1. For silicon at T=300K, Intrinsic carrier concentration $(n_i) = 1.45 \times 10^{10}\ cm^{-3}$. This silicon is doped at room temperature (300K) with Arsenic atoms (pentavalent), and the donor concentration is $(N_D) = 6\times 10^{16}\ cm^{-3}$.

Find the equilibrium concentration of electrons, holes and shift of the chemical potential (Fermi level) with respect to intrinsic chemical potential.

$n_i = 1.45 \times 10^{10}\ cm^{-3}$

$T = 300\ K$

$N_D = 6 \times 10^{16}\ cm^{-3} \simeq n$

mass-action, $np = n_i^2$

$\Rightarrow p = \dfrac{(1.45 \times 10^{10})^2}{6 \times 10^{16}} = 3.5 \times 10^{3}\ cm^{-3}$

$E_F = E_i + KT \ln\left(\dfrac{N_D}{n_i}\right)$ $\quad K = 8.617 \times 10^{-5}\ eV/K$

intrinsic energy level

$\Delta E = (8.617 \times 10^{-5} \times 300) \ln\left(\dfrac{6 \times 10^{16}}{1.45 \times 10^{10}}\right)$

$= 2585.1 \times 10^{-5} \times \ln(4.1379 \times 10^{6})$

$= 0.3938\ eV$

2. For the circuit shown, assume $\beta = h_{FE} = 100$

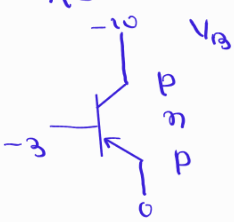
a) Find if the silicon transistor is in cutoff, saturation or in the active region.

b) Find V_O

c) Find the minimum value for the emitter resistance R_e for which the transistor operates in the active region.

Assume in cutoff, current $= 0$

$V_B = -3\ V$ $\quad V_C = -10V$ $\quad V_E = 0$

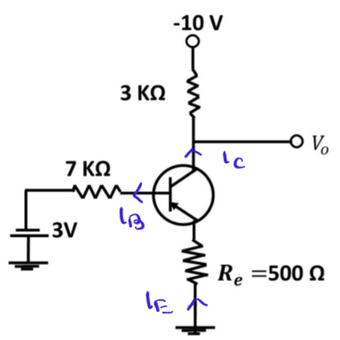


$V_E > V_B \Rightarrow$ forward

$\Rightarrow$ contradict for cutoff

let's, Q in saturation

$V_{BE} = 0.8\ V$ $\quad V_{BC} = 0.5\ V$



$I_E = -\dfrac{V_E}{\frac{500}{1000}}\ mA = -2(V_B + 0.8)$

$I_B = \dfrac{V_B + 3}{7}\ mA$ $\quad I_C = \dfrac{V_B + 0.5 + 10}{3}$

$I_E = I_B + I_C$

$\Rightarrow -2(V_B + 0.8) = \dfrac{V_B + 3}{7} + \dfrac{V_B + 10.5}{3}$

$\Rightarrow -1.6 - \dfrac{3}{7} - \dfrac{10.5}{3} = +\dfrac{V_B}{7} + \dfrac{V_B}{3} + 2V_B$

$\Rightarrow V_B = -2.232\ V$

$I_B = 0.109\ mA$

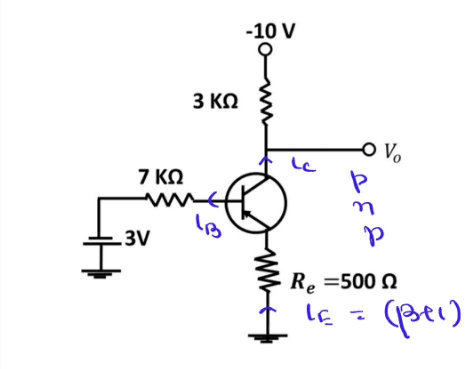
$I_C = 2.756\ mA$

$\dfrac{I_C}{I_B} = 25.28 < \beta$ $\quad \Rightarrow$ Q in saturation region

b) $V_o = -10 + 3 \times 2.756$

$= -1.732\ V$

c) $R_e = ?$ Q - to be operate in active region
B-E forward & B-C - reverse



I_c p n p
I_B
$I_E = (\beta+1) I_B$

Input side,

$-3 + 7 I_B + 0.7 + (\beta+1) I_B R_E = 0$

$I_B = \dfrac{2.3}{7+(\beta+1) R_E}$

output side,

$-3 + 7 I_B - V_{BC} - 3(\beta I_B) + 10 = 0$

$V_{BC} \geq 0$ (for reverse bias)

$\Rightarrow 7 I_B - 3\beta I_B + 7 \geq 0$

$\Rightarrow (7 - 300) I_B + 7 \geq 0$

$\Rightarrow 7 > 293 \dfrac{2.3}{7+101 R_E}$

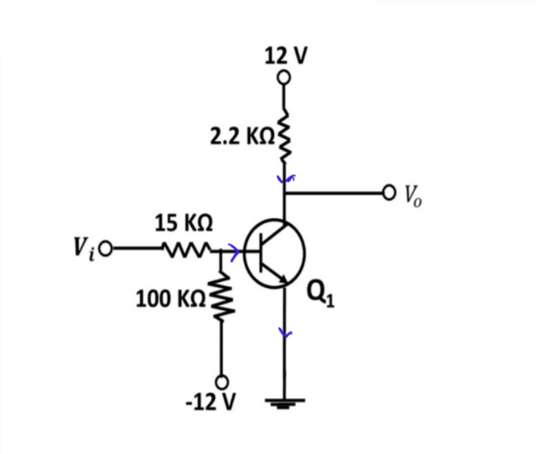
$\Rightarrow 7 + 101 R_E \geq 96.27 =$

$\Rightarrow R_E \geq 0.8838$ kΩ

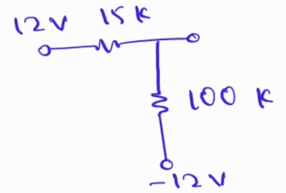
$R_E)_{min} = 883.8\ \Omega$

3.A transistor circuit is given below (silicon transistor). The transistor has a minimum value of β=30

i) Find Vo for $V_i = 12V$
ii) Find Vo for $V_i = 1V$



(i)



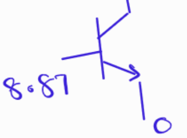
$R_{th} = \dfrac{1500}{115}$ kΩ

$= 13.04$ kΩ

$V_{th} = \dfrac{24}{115} \times 100 - 12$

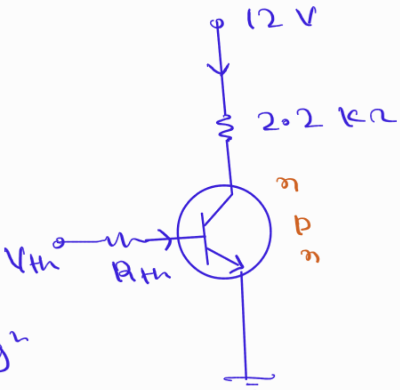
$= 8.87$ V

Assume in cutoff



$V_B > V_E \Rightarrow$ forward.
contradict cutoff

Assume in saturation



$I_B = \dfrac{8.87 - 0.8}{13.07} = 0.617$ mA

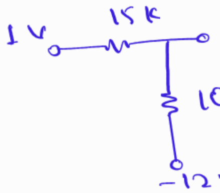
$8.87 - 13.04 \times 0.617 - 0.5 + 2.2 I_c = 12$

$\Rightarrow I_c = 5.307$ mA

$\dfrac{I_c}{I_B} = 8.601 < \beta = 30 \Rightarrow$ sat^n - reg^n

$V_o = 12 - 2.2 \times 5.307 = 0.3246$ V

ii) $V_i = 1V$



$R_{th} = \frac{1500}{115}$ kΩ

$= 13.04$ kΩ

$V_{th} = -12 + \frac{13}{115} \times 100$

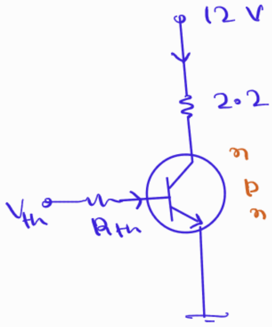
$= -0.6956$ V

Assume cutoff.

$V_B < V_E$

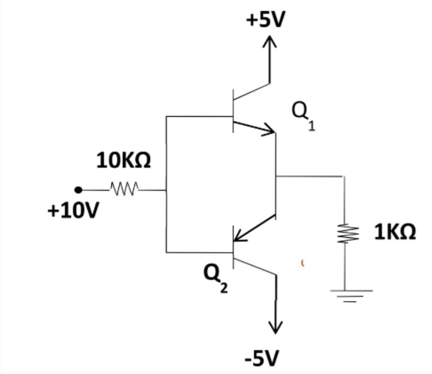
$\Rightarrow$ reverse - bias

satisfy cutoff

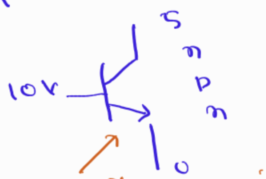


$V_o = 12$ V

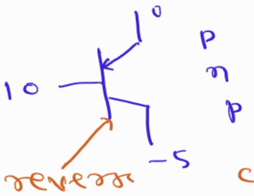
Q4. Assume $\beta_{min}=30$. Find V_B, V_E, I_{C1}, I_{C2} for the following circuit.



Assume Q_1 & Q_2 in cutoff

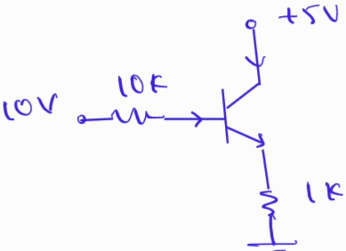


forward not in cutoff.



reverse cutoff

Remove $-Q_2$



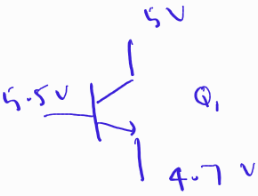
Assume saturation

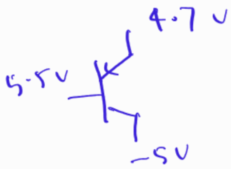
$I_B = \frac{10 - 0.5 - 5}{10} = 0.45$ mA

$\frac{10 - 4.5 - 0.8}{1} = I_E = 4.7$ mA

$I_C = 4.25$ mA $= I_{C_1}$

$\frac{I_C}{I_B} = 9.44 < \beta = 30$ $\quad$ sat^n region



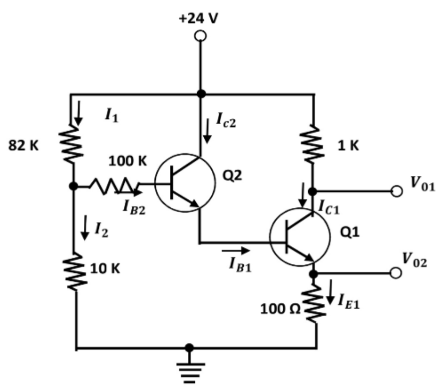


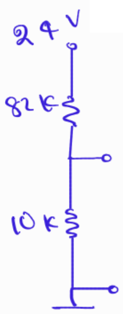
$I_{C_2} = 0$

Q5. For the circuit shown, transistors Q1 and Q2 operate in the active region with $V_{BE1} = V_{BE2} = 0.7\,V$, $\beta_1 = 100$, and $\beta_2 = 50$. The reverse saturation current may be neglected.

(a) Find the currents I_{B2}, I_1, I_2, I_{C2}, I_{B1}, I_{C1}, and I_{E1}

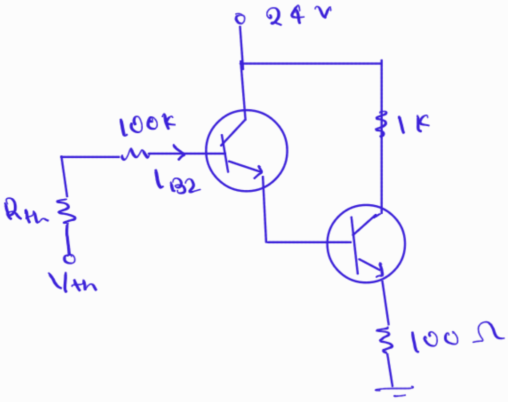
(b) Find the voltage V_{O1} and V_{O2}





$R_{th} = 82 \,||\, 10 = 8.913$ kΩ

$V_{th} = \frac{24}{92} \times 10 = 2.608$ V



$I_{B_1} = (\beta_2+1)\, I_{B2}$ $\qquad I_{C2} = \beta_2 I_{B2}$

$I_{E1} = (\beta_2+1)(\beta_1+1)\, I_{B2}$

$I_{C_1} = \beta_1 (\beta_2+1)\, I_{B_2}$

$$2.608 - 108.913 I_{B_2} - 0.7\times 2 - \frac{100}{1000} I_{E1} = 0$$

$$\Rightarrow I_{B2} = \frac{2.608 - 1.4}{108.913 + 515.1}$$

$$= 1.935\ \mu A$$

$$\frac{V-24}{82} + (1.935\ \mu A) + \frac{V}{10} = 0$$

$$\frac{V}{82} + \frac{V}{10} = 290.747\times 10^{-3}$$

$$\Rightarrow V = 2.591\ V$$

$I_2 = 0.2591$ mA

$I_1 = 0.2610$ mA