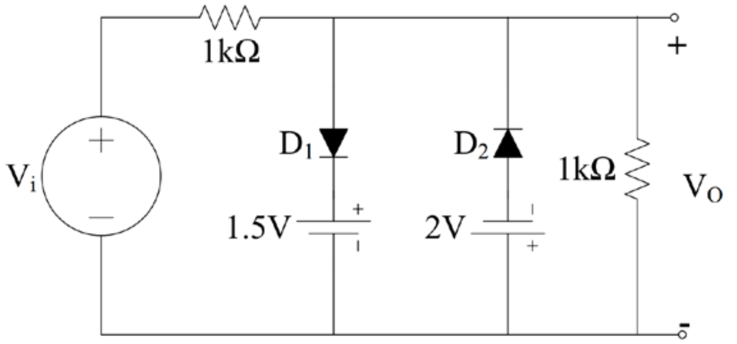
Major Quiz 1 SET-B Solution

Date – 11.02.2019

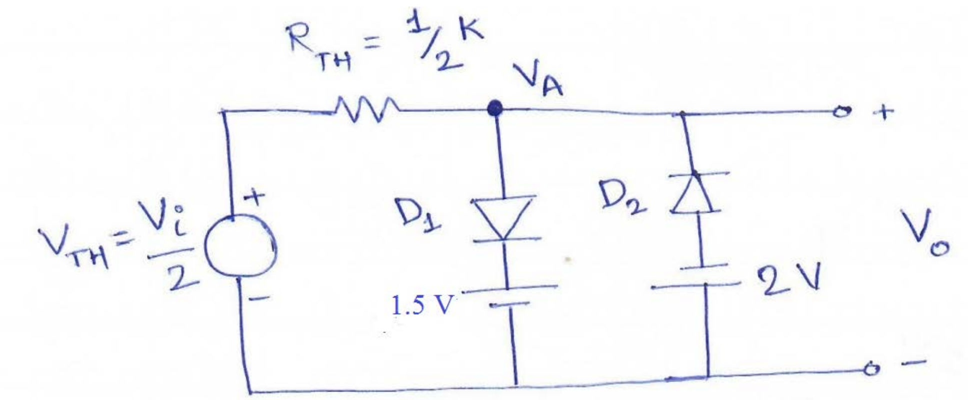
Name: ______________________ Roll No.: ___________ Section: ________ Total Marks: 40

BJT in the problems has following characteristics: $I_S = 2.03 * 10^{-15}A, V_T = 25mV, \beta = 200,\ V_A \to \infty$

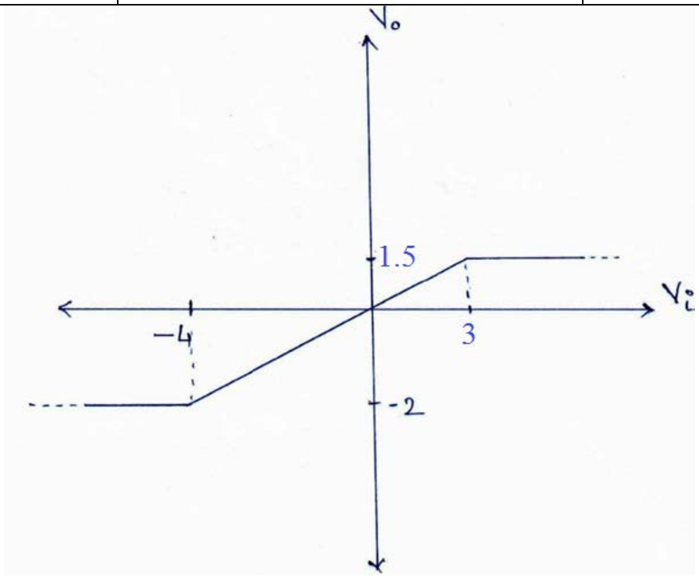
Q1. Draw the transfer characteristics (V_0 vs. V_i) of the circuit shown in figure below, if both diodes D_1 and D_2 are assumed to be ideal. (V_i varies from -5V to 5V). [10]



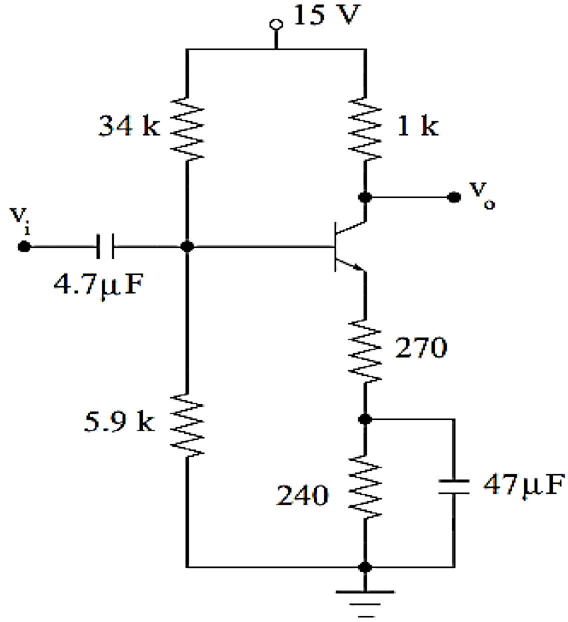
Sol. Thevenin's equivalent



Case (i)	Case (ii)	Case (iii)
$V_A < -2V$	$V_A > 1.5V$	$-2V \leq V_A \leq 1.5V$
D_1 is reversed biased (Open ckt) D_2 is forward biased (Short ckt)	D_1 is forward biased (Short ckt) D_2 is reversed biased (Open ckt)	D_1 is reversed biased (Open ckt) D_2 is reversed biased (Open ckt)
$V_0 = -2V$	$V_0 = 1.5V$	$V_0 = V_A = \frac{V_i}{2}$



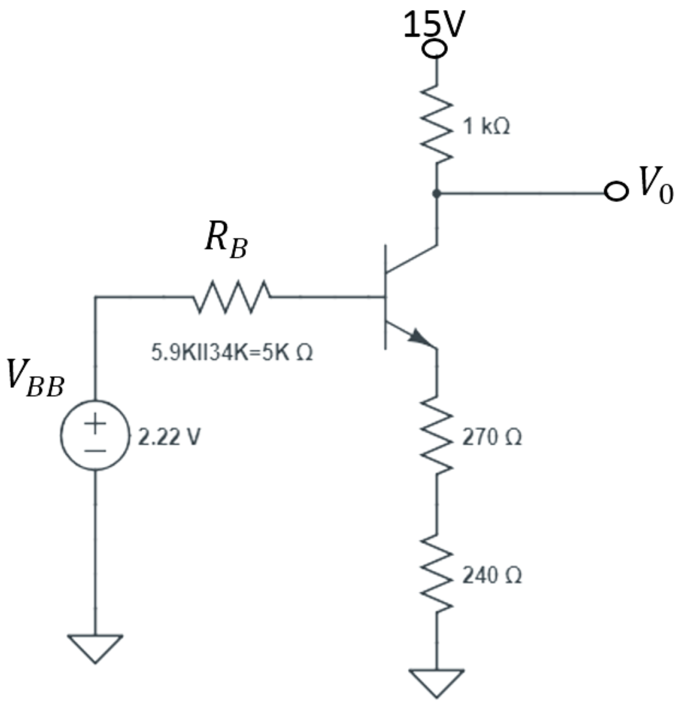
Q2. Find the bias point and the region of operation of the transistor in the circuit shown below. [10]



Sol.:

DC analysis:

The Thevenin's equivalent network at input:



$$R_B = 5.9K \| 34K \approx 5.0K\Omega$$

$$V_{BB} = \frac{5.9}{5.9 + 34} 15 = 2.22V$$

Assuming transistor is in forward active mode.

Using KVL for Input loop:

$$V_{BB} = R_B I_B + V_{BE} + 510 I_E$$

$$I_B = \frac{I_E}{1+\beta} = \frac{I_E}{201}$$

$$2.22\text{-}0.7 = I_E \left(\frac{5.0*10^3}{201} + 510\right)$$

$$I_E = 3mA \approx I_c$$

$$I_B = \frac{I_C}{\beta} = 15\mu A$$

Using KVL for Output loop:

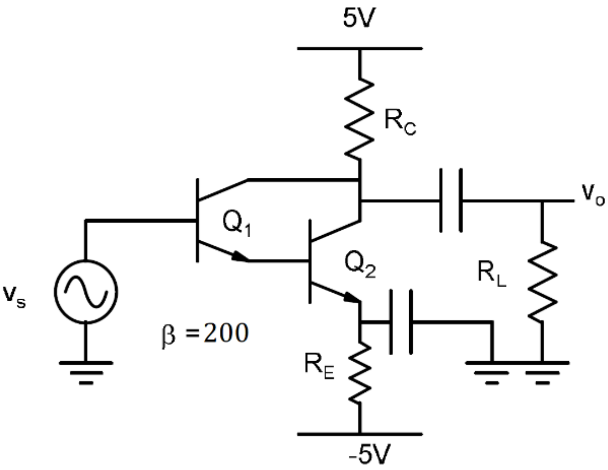
$$V_{CC} = 1000 I_C + V_{CE} + 510 I_E$$

$$V_{CE} \cong 15 - 1510 * 3 * 10^{-3} = 10.5V > 0.2V$$

Our assumption of BJT in forward active mode is justified.

Bias Summary: $V_{CE} = 10.5V$, $I_C = 3mA$, and $I_B = 15\mu A$.

Q3. The amplifier shown below is designed with bias point ($I_{CQ2} = 2.4mA\ and\ V_{CEQ2} = 3.3V$). What is the open circuit voltage gain and input resistance for this amplifier? Determine maximum output voltage swing (for HD_2 = 10% and $R_L = 2K\Omega$) and, which transistor goes into saturation first? [20]



Sol.:

$$I_{CQ2} = 2.4mA \quad \Rightarrow \quad I_{BQ2} = I_{CQ1} = \frac{2.4}{\beta} = 12\mu A$$

$$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$$

$$V_{BE1} \approx 0.6V\ , V_{BE2} \approx 0.7V$$

Applying KVL at the input loop:

$$\frac{-1.3+5}{R_E} = I_{EQ2} = \frac{1+\beta}{\beta} I_{CQ2} \Rightarrow R_E = 1.53k\Omega$$

$$\Rightarrow V_C = 3.3 - 1.3 = 2V \Rightarrow R_C = \frac{V_{CC} - V_C}{I_{CQ2}} = 1.25k\Omega$$

Small signal equivalent circuit:

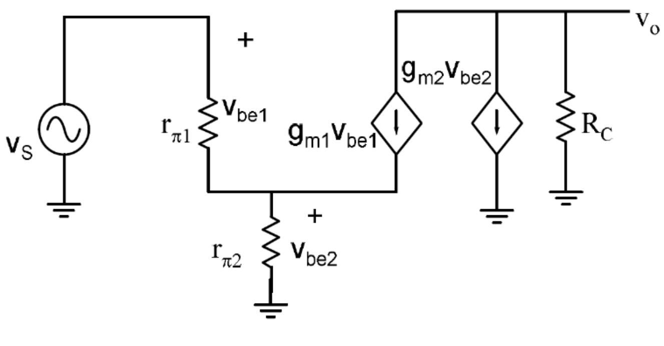
$$I_{C2} = \beta I_{B2} = \beta I_{C2}$$

We know that,

$$r_\pi = \frac{V_T}{I_{CQ}}\beta \text{ and } g_m = \frac{I_{CQ}}{V_t}$$

$$r_{\pi 1} = \beta r_{\pi 2}$$

$$g_{m2} = \beta \times g_{m1}$$



Applying KVL at input loop of small signal equivalent,

$$v_s = v_{be1} + v_{be2}$$

$$v_{be2} = g_{m1} v_{be1} \times r_{\pi 2} = \frac{I_{CQ1}}{V_T} \times \frac{V_T}{I_{CQ2}} \beta \times v_{be1} = v_{be1}$$

$$v_{be1} \cong v_{be2} = 0.5 v_s$$

The output voltage v_0 is given by:

$$v_o = -(g_{m2}v_{be2} + g_{m1}v_{be1})R_C \cong -g_{m2}v_{be2}R_C$$

$$A_{Vo} \cong -0.5g_{m2}R_C = -60$$

$$R_{in} \cong r_{\pi1} \times (1 + g_{m1}r_{\pi2}) = 2r_{\pi1} = 833k\Omega$$

$$\frac{|A_{Vo}| \times R_{in}}{R_o} = \frac{0.5g_{m2}R_C \times 2r_{\pi1}}{R_C} = \frac{I_{CQ2}}{V_T} \times \frac{V_T}{I_{CQ1}}\beta \cong \beta^2 = 4 * 10^4$$

Note that $V_{CEQ} = V_{CEQ1} + V_{BEQ2}$

Transistor Q_1 can go into saturation but not transistor Q_2.

Maximum output voltage swing:

$$v_{om} = Min\left\{V_{CEQ2} - V_{CEsat1} - 0.7; (I_{CQ2} \times R_c \parallel R_L) \times \left(\frac{HD_2}{25}\right)\right\}$$

$$v_{om} = 0.738\,V$$