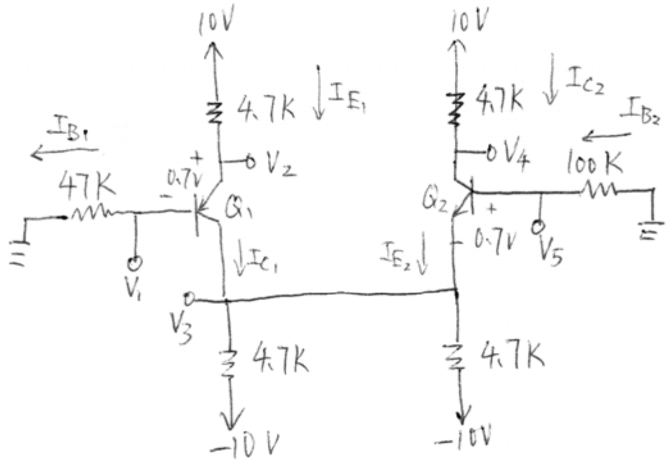
4.40



(a) $\beta = \infty \Rightarrow I_{B_1} = 0 \quad I_{B_2} = 0$

$V_1 = V_5 = 0$

$V_2 = 0.7V \quad V_3 = -0.7\,V$

$$I_{C_1} = I_{E_1} = \frac{10 - 0.7}{4.7K} = 1.98\text{ mA}$$

$$I_{C_2} = I_{E_2} = \frac{-0.7 - (-10V)}{4.7K // 4.7K} = 3.95\text{mA}$$

$$V_4 = 10V - 4.7K \cdot I_{C_2} = 0.7\,V$$

(b) $\beta = 100$

① $10 - 4.7K \cdot (\beta+1)\, I_{B_1} - 0.7 - 47K \cdot I_{B_1} = 0$

$\Rightarrow I_{B_1} = 0.0178\text{ mA} \qquad I_{C_1} = \beta I_{B_1} = 1.78\text{ mA} \qquad I_{E_1} = 1.798\text{ mA}$

② $-100K \cdot I_{B_2} - 0.7 + 10 - \frac{4.7K}{2}\left(I_{C_1} + (\beta+1)\, I_{B_2}\right) = 0$

$\Rightarrow I_{B_2} = 0.0152\text{ mA} \qquad I_{C_2} = 1.52\text{ mA} \qquad I_{E_2} = 1.535\text{ mA}$

$\Rightarrow V_3 = -10 + \frac{4.7K}{2}\left(I_{C_1} + (\beta+1) I_{B_2}\right) = -2.2V$

$V_2 = 10 - 4.7K \cdot I_{E_1} = 1.54V \qquad V_4 = 10 - 4.7K \cdot I_{C_2} = 2.88V$

4.42

(a) using the exponential characteristic

$$i_C = I_C \cdot e^{v_{be}/V_T}$$

Thus

$$i_c = i_C - I_C = I_C \cdot e^{v_{be}/V_T} - I_C$$

$$\Rightarrow \frac{i_c}{I_C} = e^{v_{be}/V_T} - 1$$

(b) using small-signal approximation

$$i_c = g_m v_{be}$$

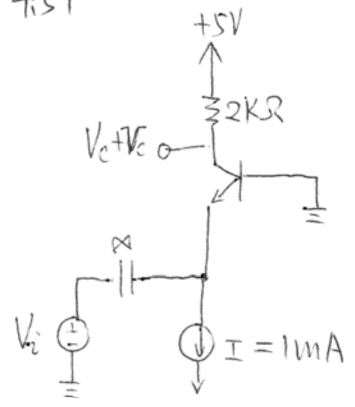
$$= \frac{I_C}{V_T} \cdot v_{be}$$

$$\Rightarrow \frac{i_c}{I_C} = \frac{v_{be}}{V_T}$$

v_{be} (mV)	i_c/I_C exponential	i_c/I_C small-signal Approx.	% error
+1	+0.041	+0.040	−2
−1	−0.039	−0.040	+2
+2	+0.083	+0.080	−4
−2	−0.077	−0.080	+4
+5	+0.221	+0.200	−9.5
−5	−0.181	−0.200	+10.3
+8	+0.377	+0.320	−15.2
−8	−0.274	−0.320	+16.8
+10	+0.492	+0.400	−18.7
−10	−0.330	−0.400	+21.3
+12	+0.616	+0.480	−22.1
−12	−0.381	−0.480	+25.9

For signal of ± 5 mV, the error introduced by small signal approximation is 10%. The error increases to 20% for signal of ± 10 mV

4.51



① Bias calculation (DC Analysis)

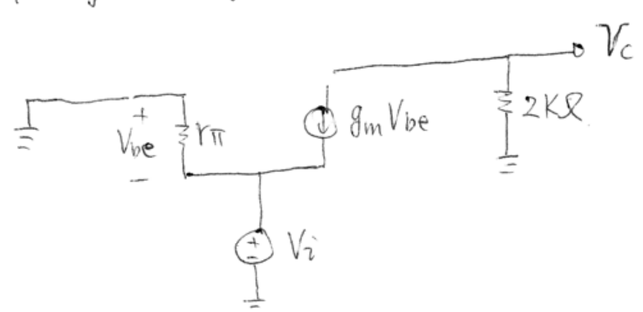
$I_E = I = 1mA$

β hig value $\Rightarrow$ $I_C \fallingdotseq I_E = 1mA$

$V_C = 5V - 2K\Omega \cdot 1mA = 3V$

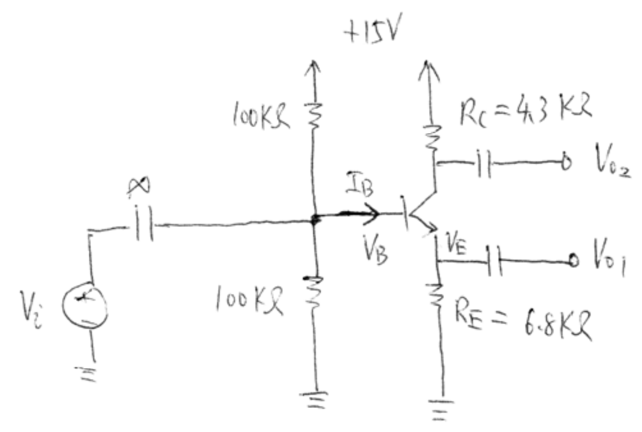
$g_m = \frac{I_C}{V_T} = \frac{1mA}{25mV} = 40mA/V$

② small-signal equivalent circuit



$$\frac{V_c}{V_i} = \frac{-g_m V_{be} \cdot 2K\Omega}{-V_{be}} = g_m \cdot 2K\Omega = 80V/V$$

4.64



① Bias calculation

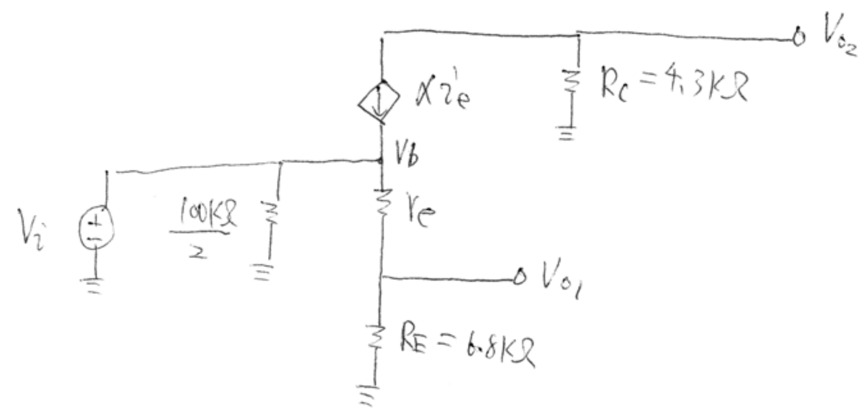
Large $\beta \Rightarrow I_B \fallingdotseq 0 \quad I_C \fallingdotseq I_E$

since $I_B = 0 \Rightarrow V_B = \frac{100K\Omega}{100K\Omega + 100K\Omega} \cdot 15V = 7.5V$

$$V_E = V_B - 0.7V = 6.8V$$

$$\Rightarrow I_E = \frac{V_E}{R_E} = \frac{6.8V}{6.8K\Omega} = 1mA = I_C$$

② Equivalent small-signal circuit (T-model)



since $V_i = V_b$, using voltage-divider rule, we have

$$V_{o1} = \frac{R_E}{R_E + r_e} \cdot V_b = \frac{R_E}{R_E + r_e} \cdot V_i$$

$$\Rightarrow \frac{V_{o1}}{V_i} = \frac{R_E}{R_E + r_e}$$

Also

$$i_e = \frac{V_b}{r_e + R_E} = \frac{V_i}{r_e + R_E}$$

$$V_{o2} = -\alpha i_e R_c = -\frac{\alpha R_c V_i}{r_e + R_E}$$

$$\Rightarrow \frac{V_{o2}}{V_i} = -\frac{\alpha R_c}{r_e + R_E}$$

For $r_e = \frac{V_T}{I_E} = 25\Omega$, $R_E = 6.8K\Omega$, $R_c = 4.3K\Omega$ and $\alpha = 1$

we have

$$\frac{V_{o1}}{V_i} = 0.996 \ V/V$$

$$\frac{V_{o2}}{V_i} = 0.63 \ V/V$$