Q1

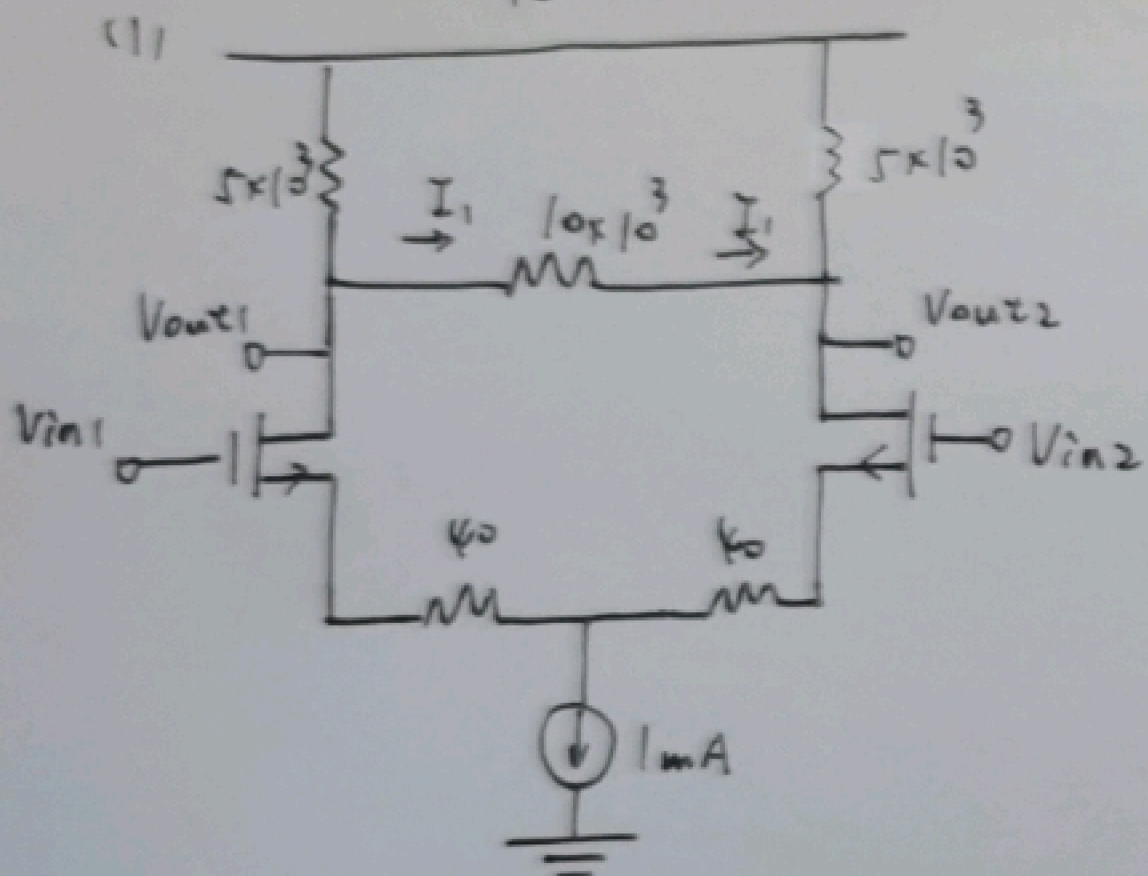
1.

$P(W) = 1mW \cdot 10^{\frac{13}{10}} = 0.1995\ W$

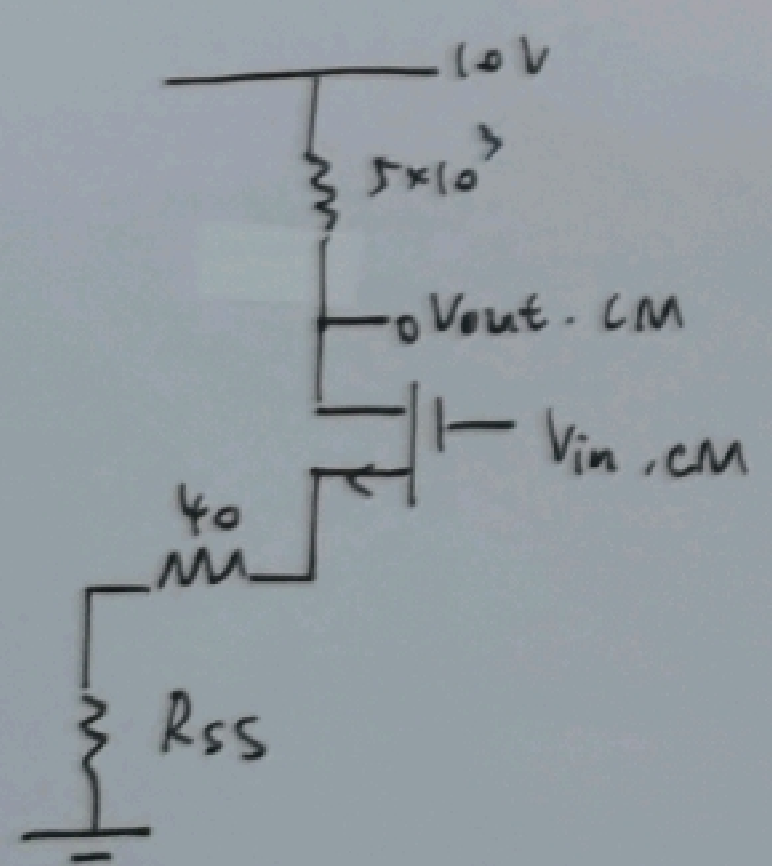
$\Rightarrow V_{rms} = \sqrt{P \cdot R} = 1\ V$

2.

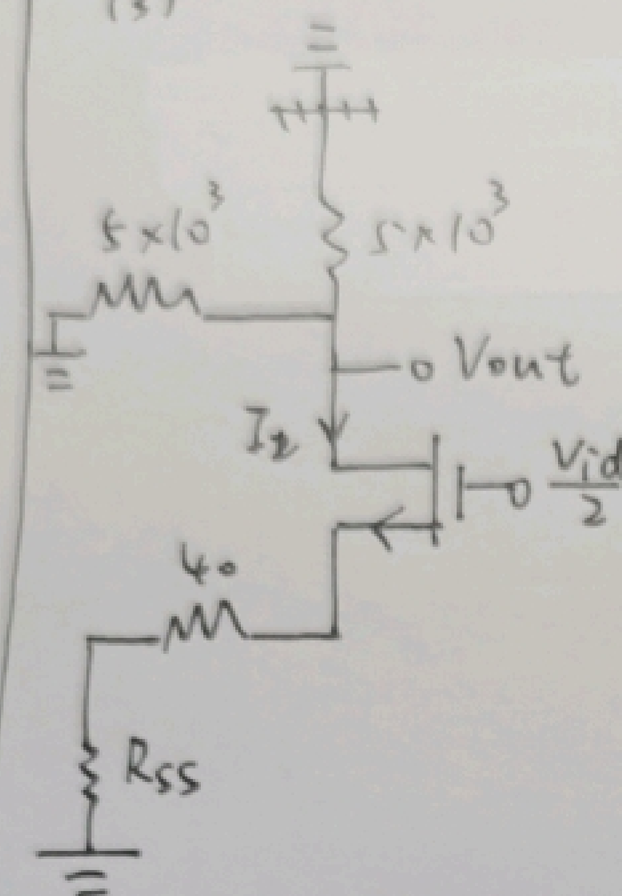
(1)



(2) $I_1 = 0$ when common mode



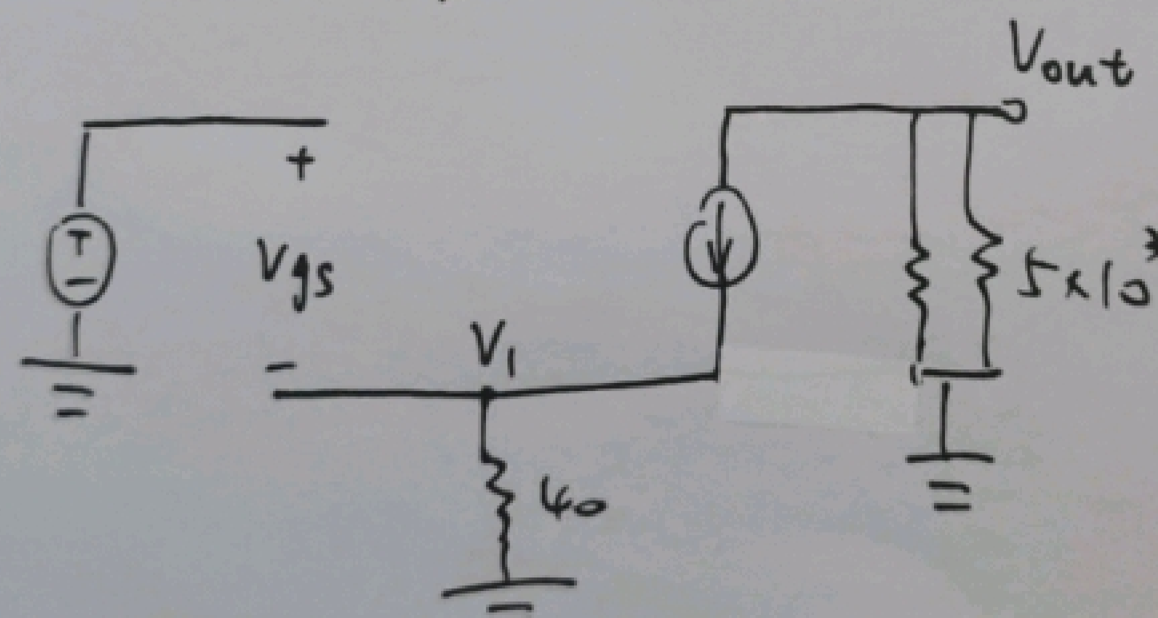
(3)



(4)

$g_m = \sqrt{2 \mu_n C_{ox} \frac{W}{L} I_2}$

$r_o = 0$, $g_{mb} = 0$



$\frac{-V_{out}}{5\times10^3} \times 2 = g_m \left(\frac{V_{id}}{2} - V_1\right)$

$= \frac{V_1}{40} = I_2$

$\frac{-V_{out}}{10^4} = \sqrt{10^{-2} I_2}\left(\frac{V_{id}}{2} - V_1\right) = \frac{V_1}{40} = I_2$

$\Rightarrow \frac{\partial V_{out}}{\partial \frac{V_{id}}{2}} = A_{VDM}$

Q1

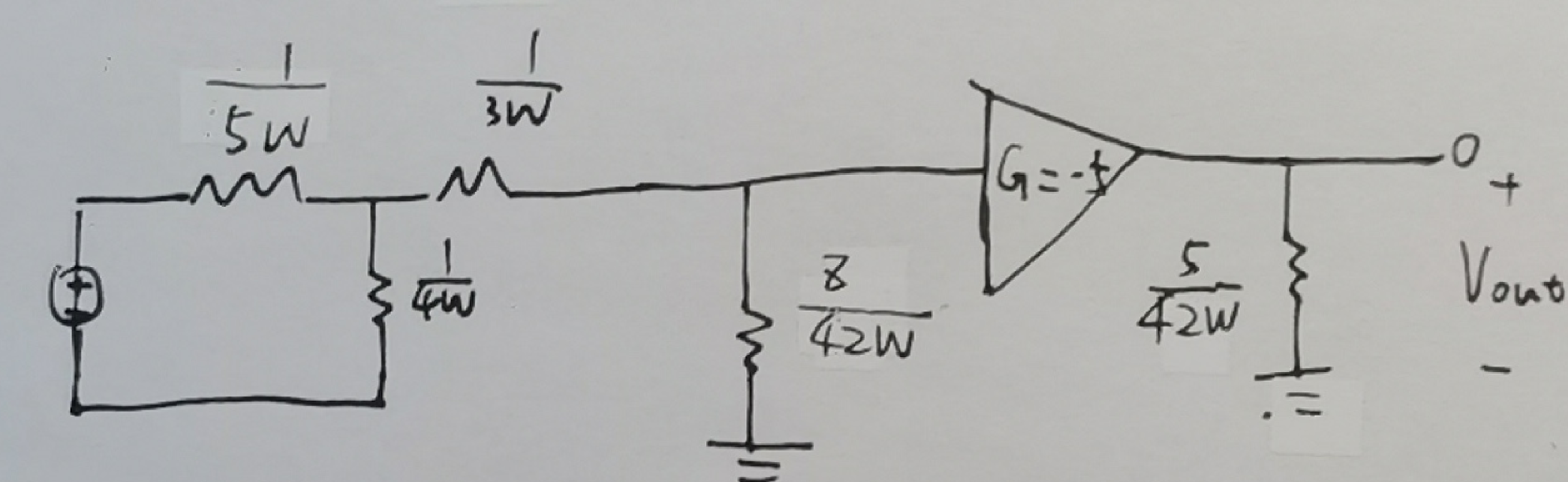
3.

$$Z_1 = \frac{Z}{1+A} = \frac{Z}{6}$$

$$Z_2 = \frac{Z}{1+\frac{1}{A}} = \frac{5}{6} Z$$

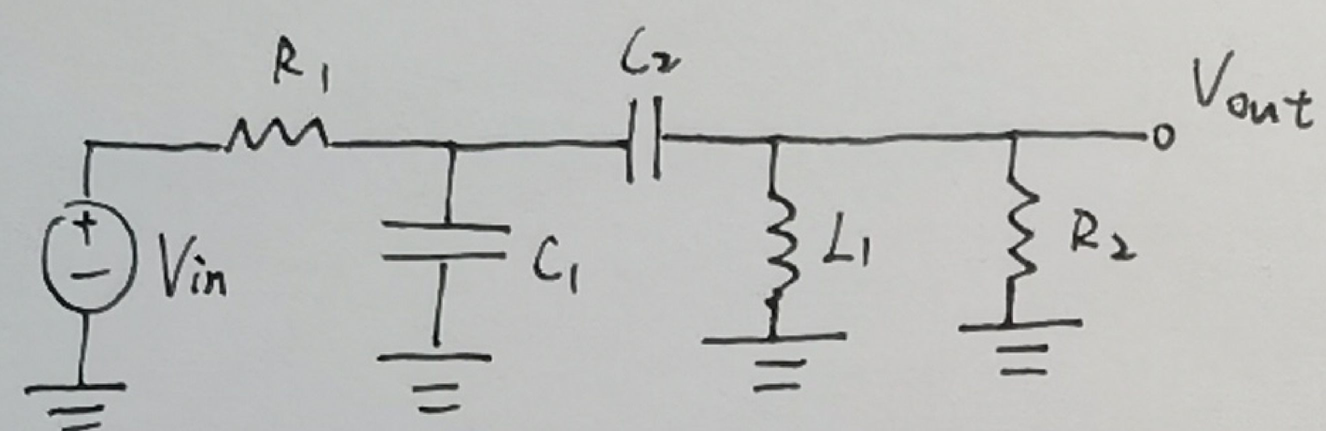
$$Z_C = \frac{1}{2\pi f C} = \frac{1}{wC}$$

$\Leftrightarrow$



$$\Rightarrow R_{out} = \frac{5}{42w} \times 10^{15}\ \Omega$$

Q3.



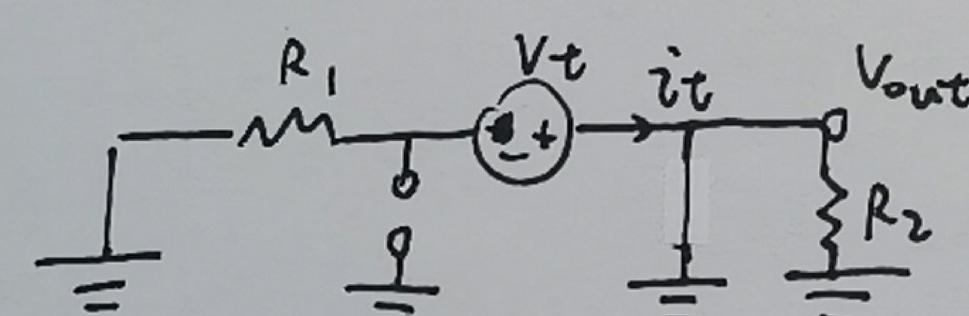
$L_1 = 10 \times 10^{-9}\,H$, $C_1 = 120 \times 10^{-15}\,F$,

$C_2 = 150 \times 10^{-15}\,F$, $R_1 = 40\Omega$ and $R_2 = 80\Omega$

Firstly, we need to calculate τ_i^0

① τ_1^0 : C_2 cut off ~~Vout = 0~~ $\Rightarrow$ $\tau_1^0 = R_1 C_1$

② τ_2^0 :

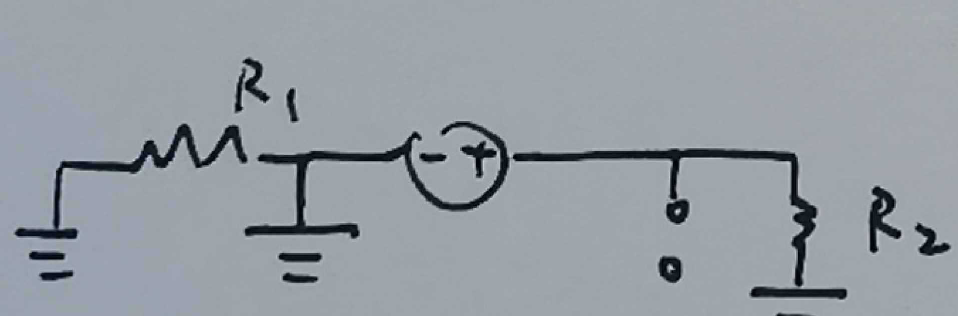


$\frac{V_t}{i_t} = R_1 \Rightarrow \tau_2^0 = R_1 C_2$

③ τ_3^0 : C_2 cut off $\Rightarrow \tau_3^0 = \frac{L_1}{R_2}$

Then we calculate τ_j^i

① τ_2^1 :



$\Rightarrow \tau_2^1 = R_2 C_2$

② τ_3^1 : $\frac{L_1}{R_2}$

③ τ_1^2 : $\frac{R_1 R_2}{(R_1 + R_2)} C_1$

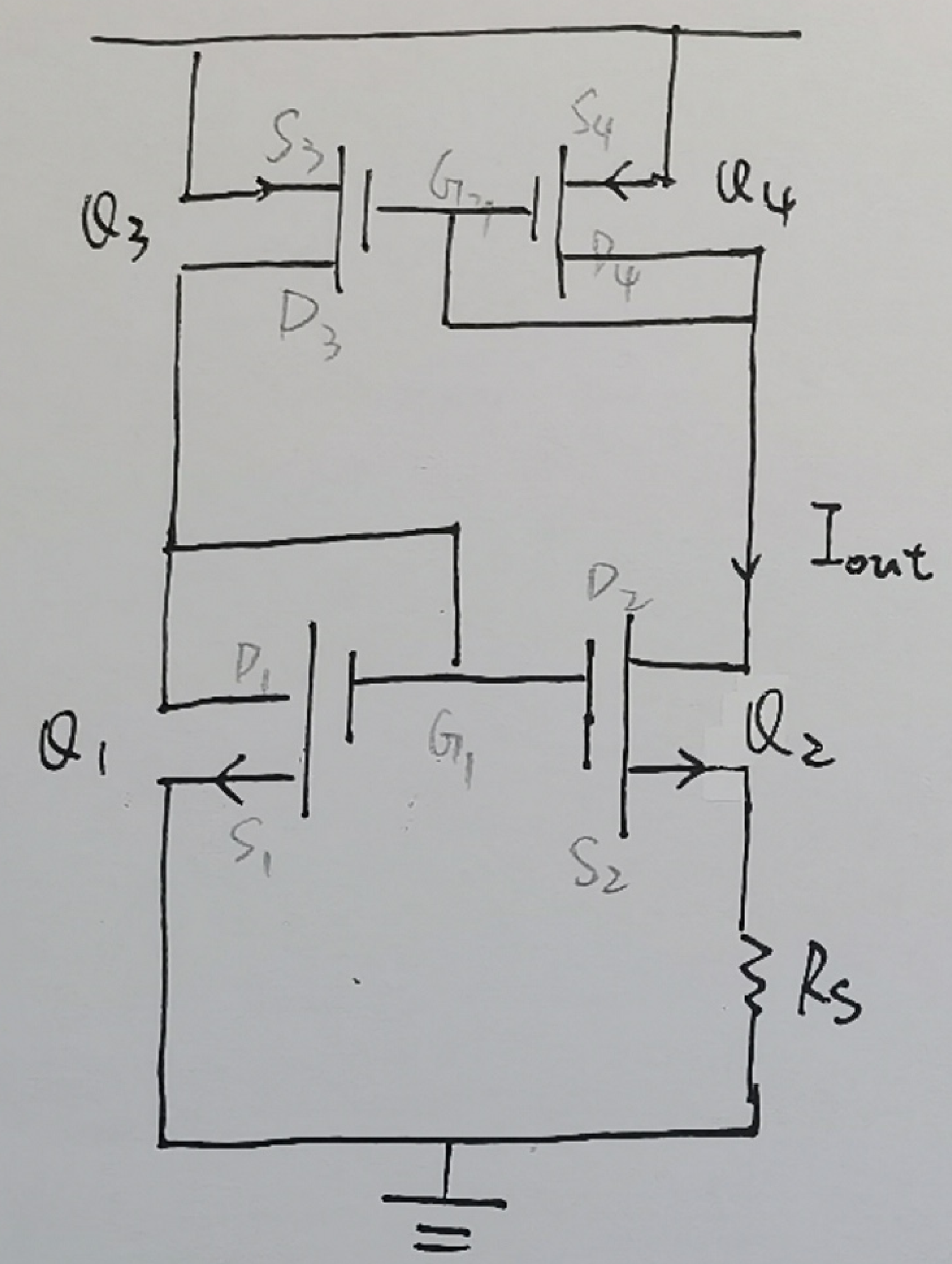
Then we need to find H^i

$H^1 = 0$

$H^2 = \frac{R_2}{R_1 + R_2}$

$H^{12} = 0$

4.



$V_{GS_1} = V_{D_3S_1}$

(a)

$\Rightarrow \lambda = 0$ and $\gamma = 0$

$V_{S_2} = I_{out} \cdot 100$

Since $V_{D_1} = V_{G_1}$

$\Rightarrow V_{DS_1} > V_{GS1} - V_{TH}$

$\Rightarrow$ saturation Q_1

$\Rightarrow I_{S_1} = \frac{1}{2}\mu_N C_{ox}(\frac{W}{L})_1(V_{GS_1} - V_{TH})^2$

Assume all saturation

$I_{D_3} = \frac{1}{2}\mu_P C_{ox}(V_{GS_3} - V_{TH})^2 \cdot (\frac{W}{L})_3$

$I_{D_4} = \frac{1}{2}\mu_P C_{ox}(V_{GS_4} - V_{TH})^2 \cdot (\frac{W}{L})_4$

$= I_{out}$

$\Rightarrow I_{D_3} = I_{out} \cdot \frac{(\frac{W}{L})_3}{(\frac{W}{L})_4} = I_{out}$

since same size

$I_{S_2} = \frac{1}{2}\mu_N C_{ox}(\frac{W}{L})_2(V_{GS_2} - V_{TH})^2$

$V_{GS_2} = V_{GS1} - I_{out} \cdot 100$

$\Rightarrow \sqrt{\frac{2I_{S_1}}{\mu_N C_{ox}(\frac{W}{L})_1}} - I_{out} \cdot 100$

$= \sqrt{\frac{2I_{S_2}}{\mu_N C_{ox}(\frac{W}{L})_2}}$

and $I_{S_1} = I_{S_2}$

$\Rightarrow (\frac{W}{L})_1(X - 0.7)^2 = (\frac{W}{L})_2(X - 100I_{out})^2$

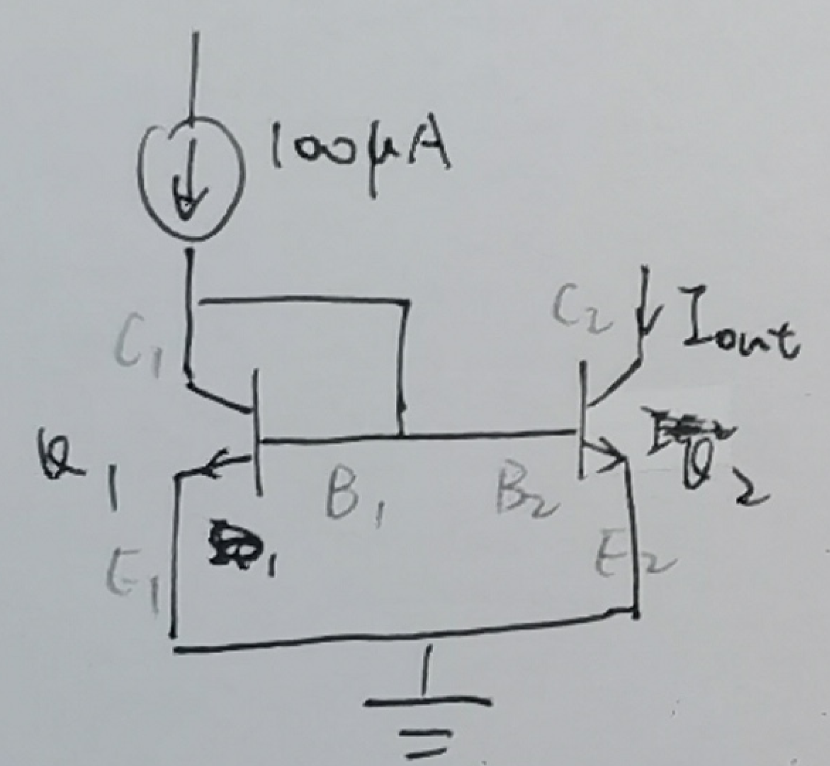
$\Rightarrow \sqrt{10}(X - 0.7) = \sqrt{(\frac{W}{L})_2}(X - 100I_{out})$

(b)

$\sqrt{10}(X - 0.7) = \sqrt{(\frac{W}{L})_2}(X - 0.5)$

$\Rightarrow \frac{10(X-0.7)^2}{(X-0.5)^2} = (\frac{W}{L})_2$

Q2.



(a)

$\cancel{I_{E_1} = (1+\beta) I_{B_1}}$

$= \cancel{I_{B_1} +} I_{C_1}$

~~ignore $I_B \Rightarrow I_{C_1} = 100\mu A$~~

$V_{BE} = V_T \ln\left(\frac{I_B}{I_S}\right) = 0.7V$

(b)

$I_B = I_S e^{\frac{V_{BE}}{V_T}} = 7.39\, nA$

$I_{out} = I_{REF} - 2I_B = 0.0147A$

2. $I_{out} = \frac{1}{4} I_{ref}$

$I_{ref} = I_u + I_{B_1} + I_{B_2}$

$(I_{out} + I_{B_2}) R_E = I_{E_2}$

$I_{out} = \beta I_{B_2}$ $I_{REF} = \beta I_{B_1}$

$V_{BE_2} = 2 V_{BE_1}$

$\frac{I_{REF}}{I_o} = e^{\frac{\Delta V_E}{V_T}}$

$I_o R_E = V_T \ln \frac{I_{REF}}{I_o}$

$\Rightarrow R_E = \frac{V_T \ln 4}{I_o}$