BJT Bias
Operating Point (H.4)

20170421-2

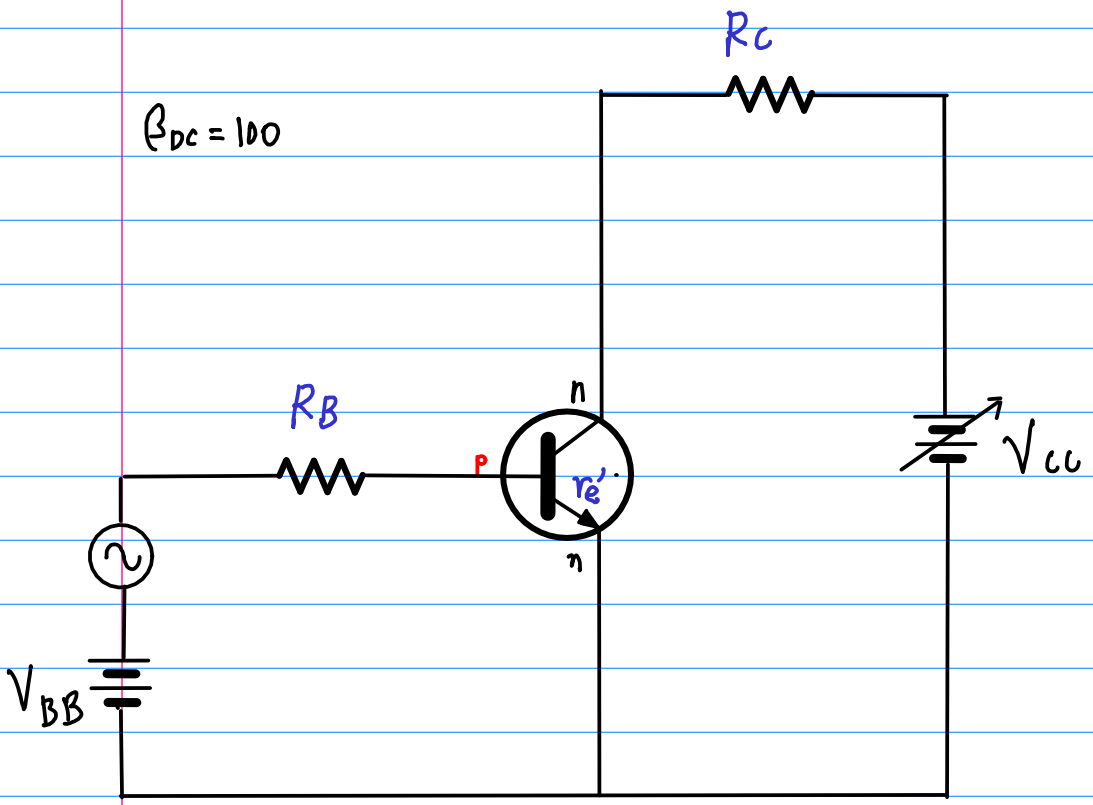
.

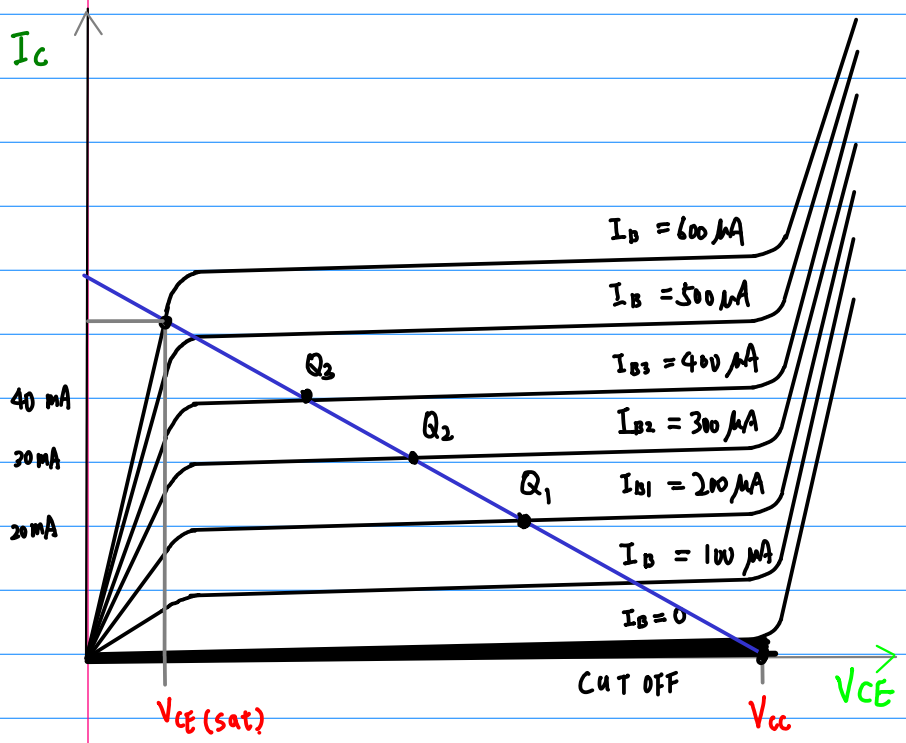
References

Based

[1] Floyd, Electronic Devices 7th ed
[2] Cook,

[2] en.wikipedia.org



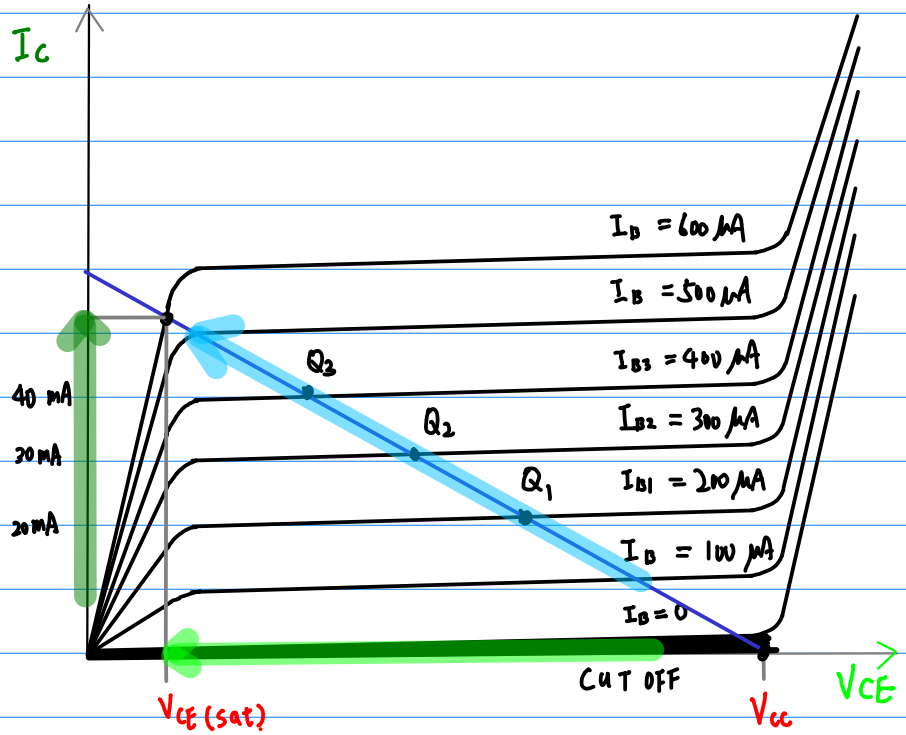


$\beta_{DC} = 100$

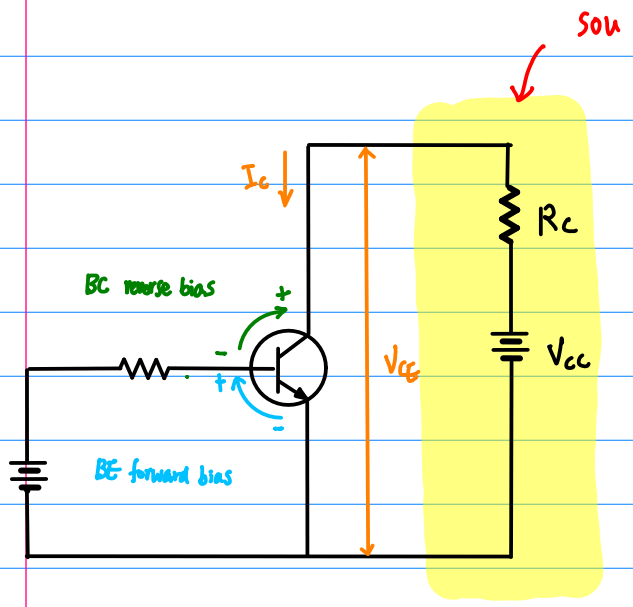
$I_{B3} = 400\,\mu A \xrightarrow{*100} I_{C3} = 40\,mA$

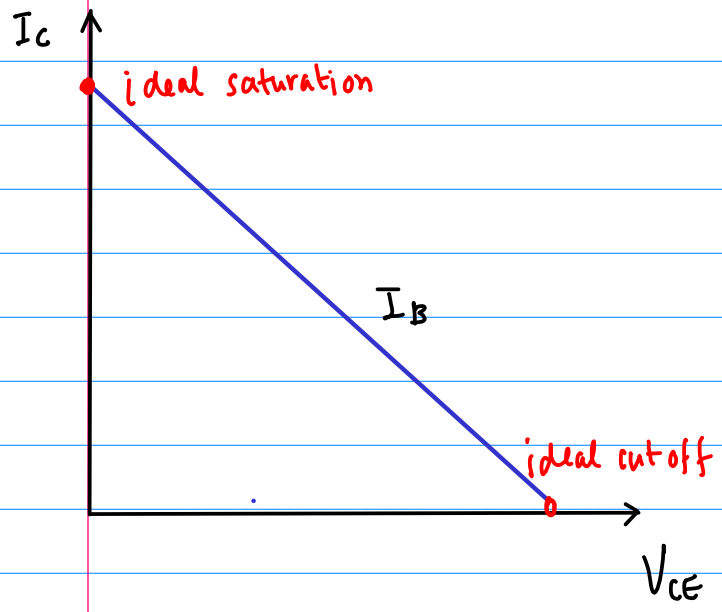
$I_{B2} = 300\,\mu A \xrightarrow{*100} I_{C2} = 30\,mA$

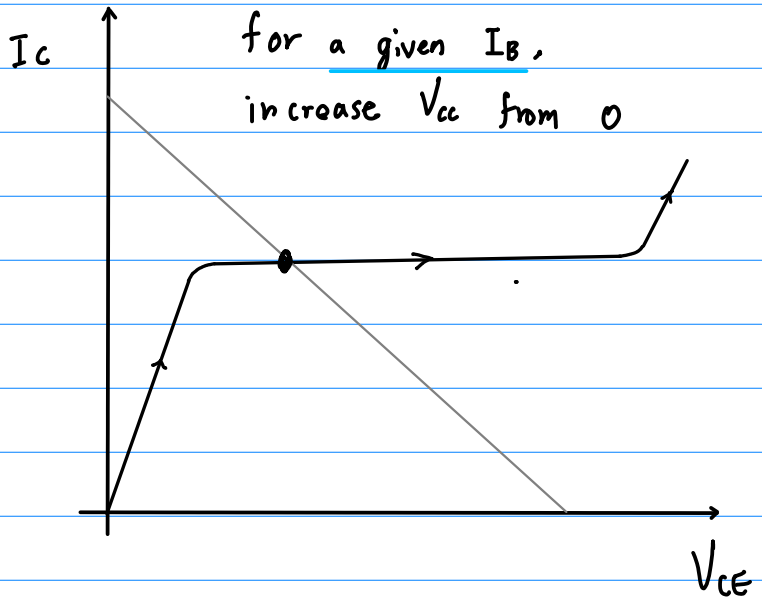
$I_{B1} = 200\,\mu A \xrightarrow{*100} I_{C1} = 20\,mA$

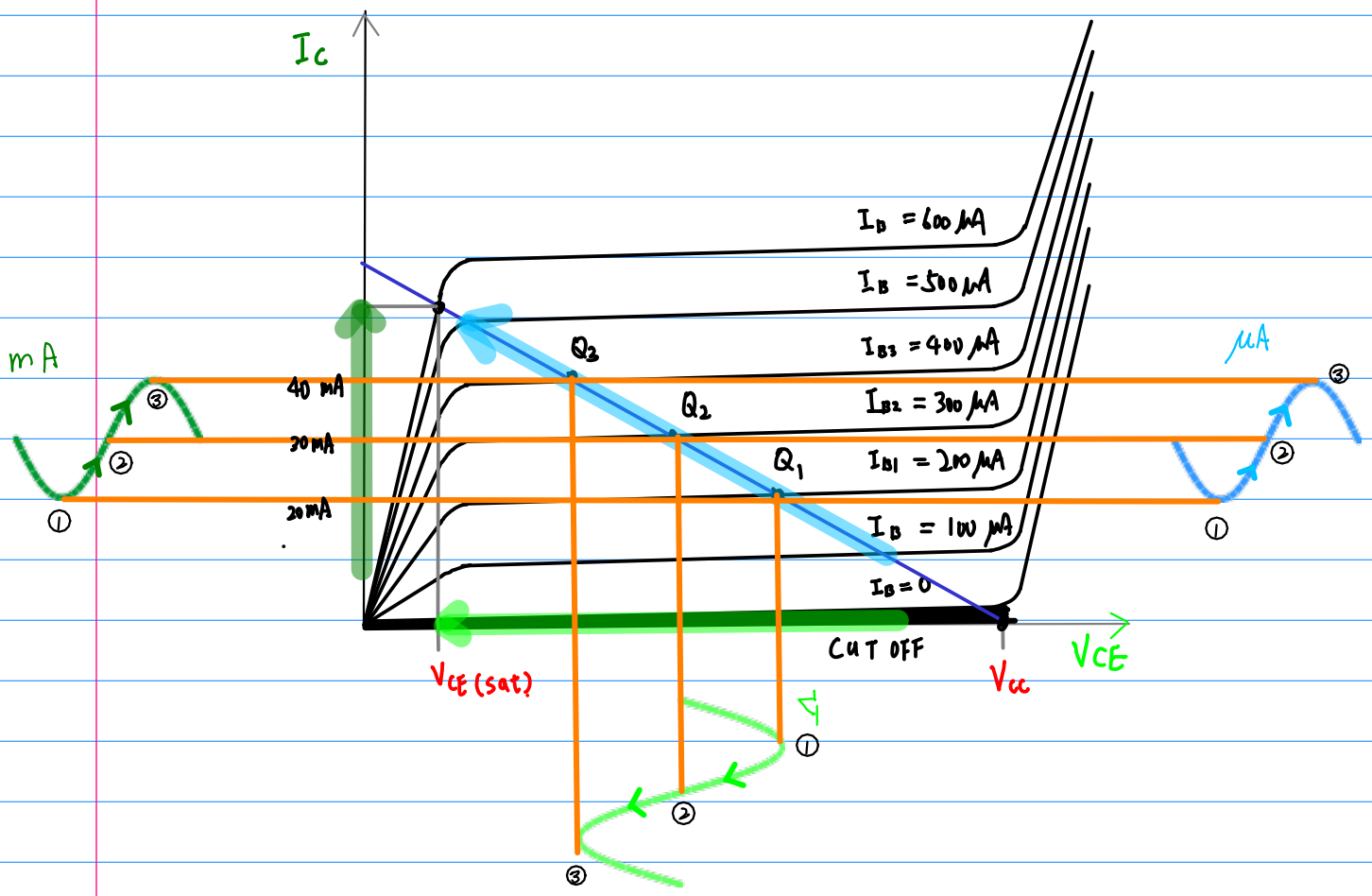

I_C
$I_B = 600\,\mu A$
$I_B = 500\,\mu A$
$I_{B3} = 400\,\mu A$
$I_{B2} = 300\,\mu A$
$I_{B1} = 200\,\mu A$
$I_B = 100\,\mu A$
$I_B = 0$
Q_3
Q_2
Q_1
40 mA
30 mA
20 mA
CUT OFF
$V_{CE(sat)}$
V_{cc}
V_{CE}

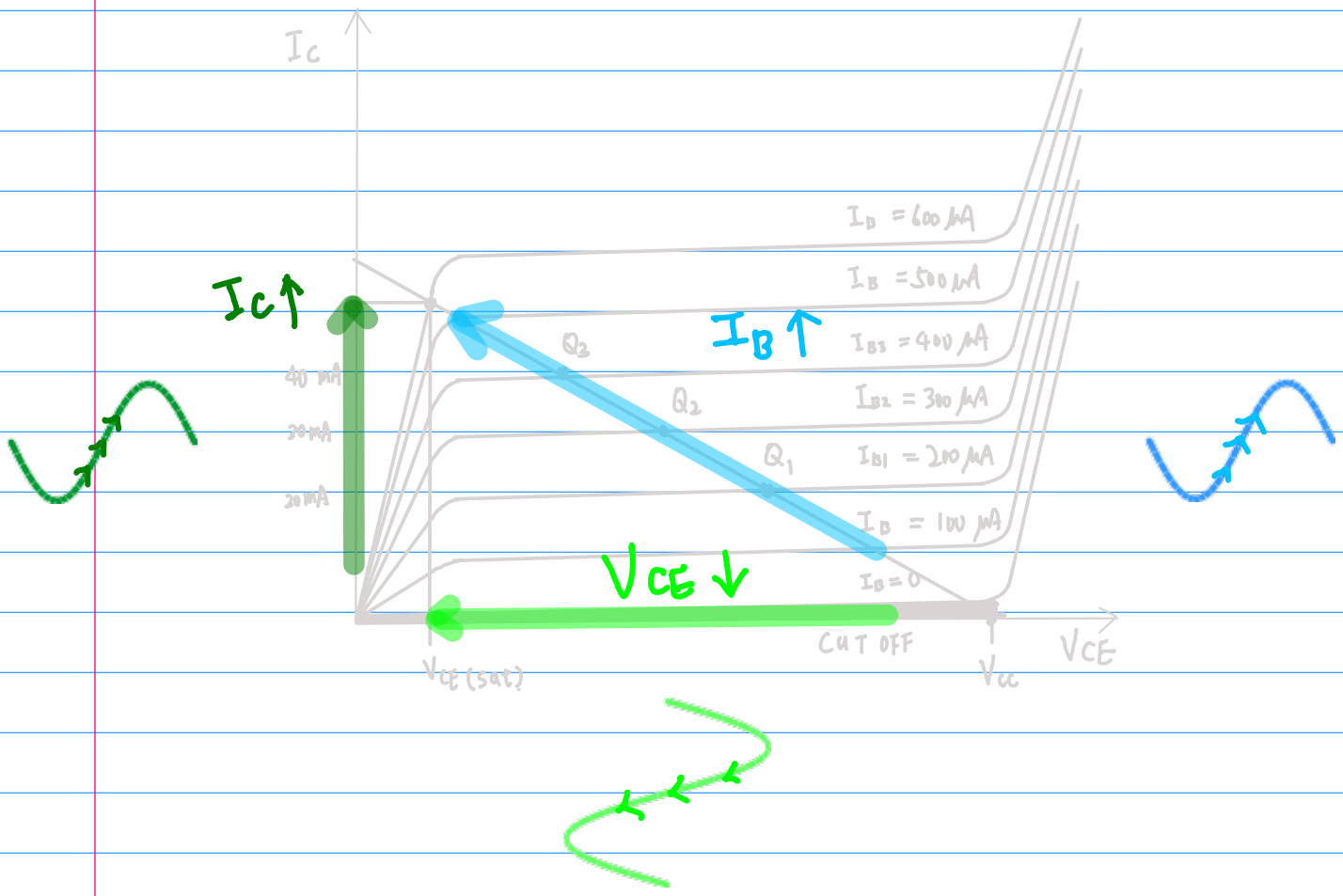
Simultaneous Equations Solution



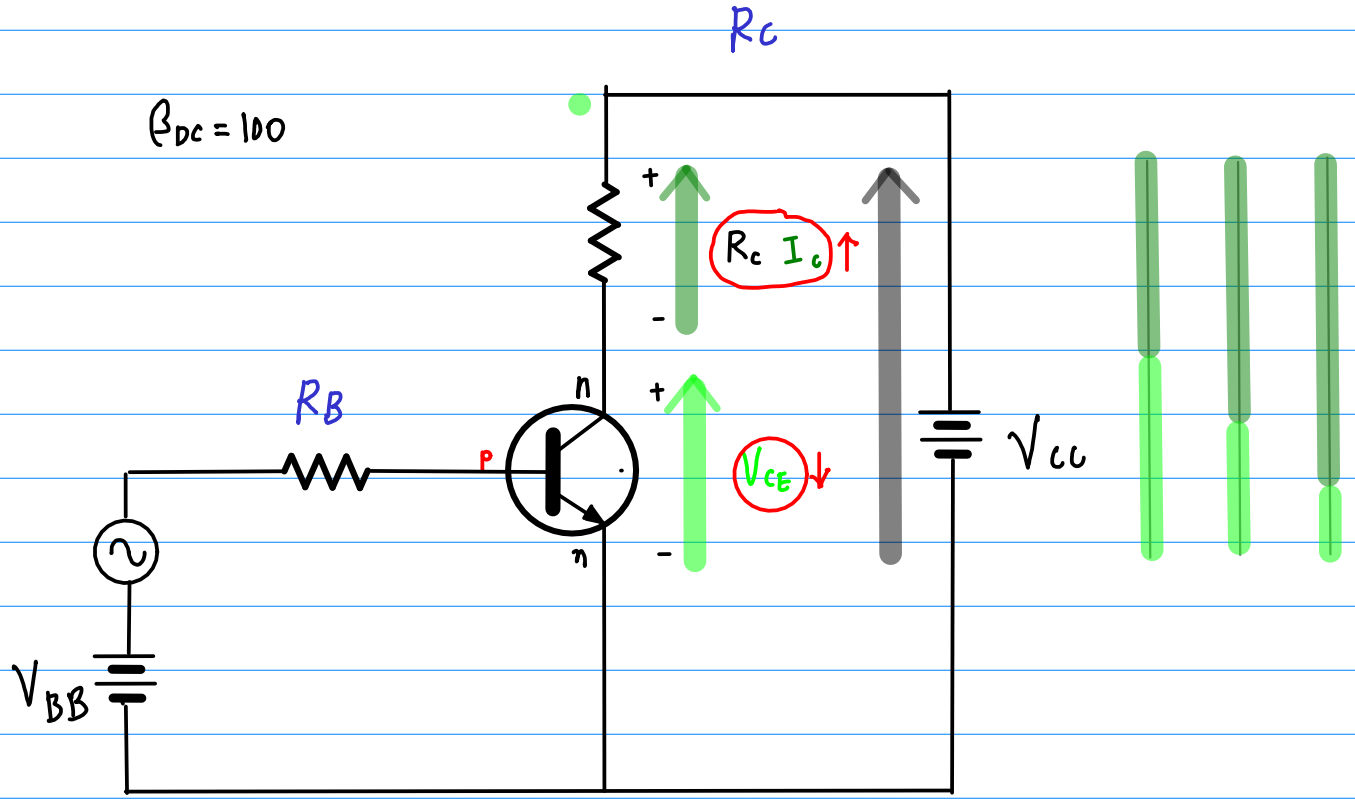


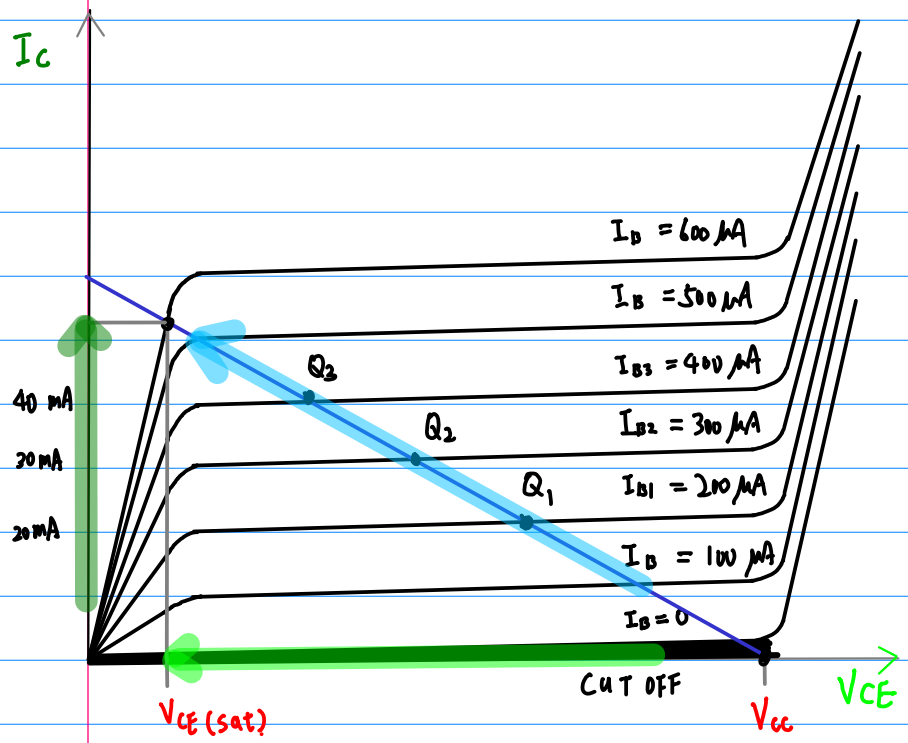


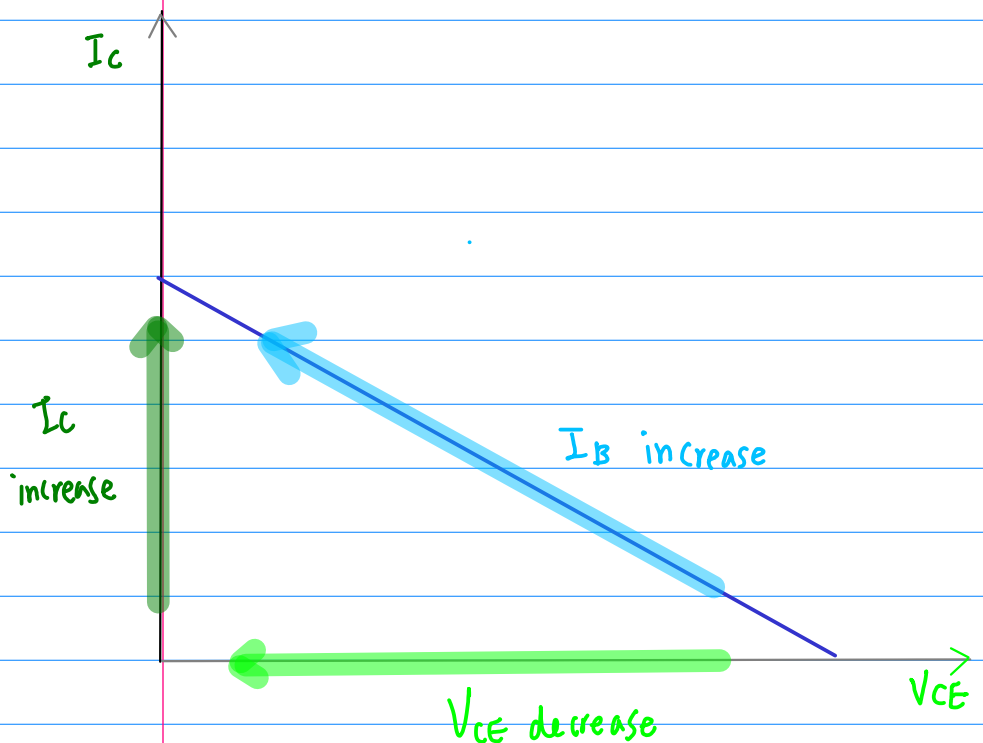

Ic
mA
μA
40 mA
30 mA
20 mA
I_B = 600 μA
I_B = 500 μA
I_{B3} = 400 μA
I_{B2} = 300 μA
I_{B1} = 200 μA
I_B = 100 μA
I_B = 0
Q_3
Q_2
Q_1
CUT OFF
$V_{CE(sat)}$
V_{cc}
V_{CE}
①
②
③


I_C
$I_C \uparrow$
40 mA
30 mA
20 mA
$I_B = 600\,\mu A$
$I_B = 500\,\mu A$
$I_{B3} = 400\,\mu A$
$I_{B2} = 300\,\mu A$
$I_{B1} = 200\,\mu A$
$I_B = 100\,\mu A$
$I_B = 0$
$I_B \uparrow$
Q_3
Q_2
Q_1
$V_{CE} \downarrow$
CUT OFF
$V_{CE(sat)}$
V_{cc}
V_{CE}

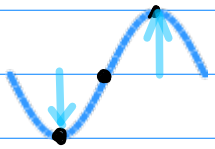
$I_C \uparrow \rightarrow V_{CE} \downarrow$




I_C
$I_B = 600\,\mu A$
$I_B = 500\,\mu A$
$I_{B3} = 400\,\mu A$
$I_{B2} = 300\,\mu A$
$I_{B1} = 200\,\mu A$
$I_B = 100\,\mu A$
$I_B = 0$
Q_3
Q_2
Q_1
40 mA
30 mA
20 mA
$V_{CE(sat)}$
CUT OFF
V_{cc}
V_{CE}


I_C
I_C increase
I_B increase
V_{CE} decrease
V_{CE}

± Δ



$I_B = 400\,\mu A$

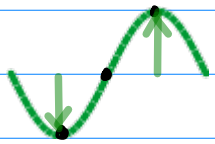
$I_B = 300\,\mu A$

$I_B = 200\,\mu A$

$300\,\mu A + 100\,\mu A = 300\,\mu A + \Delta I_B$

$300\,\mu A = 300\,\mu A$

$300\,\mu A - 100\,\mu A = 300\,\mu A - \Delta I_B$



$I_C = 40\,mA$

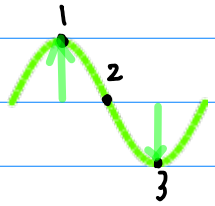
$I_C = 30\,mA$

$I_C = 20\,mA$

$30\,mA + 10\,mA = 30mA + \Delta I_C$

$30\,mA$

$30\,mA - 10mA = 30mA - \Delta I_C$



$V_{CE} = V_1$

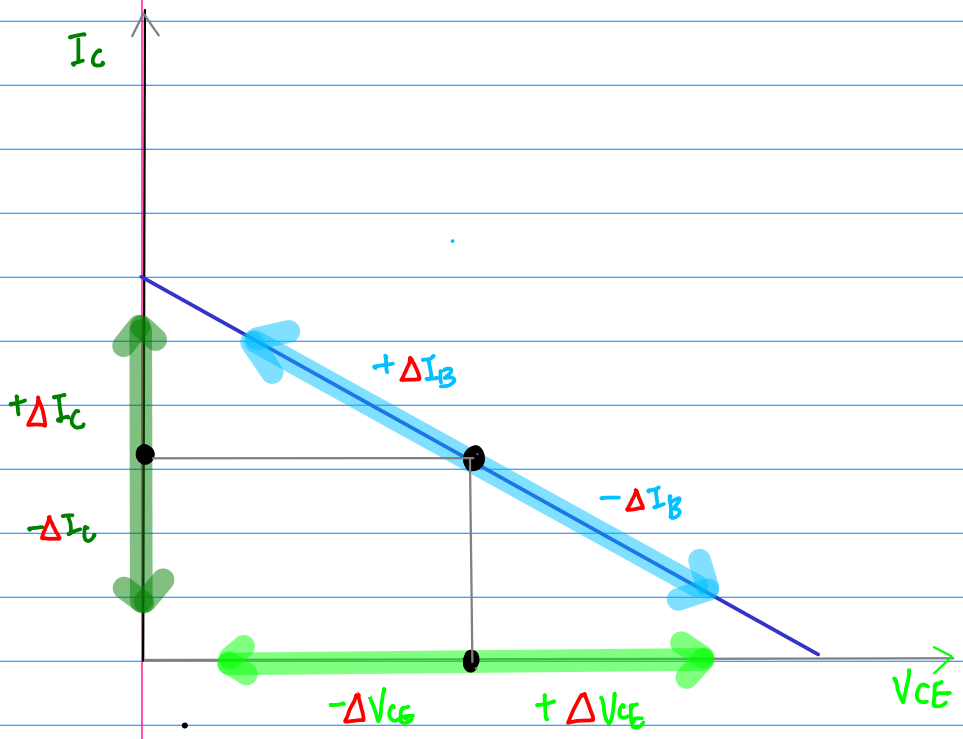
$V_{CE} = V_2$

$V_{CE} = V_3$

$V_2 + (V_1 - V_2) = V_2 + \Delta V_{CE}$

V_2

$V_2 + (V_3 - V_2) = V_2 - \Delta V_{CE}$

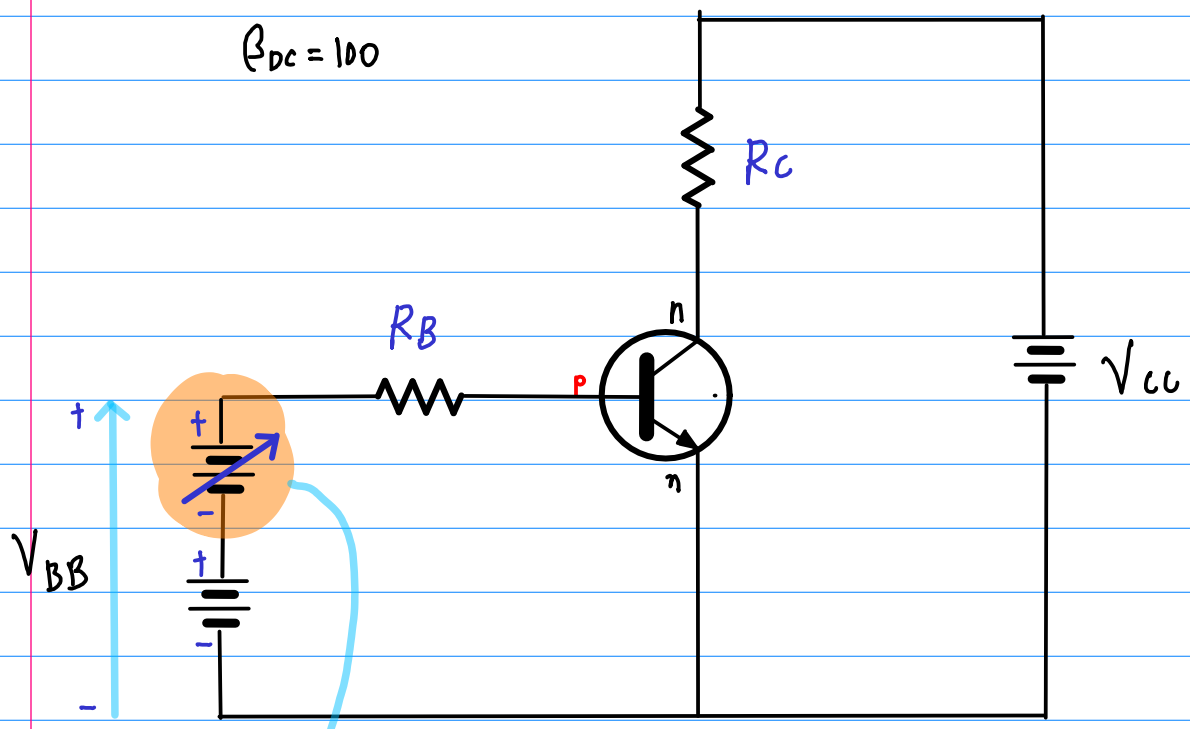


$I_B \rightarrow I_B + \Delta I_B$ ⟹ $I_C \rightarrow I_C + \Delta I_C$, $V_{CE} \rightarrow V_{CE} - \Delta V_{CE}$

$I_B \rightarrow I_B - \Delta I_B$ ⟹ $I_C \rightarrow I_C - \Delta I_C$, $V_{CE} \rightarrow V_{CE} + \Delta V_{CE}$

$$I_B = (V_{BB} - 0.7) / R_B$$

$\beta_{DC} = 100$



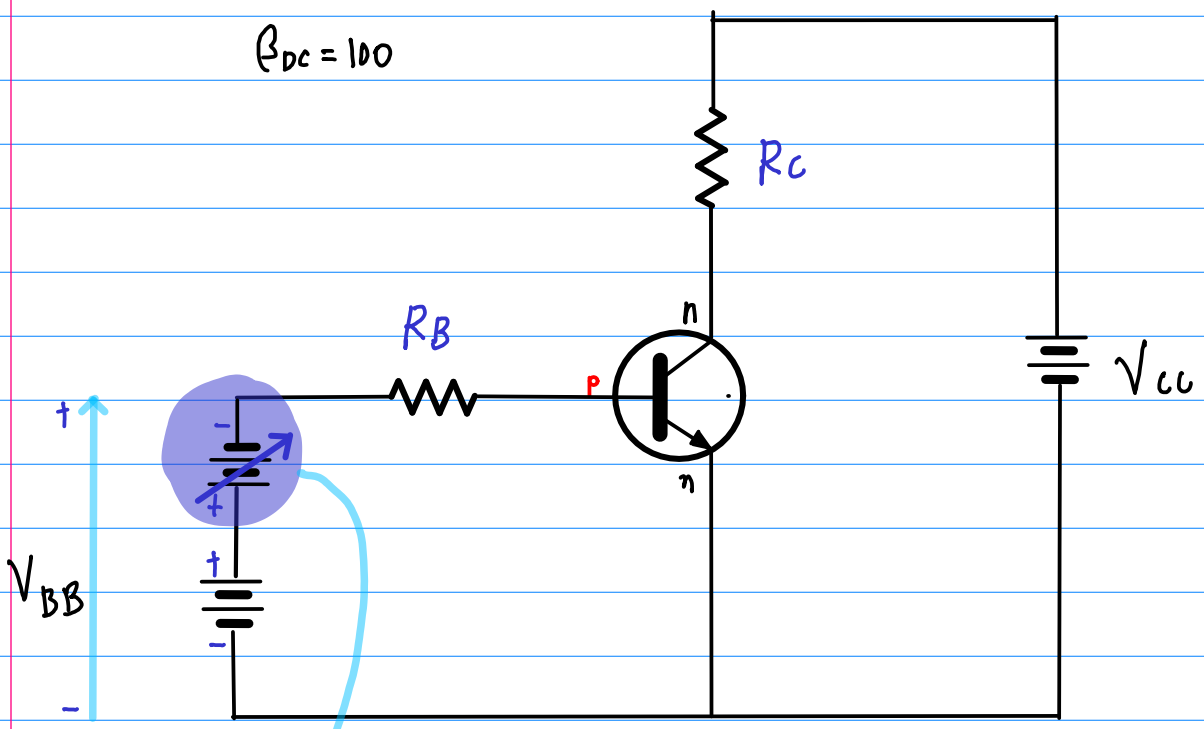
$I_B \rightarrow I_B + \Delta I_B$

$I_C \rightarrow I_C + \Delta I_C$

$V_{CE} \rightarrow V_{CE} - \Delta V_{CE}$

$$I_B = (V_{BB} - 0.7) / R_B$$

$\beta_{DC} = 100$



$I_B \rightarrow I_B - \Delta I_B$

$I_C \rightarrow I_C - \Delta I_C$

$V_{CE} \rightarrow V_{CE} + \Delta V_{CE}$

Current Controlled Device (I_B)

$I_B \uparrow \rightarrow R_{CE} \downarrow$

$I_B \uparrow \rightarrow I_C \uparrow$

$\Big\} V_{CE} \downarrow$

$$V = I \; R$$
$$\downarrow \quad \uparrow \quad \downarrow$$

decrease move faster

$$\downarrow R = \frac{V \downarrow}{I \uparrow}$$

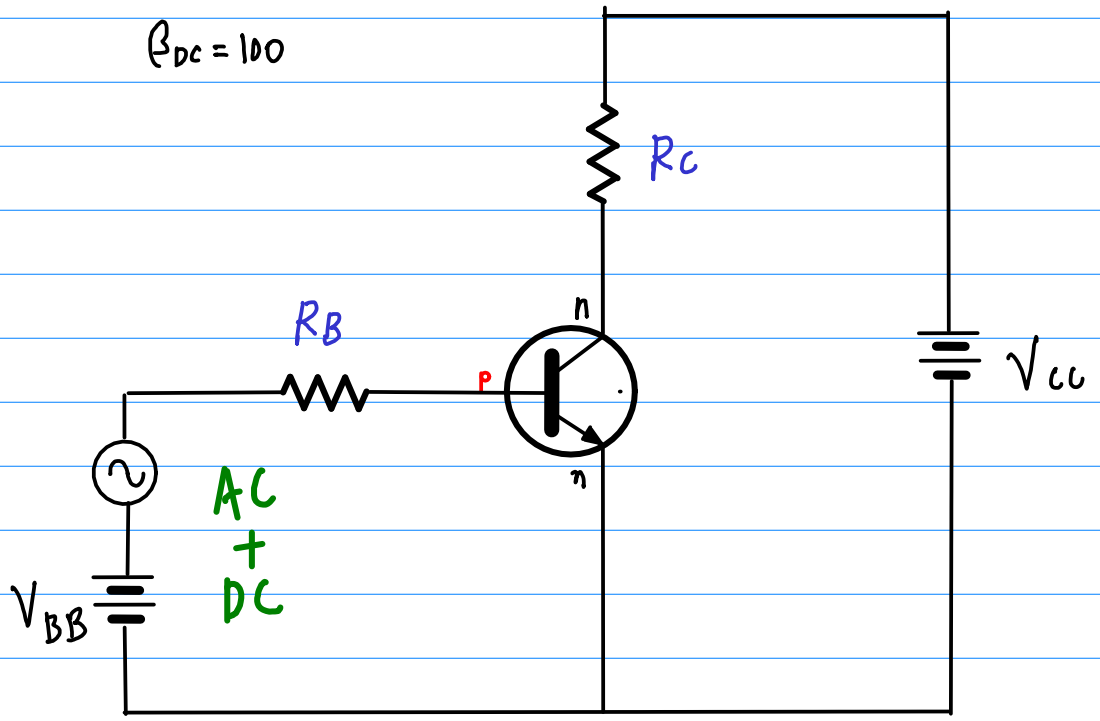
only for Active Region

$$\beta \cdot I_B = I_C$$

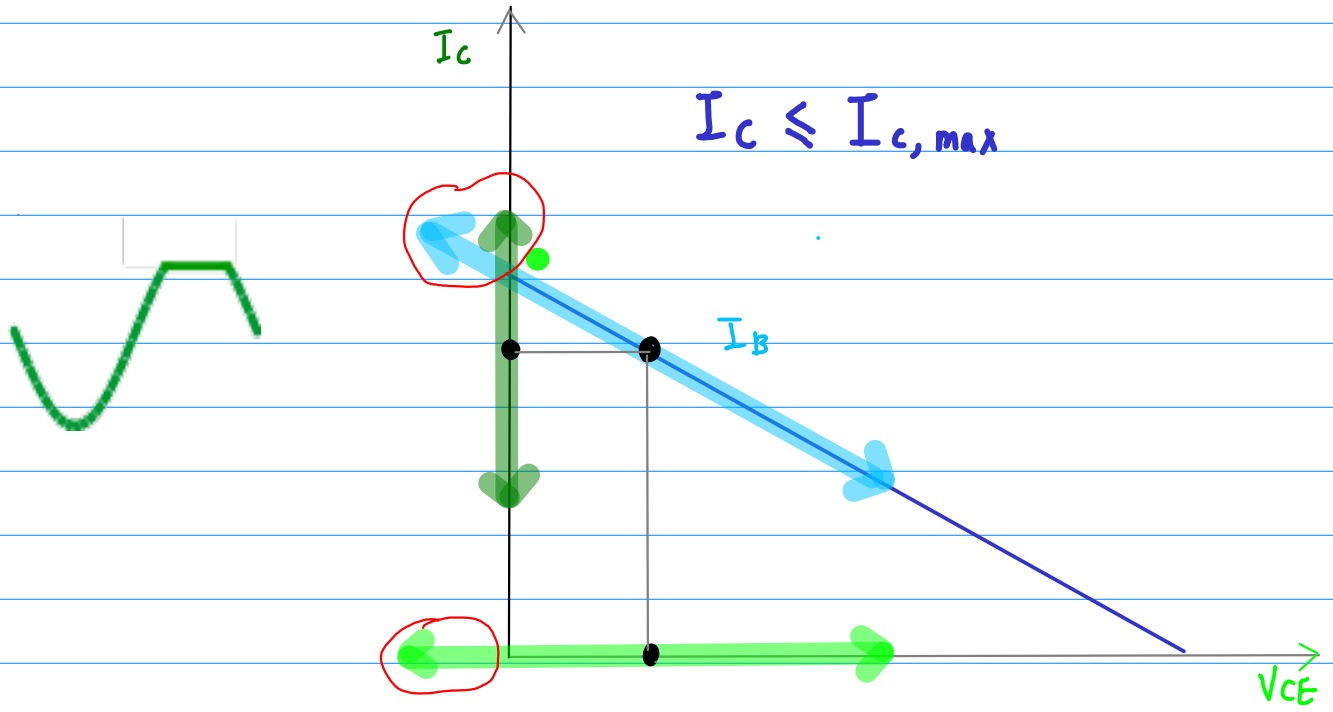
$\beta = 100 \sim 200$

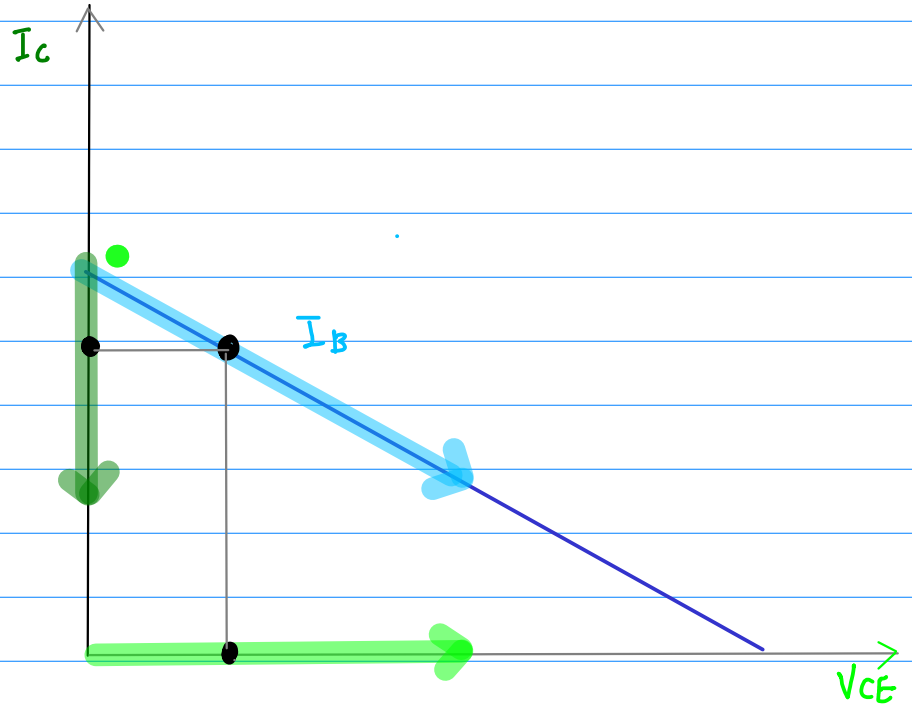
$$\beta \cdot \boxed{2I_B} = \boxed{2I_C}$$

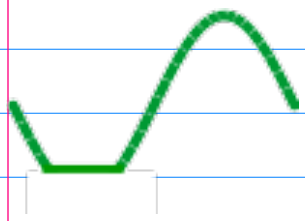
$$\beta \cdot \boxed{3I_B} = \boxed{3I_C}$$

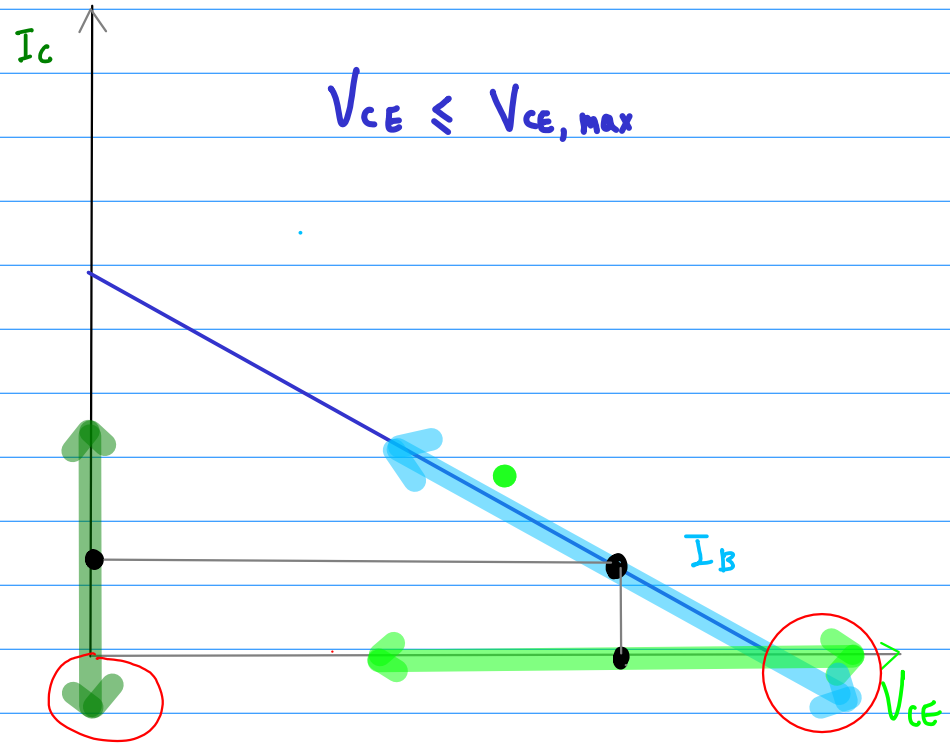

$\beta_{DC} = 100$
R_C
R_B
n
P
n
V_{CC}
AC
+
DC
V_{BB}

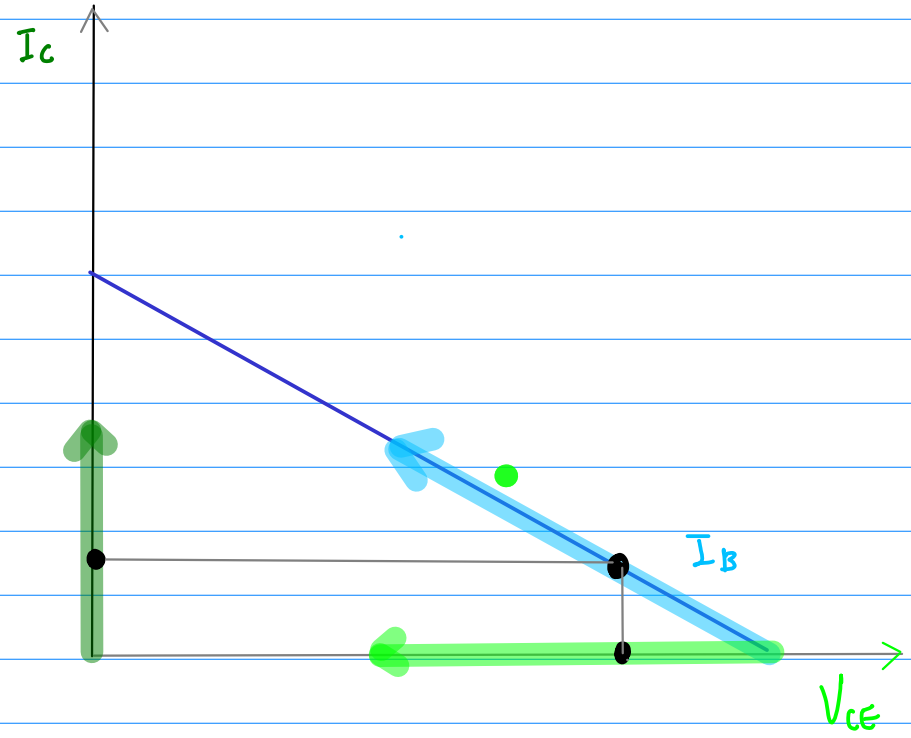
The Central Point



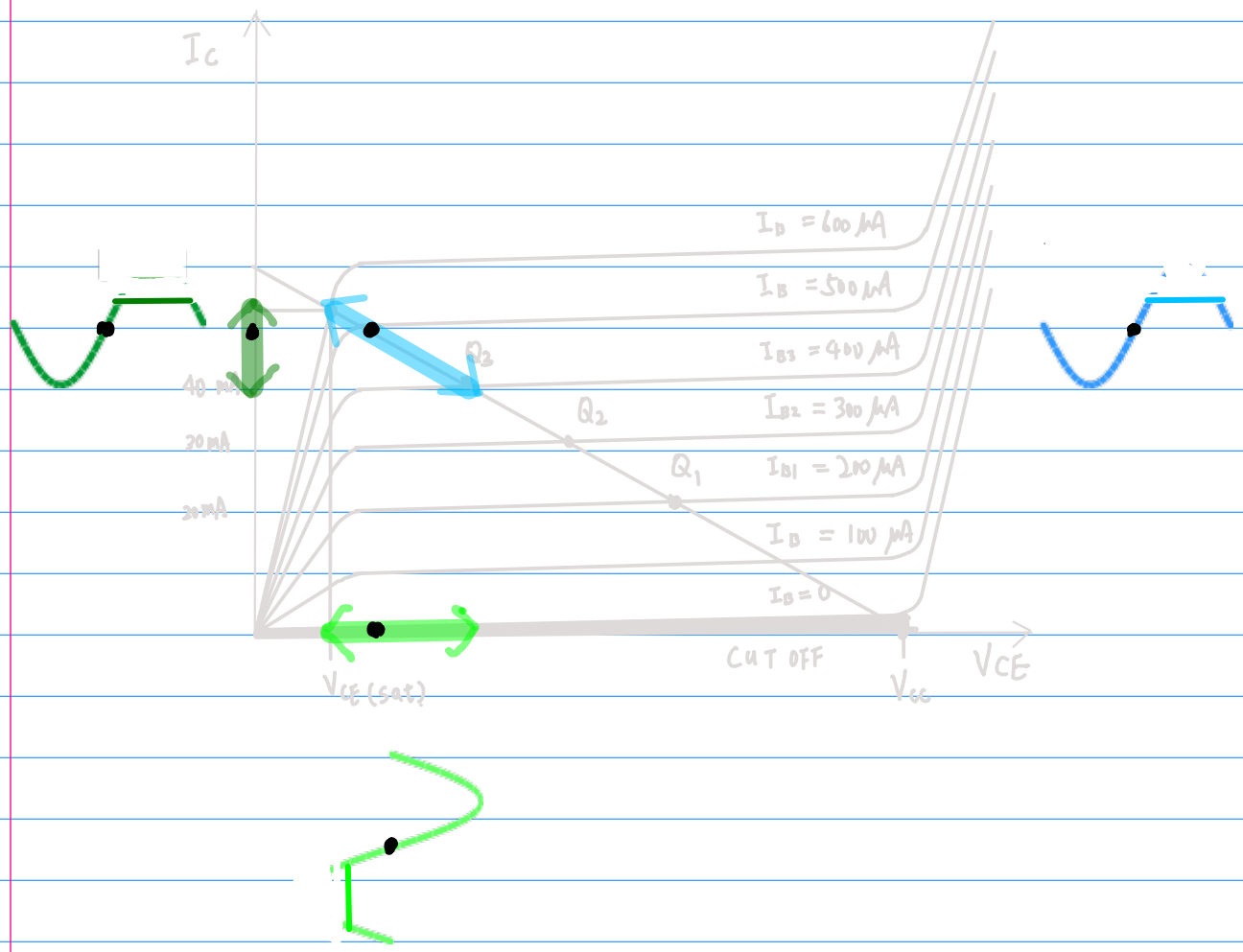


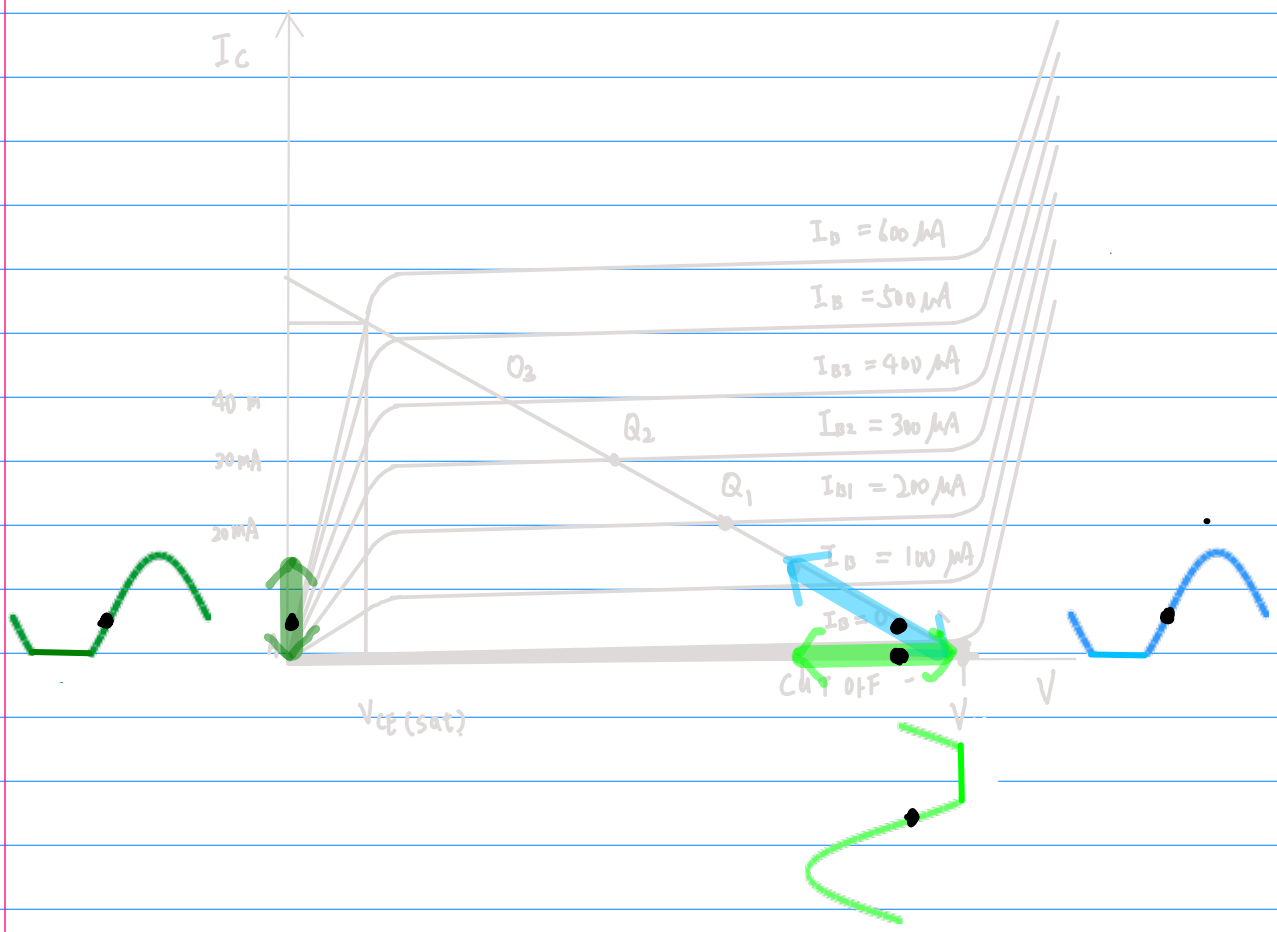



I_C
$V_{CE} \leq V_{CE,max}$
I_B
V_{CE}


I_C
I_B
V_{CE}

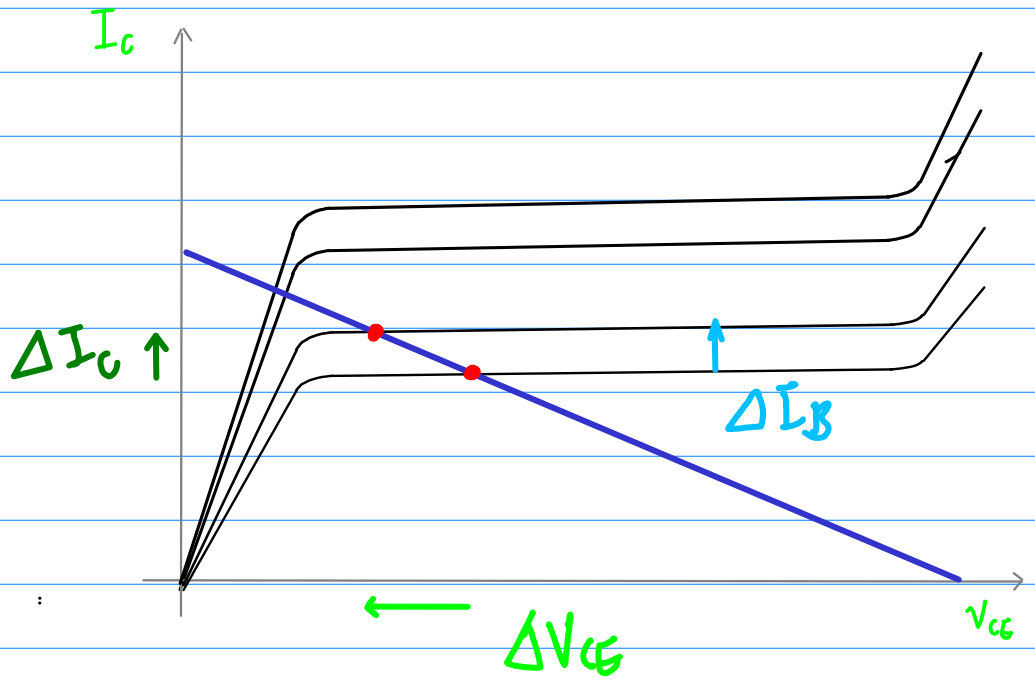
Solution Ranges




I_C
$I_B = 600\,\mu A$
$I_B = 500\,\mu A$
$I_{B3} = 400\,\mu A$
$I_{B2} = 300\,\mu A$
$I_{B1} = 200\,\mu A$
$I_B = 100\,\mu A$
Q_3
Q_2
Q_1
40 mA
30 mA
20 mA
$V_{CE(sat)}$
CUT OFF
V
V

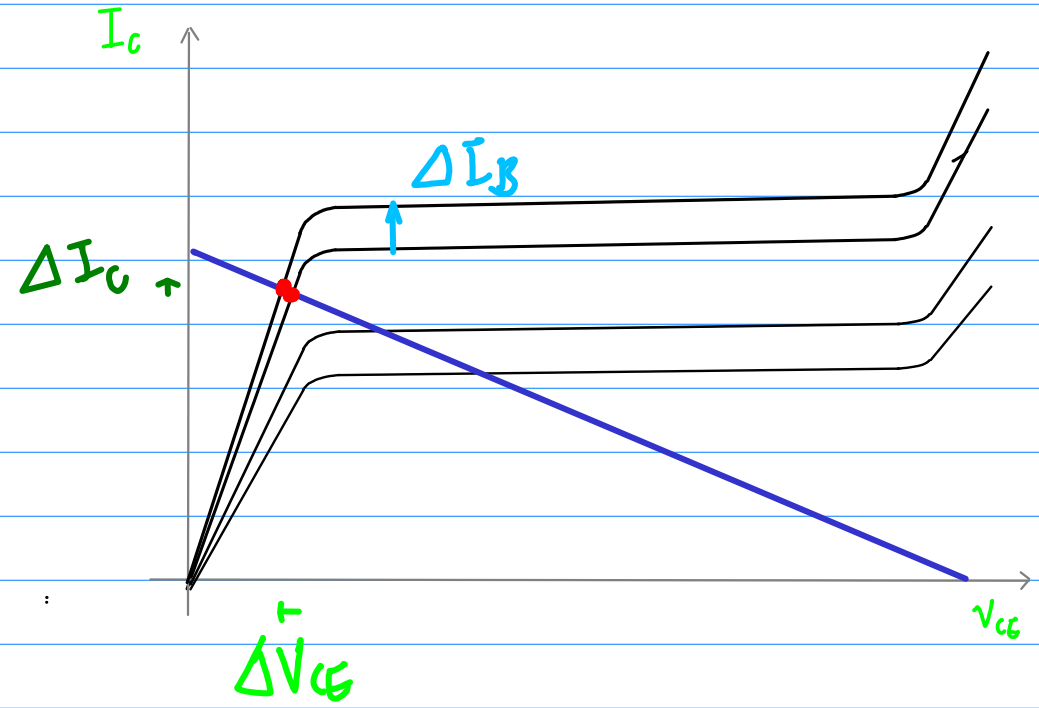
Why Saturation

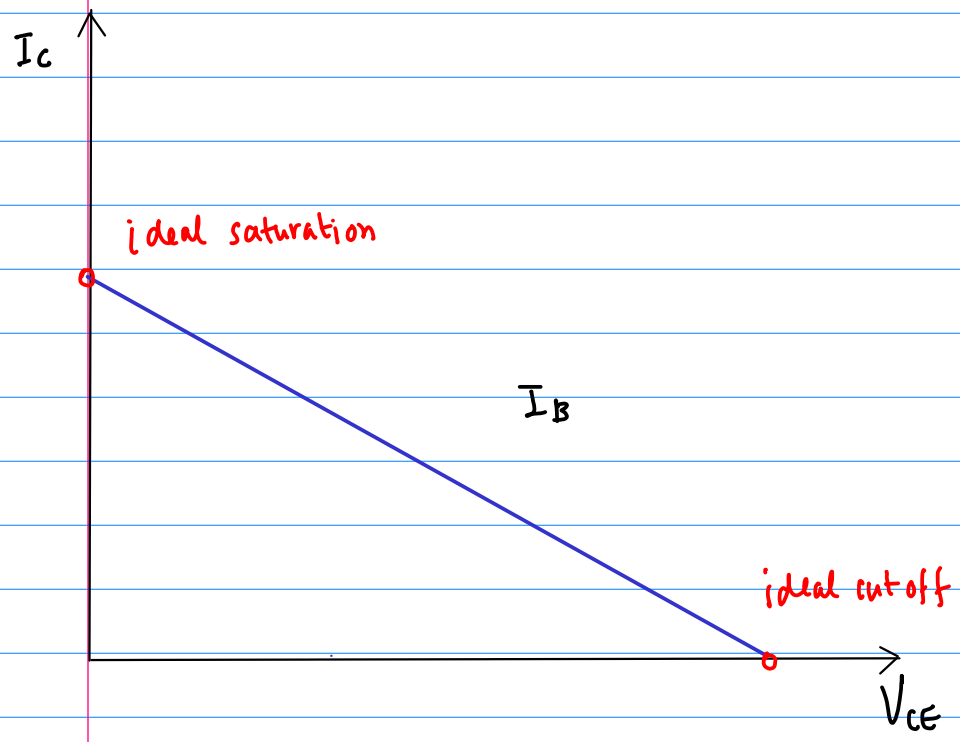
Active Region

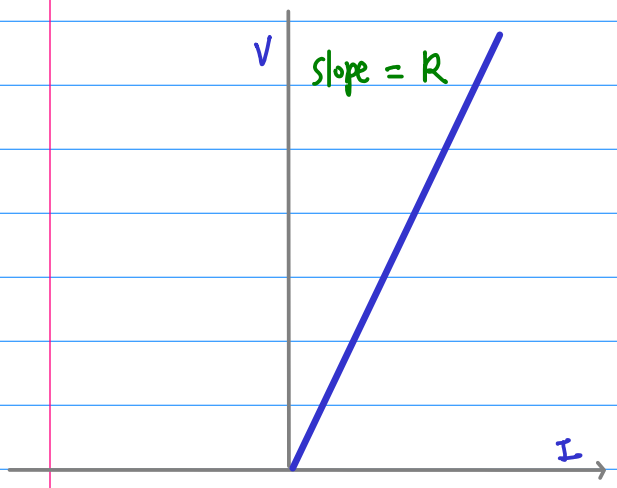


Saturation Region

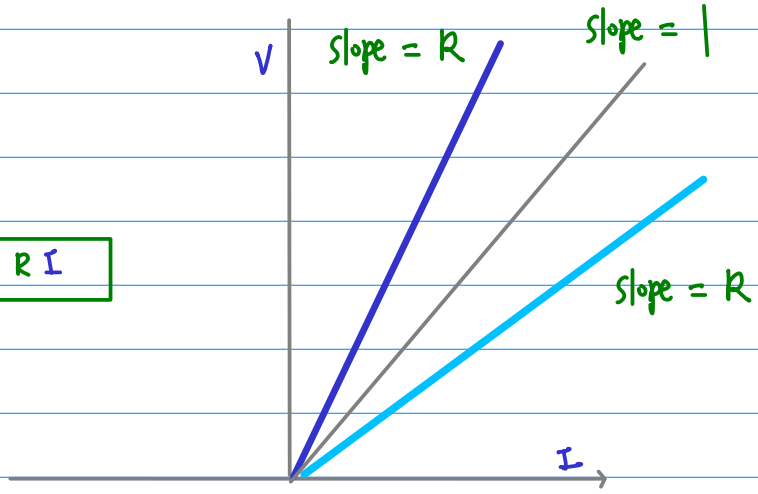
very small change
no visible change
Saturated

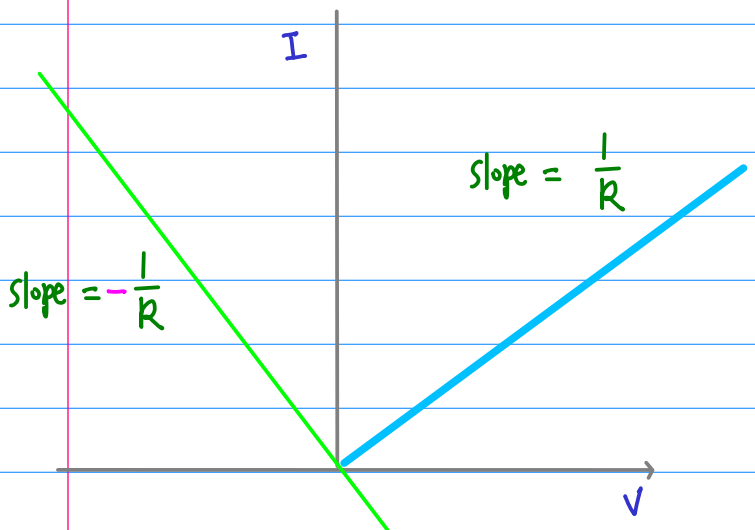



I_C
ideal saturation
I_B
ideal cut off
V_{CE}



$V = RI$

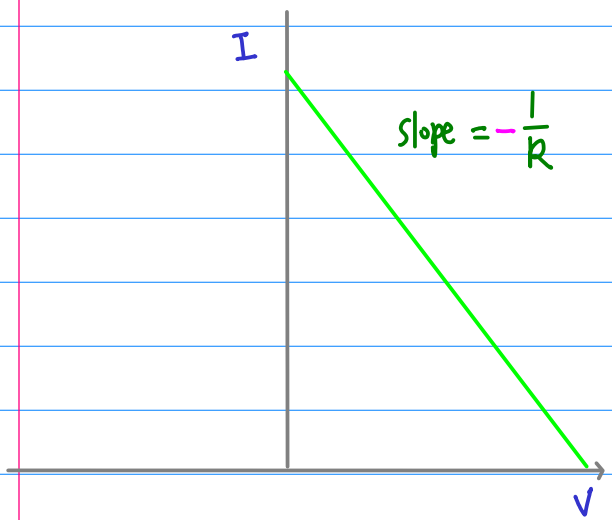




* Change axis $I \leftrightarrow V$

$V = RI \rightarrow I = \frac{1}{R} V$

* reflect along V-axis

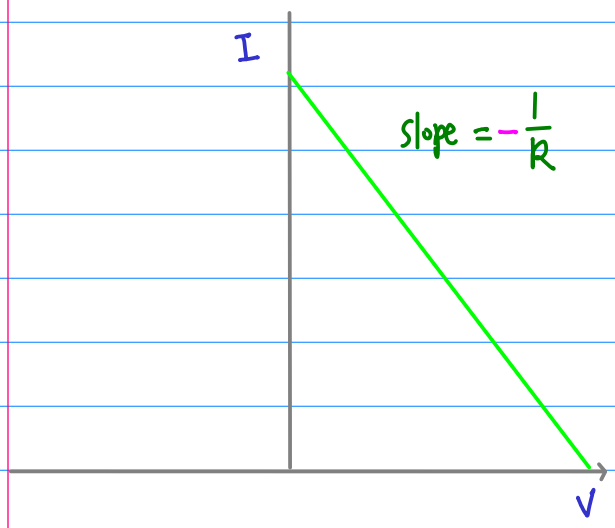


* shift to the right by V_{cc}

$I = -\frac{1}{R}(V - V_{cc})$

$IR = -V + V_{cc}$

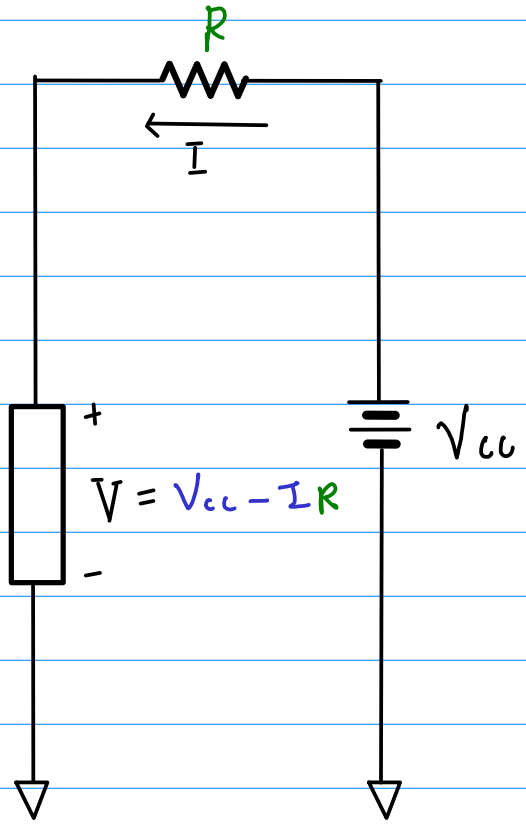
$V = V_{cc} - IR$

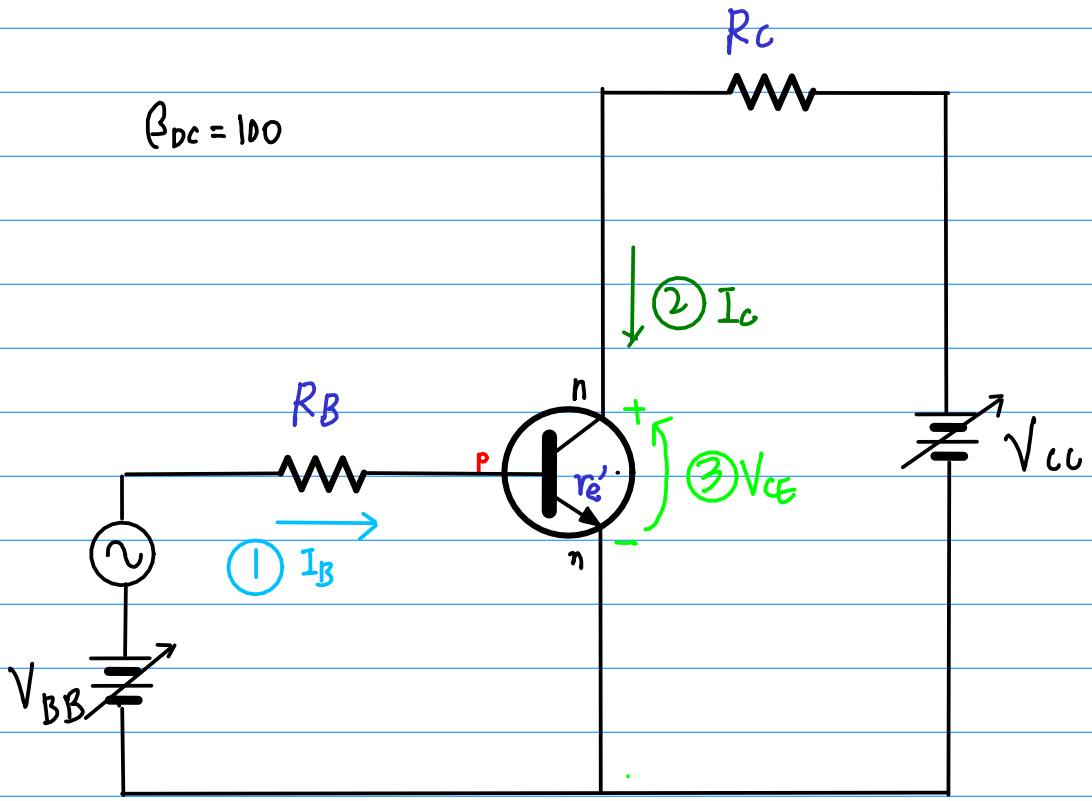


$$I = -\frac{1}{R}(V - V_{cc})$$

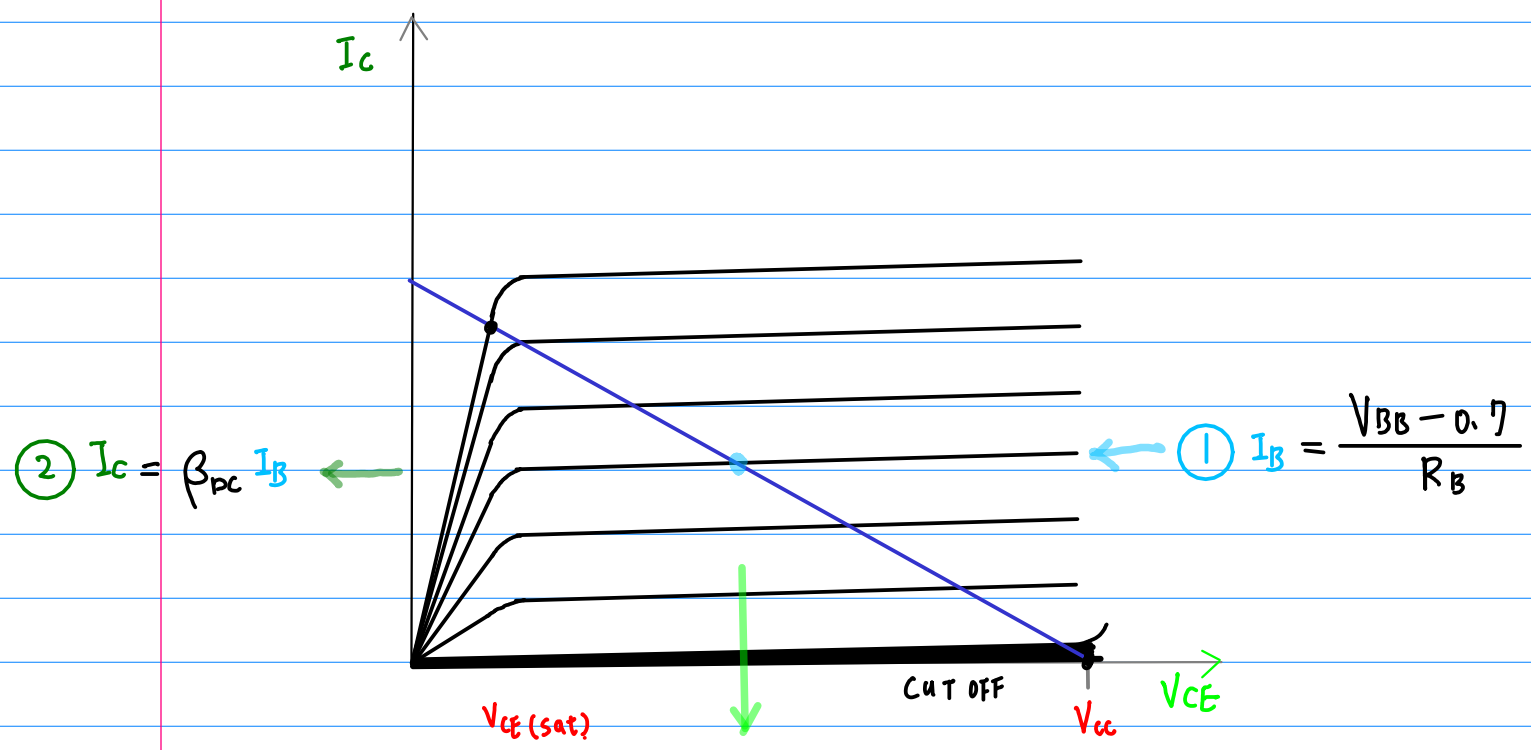
$$IR = -V + V_{cc}$$

$$V = V_{cc} - IR$$





① $I_B = \dfrac{V_{BB} - 0.7}{R_B}$ → ② $I_C = \beta_{DC} I_B$ → ③ $V_{CE} = V_{CC} - I_C R_C$



② $I_C = \beta_{DC} I_B$

① $I_B = \dfrac{V_{BB} - 0.7}{R_B}$

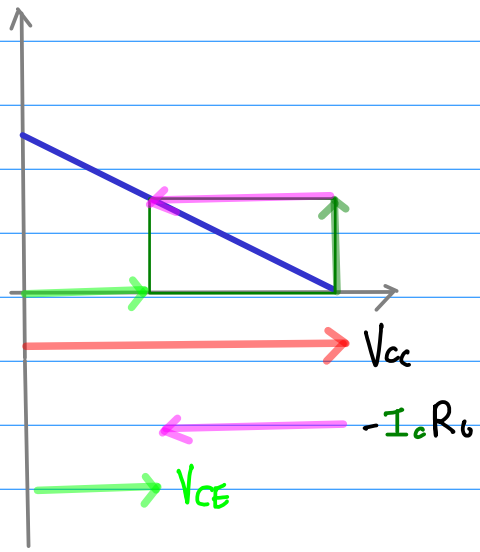
③ $V_{CE} = V_{cc} - I_c R_c$

① $I_B = \dfrac{V_{BB} - 0.7}{R_B}$ → ② $I_C = \beta_{DC} I_B$ → ③ $V_{CE} = V_{cc} - I_c R_c$

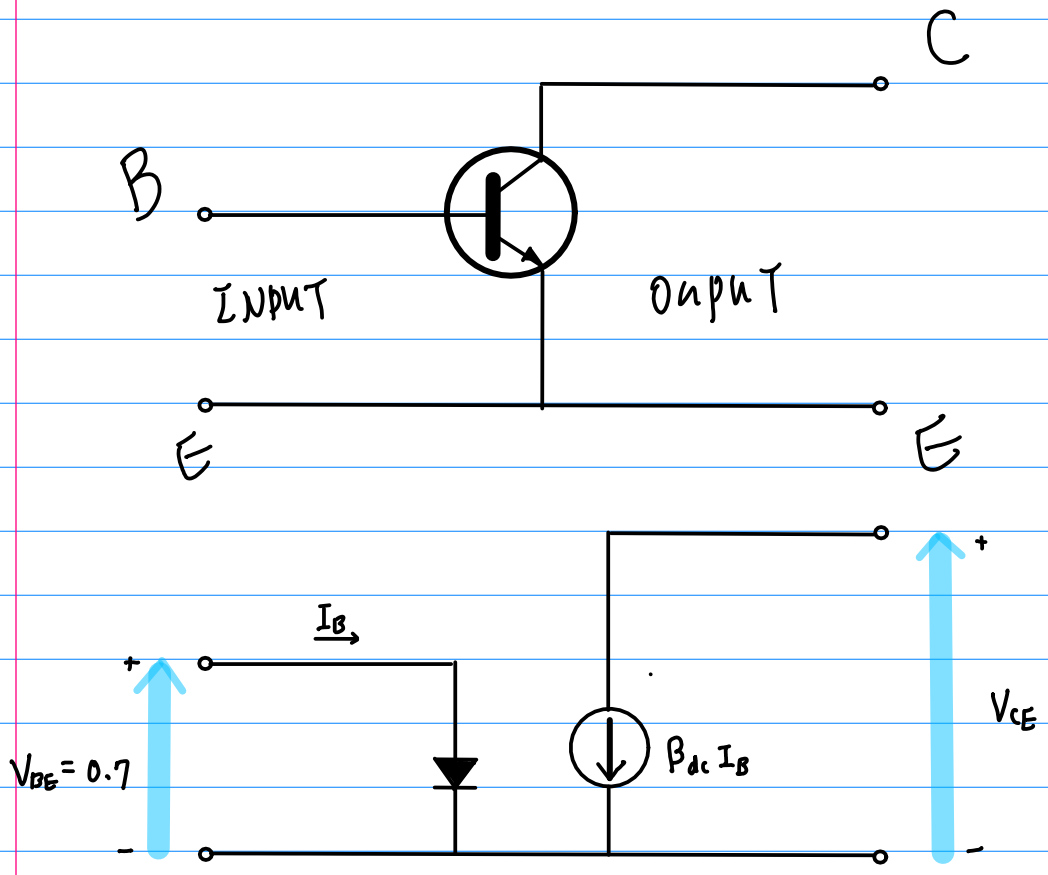
③ $V_{CE} = V_{cc} - I_c R_c$

$I_c = \frac{1}{R_c} \cdot (V_{CE} - V_{cc})$

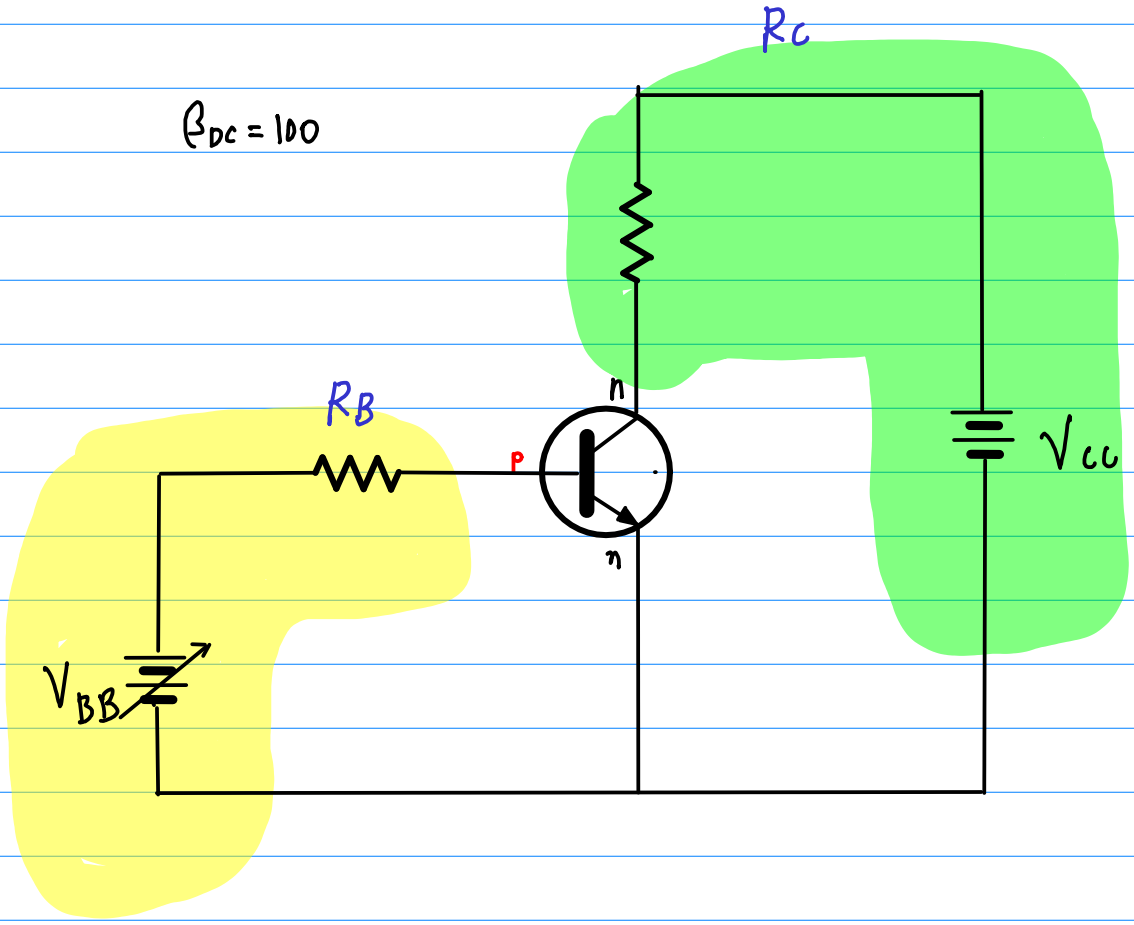
y ↓ , x ↑

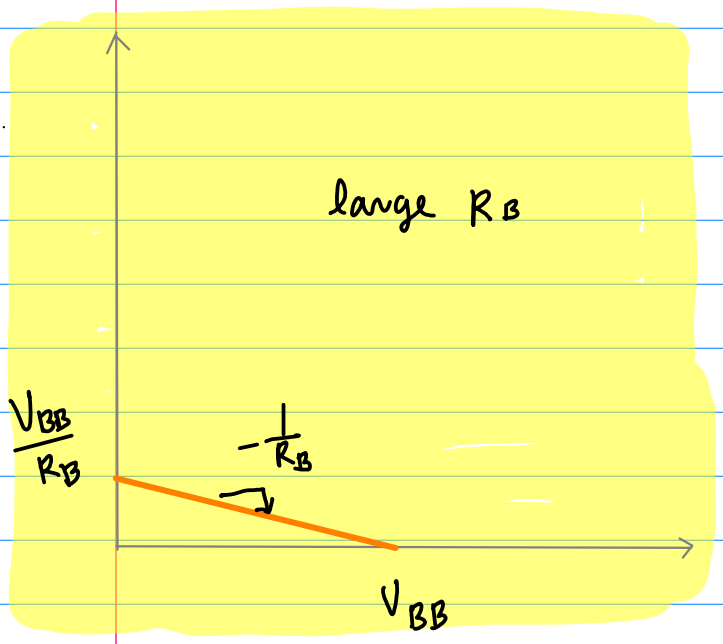


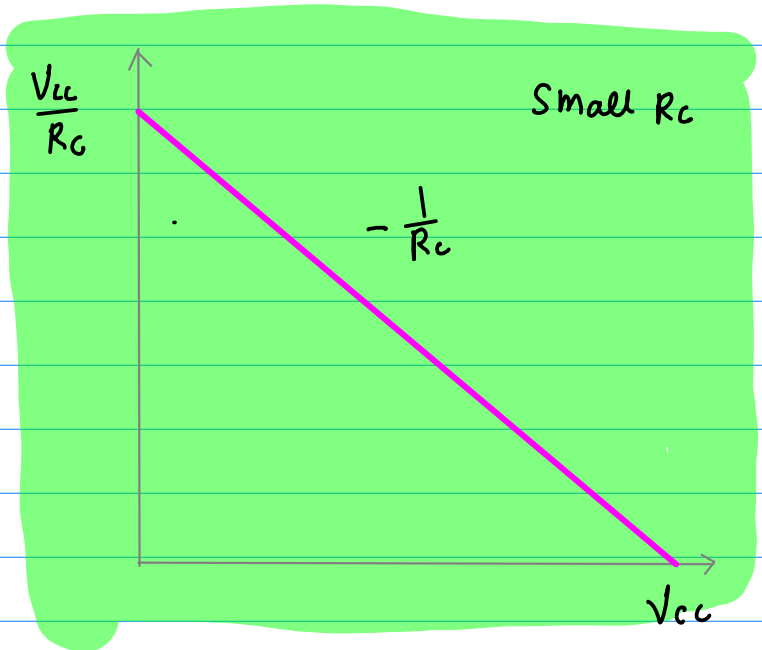
Transistor Approximation

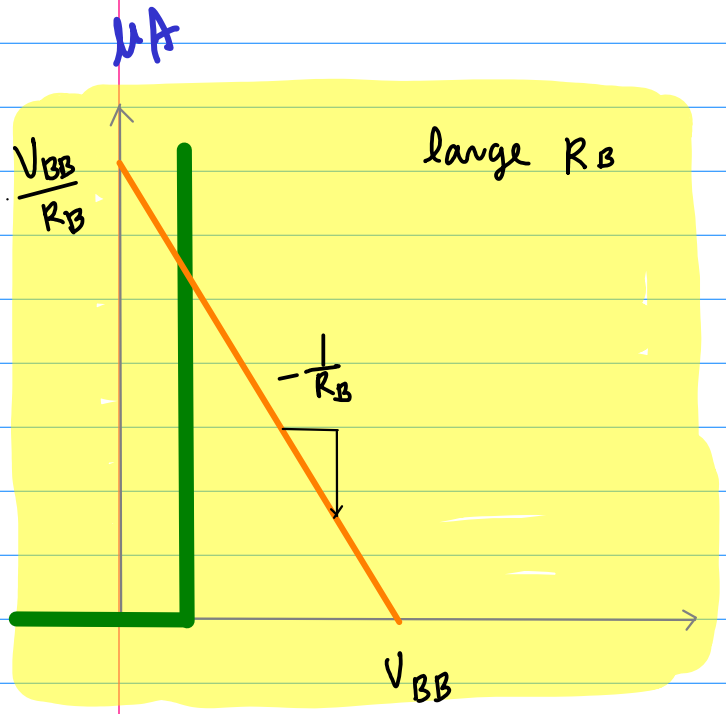


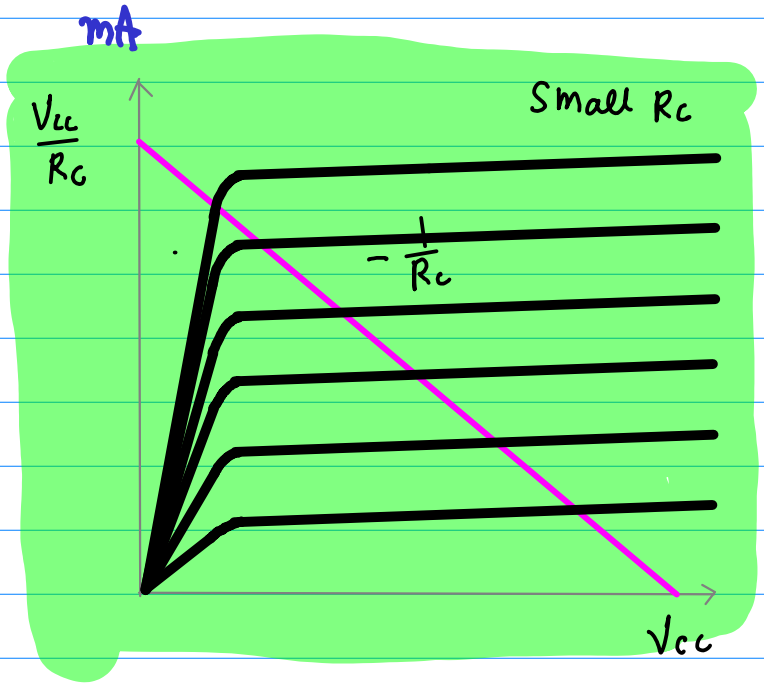
$\beta_{DC} = 100$

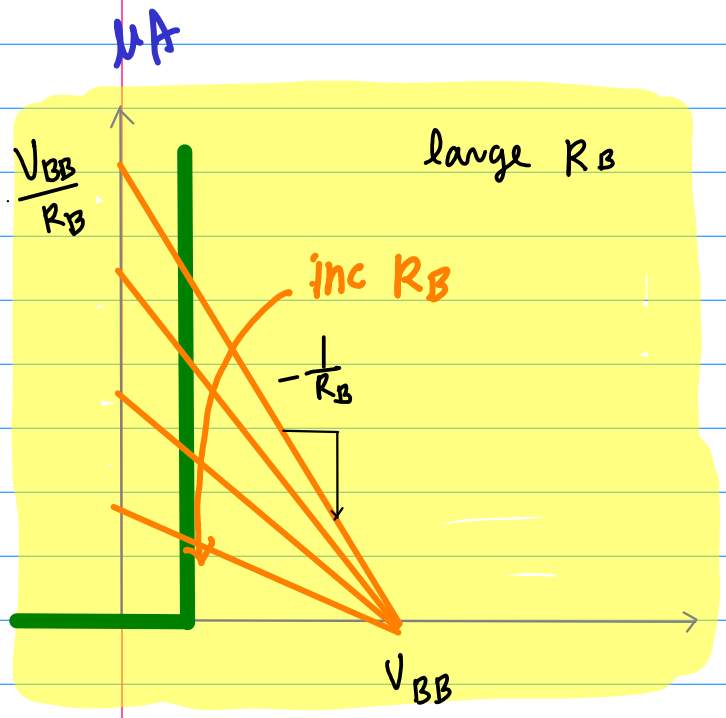

R_C
R_B
n
p
n
V_{CC}
V_{BB}

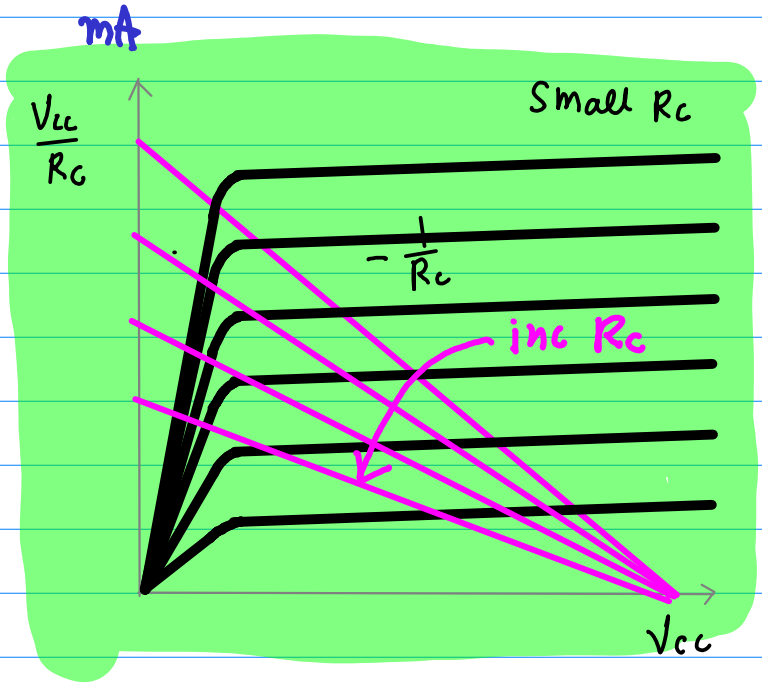

large R_B
$\frac{V_{BB}}{R_B}$
$-\frac{1}{R_B}$
V_{BB}

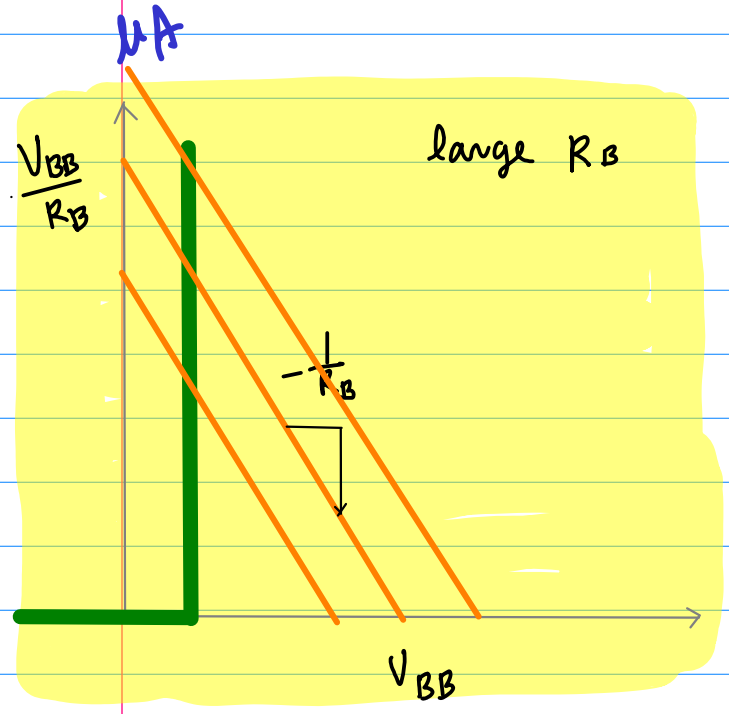

$\frac{V_{CC}}{R_C}$
Small R_C
$-\frac{1}{R_C}$
V_{CC}

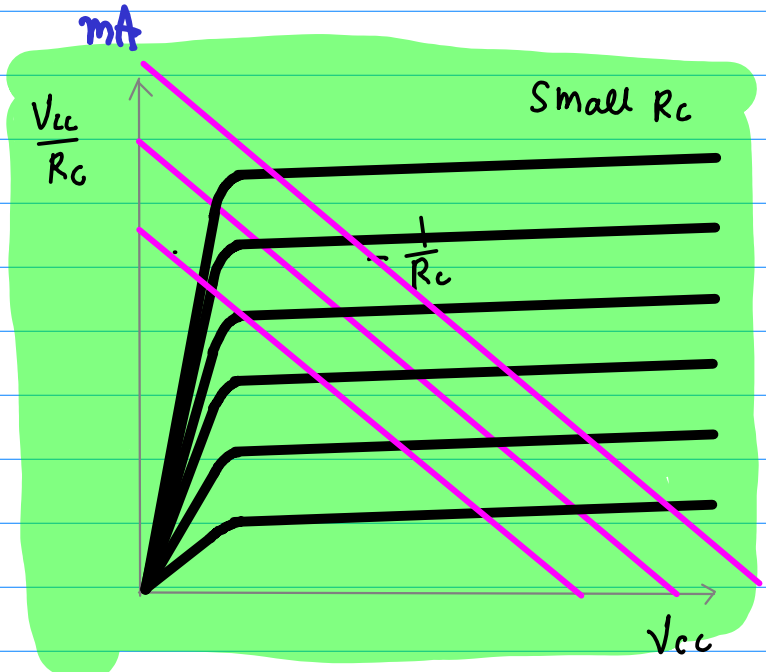

μA
$\frac{V_{BB}}{R_B}$
large R_B
$-\frac{1}{R_B}$
V_{BB}


mA
$\frac{V_{cc}}{R_c}$
Small R_c
$-\frac{1}{R_c}$
V_{cc}









→ Inc V_{BB}

→ inc V_{cc}