

③ $R_C = \frac{V_B}{I_C}$ ④ $R_E = \frac{V_B - V_{BE}}{I_E}$

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③ $R_C = R_E = \frac{V_E}{I_C}$

Millers: $Z_{C1} = C_N(1-k)$
$Z_{C2} = C_N(1-1/k)$

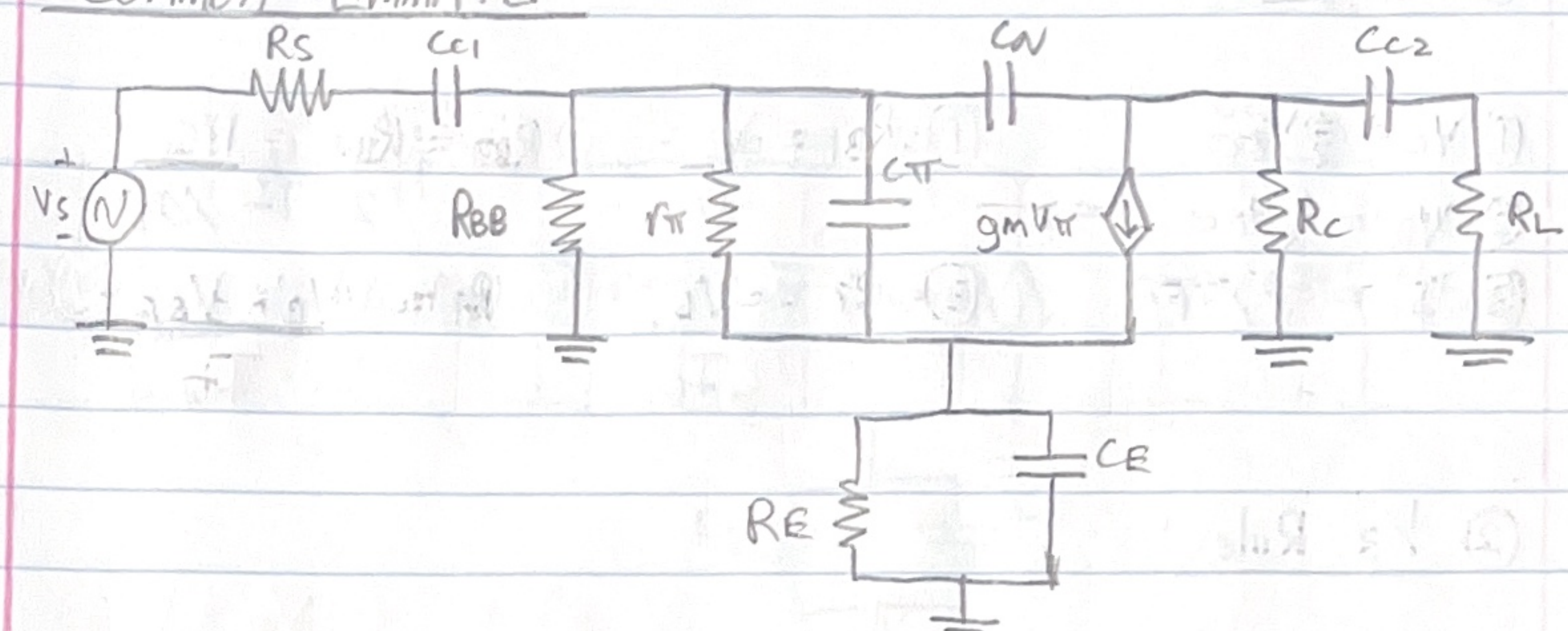
$A_M \approx g_m(R_C \| R_L)$

Finding gm:

$V_{BB} = \frac{V_{CC} R_{B2}}{R_{B1} + R_{B2}}$, $R_{BB} = R_{B1} \| R_{B2}$

KVL: $V_{BB} - I_B R_{BB} - 0.7V - (1+\beta) I_B \cdot R_E = 0$

Common-Emmitter



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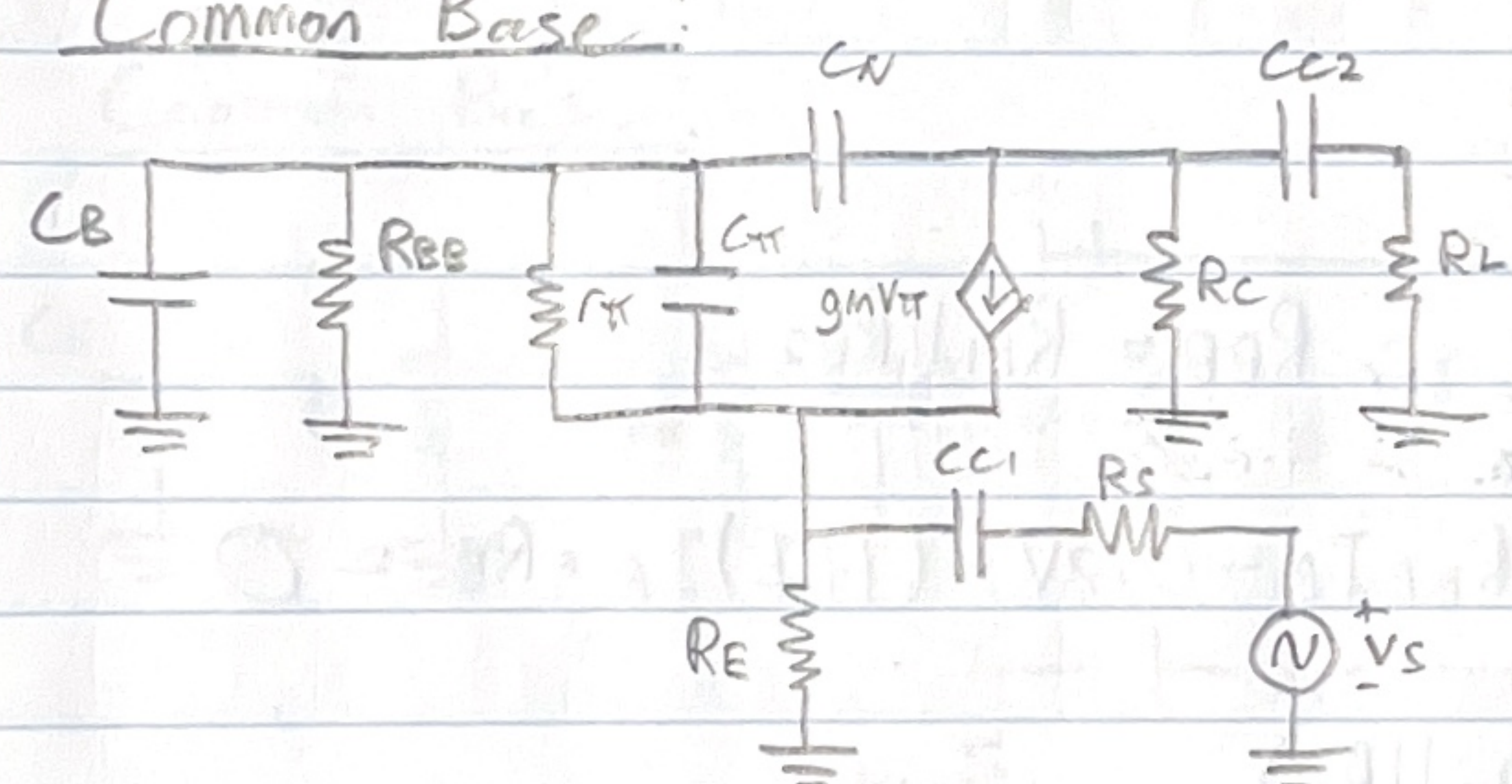
$W_{LZ2} = 0$ | $W_{LP2} = C_{C2}[R_C + R_L]$

$W_{LZ3} = 1/R_E C_E$ | $W_{LP3} = C_E\left[R_E \| \frac{r_\pi + R_{BB}\|R_S}{1+\beta}\right]$

Common Base:



$W_{LZ1} = 0$ | $W_{LP1} = C_{C1}\left[R_S + R_E \| \frac{r_\pi}{1+\beta}\right]$

$W_{LZ2} = 0$ | $W_{LP2} = C_{C2}[R_C + R_L]$

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$A_M \approx g_m(R_C \| R_L)$