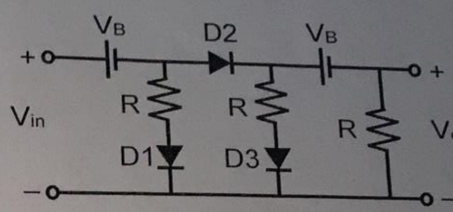
1- True or False?

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)

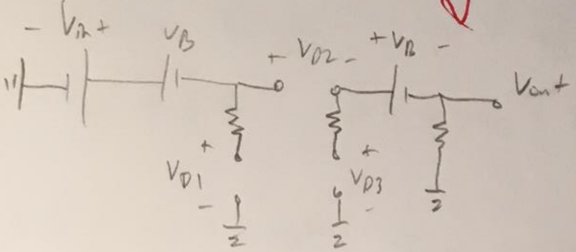
Name: **Student ID:**

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)

As $V \to -\infty$, Assume D_1, D_2, D_3 off

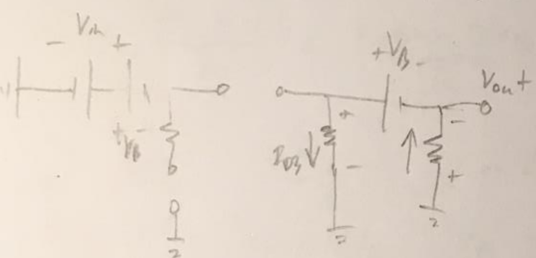


$V_{in} = V_B + V_{D1}$, $V_{D1} = V_{in} - V_B$ ✓

$V_{in} = V_B + V_{D2} + V_{D3}$

$V_B = V_{D3} > 0$ wrong assumption

As $V \to -\infty$, Assume D_1, D_2 off, D_3 on



$V_{in} = V_B + V_{D1}$, $V_{D1} < 0$ verified ✓

$V_{in} = V_B + V_{D2} + I_{D3} R$ ✓

As $V_{in} \to -\infty$, $V_{D2} < 0$ verified ✓

$V_B = I_{D3} R + I_{D3} R$

$V_B = 2 I_{D3} R$, $I_{D3} > 0$ verified ✓

$I_{D3} R = \frac{V_B}{2}$

$V_{out} = -I_{D3} R$

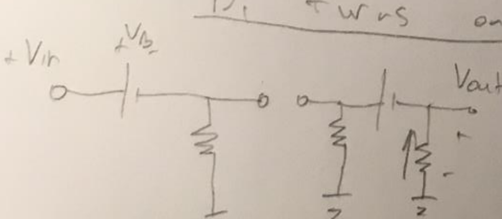
$\boxed{V_{out} = \frac{-V_B}{2}}$ ✓

$V_{in} - V_B - \frac{V_B}{2} = V_{D2}$ $V_{in} - V_B = V_{D1}$

$V_{in} - \frac{3V_B}{2} = V_{D2}$

D_2 turns on at $V_{in} = \frac{3V_B}{2}$, $\boxed{D_1 \text{ turns on at } V_B}$ So

D_1 turns on first



$V_{in} = V_B + I_{D1} R$

$\frac{V_{in} - V_B}{R} = I_{D1}$ when $V_{in} > V_B$, $I_{D1} > 0$ verified

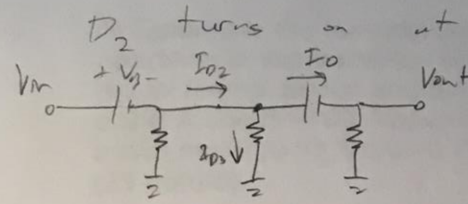
$V_{in} = V_B + V_{D2} + I_{D3} R$, $I_{D3} R = \frac{V_B}{2}$

$V_{in} - V_B - \frac{V_B}{2} = V_{D2}$ when $V_{in} = V_B$, $V_{D2} = \frac{-V_B}{2} < 0$ verified ✓

$V_{in} - \frac{3V_B}{2}$

$\boxed{V_{out} = -I_{D3} R = \frac{-V_B}{2}}$ ✓

D_2 turns on at $\frac{3V_B}{2}$



$V_{in} = V_B + I_{D1}R$

$I_{D1} = \frac{V_{in} - V_B}{R}$, $V_{in} > \frac{3V_B}{2}$, $I_{D1} > 0$ verified

$V_{out} = I_o R$ $\quad V_{in} = 2V_B + I_o R$, $\boxed{I_o = \frac{V_{in} - 2V_B}{R}}$

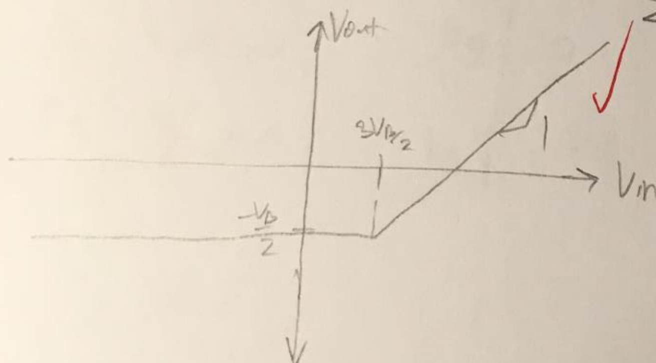
$\boxed{V_{out} = V_{in} - 2V_B}$

$V_{in} = V_B + I_{D3}R$, $I_{D3} = \frac{V_{in} - V_B}{R} > 0$ verified

$I_{D2} = I_{D3} + I_o$

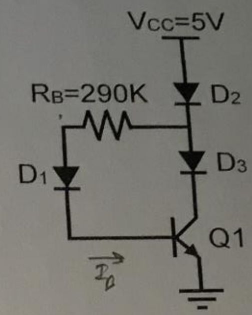
$= \frac{V_{in} - V_B}{R} + \frac{V_{in} - 2V_B}{R} = \frac{2V_{in} - 3V_B}{R} > 0$ when $V_{in} > \frac{3V_B}{2}$ Verified

$$V_{out} = \begin{cases} -\frac{V_B}{2} & V_{in} < \frac{3V_B}{2} \\ V_{in} - 2V_B & V_{in} > \frac{3V_B}{2} \end{cases}$$



$\frac{3V_B}{2} - 2V_B = -\frac{1}{2}V_B$

3- Determine the terminal currents and the region of operation in this transistor circuit. Use a piecewise linear model for the diodes and assume V_{Don}=0.7V. 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)



Assume Active

$5 = 0.7 + 290k(I_B) + 0.7 + 0.7$

$\frac{2.9}{290k} = I_B = \cancel{1mA} > 0$ verified ✓

$5 = 0.7 + 0.7 + V_{CE}$

$V_{CE} = 3.6 > V_{CE\,sat}$ ✓ verified ✓ Assumption verified

$I_C = \beta_F I_B = 1mA$

$I_E = (\beta+1) I_B = 1.01mA$

$5 - .7 - 290k(1\,uA) - .7 = V_B$

$V_B = .7V$

I_C	1 mA	V_C	3.6 V
I_E	1.01 mA	V_E	0
I_B	$\cancel{1}$ uA	V_B	.7V

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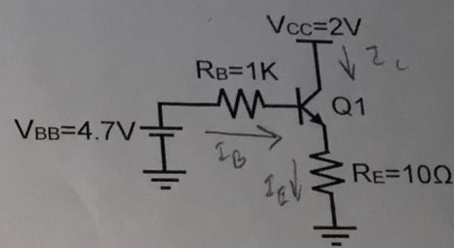
4- Determine the terminal currents and the region of operation in this transistor circuit. In forward active mode $\beta_F=99$, $V_{BEon}=0.7V$, $V_{CEsat}=0.2V$, and in reverse active mode $\beta_R=3$, $V_{BCon}=0.7V$, $V_{ECsat}=0.2V$.



(25 points) Assume Active

$2 = V_{CE} + I_E R_E$

$2 - I_E R_E = V_{CE}$

$2 - \frac{1}{5}(10) = V_{CE} = 0$

$V_{CE} < V_{CE\,sat}$

Wrong Assumption

$4.7 = I_B(1k) + V_{BE\,on} + I_E R_E$

$4 = I_E\left(R_E + 1k\left(\frac{1}{\beta+1}\right)\right)$

$I_E = \frac{4}{R_E + \frac{1000}{100}} = \frac{4}{10+10} = \frac{4}{20} = \boxed{\frac{1}{5} A}$

$I_B = \frac{1}{\beta+1} I_E = \frac{1}{100}\left(\frac{1}{5}\right) = \boxed{\frac{1}{500} A}$

$I_B > 0$ verified ✓

$I_C = \beta I_B$

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

Assume Saturation

$2 = V_{CE\,sat} + I_E R_E$

$I_E = \frac{1.8}{10} = \boxed{0.18 A}$

$4.7 = 1k(I_B) + V_{BE\,on} + 10 I_B$

$I_B = \frac{4 - 10(0.18)}{1000}$

$= 0.0022 A$

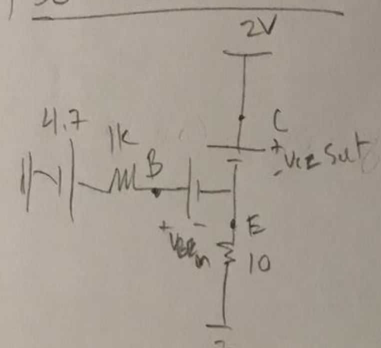
$I_E = I_B + I_C$

$I_C = I_E - I_B = \boxed{0.1778 A}$

$\beta I_B = 0.22 A$

$I_C < \beta I_B$, so verified ✓

I_C	0.1778 A	V_C	2V
I_B	0.0022 A	V_B	2.5 V
I_E	0.18 A	V_E	1.8 V



$V_B = 4.7 - 1k(I_B) = 4.7 - 2.2 = 2.5$

$V_E = V_B - 0.7 = 1.8V$