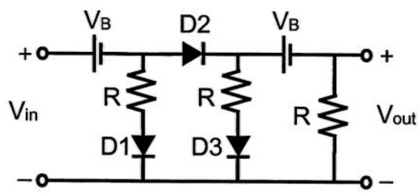
1- True or False?

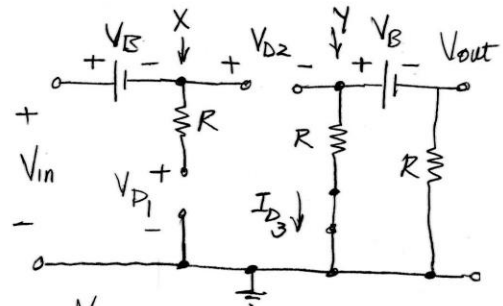
T	In an NPN BJT the emitter is N+ to ensure the BE current is dominated by free electrons.
F	In a PNP BJT the base layer is thin to ensure the rate of thermal ionization is sufficiently high.
F	N-type semiconductors are made by adding a dopant element from group V of the periodic table to a crystalline material of atoms from group III.
F	In a PN junction the width of the depletion region is larger on the P side.
T	A semiconductor becomes more conductive as the temperatures rises above the room temperature.

(10 points)

2- Find V_{out} versus V_{in}, as V_{in} varies from $-\infty$ to $+\infty$, if the diodes have a turn on voltage of $V_{Don}=0$ and are otherwise ideal (Use a piece-wise linear model). V_B is larger than 0.

(40 points)





* For $V_{in} = -\infty$ we assume D1 and D2 are OFF. With these two turned off it's reasonable to assume that V_{B2} will turn D3 ON.

$$I_{D_3} = \frac{V_B}{2R} \rightarrow V_{out} = \frac{V_B}{2R} R - V_B = -\frac{V_B}{2}$$

$$\rightarrow V_y = V_{out} + V_B = \frac{V_B}{2}$$

$$V_X = V_{in} - V_B \rightarrow V_{D_1} = V_{in} - V_B \text{ and } V_{D_2} = V_X - V_Y = V_{in} - \frac{3}{2} V_B$$

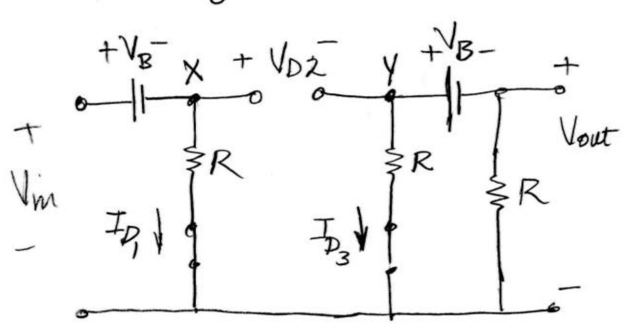
Verify the assumptions: $I_{D_3} > 0$, $V_{D_1} < 0$, $V_{D_2} < 0$

① For D1 to turn ON: $V_{in} > V_B$

② For D2 to turn ON: $V_{in} > \frac{3}{2} V_B$

③ For D3 to turn OFF: I_{D_3} should be negative, not possible.

So ① happens first.



* When V_{in} exceeds V_B:

$$I_{D_1} = \frac{V_{in} - V_B}{R} \qquad V_X = V_{in} - V_B$$

$$I_{D_3} = \frac{V_B}{2R} \text{ and } V_{out} = -\frac{V_B}{2}$$

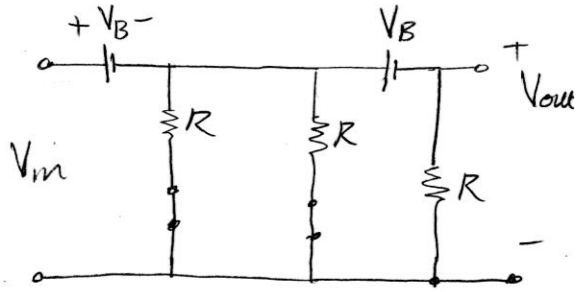
$$V_y = \frac{V_B}{2} \rightarrow V_{D_2} = V_X - V_Y = V_{in} - \frac{3}{2} V_B.$$

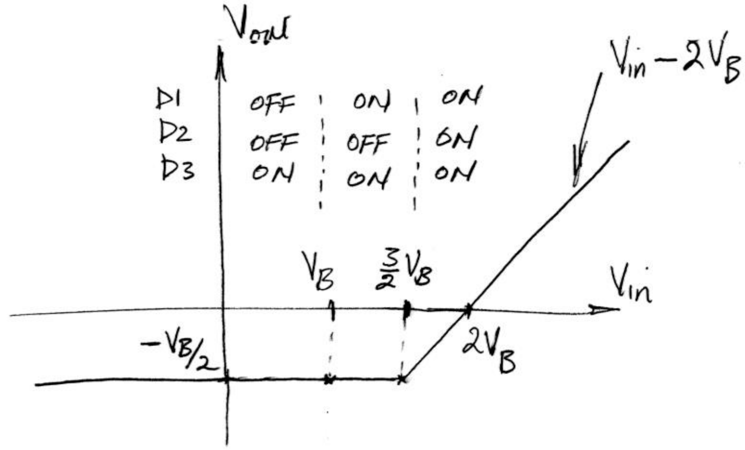
Clearly the next important point is when D_2 turns ON.

* When V_{in} exceeds $\frac{3}{2}V_B$:

$V_{out} = V_{in} - 2V_B$

It's easy to see that the diodes will remain ON after that.

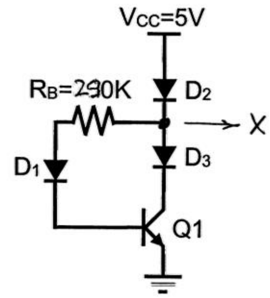




Name: **Student ID:** **Page:5/8**

3- Determine the terminal currents and the region of operation in this transistor circuit. In forward active mode β_F=100, V_{BEon}=0.7V, V_{CEsat}=0.2V, and in reverse active mode β_R=3, V_{BCon}=0.7V, V_{ECsat}=0.2V.
(25 points)

$V_{D_{ON}} = 0.7_V$



* If we start with the assumption of forward active mode, all diode will inevitably be turned on. Therefore:

$V_X = 5_V - V_{D_{ON}} = 4.3_V \rightarrow 4.3_V = I_B \times 290_K + 0.7_V + 0.7_V$

$\rightarrow I_B = \frac{4.3_V - 0.7_V - 0.7_V}{290_K} = \frac{2.9_V}{290_K} = 0.01_{mA} \rightarrow I_B > 0$ ✓

$I_C = 1_{mA}$ $I_E = 1.01_{mA}$

$V_B = 0.7_V$ $V_E = 0$ $V_C = 5_V - 0.7_V - 0.7_V = 3.6_V \rightarrow$

$V_{CE} = 3.6_V > V_{CE_{sat}}$ ✓✓

$I_{D_1} = I_B > 0$ ✓

$I_{D_2} = I_B + I_C > 0$ ✓

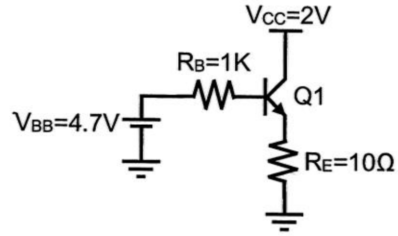
$I_{D_3} = I_C > 0$ ✓

All initial assumption are correct and therefore the transistor is in the forward active mode and all diodes are ON.

Name: **Student ID:** **Page:7/8**

4- Determine the terminal currents and the region of operation in this transistor circuit. In forward active mode β_F=99, , V_{BEon}=0.7V, V_{CEsat}=0.2V, and in reverse active mode β_R=3, V_{BCon}=0.7V, V_{ECsat}=0.2V.

(25 points)



Assuming forward active mode:

KVL @ base: $4.7_V = I_B \times 1_K + 0.7_V + \underbrace{(1+\beta) I_B}_{I_E} \times 10_\Omega$

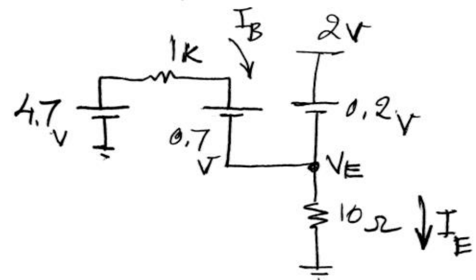
$\rightarrow I_B = \dfrac{4_V}{1_K \times 100 \times 10_\Omega} = \dfrac{4_V}{2_K} = 2\,mA \rightarrow \quad I_B > 0$

$I_C = 198_{mA} \qquad I_E = 200_{mA}$

However: $V_C = 2_V$ and $V_E = 10_\Omega \times 200_{mA} = 2_V \rightarrow$

$V_{CE} = 0 < V_{CE_{sat}}$ X Transistor likely in saturation.

Resolve assuming saturation:



$V_E = 2_V - 0.2_V = 1.8_V \rightarrow$

$I_E = \dfrac{1.8_V}{10_\Omega} = 180_{mA}$

$I_B = \dfrac{4.7_V - 0.7_V - 1.8_V}{1_K} = \dfrac{2.2_V}{1_K} = 2.2_{mA} > 0$ ✓

$\rightarrow I_C = I_E - I_B = 177.8_{mA} < \beta I_B = 99 \times 2.2_{mA}$ ✓✓

Transistor is in saturation