EE320 Homework #6

① PROBLEM 6.1

npn

Case	E	B	C	Mode	
1	0	0.7	0.7	Active	$V_{BE} = 0.7$, $V_{BC} = 0 < 0.4$
2	0	0.8	0.1	Saturation	$V_{BE} = 0.8 > 0.5V$, $V_{BC} = 0.7$
3	-0.7	0	1.0	Active	$V_{BE} = 0.7$, $V_{BC} = -1 < 0$
4	-0.7	0	-0.6	Saturation	$V_{BE} = 0.7$, $V_{BC} = 0.6 > 0$
5	+1.3	+2	5.0	Active	$V_{BE} = 0.7$, $V_{BC} = -3V < 0$
6	0	0	5.0	Cutoff	$V_{BE} = 0$, $V_{BC} = -5 < 0$

npn

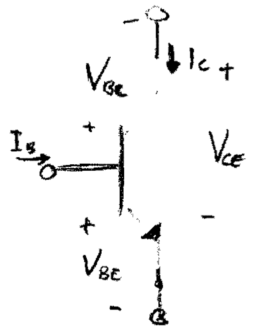
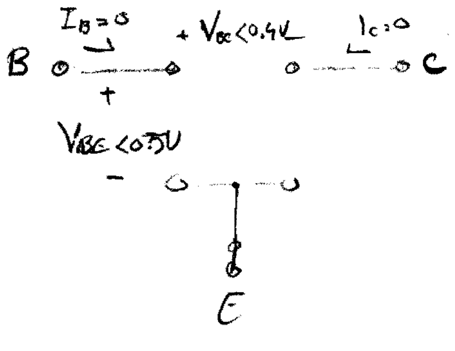
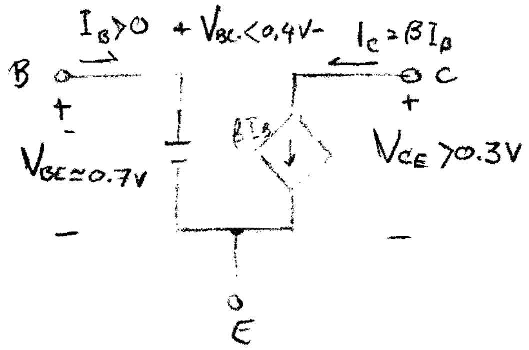


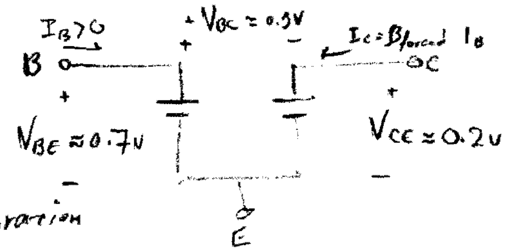
Table 6.3



Cutoff



Active



Saturation

EE320 Homework #6

② PROBLEM 6.7

npn transistor $V_{BE} = 0.76\,V$, $I_C = 10\,mA$, what current will it conduct at $V_{BE} = 0.7V$? what is V_{BE} for $I_C = 10\,\mu A$

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

$$\frac{I_{C2}}{I_{C1}} = e^{\left(\frac{V_{BE2} - V_{BE1}}{V_T}\right)}$$

$$I_{C2} = I_{C1} \times e^{\left(\frac{V_{BE2} - V_{BE1}}{V_T}\right)}$$

$$= 5\,mA \times e^{\frac{0.7 - 0.76}{0.025}} = \underline{0.45\,mA}$$

$$\ln\left(\frac{I_{C2}}{I_{C1}}\right) = \frac{V_{BE2} - V_{EB1}}{V_T}$$

$$V_{BE2} = V_{EB1} + V_T \ln\left(\frac{I_{C2}}{I_{C1}}\right)$$

$$= 0.76 + 0.025 \ln\left(\frac{5\,\mu A}{5\,mA}\right) = \underline{0.587\,V}$$

EE320 Homework #6

③ Problem 6.15

Transistor	a	b	c	d	e
V_{BE} (mV)	700	690	580	780	820
I_C (mA)	1.000	1.000	0.230	10.10	73.95
I_B (uA)	10	20	5	120	1050
I_E (mA)	1.01	1.020	0.235	10.22	75
α	0.9901	0.98	0.979	0.988	0.986
β	100	50	46	84	70
I_S (A)	6.914×10^{-16}	1.0×10^{-15}	1.9×10^{-14}	2.85×10^{-16}	4.21×10^{-16}

$$I_E = I_C + I_B$$

$$I_C = \alpha I_E \longrightarrow \alpha = \frac{I_C}{I_E}$$

$$I_C = \beta I_B \longrightarrow \beta = \frac{I_C}{I_B}$$

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

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

④ PROBLEM 6.23

PnP Transistor, $V_{EB} = 0.8V$ $i_C = 1A$, find V_{EB} at $I_C = 10mA$, 100mA

$I_C = I_S \cdot e^{V_{BE}/V_T}$ $\Rightarrow \frac{I_{C2}}{I_{C1}} = e^{\frac{V_{EB2} - V_{EB1}}{V_T}}$

$V_{EB2} = V_{EB1} + V_T \times \ln\left(\frac{I_{C2}}{I_{C1}}\right)$

At $I_C = 1\ mA$, $V_{EB} = 0.7V$

at $i_C = 10\ mA$,

$V_{EB} = 0.7 + V_T \ln\left(\frac{10}{1}\right)$

$= 0.7 + 0.025 \ln\left(\frac{10}{1}\right) = \underline{0.7575V}$

at $i_C = 100\ mA$,

$V_{EB} = 0.7 + 0.025 \ln\left(\frac{100}{1}\right) = \underline{0.8151V}$

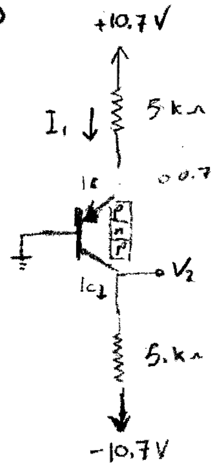
V_{EB} increases by $\approx 60mV$ for every decade increase in I_C.

(5) Problem 6.28

Assume active mode operation for all cases.

$V_{EB} = 0.7 \rightarrow V_E - V_B = 0.7$, $V_B = 0$ so $V_E = 0.7V$

(a)



$$I_1 = \frac{10.7 - 0.7}{5k} = 2\ mA = I_E$$

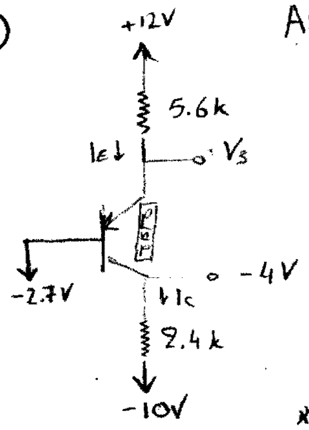
$$I_C = \alpha I_1 \qquad \alpha \approx 1 \leftarrow \beta = \infty$$

$$I_C = 1 \times 2mA = \underline{2mA}$$

$$V_2 = 5k(I_C) - 10.7 = \underline{-0.7V}$$

* CHECK : $V_{EB} = 0.7 - 0 = 0.7V$, $V_{CB} < 0.4$ So transistor is Active.

(b)



Assuming Active mode:

$V_C = -4V$, $V_B = -2.7V$

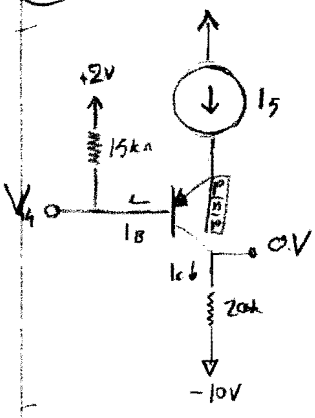
$$I_C = \frac{-4 - (-10)}{2.4k} = 2.5\ mA$$

$$I_E = \frac{I_C}{\alpha} = I_C = 2.5mA$$

$$V_E = V_3 = 12 - 5.6k(I_E) = \underline{-2V}$$

*CHECK : $V_{EB} = -2.7 - (-2) = 0.7V$, And $V_{CB} = -4 - (-2.7) = -1.3V < 0.4$
So the transistor is Active mode.

(C)



$$I_C = \frac{0 - (-10)}{20k} = 0.5mA$$

Assuming Active mode and Utilizing the fact that β is large

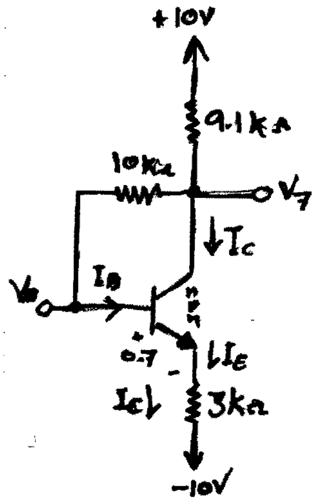
$\therefore I_B \approx 0$, $V_4 = 2V$

* CHECK : $V_{CB} < 0.4$ So the transistor is operating in the active region.

$$I_5 = I_E = \frac{I_C}{\alpha} \approx I_C = \underline{0.5\ mA}$$

*CHECK : See Table 6.3

(5) Cont. PROBLEM 6.28



Since the base and collector connected with 10k resistor and β is assumed to be very high, the voltage drop across the 10kΩ resistor will be close to zero.

and $V_B = V_7$, also $V_{EB} = 0.7$ in Active mode

$$V_E = V_7 - 0.7$$

$$I_E = I_6 = \frac{V_7 - 0.7 - (-10)}{3k} = \frac{V_7 + 9.3}{3k}$$

Since $I_B = 0$, ⟶ $I_c = \dfrac{10 - V_7}{9.1k}$

$I_C = \alpha \cdot I_E$ $\alpha \cong 1$ So $I_E = I_C = I_6$

$$I_E = I_C$$

$$\frac{V_7 + 9.3}{3k} = \frac{10 - V_7}{9.1k}$$ by solving for V_7

$$V_7 = \underline{-4.5}\,V$$

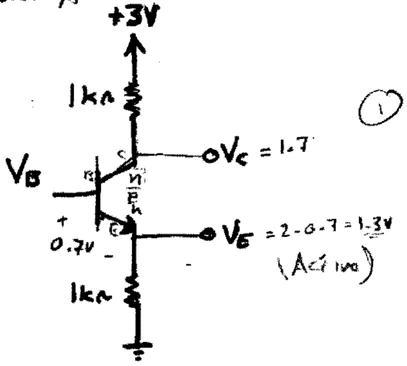
So $I_6 = \dfrac{-4.5 - 0.7 + 10}{3k} = \underline{1.6\text{ mA}}$

⑥ PROBLEM 6.51

The transistor in circuit has very high β. Find V_E, V_C for V_B = +1.5V, 1V, and 0V.

(a)

Assume Active



npn, for $V_B = 2V$,

Assume Active mode $V_{BE} = 0.7V$, $\beta = \infty$ so $\alpha = 1$

① $V_B - V_E = 0.7 \longrightarrow V_E = V_B - 0.7 = 2 - 0.7 = 1.3V$

$I_E = \frac{1.3 - 0}{1k} = 1.3mA$

$I_C = \alpha I_E = 1 \times 1.3mA = 1.3mA$

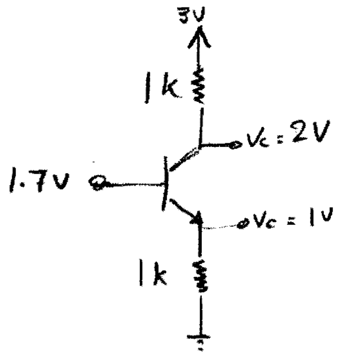
$V_C = 3 - V_R = 3 - (1.3mA) \times 1k = 1.7V$

* CHECK: So, $V_{BC} = V_B - V_C = 2 - 1.7 = 0.3V$,

$V_{BC} < 0.4$ So the transistor is operating in the Active region

"* CHECK Using Table 6.3"

(b)



Assume Active mode so $V_{BE} = 0.7$

$V_{BE} = V_B - V_E = 1.7 - V_E = 0.7V$

$V_E = 1V$

$I_C = \alpha I_E \approx I_E$

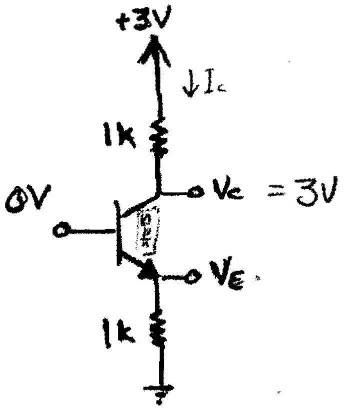
$I_E = \frac{1 - 0}{1k} = 1mA$

$V_C = 3 - (1k) \times (1mA) = 2V$

* CHECK: $V_{BC} = 1.7 - 2 = -0.3 < 0.4$ So it is Active.

⑥ Cont. PROBLEM 6.51

ⓒ



Assume Cut-off

$I_B = I_C = I_E = 0$ A

$V_C = 3 - (1k) \times 0A = 3V$

$V_E = 0V$

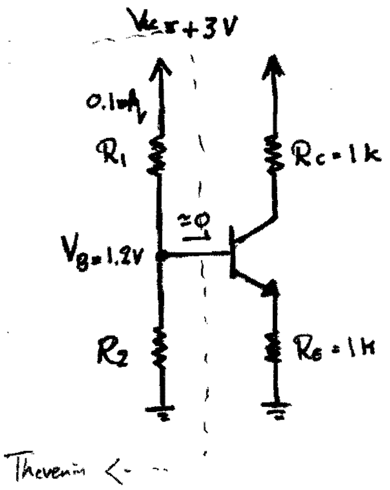
$V_{BE} = 0 - 0 = 0V$

$V_{BC} = 0 - 3 = -3V$

* CHECK : $V_{BE} < 0.5$ and $V_{BC} < 0.4$ So it is operating in the Cut-off Region

EE320 Homework #6

⑦ PROBLEM 6.55



$$R_1 + R_2 = \frac{V_{cc}}{0.1mA} = \frac{3}{0.1mA} = 30\,k\Omega$$

$$V_{cc} \frac{R_2}{R_1+R_2} = 1.2V$$

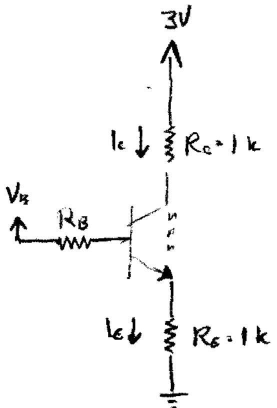
$$R_1 = \frac{3-1.2}{0.1mA} = 18\,k\Omega$$

$$R_2 = \frac{1.2V}{0.1mA} = 12\,k\Omega$$

$\beta = 100$ to obtain the Collector current we replace the Voltage divider with its Thevenin equivalent Consisting of

$$V_{BB} = 3 \times \frac{R_2}{R_1+R_2} = 3 \times \frac{12}{18+12} = 1.2V$$

$$R_B = R_1 // R_2 = 7.2\,k\Omega$$



$$V_{BB} = I_B R_B + V_{BE} + I_E R_E \quad (1)$$

Using $\left(I_E = \frac{I_C}{\alpha} \text{ and } I_B = \frac{I_C}{\beta} \right)$ to chage I_B to I_E

$$I_B = \frac{I_C}{\beta} = \frac{(I_E \cdot \alpha)}{\beta} = \frac{I_E \times \left(\frac{\beta}{\beta+1}\right)}{\beta} = \frac{I_E}{\beta+1}$$

So Eq (1)

$$V_{BB} = \frac{I_E}{\beta+1} + V_{BE} + I_E \cdot R_E$$

$$1.2 = \frac{I_E}{\beta+1} + 0.7 + I_E \times 1 \quad \text{(Solve for } I_E\text{)}$$

$$I_E = \frac{1.2 - 0.7}{\frac{7.2V}{101} + 1k} = \underline{0.47\,mA}$$

$$I_C = \alpha I_E = 0.99 \times 0.47 = \underline{0.46\,mA}$$

$$V_C = +3 - 0.46m \times 1k = \underline{2.54\,V}$$

$V_C > V_B - 0.4$ so, transistor is operating in Active region.