# Assignment # 3

5.7) $I_C = I_S e^{\frac{V_{BE}}{V_T}} \Rightarrow I_S = I_C e^{\frac{-V_{BE}}{V_T}}$ ; $V_T = 25mV$

$\alpha = \frac{\beta}{1+\beta}$ ; $\beta = \frac{\alpha}{1-\alpha}$ ; $I_C = \beta I_B = \alpha I_E$

; $I_C + I_B = I_E$

| Transistor | a | b | c | d | e |
|---|---|---|---|---|---|
| $V_{BE}$ (mV) | 690 | 690 | 580 | 780 | 820 |
| $I_C$ (mA) | 1.00 | 1.00 | 0.13 | 10.10 | 73.95 |
| $I_B$ (μA) | 50 | 70 | 7 | 120 | 1050 |
| $I_E$ (mA) | 1.05 | 1.07 | 0.137 | 10.22 | 75.00 |
| $\alpha$ | 0.952 | 0.935 | 0.949 | 0.988 | 0.986 |
| $\beta$ | 20 | 14.286 | 18.571 | 84.167 | 70.429 |
| $I_s$ (A) | $1.03*10^{-15}$ | $1.03*10^{-15}$ | $1.09*10^{-14}$ | $2.85*10^{-16}$ | $4.2*10^{-16}$ |

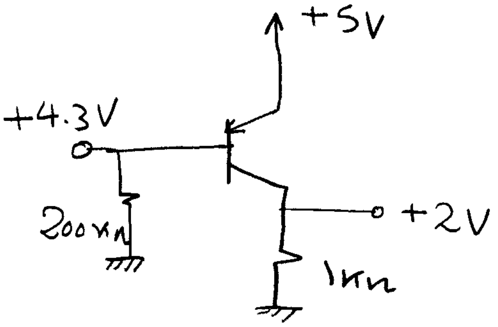
5.21)

$\beta = ?$

a) $I_B = \frac{4.3}{200} = 0.0215 mA$

$I_C = \frac{2}{1} = 2 mA$

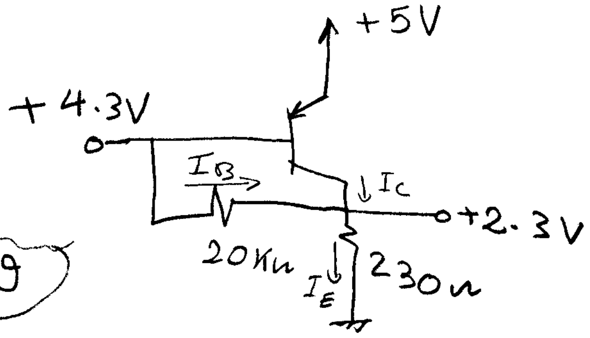
$\beta = \frac{I_C}{I_B} = \frac{2}{0.0215} = \boxed{93}$



b) $I_E = \frac{2.3}{0.23} = 10 mA$

$I_B = \frac{4.3-2.3}{20} = 0.1 mA$

$1+\beta = \frac{I_E}{I_B} = 100 \Rightarrow \boxed{\beta = 99}$



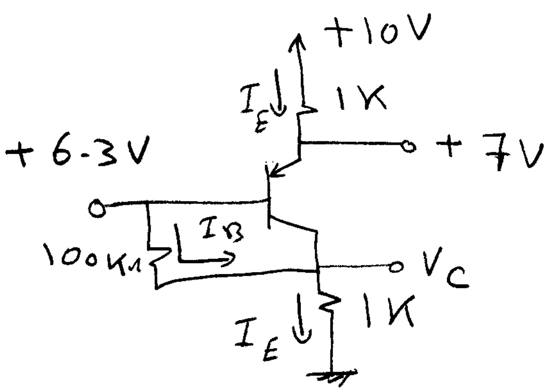
c) $I_E = \frac{10-7}{1K} = 3 mA$

$V_C = I_E * 1K = 3 V$

$I_B = \frac{6.3-3}{100} = 0.033 mA$

$1+\beta = \frac{I_E}{I_B} = 90.91$

$\Rightarrow \beta = \boxed{89.91}$



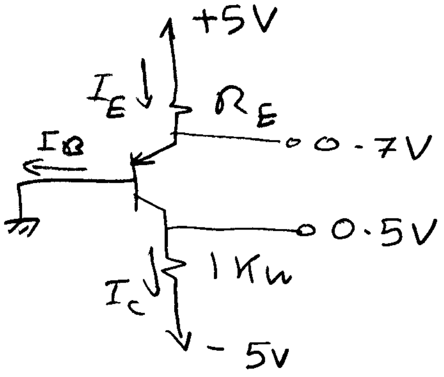
5.39) $r_o = \frac{V_A}{I_c} = \frac{200}{I_c}$

$I_c = 1mA \Rightarrow r_o = \boxed{200K\Omega}$

$I_c = 100\mu A \Rightarrow r_o = \boxed{2M\Omega}$

5.66) $R_E = ?$ ; $\beta_{forced} = 10$ ; $V_{EB} = 0.7V$

$V_{ECsat} = 0.2V$



$I_c = \frac{0.5-(-5)}{1} = 5.5mA$

$I_B = \frac{I_c}{\beta_{forced}} = \frac{5.5}{10} = 0.55\ mA$

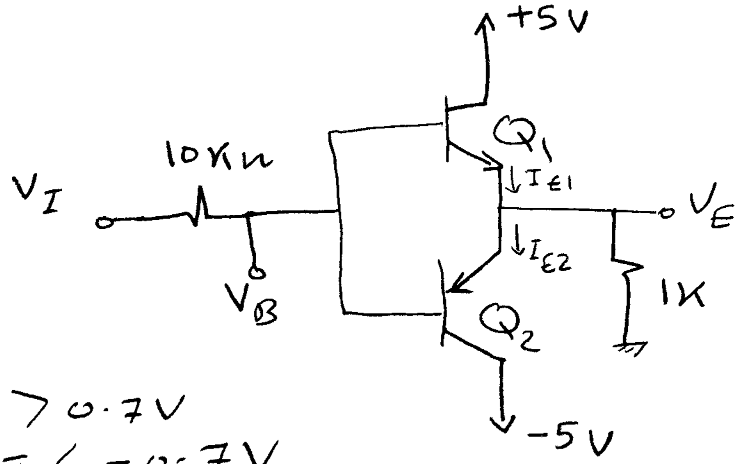
$I_E = I_c + I_B = 6.05mA$

$R_E = \frac{5-0.7}{I_E} = \frac{4.3}{6.05} = \boxed{0.71\ K\Omega}$

5.86) $\beta = 100$

$V_B = ?$ , $V_E = ?$

for $V_I = 0, +3, -5$ & $-10V$



note that $Q_1$ & $Q_2$ can't be on at the same time

⇒ this is push-pull ckt

for $Q_1$ to be on $\Rightarrow V_I > 0.7V$

for $Q_2$ to be on $\Rightarrow V_I < -0.7V$

$-0.7 < V_I < 0.7V \Rightarrow$ both $Q_1$ & $Q_2$ off

$V_I = 0\ V$

$Q_1, Q_2$ are off $\Rightarrow V_E = \boxed{0V}$, $V_B = \boxed{0V}$

$V_I = +3V$

$Q_1$ on & $Q_2$ off $\Rightarrow I_{E1} = \frac{3-0.7}{1+\frac{10}{101}} = 2.09mA$

$\therefore V_E = \boxed{2.09V}$ , $V_B = \boxed{2.79V}$

$V_I = -5V$ $Q_1$ off & $Q_2$ on $\Rightarrow I_{E2} = \frac{5-0.7}{1+\frac{10}{101}} = 3.91mA$

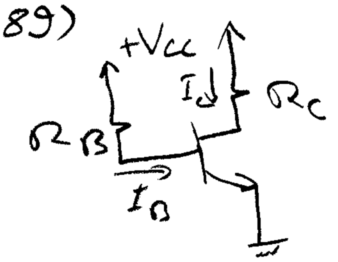
$V_E = \boxed{-3.91V}$ ; $V_B = \boxed{-4.61V}$

$V_I = -10V$ $Q_1$ off & $Q_2$ on (sat)

$\therefore V_E = \boxed{-4.8V}$ ; $V_B = \boxed{-5.5V}$

# H.W # 3

5.89)



$R_C = 3\,K\Omega$ , $V_{CC} = +5V$ , $\beta = 100$

$R_B = ?$ for $I_C = 1mA$

Solution:

$$I_B = \frac{V_{CC}-V_{BE}}{R_B} = \frac{I_C}{\beta} \Rightarrow \frac{5-0.7}{R_B} = \frac{1}{100}$$

$$\therefore \boxed{R_B = 430\,K\Omega}$$

Now $$I_C = \beta\left(\frac{V_{CC}-V_{BE}}{R_B}\right) = 0.01\beta\ mA$$

$$50 \leq \beta \leq 150$$

$$0.5mA \leq I_C \leq 1.5mA$$

Also, $V_{CE} = V_{CC} - I_C R_C$

$$\underset{\beta=150}{0.5V} \leq V_{CE} \leq \underset{\beta=50}{3.5V}$$

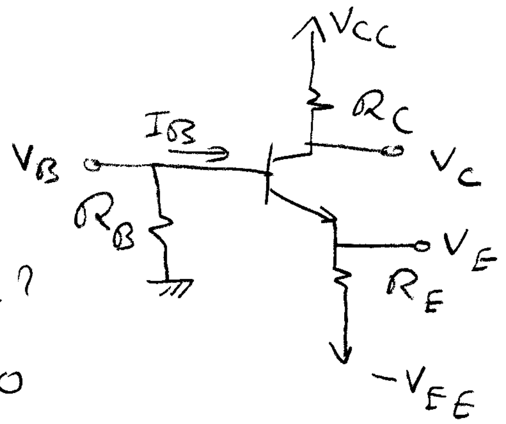
Note that for $\beta=150$ the transistor is near saturation.

Comment:

This design is not recommended since it is too sensitive to $\beta$ variations.

5.93) $V_{CC} = V_{EE} = 3V$

$I_C = 3mA$ ; $V_C$ is placed mid way between $V_{CC}$ & $V_E$



a) For $\beta = \infty$ ; Calculate $R_E$ & $R_C$?

Since $\beta = \infty \Rightarrow I_B = 0 \Rightarrow V_B = 0$

$\therefore V_E = -0.7V \Rightarrow R_E = \frac{V_E - (-V_{EE})}{I_E}$

$\therefore R_E = \frac{-0.7-(-3)}{3} = \boxed{0.767\ K\Omega}$

$V_C = \frac{V_E + V_{CC}}{2} = \frac{-0.7+3}{2} = 1.15V$

$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{3-1.15}{3} = \boxed{0.617\ K\Omega}$

b) $\beta_{min} = 90$ ; find the largest $R_B$ to limit the voltage drop across $R_B$ to 0.1 the voltage drop across $R_E$.

$I_B R_B \le 0.1 I_E R_E \Rightarrow R_B \le 0.1(1+\beta)R_E$

$R_B \le 0.1(1+\beta_{min}) R_E \Rightarrow R_B \le 0.1 * 91 * 0.767$

$\therefore$ largest $R_B = \boxed{6.98\ K\Omega}$

c) using Appendix G ( 5% - resistor Values)

$\therefore \boxed{R_B = 6.8\ K\Omega}$ $\boxed{R_E = 750\ \Omega}$ $\boxed{R_C = 620\ \Omega}$

d) For the values in part "C" find $I_C, V_B, V_E$ & $V_C$ for $\beta = \infty$ & $\beta = 90$

i) $\beta = \infty \Rightarrow \boxed{V_B = 0V}$ , $\boxed{V_E = -0.7V}$

$I_C = I_E = \frac{-0.7-(-3)}{0.75} = \boxed{3.07mA}$ ; $V_C = 3 - I_C R_C = \boxed{1.1V}$

ii) $\beta = 90 \Rightarrow I_B = \frac{V_{EE} - V_{BE}}{R_B + (1+\beta)R_E} = \frac{3-0.7}{6.8 + 91*0.75} = 30.6\mu A$

$\therefore I_C = \beta I_B = \boxed{2.76\ mA}$

$V_B = -I_B R_B = \boxed{-0.208V}$ ; $V_E = \boxed{-0.908V}$

$V_C = V_{CC} - I_C R_C = \boxed{1.29V}$

5-107) $g_{m\,nom} = 60\ mAV$, $50 \le \beta \le 200$, $I_c$ has ±20% vari.

extreme values for $r_\pi = ?$

$$g_m = \frac{I_c}{V_T} \Rightarrow 0.8 * 60 \le g_m \le 1.2 * 60\ mA/V$$

$$48 \le g_m \le 72\ mA/V$$

$$50 \le \beta \le 200$$

$$r_\pi = \frac{\beta}{g_m} \Rightarrow \frac{50}{72} \le r_\pi \le \frac{200}{48}$$

$$\boxed{0.694 \le r_\pi \le 4.167\ K\Omega}$$

$\boxed{r_{\pi\,max} = 4.167\ K\Omega}$ $\boxed{r_{\pi\,min} = 694\ \Omega}$

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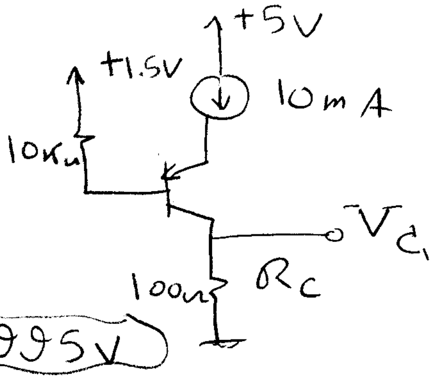
5.116) $\beta = 200$, dc voltage at collector = ?

$R_{ib} = ?$, $R_{in} = ?$, $\frac{v_o}{v_{sig}} = ?$

D.C operation:



$$V_c = I_C * R_C = \alpha I_E R_C$$

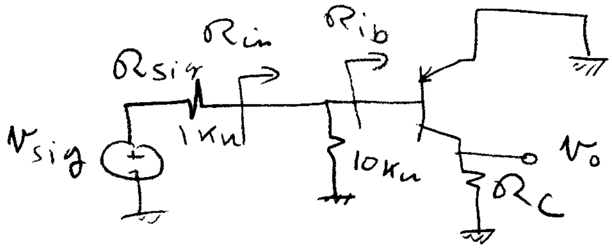
$$\alpha = \frac{\beta}{1+\beta} = \frac{200}{201} = 0.995$$

$$\therefore V_c = 0.995 * 10 * 0.1 = \boxed{0.995V}$$

A.C operation

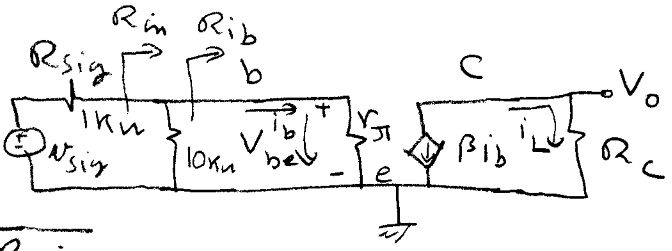
$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_c}$$

$$= \frac{200 * 0.025}{9.95} = \boxed{0.5\ K\Omega}$$



$$R_{ib} = r_\pi = \boxed{0.5\ K\Omega}$$

$$R_{in} = 10\ K\Omega \| r_\pi = \boxed{0.476\ K\Omega}$$



$$\frac{V_o}{V_{sig}} = \frac{V_o}{i_L} \cdot \frac{i_L}{i_b} \cdot \frac{i_b}{V_{be}} \cdot \frac{V_{be}}{V_{sig}}$$

$$= R_c * (-\beta) * \frac{1}{r_\pi} * \frac{R_{in}}{R_{in}+R_{sig}}$$

$$= -0.1 * 200 * \frac{1}{0.5} * \frac{0.476}{0.476+1} = \boxed{-12.9\ V/V}$$

for $v_o = \pm 0.4V \Rightarrow \boxed{V_{sig} = \mp 31mV}$ $\boxed{v_b = \pm 10mV}$

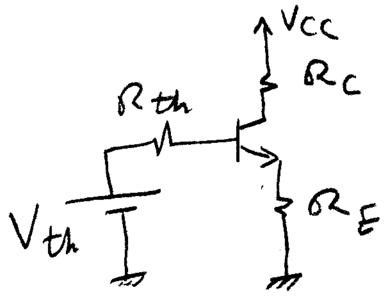
130) $V_{cc} = 9V$, $R_1 = 27K\Omega$, $R_2 = 15K\Omega$, $R_E = 1.2K\Omega$, $R_C = 2.2K\Omega$

$\beta = 100$, $V_A = 100V$, $R_{sig} = 10K\Omega$, & $R_L = 2K\Omega$.

$I_E = ?$ ; $R_{in} = ?$ ; $\frac{v_o}{v_{sig}} = ?$ & $\frac{i_o}{i_i} = ?$

* D.C Analysis:

All C's open ; all a.c zero



$R_{th} = R_1 || R_2 = \boxed{9.64\ K\Omega}$

$V_{th} = V_{cc} * \frac{R_2}{R_1+R_2} = \boxed{3.21V}$

applying KVL at E-B loop

$V_{th} = I_B R_{th} + V_{BE} + I_E R_E \Rightarrow I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{1+\beta}}$

$\therefore I_E = \frac{3.21 - 0.7}{1.2 + \frac{9.64}{101}} = \boxed{1.94\ mA}$

$I_C = \alpha I_E = 0.99 * 1.94 = \boxed{1.92mA}$

check: $V_{CE} = V_{cc} - I_C R_C - I_E R_E = 2.45V > V_{CEsat}$

* small signal parameters:

$g_m = \frac{I_C}{V_T} = 40 I_C = \boxed{76.8\ mA/V}$ ; $r_\pi = \frac{\beta}{g_m} = \boxed{1.3\ K\Omega}$

; $r_o = \frac{V_A}{I_C} = \boxed{52.1 K\Omega}$

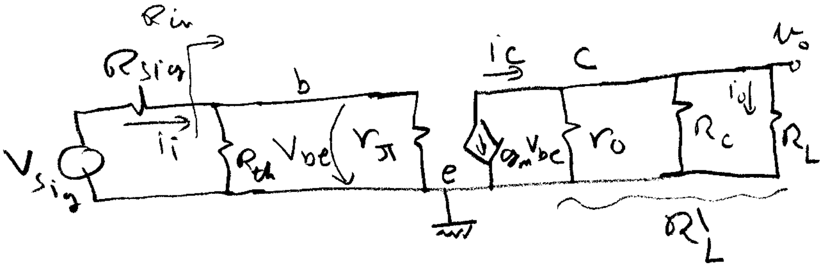
* A C Analysis:

All C's short, all d.c zero

$R_{in} = \frac{V_{be}}{i_i} = R_{th} || r_\pi$

$= 9.64K || 1.3K$

$= \boxed{1.15\ K\Omega}$



$R'_L = r_o || R_C || R_L$

$= \boxed{1.03\ K\Omega}$

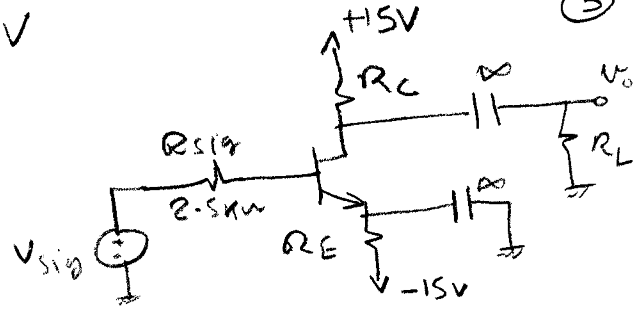
$\frac{v_o}{v_{sig}} = \frac{v_o}{i_c} \cdot \frac{i_c}{v_{be}} \cdot \frac{v_{be}}{v_{sig}} = R'_L * (-g_m) * \frac{R_{in}}{R_{in} + R_{sig}}$

$= 1.03 * (-76.8) * \frac{1.15}{1.15 + 10} = \boxed{-8.16\ V/V}$

$\frac{i_o}{i_i} = \frac{v_o / R_L}{v_{sig} / (R_{sig} + R_{in})} = \frac{v_o}{v_{sig}} * \frac{R_{sig} + R_{in}}{R_L}$

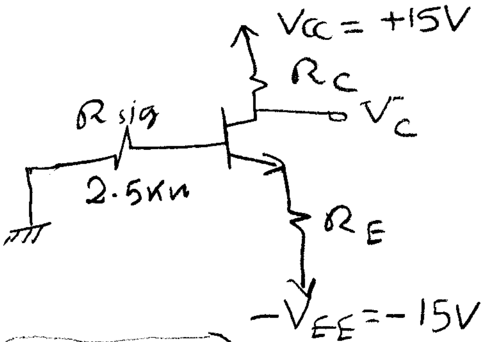
$= -8.16 * \frac{10 + 1.15}{2} = \boxed{-45.5\ A/A}$

134) $\beta = 100$, $I_E \approx 0.5mA$, $V_C = +5V$
$R_L = 10K\Omega$, $r_o = 200K\Omega$.
$R_C = ?$, $R_E = ?$, $A_v = \frac{v_o}{v_{sig}} = ?$



* D.C circuit:

All C's open, all a.c sources are zero
applying KVL at B-E loop



$$\therefore R_{sig} I_B + V_{BE} + R_E I_E - V_{EE} = 0$$

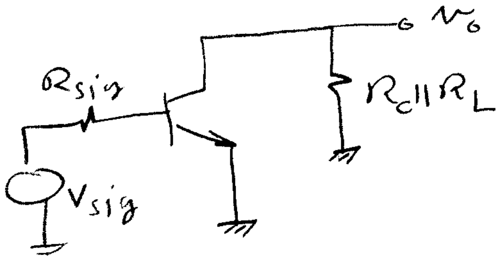
$$\therefore R_E = \frac{V_{EE} - V_{BE} - \frac{I_E}{1+\beta} R_{sig}}{I_E}$$

$$= \frac{15 - 0.7 - \frac{0.5}{101} * 2.5}{0.5} = \boxed{28.6K\Omega}$$

$$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{V_{CC} - V_C}{\alpha I_E} = \frac{15 - 5}{0.99 * 0.5} = \boxed{20.2K\Omega}$$

* A.C Analysis:

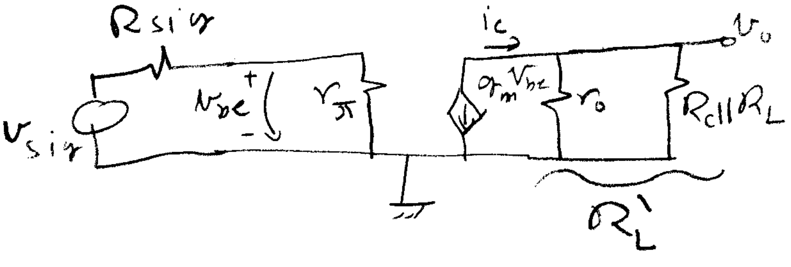
All C's short, all d.c zero



$$g_m = \frac{I_C}{V_T} = 40 I_C = 40 \alpha I_E$$

$$= \boxed{19.8 \ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{19.8} = \boxed{5.05K\Omega}$$



$$\frac{v_o}{v_{sig}} = \frac{v_o}{i_c} \cdot \frac{i_c}{v_{be}} \cdot \frac{v_{be}}{v_{sig}}$$

$$= R'_L * (-g_m) * \frac{r_\pi}{r_\pi + R_{sig}}$$

$$= 6.47 * (-19.8) * \frac{5.05}{7.55}$$

$$= \boxed{-85.72 \ V/V}$$

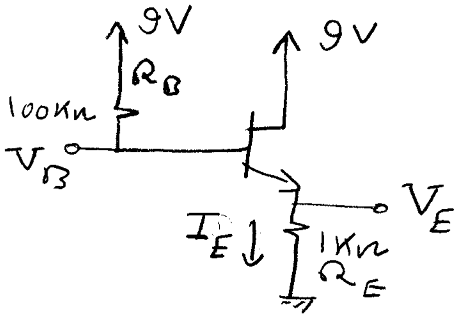
$$\boxed{R'_L = R_C \| R_C \| r_o = 6.47K\Omega}$$

5.143) $\beta_{min} = 40$, $\beta_{max}=200$

for both values of $\beta$ find $I_E, V_E, \& V_B$ ; $R_{in}$ , $\frac{v_o}{v_{sig}}$

* D.C Analysis:

All c's open, a.c sources zero



$$I_E = \frac{9 - V_{BE}}{R_E + \frac{R_B}{1+\beta}} = \frac{8.3}{1 + \frac{100}{1+\beta}} \text{ mA}$$

$$V_E = I_E R_E \text{ V}$$

$$V_B = V_E + V_{BE} = V_E + 0.7V$$

for $\beta = 40$

$I_E = 2.41 \text{ mA}$ ; $V_E = 2.41V$ ; $V_B = 3.11V$

for $\beta = 200$

$I_E = 5.54\text{mA}$ ; $V_E = 5.54 V$ ; $V_B = 6.24V$

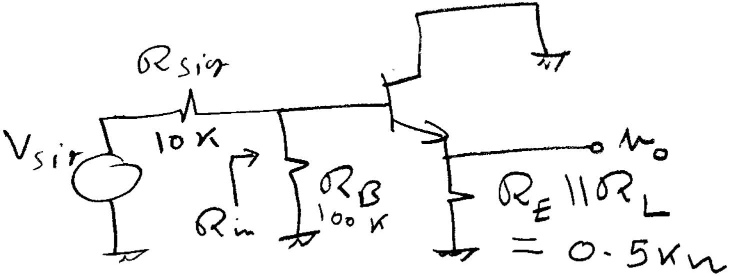
* A.C Analysis:

All c's short ; d.c sources zero

$$R_{in} = \frac{v_b}{i_i} = R_B || (1+\beta)(r_e + R_L')$$

$$\frac{v_o}{v_{sig}} = \frac{v_o}{v_b} * \frac{v_b}{v_{sig}}$$

$$= \frac{R_L'}{R_L' + r_e} * \frac{R_{in}}{R_{in} + R_{sig}}$$

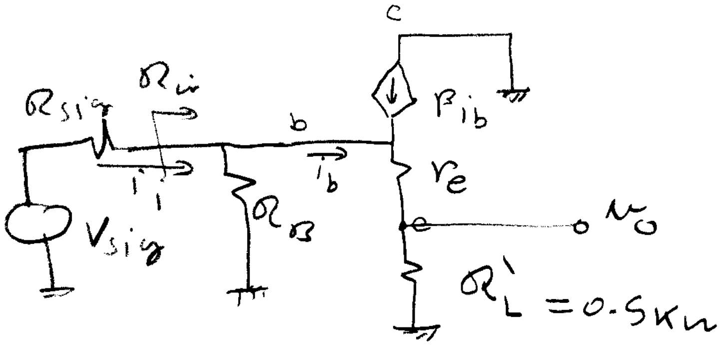


for $\beta = \beta_{min} = 40$

$$r_e = \frac{V_T}{I_C} = \frac{25m}{0.98 * I_E} = \boxed{10.6\Omega}$$

$$R_{in} = \boxed{17.3 K\Omega}$$

$$\frac{v_o}{v_{sig}} = \boxed{0.62 V/V}$$



for $\beta = \beta_{max} = 200$

$$r_e = \frac{V_T}{I_c} = \frac{25m}{0.98 * 5.54m} = \boxed{4.6\Omega}$$

$$R_{in} = \boxed{50.35 K\Omega}$$

$$\frac{v_o}{v_{sig}} = \boxed{0.83 V/V}$$