Chapter 3

Exercise Solutions

E3.1

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

For $\alpha = 0.980$, $\beta = \frac{0.980}{1-0.980} = 49$

For $\alpha = 0.995$, $\beta = \frac{0.995}{1-0.995} = 199$

$\underline{49 \le \beta \le 199}$

E3.2

$\alpha = \frac{\beta}{1+\beta} = \frac{75}{76} = \underline{0.9868}$

$\alpha = \frac{125}{126} = \underline{0.9921}$

E3.3

$I_E = (1+\beta)I_B$

So $(1+\beta) = \frac{I_E}{I_B} = \frac{0.780}{0.00960} = 81.25 \Rightarrow \underline{\beta = 80.3}$

$\alpha = \frac{\beta}{1+\beta} = \frac{80.3}{81.3} \Rightarrow \underline{\alpha = 0.9877}$

$I_C = \beta I_B = (80.3)(9.60\ \mu A) \Rightarrow \underline{I_C = 0.771\ mA}$

E3.4

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.990}{1-0.990} \Rightarrow \underline{\beta = 99}$

$I_B = \frac{I_E}{(1+\beta)} = \frac{2.150}{100} \Rightarrow \underline{I_B = 21.50\ \mu A}$

$I_C = \alpha I_E = (0.990)(2.150) \Rightarrow \underline{I_C = 2.13\ mA}$

E3.5

$r_0 = \frac{V_A}{I_C} = \frac{150}{I_C}$

$I_C = 0.1\ mA \Rightarrow r_0 = 1.5\ M\Omega$

$I_C = 1.0\ mA \Rightarrow r_0 = 150\ k\Omega$

$I_C = 10\ mA \Rightarrow r_0 = 15\ k\Omega$

E3.6

$I_C = I_0\left(1 + \frac{V_{CE}}{V_A}\right)$

At $V_{CE} = 1$, $I_C = 1$

a. $V_A = 75$

$I_C = 1 = I_0\left(1 + \frac{1}{75}\right) \Rightarrow I_0 = 0.9868\ mA$

At $V_{CE} = 10$, $I_C = (0.9868)\left(1 + \frac{10}{75}\right) \Rightarrow$

$\underline{I_C = 1.12\ mA}$

b. $V_A = 150$

$I_C = 1 = I_0\left(1 + \frac{1}{150}\right) \Rightarrow I_0 = 0.9934\ mA$

At $V_{CE} = 10$, $I_C = (0.9934)\left(1 + \frac{10}{150}\right) \Rightarrow$

$\underline{I_C = 1.06\ mA}$

E3.7

$BV_{CEO} = \frac{BV_{CBO}}{\sqrt[n]{\beta}} = \frac{200}{\sqrt[3]{120}} = 40.5$ volts

E3.8

$BV_{CEo} = \frac{BV_{CBo}}{\sqrt[3]{\beta}}$

$BV_{CBo} = \left(\sqrt[3]{100}\right)(30) = 139\ V$

E3.9

a. $V_I = 0.2 < V_{BE}(\text{on}) \Rightarrow \underline{I_B = I_C = 0}$, $\underline{V_0 = 5\ V}$
$P = 0$

b. $V_I = 3.6$ Transistor is driven into saturation.

$I_B = \frac{3.6 - 0.7}{0.64} \Rightarrow \underline{I_B = 4.53\ mA}$

$I_C = \frac{5 - V_{CE}(\text{sat})}{R_C} = \frac{5 - 0.2}{0.44} \Rightarrow \underline{I_C = 10.9\ mA}$

Note that $\frac{I_C}{I_B} = \frac{10.9}{4.53} = 2.41 < \beta$ which shows that the transistor is indeed in saturation.

$P = I_C V_{CE} + I_B V_{BE} = (10.9)(0.2) + (4.53)(0.7)$

$= 2.18 + 3.17$

$P = 5.35\ mW$

E3.10

For $V_{BC} = 0 \Rightarrow V_0 = 0.7\ V$

Then $I_C = \frac{5 - 0.7}{0.44} \Rightarrow I_C = 9.77\ mA$

and $I_B = \frac{I_C}{\beta} = \frac{9.77}{50} = 0.195\ mA$

$V_I = I_B R_B + V_{BE}(\text{on}) = (0.195)(0.64) + 0.7$

$\Rightarrow V_I = 0.825\ V$

Power $= I_C V_{CE} + I_B V_{BE}$

$= (9.77)(0.7) + (0.195)(0.7)$

$\underline{\text{Power} = 6.98\ mW}$

E3.11

For $V_C = 4$ V and $I_{CQ} = 1.5$ mA

$$R_C = \frac{10-4}{1.5} \Rightarrow \underline{R_C = 4\ \text{k}\Omega}$$

$$I_E = \frac{-V_{BE}(\text{on}) - (-10)}{R_E}$$

$$I_E = \left(\frac{101}{100}\right) I_C = 1.515\ \text{mA}$$

$$R_E = \frac{10-0.70}{1.515} \Rightarrow \underline{R_E = 6.14\ \text{k}\Omega}$$

E3.12

$$I_C = \frac{10-V_C}{R_C} = \frac{10-6.34}{4} \Rightarrow I_C = 0.915\ \text{mA}$$

$$I_E = \frac{-V_{BE}(\text{on}) - (-10)}{R_E} = \frac{10-0.7}{10} \Rightarrow$$

$$\underline{I_E = 0.930\ \text{mA}}$$

$$I_C = \alpha I_E \Rightarrow \alpha = \frac{I_C}{I_E} = \frac{0.915}{0.930} \Rightarrow \underline{\alpha = 0.9839}$$

$$I_B = I_E - I_C = 0.930 - 0.915 \Rightarrow \underline{I_B = 0.0150\ \text{mA}}$$

$$\beta = \frac{I_C}{I_B} = \frac{0.915}{0.015} \Rightarrow \underline{\beta = 61}$$

$$V_{CE} = V_C - V_E = 6.34 - (-0.70) \Rightarrow$$

$$\underline{V_{CE} = 7.04\ \text{V}}$$

E3.13

$$I_E = \frac{10 - V_{EB}(\text{on})}{R_E} = \frac{10-0.7}{8} \Rightarrow \underline{I_E = 1.16\ \text{mA}}$$

$$I_B = \frac{I_E}{(1+\beta)} = \frac{1.16}{51} \Rightarrow \underline{I_B = 2.27\ \mu\text{A}}$$

$$I_C = \frac{\beta}{1+\beta} I_E = \frac{50}{51}(1.16) \Rightarrow \underline{I_C = 1.14\ \text{mA}}$$

$$V_C = I_C R_C - 10 = (1.14)(4) - 10 = -5.44$$

$$V_{EC} = 0.7 - (-5.44) \Rightarrow \underline{V_{EC} = 6.14\ \text{V}}$$

E3.14

$$I_E = \frac{V_{BB} - V_{EB}(\text{on})}{R_E}$$

$$\Rightarrow R_E = \frac{4-0.7}{1.0} \Rightarrow \underline{R_E = 3.3\ \text{k}\Omega}$$

$$I_C = \alpha I_E = (0.9920)(1.0) \Rightarrow \underline{I_C = 0.992\ \text{mA}}$$

$$I_B = I_E - I_C = 1.0 - 0.9920 \Rightarrow \underline{I_B = 0.0080\ \text{mA}}$$

$$V_{CB} = -V_{BC} = I_C R_C - V_{CC} = (0.992)(1) - 5$$

$$\Rightarrow \underline{V_{BC} = 4.01\ \text{V}}$$

E3.15

$$V_{BB} = I_B R_B + V_{BE}(\text{on}) + I_E R_E$$

$$= I_B R_B + V_{BE}(\text{on}) + (1+\beta) I_B R_E$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + (1+\beta)R_E} = \frac{2-0.7}{10+(76)(1)}$$

$$\Rightarrow \underline{I_B = 15.1\ \mu\text{A}}$$

$$I_C = \beta I_B = (75)(15.1\ \mu\text{A}) \Rightarrow \underline{I_C = 1.13\ \text{mA}}$$

$$I_E = (1+\beta) I_B = (76)(15.1\ \mu\text{A}) \Rightarrow \underline{I_E = 1.15\ \text{mA}}$$

$$V_{CE} = V_{CC} + V_{BB} - I_C R_C - I_E R_E$$

$$= 8 + 2 - (1.13)(2.5) - (1.15)(1)$$

$$\underline{V_{CE} = 6.03\ \text{V}}$$

E3.16

$$V_{CE} = 2.5 \Rightarrow V_E = 2.5\ \text{V} = I_E R_E$$

$$V_{BB} = I_B R_B + V_{BE}(\text{on}) + V_E$$

$$I_B = \frac{V_{BB} - V_{BE}(\text{on}) - V_E}{R_B} = \frac{5 - 0.7 - 2.5}{10}$$

$$I_B = 0.18\ \text{mA} \Rightarrow I_E = (101)(0.18)$$

$$\Rightarrow I_E = 18.18\ \text{mA}$$

$$\text{So } R_E = \frac{2.5}{18.18} \Rightarrow \underline{R_E = 0.138\ \text{k}\Omega = 138\ \Omega}$$

E3.17

$$V_{BB} = I_E R_E + V_{EB}(\text{on}) + I_B R_B$$

$$I_E = 2.2\ \text{mA} \Rightarrow I_B = \frac{2.2}{51} = 0.0431\ \text{mA}$$

$$I_C = \left(\frac{\beta}{1+\beta}\right) I_E = \left(\frac{50}{51}\right)(2.2) \Rightarrow \underline{I_C = 2.16\ \text{mA}}$$

$$V_{BB} = (2.2)(1) + 0.7 + (0.0431)(50)$$

$$\Rightarrow \underline{V_{BB} = 5.06\ \text{V}}$$

$$V_{EC} = 5 - I_E R_E = 5 - (2.2)(1)$$

$$\Rightarrow \underline{V_{EC} = 2.8\ \text{V}}$$

E3.18

(1) $6 = I_B R_B + V_{BE}(\text{on}) + I_E R_E$

(2) $5 = I_C R_C + V_{CE}(\text{sat}) + I_E R_E$

$I_E = I_B + I_C$

(1) $6 = 10 I_B + 0.7 + (I_B + I_C)(1)$

(2) $5 = 4 I_C + 0.2 + (I_B + I_C)(1)$

(1) $[5.3 = I_C + 11 I_B] \times 5 -$ $\quad 26.5 = 5 I_C + 55 I_B$

(2) $4.8 = 5 I_C + I_B$ $\quad \underline{4.8 = 5 I_C + \quad I_B}$

$21.7 = 54 I_B$

$\Rightarrow \underline{I_B = 0.402\ \text{mA}}$

From (1), $I_C = 5.3 - 11 I_B \Rightarrow \underline{I_C = 0.880\ \text{mA}}$

$\underline{I_E = 1.28\ \text{mA}}$, $\quad \underline{V_{CE} = V_{CE}(\text{sat}) = 0.2\ \text{V}}$

E3.19

$$\underline{V_{EC} = V_{EC}(\text{sat}) = 0.2\ \text{V}}$$

$$I_C = \frac{-0.2 - (-5)}{R_C} = \frac{5-0.2}{10} \Rightarrow \underline{I_C = 0.48\ \text{mA}}$$

$$I_B = \frac{I_C}{2} = \frac{0.48}{2} = \underline{0.24 = I_B}$$

$$V_I + I_B R_B + V_{EB}(\text{on}) = 0$$

$$\Rightarrow V_I = -(0.24)(20) - 0.7 \Rightarrow \underline{V_I = -5.5\ \text{V}}$$

E3.20

a. $V_I = -4.5\ V \Rightarrow V_{BE} < V_{BE}(\text{on}) \Rightarrow$ Transistor is cutoff. $\underline{I_B = I_C = I_E = 0}$. $\underline{V_{CE} = 10\ V}$

b. $V_I = -3.5$ V Transistor is active.

$$V_I = I_B R_B + V_{BE}(\text{on}) + I_E R_E - 5$$

$$5 - 3.5 = I_B(10) + 0.7 + (76)I_B(4)$$

$$I_B = \frac{5 - 3.5 - 0.7}{10 + (76)(4)} = 0.00255 \text{ mA}$$

$$\Rightarrow \underline{I_B = 2.55\ \mu A}$$

$$I_C = \beta I_B = (75)(2.55\ \mu A) \Rightarrow \underline{I_C = 0.191 \text{ mA}}$$

$$I_E = (1+\beta)I_B = (76)(2.55\ \mu A)$$

$$\Rightarrow \underline{I_E = 0.194 \text{ mA}}$$

$$V_{CE} = 10 - I_C R_C - I_E R_E$$

$$= 10 - (0.191)(2) - (0.194)(4)$$

$$\underline{V_{CE} = 8.84\ V}$$

c. $V_I = +3.5$ V Transistor is in saturation.

(1) $3.5 = I_B R_B + V_{BE}(\text{on}) + I_E R_E - 5$

(2) $5 = I_C R_C + V_{CE}(\text{sat}) + I_E R_E - 5$

(3) $I_E = I_B + I_C$

(1) $3.5 + 5 - 0.7 = 10 I_B + 4(I_B + I_C)$

(2) $5 + 5 - 0.2 = 2 I_C + 4(I_B + I_C)$

(1) $7.8 = 14 I_B + 4 I_C$

(2) $9.8 = 4 I_B + 6 I_C$

$3 \times (1) \Rightarrow 23.4 = 42 I_B + 12 I_C$

$2 \times (2) \Rightarrow \underline{19.6 = 8 I_B + 12 I_C}$

$3.8 = 34 I_B$

$$\Rightarrow \underline{I_B = 0.112 \text{ mA}}$$

$$7.8 = 14(0.112) + 4I_C = 1.568 + 4I_C$$

$$\Rightarrow \underline{I_C = 1.56 \text{ mA}}$$

$\dfrac{I_C}{I_B} = 13.9 < \beta \Rightarrow$ In saturation.

$$I_E = I_B + I_C \Rightarrow \underline{I_E = 1.67 \text{ mA}}$$

$$\underline{V_{CE} = V_{CE}(\text{sat}) = 0.2}$$

E3.21

$$I_C(sat) = \frac{5 - 1.5 - 0.2}{R} = 15 \Rightarrow \underline{R = 0.220\ k\Omega}$$

$$I_B = \frac{I_C}{20} = \frac{15}{20} = 0.75\ mA = \frac{5 - 0.8}{R_B}$$

or

$$\underline{R_B = 5.6\ k\Omega}$$

E3.22

a. $V_1 = V_2 = 0$, $I_{B1} = I_{B2} = I_{C1} = I_{C2} = I_R = 0$
$V_0 = 5$ V

b. $V_1 = 5$ V, $V_2 = 0$, $I_{B2} = I_{C2} = 0$

$$I_{B1} = \frac{5 - 0.7}{0.95} \Rightarrow I_{B1} = 4.53 \text{ mA}$$

$$I_{C1} = \frac{5 - 0.2}{0.6} \Rightarrow I_{C1} = I_R = 8 \text{ mA}$$

$$V_0 = 0.2\ V$$

c. $V_1 = V_2 = 5$ V, $I_{B1} = I_{B2} = 4.53$ mA

$I_R = 8$ mA, $I_{C1} = I_{C2} = 4$ mA, $V_0 = 0.2$ V

E3.23

$$v_O = 5 - i_C R_C = 5 - \beta i_B R_C$$

and

$$i_B = \frac{V_{BB} + \Delta v_I - V_{BE}(on)}{R_B}$$

Then

$$\Delta v_O = \frac{-\beta R_C \Delta v_I}{R_B}$$

or

$$\frac{\Delta v_O}{\Delta v_I} = \frac{-\beta R_C}{R_B}$$

Let $\beta = 100$, $R_C = 5\ k\Omega$, $R_B = 100\ k\Omega$

Then

$$\frac{\Delta v_O}{\Delta v_I} = \frac{-(100)(5)}{100} = -5$$

Want Q-point to be

$$v_O(Q-pt) = 2.5 = 5 - (100) I_{BQ}(5)$$

Then

$$\underline{I_{BQ} = 0.005\ mA},\quad I_{BQ} = 0.005 = \frac{V_{BB} - 0.7}{100}$$

or

$$\underline{V_{BB} = 1.2\ V}$$

Also $I_{CQ} = \beta I_{BQ} = (100)(0.005)$

Or

$$\underline{I_{CQ} = 0.5\ mA}$$

E3.24

a. For $V_{CEQ} = 2.5\ V \Rightarrow I_{CQ} = \dfrac{5 - 2.5}{2}$
$\Rightarrow \underline{I_{CQ} = 1.25 \text{ mA}}$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{1.25}{100} \Rightarrow \underline{I_{BQ} = 12.5\ \mu A}$$

Then $R_B = \dfrac{5 - 0.7}{0.0125} \Rightarrow \underline{R_B = 344\ k\Omega}$

b. I_{BQ} is independent of β.

For $V_{CEQ} = 1$ V, $I_C = \dfrac{5 - 1}{2} = 2$ mA

$\beta = \frac{I_C}{I_B} = \frac{2}{0.0125} \Rightarrow \beta = 160$

For $V_{CEQ} = 4$ V, $I_C = \frac{5-4}{2} = 0.5$ mA

$\beta = \frac{I_C}{I_B} = \frac{0.5}{0.0125} \Rightarrow \beta = 40$

So $\underline{40 \le \beta \le 160}$

E3.25

$I_{BQ} = \frac{5-0.7}{800} \Rightarrow I_{BQ} = 0.005375$ mA

$\beta = 75 \Rightarrow I_{CQ} = (75)(0.005375) = 0.403$ mA

$\beta = 150 \Rightarrow I_{CQ} = (150)(0.005375) = 0.806$ mA

Largest $I_{CQ} \Rightarrow$ Smallest V_{CEQ}

$\beta = 150 \Rightarrow R_C = \frac{5-1}{0.806} = 4.96$ kΩ

$\beta = 75 \Rightarrow R_C = \frac{5-4}{0.403} = 2.48$ kΩ

For a nominal $I_C = 0.604$ mA and $V_{CEQ} = 2.5$

$$R_C = \frac{5-2.5}{0.604} = \underline{4.14 = R_C}$$

For $I_{CQ} = 0.403$,

$V_{CEQ} = 5 - (0.403)(4.14) = 3.33$ V

For $I_{CQ} = 0.806$,

$V_{CEQ} = 5 - (0.806)(4.14) = 1.66$ V

So for $R_C = 4.14$, $\underline{1.66 \text{ V} \le V_{CEQ} \le 3.33 \text{ V}}$

E3.26

a. $R_{TH} = R_1 \| R_2 = 9 \| 2.25 \Rightarrow \underline{R_{TH} = 1.8 \text{ k}\Omega}$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{2.25}{9 + 2.25}\right)(5)$$

$\Rightarrow \underline{V_{TH} = 1.0 \text{ V}}$

b. $I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{1 - 0.7}{1.8 + (151)(0.2)}$

$\Rightarrow \underline{I_{BQ} = 9.375\ \mu\text{A}}$

$I_{CQ} = \beta I_{BQ} = (150)(9.375\ \mu\text{A})$

$\Rightarrow \underline{I_{CQ} = 1.41 \text{ mA}}$

$I_{EQ} = (1+\beta) I_{BQ} \Rightarrow \underline{I_{EQ} = 1.42 \text{ mA}}$

$V_{CEQ} = 5 - I_{CQ} R_C - I_{EQ} R_E$

$= 5 - (1.41)(1) - (1.42)(0.2)$

$\underline{V_{CEQ} = 3.31 \text{ V}}$

c. For $\beta = 75$

$I_{BQ} = \frac{1 - 0.7}{1.8 + (76)(0.2)} \Rightarrow \underline{I_{BQ} = 17.6\ \mu\text{A}}$

$I_{CQ} = \beta I_{BQ} = (75)(17.6\ \mu\text{A})$

$\Rightarrow \underline{I_{CQ} = 1.32 \text{ mA}}$

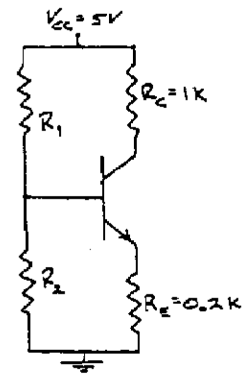
$I_{EQ} = (1+\beta) I_{BQ} = (76)(17.6\ \mu\text{A})$

$\Rightarrow \underline{I_{EQ} = 1.34 \text{ mA}}$

$V_{CEQ} = 5 - (1.32)(1) - (1.34)(0.2)$

$\Rightarrow \underline{V_{CEQ} = 3.41 \text{ V}}$

E3.27



$R_1 + R_2 = 11.25$ kΩ, $\beta = 150$

$I_C \approx I_E$, $V_{CEQ} = 2.5$ V

So $I_{CQ} \approx I_{EQ} = \frac{5 - 2.5}{1 + 0.2} = 2.081$ mA

$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2.08}{150} = 13.9\ \mu\text{A}$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E}$$

$$0.0139 = \frac{\left(\frac{R_2}{R_1 + R_2}\right) V_{CC} - V_{BE}(\text{on})}{\frac{R_1 R_2}{R_1 + R_2} + (1+\beta)R_E}$$

$$= \frac{\left(\frac{R_2}{11.25}\right)(5) - 0.7}{\frac{R_1 R_2}{(11.25)} + (151)(0.2)}$$

$R_2 = 11.25 - R_1$, so

$0.0139[R_1(11.25 - R_1) + (151)(0.2)(11.25)]$

$= 5R_2 - (0.7)(11.25)$

$= 5(11.25 - R_1) - (0.7)(11.25)$

$0.156 R_1 - 0.0139 R_1^2 + 4.72 = 56.25 - 5R_1 - 7.875$

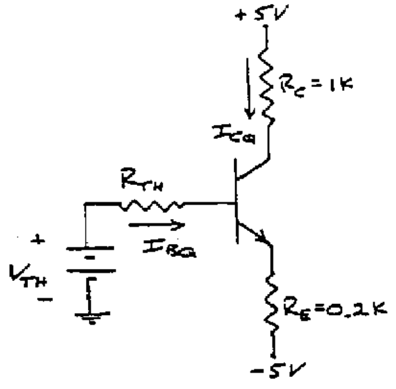
$0.0139 R_1^2 - 5.156 R_1 + 43.66 = 0$

$$R_1 = \frac{5.156 \pm \sqrt{(5.156)^2 - 4(0.0139)(43.66)}}{2(0.0139)}$$

$\Rightarrow R_1 = 8.67$ kΩ and $R_2 = 2.58$ kΩ

E3.28

dc equivalent circuit



$\beta = 150,\ R_{TH} = R_1 \| R_2,$

$V_{TH} = \left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 5$

$I_{CQ} = \dfrac{5-0}{1} = 5 \text{ mA}$

$I_{BQ} = \dfrac{I_{CQ}}{\beta} = \dfrac{5}{150} = 0.0333 \text{ mA}$

$I_{BQ} = \dfrac{V_{TH} + 5 - 0.7}{R_{TH} + (1+\beta)R_E}$

Set $R_{TH} = (0.1)(1+\beta)R_E$

$I_{BQ} = \dfrac{V_{TH} + 4.3}{(1.1)(1+\beta)R_E}$

$\Rightarrow 0.0333 = \dfrac{\left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 5 + 4.3}{(1.1)(151)(0.2)}$

$(0.0333)(1.1)(151)(0.2) = \left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 0.7$

So $\left(\dfrac{R_2}{R_1 + R_2}\right) = 0.1806$

$R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2} = (0.1)(151)(0.2) = 3.02 \text{ k}\Omega$

Then $R_1(0.1806) = 3.02 \Rightarrow \underline{R_1 = 16.7 \text{ k}\Omega}$

$R_2 = (0.1806)(16.7 + R_2) \Rightarrow 0.8194 R_2 = 3.02$

$\Rightarrow \underline{R_2 = 3.68 \text{ k}\Omega}$

E3.29

$\beta = 120,\ V_{CEQ} = 5 \text{ V}$

$R_{TH} = R_1 \| R_2,\ V_{TH} = \left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 5$

$I_{CQ} \approx I_{EQ}$

So $I_{CQ} = \dfrac{10 - V_{CEQ}}{R_C + R_E}$

$I_{CQ} = \dfrac{10-5}{1.2 + 0.3} \Rightarrow \underline{I_{CQ} = 3.33 \text{ mA}}$

$I_{BQ} = \dfrac{I_{CQ}}{\beta} = \dfrac{3.33}{120} \Rightarrow I_{BQ} = 0.0278 \text{ mA}$

$I_{BQ} = \dfrac{V_{TH} + 5 - 0.7}{R_{TH} + (1+\beta)R_E}$

Set $R_{TH} = (0.1)(1+\beta)R_E$

$I_{BQ} = 0.0278 = \dfrac{\left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 5 + 5 - 0.7}{(1.1)(121)(0.3)}$

$(0.0278)(1.1)(121)(0.3) = \left(\dfrac{R_2}{R_1 + R_2}\right)(10) - 0.7$

$\left(\dfrac{R_2}{R_1 + R_2}\right) = 0.181$

$R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2} = R_1(0.181) = (0.1)(121)(0.3)$

$\Rightarrow \underline{R_1 = 20.1 \text{ k}\Omega}$

$R_2 = (0.181)(20.1 + R_2) \Rightarrow 0.819 R_2 = 3.63 \text{ k}\Omega$

$\Rightarrow \underline{R_2 = 4.44 \text{ k}\Omega}$

E3.30

a. $I_{CQ} = \left(\dfrac{\beta}{1+\beta}\right) I_{EQ} = \left(\dfrac{100}{101}\right)(1) = 0.99 \text{ mA}$

$I_{BQ} = \dfrac{1 \text{ mA}}{1+\beta} = \dfrac{1}{101} \Rightarrow 9.90\ \mu\text{A}$

$V_B = -I_{BQ} R_B = -(0.0099)(50)$

$\Rightarrow \underline{V_B = -0.495 \text{ V}}$

$V_{BE} = V_T \ln\left(\dfrac{I_{CQ}}{I_S}\right) = (0.026)\ln\left(\dfrac{0.99 \times 10^{-3}}{3 \times 10^{-14}}\right)$

$\Rightarrow V_{BE} = 0.630 \text{ V}$

$V_E = V_B - V_{BE} = -0.495 - 0.630$

$\Rightarrow V_E = -1.13 \text{ V}$

$V_C = 10 - (0.99)(5) = 5.05 \text{ V}$

$V_{CEQ} = V_C - V_E = 5.05 - (-1.13)$

$\Rightarrow \underline{V_{CEQ} = 6.18 \text{ V}}$

b. $I_{EQ} = 1 \text{ mA},\ I_B = \dfrac{1}{51} = 0.0196 \text{ mA}$

$V_B = -(0.0196)(50) = \underline{-0.98 \text{ V} = V_B}$

$I_{CQ} = \left(\dfrac{50}{51}\right)(1) = 0.98 \text{ mA}$

$V_{BE} = (0.026)\ln\left(\dfrac{0.98 \times 10^{-3}}{3 \times 10^{-14}}\right) = 0.629 \text{ V}$

$V_E = -0.98 - 0.629 = -1.61$

$V_C = 10 - (0.98)(5) = 5.1 \text{ V}$

$V_{CEQ} = 5.1 - (-1.61) \Rightarrow \underline{V_{CEQ} = 6.71 \text{ V}}$

E3.31

$$I_B = \frac{I_Q}{1+\beta} = \frac{I_Q}{121},\ V_B = \left(\frac{I_Q}{121}\right)(20) = I_Q(0.165)$$

$$V_E = I_Q(0.165) + 0.7$$

$$I_{CQ} = \left(\frac{\beta}{1+\beta}\right)I_{EQ} = \left(\frac{120}{121}\right)I_Q = (0.992)I_Q$$

$$V_C = I_{CQ}R_C - 5 = (0.992)I_Q(4) - 5$$

$$= 3.97I_Q - 5$$

$$V_{ECQ} = V_E - V_C$$

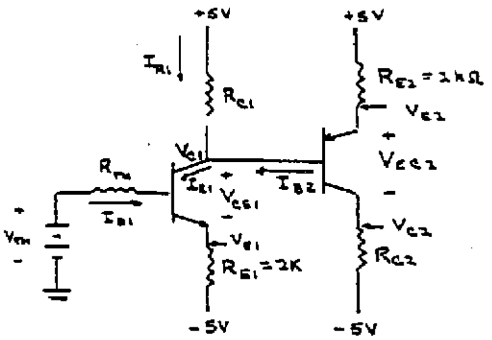
$$= [I_Q(0.165) + 0.7] - [3.97I_Q - 5]$$

$$= -3.805I_Q + 5.7$$

$$-3.805I_Q + 5.7 = 3$$

$$\Rightarrow \underline{I_Q = 0.710\ \text{mA}}$$

E3.32



$$R_{TH} = 50\|100 = 33.3\ \text{k}\Omega$$

$$V_{TH} = \left(\frac{50}{150}\right)(10) - 5 = -1.67\ \text{V}$$

$$I_{B1} = \frac{5 - 1.67 - 0.7}{33.3 + (101)(2)} = \frac{2.63}{235} = 11.2\ \mu\text{A}$$

$$I_{C1} = 1.12\ \text{mA},\ I_{E1} = 1.13\ \text{mA}$$

$$V_{E1} = I_{E1}R_{E1} - 5 = (1.13)(2) - 5 = -2.74\ \text{V}$$

$$V_{CE1} = 3.25\ \text{V} \Rightarrow V_{C1} = 0.51\ \text{V}$$

$$\Rightarrow V_{E2} = 0.51 + 0.7 = 1.21\ \text{V}$$

$$I_{E2} = \frac{5 - 1.21}{2} = 1.90\ \text{mA} \Rightarrow I_{B2} = 18.8\ \mu\text{A}$$

$$I_{C2} = 1.88\ \text{mA}$$

$$I_{R1} = I_{C1} - I_{B2} = 1.12 - 0.0188 = 1.10\ \text{mA}$$

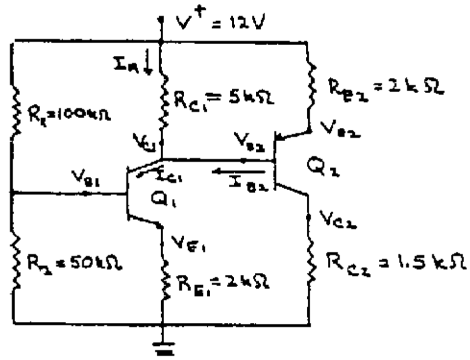
$$R_{C1} = \frac{5 - 0.51}{1.10} \Rightarrow \underline{R_{C1} = 4.08\ \text{k}\Omega}$$

$$V_{EC2} = 2.5 \Rightarrow V_{C2} = V_{E2} - V_{EC2}$$

$$= 1.21 - 2.5 = -1.29$$

$$R_{C2} = \frac{-1.29 - (-5)}{1.88} \Rightarrow \underline{R_{C2} = 1.97\ \text{k}\Omega}$$

E3.33



$$I_{B1} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_{E1}} = \frac{4 - 0.7}{33.3 + (101)(2)}$$

$$\underline{I_{B1} = 14\ \mu\text{A}},\ \underline{I_{C1} = 1.40\ \text{mA}},\ \underline{I_{E1} = 1.42\ \text{mA}},$$

$$V_{B1} = 4 - (0.014)(33.3)$$

$$\Rightarrow \underline{V_{B1} = 3.53\ \text{V}},\quad \underline{V_{E1} = 2.83\ \text{V}}$$

$$I_R + I_{B2} = I_{C1}$$

$$\Rightarrow \frac{12 - V_{C1}}{5} + \frac{12 - (V_{C1} + 0.7)}{(101)(2)} = 1.40$$

$$\frac{12}{5} + \frac{(12 - 0.7)}{(101)(2)} - 1.40 = \frac{V_{C1}}{5} + \frac{V_{C1}}{(101)(2)}$$

$$2.4 + 0.0559 - 1.40 = V_{C1}(0.2 + 0.00495)$$

$$\underline{V_{C1} = V_{B2} = 5.15\ \text{V}},\quad \underline{V_{E2} = 5.85}$$

$$I_{E2} = \frac{12 - 5.85}{2} \Rightarrow \underline{I_{E2} = 3.08\ \text{mA}}.$$

$$\underline{I_{C2} = 3.04\ \text{mA}},\quad \underline{I_{B2} = 30.4\ \mu\text{A}}$$

$$V_{C2} = (3.04)(1.5) \Rightarrow \underline{V_{C2} = 4.56\ \text{V}}$$

Chapter 3

Problem Solutions

3.1

(a) $\beta_F = \dfrac{i_C}{i_B} = \dfrac{510}{6} \Rightarrow \underline{\beta_F = 85}$

$\alpha_F = \dfrac{\beta_F}{1+\beta_F} = \dfrac{85}{86} \Rightarrow \underline{\alpha_F = 0.9884}$

$i_E = (1+\beta_F)i_B = (86)(6) \Rightarrow \underline{i_E = 516\ \mu A}$

(b) $\beta_F = \dfrac{2.65}{0.050} \Rightarrow \underline{\beta_F = 53}$

$\alpha_F = \dfrac{53}{54} \Rightarrow \underline{\alpha_F = 0.9815}$

$i_E = (1+\beta_F)i_B = (54)(0.050) \Rightarrow \underline{i_E = 2.70\ mA}$

3.2

(a)

For $\beta = 110$:

$\alpha = \dfrac{\beta}{1+\beta} = \dfrac{110}{111} = 0.99099$

For $\beta = 180$:

$\alpha = \dfrac{180}{181} = 0.99448$

$\underline{0.99099 \le \alpha \le 0.99448}$

(b) $I_C = \beta I_B = 110(50\ \mu A) \Rightarrow I_C = 5.50\ mA$

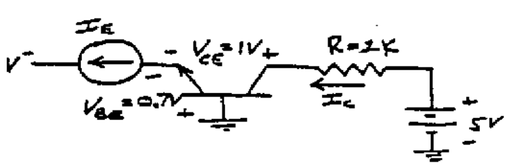
or

$I_C = 180(50\ \mu A) \Rightarrow I_C = 9.00\ mA$

so

$\underline{5.50 \le I_C \le 9.0\ mA}$

3.3



$5 = I_C R + V_{CE} - V_{BE} = I_C(2) + 1 - 0.7$

$\Rightarrow I_C = 2.35$ mA

$I_E = \dfrac{I_C}{\alpha} = \dfrac{2.35}{0.982} \Rightarrow \underline{I_E = 2.39 \text{ mA}}$

3.4

Same Figure as Problem 3.3

$v_C = -0.7 + 2 = 1.3\,V$; $i_C = \dfrac{5-1.3}{2} \Rightarrow \underline{i_C = 1.85\ mA}$

For $\beta_F = 120$, $i_B = \dfrac{i_C}{\beta_F} = \dfrac{1.85}{120} \Rightarrow \underline{i_B = 15.4\ \mu A}$

$i_E = \left(\dfrac{1+\beta_F}{\beta_F}\right) i_C = \left(\dfrac{121}{120}\right)(1.85) \Rightarrow \underline{i_E = 1.865\ mA}$

3.5

$\alpha = \dfrac{\beta}{1+\beta} = \dfrac{60}{61} \Rightarrow \underline{\alpha = 0.9836}$

$I_E = \dfrac{I_C}{\alpha} = \dfrac{0.85}{0.9836} \Rightarrow \underline{I_E = 0.864 \text{ mA}}$

$I_B = \dfrac{I_C}{\beta} = \dfrac{0.85}{60} \Rightarrow \underline{I_B = 14.2\ \mu\text{A}}$

3.6

$i_E = I_S e^{v_{BE}/V_T} = (10^{-13}) e^{0.685/0.026} \Rightarrow \underline{i_E = 27.7\ mA}$

$i_C = \left(\dfrac{90}{91}\right)(27.7) \Rightarrow \underline{i_C = 27.4\ mA}$

$i_B = \dfrac{i_E}{1+\beta} = \dfrac{27.7}{91} \Rightarrow \underline{i_B = 0.304\ mA}$

3.7

Device 1: $i_E = I_{S1} e^{v_{BE}/V_T} \Rightarrow 0.5x10^{-3} = I_{S1} e^{0.650/0.026}$

So that

$\underline{I_{S1} = 6.94x10^{-15}\ A}$

Device 2: $12.2x10^{-3} = I_{S2} e^{0.650/0.026}$

Or

$\underline{I_{S2} = 1.69x10^{-13}\ A}$

Ratio of areas $= \dfrac{I_{S2}}{I_{S1}} = \dfrac{1.69x10^{-13}}{6.94x10^{-15}} \Rightarrow \underline{\text{Ratio} = 24.4}$

3.8

(a) $r_o = \dfrac{V_A}{I_C} = \dfrac{250}{1} \Rightarrow r_o = 250\ k\Omega$

(b) $r_o = \dfrac{V_A}{I_C} = \dfrac{250}{0.1} \Rightarrow r_o = 2.50\ M\Omega$

3.9

$BV_{CEO} = \dfrac{BV_{CBO}}{\sqrt[3]{\beta}} = \dfrac{60}{\sqrt[3]{100}}$

$\underline{BV_{CEO} = 12.9 \text{ V}}$

3.10

$$BV_{CE0} = \frac{BV_{CB0}}{\sqrt[3]{\beta}}$$

$$56 = \frac{220}{\sqrt[3]{\beta}} \Rightarrow \sqrt[3]{\beta} = \frac{220}{56} = 3.93$$

$$\underline{\beta = 60.6}$$

3.11

$$BV_{CE0} = \frac{BV_{CB0}}{\sqrt[3]{\beta}}$$

$$BV_{CB0} = (BV_{CE0})\sqrt[3]{\beta} = (50)\sqrt[3]{50}$$

$$\underline{BV_{CB0} = 184 \text{ V}}$$

3.12

(a) $I_E = \frac{12-0.7}{10} \Rightarrow \underline{I_E = 1.13\,mA}$

$$I_C = \left(\frac{75}{76}\right)(1.13) = 1.12\,mA$$

$$V_{CE} = 24 - (1.13)(10) - (1.12)R_C = 6$$

so that

$R_C = 5.98\,k\Omega$

(b) $I_B = \frac{1}{76} = 0.0132\,mA$

$$V_B = -I_B R_B = -(0.0132)(50) \Rightarrow \underline{V_B = -0.658\,V}$$

$$I_C = \left(\frac{75}{76}\right)(1) = 0.987\,mA$$

$$R_C = \frac{5-2}{0.987} \Rightarrow \underline{R_C = 3.04\,k\Omega}$$

c. $I_B = \frac{8 - 0.7 - (-2)}{10 + (76)(10)} \Rightarrow I_B = 12.1\ \mu\text{A}$

$\underline{I_C = 0.906 \text{ mA}}$

$V_E = 0.7 + (0.0121)(10) - 2$

$V_E = -1.18$ V

$V_C = I_C R_C - 8 = (0.906)(3) - 8$

$\Rightarrow V_C = -5.28$ V

$V_{EC} = V_E - V_C = -1.18 - (-5.28)$

$\Rightarrow \underline{V_{EC} = 4.1 \text{ V}}$

d. $5 = (1+\beta)I_B(10) + I_B(20) + 0.7 + (1+\beta)I_B(2)$

$5 = I_B[760 + 20 + 152] + 07 \Rightarrow \underline{I_B = 4.61\ \mu\text{A}}$

$I_C = \beta I_B = (75)(4.61) \Rightarrow I_C = 0.346$ mA

$V_C = 5 - (1+\beta)I_B R_C = 5 - (76)(0.00461)(10)$

$\Rightarrow \underline{V_C = 1.50}$

3.13

(a) Figure P3.12(c)

$$8 = (76)I_B(10) + 0.7 + I_B(10) - 2$$

$$I_B = \frac{10-0.7}{10+(76)(10)} = 0.01208\,mA$$

Then

$I_C = (75)I_B \Rightarrow \underline{I_C = 0.906\,mA}$

and $\underline{I_E = 0.918\,mA}$

$$V_{EC} = 8 - I_E R_E - I_C R_C - (-8)$$

$$V_{EC} = 16 - (0.918)(10) - (0.906)(R_C)$$

$$V_{EC} = 6.82 - (0.906)R_C$$

$R_C = 3\,k\Omega \pm 5\% \Rightarrow \quad 2.85 \le R_C \le 3.15\,k\Omega$

Then

$\underline{3.97 \le V_{EC} \le 4.24\,V}$

(b) Figure P3.12(d)

$$5 = (1+\beta)I_B R_C + I_B(20) + 0.7 + (1+\beta)I_B(2)$$

$$5 = (76)I_B R_C + I_B(20) + 0.7 + (76)I_B(2)$$

Now $R_C = 10\,k\Omega \pm 5\% \Rightarrow \quad 9.5 \le R_C \le 10.5\,k\Omega$

Then $0.00443 \le I_B \le 0.00481\,mA$

And $V_C = 5 - (1+\beta)I_B R_C$

So that $\underline{1.46 \le V_C \le 1.53\,V}$

3.14

$$R_B = \frac{V_{BB} - V_{EB}}{I_B} = \frac{2.5-0.7}{0.015} \Rightarrow \underline{R_B = 120\,k\Omega}$$

$$I_{CQ} = (70)(15\,\mu A) \Rightarrow 1.05\,mA$$

$$R_C = \frac{V_{CC} - V_{ECQ}}{I_{CQ}} = \frac{5-2.5}{1.05} \Rightarrow \underline{R_C = 2.38\,k\Omega}$$

3.15

a. $V_B = -I_B R_B \Rightarrow I_B = \frac{-V_B}{R_B} = \frac{-(-1)}{500}$

$I_B = 2.0\ \mu\text{A}$

$V_E = -1 - 0.7 = -1.7$ V

$$I_E = \frac{V_E - (-3)}{R_E} = \frac{-1.7 + 3}{4.8} = 0.2708 \text{ mA}$$

$$\frac{I_E}{I_B} = (1+\beta) = \frac{0.2708}{0.002} = 135.4 \Rightarrow \underline{\beta = 134.4}$$

$$\alpha = \frac{\beta}{1+\beta} \Rightarrow \underline{\alpha = 0.9926}$$

$I_C = \beta I_B \Rightarrow \underline{I_C = 0.269 \text{ mA}}$

$V_{CE} = 3 - V_E = 3 - (-1.7) \Rightarrow \underline{V_{CE} = 4.7 \text{ V}}$

b. $I_E = \frac{5-.4}{2} \Rightarrow I_E = 0.5 \text{ mA}$

$4 = 0.7 + I_B R_B + (I_B + I_C) R_C - 5$

$I_B + I_C = I_E$

$4 = 0.7 + I_B(100) + (0.5)(8) - 5$

$I_B = 0.043 \Rightarrow \frac{I_E}{I_B} = (1+\beta) = \frac{0.5}{0.043} = 11.63$

$\underline{\beta = 10.63}, \quad \alpha = \frac{\beta}{1+\beta} \Rightarrow \underline{\alpha = 0.9140}$

3.16

a. $V_B = 0 \Rightarrow$ Cutoff $\Rightarrow \underline{I_E = 0}, \ \underline{V_C = 6 \text{ V}}$

b. $V_B = 1 \text{ V}, \ I_E = \frac{1-0.7}{1} \Rightarrow \underline{I_E = 0.3 \text{ mA}}$

$I_C \approx I_E \Rightarrow V_C = 6 - (0.3)(10) \Rightarrow \underline{V_C = 3 \text{ V}}$

c. $V_B = 2$ V. Assume active-mode

$I_E = \frac{2-0.7}{1} = I_E = 1.3 \text{ mA} \approx I_C$

$V_C = 6 - (1.3)(10) = -7$ V!

Transistor in saturation

$I_E = \frac{2-0.7}{1} \Rightarrow \underline{I_E = 1.3 \text{ mA}}$

$V_E = 1.3 \text{ V}, \ V_{CE}(\text{sat}) = 0.2 \text{ V}$

$V_C = V_E + V_{CE}(\text{sat}) = 1.3 + 0.2$

$\Rightarrow \underline{V_C = 1.5 \text{ V}}$

3.17

a. $V_{BB} = 0$,

Cutoff $V_0 = \left(\frac{R_L}{R_C + R_L}\right) V_{CC} = \left(\frac{10}{10+5}\right)(5)$

$\underline{V_0 = 3.33 \text{ V}}$

b. $V_{BB} = 1 \text{ V}$

$I_B = \frac{1-0.7}{50} \Rightarrow 6 \ \mu\text{A}$

$I_C = \beta I_B = (75)(6) \Rightarrow I_C = 0.45 \text{ mA}$

$\frac{5 - V_0}{5} = I_C + \frac{V_0}{10}$

$1 - 0.45 = V_0\left(\frac{1}{5} + \frac{1}{10}\right) \Rightarrow \underline{V_0 = 1.83 \text{ V}}$

c. Transistor in saturation

$\underline{V_0 = V_{CE}(\text{sat}) = 0.2 \text{ V}}$

3.18

(a) $\beta_F = 100$

(i) $I_Q = 0.1\, mA \qquad I_C = \left(\frac{100}{101}\right)(0.1) = 0.0990\, mA$

$V_O = 5 - (0.099)(5) \Rightarrow \underline{V_O = 4.505\, V}$

(ii) $I_Q = 0.5\, mA \qquad I_C = \left(\frac{100}{101}\right)(0.5) = 0.495\, mA$

$V_O = 5 - (0.495)(5) \Rightarrow \underline{V_O = 2.525\, V}$

(iii) $I_Q = 2\, mA$ Transistor is in saturation

$V_O = -V_{BE}(sat) + V_{CE}(sat) = -0.8 + 0.2 \Rightarrow$

$\underline{V_O = -0.6\, V}$

(b) $\beta_F = 150$

(i) $I_Q = 0.1\, mA \qquad I_C = \left(\frac{150}{151}\right)(0.1) = 0.09934\, mA$

$V_O = 5 - (0.09934)(5) \Rightarrow \underline{V_O = 4.503\, V}$

% change $= \frac{4.503 - 4.505}{4.503} x100\% = \underline{-0.044\%}$

(ii) $I_Q = 0.5\, mA \qquad I_C = \left(\frac{150}{151}\right)(0.5) = 0.4967\, mA$

$V_O = 5 - (0.4967)(5) \Rightarrow \underline{V_O = 2.517\, V}$

% change $= \frac{2.517 - 2.525}{2.525} x100\% = \underline{-0.32\%}$

(iii) $I_Q = 2\, mA$ Transistor in saturation

$\underline{V_O = -0.6\, V}$ No change

3.19

$I_E = \frac{V_B - 0.7}{1}$

$I_C = \left(\frac{\beta}{1+\beta}\right) I_E = \left(\frac{50}{51}\right)(V_B - 0.7) = \frac{6 - V_C}{10}$

and $V_C = V_B$

$\left(\frac{50}{51}\right)(V_B - 0.7) = \frac{6 - V_B}{10}$

$9.80(V_B - 0.7) = 6 - V_B$

$10.80 V_B = 6 + (0.7)(9.80) \Rightarrow \underline{V_B = 1.19 \text{ V}}$

$I_E = \frac{1.19 - 0.7}{1} \Rightarrow \underline{I_E = 0.49 \text{ mA}}$

3.20

$V_{CB} = 0.5\, V \Rightarrow V_O = 0.5\, V, \ I_C = \frac{5 - 0.5}{5} = 0.90\, mA$

$I_Q = \left(\frac{101}{100}\right)(0.90) \Rightarrow \underline{I_Q = 0.909\, mA}$

3.21

$$I_E = \frac{10 - V_E}{10} = \frac{10-2}{10} \Rightarrow \underline{I_E = 0.80 \text{ mA}}$$

$$V_B = V_E - 0.7 = 2 - 0.7 = 1.3 \text{ V}$$

$$I_B = \frac{V_B}{R_B} = \frac{1.3}{50} \Rightarrow \underline{I_B = 0.026 \text{ mA}}$$

$$I_C = I_E - I_B = 0.80 - 0.026 \Rightarrow \underline{I_C = 0.774 \text{ mA}}$$

$$\beta = \frac{I_C}{I_B} = \frac{0.774}{0.026} \Rightarrow \underline{\beta = 29.77}$$

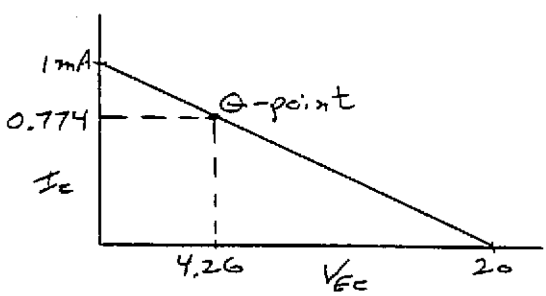
$$\alpha = \frac{\beta}{1+\beta} = \frac{29.77}{30.77} \Rightarrow \underline{\alpha = 0.9675}$$

$$V_{EC} = V_E - V_C = V_E - (I_C R_C - 10)$$

$$= 2 - [(0.774)(10) - 10]$$

$$\underline{V_{EC} = 4.26 \text{ V}}$$

Load line developed assuming the V_B voltage can change and the R_B resistor is removed.



3.22

$$I_C = \left(\frac{50}{51}\right)(1) = 0.98\ mA$$

$$V_C = I_C R_C - 9 = (0.98)(4.7) - 9$$

or $\underline{V_C = -4.39\ V}$

$$I_B = \frac{1}{51} = 0.0196\ mA$$

$$V_E = I_B R_B + V_{EB}(on) = (0.0196)(50) + 0.7$$

or $\underline{V_E = 1.68\ V}$

3.23

$$I_C = \left(\frac{50}{51}\right)(0.5) = 0.49\ mA\ ,\ I_B = \frac{0.5}{51} = 0.0098\ mA$$

$$V_E = I_B R_B + V_{EB}(on) = (0.0098)(50) + 0.7$$

or $V_E = 1.19\ V$

$$V_C = I_C R_C - 9 = (0.49)(4.7) - 9 = -6.70\ V$$

Then $V_{EC} = V_E - V_C = 1.19 - (-6.7) = 7.89\ V$

$$P_Q = I_C V_{EC} + I_B V_{EB} = (0.49)(7.89) + (0.0098)(0.7)$$

or $\underline{P_Q = 3.87\ mW}$

Power Supplied $= P_S = I_Q(9 - V_E) = (0.5)(9 - 1.19)$

Or $\underline{P_S = 3.91\ mW}$

3.24

For $I_Q = 0$, then $\underline{P_Q = 0}$

For $I_Q = 0.5\ mA$, $I_C = \left(\frac{50}{51}\right)(0.5) = 0.49\ mA$

$$I_B = \frac{0.5}{51} = 0.0098\ mA,\ V_B = 0.490\ V,\ V_E = 1.19\ V$$

$$V_C = (0.49)(4.7) - 9 = -6.70\ V \Rightarrow\ V_{EC} = 7.89\ V$$

$$P \cong I_C V_{EC} = (0.49)(7.89) \Rightarrow\ \underline{P = 3.87\ mW}$$

For $I_Q = 1.0\ mA$, Using the same calculations as above, we find $P = 5.95\ mW$

For $I_Q = 1.5\ mA$, $P = 6.26\ mW$

For $I_Q = 2\ mA$, $P = 4.80\ mW$

For $I_Q = 2.5\ mA$, $P = 1.57\ mW$

For $I_Q = 3\ mA$, Transistor is in saturation.

$$0.7 + I_B(50) = 0.2 + I_C(4.7) - 9$$

$$I_E = I_Q = I_B + I_C \Rightarrow I_B = 3 - I_C$$

Then, $0.7 + (3 - I_C)(50) = 0.2 + I_C(4.7) - 9$

Which yields $I_C = 2.916\ mA$ and $I_B = 0.084\ mA$

$$P = I_B V_{EB} + I_C V_{EC} = (0.084)(0.7) + (2.916)(0.2)$$

or $P = 0.642\ mW$

3.25

$$I_{E1} = I_{E2} = \frac{I}{2} \Rightarrow \underline{I_{E1} = I_{E2} = 0.5 \text{ mA}}$$

$$I_{C1} = I_{C2} \approx 0.5 \text{ mA}$$

$$V_{C1} = V_{C2} = 5 - (0.5)(4) \Rightarrow \underline{V_{C1} = V_{C2} = 3 \text{ V}}$$

3.26

a. $$I_{BQ} = \frac{V_{CC} - V_{BE}(\text{on})}{R_B}$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2}{60} = 0.0333 \text{ mA}$$

$$R_B = \frac{24 - 0.7}{0.0333} \Rightarrow \underline{R_B = 699 \text{ k}\Omega}$$

$$I_{CQ} = \frac{V_{CC} - V_{CEQ}}{R_C} \Rightarrow R_C = \frac{24 - 12}{2}$$

$$\Rightarrow \underline{R_C = 6 \text{ k}\Omega}$$

b. $$I_{BQ} = \frac{V_{CC} - V_{BE}(\text{on})}{R_B} = \frac{24 - 0.7}{699}$$

$= 0.0333$ mA (Unchanged)

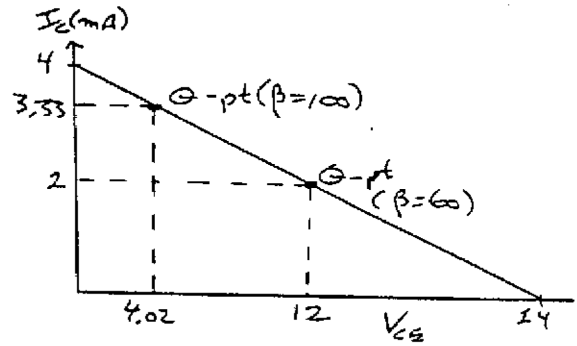
$$I_{CQ} = \beta I_{BQ} = (100)(0.0333)$$

$$\Rightarrow \underline{I_{CQ} = 3.33 \text{ mA}}$$

$$V_{CEQ} = V_{CC} - I_{CQ} R_C = 24 - (3.33)(6)$$

$$\Rightarrow \underline{V_{CEQ} = 4.02 \text{ V}}$$

(c) $V_{CE} = V_{CC} - I_C R_C = 24 - I_C(6)$



3.27

$$I_E = \frac{V_{EE} - V_{EB}(\text{on})}{R_E} = \frac{9 - 0.7}{4}$$

$\Rightarrow \underline{I_E = 2.075 \text{ mA}}$

$I_C = \alpha I_E = (0.9920)(2.075)$

$\Rightarrow \underline{I_C = 2.06 \text{ mA}}$

$V_{BC} + I_C R_C = V_{CC}$

$V_{BC} = 9 - (2.06)(2.2) \Rightarrow \underline{V_{BC} = 4.47 \text{ V}}$

3.28

$$I_{CQ} = \frac{V_{CC} - V_{CEQ}}{R_C} = \frac{12 - 6}{2.2} = 2.73 \text{ mA}$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2.73}{30} \Rightarrow I_{BQ} = 0.091 \text{ mA}$$

$$I_{R2} = \frac{0.7 - (-12)}{100} = 0.127 \text{ mA}$$

$I_{R1} = I_{R2} + I_{BQ} = 0.127 + 0.091 = 0.218 \text{ mA}$

$V_1 = I_{R1} R_1 + 0.7 = (0.218)(15) + 0.7$

$\Rightarrow \underline{V_1 = 3.97 \text{ V}}$

3.29

For $V_{CE} = 4.5$

$$I_{CQ} = \frac{5 - 4.5}{1} = 0.5 \text{ mA}$$

$$I_{BQ} = \frac{0.5}{25} = 0.02 \text{ mA}$$

$$I_{R2} = \frac{0.7 - (-5)}{100} = 0.057 \text{ mA}$$

$I_{R1} = I_{R2} + I_{BQ} = 0.057 + 0.02 = 0.077 \text{ mA}$

$V_1 = I_{R1} R_1 + V_{BE}(\text{on}) = (0.077)(15) + 0.7$

$= 1.86 \text{ V}$

For $V_{CE} = 1.0$

$$I_{CQ} = \frac{5 - 1}{1} = 4 \text{ mA}$$

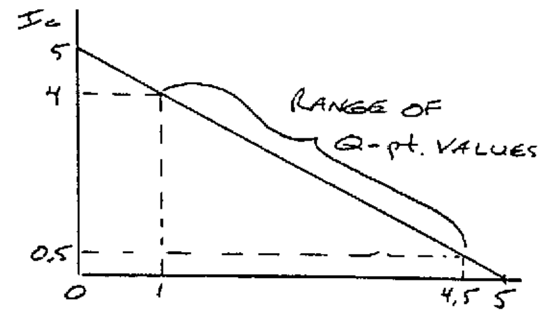
$$I_{BQ} = \frac{4}{25} = 0.16 \text{ mA}$$

$I_{R2} = 0.057 \text{ mA}$

$I_{R1} = I_{R2} + I_{BQ} = 0.057 + 0.16 = 0.217 \text{ mA}$

$V_1 = (0.217)(15) + 0.7 \Rightarrow 3.96 \text{ V}$

So $\underline{1.86 \le V_1 \le 3.96 \text{ V}}$



3.30

$R_{TH} = R_1 \| R_2 = 33 \| 10 = 7.67 \text{ k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{10}{10 + 33}\right)(18)$$

$= 4.19 \text{ V}$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1 + \beta) R_E} = \frac{4.19 - 0.7}{7.67 + (51)(1)}$$

$I_{BQ} = 0.0595 \text{ mA}$

$I_{CQ} = \beta I_{BQ} \Rightarrow \underline{I_{CQ} = 2.97 \text{ mA}}$

$I_{EQ} = 3.03 \text{ mA}$

$V_{CEQ} = V_{CC} - I_{CQ} R_C - I_{EQ} R_E$

$= 18 - (2.97)(2.2) - (3.03)(1)$

$\Rightarrow \underline{V_{CEQ} = 8.44 \text{ V}}$

3.31

$I_{CQ} = 1.2\, mA, \quad V_{CEQ} = 9\, V, \quad R_{TH} = 50\, k\Omega$

Also $I_B = \dfrac{1.2}{80} = 0.015\, mA$

$V_{TH} = I_{BQ} R_{TH} + V_{BE}(on) + (1 + \beta) I_{BQ} R_E$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(V_{CC}) = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = \frac{1}{R_1}(50)(18)$$

Then

$$\frac{1}{R_1}(50)(18) = (0.015)(50) + 0.7 + (81)(0.015)(1)$$

or $\underline{R_1 = 338\, k\Omega}$. Then $\dfrac{338 R_2}{338 + R_2} = 50 \Rightarrow$

$\underline{R_2 = 58.7\, k\Omega}$ $\qquad I_{EQ} = \left(\dfrac{81}{80}\right)(1.2) = 1.215\, mA$

$18 = I_{CQ} R_C + V_{CEQ} + I_{EQ} R_E$

$18 = (1.2) R_C + 9 + (1.215)(1) \Rightarrow \underline{R_C = 6.49\, k\Omega}$

3.32

$R_{TH} = R_1 \| R_2 = 20 \| 15 = 8.57\ k\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(V_{CC}) = \left(\frac{15}{15+20}\right)(10) = 4.29\ V$$

$$V_{CC} = I_{EQ}R_E + V_{EB}(on) + \frac{I_{EQ}}{1+\beta} \cdot R_{TH} + V_{TH}$$

$$10 = I_{EQ}(1) + 0.7 + I_{EQ}\left(\frac{8.57}{101}\right) + 4.29$$

Then

$$I_{EQ} = \frac{10 - 0.7 - 4.29}{1 + \frac{8.57}{101}} = \frac{5.01}{1.085} \Rightarrow \underline{I_{EQ} = 4.62\ mA}$$

$$V_B = \frac{I_{EQ}}{1+\beta} \cdot R_{TH} + V_{TH} = \left(\frac{4.62}{101}\right)(8.57) + 4.29$$

or

$\underline{V_B = 4.68\ V}$

3.33

a. $R_{TH} = R_1 \| R_2 = 58 \| 42 = 24.36\ \text{k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{42}{42+58}\right)(24)$$

$$= 10.1\ \text{V}$$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{10.1 - 0.7}{24.36 + (126)(10)}$$

$I_{BQ} = 0.00732\ \text{mA}$

$I_{CQ} = \beta I_{BQ} = (125)(0.00732)$

$\Rightarrow \underline{I_{CQ} = 0.915\ \text{mA}}$

$I_{EQ} = 0.922 \Rightarrow V_{CEQ} = 24 - (0.922)(10)$

$\Rightarrow \underline{V_{CEQ} = 14.8\ \text{V}}$

b. Let

$R_2 = 42\ \text{k}\Omega + 5\% = 44.1\ \text{k}\Omega$

$R_1 = 58\ \text{k}\Omega - 5\% = 55.1\ \text{k}\Omega$

$R_E = 10\ \text{k}\Omega - 5\% = 9.5\ \text{k}\Omega$

$R_{TH} = R_1 \| R_2 = 24.5\ \text{k}\Omega$

$$V_{TH} = \left(\frac{44.1}{44.1+55.1}\right)(24) = 10.7\ \text{V}$$

$$I_{BQ} = \frac{10.7 - 0.7}{24.5 + (126)(9.5)} = 0.00819$$

$\underline{I_{CQ} = 1.02\ \text{mA}}$, $I_{EQ} = 1.03\ \text{mA}$

$V_{CEQ} = 24 - (1.03)(9.5) \Rightarrow \underline{V_{CEQ} = 14.2\ \text{V}}$

Let

$R_2 = 42\ \text{k}\Omega - 5\% = 39.9\ \text{k}\Omega$

$R_1 = 58\ \text{k}\Omega + 5\% = 60.9\ \text{k}\Omega$

$R_E = 10\ \text{k}\Omega + 5\% = 10.5\ \text{k}\Omega$

$R_{TH} = R_1 \| R_2 = 24.1\ \text{k}\Omega$

$$V_{TH} = \left(\frac{39.9}{39.9+60.9}\right)(24) = 9.5\ \text{V}$$

$$I_{BQ} = \frac{9.5 - 0.7}{24.1 + (126)(10.5)} = 0.00653\ \text{mA}$$

$\underline{I_{CQ} = 0.817\ \text{mA}}$, $I_{EQ} = 0.823\ \text{mA}$

$V_{CEQ} = 24 - (0.823)(10.5) \Rightarrow \underline{V_{CEQ} = 15.4\ \text{V}}$

So $0.817 \le I_{CQ} \le 1.02$ mA and
$14.2 \le V_{CEQ} \le 15.4$ V.

3.34

a. $R_{TH} = R_1 \| R_2 = 25 \| 8 = 6.06\ \text{k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{8}{8+25}\right)(24)$$

$$= 5.82\ \text{V}$$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{5.82 - 0.7}{6.06 + (76)(1)}$$

$\underline{I_{BQ} = 0.0624\ \text{mA}}$, $\underline{I_{CQ} = 4.68\ \text{mA}}$

$I_{EQ} = 4.74$

$V_{CEQ} = V_{CC} - I_{CQ}R_C - I_{EQ}R_E$

$= 24 - (4.68)(3) - (4.74)(1)$

$\underline{V_{CEQ} = 5.22\ \text{V}}$

b. $$I_{BQ} = \frac{5.82 - 0.7}{6.06 + (151)(1)} \Rightarrow \underline{I_{BQ} = 0.0326\ \text{mA}}$$

$\underline{I_{CQ} = 4.89\ \text{mA}}$

$I_{EQ} = 4.92$

$V_{CEQ} = 24 - (4.89)(3) - (4.92)(1)$

$\underline{V_{CEQ} = 4.41\ \text{V}}$

3.35

(a) $I_{CQ} \cong I_{EQ} = 0.4\ mA$

$$R_C = \frac{3}{0.4} \Rightarrow R_C = 7.5\ k\Omega;\ R_E = \frac{3}{0.4} \Rightarrow R_E = 7.5\ k\Omega$$

$$R_1 + R_2 \cong \frac{9}{(0.2)(0.4)} = 112.5\ k\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(V_{CC}) = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E$$

$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(112.5 - R_2)R_2}{112.5},$$

$$I_{BQ} = \frac{0.4}{100} = 0.004\ mA$$

$$R_2\left(\frac{9}{112.5}\right) = (0.004)\left[\frac{(112.5 - R_2)R_2}{112.5}\right] + 0.7 + (101)(0.004)(7.5)$$

We obtain

$R_2(0.08) = 0.004R_2 - 3.56x10^{-5}R_2^2 + 3.73$

From this quadratic, we find

$\underline{R_2 = 48\ k\Omega \Rightarrow R_1 = 64.5\ k\Omega}$

(b) Standard resistor values:
Set $R_E = R_C = 7.5\ k\Omega$ and
$R_1 = 62\ k\Omega,\quad R_2 = 47\ k\Omega$
Now $R_{TH} = R_1 \| R_2 = 62 \| 47 = 26.7\ k\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(V_{CC}) = \left(\frac{47}{47+62}\right)(9) = 3.88\ V$$

$$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E$$

So

$$I_{BQ} = \frac{3.88 - 0.7}{26.7 + (101)(7.5)} = 0.00406\ mA$$

Then
$I_{CQ} = 0.406\ mA$
$V_{RC} = V_{RE} = (0.406)(7.5) = 3.05\ V$

3.36

a. $R_{TH} = R_1 \| R_2 = 12 \| 2 = \underline{1.71\ \text{k}\Omega = R_{TH}}$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(10) - 5 = \left(\frac{2}{12+2}\right)(10) - 5$$
$$= \underline{-3.57\ \text{V}} = V_{TH}$$

b.

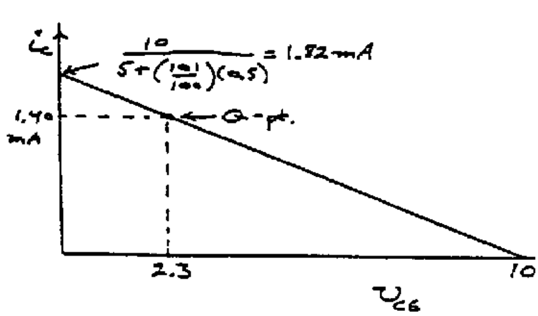
$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on}) - (-5)}{R_{TH} + (1+\beta)R_E}$$
$$= \frac{-3.57 - 0.7 + 5}{1.71 + (101)(0.5)} = \frac{0.73}{52.2}$$

$\Rightarrow I_{BQ} = 0.0140$ mA
$\underline{I_{CQ} = 1.40\ \text{mA}},\ I_{EQ} = 1.41$ mA

$$V_{CEQ} = 10 - I_{CQ}R_C - I_{EQ}R_E$$
$$= 10 - (1.40)(5) - (1.41)(0.5)$$

$\underline{V_{CEQ} = 2.30\ \text{V}}$

c.



d. For

$R_2 = 2\ \text{k}\Omega + 5\% = 2.1\ \text{k}\Omega$
$R_1 = 12\ \text{k}\Omega - 5\% = 11.4\ \text{k}\Omega$
$R_E = 0.5\ \text{k}\Omega - 5\% = 0.475\ \text{k}\Omega$
$R_{TH} = R_1 \| R_2 = 1.77\ \text{k}\Omega$

$$V_{TH} = \left(\frac{2.1}{2.1 + 1.4}\right)(10) - 5 = -3.44\ \text{V}$$

$$I_{BQ} = \frac{-3.44 - 0.7 + 5}{1.77 + (101)(0.475)} = \frac{0.86}{49.7} = 0.0173\ \text{mA}$$

$\underline{I_{CQ} = 1.73\ \text{mA}},\ I_{EQ} = 1.75$ mA
For $R_C = 5\ \text{k}\Omega + 5\% = 5.25\ \text{k}\Omega$
$V_{CEQ} = 10 - (1.73)(5.25) - (1.75)(0.475)$
$\Rightarrow V_{CEQ} = 0.0863$ V (Saturation)

For
$R_2 = 2\ \text{k}\Omega - 5\% = 1.9\ \text{k}\Omega$
$R_1 = 12\ \text{k}\Omega + 5\% = 12.6\ \text{k}\Omega$
$R_E = 0.5\ \text{k}\Omega + 5\% = 0.525\ \text{k}\Omega$
$R_{TH} = R_1 \| R_2 = 1.65\ \text{k}\Omega$

$$V_{TH} = \left(\frac{1.9}{12.6 + 1.9}\right)(10) - 5 = -3.69\ \text{V}$$

$$I_{BQ} = \frac{-3.69 - 0.7 + 5}{1.65 + (101)(0.525)} = \frac{0.61}{54.7} = 0.0112\ \text{mA}$$

$\underline{I_{CQ} = 1.12\ \text{mA}},\ I_{EQ} = 1.13$ mA
For $R_C = 5\ \text{k}\Omega - 5\% = 4.75\ \text{k}\Omega$
$V_{CEQ} = 10 - (1.12)(4.75) - (1.13)(0.525)$
$\Rightarrow V_{CEQ} = 4.09$ V

So $1.12 \le I_{CQ} \le 1.73$ mA and
$\underbrace{0.0863}_{\text{Saturation}} \le V_{CEQ} \le 4.09$ V.

3.37

$R_{TH} = R_1 \| R_2 = 9 \| 1 = 0.90\ \text{k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(-12) = \left(\frac{1}{1+9}\right)(-12)$$
$$= -1.2\ \text{V}$$

$$I_{EQ}R_E + V_{EB}(\text{on}) + I_{BQ}R_{TH} + V_{TH} = 0$$

$$I_{BQ} = \frac{-V_{TH} - V_{EB}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{1.2 - 0.7}{0.90 + (76)(0.1)}$$

$I_{BQ} = 0.0588,\ \underline{I_{CQ} = 4.41\ \text{mA}}$
$I_{EQ} = 4.47$ mA

Center of load line $\Rightarrow \underline{V_{ECQ} = 6\ \text{V}}$
$I_{EQ}R_E + V_{ECQ} + I_{CQ}R_C - 12 = 0$
$(4.47)(0.1) + 6 + (4.41)R_C = 12$
$\Rightarrow \underline{R_C = 1.26\ \text{k}\Omega}$

3.38

(a) $R_{TH} = (0.1)(1+\beta)R_E = (0.1)(101)(0.5) = 5.05\ k\Omega$

$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E$

$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{0.8}{100} = 0.008\ mA$

Then

$\frac{1}{R_1}(5.05)(10) = (0.008)(5.05) + 0.7 + (101)(0.008)(0.5)$

or

$\underline{R_1 = 44.1\ k\Omega}$, $\frac{44.1R_2}{44.1+R_2} = 5.05 \Rightarrow$ $\underline{R_2 = 5.70\ k\Omega}$

Now $I_{EQ} = \left(\frac{101}{100}\right)(0.8) = 0.808\ mA$

$V_{CC} = I_{CQ}R_C + V_{CEQ} + I_{EQ}R_E$

$10 = (0.8)R_C + 5 + (0.808)(0.5)$

$\underline{R_C = 5.75\ k\Omega}$

(b) For $75 \le \beta \le 150$

$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(V_{CC}) = \left(\frac{5.7}{5.7+44.1}\right)(10) = 1.145\ V$

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E$

For $\beta = 75$, $I_{BQ} = \frac{1.145-0.7}{5.05+(76)(0.5)} = 0.0103\ mA$

Then $I_{CQ} = (75)(0.0103) = 0.775\ mA$

For $\beta = 150$, $I_{BQ} = \frac{1.145-0.7}{5.05+(151)(0.5)} = 0.00552\ mA$

Then $I_{CQ} = 0.829\ mA$

% Change $= \frac{\Delta I_{CQ}}{I_{CQ}} = \frac{0.829-0.775}{0.80} x100\% \Rightarrow$

<u>% Change = 6.75%</u>

(c) For $R_E = 1\ k\Omega$

$R_{TH} = (0.1)(101)(1) = 10.1\ k\Omega$

$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = \frac{1}{R_1}(10.1)(10) =$

$(0.008)(10.1) + 0.7 + (101)(0.008)(1)$

which yields $\underline{R_1 = 63.6\ k\Omega}$

And $\frac{63.6R_2}{63.6+R_2} = 10.1 \Rightarrow$ $\underline{R_2 = 12.0\ k\Omega}$

Now $V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(V_{CC}) = \left(\frac{12}{12+63.6}\right)(10) = 1.587\ V$

For $\beta = 75$, $I_{BQ} = \frac{1.587-0.7}{10.1+(76)(1)} = 0.0103\ mA$

So $I_{CQ} = 0.773\ mA$

For $\beta = 150$, $I_{BQ} = \frac{1.587-0.7}{10.1+(151)(1)} = 0.00551\ mA$

Then $I_{CQ} = 0.826\ mA$

% Change $= \frac{\Delta I_{CQ}}{I_{CQ}} = \frac{0.826-0.773}{0.8} x100\% \Rightarrow$

<u>% Change = 6.63%</u>

3.39

$V_{CC} \cong I_{CQ}(R_C + R_E) + V_{CEQ}$

$10 = (0.8)(R_C + R_E) + 5 \Rightarrow R_C + R_E = 6.25\ k\Omega$

Let $R_E = 1\ k\Omega$

Then, for bias stable $R_{TH} = (0.1)(121)(1) = 12.1\ k\Omega$

$I_{BQ} = \frac{0.8}{120} = 0.00667\ mA$

$\frac{1}{R_1}(12.1)(10) = (0.00667)(12.1) + 0.7$

$+ (121)(0.00667)(1)$

So $R_1 = 76.2\ k\Omega$ and $\frac{76.2R_2}{76.2+R_2} = 12.1 \Rightarrow$

$R_2 = 14.4\ k\Omega$

Then $I_R \cong \frac{10}{76.2+14.4} = 0.110\ mA$

This is close to the design specification.

3.40

$I_{CQ} \approx I_{EQ} \Rightarrow V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$

$6 = 12 - I_{CQ}(2 + 0.2)$

$\underline{I_{CQ} = 2.73\ \text{mA}}$, $\underline{I_{BQ} = 0.0218\ \text{mA}}$

$\underline{V_{CEQ} = 6\ \text{V}}$

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + (1+\beta)I_{BQ}R_E - 6$

$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(12) - 6, \quad R_{TH} = R_1 \| R_2$

Bias stable $\Rightarrow$

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(126)(0.2) = 2.52\ \text{k}\Omega$

$V_{TH} = \left(\frac{1}{R_1}\right)(R_{TH})(12) - 6$

$\frac{1}{R_1}(2.52)(12) - 6 = (0.0218)(2.52) + 0.7$

$+ (126)(0.0218)(0.2) - 6$

$\frac{1}{R_1}(30.24) = 0.7549 + 0.5494$

$\underline{R_1 = 23.2\ \text{k}\Omega}$, $\frac{23.2R_2}{23.2+R_2} = 2.52$

$\underline{R_2 = 2.83\ \text{k}\Omega}$

3.41

a. $I_{CQ} = 1$ mA, $I_{EQ} = \left(\frac{80}{81}\right)(1) = 1.01$ mA

$V_{CEQ} = 12 - (1)(2) - (1.01)(0.2) \Rightarrow \underline{V_{CEQ} = 9.80\text{ V}}$

$I_{BQ} = \frac{1}{80} = 0.0125$ mA

$R_{TH} = +(0.1)(1+\beta)R_E = (0.1)(81)(0.2) = 1.62$ kΩ

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(12) - 6 = \frac{1}{R_1}(R_{TH})(12) - 6$$

$$= \frac{1}{R_1}(19.44) - 6$$

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + (1+\beta)I_{BQ}R_E - 6$

$$\frac{1}{R_1}(19.44) - 6 = (0.0125)(1.62) + 0.7$$

$$+ (81)(0.0125)(0.2) - 6$$

$$\frac{1}{R_1}(19.44) = 0.923$$

$\underline{R_1 = 21.1\text{ k}\Omega}$, $\frac{21.1R_2}{21.1+R_2} = 1.62$

$\underline{R_2 = 1.75\text{ k}\Omega}$

b.

$R_1 = 22.2$ kΩ or $R_1 = 20.0$ kΩ

$R_2 = 1.84$ kΩ or $R_2 = 1.66$ kΩ

$R_E = 0.21$ kΩ or $R_E = 0.19$ kΩ

$R_C = 2.1$ kΩ or $R_C = 1.9$ kΩ

$R_2(\max)$, $R_1(\min)$, $R_E(\min)$

$R_{TH} = (1.84)\|(20.0) = 1.685$ kΩ

$$V_{TH} = \left(\frac{1.84}{1.84+20.0}\right)(12) - 6 = -4.99\text{ V}$$

$$I_{BQ} = \frac{-4.99 - 0.7 - (-6)}{1.685 + (81)(0.19)} = \frac{0.31}{17.08} = 0.0182\text{ mA}$$

$\underline{I_{CQ} = 1.45\text{ mA}}$

For max. $R_C \Rightarrow$

$V_{CE} = 12 - (1.45)(2.1) - (1.47)(0.19)$

$V_{CE} = 8.68$ V

$R_2(\min)$, $R_1(\max)$, $R_E(\max)$

$R_{TH} = (1.66)\|(22.2) = 1.547$ kΩ

$$V_{TH} = \left(\frac{1.66}{1.66+22.2}\right)(12) - 6 = -5.165\text{ V}$$

$$I_{BQ} = \frac{-5.165 - 0.7 + 6}{1.547 + (81)(0.21)} = \frac{0.135}{18.56} = 0.00727\text{ mA}$$

For min. $R_C \Rightarrow \underline{I_{CQ} = 0.582\text{ mA}}$, $I_E = 0.589$

$V_{CEQ} = 12 - (0.582)(1.9) - (0.589)(0.21)$

$V_{CEQ} = 10.77$ V

So $0.582 \le I_C \le 1.45$ mA

$8.68 \le V_{CEQ} \le 10.77$ V

3.42

$V_{CEQ} \cong V_{CC} - I_{CQ}(R_C + R_E)$

$5 = 12 - 3(R_C + R_E) \Rightarrow R_C + R_E = 2.33\ k\Omega$

Let $\underline{R_E = 0.33\ k\Omega}$ and $\underline{R_C = 2\ k\Omega}$

Nominal value of $\beta = 100$

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(101)(0.33) = 3.33\ k\Omega$

$I_{BQ} = \frac{3}{100} = 0.03\ mA$

$V_{TH} = \frac{1}{R_1}\cdot R_{TH}\cdot(12) - 6 = \frac{1}{R_1}(3.33)(12) - 6$

Then

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E - 6$

$$\frac{1}{R_1}(3.33)(12) - 6 = (0.03)(3.33) + 0.7 + (101)(0.03)(0.33) - 6$$

which yields $\underline{R_1 = 22.2\ k\Omega}$ and $\underline{R_2 = 3.92\ k\Omega}$

Now

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(12) - 6 = \left(\frac{3.92}{3.92+22.2}\right)(12) - 6$$

or

$V_{TH} = -4.20\ V$

For $\beta = 75$,

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E - 6$

$$I_{BQ} = \frac{V_{TH} + 6 - 0.7}{R_{TH} + (1+\beta)R_E} = \frac{-4.2 + 6 - 0.7}{3.33 + (76)(0.33)}$$

$= 0.0387\ mA \Rightarrow \underline{I_C = 2.90\ mA}$

For $\beta = 150$,

$$I_{BQ} = \frac{-4.2 + 6 - 0.7}{3.33 + (151)(0.33)} = 0.0207\ mA$$

Then

$\underline{I_C = 3.10\ mA}$

Specifications are met.

3.43

$R_{TH} = R_1\|R_2 = 3\|12 = 2.4\ k\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)V_{CC} = \left(\frac{12}{12+3}\right)(20) = 16\ V$$

(a) For $\beta = 75$

$20 = (1+\beta)I_{BQ}R_E + V_{EB}(on) + I_{BQ}R_{TH} + V_{TH}$

$20 - 0.7 - 16 = I_{BQ}[(76)(2) + 2.4]$

So

$I_{BQ} = 0.0214\ mA$, $I_{CQ} = 1.60\ mA$, $I_{EQ} = 1.62\ mA$

$V_{ECQ} = 20 - (1.6)(1) - (1.62)(2)$

or

$V_{ECQ} = 15.16\ V$

(b) For $\beta = 100$, we find

$I_{BQ} = 0.0161\ mA$, $I_{CQ} = 1.61\ mA$, $V_{ECQ} = 15.13\ V$

3.44

$I_{CQ} = 4.8 \text{ mA} \rightarrow I_{EQ} = 4.84 \text{ mA}$

$V_{CEQ} = V_{CC} - I_{CQ}R_C - I_{EQ}R_E$

$6 = 18 - (4.8)(2) - (4.84)R_E \Rightarrow \underline{R_E = 0.496 \text{ k}\Omega}$

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(121)(0.496) = 6.0 \text{ k}\Omega$

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + (1+\beta)I_{BQ}R_E$

$I_{BQ} = 0.040 \text{ mA}$

$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = \frac{1}{R_1}(6.0)(18)$

$\frac{1}{R_1}(6.0)(18) = (0.04)(6.0) + 0.70$

$+ (121)(0.04)(0.496)$

$\frac{1}{R_1}(108) = 3.34$

$\underline{R_1 = 32.3 \text{ k}\Omega}, \quad \frac{32.3R_2}{32.3 + R_2} = 6.0$

$\underline{R_2 = 7.37 \text{ k}\Omega}$

3.45

For nominal $\beta = 70$

$I_{BQ} = \frac{2}{70} = 0.0286 \text{ mA} - I_{EQ} = 2.03 \text{ mA}$

$V_{CEQ} = V_{CC} - I_{CQ}R_C - I_{EQ}R_E$

$10 = 20 - (2)(4) - (2.03)R_E \Rightarrow \underline{R_E = 0.985 \text{ K}}$

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(71)(0.985) = 6.99 \text{ K}$

$V_{TH} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + I_{EQ}R_E$

$\frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = I_{BQ}R_{TH} + V_{BE}(\text{on}) + I_{EQ}R_E$

$\frac{1}{R_1}(6.99)(20) = (0.0286)(6.99) + 0.70$

$+ (2.03)(0.985)$

$\frac{1}{R_1}(139.8) = 2.90$

$\underline{R_1 = 48.2 \text{ K}}, \quad \frac{48.2R_2}{48.2 + R_2} = 6.99$

$\underline{R_2 = 8.18 \text{ K}}$

Check: For $\beta = 50$

$V_{TH} = \left(\frac{8.18}{8.18 + 48.2}\right)(20) = 2.90$

$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{2.90 - 0.7}{6.99 + (51)(0.985)}$

$= 0.0384 \text{ mA}$

$\underline{I_{CQ} = 1.92 \text{ mA}}$

For $\beta = 90$

$I_{BQ} = \frac{2.90 - 0.7}{6.99 + (91)(0.985)} = 0.0228 \text{ mA}$

$\underline{I_{CQ} = 2.05 \text{ mA}}$

Design criterion is satisfied.

3.46

$I_{CQ} = 1 \text{ mA} \rightarrow I_{EQ} = 1.02 \text{ mA}$

$V_{CEQ} = V_{CC} - I_{CQ}R_C - I_{EQ}R_E$

$5 = 15 - (1)(5) - (1.02)R_E \Rightarrow \underline{R_E = 4.90 \text{ k}\Omega}$

Bias stable:

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(61)(4.9) = 29.9 \text{ k}\Omega$

$I_{BQ} = \frac{1}{60} = 0.0167 \text{ mA}$

$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = I_{BQ}R_{TH} + V_{BE}(\text{on})$

$+ I_{EQ}R_E$

$\frac{1}{R_1}(29.9)(15) = (0.0167)(29.9) + 0.70$

$+ (1.02)(4.90)$

$\frac{1}{R_1}(448.5) = 6.197$

$\underline{R_1 = 72.4 \text{ k}\Omega}, \quad \frac{72.4R_2}{72.4 + R_2} = 29.9$

$\underline{R_2 = 50.9 \text{ k}\Omega}$

Check: For $\beta = 45$

$V_{TH} = \left(\frac{50.9}{50.9 + 72.4}\right)(15) = 6.19 \text{ V}$

$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_E} = \frac{6.19 - 0.7}{29.9 + (46)(4.90)}$

$= 0.0215 \text{ mA}$

$\underline{I_{CQ} = 0.968 \text{ mA}}, \quad \frac{\Delta I_C}{I_C} = 3.2\%$

Check: For $\beta = 75$

$I_{BQ} = \frac{6.19 - 0.7}{29.9 + (76)(4.90)} = 0.0136 \text{ mA}$

$\underline{I_{CQ} = 1.02 \text{ mA}}, \quad \frac{\Delta I_C}{I_C} = 2.0\%$

Design criterion is satisfied.

3.47

(a) $V_{CC} \cong I_{CQ}(R_C + R_E) + V_{CEQ}$

$3 = (0.1)(5R_E + R_E) + 1.4 \Rightarrow \underline{R_E = 2.67 \text{ k}\Omega}$

$\underline{R_C = 13.3 \text{ k}\Omega}, \quad I_{BQ} = \frac{100}{120} = 0.833 \ \mu A$

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(121)(2.67) = 32.3 \text{ k}\Omega$

$V_{TH} = \frac{1}{R_1} \cdot R_{TH} \cdot V_{CC} = \frac{1}{R_1}(32.3)(3)$

$= I_{BQ}R_{TH} + V_{BE}(on) + (1+\beta)I_{BQ}R_E$

$= (0.000833)(32.3) + 0.7 + (121)(0.000833)(2.67)$

which gives $\underline{R_1 = 97.3 \text{ k}\Omega}$, and $\underline{R_2 = 48.4 \text{ k}\Omega}$

(b) $I_R \cong \dfrac{3}{R_1+R_2} = \dfrac{3}{97.3+48.4} \Rightarrow 20.6\ \mu A$

$I_{CQ} = 100\ \mu A$

$P = (I_{CQ}+I_R)V_{CC} = (100+20.6)(3)$

or

$\underline{P = 362\ \mu W}$

3.48

$$I_E = \frac{5-V_E}{R_E} = \frac{5}{3} = 1.67\text{ mA}$$

$$R_{TH} = R_1\|R_2 = (0.1)(1+\beta)R_E = (0.1)(101)(3) = 30.3\text{ k}\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(4) - 2 = \frac{1}{R_1}\cdot R_{TH}\cdot(4) - 2$$

$$I_{BQ} = \frac{I_{EQ}}{1+\beta} = 0.0165\text{ mA}$$

$$5 = I_{EQ}R_E + V_{EB}(\text{on}) + I_B R_{TH} + V_{TH}$$

$$5 = (1.67)(3) + 0.7 + (0.0165)(30.3) + \frac{1}{R_1}(30.3)(4) - 2$$

$$0.80 = \frac{1}{R_1}(30.3)(4) \Rightarrow \underline{R_1 = 152\text{ k}\Omega}$$

$$\frac{152R_2}{152+R_2} = 30.3 \Rightarrow \underline{R_2 = 37.8\text{ k}\Omega}$$

3.49

a. $R_{TH} = R_1\|R_2 = 10\|20 \Rightarrow \underline{R_{TH} = 6.67\text{ k}\Omega}$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(10) - 5 = \left(\frac{20}{20+10}\right)(10) - 5$$

$\Rightarrow \underline{V_{TH} = 1.67\text{ V}}$

b. $10 = (1+\beta)I_{BQ}R_E + V_{EB}(\text{on}) + I_{BQ}R_{TH} + V_{TH}$

$$I_{BQ} = \frac{10-0.7-1.67}{6.67+(61)(2)} = \frac{7.63}{128.7}$$

$\Rightarrow \underline{I_{BQ} = 0.0593\text{ mA}}$

$\underline{I_{CQ} = 3.65\text{ mA}}$, $I_{EQ} = 3.62\text{ mA}$

$V_E = 10 - I_{EQ}R_E = 10 - (3.62)(2)$

$\underline{V_E = 2.76\text{ V}}$

$V_C = I_{CQ}R_C - 10 = (3.56)(2.2) - 10$

$\underline{V_C = -2.17\text{ V}}$

3.50

$V^+ - V^- \cong I_{CQ}(R_C+R_E) + V_{ECQ}$

$20 = (0.5)(R_C+R_E) + 8 \Rightarrow (R_C+R_E) = 24\ k\Omega$

Let $\underline{R_E = 10\ k\Omega}$ then $\underline{R_C = 14\ k\Omega}$

Let $\beta = 60$ from previous problem.

$R_{TH} = (0.1)(1+\beta)R_E = (0.1)(61)(10)$

Or $R_{TH} = 61\ k\Omega$

$$I_{BQ} = \frac{0.5}{60} = 0.00833\ mA$$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(10) - 5 = \frac{1}{R_1}\cdot R_{TH}\cdot 10 - 5$$

Now

$$10 = (1+\beta)I_{BQ}R_E + V_{EB}(on) + I_{BQ}R_{TH} + V_{TH}$$

$$10 = (61)(0.00833)(10) + 0.7 + (0.00833)(61) + \frac{1}{R_1}(61)(10) - 5$$

Then $\underline{R_1 = 70.0\ k\Omega}$ and $\underline{R_2 = 474\ k\Omega}$

$$I_R \cong \frac{10}{R_1+R_2} = \frac{10}{70+474} \Rightarrow 18.4\ \mu A$$

So the $40\ \mu A$ current limit is met.

3.51

a. $R_{TH} = R_1\|R_2 = 35\|20 \Rightarrow \underline{R_{TH} = 12.7\text{ k}\Omega}$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(7) - 5 = \left(\frac{20}{20+35}\right)(7) - 5$$

$\Rightarrow \underline{V_{TH} = -2.45\text{ V}}$

b.

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on}) - (-10)}{R_{TH} + (1+\beta)R_E} = \frac{-2.45 - 0.7 + 10}{12.7 + (76)(0.5)}$$

$\Rightarrow \underline{I_{BQ} = 0.135\text{ mA}}$

$\underline{I_{CQ} = 10.1\text{ mA}}$, $I_{EQ} = 10.3\text{ mA}$

$$V_{CEQ} = 20 - I_{CQ}R_C - I_{EQ}R_E = 20 - (10.1)(0.8) - (10.3)(0.5)$$

$\underline{V_{CEQ} = 6.77\text{ V}}$

c.

$R_2 = 20 + 5\% = 21\text{ k}\Omega$

$R_1 = 35 - 5\% = 33.25\text{ k}\Omega$

$R_E = 0.5 - 5\% = 0.475\text{ k}\Omega$

$R_{TH} = R_1\|R_2 = 21\|33.25 = 12.9\text{ k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(7) - 5 = \left(\frac{21}{21+33.25}\right)(7) - 5 = -2.29\text{ V}$$

$$I_{BQ} = \frac{-2.29 - 0.7 - (-10)}{12.9 + (76)(0.475)} = 0.143\text{ mA}$$

$\underline{I_{CQ} = 10.7\text{ mA}}$, $I_{EQ} = 10.9\text{ mA}$

For $R_C = 0.8 + 5\% = 0.84\text{ k}\Omega$

$V_{CEQ} = 20 - (10.7)(0.84) - (10.9)(0.475)$

$\Rightarrow V_{CEQ} = 5.83\text{ V}$

For $R_C = 0.8 - 5\% = 0.76\text{ k}\Omega$

$V_{CEQ} = 20 - (10.7)(0.76) - (10.9)(0.475)$

$\Rightarrow V_{CEQ} = 6.69\text{ V}$

$R_2 = 20 - 5\% = 19\text{ k}\Omega$

$R_1 = 35 + 5\% = 36.75\text{ k}\Omega$

$R_E = 0.5 + 5\% = 0.525\text{ k}\Omega$

$R_{TH} = R_1 \| R_2 = 19 \| 36.75 = 12.5\text{ k}\Omega$

$$V_{TH} = \left(\frac{19}{19+36.75}\right)(7) - 5 = -2.61\text{ V}$$

$$I_{BQ} = \frac{-2.61 - 0.7 - (-10)}{12.5 + (76)(0.525)} = 0.128\text{ mA}$$

$\underline{I_{CQ} = 9.58\text{ mA}}$, $I_{EQ} = 9.70\text{ mA}$

For $R_C = 0.84\text{ k}\Omega$

$V_{CEQ} = 20 - (9.58)(0.84) - (9.70)(0.525)$

$\Rightarrow V_{CEQ} = 6.86\text{ V}$

For $R_C = 0.76\text{ k}\Omega$

$V_{CEQ} = 20 - (9.58)(0.76) - (9.70)(0.525)$

$\Rightarrow V_{CEQ} = 7.63\text{ V}$

So $\quad 9.58 \le I_{CQ} \le 10.7\text{ mA}$

and

$\quad 5.83 \le V_{CEQ} \le 7.63\text{ V}$

3.52

a. $\quad R_{TH} = 500\text{ k}\Omega \| 500\text{ k}\Omega \| 70\text{ k}\Omega = 250\text{ k}\Omega \| 70\text{ k}\Omega$

$\Rightarrow \underline{R_{TH} = 54.7\text{ k}\Omega}$

$$\frac{5 - V_{TH}}{500} + \frac{3 - V_{TH}}{500} = \frac{V_{TH} - (-5)}{70}$$

$$\frac{5}{500} + \frac{3}{500} - \frac{5}{70} = V_{TH}\left(\frac{1}{500} + \frac{1}{500} + \frac{1}{70}\right)$$

$-0.0554 = V_{TH}(0.0183)$

$\underline{V_{TH} = -3.03\text{ V}}$

b.

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on}) - (-5)}{R_{TH} = (1+\beta)R_E}$$

$$= \frac{-3.03 - 0.7 + 5}{54.7 + (101)(5)}$$

$I_{BQ} = 0.00227\text{ mA}$

$\underline{I_{CQ} = 0.227\text{ mA}}$, $\quad I_{EQ} = 0.229$

$V_{CEQ} = 20 - (0.227)(50) - (0.229)(5)$

$\underline{V_{CEQ} = 7.51\text{ V}}$

3.53

$R_{TH} = 30 \| 60 \| 20 \Rightarrow \underline{R_{TH} = 10\text{ k}\Omega}$

$$\frac{5 - V_{TH}}{30} + \frac{5 - V_{TH}}{60} = \frac{V_{TH}}{20}$$

$$\left(\frac{5}{30} + \frac{5}{60}\right) = V_{TH}\left(\frac{1}{30} + \frac{1}{60} + \frac{1}{20}\right)$$

$\underline{V_{TH} = 2.5\text{ V}}$

For $\beta = 100$

$$I_{BQ} = \frac{V_{TH} - V_{BE}(\text{on}) - (-5)}{R_{TH} + (1+\beta)R_E}$$

$$= \frac{2.5 - 0.7 + 5}{10 + (101)(0.2)}$$

$I_{BQ} = 0.225\text{ mA}$

$\underline{I_{CQ} = 22.5\text{ mA}}$, $\quad I_{EQ} = 22.7\text{ mA}$

$V_{CEQ} = 15 - (22.5)(0.5) - (22.7)(0.2)$

$V_{CEQ} = -0.79$! $\quad$ In saturation

$\Rightarrow \underline{V_{CEQ} = 0.2\text{ V}}$

$V_E = V_{TH} - I_{BQ}R_{TH} - V_{BE}(\text{on})$

$\quad = 2.5 - (0.225)(10) - 0.7$

$V_E = -0.45\text{ V} \Rightarrow V_C = -0.45 + 0.2 = -0.25\text{ V}$

$$I_{CQ} = \frac{10 - (-0.25)}{0.5} \Rightarrow \underline{I_{CQ} = 20.5\text{ mA}}$$

3.54

$R_{TH} = R_1 \| R_2 = 100 \| 40 = 28.6\text{ k}\Omega$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)(10) = \left(\frac{40}{40+100}\right)(10) = 2.86\text{ V}$$

$$I_{B1} = \frac{V_{TH} - V_{BE}(\text{on})}{R_{TH} + (1+\beta)R_{E1}} = \frac{2.86 - 0.7}{28.6 + (121)(1)}$$

$\underline{I_{B1} = 0.0144\text{ mA}}$

$\underline{I_{C1} = 1.73\text{ mA}}$, $\quad \underline{I_{E1} = 1.75\text{ mA}}$

$$\frac{10 - V_{B2}}{3} = I_{C1} + I_{B2}$$

$$I_{E2} = \frac{V_{B2} - V_{BE}(\text{on}) - (-10)}{5}$$

$$\frac{10 - V_{B2}}{3} = I_{C1} + \frac{V_{B2} - 0.7 + 10}{(121)(5)}$$

$$\frac{10}{3} - 1.73 - \frac{9.3}{605} = V_{B2}\left(\frac{1}{3} + \frac{1}{(121)(5)}\right)$$

$1.59 = V_{B2}(0.335) \Rightarrow V_{B2} = 4.75\text{ V}$

$$I_{E2} = \frac{4.75 - 0.7 - (-10)}{5} \Rightarrow \underline{I_{E2} = 2.81\text{ mA}}$$

$\underline{I_{B2} = 0.0232\text{ mA}}$

$\underline{I_{C2} = 2.79\text{ mA}}$

$V_{CEQ1} = 4.75 - (1.75)(1) \Rightarrow \underline{V_{CEQ1} = 3.0\text{ V}}$

$V_{CEQ2} = 10 - (4.75 - 0.7) \Rightarrow \underline{V_{CEQ2} = 5.95\text{ V}}$

3.55

$$V_{E1} = -0.7$$
$$I_{R1} = \frac{-0.7-(-5)}{20} = 0.215 \text{ mA}$$
$$V_{E2} = -0.7 - 0.7 = -1.4$$
$$I_{E2} = \frac{-1.4-(-5)}{1} \Rightarrow \underline{I_{E2} = 3.6 \text{ mA}}$$
$$\underline{I_{B2} = 0.0444 \text{ mA}}$$
$$\underline{I_{C2} = 3.56 \text{ mA}}$$

$$I_{E1} = I_{R1} + I_{B2} = 0.215 + 0.0444$$
$$\underline{I_{E1} = 0.259 \text{ mA}}$$
$$\underline{I_{B1} = 0.00320 \text{ mA}}$$
$$\underline{I_{C1} = 0.256 \text{ mA}}$$

3.56

Current through V^- source $= I_{E1} + I_{E2}$ and

$I_{E1} = I_{E2} = (1+\beta)I_{B1} = (51)(8.26)\ \mu\text{A}$

So total current $= 2(51)(8.26)\ \mu\text{A} = 843\ \mu\text{A}$

$P^- = I \cdot |V^-| = (0.843)(5) \Rightarrow \underline{P^- = 4.22 \text{ mW}}$

(From V^- source)

From Example 3.15, $I_Q = 0.413$ mA

So $I_{C0} = \left(\frac{50}{51}\right)(0.413) = 0.405$ mA

$P^+ = I \cdot V^+ = (0.405)(5) \Rightarrow \underline{P^+ = 2.03 \text{ mW}}$

(From V^+ source)

3.57

$$R_{TH} = R_1 \| R_2 = 50 \| 100 = 33.3 \text{ k}\Omega$$
$$V_{TH} = \left(\frac{R_2}{R_1+R_2}\right)(10) - 5$$
$$= \left(\frac{100}{100+50}\right)(10) - 5 = 1.67 \text{ V}$$
$$5 = I_{E1}R_{E1} + V_{EB}(\text{on}) + I_{B1}R_{TH} + V_{TH}$$

$$I_{E1} = \left(\frac{101}{100}\right)(0.8) = 0.808 \text{ mA}$$
$$I_{B1} = 0.008 \text{ mA}$$
$$5 = (0.808)R_{E1} + 0.7 + (0.008)(33.3) + 1.67$$
$$R_{E1} = 2.93 \text{ k}\Omega$$

$$V_{E1} = 5 - (0.808)(2.93) = 2.63 \text{ V}$$
$$V_{C1} = V_{E1} - V_{ECQ1} = 2.63 - 3.5 = -0.87 \text{ V}$$
$$V_{E2} = -0.87 - 0.70 = -1.57 \text{ V}$$
$$I_{E2} = \frac{-1.57-(-5)}{R_{E2}} = 0.808 \Rightarrow \underline{R_{E2} = 4.25 \text{ k}\Omega}$$

$$V_{CEQ2} = 4 \Rightarrow V_{C2} = -1.57 + 4 = 2.43 \text{ V}$$
$$R_{C2} = \frac{5-2.43}{0.8} \Rightarrow \underline{R_{C2} = 3.21 \text{ k}\Omega}$$
$$I_{RC1} = I_{C1} - I_{B2} = 0.8 - 0.008 = 0.792 \text{ mA}$$
$$R_{C1} = \frac{-0.87-(-5)}{0.792} \Rightarrow \underline{R_{C1} = 5.21 \text{ k}\Omega}$$