EXAMPLE 4.4 For the emitter-bias network of Fig. 4.23, determine:

a. I_B.
b. I_C.
c. V_{CE}.
d. V_C.
e. V_E.
f. V_B.
g. V_{BC}.

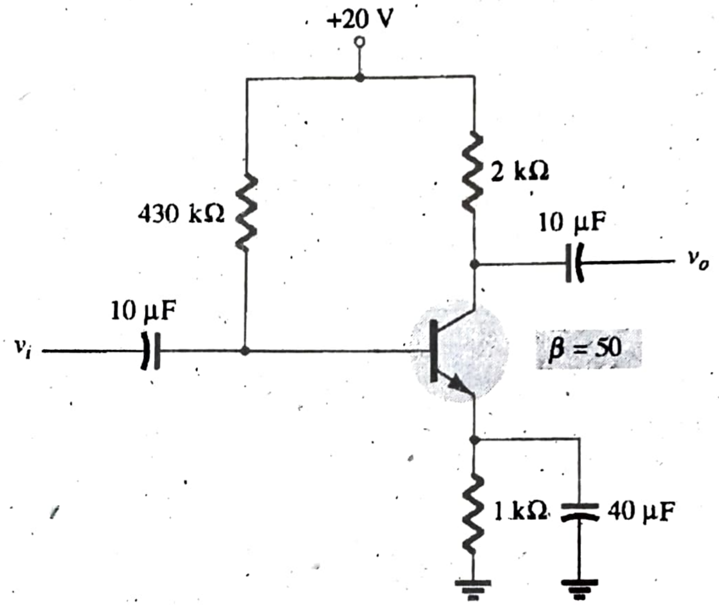

FIG. 4.23
Emitter-stabilized bias circuit for Example 4.4.

Solution:

a. Eq. (4.17): $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$$

$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

b. $I_C = \beta I_B$

$= (50)(40.1\ \mu\text{A})$

$\cong$ **2.01 mA**

c. Eq. (4.19):

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$
$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega) = 20\text{ V} - 6.03\text{ V}$$
$$= \mathbf{13.97\text{ V}}$$

d.
$$V_C = V_{CC} - I_C R_C$$
$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega) = 20\text{ V} - 4.02\text{ V}$$
$$= \mathbf{15.98\text{ V}}$$

e.
$$V_E = V_C - V_{CE}$$
$$= 15.98\text{ V} - 13.97\text{ V}$$
$$= \mathbf{2.01\text{ V}}$$

or
$$V_E = I_E R_E \cong I_C R_E$$
$$= (2.01\text{ mA})(1\text{ k}\Omega)$$
$$= \mathbf{2.01\text{ V}}$$

f.
$$V_B = V_{BE} + V_E$$
$$= 0.7\text{ V} + 2.01\text{ V}$$
$$= \mathbf{2.71\text{ V}}$$

g.
$$V_{BC} = V_B - V_C$$
$$= 2.71\text{ V} - 15.98\text{ V}$$
$$= \mathbf{-13.27\text{ V}} \text{ (reverse-biased as required)}$$

EXAMPLE 4.8 Determine the dc bias voltage V_{CE} and the current I_C for the voltage-divider configuration of Fig. 4.35.

Solution: Eq. (4.28): $R_{Th} = R_1 \| R_2$

$$= \frac{(39\text{ k}\Omega)(3.9\text{ k}\Omega)}{39\text{ k}\Omega + 3.9\text{ k}\Omega} = 3.55\text{ k}\Omega$$

Eq. (4.29): $E_{Th} = \dfrac{R_2 V_{CC}}{R_1 + R_2}$

$$= \frac{(3.9\text{ k}\Omega)(22\text{ V})}{39\text{ k}\Omega + 3.9\text{ k}\Omega} = 2\text{ V}$$

Eq. (4.30): $I_B = \dfrac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$

$$= \frac{2\text{ V} - 0.7\text{ V}}{3.55\text{ k}\Omega + (101)(1.5\text{ k}\Omega)} = \frac{1.3\text{ V}}{3.55\text{ k}\Omega + 151.5\text{ k}\Omega}$$

$$= 8.38\ \mu\text{A}$$

$$I_C = \beta I_B$$
$$= (100)(8.38\ \mu\text{A})$$
$$= \mathbf{0.84\ mA}$$

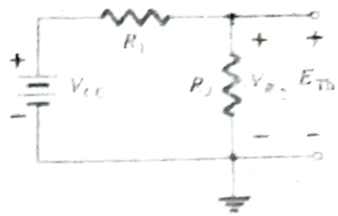

FIG. 4.33
Determining E_{Th}.

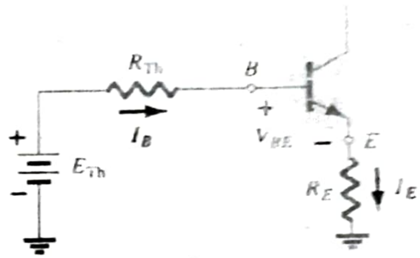

FIG. 4.34
Inserting the Thévenin equivalent circuit.

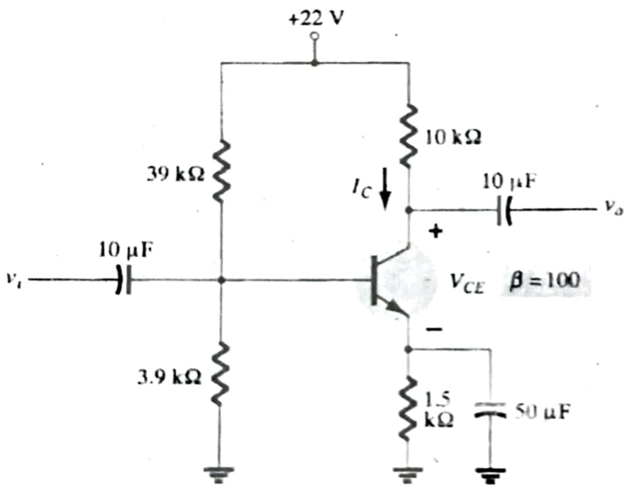

FIG. 4.35
Beta-stabilized circuit for Example 4.8.

Eq. (4.31): $V_{CE} = V_{CC} - I_C(R_C + R_E)$

$$= 22\text{ V} - (0.84\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$$
$$= 22\text{ V} - 9.66\text{ V}$$
$$= 12.34\text{ V}$$

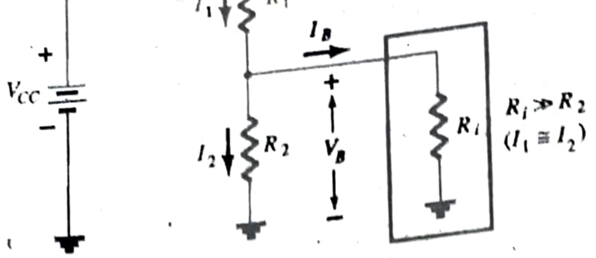

FIG. 4.36
Partial-bias circuit for calculating the approximate base voltage V_B.

determined using the voltage-divider rule (hence the name for the configuration). That is,

$$\boxed{V_B = \frac{R_2 V_{CC}}{R_1 + R_2}} \tag{4.32}$$

Because $R_i = (\beta + 1)R_E \cong \beta R_E$ the condition that will define whether the approximate approach can be applied is

$$\boxed{\beta R_E \geq 10R_2} \tag{4.33}$$

In other words, if β times the value of R_E is at least 10 times the value of R_2, the approximate approach can be applied with a high degree of accuracy.

Once V_B is determined, the level of V_E can be calculated from

$$\boxed{V_E = V_B - V_{BE}} \tag{4.34}$$

and the emitter current can be determined from

$$\boxed{I_E = \frac{V_E}{R_E}} \tag{4.35}$$

and

$$\boxed{I_{C_Q} \cong I_E} \tag{4.36}$$

The collector-to-emitter voltage is determined by

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

but because $I_E \cong I_C$,

$$\boxed{V_{CE_Q} = V_{CC} - I_C(R_C + R_E)} \tag{4.37}$$

Note in the sequence of calculations from Eq. (4.33) through Eq. (4.37) that β does not appear and I_B was not calculated. The Q-point (as determined by I_{C_Q} and V_{CE_Q}) is therefore independent of the value of β.

EXAMPLE 4.9 Repeat the analysis of Fig. 4.35 using the approximate technique, and compare solutions for I_{C_Q} and V_{CE_Q}.

Solution: Testing:

$$\beta R_E \geq 10R_2$$
$$(100)(1.5\text{ k}\Omega) \geq 10(3.9\text{ k}\Omega)$$
$$150\text{ k}\Omega \geq 39\text{ k}\Omega\ (\textit{satisfied})$$

Eq. (4.32): $V_B = \frac{R_2 V_{CC}}{R_1 + R_2}$

$$= \frac{(3.9\text{ k}\Omega)(22\text{ V})}{39\text{ k}\Omega + 3.9\text{ k}\Omega}$$

$$= 2\text{ V}$$

Note that the level of V_B is the same as E_{Th} determined in Example 4.7. Essentially, therefore, the primary difference between the exact and approximate techniques is the effect of R_{Th} in the exact analysis that separates E_{Th} and V_B.

Eq. (4.34): $V_E = V_B - V_{BE}$

$$= 2\text{ V} - 0.7\text{ V}$$

$$= 1.3\text{ V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E} = \frac{1.3\text{ V}}{1.5\text{ k}\Omega} = \mathbf{0.867\text{ mA}}$$

compared to 0.84 mA with the exact analysis. Finally,

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$

$$= 22\text{ V} - (0.867\text{ mA})(10\text{ kV} + 1.5\text{ k}\Omega)$$

$$= 22\text{ V} - 9.97\text{ V}$$

$$= \mathbf{12.03\text{ V}}$$

versus 12.34 V obtained in Example 4.8.

The results for I_{C_Q} and V_{CE_Q} are certainly close, and considering the actual variation in parameter values, one can certainly be considered as accurate as the other. The larger the level of R_i compared to R_2, the closer is the approximate to the exact solution. Example 4.11 will compare solutions at a level well below the condition established by Eq. (4.33).

EXAMPLE 4.10 Repeat the exact analysis of Example 4.8 if β is reduced to 50, and compare solutions for I_{C_Q} and V_{CE_Q}.

Solution: This example is not a comparison of exact versus approximate methods, but a testing of how much the Q-point will move if the level of β is cut in half. R_{Th} and E_{Th} are the same:

$$R_{Th} = 3.55\text{ k}\Omega, \qquad E_{Th} = 2\text{ V}$$

$$I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$$

$$= \frac{2\text{ V} - 0.7\text{ V}}{3.55\text{ k}\Omega + (51)(1.5\text{ k}\Omega)} = \frac{1.3\text{ V}}{3.55\text{ k}\Omega + 76.5\text{ k}\Omega}$$

$$= 16.24\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B$$

$$= (50)(16.24\ \mu\text{A})$$

$$= \mathbf{0.81\text{ mA}}$$

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$

$$= 22\text{ V} - (0.81\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$$

$$= \mathbf{12.69\text{ V}}$$

Tabulating the results, we have:

Effect of β variation on the response of the voltage-divider configuration of Fig. 4.35.

β	I_{C_Q} (mA)	V_{CE_Q} (V)
100	0.84 mA	12.34 V
50	0.81 mA	12.69 V

…e results clearly show the relative insensitivity of the circuit to the change in β. Even though …rastically cut in half, from 100 to 50, the levels of I_{C_Q} and V_{CE_Q} are essentially the same.

Because $I'_C \cong I_C$ and $I_E \cong I_C$, we have

$$I_C(R_C + R_E) + V_{CE} - V_{CC} = 0$$

and

$$\boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)} \tag{4.42}$$

which is exactly as obtained for the emitter-bias and voltage-divider bias configurations.

EXAMPLE 4.12 Determine the quiescent levels of I_{C_Q} and V_{CE_Q} for the network of Fig. 4.41.

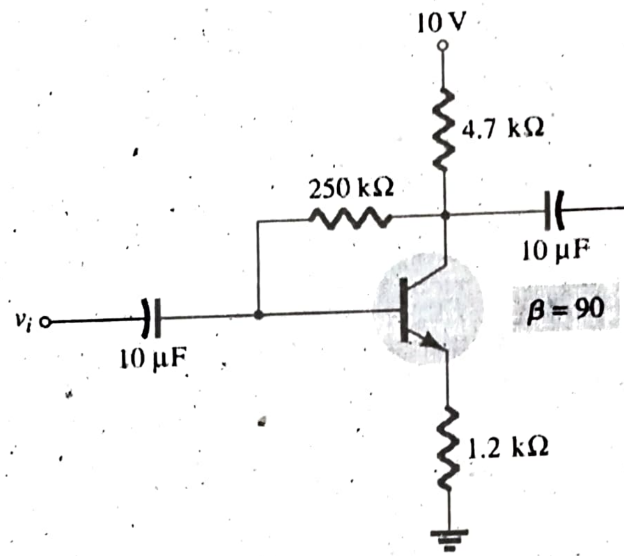

FIG. 4.41
Network for Example 4.12.

Solution: Eq. (4.41):
$$
\begin{aligned}
I_B &= \frac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)} \\
&= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)} \\
&= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega} \\
&= 11.91\ \mu\text{A} \\
I_{C_Q} &= \beta I_B = (90)(11.91\ \mu\text{A}) \\
&= \mathbf{1.07\ mA} \\
V_{CE_Q} &= V_{CC} - I_C(R_C + R_E) \\
&= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega) \\
&= 10\text{ V} - 6.31\text{ V} \\
&= \mathbf{3.69\ V}
\end{aligned}
$$

ive to changes in β.

4.5 Voltage-Divider Bias Configuration

15. For the voltage-divider bias configuration of Fig. 4.125, determine:
    a. I_{B_Q}.
    b. I_{C_Q}.
    c. V_{CE_Q}.
    d. V_C.
    e. V_E.
    f. V_B.

16. a. Repeat problem 15 for $\beta = 140$ using the general approach (not the approximate).
    b. What levels are affected the most? Why?

17. Given the information provided in Fig. 4.126, determine:
    a. I_C.
    b. V_E.
    c. V_B.
    d. R_1.

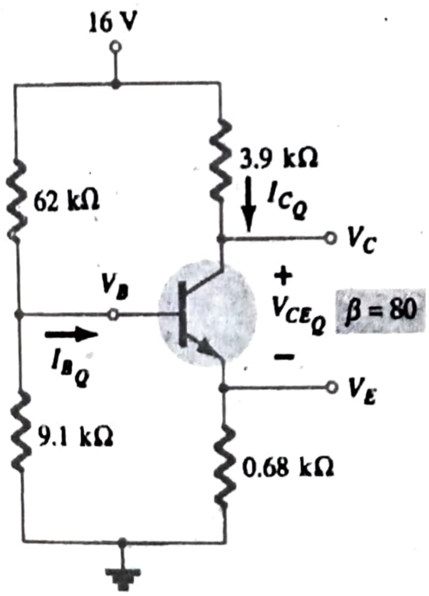

FIG. 4.125
Problems 15, 16, 20, 23, 25, 67, 69, 70, 73, and 77.

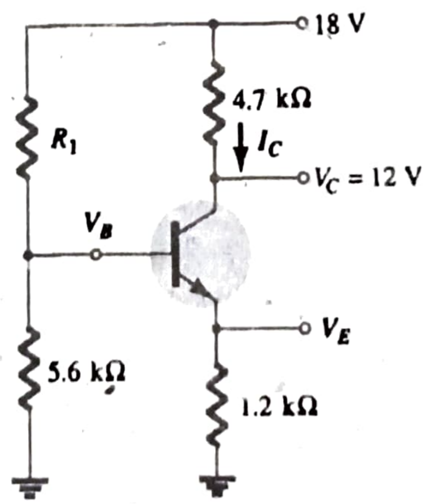

FIG. 4.126
Problems 17 and 19.

18. Given the information appearing in Fig. 4.127, determine:
    a. I_C.
    b. V_E.
    c. V_{CC}.
    d. V_{CE}.
    e. V_B.
    f. R_1.

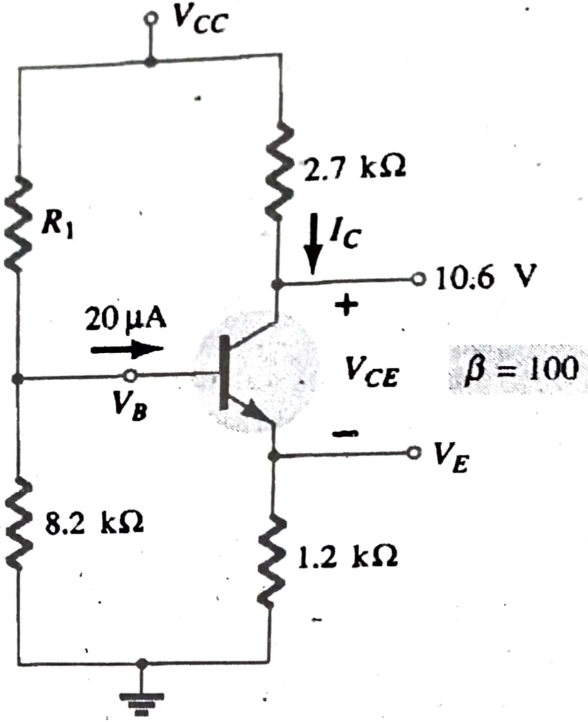

FIG. 4.127
Problem 18.

4.6 Collector-Feedback Configuration

27. For the collector-feedback configuration of Fig. 4.129, determine:

  a. I_B.
  b. I_C.
  c. V_C.

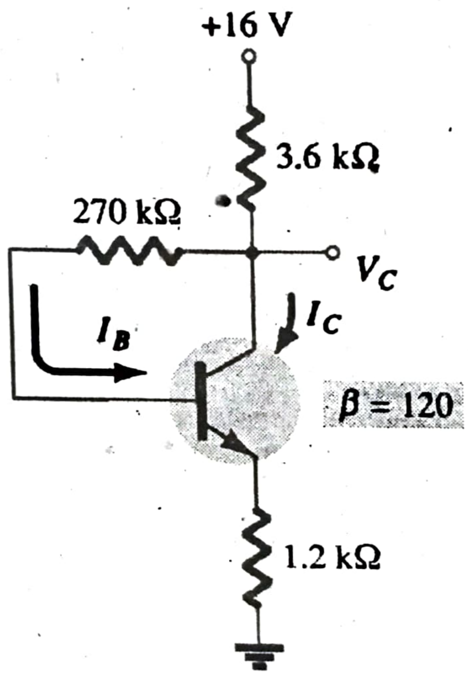

FIG. 4.129
Problems 27, 28, 74, and 78.