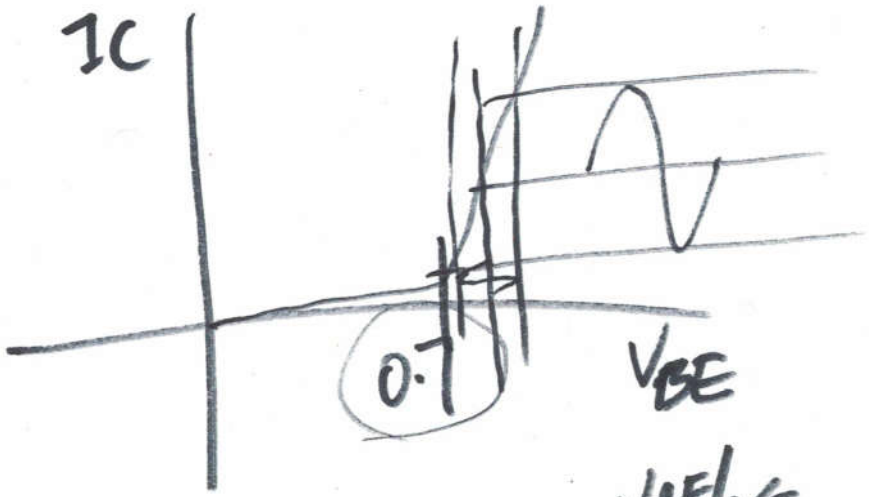
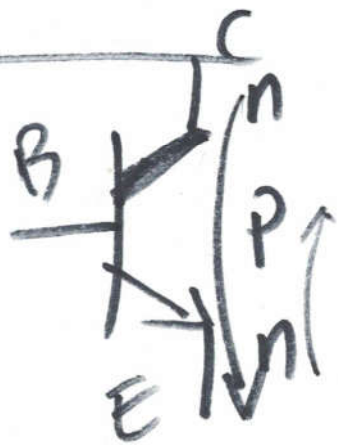
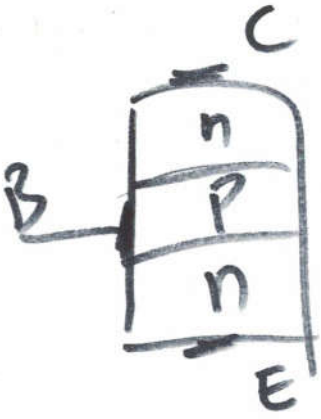
More of BJTs







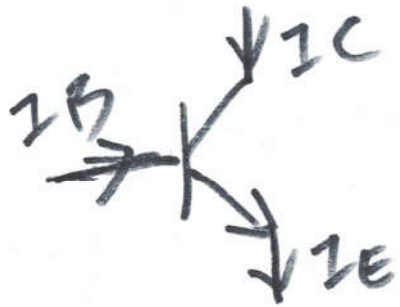
$$I_C = I_S e^{V_{BE}/V_T} \Rightarrow \frac{I_C}{I_S} = e^{V_{BE}/V_T} \Rightarrow \ln\frac{I_C}{I_S} = \ln e^{V_{BE}/V_T}$$

$$\Rightarrow \ln\frac{I_C}{I_S} = \frac{V_{BE}}{V_T}$$

$$\Rightarrow V_{BE} = V_T \cdot \ln\frac{I_C}{I_S}$$

V_T: thermal voltage
25 mV at room temperature

I_S: Saturation current < junction area, base width, temperature.



$I_E = I_C + I_B$

$I_C = \beta I_B$

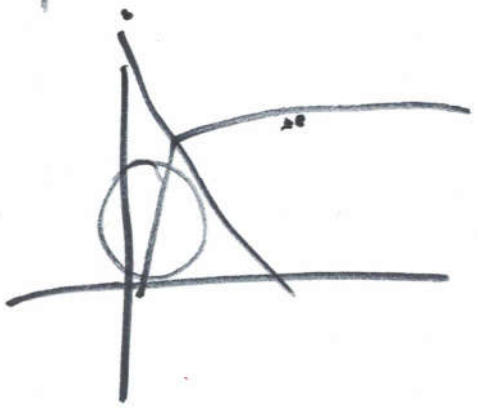
$I_E = \alpha I_C \quad \frac{1}{\alpha} I_C$

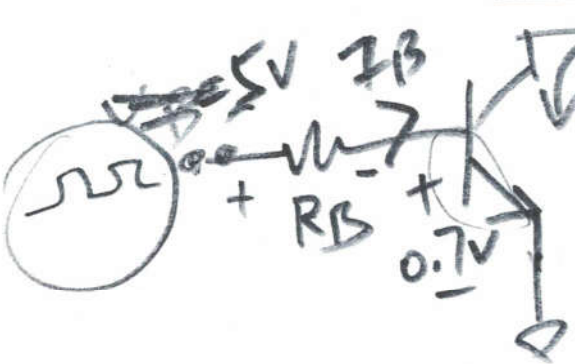
$\alpha = \frac{\beta}{1+\beta}$

$\beta = \frac{\alpha}{1-\alpha}$

$\beta = 50, 100, 200$

$\alpha = 0.9 \ldots$





$\beta = 100$

① If R_B is too small, blows up the BJT.

② If R_B is too large, BJT is off

If $R_B = 1K\Omega$, $V_{RB} = 5 - 0.7 = 4.3V$

$I_B = \frac{V_{RB}}{R_B} = \frac{4.3V}{1K\Omega} = 4.3mA$

$I_C = \beta \cdot I_B = 100 \cdot 4.3mA = 430mA$

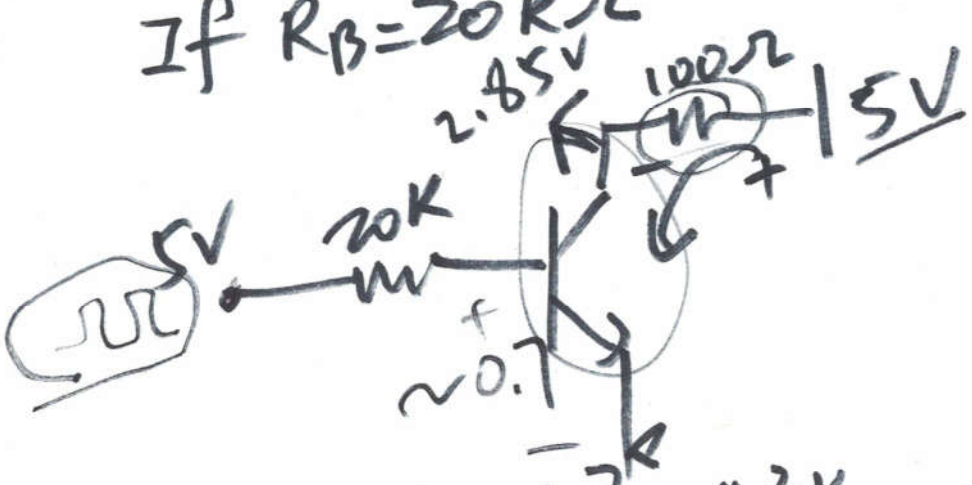
$V_{RC} = (100\Omega)(430mA)$

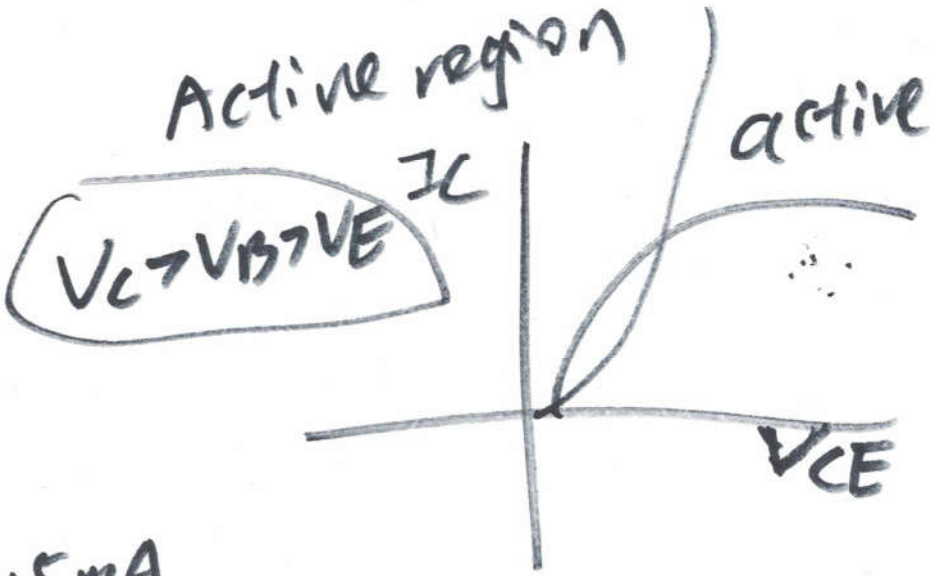
$= 43000 mV$

$= 43V$

(2)

If $R_B = 20k\Omega$





$$I_B = \frac{5V - 0.7}{20K} = \frac{4.3V}{20K} = 0.215mA$$

$$I_C = \beta \cdot I_B = 100 \cdot 0215\,mA = 21.5mA$$

$$V_{RC} = I_C \cdot R_C = 100\Omega \cdot 21.5mA = 2150\,mV = 2.15V$$

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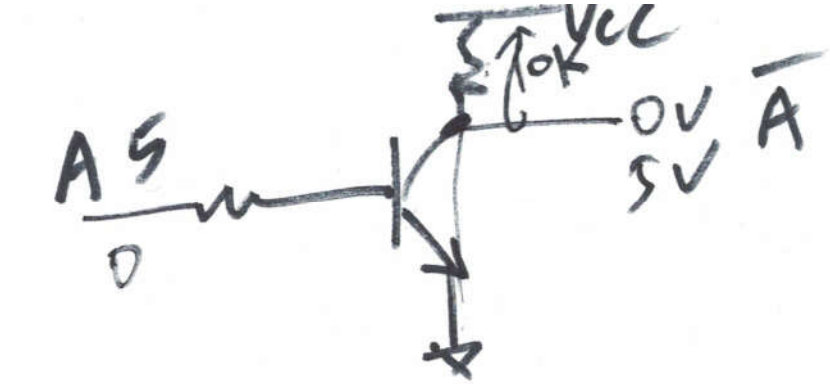
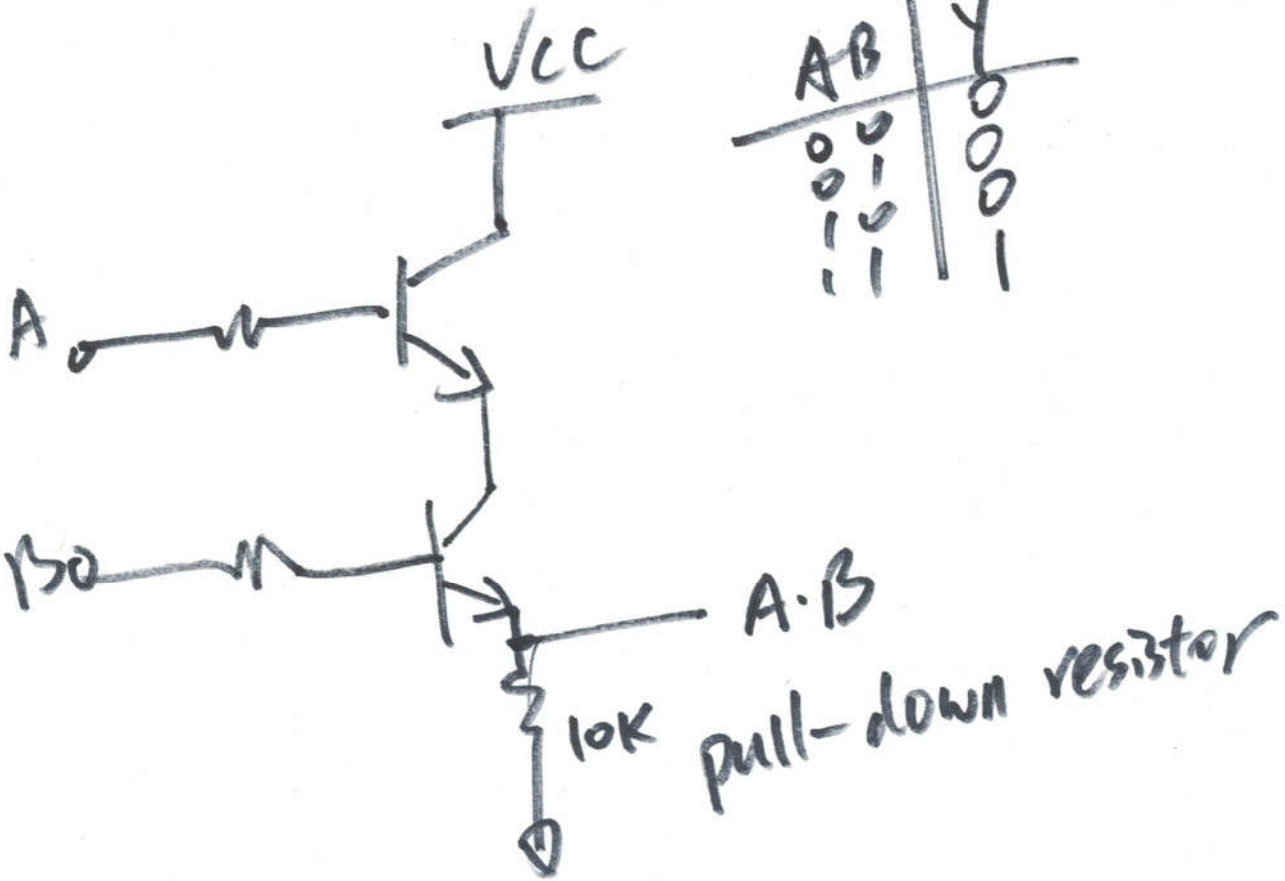
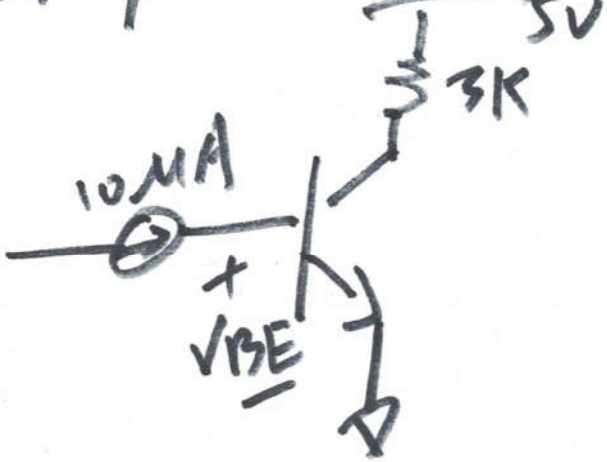
(3)



AB	Y
0 0	0
0 1	0
1 0	0
1 1	1



Example: NPN BJT, $I_S = 10^{-15}$ A, $\beta = 100$



① Find V_{BE} and V_{CE}?

$I_C = I_S \cdot e^{V_{BE}/V_T}$

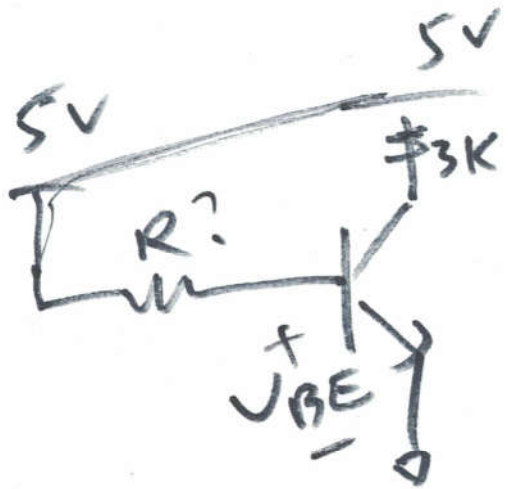
$V_{BE} = V_T \cdot \ln \frac{I_C}{I_S}$

$V_T = 25mV$

$I_C = \beta \cdot I_B = 100 \cdot 10\mu A = 1mA$

$I_S = 10^{-15}$ A

$V_{BE} = 0.69V$



② Replace the 10μA current source with a resistor and 5V. R?

$V_R = 5V - V_{BE} = 5 - 0.69 = 4.31V$

$R = \frac{V_R}{I_B} = \frac{4.31V}{10\mu A} = 431\ k\Omega$

Example: NPN, $V_{BE} = 0.7V$ at $I_C = 1mA$.
Find V_{BE} at $I_C = 0.1mA$ and $10mA$.

$$I_C = I_S e^{V_{BE}/V_T}$$

$$\begin{cases} I_{C_1} = I_S e^{V_{BE1}/V_T} \\ I_{C_2} = I_S e^{V_{BE2}/V_T} \end{cases}$$

$$\frac{I_{C1}}{I_{C2}} = \frac{\cancel{I_S} e^{V_{BE1}/V_T}}{\cancel{I_S} e^{V_{BE2}/V_T}}$$

$$\frac{1mA}{0.1mA} = e^{(0.7V - V_{BE2})/V_T}$$

$$V_T \ln 10 = 0.7V - V_{BE2}$$

$25mV$

$$V_{BE} = 0.64V.$$