The results are a close match with those of Example 4.4 with $I_C = 2.217$ mA, $V_B = 2.636$ V, $V_C = 15.557$ V, and $V_E = 2.26$ V.

The relatively few comments required here to permit the analysis of transistor networks is a clear indication that the breadth of analysis using Multisim can be expanded dramatically without having to learn a whole new set of rules—a very welcome characteristic of most technology software packages.

PROBLEMS

**Note:* Asterisks indicate more difficult problems.

4.3 Fixed-Bias Configuration

1. For the fixed-bias configuration of Fig. 4.118, determine:
   a. I_{B_Q}.
   b. I_{C_Q}.
   c. V_{CE_Q}.
   d. V_C.
   e. V_B.
   f. V_E.

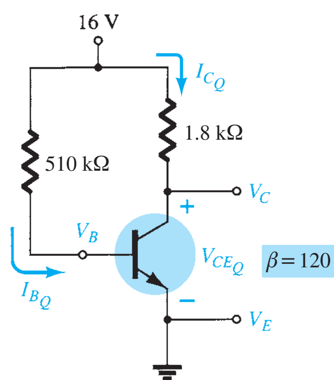

FIG. 4.118
Problems 1, 4, 6, 7, 14, 65, 69, 71, and 75.

2. Given the information appearing in Fig. 4.119, determine:
   a. I_C.
   b. R_C.
   c. R_B.
   d. V_{CE}.

3. Given the information appearing in Fig. 4.120, determine:
   a. I_C.
   b. V_{CC}.
   c. β.
   d. R_B.

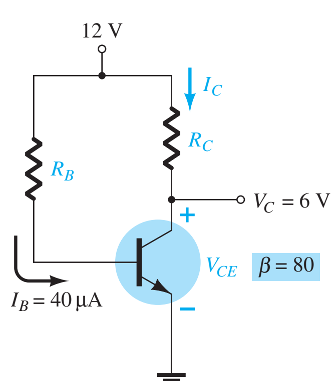

FIG. 4.119
Problem 2.

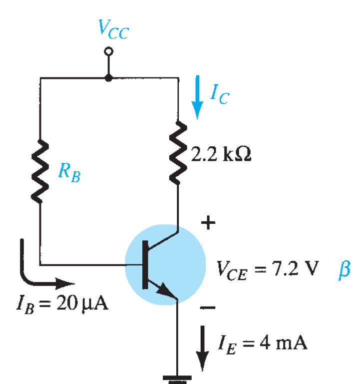

FIG. 4.120
Problem 3.

4. Find the saturation current ($I_{C_{sat}}$) for the fixed-bias configuration of Fig. 4.118.

***5.** Given the BJT transistor characteristics of Fig. 4.121:

a. Draw a load line on the characteristics determined by $E = 21$ V and $R_C = 3$ kΩ for a fixed-bias configuration.

b. Choose an operating point midway between cutoff and saturation. Determine the value of R_B to establish the resulting operating point.

c. What are the resulting values of I_{C_Q} and V_{CE_Q}?

d. What is the value of β at the operating point?

e. What is the value of α defined by the operating point?

f. What is the saturation current ($I_{C_{sat}}$) for the design?

g. Sketch the resulting fixed-bias configuration.

h. What is the dc power dissipated by the device at the operating point?

i. What is the power supplied by V_{CC}?

j. Determine the power dissipated by the resistive elements by taking the difference between the results of parts (h) and (i).

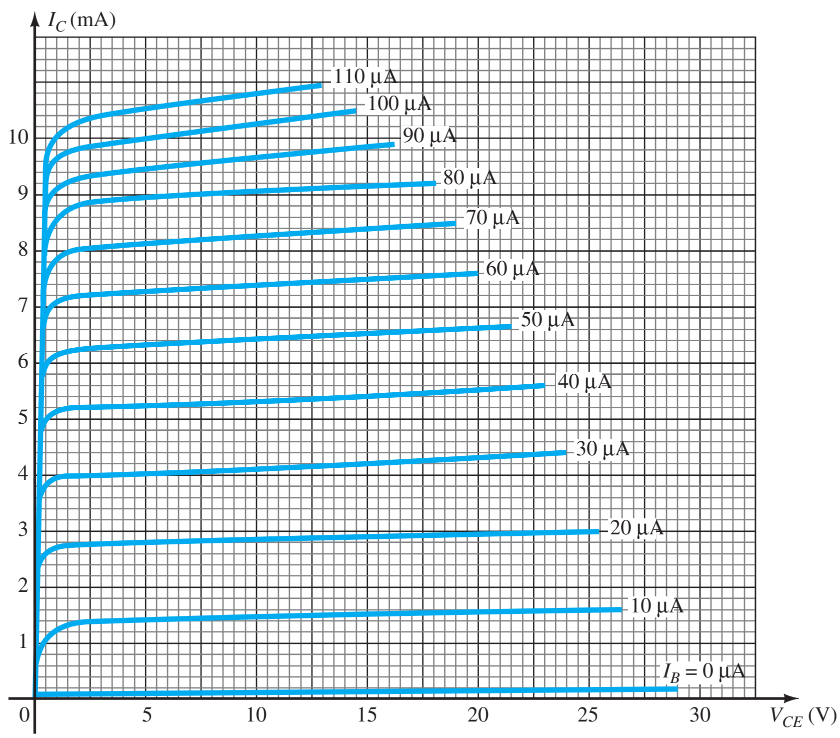

FIG. 4.121
Problems 5, 6, 9, 13, 24, 44, and 57.

6. a. Ignoring the provided value of $\beta_{(120)}$ draw the load line for the network of Fig. 4.118 on the characteristics of Fig. 4.121.

b. Find the Q-point and the resulting I_{C_Q} and V_{CE_Q}.

c. What is the beta value at this Q-point?

7. If the base resistor of Fig. 4.118 is increased to 910 kΩ, find the new Q-point and resulting values of I_{C_Q} and V_{CE_Q}.

4.4 Emitter-Bias Configuration

8. For the emitter-stabilized bias circuit of Fig. 4.122, determine:

a. I_{B_Q}.

b. I_{C_Q}.

c. V_{CE_Q}.

d. V_C.

e. V_B.

f. V_E.

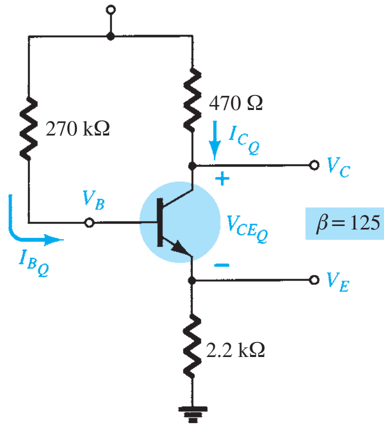

FIG. 4.122
Problems 8, 9, 12, 14, 66, 69, 72, and 76.

9. **a.** Draw the load line for the network of Fig. 4.122 on the characteristics of Fig. 4.121 using β from problem 8 to find I_{B_Q}.
b. Find the Q-point and resulting values I_{C_Q} and V_{CE_Q}.
c. Find the value of β at the Q-point.
d. How does the value of part (c) compare with $\beta = 125$ in problem 8?
e. Why are the results for problem 9 different from those of problem 8?

10. Given the information provided in Fig. 4.123, determine:
a. R_C.
b. R_E.
c. R_B.
d. V_{CE}.
e. V_B.

11. Given the information provided in Fig. 4.124, determine:
a. β.
b. V_{CC}.
c. R_B.

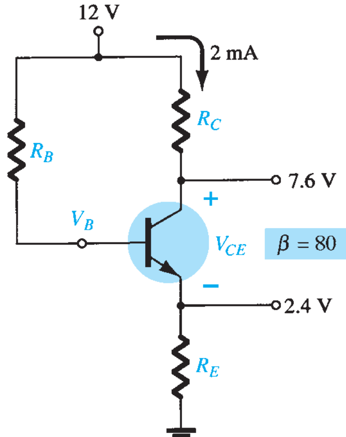

FIG. 4.123
Problem 10.

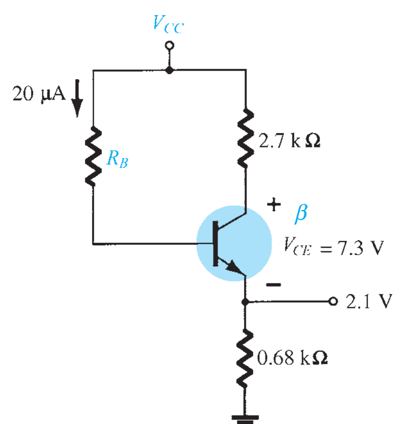

FIG. 4.124
Problem 11.

12. Determine the saturation current ($I_{C_{sat}}$) for the network of Fig. 4.122.

***13.** Using the characteristics of Fig. 4.121, determine the following for an emitter-bias configuration if a Q-point is defined at $I_{C_Q} = 4$ mA and $V_{CE_Q} = 10$ V.
a. R_C if $V_{CC} = 24$ V and $R_E = 1.2\ \text{k}\Omega$.
b. β at the operating point.
c. R_B.
d. Power dissipated by the transistor.
e. Power dissipated by the resistor R_C.

*14. a. Determine I_C and V_{CE} for the network of Fig. 4.118.
b. Change β to 180 and determine the new value of I_C and V_{CE} for the network of Fig. 4.118.
c. Determine the magnitude of the percentage change in I_C and V_{CE} using the following equations:

$$\%\Delta I_C = \left|\frac{I_{C_{(\text{part b})}} - I_{C_{(\text{part a})}}}{I_{C_{(\text{part a})}}}\right| \times 100\%, \qquad \%\Delta V_{CE} = \left|\frac{V_{CE_{(\text{part b})}} - V_{CE_{(\text{part a})}}}{V_{CE_{(\text{part a})}}}\right| \times 100\%$$

d. Determine I_C and V_{CE} for the network of Fig. 4.122.
e. Change β to 187.5 and determine the new value of I_C and V_{CE} for the network of Fig. 4.122.
f. Determine the magnitude of the percentage change in I_C and V_{CE} using the following equations:

$$\%\Delta I_C = \left|\frac{I_{C_{(\text{part c})}} - I_{C_{(\text{part d})}}}{I_{C_{(\text{part d})}}}\right| \times 100\%, \qquad \%\Delta V_{CE} = \left|\frac{V_{CE_{(\text{part c})}} - V_{CE_{(\text{part d})}}}{V_{CE_{(\text{part d})}}}\right| \times 100\%$$

g. In each of the above, the magnitude of β was increased 50%. Compare the percentage change in I_C and V_{CE} for each configuration, and comment on which seems to be less sensitive 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.

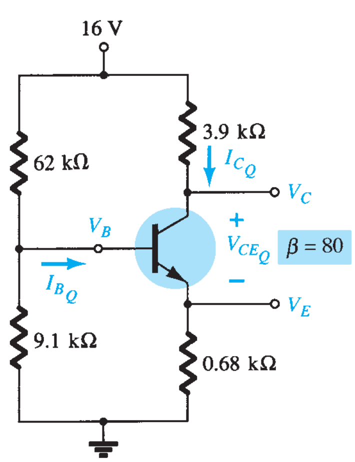

FIG. 4.125
Problems 15, 16, 20, 23, 25, 67, 69, 70, 73, and 77.

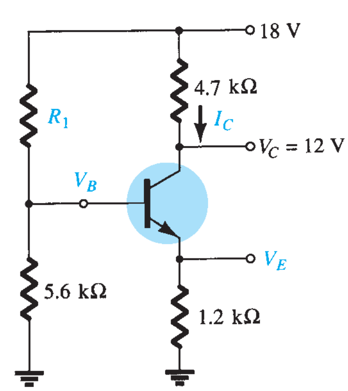

FIG. 4.126
Problems 17 and 19.

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.

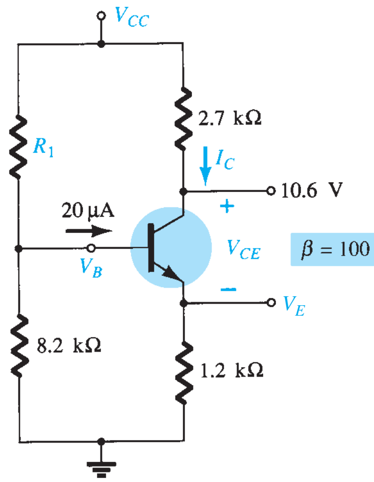

FIG. 4.127
Problem 18.

19. Determine the saturation current ($I_{C_{sat}}$) for the network of Fig. 4.125.

20. **a.** Repeat problem 16 with $\beta = 140$ using the approximate approach and compare results.
b. Is the approximate approach valid?

***21.** Determine the following for the voltage-divider configuration of Fig. 4.128 using the approximate approach if the condition established by Eq. (4.33) is satisfied.
a. I_C.
b. V_{CE}.
c. I_B.
d. V_E.
e. V_B.

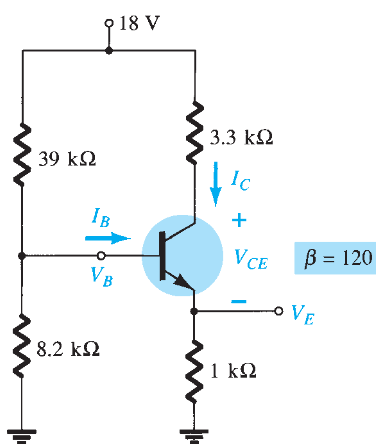

FIG. 4.128
Problems 21, 22, and 26.

***22.** Repeat Problem 21 using the exact (Thévenin) approach and compare solutions. Based on the results, is the approximate approach a valid analysis technique if Eq. (4.33) is satisfied?

23. **a.** Determine I_{C_Q}, V_{CE_Q}, and I_{B_Q} for the network of Problem 15 (Fig. 4.125) using the approximate approach even though the condition established by Eq. (4.33) is not satisfied.
b. Determine I_{C_Q}, V_{CE_Q}, and I_{B_Q} using the exact approach.
c. Compare solutions and comment on whether the difference is sufficiently large to require standing by Eq. (4.33) when determining which approach to employ.

***24.** **a.** Using the characteristics of Fig. 4.121, determine R_C and R_E for a voltage-divider network having a Q-point of $I_{C_Q} = 5$ mA and $V_{CE_Q} = 8$ V. Use $V_{CC} = 24$ V and $R_C = 3R_E$.
b. Find V_E.
c. Determine V_B.
d. Find R_2 if $R_1 = 24\ \text{k}\Omega$ assuming that $\beta R_E > 10R_2$.
e. Calculate β at the Q-point.
f. Test Eq. (4.33), and note whether the assumption of part (d) is correct.

*25. a. Determine I_C and V_{CE} for the network of Fig. 4.125.
b. Change β to 120 (50% increase), and determine the new values of I_C and V_{CE} for the network of Fig. 4.125.
c. Determine the magnitude of the percentage change in I_C and V_{CE} using the following equations:

$$\%\Delta I_C = \left|\frac{I_{C(\text{part b})} - I_{C(\text{part a})}}{I_{C(\text{part a})}}\right| \times 100\%, \quad \%\Delta V_{CE} = \left|\frac{V_{CE(\text{part b})} - V_{CE(\text{part a})}}{V_{CE(\text{part a})}}\right| \times 100\%$$

d. Compare the solution to part (c) with the solutions obtained for parts (c) and (f) of Problem 14.
e. Based on the results of part (d), which configuration is least sensitive to variations in β?

*26. a. Repeat parts (a) through (e) of Problem 25 for the network of Fig. 4.128. Change β to 180 in part (b).
b. What general conclusions can be made about networks in which the condition $\beta R_E > 10R_2$ is satisfied and the quantities I_C and V_{CE} are to be determined in response to a change in β?

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.

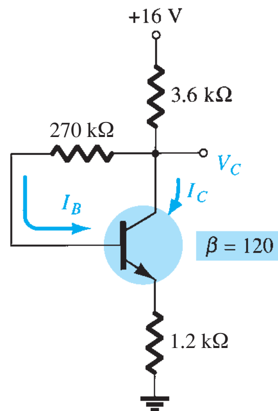

FIG. 4.129
Problems 27, 28, 74, and 78.

28. For the network of problem 27
a. Determine I_{C_Q} using the equation $I_{C_Q} \cong \dfrac{V'}{R'} = \dfrac{V_{CC} - V_{BE}}{R_C + R_E}$
b. Compare with the results of problem 27 for I_{C_Q}.
c. Compare R' to $R_{F/\beta}$.
d. Is the statement valid that the larger R′ is compared with $R_{F/\beta}$, the more accurate the equation $I_{C_Q} \cong \dfrac{V'}{R'}$? Prove using a short derivation for the exact current I_{C_Q}.
e. Repeat parts (a) and (b) for $\beta = 240$ and comment on the new level of I_{C_Q}.

29. For the voltage feedback network of Fig. 4.130, determine:
a. I_C.
b. V_C.
c. V_E.
d. V_{CE}.

30. a. Compare levels of $R' = R_C + R_E$ to $R_{F/\beta}$ for the network of Fig. 4.131.
b. Is the approximation $I_{C_Q} \cong V'/R'$ valid?

*31. a. Determine the levels of I_C and V_{CE} for the network of Fig. 4.131.
b. Change β to 135 (50% increase), and calculate the new levels of I_C and V_{CE}.
c. Determine the magnitude of the percentage change in I_C and V_{CE} using the following equations:

$$\%\Delta I_C = \left|\frac{I_{C(\text{part b})} - I_{C(\text{part a})}}{I_{C(\text{part a})}}\right| \times 100\%, \quad \%\Delta V_{CE} = \left|\frac{V_{CE(\text{part b})} - V_{CE(\text{part a})}}{V_{CE(\text{part a})}}\right| \times 100\%$$

d. Compare the results of part (c) with those of Problems 14(c), 14(f), and 25(c). How does the collector-feedback network stack up against the other configurations in sensitivity to changes in β?

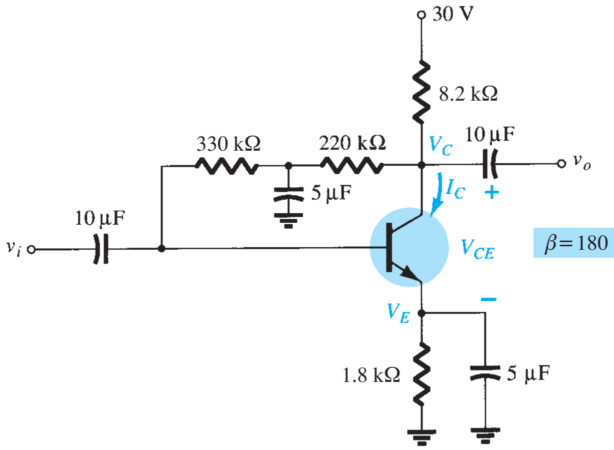

FIG. 4.130
Problems 29 and 30.

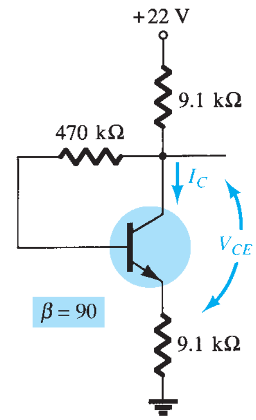

FIG. 4.131
Problems 30 and 31.

32. Determine the range of possible values for V_C for the network of Fig. 4.132 using the 1-MΩ potentiometer.

***33.** Given $V_B = 4$ V for the network of Fig. 4.133, determine:

a. V_E.
b. I_C.
c. V_C.
d. V_{CE}.
e. I_B.
f. β.

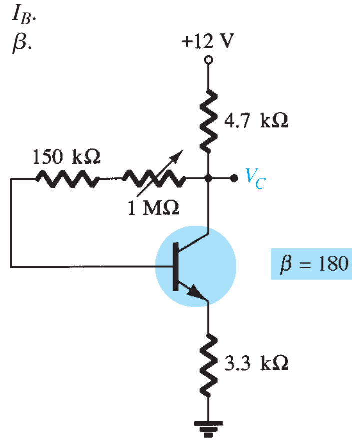

FIG. 4.132
Problem 32.

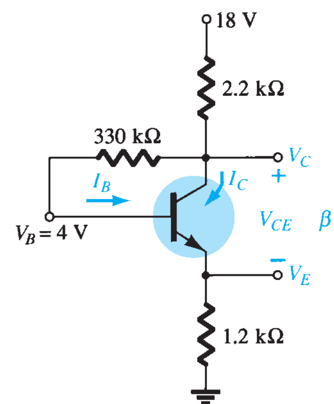

FIG. 4.133
Problem 33.

4.7 Emitter-Follower Configuration

***34.** Determine the level of V_E and I_E for the network of Fig. 4.134.

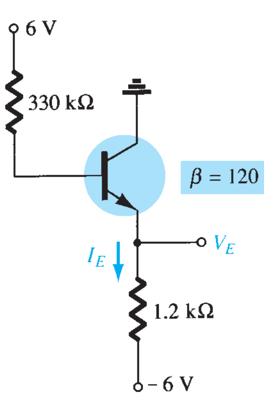

FIG. 4.134
Problem 34.

35. For the emitter follower network of Fig. 4.135
  a. Find I_B, I_C, and I_E.
  b. Determine V_B, V_C, and V_E.
  c. Calculate V_{BC} and V_{CE}.

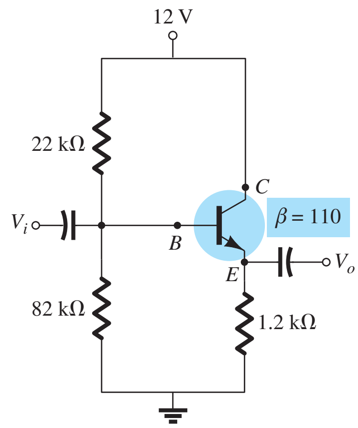

FIG. 4.135
Problem 35.

4.8 Common-Base Configuration

***36.** For the network of Fig. 4.136, determine:
  a. I_B.
  b. I_C.
  c. V_{CE}.
  d. V_C.

***37.** For the network of Fig. 4.137, determine:
  a. I_E.
  b. V_C.
  c. V_{CE}.

38. For the common-base network of Fig. 4.138
  a. Using the information provided determine the value of R_C.
  b. Find the currents I_B and I_E.
  c. Determine the voltages V_{BC} and V_{CE}.

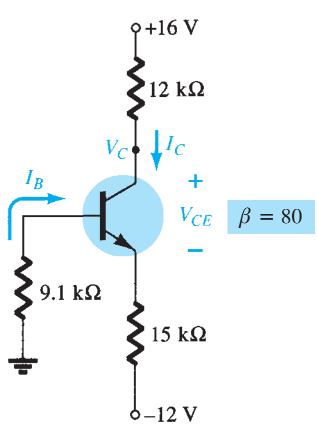

FIG. 4.136
Problem 36.

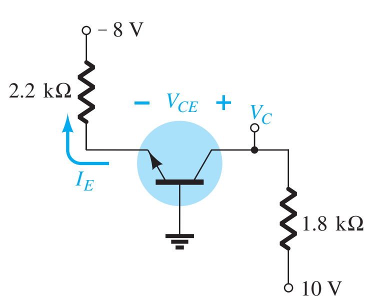

FIG. 4.137
Problem 37.

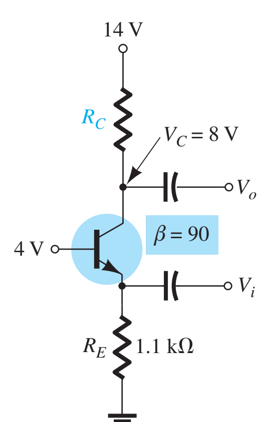

FIG. 4.138
Problem 38.

4.9 Miscellaneous Bias Configurations

***39.** For the network of Fig. 4.139, determine:
  a. I_B.
  b. I_C.
  c. V_E.
  d. V_{CE}.

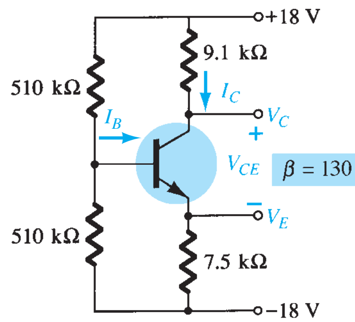

FIG. 4.139
Problem 39.

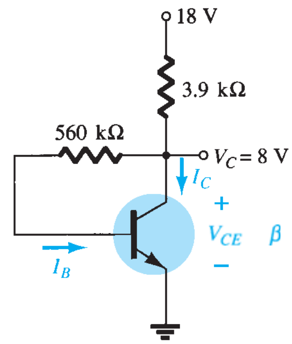

FIG. 4.140
Problems 40 and 68.

40. Given $V_C = 8$ V for the network of Fig. 4.140, determine:
- **a.** I_B.
- **b.** I_C.
- **c.** β.
- **d.** V_{CE}.

4.11 Design Operations

41. Determine R_C and R_B for a fixed-bias configuration if $V_{CC} = 12$ V, $\beta = 80$, and $I_{C_Q} = 2.5$ mA with $V_{CE_Q} = 6$ V. Use standard values.

42. Design an emitter-stabilized network at $I_{C_Q} = \frac{1}{2}I_{C_{sat}}$ and $V_{CE_Q} = \frac{1}{2}V_{CC}$. Use $V_{CC} = 20$ V, $I_{C_{sat}} = 10$ mA, $\beta = 120$, and $R_C = 4R_E$. Use standard values.

43. Design a voltage-divider bias network using a supply of 24 V, a transistor with a beta of 110, and an operating point of $I_{C_Q} = 4$ mA and $V_{CE_Q} = 8$ V. Choose $V_E = \frac{1}{8}V_{CC}$. Use standard values.

***44.** Using the characteristics of Fig. 4.121, design a voltage-divider configuration to have a saturation level of 10 mA and a Q-point one-half the distance between cutoff and saturation. The available supply is 28 V, and V_E is to be one-fifth of V_{CC}. The condition established by Eq. (4.33) should also be met to provide a high stability factor. Use standard values.

4.12 Multiple BJT Networks

45. For the R–C-coupled amplifier of Fig. 4.141 determine
- **a.** the voltages V_B, V_C, and V_E for each transistor.
- **b.** the currents I_B, I_C, and I_E for each transistor

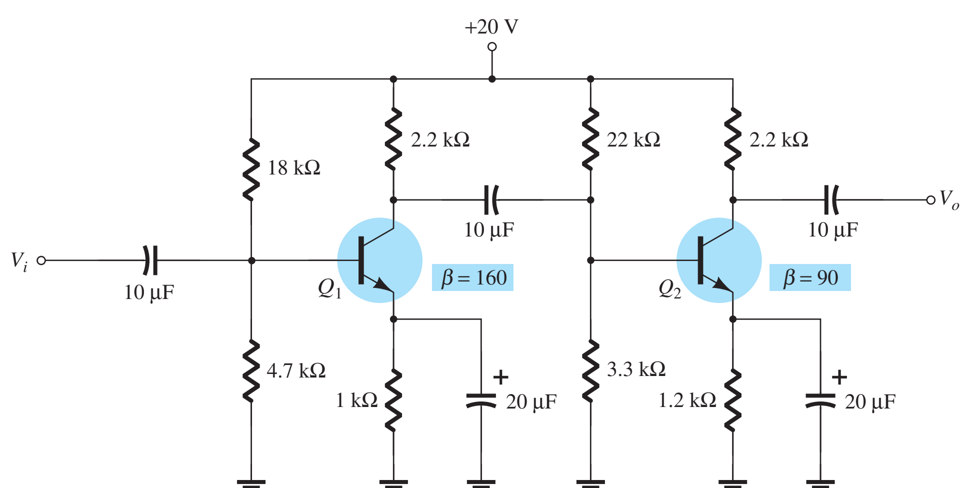

FIG. 4.141
Problem 45.

46. For the Darlington amplifier of Fig. 4.142 determine
- **a.** the level of β_D.
- **b.** the base current of each transistor.
- **c.** the collector current of each transistor.
- **d.** the voltages V_{C_1}, V_{C_2}, V_{E_1}, and V_{E_2}.

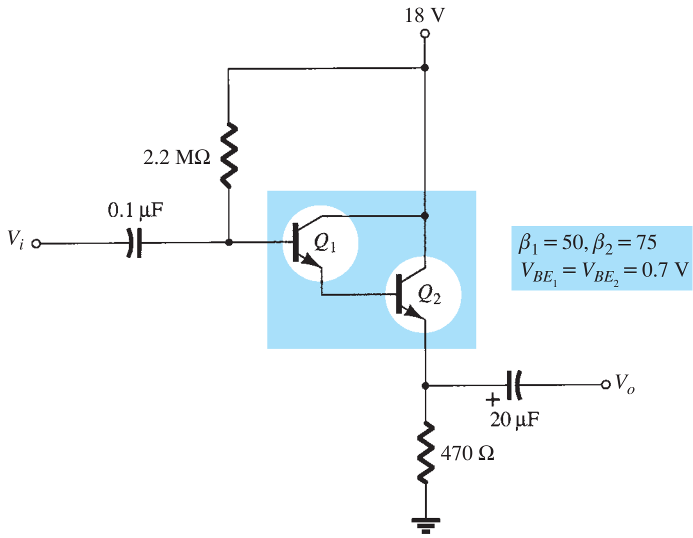

FIG. 4.142
Problem 46.

47. For the cascode amplifier of Fig. 4.143 determine
  a. the base and collector currents of each transistor.
  b. the voltages V_{B_1}, V_{B_2}, V_{E_1}, V_{C_1}, V_{E_2}, and V_{C_2}.

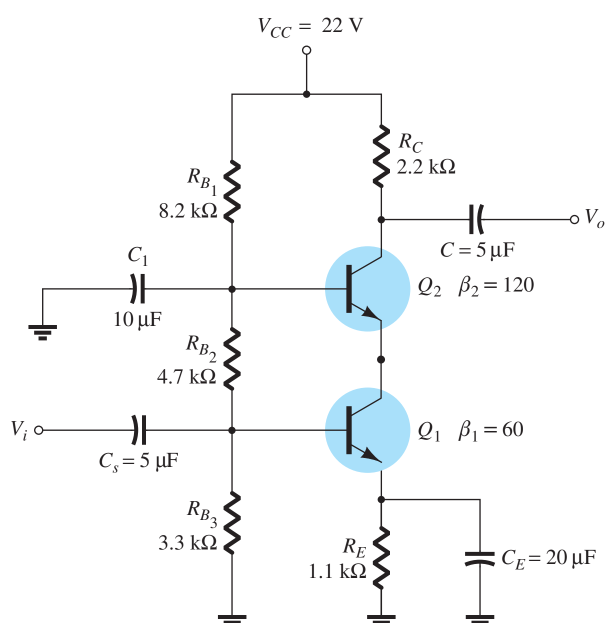

FIG. 4.143
Problem 47.

48. For the feedback amplifier of Fig. 4.144 determine
  a. the base and collector current of each transistor.
  b. the base, emitter, and collector voltages of each transistor.

4.13 Current Mirror Circuits

49. Calculate the mirrored current I in the circuit of Fig. 4.145.

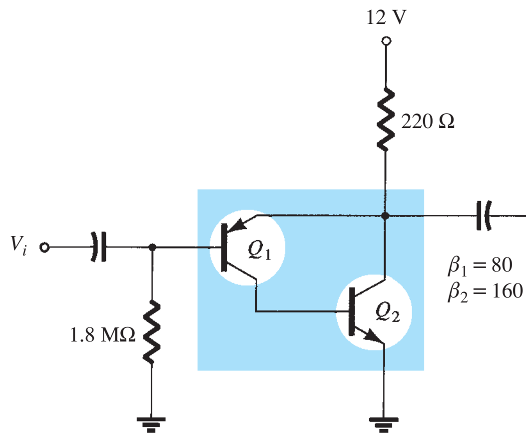

FIG. 4.144
Problem 48.

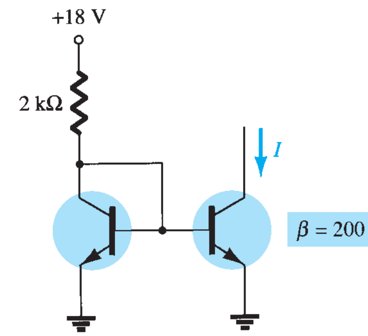

FIG. 4.145
Problem 49.

***50.** Calculate collector currents for Q_1 and Q_2 in Fig. 4.146.

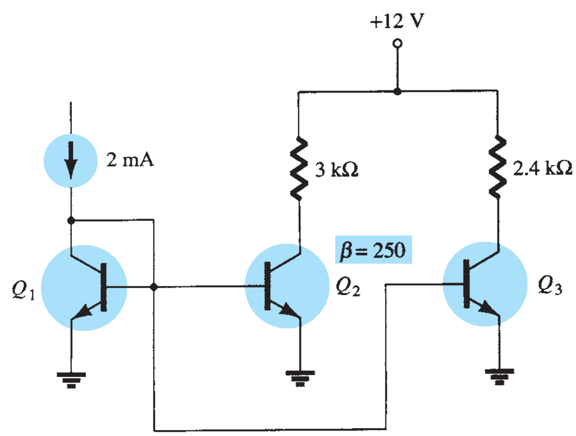

FIG. 4.146
Problem 50.

4.14 Current Source Circuits

51. Calculate the current through the 2.2-kΩ load in the circuit of Fig. 4.147.

52. For the circuit of Fig. 4.148, calculate the current I.

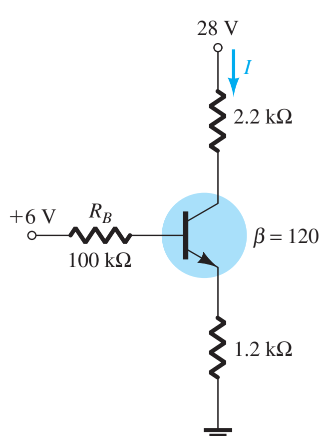

FIG. 4.147
Problem 51.

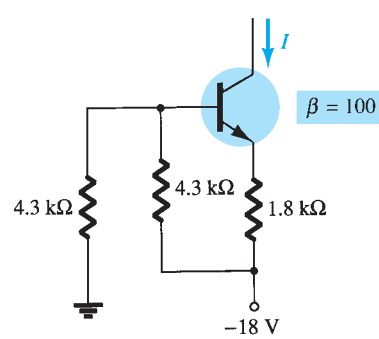

FIG. 4.148
Problem 52.

***53.** Calculate the current I in the circuit of Fig. 4.149.

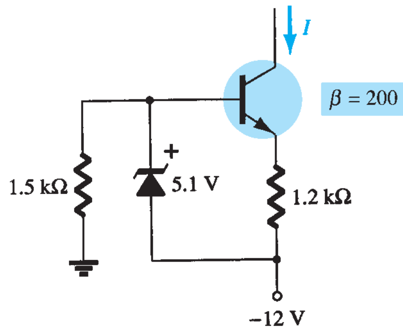

FIG. 4.149
Problem 53.

4.15 *pnp* Transistors

54. Determine V_C, V_{CE}, and I_C for the network of Fig. 4.150.

55. Determine V_C and I_B for the network of Fig. 4.151.

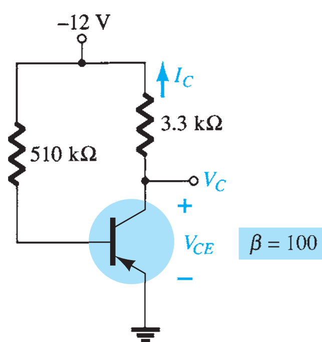

FIG. 4.150
Problem 54.

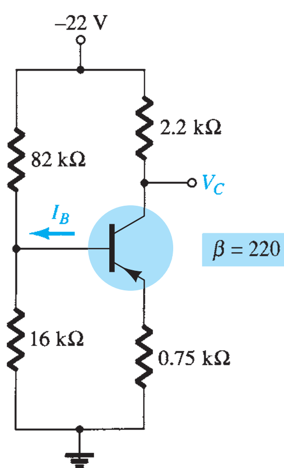

FIG. 4.151
Problem 55.

56. Determine I_E and V_C for the network of Fig. 4.152.

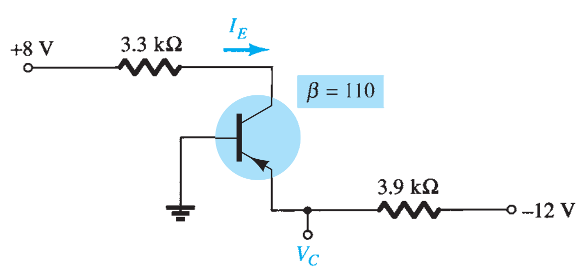

FIG. 4.152
Problem 56.

4.16 Transistor Switching Networks

***57.** Using the characteristics of Fig. 4.121, determine the appearance of the output waveform for the network of Fig. 4.153. Include the effects of $V_{CE_{sat}}$, and determine I_B, $I_{B_{max}}$, and $I_{C_{sat}}$ when $V_i = 10$ V. Determine the collector-to-emitter resistance at saturation and cutoff.

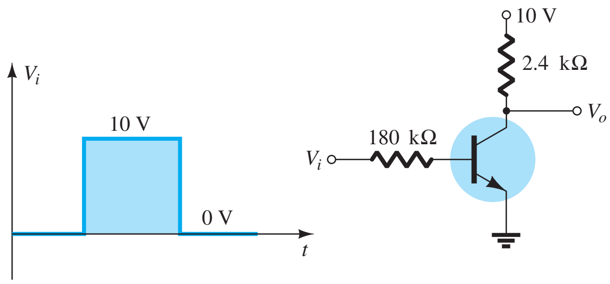

FIG. 4.153
Problem 57.

***58.** Design the transistor inverter of Fig. 4.154 to operate with a saturation current of 8 mA using a transistor with a beta of 100. Use a level of I_B equal to 120% of $I_{B_{max}}$ and standard resistor values.

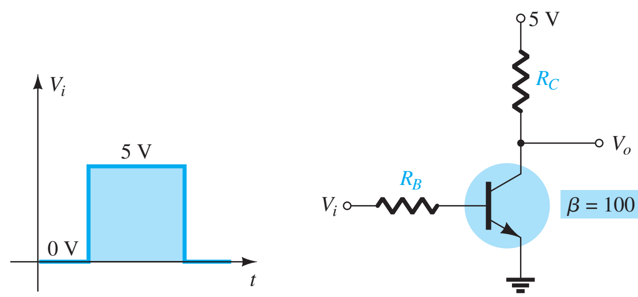

FIG. 4.154
Problem 58.

59. a. Using the characteristics of Fig. 3.23e, determine t_{on} and t_{off} at a current of 2 mA. Note the use of log scales and the possible need to refer to Section 9.2.

b. Repeat part (a) at a current of 10 mA. How have t_{on} and t_{off} changed with increase in collector current?

c. For parts (a) and (b), sketch the pulse waveform of Fig. 4.91 and compare results.

4.17 Troubleshooting Techniques

***60.** The measurements of Fig. 4.155 all reveal that the network is not functioning correctly. List as many reasons as you can for the measurements obtained.

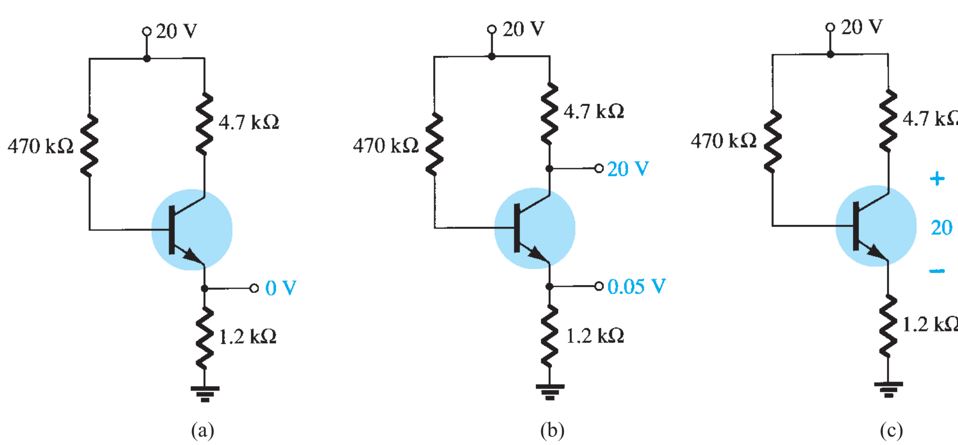

FIG. 4.155
Problem 60.

***61.** The measurements appearing in Fig. 4.156 reveal that the networks are not operating properly. Be specific in describing why the levels obtained reflect a problem with the expected network behavior. In other words, the levels obtained reflect a very specific problem in each case.

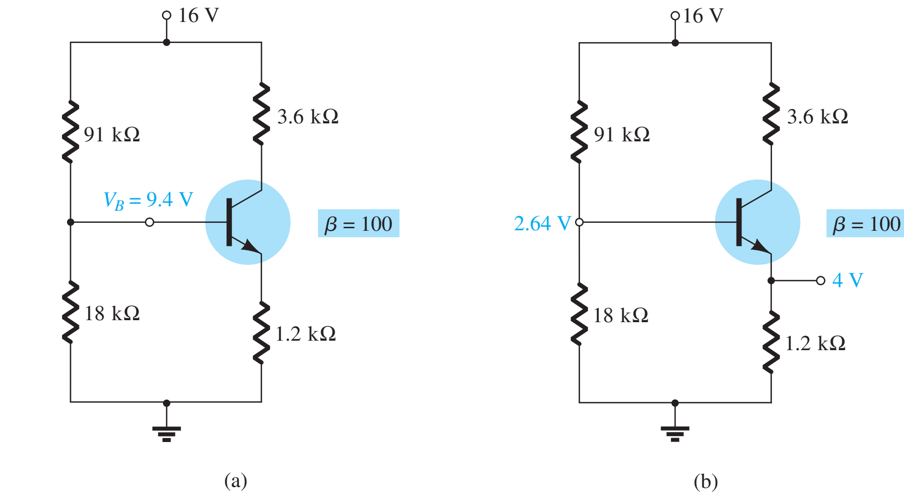

FIG. 4.156
Problem 61.

62. For the circuit of Fig. 4.157:
- **a.** Does V_C increase or decrease if R_B is increased?
- **b.** Does I_C increase or decrease if β is reduced?
- **c.** What happens to the saturation current if β is increased?
- **d.** Does the collector current increase or decrease if V_{CC} is reduced?
- **e.** What happens to V_{CE} if the transistor is replaced by one with smaller β?

63. Answer the following questions about the circuit of Fig. 4.158:
- **a.** What happens to the voltage V_C if the transistor is replaced by one having a larger value of β?
- **b.** What happens to the voltage V_{CE} if the ground leg of resistor R_{B_2} opens (does not connect to ground)?
- **c.** What happens to I_C if the supply voltage is low?
- **d.** What voltage V_{CE} would occur if the transistor base–emitter junction fails by becoming open?
- **e.** What voltage V_{CE} would result if the transistor base–emitter junction fails by becoming a short?

***64.** Answer the following questions about the circuit of Fig. 4.159:
- **a.** What happens to the voltage V_C if the resistor R_B is open?
- **b.** What should happen to V_{CE} if β increases due to temperature?
- **c.** How will V_E be affected when replacing the collector resistor with one whose resistance is at the lower end of the tolerance range?
- **d.** If the transistor collector connection becomes open, what will happen to V_E?
- **e.** What might cause V_{CE} to become nearly 18 V?

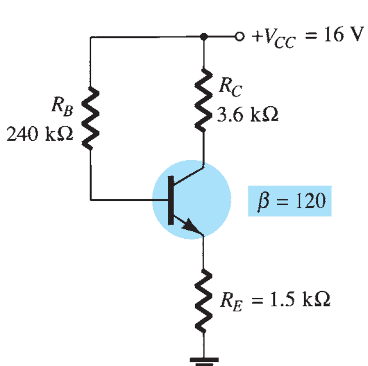

FIG. 4.157
Problem 62.

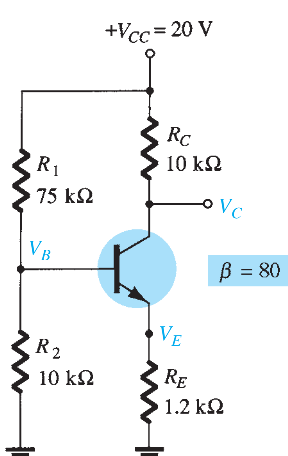

FIG. 4.158
Problem 63.

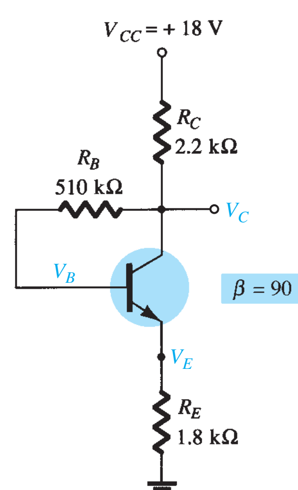

FIG. 4.159
Problem 64.

4.18 Bias Stabilization

65. Determine the following for the network of Fig. 4.118:
- **a.** $S(I_{CO})$.
- **b.** $S(V_{BE})$.
- **c.** $S(\beta)$, using T_1 as the temperature at which the parameter values are specified and $\beta(T_2)$ as 25% more than $\beta(T_1)$.
- **d.** Determine the net change in I_C if a change in operating conditions results in I_{CO} increasing from 0.2 μA to 10 μA, V_{BE} drops from 0.7 V to 0.5 V, and β increases 25%.

***66.** For the network of Fig. 4.122, determine:
- **a.** $S(I_{CO})$.
- **b.** $S(V_{BE})$.
- **c.** $S(\beta)$, using T_1 as the temperature at which the parameter values are specified and $\beta(T_2)$ as 25% more than $\beta(T_1)$.
- **d.** Determine the net change in I_C if a change in operating conditions results in I_{CO} increasing from 0.2 μA to 10 μA, V_{BE} drops from 0.7 V to 0.5 V, and β increases 25%.

***67.** For the network of Fig. 4.125, determine:
- **a.** $S(I_{CO})$.
- **b.** $S(V_{BE})$.
- **c.** $S(\beta)$, using T_1 as the temperature at which the parameter values are specified and $\beta(T_2)$ as 25% more than $\beta(T_1)$.
- **d.** Determine the net change in I_C if a change in operating conditions results in I_{CO} increasing from 0.2 μA to 10 μA, V_{BE} drops from 0.7 V to 0.5 V, and β increases 25%.

***68.** For the network of Fig. 4.140, determine:
- **a.** $S(I_{CO})$.
- **b.** $S(V_{BE})$.
- **c.** $S(\beta)$, using T_1 as the temperature at which the parameter values are specified and $\beta(T_2)$ as 25% more than $\beta(T_1)$.
- **d.** Determine the net change in I_C if a change in operating conditions results in I_{CO} increasing from 0.2 μA to 10 μA, V_{BE} drops from 0.7 V to 0.5 V, and β increases 25%.

***69.** Compare the relative values of stability for Problems 65 through 68. The results for Exercises 65 and 67 can be found in Appendix E. Can any general conclusions be derived from the results?

***70.**
- **a.** Compare the levels of stability for the fixed-bias configuration of Problem 65.
- **b.** Compare the levels of stability for the voltage-divider configuration of Problem 67.
- **c.** Which factors of parts (a) and (b) seem to have the most influence on the stability of the system, or is there no general pattern to the results?

4.21 Computer Analysis

71. Perform a PSpice analysis of the network of Fig. 4.118. That is, determine I_C, V_{CE}, and I_B.

72. Repeat Problem 71 for the network of Fig. 4.122.

73. Repeat Problem 71 for the network of Fig. 4.125.

74. Repeat Problem 71 for the network of Fig. 4.129.

75. Repeat Problem 71 using Multisim.

76. Repeat Problem 72 using Multisim.

77. Repeat Problem 73 using Multisim.

78. Repeat Problem 74 using Multisim.