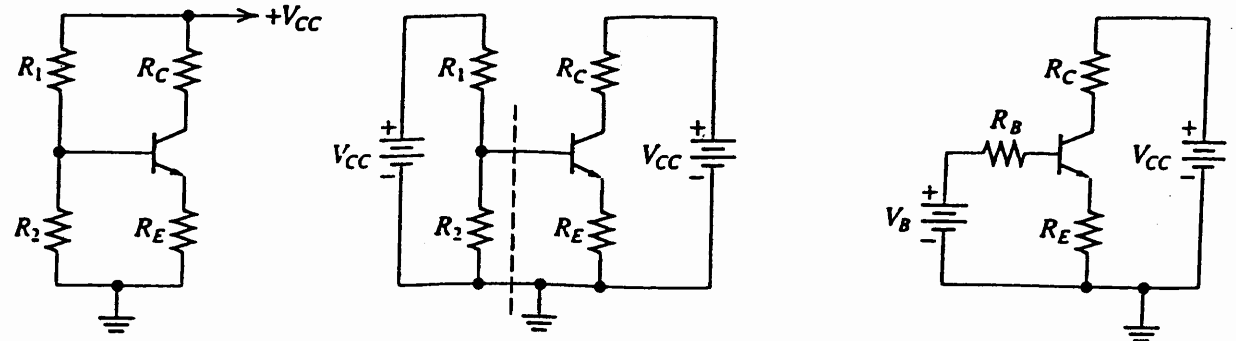
PROBLEM 3

BJT dc Large Signal Model--Four Resistor Biasing



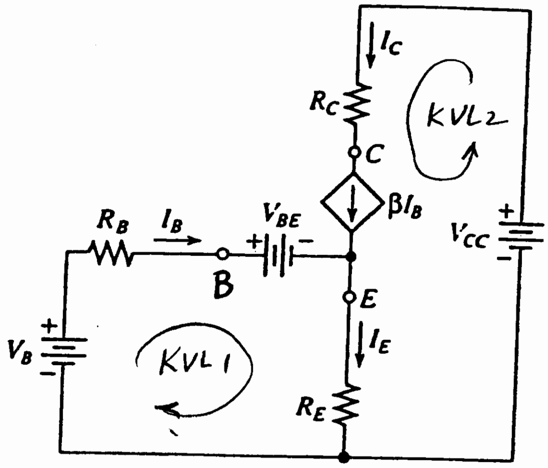
(a) Original circuit

(b) Equivalent showing separate voltage sources for base and collector circuits

(c) Circuit using Thévenin equivalent in place of V_{CC}, R_1, and R_2

Consider the ideal BJT in a Four-resistor (voltage divider) bias configuration. Assume BJT is operating in active region. Refer to figures and in explicit and clear steps obtain expressions for the following in terms of V_{BE}, V_{CC}, R_1, R_2, R_C, R_E, and β:

a) V_B
b) R_B
c) I_B
d) I_E
e) Slope and intersection of the dc load line with the V_{CE} and I_C axes.



(d) Equivalent to part (c) with active-region transistor model

a) V_B is the thevenin voltage of the left circuit in figure (b)

$$\boxed{V_B = V_{oc} = \frac{R_2}{R_1+R_2} V_{cc}}$$

b) R_B is the Thevenin resistance for same circuit

$$\boxed{R_B = \frac{R_2 R_1}{R_1+R_2}}$$

c) Using Circuit (d) $\quad R_B I_B + V_{BE} + R_E I_E - V_B = 0 \quad$ (KVL 1)

KCL $\Rightarrow$ $I_E = I_C + I_B \quad \therefore \quad I_E = (\beta+1) I_B$

Substituting for I_E $\Rightarrow$

$$R_B I_B + V_{BE} + R_E (\beta+1) I_B - V_B = 0$$

$$\therefore \boxed{I_B = \frac{V_B - V_{BE}}{R_B + (\beta+1) R_E}} \quad \text{OR} \quad \boxed{I_B = \frac{\left(\frac{R_2}{R_1+R_2}\right) V_{cc} - V_{BE}}{R_B + (\beta+1) R_E}}$$

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d) $I_E = (\beta+1)\, I_B$

$\therefore \boxed{I_E = (\beta+1)\dfrac{V_B - V_{BE}}{R_B + (\beta+1) R_E}}$ OR $\boxed{I_E = (\beta+1)\dfrac{\left(\frac{R_2}{R_1+R_2}\right)V_{CC} - V_{BE}}{R_B + (\beta+1) R_E}}$

or $\boxed{I_E = \dfrac{V_B - V_{BE}}{\left(\frac{1}{\beta+1}\right)R_B + R_E}}$ or $\boxed{I_E = \dfrac{\left(\frac{R_2}{R_1+R_2}\right)V_{CC} - V_{BE}}{\frac{1}{(\beta+1)} R_B + R_E}}$

e) KVL 2: $R_C I_C + V_{CE} + R_E I_E = V_{CC}$

$I_E = (\beta+1) I_B \Rightarrow I_E = \dfrac{(\beta+1)}{\beta} I_C$

$\therefore$ KVL$_2$ $\Rightarrow \left(R_C + \left(\frac{\beta+1}{\beta}\right) R_E\right) I_C = V_{CC} - V_{CE}$

$\therefore I_C = \dfrac{V_{CC} - V_{CE}}{R_C + \left(\frac{\beta+1}{\beta}\right) R_E}$ Load line Eq.

$$\boxed{I_C = \underbrace{\left[-\frac{1}{R_C + \left(\frac{\beta+1}{\beta}\right) R_E}\right]}_{\text{Slope}} V_{CE} + \underbrace{\left[\frac{1}{R_C + \left(\frac{\beta+1}{\beta}\right) R_E}\right] V_{CC}}_{\text{Intercept with } I_C \text{ axis}}}$$

$\boxed{\text{Intercept with } V_{CE} \text{ axis} = V_{CC}}$