ELECTRONISC II * Midterm 1 * 90 minutes * closed books and notes * July 23, 2010

I have neither given nor received unauthorized help with this exam, nor do I have reason that anybody else has.

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cancelled 1) For the amplifier circuit below, assume that V_s has a zero dc component and that I_{B1} is much smaller than the current in R_f. Find the dc voltages at all nodes and the dc emitter currents of Q_1 and Q_2. Let the BJTs have $\beta = 100$. Find small signal voltage gain v_o/v_s and R_{in}.

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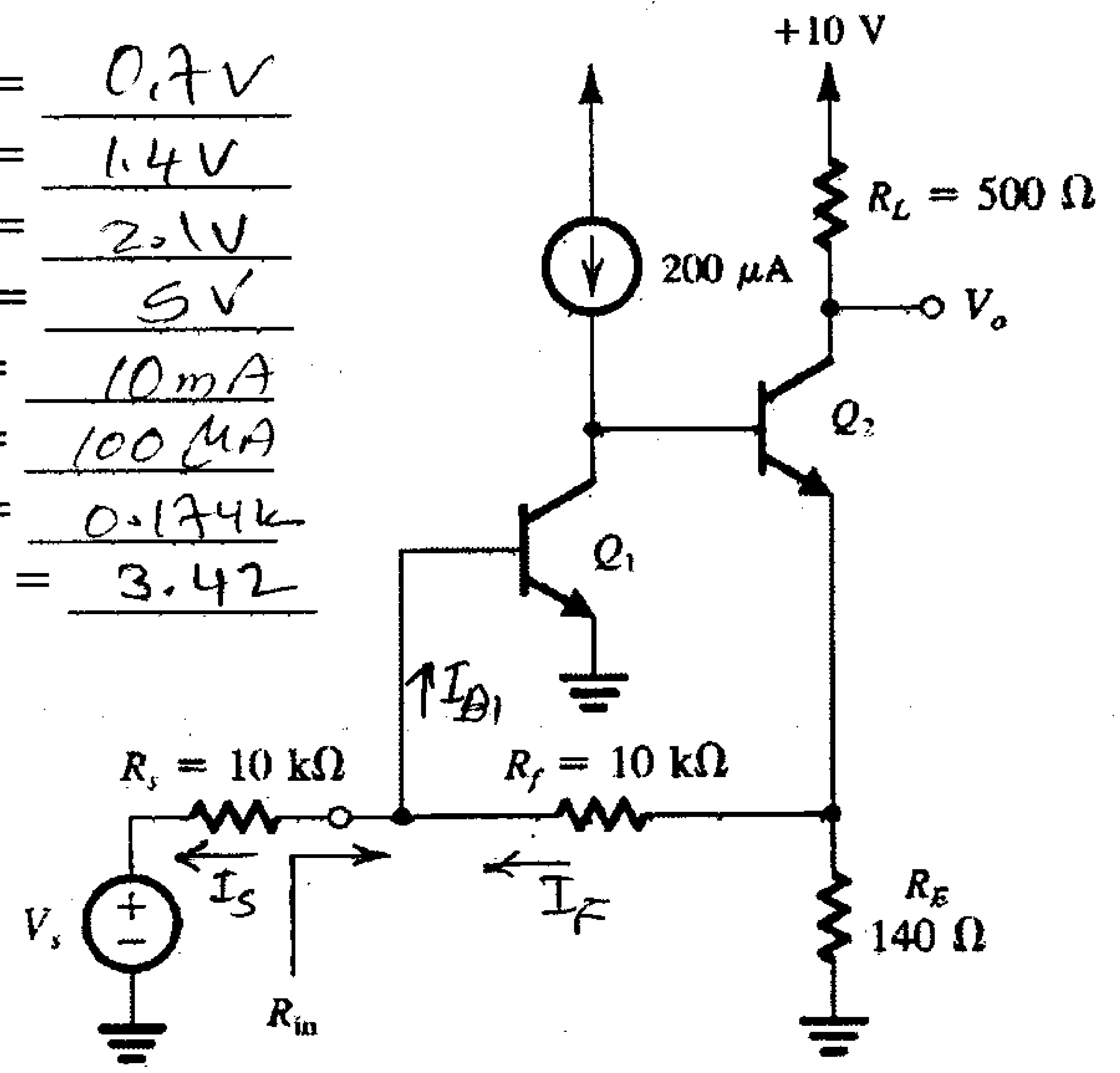
V_{B1} = 0.7V
V_{E2} = 1.4V
V_{B2} = 2.1V
V_{C2} = 5V
I_{E2} = 10mA
I_{E1} = 100μA
R_{in} = 0.174k
v_o/v_s = 3.42



$I_{B1} \ll I_F$ given

Q_1: active mode $\rightarrow V_{BE1} = 0.7V$

$V_{E1} = 0 \rightarrow V_{B1} = 0.7V$

Bias current $I_s \cong I_F = \frac{0.7}{10k}$

$V_{E2} = 2 \times I_s \times 10k$
$= 1.4\ V.$

$V_{B2} = V_{BE2} + V_{E2} = 2.1V$

$I_{E2} = \frac{V_{E2}}{0.140 \| 20k} \simeq \frac{1.4}{0.14} = 10mA$

$I_{C2} \simeq I_{E2}$ $\quad V_{C2} = 10 - 10 \times 0.5 = 5V$

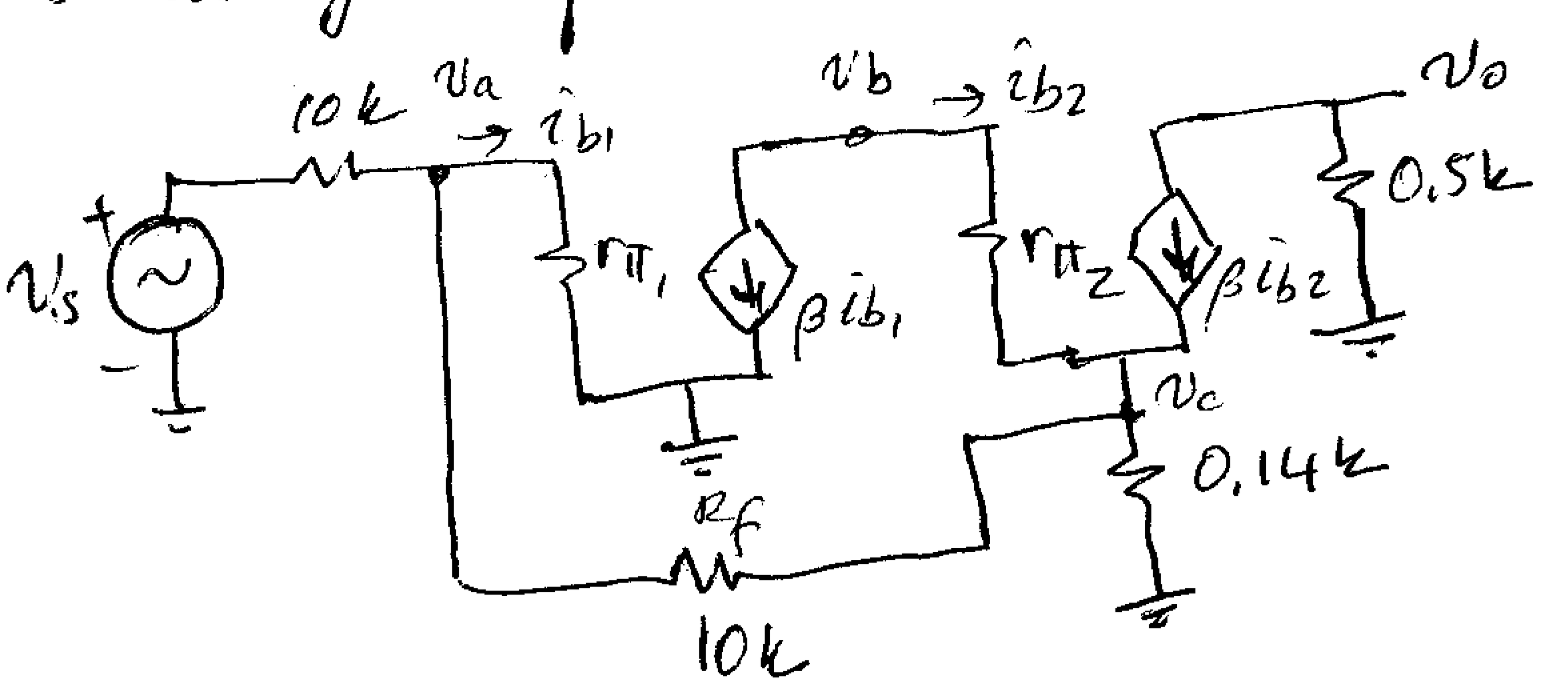
$I_{B2} = \frac{10}{100}\ mA = 0.1mA = 100\mu A$

$I_{C1} = 200 - 100 = 100\ \mu A = I_{E1}$

$g_{m1} = \frac{0.1}{0.025} = 4\ mA/V$, $\quad r_{\pi 1} = \frac{\beta}{g_{m1}} = \frac{100}{4} = 25k\Omega$

$g_{m2} = \frac{10}{0.025} = 400\ mA/V$, $\quad r_{\pi 2} = \frac{\beta}{g_{m2}} = \frac{100}{400} = 0.25\ k\Omega$

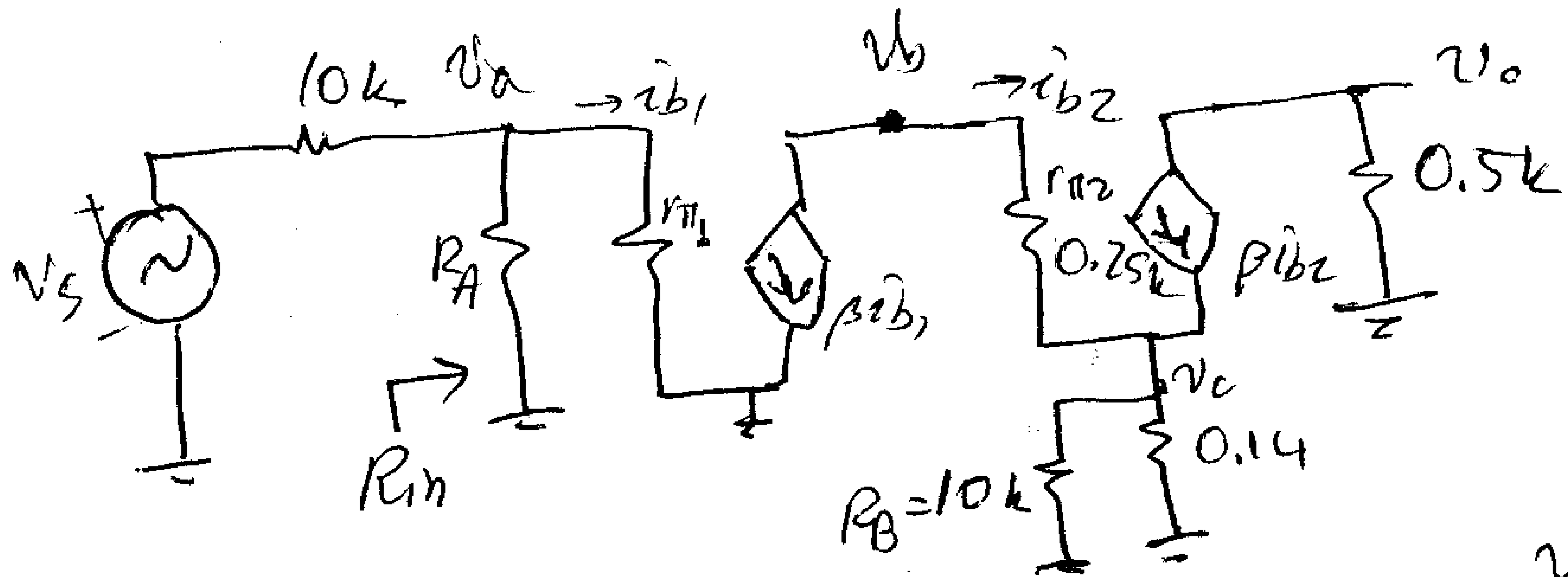
Small signal Eq. ckt:



Apply Miller's theorem on R_f

$R_A = \frac{R_f}{1 - \frac{v_c}{v_a}}$, $\quad R_B \simeq R_f$

$R_{in} = R_A \| r_{\pi 1} \simeq 0.174 \| 25 = 0.174k$



$\frac{v_c}{v_b} = \frac{(101)(0.14 \| 10)}{0.25 + (101)(0.14 \| 10)} = 0.98$

$\frac{v_b}{v_a} = \frac{-\beta(r_{\pi 2} + (\beta+1)(0.14 \| 10))}{r_{\pi 1}}$

$= \frac{-100 \times 14.36}{25} = -57.44$

$\frac{v_c}{v_a} = -57.44 \times 0.98 = -56.44$

$R_A = \frac{10}{57.44} = 0.174k$

$\frac{v_o}{v_b} = \frac{-100 \times 0.5}{14.36} = -3.48$

$\frac{v_o}{v_a} = (-3.48)(-57.44) = 200$

$\frac{v_o}{v_s} = 200 \frac{0.174}{10.174}$
$= 3.42$

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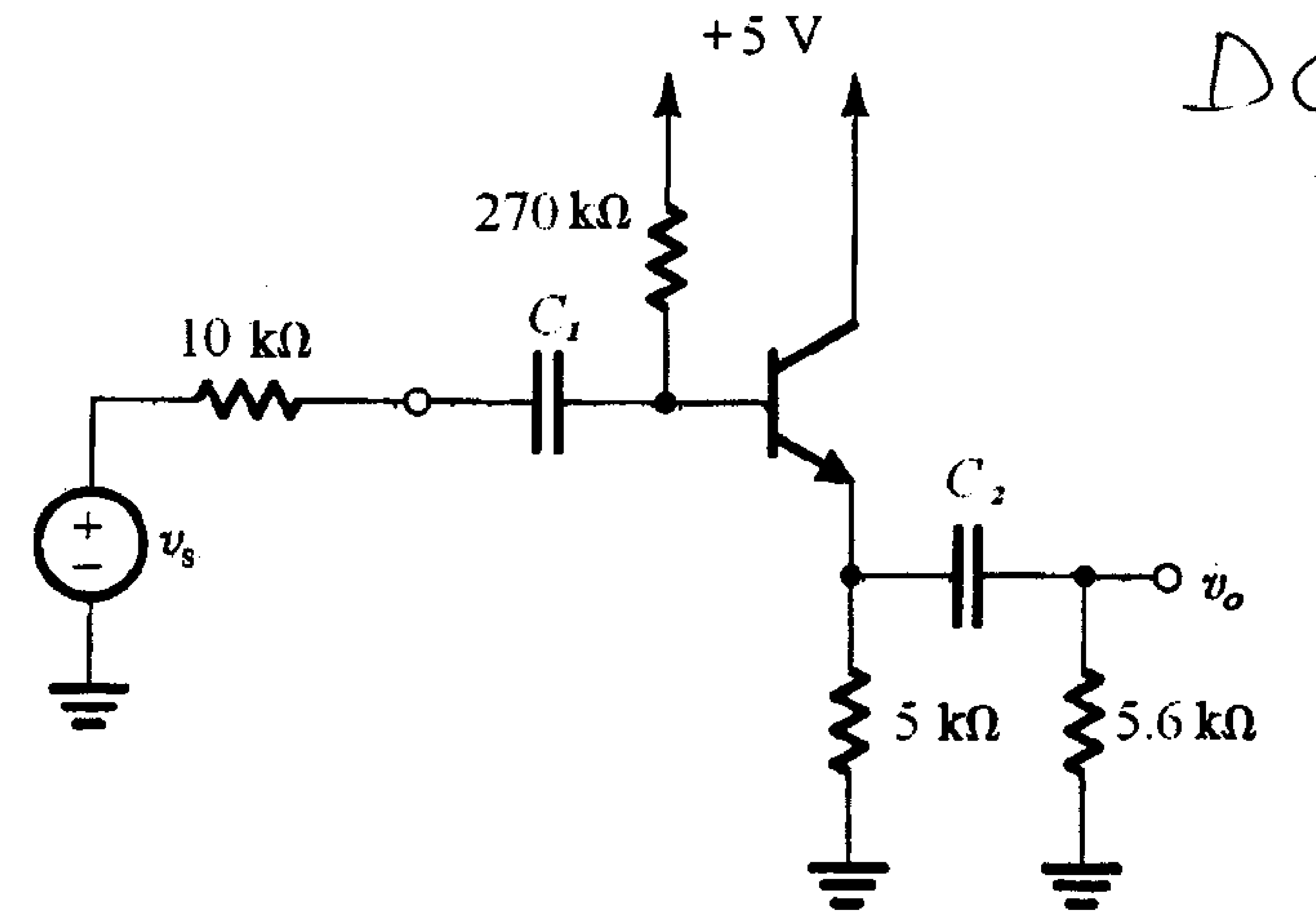
2) Select C_1 and C_2 in the circuit below so that the low 3dB cutoff frequency is 10 Hz. The BJTs have $\beta = 120$.

$C_1 =$ 0.8 µF $\quad C_2 =$ 3 µF



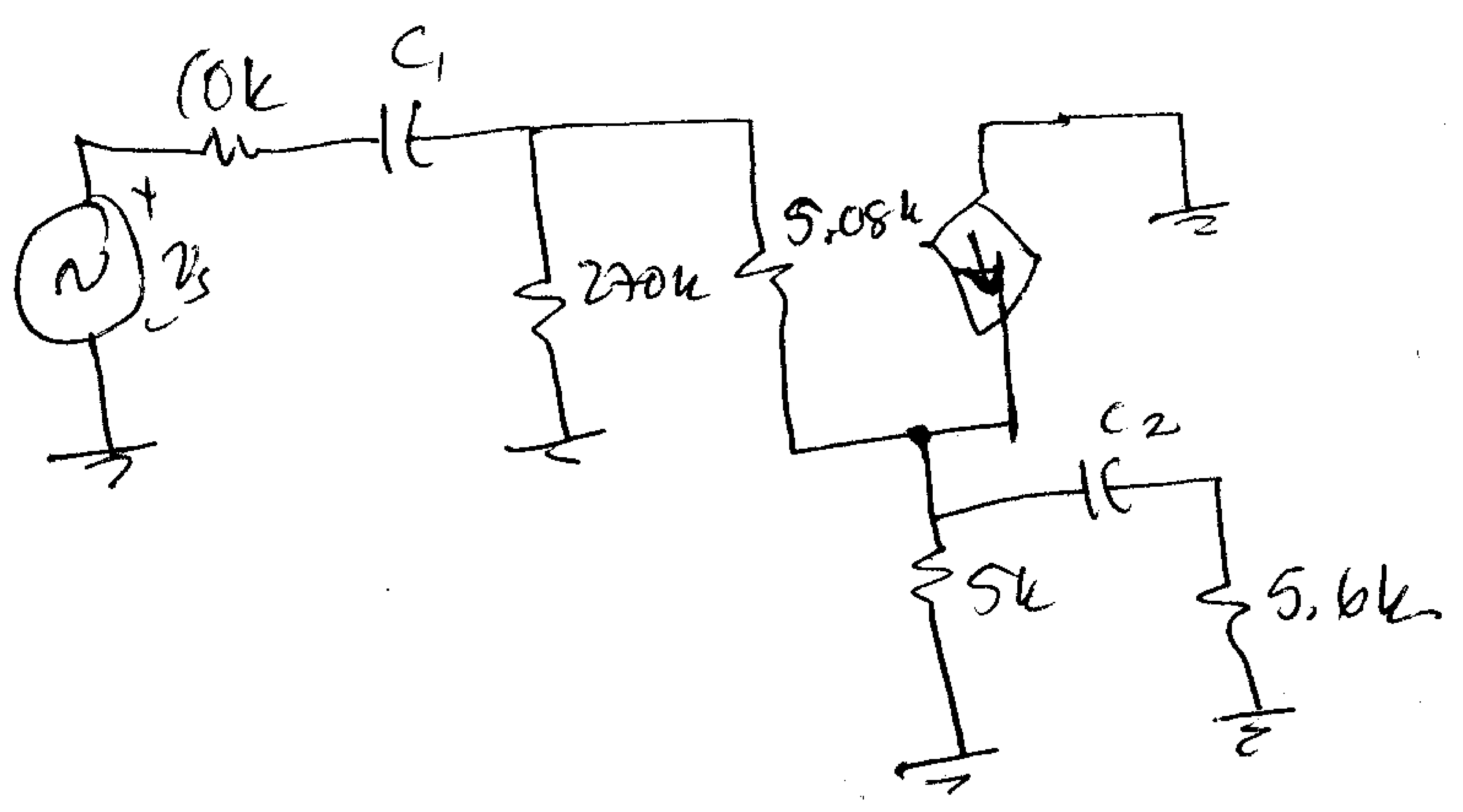
DC analysis: $5\times(\beta+1)I_B + 0.7 + 270 I_B = 5$

$I_B = \dfrac{5-0.7}{121\times 5 + 270} = 0.0049$

$I_C = 120\, I_B = 0.589$ mA

$g_m = \dfrac{0.589}{0.025} = 23.58$

$r_\pi = \dfrac{\beta}{g_m} = \dfrac{120}{23.58} = 5.08\ k\Omega$



C_2 has smaller Thevenin resistance; hence, its pole frequency should be larger for a small cap. value.

Let $\left.\begin{array}{l} f_2 = 9\text{ Hz} \\ f_1 = 1\text{ Hz}\end{array}\right\} f_L \cong f_1 + f_2 = 10\text{ Hz}$

C_1 is short cct when finding R_{th2}
C_2 is open cct " " R_{th1}

$R_{th1} = 10 + 270 \| [5.08 + 121\times 5] = 197.16\ k\Omega$ (C_2 open)

$R_{th2} = 5.6 + 5 \| \dfrac{(10\|270)+5.08}{\beta+1} = 5.6 + 0.118 = 5.718\ k\Omega$ (C_1 short)

$C_1 = \dfrac{1}{2\pi f_1 R_{th1}} = \dfrac{1}{2\pi\times 1\times 197160} = 0.8\times 10^{-6}\,F$

$C_2 = \dfrac{1}{2\pi f_2 R_{th2}} = \dfrac{1}{2\pi\times 9\times 5718} = 3.09\times 10^{-6}\,F$

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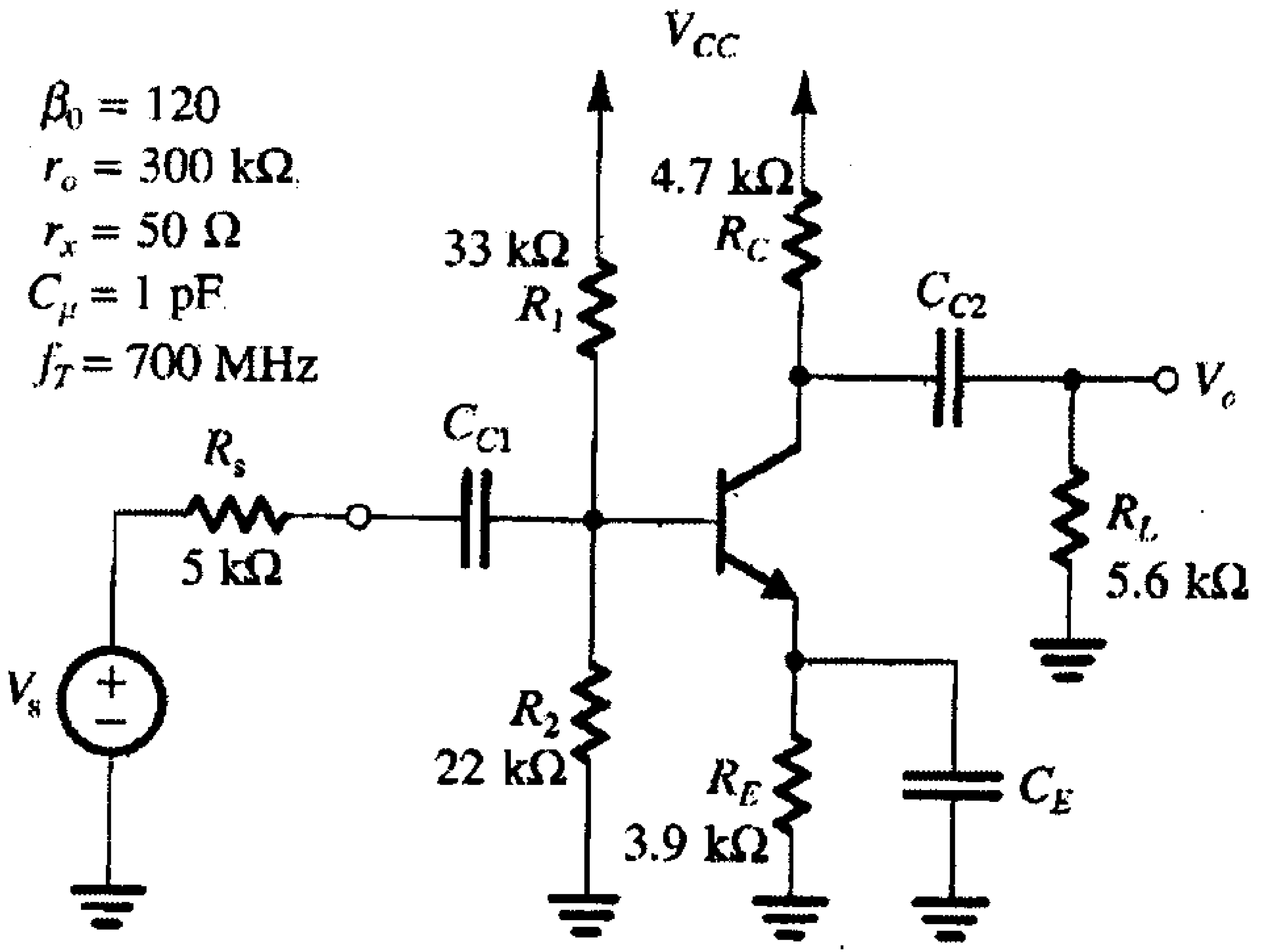
3) Using Miller's theorem, find the high 3-dB cutoff frequency for the amplifier given below.
Assume $I_C = 0.3$ mA.

$f_H =$ 1.78 MHz

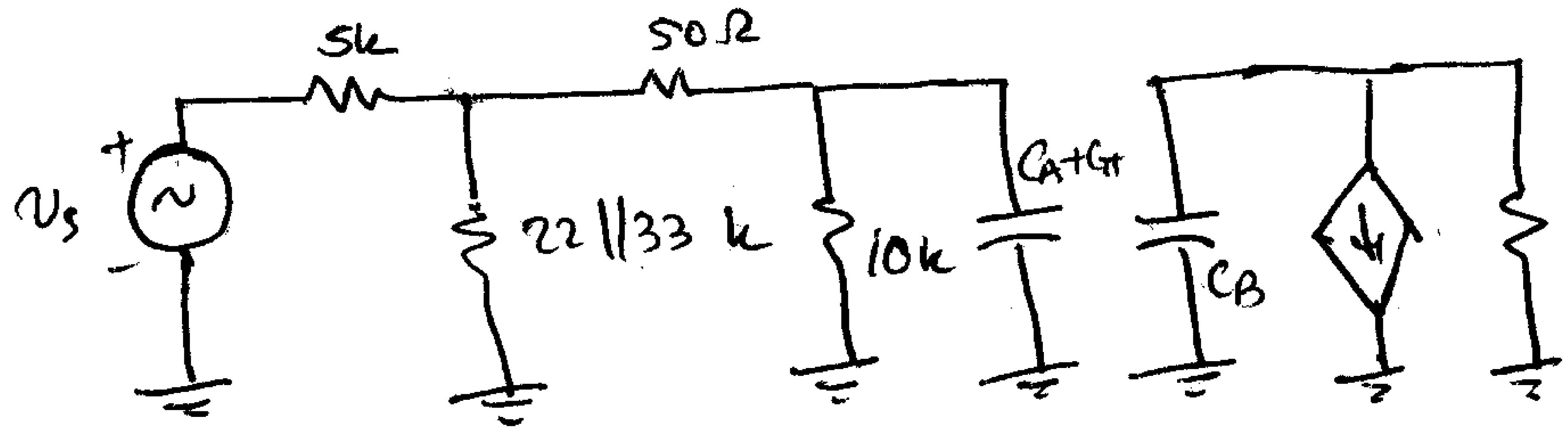


$I_c = 0.3\,mA$, $g_m = \frac{0.3}{0.025} = 12\,mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{120}{12} = 10\,k\Omega$

$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu = \frac{12\times10^{-3}}{2\pi\times700\times10^{6}} - 1\times10^{-12} = 1.73\,pF$

Small signal Equivalent ckt (Millers Theorem is applied on C_μ):



$R_{sh} = 4.7\|5.6\|300 = 2.53\,k\Omega$

$g_m R_{sh} = 30.4$

$C_A = C_\mu(1+g_m R_{sh}) = 1pF(30.4+1) = 31.4\,pF$

$C_B = C_\mu\left(1+\frac{1}{g_m R_{sh}}\right) \cong 1pF$

There are two HF poles: $\omega_A = \frac{1}{(C_A+C_\pi)R_{thA}}$, $\omega_B = \frac{1}{C_B R_{thB}}$

$R_{thA} = 10k\|[50 + 5k\|22k\|33k] = 2.68\,k\Omega$

$R_{thB} = R_{sh} = 2.53\,k\Omega$

$\omega_A = \frac{1}{(31.4+1.73)\times10^{-12}\times2680} = 11.23\times10^{6}\,rad/s$

$\omega_B = \frac{1}{1\times10^{-12}\times2530} = 395\times10^{6}\,rad/s$

$\omega_H = \frac{1}{\frac{1}{\omega_A}+\frac{1}{\omega_B}} \simeq \omega_A$ for $\omega_B \gg \omega_A$

$f_H = \frac{\omega_H}{2\pi} = \frac{11.23\times10^{6}}{2\pi} = 1.78\,MHz$