CHAPTER

3.2

BASIC BJT CIRCUITS

Use $V_{BE(ON)} = 0.7$ V, $V_{CE(Sat)} = 0.2$ V for *npn* transistor if not given in problem.

Statement for Q.1-4:

The common-emitter current gain of the transistor is $\beta = 75$. The voltage V_{BE} in ON state is 0.7 V.

1. I_E , $R_C = ?$

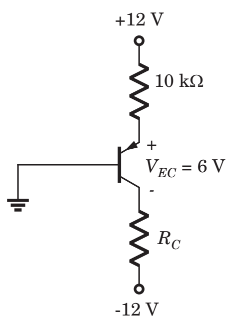

Fig. P3.3.1

(A) 1.46 mA, 6.74 kW
(B) 0.987 mA, 3.04 kW
(C) 1.13 mA,, 5.98 kW
(D) None of the above

2. $V_{EC} = ?$

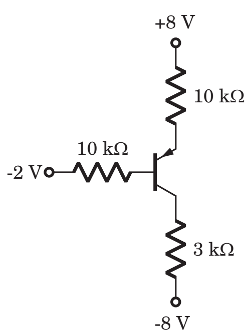

Fig. P3.3.2

(A) 8.4 V
(B) 6.2 V
(C) 4.1 V
(D) None of the above

3. I_C , $R_C = ?$

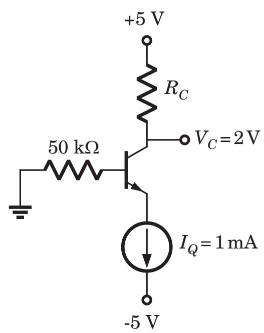

Fig. P3.3.3

(A) 0.987 mA, 3.04 kΩ
(B) 1.013 mA, 2.96 kΩ
(D) 0.946 mA, 4.18 kΩ
(D) 1.057 mA, 3.96 kΩ

4. $V_C = ?$

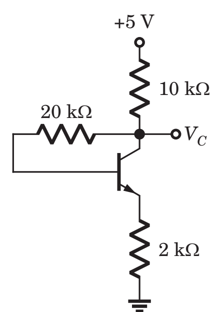

Fig. P3.3.4

(A) 1.49 V
(B) 2.9 V
(C) 1.78 V
(D) 2.3 V

Statement for Q.5-6:

In the circuit of fig.P3.3.5-6 $V_B = -1$ V

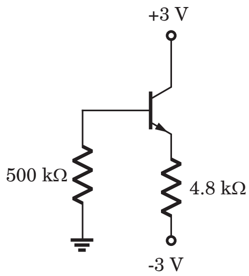

Fig. P3.3.5-6

5. $\beta = ?$

(A) 103.4 (B) 135.5

(C) 134.5 (D) 102.4

6. $V_{CE} = ?$

(A) 6.4 V (B) 4.7 V

(C) 1.3 V (D) 4.2 V

7. In the circuit shown in fig. P3.3.7 voltage $V_E = 4$ V. The value of α and β are respectively

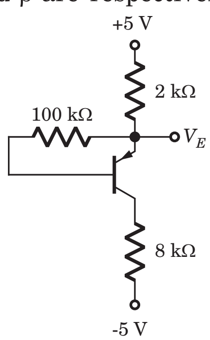

Fig. P3.3.7

(A) 0.943, 17.54 (B) 0.914, 17.54

(C) 0.914, 11.63 (D) 0.914, 11.63

Statement for Q.8-10:

For the transistor in circuit shown in fig. P3.3.8-10, $\beta = 200$. Determine the value of I_E and I_C for given value of V_B in question.

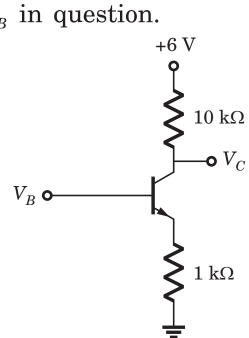

Fig. P3.3.8-10

8. $V_B = 0$ V

(A) 6.43 mA, 2.4 V (B) 2.18 mA, 3.4 V

(C) 0 A, 6 V (D) None of the above

9. $V_B = 1$ V

(A) 4 V (B) 3 V

(C) 1 V (D) 1.9 V

10. $V_B = 2$ V

(A) –7 V (B) 1.5 V

(C) 2.6 V (D) None of the above

Statement for Q.11-12:

The transistor in circuit shown in fig. P3.3.11-12 has $\beta = 200$. Determine the value of voltage V_o for given value of V_{BB}.

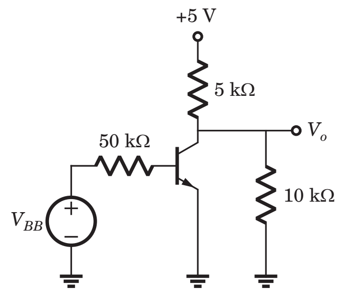

Fig. P3.3.11-12

11. $V_{BB} = 0$

(A) 2.46 V (B) 1.83 V

(C) 3.33 V (D) 4.04 V

12. $V_{BB} = 1$ V

(A) 4.11 V (B) 1.83 V

(C) 2.46 V (D) 3.44 V

13. $V_{BB} = 2$ V

(A) 3.18 V (B) 1.46 V

(C) 0.2 V (D) None of the above

Statement for Q.14-16:

The transistor shown in the circuit of fig. P3.3.14-16 has $\beta = 150$. Determine V_o for given value of I_Q in question.

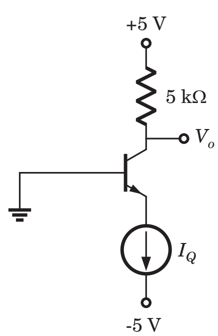

Fig. P3.3.14-16

14. $I_Q = 0.1$ mA

(A) 1.4 V (B) 4.5 V

(C) 3.2 V (D) None of the above

15. $I_Q = 0.5$ mA

(A) 3.16 V (B) 2.52 V

(C) 2.14 V (D) 3.94V

16. $I_Q = 2$ mA

(A) 4.9 V (B) –4.9 V

(C) 0.5 V (D) –0.5 V

17. For the circuit in fig. P3.3.17 $V_B = V_C$ and $\beta = 50$. The value of V_B is

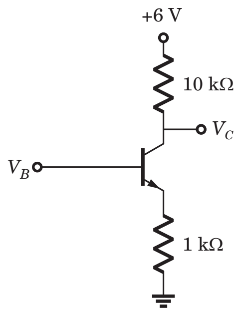

Fig. P3.317

(A) 0.9 V (B) 1.19 V

(C) 2.14 V (D) 1.84 V

18. For the circuit shown in fig. P3.3.18, $V_{CB} = 0.5$ V and $\beta = 100$. The value of I_Q is

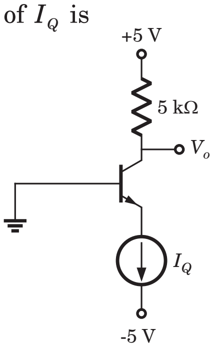

Fig. P3.3.18

(A) 1.68 mA (B) 0.909 mA

(C) 0.134 mA (D) None of the above

19. For the circuit shown in fig. P3.3.19 the emitter voltage is $V_E = 2$ V. The value of α is

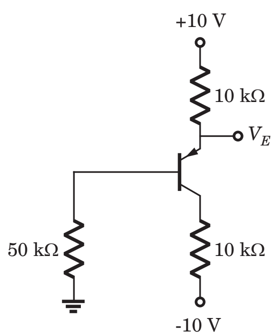

Fig. P3.3.19

(A) 0.991 (B) 0.939

(C) 0.968 (D) 0.914

20. For the transistor in fig. P3.3.20 , $\beta = 50$. The value of voltage V_{EC} is

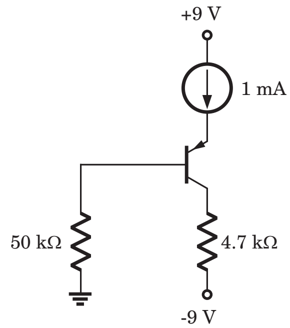

Fig. P3.3.20

(A) 3.13 V (B) 4.24 V

(C) 5.18 V (D) 6.07 V

21. In the circuit shown in fig. P3.3.21 if $\beta = 50$, the power dissipated in the transistor is

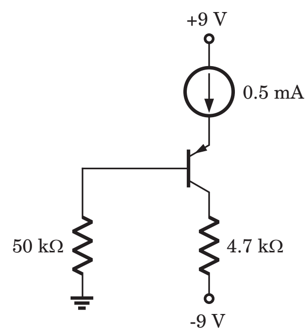

Fig. P3.3.21

(A) 3.87 mW (B) 10.46 mW

(C) 7.49 mW (D) 18.74 mW

22. For the circuit shown in fig. P3.3.22 the Q-point is $V_{CEQ} = 12$ V and $I_{CQ} = 2$ A when $\beta = 60$. The value of resistor R_C and R_B are

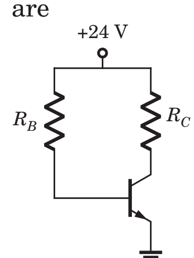

Fig. P3.3.22

(A) 10 kΩ, 241 kΩ (B) 10 kΩ, 699 kΩ

(C) 6 kΩ, 699 kΩ (D) 6 kΩ, 241 kΩ

29. For the transistor in the circuit of fig. P3.3.29, $\beta = 100$. The voltage V_B is

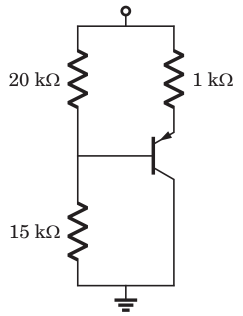

Fig. P3.3.29

(A) 3.6 V (B) 4.29 V

(C) 3.9 V (D) 4.69 V

30. The current gain of the transistor shown in the circuit of fig. P3.3.30 is $\beta = 125$. The Q-point values (I_{CQ}, V_{CEQ}) are

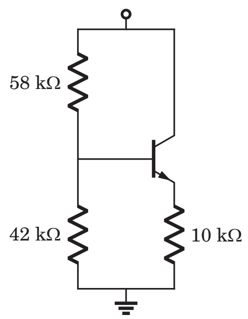

Fig. P3.3.30

(A) (0.418 mA, 20.4 V) (B) (0.915 mA, 14.8 V)

(C) (0.915 mA, 16.23 V) (D) (0.418 mA, 18.43 V)

31. For the circuit shown in fig. P3.3.31, let $\beta = 75$. The Q-point (I_{CQ}, V_{CEQ}) is

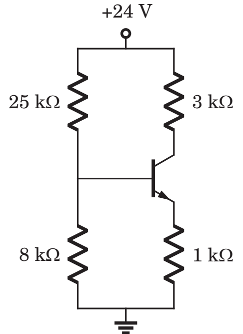

Fig. P3.3.31

(A) (4.68 mA, 16.46 V) (B) (3.12 mA, 1.86 V)

(C) (3.12 mA, 8.46 V) (D) (4.68 mA , 5.22 V)

32. The current gain of the transistor shown in the circuit of fig.P3.3.32 is $\beta = 100$. The values of Q-point (I_{CQ}, V_{CEQ}) is

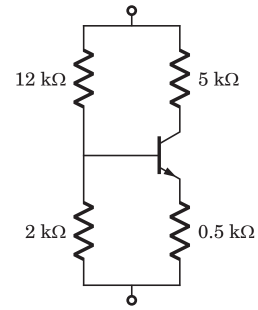

Fig. P3.3.32

(A) (1.8 mA, 2.1 V) (B) (1.4 mA, 2.3 V)

(C) (1.4 mA , 1.8 V) (D) (1.8 mA, 1.4 V)

33. For the circuit in fig. P3.3.33, let $\beta = 60$. The value of V_{ECQ} is

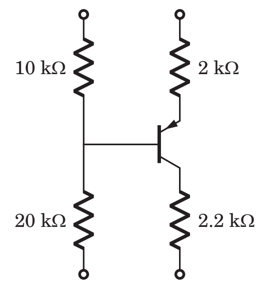

Fig.P3.3.33

(A) 2.68 V (B) 4.94 V

(C) 3.73 V (D) 5.69 V

34. In the circuit of fig. P3.3.34 Zener voltage is $V_Z = 5$ V and $\beta = 100$. The value of I_{CQ} and V_{CEQ} are

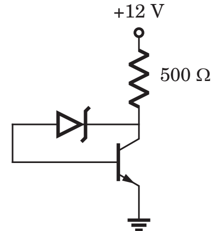

Fig. P3.3.34

(A) 12.47 mA, 4.3 V (B) 12.47 mA, 5.7 V

(C) 10.43 A, 5.7 V (D) 10.43 A , 4.3 V

35. The two transistor in fig. P3.2.35 are identical. If $\beta = 25$, the current I_{C2} is

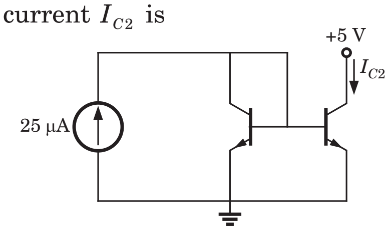

Fig. P3.2.35

(A) 28 μA (B) 23.2 μA

(C) 26 μA (D) 24 μA

36. In the shunt regulator of fig. P3.2.26, the $V_Z = 8.2$ V and $V_{BE} = 0.7$ V. The regulated output voltage V_o is

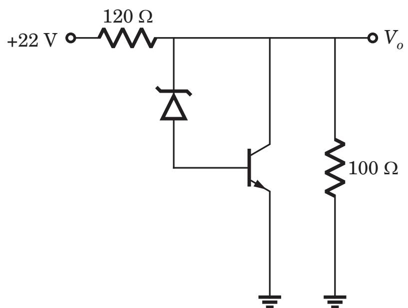

Fig. P3.2.36

(A) 11.8 V (B) 7.5 V

(C) 12.5 V (D) 8.9 V

37. In the series voltage regulator circuit of fig. P3.2.37 $V_{BE} = 0.7$ V, $\beta = 50$, $V_Z = 8.3$ V. The output voltage V_o is

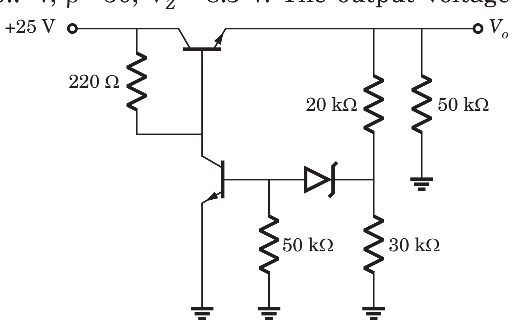

Fig. P3.2.37

(A) 25 V (B) 25.7 V

(C) 15 V (D) 15.7 V

38. In the regulator circuit of fig. P3.2.38 $V_Z = 12$ V, $\beta = 50$, $V_{BE} = 0.7$ V. The Zener current is

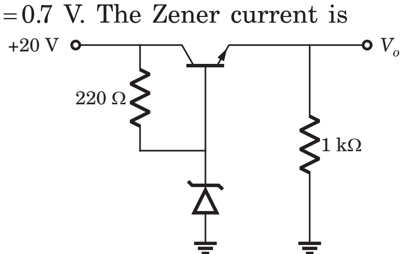

Fig. P3.2.38

(A) 36.63 mA (B) 36.17 mA

(C) 49.32 mA (D) 49.78 mA

39. In the bipolar current source of fig. P3.2.39 the diode voltage and transistor BE voltage are equal. If base current is neglected then collector current is

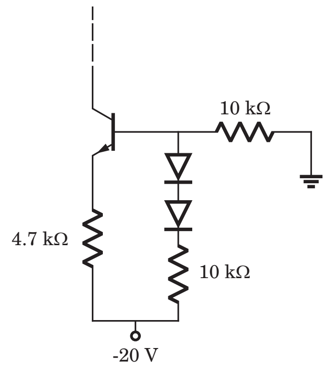

Fig. P3.2.39

(A) 6.43 mA (B) 2.13 mA

(C) 1.48 mA (D) 9.19 mA

40. In the current mirror circuit of fig. P3.2.40. the transistor parameters are $V_{BE} = 0.7$ V, $\beta = 50$ and the Early voltage is infinite. Assume transistor are matched. The output current I_o is

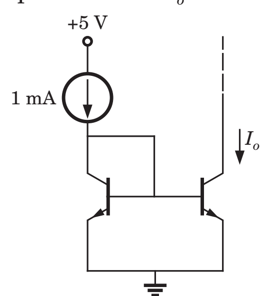

Fig. P3.2.40

(A) 1.04 mA (B) 1.68 mA

(C) 962 μA (D) 432 μA

41. All transistor in the N output mirror in fig. P3.2.41 are matched with a finite gain β and early voltage $V_A = \infty$. The expression for each load current is

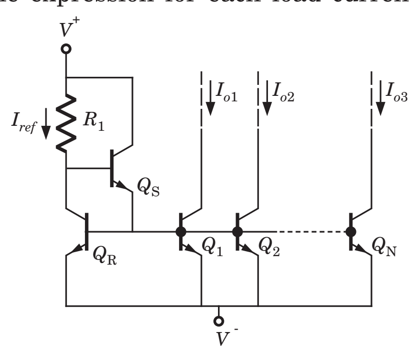

Fig. P32.41

(A) $\dfrac{I_{ref}}{\left(1+\dfrac{(1+N)}{\beta(\beta+1)}\right)}$ (B) $\dfrac{I_{ref}}{\left(1+\dfrac{N}{(\beta+1)}\right)}$

(C) $\dfrac{\beta I_{ref}}{\left(1+\dfrac{(1+N)}{(\beta+1)}\right)}$ (D) $\dfrac{\beta I_{ref}}{\left(1+\dfrac{N}{\beta+1}\right)}$

42. Consider the basic three transistor current source in fig. P3.2.42. Assume all transistor are matched with finite gain and early voltage $V_A = \infty$. The expression for I_o is

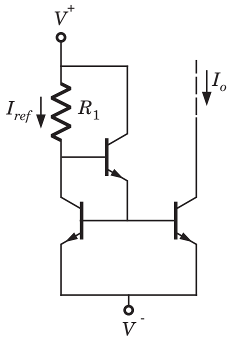

Fig. P3.2.42

(A) $\dfrac{I_{ref}}{\left(1+\dfrac{2}{(1+\beta)}\right)}$ (B) $\dfrac{I_{ref}}{\left(1+\dfrac{1}{(2+\beta)}\right)}$

(C) $\dfrac{I_{ref}}{\left(1+\dfrac{2}{\beta(1+\beta)}\right)}$ (D) $\dfrac{I_{ref}}{\left(1+\dfrac{1}{\beta(2+\beta)}\right)}$

43. Consider the wilder current source of fig. P3.2.43. Both of transistor are identical and $\beta >> 1$ and $V_{BE1} = 0.7$ V. The value of resistance R_1 and R_E to produce $I_{ref} = 1$ mA and $I_o = 12\ \mu$A is ($V_t = 0.026$)

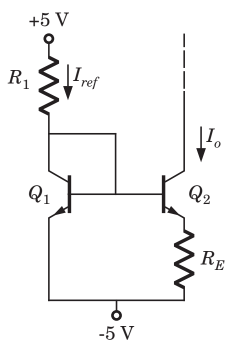

Fig. P3.2.43

(A) 9.3 kΩ, 18.23 kΩ (B) 9.3 kΩ , 9.58 kΩ

(C) 15.4 kΩ , 16.2 kΩ (D) 15.4 kΩ , 32.4 kΩ

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SOLUTIONS

1. (C) $I_E = \dfrac{12-0.7}{10\text{k}} \Rightarrow I_E = 1.13\text{ mA}$

$I_C = \left(\dfrac{75}{75+1}\right)(1.13) = 1.12\text{ mA}$

$V_{CE} = 12 - 1.13\times 10 - 1.12R_C - (-12) = 6\text{ V}$

$R_C = 5.98\text{ k}\Omega$

2. (C) $8 = 10\times(75+1)I_B + 0.7 + 10I_B - 2$

$I_B = \dfrac{9.3}{10+760} = 12.08\ \mu\text{A},$

$I_C = \beta I_B = 0.906\text{ mA},\ I_E = (\beta+1)I_B = 0.918\text{ mA}$

$8 = 10(0.918) + V_{EC} + 3(0.906) - 8$

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

3. (A) $I_C = \left(\dfrac{75}{75+1}\right)I_E = \dfrac{75}{76}(1\text{m}) = 0.987\text{ mA}$

$R_C = \dfrac{5.2}{0.987\text{m}} = 3.04\text{ k}\Omega$

4. (A) $5 = (1+\beta)10\text{k}I_B + 20\text{k}I_B + 0.7 + \beta 2\text{k}I_B$

$5 = (760\text{k} + 20\text{k} + 150\text{k})I_B + 0.7$

$\Rightarrow I_B = 4.62\ \mu\text{A},$

$I_C = \beta I_B = 0.347\text{ mA}$

$V_C = 5 - (\beta+1)I_B R_C = 5 - 760\times 4.62\times 10^{-3} = 1.49\text{ V}$

5. (C) $V_B = -I_B R_B$

$\Rightarrow I_B = \dfrac{-V_B}{R_B} = \dfrac{1}{500\text{k}} = 2.0\ \mu\text{A}$

$V_E = -1 - 0.7 = -1.7\text{ V}$

$I_E = \dfrac{V_E - (-3)}{4.8\text{k}} = \dfrac{-1.7+3}{4.8\text{k}} = 0.271\text{ mA}$

$\dfrac{I_E}{I_B} = (\beta+1) = \dfrac{0.271\text{m}}{2\mu}$

$\Rightarrow \beta = 134.5$

6. (B) $V_{CE} = 3 - V_E = 3 - (-1.7) = 4.7\text{ V}$

7. (C) $I_E = \dfrac{5.4}{2\text{k}} = 0.5\text{ mA}$

$4 = 0.7 + I_B R_B + I_C R_C - 5,\ I_C \approx I_E$,

$8.3 = 100I_B + 0.5\times 8$

$\Rightarrow I_B = 43\ \mu\text{A}$,

$\dfrac{I_E}{I_B} = 1+\beta = \dfrac{0.5\text{m}}{43\mu} = 11.63$

$\beta = 10.63,\ \alpha = \frac{\beta}{1+\beta} \rightarrow \alpha = 0.914$

8. (C) $V_B = 0$ Transistor is in cut-off region.

$I_E = 0,\ V_C = 6\text{ V}$

9. (B) $V_B = 1\text{ V}\ ,\ I_E = \frac{1-0.7}{1\text{k}} = 0.3\text{ mA}$

$I_C \approx I_E = 0.3\text{ mA}$

$V_C = 6 - I_C R_C = 6 - (0.3)(10) = 3\text{ V}$

10. (B) $V_B = 2\text{ V},\ I_E = \frac{2-0.7}{1} = 1.3\text{ mA},$

$I_C \approx I_E = 1.3\text{ mA}$

$V_C = 6 - (1.3)(10) = -7\text{ V}$

Transistor is in saturation. The saturation voltage

$V_{CE} = 0.2\text{ V}$

$V_E = (1.3)(1) = 1.3\text{ V}\ ,\ V_C = V_{CE} + V_E = 1.5\text{ V}$

11. (C) $V_{BB} =$ 0, Transistor is in cutoff region

$V_o = \frac{R_L}{R_C + R_L} V_{CC} = \frac{10(5)}{10} + 5 = 3.33\text{ V}$

12. (B) $I_B = \frac{1-0.7}{50\text{k}} = 6\ \mu\text{A}$

$I_C = \beta I_B = 75 \times 6\mu = 0.45\text{ mA}$

$\frac{5 - V_o}{5\text{k}} = I_C + \frac{V_o}{10k}$

$(1 - 0.45) = \frac{V_o}{5} + \frac{V_o}{10},\quad \Rightarrow \quad V_o = 1.83\text{ V}$

13. (C) $I_B = \frac{2-0.7}{50\text{k}} = 26\ \mu\text{A}$

$I_C = \beta I_B = 75 \times 26\ \mu\text{A} = 1.95\text{ mA}$

$V_C = 5 - I_C R_C = 5 - 5 \times 1.95 = -4.75\text{ V}$

Transistor is in saturation, $V_{CE} = 0.2\text{ V} = V_C = V_o$

14. (B) $I_E = 0.1\text{ mA}$

$I_C = \frac{\beta}{(\beta+1)} I_E = \frac{150}{151}(0.1) = 0.099\text{ mA}$

$V_o = 5 - R_C I_C = 5 - 5(0.099) = 4.50\text{ V}$

15. (B) $I_E = I_Q = 0.5\text{ mA}$

$I_C = \left(\frac{150}{150+1}\right)(0.5\text{m}) = 0.497\text{ mA}$

$V_o = 5 - R_C I_C = 2.517\text{ V}$

16. (D) Transistor is in saturation

$V_o = V_{CE(sat)} - V_{BE} = 0.2 - 0.7 = -0.5\text{ V}$

17. (B) $I_E = \frac{V_B - 0.7}{1\text{k}}$

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

$I_C = \frac{6 - V_C}{10}\text{ mA},\ V_C = V_B$

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

$10.8\ V_B = 12.86\ ,\ V_B = 1.19\text{ V}$

18. (B) $V_{CB} = 0.5\text{ V}\ ,\ V_C = 0.5\text{ V}$

$I_C = \frac{5-0.5}{5\text{k}} = 0.9\text{ mA},\ I_Q = \left(\frac{101}{100}\right)0.9 = 0.909\text{ mA}$

19. (C) $I_E = \frac{10 - V_E}{10\text{k}} = 0.8\text{ mA}$

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

$I_B = \frac{V_B}{R_B} = \frac{1.3}{50\text{k}} = 26\ \mu\text{A}$

$\beta + 1 = \frac{I_E}{I_B} = \frac{0.8\text{m}}{26\mu} = 30.77 \quad \Rightarrow \quad \beta = 29.77$

$\alpha = \frac{\beta}{\beta+1} = \frac{29.77}{30.77} = 0.968$

20. (D) $I_C = \left(\frac{\beta}{\beta+1} I_E\right) = \frac{50}{51}\text{ mA} = 0.98\text{ mA}$

$V_C = I_C R_C - 9 = (0.98)(4.7) - 9 = -4.394\text{ V}$

$I_B = \frac{I_E}{(\beta+1)} = \frac{1}{51}\text{ mA} = 19.6\ \mu\text{A}$

$V_E = I_B R_B + V_{EB} = 50(0.0196) + 0.7 = 1.68\text{ V}$

$V_{EC} = 1.68 - (-4.394) = 6.074\text{ V}$

21. (A) $I_C = \left(\frac{\beta}{\beta+1}\right) I_E = \frac{50}{51}(0.5) = 0.49\text{ mA}$

$I_B = \frac{0.5}{51} = 9.8\ \mu\text{A}$

$V_E = I_B R_B + V_{EB} = (0.0098)(50) + 0.7 = 1.19\text{ V}$

$V_C = I_C R_C - 9 = (0.49)(4.7) - 9 = -6.7\text{ V}$

$V_{EC} = 1.19 - (-6.7) = 7.89\text{ V}$

$P_Q = I_C V_{EC} + I_B V_{EB}$

$= (0.49)(7.89) + (0.0098)(0.7)\text{ mW} = 3.87\text{ mW}$

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

$$10 = I_E(1\text{k}) + V_{EB} + \frac{I_E}{\beta + 1}(8.57\text{k}) + 4.29$$

$$10 = I_E + 0.7 + \frac{I_E}{101}(8.57\text{k}) + 4.29$$

$$\Rightarrow \quad I_E = 4.62 \text{ MA}$$

$$I_B = \frac{I_E}{\beta + 1} = 0.046 \text{ mA}$$

$$V_B = (8.57)(0.046) + 4.29 = 4.69 \text{ V}$$

30. (B) $R_1 = 58 \text{ k}\Omega,\ R_2 = 42 \text{ k}\Omega$

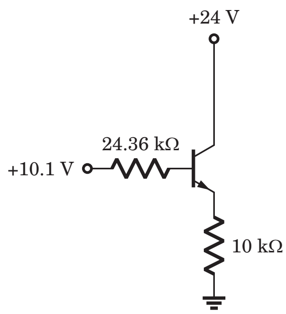

Fig. S3.3.30

$$R_{TH} = 58 \,||\, 42 = 24.36 \text{ k}\Omega$$

$$V_{TH} = \left(\frac{42}{42 + 58}\right)(24) = 10.1 \text{ V}$$

$$10.1 = I_{BQ}(24.36\text{k}) + V_{BE} + (\beta + 1)I_{BQ}(10\text{k})$$

$$10.1 - 0.7 = I_{BQ}(24.36\text{k} + 1260\text{k})$$

$$I_{BQ} = 7.32 \ \mu\text{A}$$

$$I_{CQ} = \beta I_{BQ} = 0.915 \text{ mA}$$

$$I_{EQ} = (\beta + 1)I_{BQ} = 0.922 \text{ mA}$$

$$V_{CEQ} = 24 - (0.922)(10) = 14.8 \text{ V}$$

31. (D) $R_1 = 25 \text{ k}\Omega,\ R_2 = 8 \text{ k}\Omega$

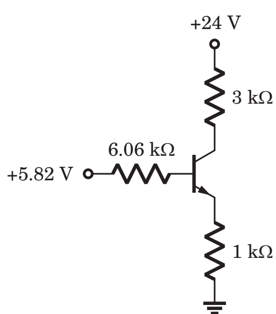

Fig. S3.3.31

$$R_{TH} = 25 \,||\, 8 = 6.06 \text{ k}\Omega,\ V_{TH} = \left(\frac{8}{25 + 8}\right)(24) = 5.82 \text{ V}$$

$$5.82 = (6.06\text{k})(I_{BQ}) + V_{BE} + (\beta + 1)I_B(1\text{k})$$

$$5.82 - 0.7 = (6.06\text{k} + 76\text{k})I_{BQ}$$

$$\Rightarrow \quad I_{BQ} = 62.4 \ \mu\text{A}$$

$$I_{EQ} = (\beta + 1)\, I_{BQ} = 4.74 \text{ mA}$$

$$I_{CQ} = \beta I_{BQ} = 4.68 \text{ mA}$$

$$V_{CEQ} = 24 - I_{CQ}R_C - I_{EQ}R_E$$

$$= 24 - (4.68)(3) - (4.74)(1) = 5.22 \text{ V}$$

32. (B) $R_1 = 12 \text{ k}\Omega,\ R_2 = 2 \text{ k}\Omega$

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

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

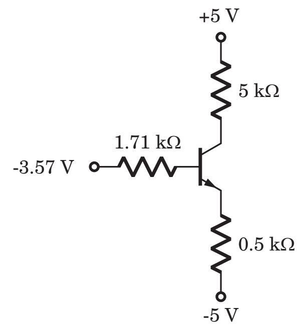

Fig. S3.3.32

$$-3.57 = I_{BQ}(1.71\text{k}) + V_{BE} + (\beta + 1)I_{BQ}(0.5\text{k}) - 5$$

$$5 - 3.57 - 0.7 = (1.71 + 50.5)I_{BQ}$$

$$\Rightarrow \quad I_{BQ} = 14 \ \mu\text{A}$$

$$I_{EQ} = (100 + 1)I_{BQ} = 1.412 \text{ mA}$$

$$I_{CQ} = 100 I_{BQ} = 1.4 \text{ mA}$$

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

$$= 5 - (5)(1.4) - (0.5)(1.412) + 5 = 2.3 \text{ V}$$

33. (B) $R_{TH} = 20 \,||\, 10 = 6.67 \text{ k}\Omega$

$$V_{TH} = \left(\frac{20}{10 + 20}\right) 10 - 5 = 1.67 \text{ V}$$

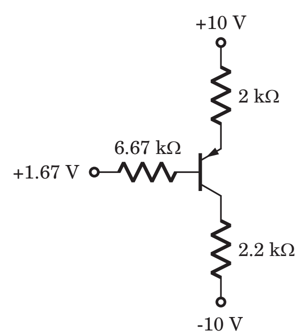

Fig. S3.3.33

$$10 = (1 + \beta)I_{BQ}(2) + V_{EB} + I_{BQ}(6.67) + 1.67$$

$$10 - 1.67 - 0.7 = I_{BQ}(6.67 + 122)$$

41. (A) $I_{ref} = I_{CR} + I_{BS} = I_{CR} + \dfrac{I_{ES}}{1+\beta}$

$I_{ES} = I_{BR} + I_{B1} + I_{B2} + \ldots\ldots. I_{BN}$

$I_{BR} = I_{Bi}, \quad I_{CR} = I_{Ci} = I_{oi}$

$I_{ES} = (1+N)I_{BR} = \dfrac{(1+N)I_{CR}}{\beta}$

Then $I_{ref} = I_{CR} + \dfrac{I_{ES}}{\beta+1} = I_{CR} + \dfrac{(1+N)\,I_{CR}}{\beta\,(\beta+1)}$

$= I_{Oi}\left(1 + \dfrac{(1+N)}{\beta(\beta+1)}\right)$

$$I_{oi} = \frac{I_{ref}}{\left(1 + \dfrac{(1+N)}{\beta(\beta+1)}\right)}$$

42. (C) $I_{ref} = I_{C1} + I_{B3}$, $I_{B1} = I_{B2}$, $I_{E3} = 2I_{B2}$

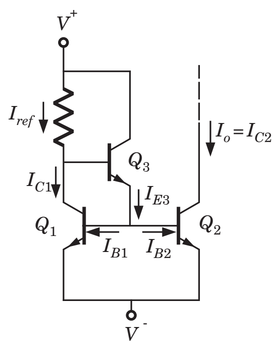

Fig. S3.2.42

$I_{E3} = (1+\beta)I_{B3}$

$I_{ref} = I_{C1} + \dfrac{I_{E3}}{(1+\beta)} = I_{C1} + \dfrac{2I_{B2}}{(1+\beta)}$

$I_{C1} = I_{C2} = \beta I_{B2}$

$I_{ref} = I_{C2} + \dfrac{2I_{C2}}{\beta(1+\beta)} = I_{C2}\left(1 + \dfrac{2}{\beta(1+\beta)}\right)$

$$I_{C2} = I_o = \frac{I_{ref}}{\left(1 + \dfrac{2}{\beta(1+\beta)}\right)}$$

43. (B) If $\beta >> 1$ and transistor are identical

$I_{ref} \approx I_{C1} = I_S e^{\frac{V_{BE1}}{V_t}}$, $I_o = I_{C2} = I_S e^{\frac{V_{BE2}}{V_t}}$

$V_{BE1} = V_t \ln\left(\dfrac{I_{ref}}{I_S}\right)$, $V_{BE2} = V_t \ln\left(\dfrac{I_o}{I_S}\right)$

$V_{BE1} - V_{BE2} = V_t \ln\left(\dfrac{I_{ref}}{I_o}\right)$

From the circuit,

$V_{BE1} - V_{BE2} = I_{E2}R_E \approx I_o R_E$

$I_o R_E = V_t \ln\left(\dfrac{I_{ref}}{I_o}\right)$

$R_E = \dfrac{0.026}{12 \times 10^{-6}} \ln\left(\dfrac{1 \times 10^{-3}}{12 \times 10^{-6}}\right) = 9.58\ \text{k}\Omega$

$R_1 = \dfrac{V^+ - V_{BE1} - V^-}{I_{ref}} = \dfrac{5 - 7 - (-5)}{1\text{m}} = 9.3\ \text{k}\Omega$

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