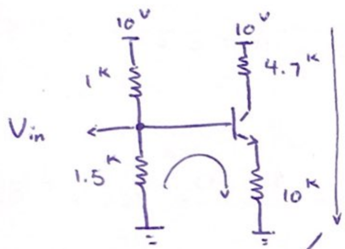
یا لطیف

تمرین سری ۱ الک 2 :

#1. Determine bias points in the following circuits. In which of the following circuits, the base current can be neglected?

$\beta = 100$, $|V_{be,on}| = 0.7^v$, $|V_{ce,sat}| = 0.2^v$

a)



$$V_{in} = \frac{1.5 \times 10}{1.5 + 1} = 6^v$$

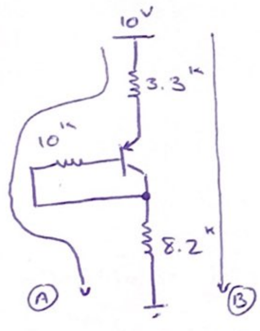
$$KVL: -6 + \underbrace{(1^k || 1.5^k)}_{= 0.6^k} I_B + 0.7 + 10^k I_c = 0$$

$$R_c + R_E >> \frac{R_B}{\beta + 1} \longrightarrow 10 I_c = 5.3 \Rightarrow \boxed{I_c = 0.53^{mA}}$$

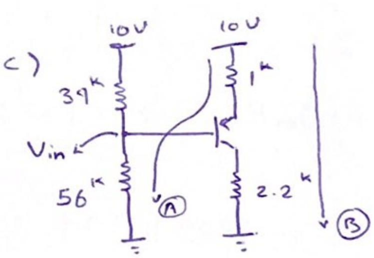
می‌توان از جریان بیس صرف نظر کرد

$$-10 + 4.7 I_c + V_{CE} + 10^k I_c = 0 \xrightarrow{I_c = 0.53^{mA}} V_{CE} = 2.209^v > V_{CE,sat}$$

b)



c)



$$KVL @ A: -10 + 3.3^k I_c + 0.7 + \cancel{10^k I_B} + 8.2^k I_c = 0$$

$$\Rightarrow \boxed{I_c = 0.808^{mA}}$$

$$KVL @ B: -10 + 3.3 I_c + V_{CE} + 8.2^k I_c = 0$$

$$\xrightarrow{I_c = 0.808^{mA}} V_{CE} = 0.72^v > V_{CE,sat}$$

$$V_{in} = \frac{56 \times 10}{56 + 39} = 5.89$$

$$KVL @ A: -10 + 1^k I_c + 0.7 + 39^k || 56^k \left(\frac{I_c}{100}\right) + 5.89 = 0$$

$$\Rightarrow \boxed{I_c = 2.79^{mA}}$$

می‌توان از جریان بیس صرف نظر کرد.

$$KVL @ B: -10 + 1^k I_c + V_{CE} + 2.2^k I_c = 0$$

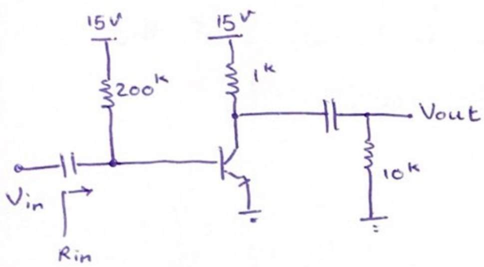
$$\xrightarrow{I_c = 2.79^{mA}} V_{CE} = 1.35 > V_{CE,sat}$$

#2. Calculate the input resistance (R_i) as well as the voltage gain ($A_v = \frac{V_o}{V_i}$) in the circuit shown below.

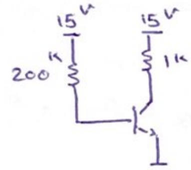
$V_A = \infty$, $V_T = 25^{mV}$, $\beta = 100$

hint: capacitor in dc : open circuit

capacitor in ac : short circuit



dc Analysis :

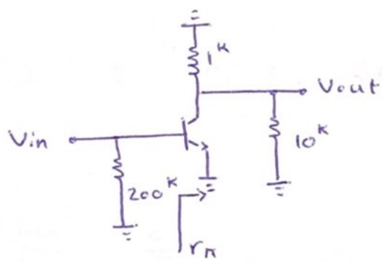


KVL : $-15 + 200^k\left(\frac{I_c}{100}\right) + 0.7 = 0$

$\Rightarrow I_c = 7.15^{mA}$

KVL : $-15 + 1^k I_c + V_{CE} = 0 \xrightarrow{I_c = 7.15^{mA}} V_{CE} = 7.85 > V_{CE,sat}$

ac Analysis :



$g_m = \frac{I_c}{V_T} = 40 I_c = 286$ mmho

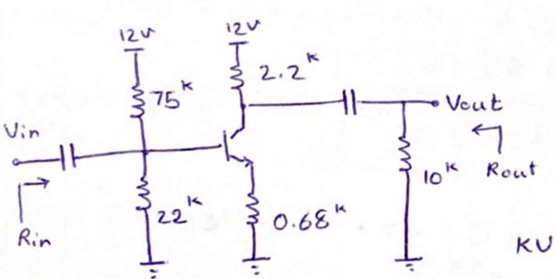
$r_\pi = \frac{\beta}{g_m} = \frac{100}{286} = 0.34^{k\Omega}$

$r_o = \frac{V_A}{I_c} = \infty$

$A_v = \frac{V_{out}}{V_{in}} = -g_m R_c = -286\left(10^k \| 1^k\right) = -259.9\bar{9}$

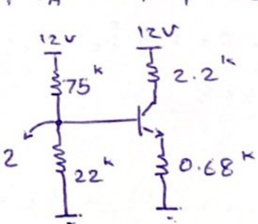
$R_{in} = 200^k \| r_\pi = 200^k \| 0.34^k \simeq \boxed{0.34^k}$

#3. In the following circuit, calculate the voltage gain, input resistance and output resistance. $V_{BE} = 0.6$, $V_{CE,sat} = 0.2$, $V_A = 100$, $V_T = 25^{mV}$, $\beta = 100$



dc Analysis :

$V_{in} = 2.72$



KVL : $-2.72 + 22^k \| 75^k\left(\frac{I_c}{100}\right) + 0.6 + 0.68^k I_c = 0$

$\Rightarrow I_c = 2.5^{mA}$

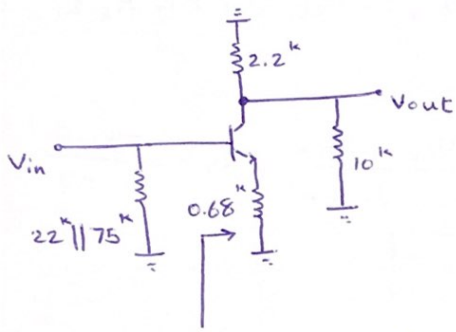
KVL : $-12 + 2.2^k I_c + V_{CE} + 0.68^k I_c = 0$

$\Rightarrow V_{CE} = 4.8 > V_{CE,sat}$

ac Analysis : $g_m = 40 I_c = 40 \times 2.5 = 100^{\,mmho}$, $r_\pi = \frac{\beta}{g_m} = \frac{100}{100} = 1^k$

$r_o = \frac{V_A}{I_c} = \frac{100}{\cancel{100}\ 2.5} = 40^k$

$A_v = \frac{V_{out}}{V_{in}} = \frac{-R_c}{R_E + \underbrace{r_m}_{=\frac{1}{g_m}}} = \frac{-(2.2^k \| 10^k)}{0.68^k + \frac{1}{100}} = \boxed{-2.61}$

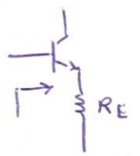


$R_{in} = 22^k \| 75^k \| 70^k \simeq \boxed{13.7^k}$

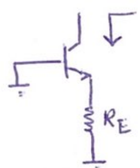
$R_{out} = 10^k \| 2.2^k \| \left[40^k(1 + 100(0.68^k \| 1^k))\right] \simeq 70^k$

$r_\pi + (1+\beta) R_E = 1^k + 101(0.68^k) \simeq 70^k$

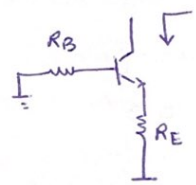
hint :



$r_\pi + (\beta+1) R_E$



$(1 + g_m r_o)(R_E \| r_\pi) + r_o$
$\simeq r_o(1 + g_m(R_E \| r_\pi))$



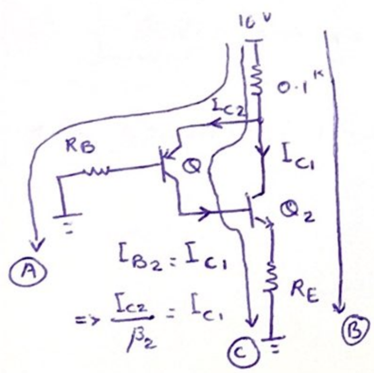
$r_o\left[1 + \frac{\beta R_E}{R_E + r_\pi + R_B}\right]$

#4. In the following circuit :

a) Determine the bias points of the transistors. Assume $R_E = 0$

b) Calculate the maximum value of R_E for which Q_1 remains in the active region.

$V_{CC} = 16^V$, $R_C = 0.1^k$, $R_B = 1500^k$, $V_{CE,sat} = 0.2^V$, $V_{BE,ON} = 0.7$, $\beta_1 = 160$
$\beta_2 = 200$



$I_{B_2} = I_{C_1}$

$\Rightarrow \frac{I_{C2}}{\beta_2} = I_{C_1}$

a) KVL @A : $-16 + 0.1^k(I_{C_1} + I_{C_2}) + 0.7 + 1500^k I_{B_1} = 0$

$\Rightarrow 9.475 I_{C_1} + 0.1 I_{C_2} = 15.3 \xrightarrow{I_{C2} = \beta_2 I_{C1}}$

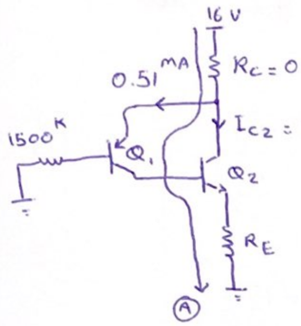
$\boxed{I_{C_1} = 0.51^{mA}}$, $\boxed{I_{C_2} = 103^{mA}}$

KVL @ B : $-16 + 0.1(I_{C_1} + I_{C_2}) + V_{CE_2} = 0$

$\Rightarrow V_{CE_2} = 5.649 > V_{CE,sat}$

KVL @ C : $-16 + 0.1^k(I_{C_1} + I_{C_2}) + V_{CE_1} + 0.7 = 0 \Rightarrow V_{CE_1} = 4.95 > V_{CE,sat}$

b) $i_{c_1} = 0.51^{mA}$



$I_{B_2} = I_{c_1} = 0.51 \Rightarrow \frac{I_{c_2}}{\beta_2} = 0.51$

$\Rightarrow I_{c_2} = 200\,(0.51) = 102^{mA}$

KVL @ A : $-16 + 0.1^k(I_{c_1} + I_{c_2}) + V_{CE_1} + 0.7 + R_E I_{c_2} = 0$

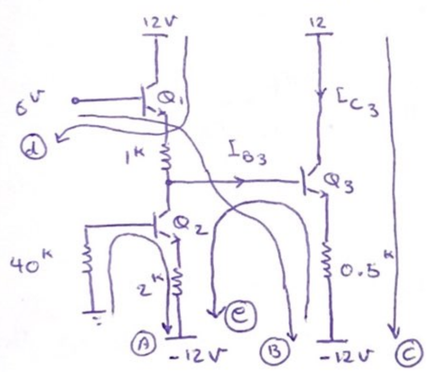
$\Rightarrow 102\,R_E = 5.049 - V_{CE}$

$R_E = \frac{5.049 - V_{CE}}{102}$ $\xrightarrow[R_E \to max]{\text{If } V_{CE} \to min}$ $R_E = \frac{5.049 - 0.2}{102}$

$R_{E,max} = 0.047^k = \boxed{47.5^{\Omega}}$

#5. In the circuit shown below, the transistor are the same. Determine the bias points.

$\beta = 100$, $V_{be,on} = 0.6^v$



KVL @ A : $40^k\left(\frac{I_{c_2}}{100}\right) + 0.6 - 12 + 2^k I_{c_2} = 0$

$\Rightarrow I_{c_2} = 4.75^{mA} = \boxed{I_{c_1}}$

KVL @ B : $-6 + 0.6 + 1^k I_{c_1} + 0.6 + 0.5^k I_{c_3} - 12 = 0$

$\Rightarrow \boxed{I_{c_3} = 24.1^{mA}}$

KVL @ C : $-12 + V_{CE_3} + 0.5\,I_{c_3} - 12 = 0$

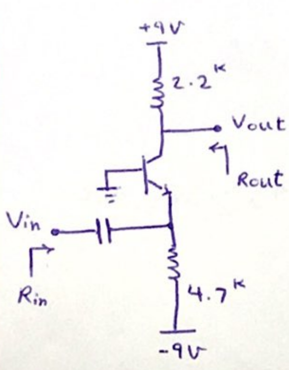
$\Rightarrow \boxed{V_{CE_3} = 11.95^v}$

KVL @ d : $-12 + V_{CE_1} - 0.6 + 6 = 0 \Rightarrow \boxed{V_{CE_1} = 6.6^v}$

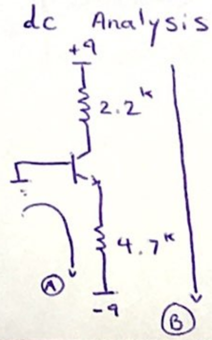
KVL @ e : $\cancel{+12} - 0.5^k I_{c_3} - 0.6 + V_{CE_2} + 2^k I_{c_2} \cancel{-12} = 0 \Rightarrow \boxed{V_{CE_2} = 3.15^v}$

#6. Calculate the voltage gain, input resistance and output resistance of the following scheme.

$V_{BE} = 0.7$, $V_{CE,sat} = 0.2$, $V_A = \infty$, $V_T = 25^{mv}$, $\beta = 100$



dc Analysis :



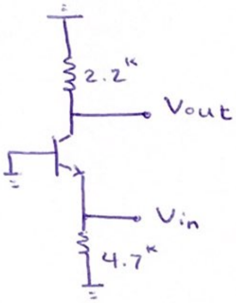
KVL @ A : $+0.7 + 4.7^k I_c - 9 = 0$

$\Rightarrow \boxed{I_c = 1.76^{mA}}$

KVL @ B : $-9 + 2.2^k I_c + V_{CE} + 4.7^k I_c - 9 = 0$

$\Rightarrow V_{CE} = 5.85^v > V_{CE,sat}$

ac Analysis : $g_m = 40 I_c = 70.4$ mmho , $r_\pi = \frac{\beta}{g_m} = 1.42^k$, $r_o = \infty$

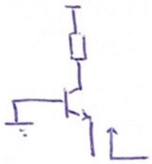


$A_v = +g_m R_c = \cancel{40}\ 70.4 \times 2.2^k = \boxed{154.88}$

$R_{out} = 2.2^k \parallel \infty = 2.2^k$

$R_{in} = 4.7^k \parallel \underbrace{r_m}_{=\frac{1}{g_m}} = 0.013^k = \boxed{13.9\ \Omega}$

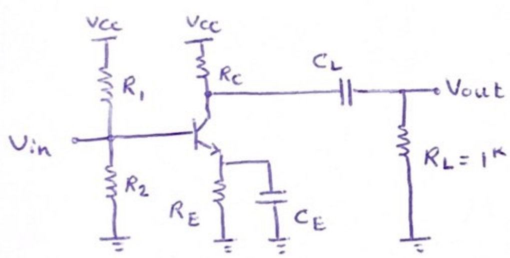
<u>hint</u> :



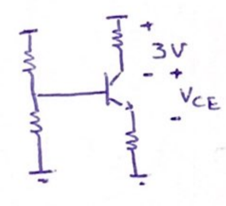
$\frac{1}{g_m} \parallel r_\pi \parallel r_o \approx r_m$

#7. In the following circuit, the voltage gain and the dc voltage drop on R_c is $-48\ \frac{V}{V}$ and 3^V, Respectively. Determine R_c.

$V_{CE,sat} = 0^V$, $V_T = 25^{mV}$, $R_L = 1^k$



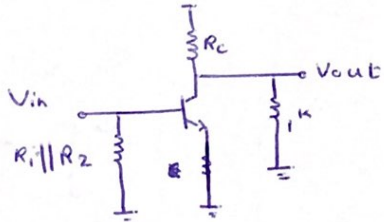
dc Analysis :



$V_c = I_c R_c \Rightarrow I_c = \frac{3}{R_c}$

$g_m = 40 I_c = \frac{120}{R_c}$

ac Analysis :



$A_v = \frac{V_{out}}{V_{in}} = -g_m R_c = -\frac{120}{R_c}\left(R_c \parallel R_L\right) = -48$

$\frac{-120}{R_c}\left[\frac{R_c \times 1^k}{R_c + 1^k}\right] = -48 \Rightarrow \boxed{R_c = 1.5^k}$

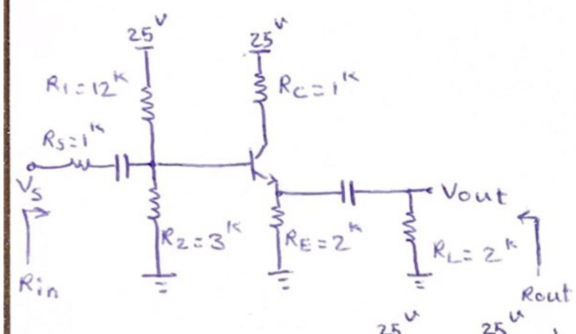
#8. In the following circuit:

a) calculate the voltage gain ($V_{be,on} = 0.7$)

b) determine the output voltage (V_o) swing.

c) Modify R_1 in order to maximize the output voltage swing

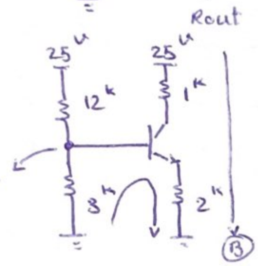
$V_{BE} = 0.6$, $V_{CE,sat} = 0.2^{v}$, $V_A = \infty$, $V_T = 25^{mV}$, $\beta = 80$



KVL : $-5^{v} + 3^{k} \| 12^{k} \left(\frac{I_c}{80} \right) + 0.6 + 2^{k} I_c = 0$

$\Rightarrow \boxed{I_c = 2.1^{mA}}$

DC Analysis :

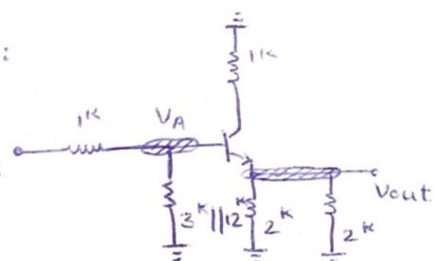


$\frac{3 \times 25}{3+12} = 5^{v}$

KVL @ B : $-25 + 1^{k}(2.1^{m}) + V_{CE} + 2^{k}(2.1^{m}) = 0$

$\Rightarrow V_{CE} = 18.7 > V_{CE,sat}$

ac Analysis :



$$\begin{cases} g_m = 40 I_c = 40(2.1) = 84^{mmho} \\ \beta = 80 \\ r_\pi = \frac{\beta}{g_m} = 0.95^{k} \\ r_o = \infty \end{cases}$$

$$A_v = \frac{V_{out}}{V_s} = \frac{V_{out}}{V_A} \times \frac{V_A}{V_s} = \left[\frac{R_E}{R_E + r_m} \right] \times \left[\frac{(3^{k} \| 12^{k}) \| r_\pi + (1+\beta) R_E}{\left(3^{k} \| 12^{k} \| r_\pi + (1+\beta) R_E\right) + 1} \right]$$

$$= \left[\frac{2^{k} \| 2^{k}}{2^{k} \| 2^{k} + \frac{1}{84}} \right] \times \left[\frac{3^{k} \| 12^{k} \| 80.95^{k}}{(3^{k} \| 12^{k} \| 80.95^{k}) + 1^{k}} \right] \simeq 0.98 \times 0.7 = \boxed{0.686 \ \tfrac{v}{v}}$$

b) Swing V_o :

$$\text{swing}_{V_{CE}} = \min \left\{ V_{CE,Q} - V_{CE,sat} \ , \ R_{AC} I_c \right\}$$

$R_{AC} = \left[R_E + R_c \right]_{in\ ac}$

$$= \min \left\{ 18.7 - 0.2 \ , \ 2^{k} \times 2.1^{mA} \right\} = \min \left\{ 18.5 , 4.2 \right\}$$

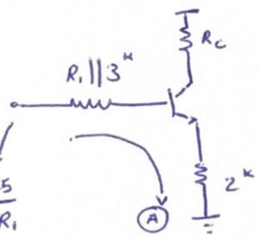
$$= \boxed{4.2} \quad \Rightarrow \text{Swing}_{V_o} = \frac{R_c}{R_c + R_E} \cdot \text{Swing}_{V_{CE}} = \boxed{2.1^{v}}$$

$R_{DC} = \left[R_E + R_c \right]_{in\ dc}$

c) $R_{ac} = 2^k$ $\xrightarrow[\text{شود}]{\text{برای اینکه سوئینگ ماکزیمم}}$ $I_c = \dfrac{V_{cc} - V_{ce,sat}}{R_{ac} + R_{dc}} = \dfrac{25 - 0.2}{3 + 2} = 5^{mA}$

$R_{dc} = 3^k$

DC Analysis :



$V_{TH} = \dfrac{3 \times 25}{3 + R_1}$

KVL @ A : $\dfrac{-75}{R_1 + 3} + 0.6 + 2^k(5^{mA}) = 0$ $\Rightarrow$ $10.6\, R_1 = 43.2$ $\Rightarrow$ $\boxed{R_1 = 4^k}$