Chapter 5

1. a. E and R_1
   b. R_1 and R_2
   c. E_1, E_2, and R_1
   d. E and R_1; R_3, R_4, and R_5

2. a. E_1 and R_1; E_2, R_3, and R_4
   b. E_1 and R_1; R_5 and R_6
   c. R_2 and R_3
   d. E_1 and R_1

3. a. $R_T = 0.1\ \text{k}\Omega + 0.39\ \text{k}\Omega + 1.2\ \text{k}\Omega + 6.8\ \text{k}\Omega =$ **8.49 kΩ**
   b. $R_T = 1.2\ \Omega + 2.7\ \Omega + 8.2\ \Omega =$ **12.1 Ω**
   c. $R_T = 1.2\ \Omega + 2.2\ \Omega + 3.3\ \Omega + 4.7\ \Omega =$ **11.4 Ω**

4. a. $R_T = 8.2\ \text{k}\Omega + 10\ \text{k}\Omega + 9.1\ \text{k}\Omega + 1.8\ \text{k}\Omega + 2.7\ \text{k}\Omega =$ **31.8 kΩ**
   b. $R_T = 47\ \Omega + 820\ \Omega + 91\ \Omega + 1.2\ \text{k}\Omega =$ **2158.0 Ω**
   c. $R_T = 3.3\ \Omega + 10\ \text{k}\Omega =$ **13.3 kΩ**

5. a. $R_T = 1.2\ \text{k}\Omega + 1\ \text{k}\Omega + 2.2\ \text{k}\Omega + 3.3\ \text{k}\Omega =$ **7.7 kΩ**
   b. $R_T = 1\ \text{k}\Omega + 2\ \text{k}\Omega + 3\ \text{k}\Omega + 4.7\ \text{k}\Omega + 6.8\ \text{k}\Omega =$ **17.5 kΩ**

6. a. **1 MΩ**
   b. **100 Ω**, **1 kΩ**
   c. $R_T = 100\ \Omega + 1\ \text{k}\Omega + 1\ \text{M}\Omega + 200\ \text{k}\Omega =$ **1.2011 MΩ** vs. **1.2 MΩ** for part b.

7. a. Reading = $10\ \Omega + 33\ \Omega + 56\ \Omega + 68\ \Omega =$ **167 Ω**
   b. Reading = $0.82\ \text{k}\Omega + 1.2\ \text{k}\Omega + 3.3\ \text{k}\Omega =$ **5.32 kΩ**

8. a. $R_T = 129\ \text{k}\Omega = R + 56\ \text{k}\Omega + 22\ \text{k}\Omega + 33\ \text{k}\Omega$, Reading = **18 kΩ**
   b. $R_T = 103\ \text{k}\Omega = 24\ \text{k}\Omega + R_1 + 43\ \text{k}\Omega + 2R_1 = 67\ \text{k}\Omega + 3R_1$, $R_1 =$ **12 kΩ**
   $R_2 =$ **24 kΩ**

9. a. $1.2\ \text{k}\Omega + 2.2\ \text{k}\Omega =$ **3.4 kΩ**
   b. **0 Ω**
   c. **∞ Ω**

10. a. $R_T = 10\ \Omega + 12\ \Omega + 18\ \Omega =$ **40 Ω**
    b. $I_s = \dfrac{E}{R_T} = \dfrac{72\ \text{V}}{40\ \Omega} =$ **1.8 A**
    c. $V_1 = I_1R_1 = (1.8\ \text{A})(10\ \Omega) =$ **18 V**, $V_2 = I_2R_2 = (1.8\ \text{A})(12\ \Omega) =$ **21.6 V**,
    $V_3 = I_3R_3 = (1.8\ \text{A})(18\ \Omega) =$ **32.4 V**
    d. $P_s = EI_s = (72\ \text{V})(1.8\ \text{A}) =$ **129.6 W**
    e. $P_{18\,\Omega} = V_3I_3 = (32.4\ \text{V})(1.8\ \text{A}) =$ **58.32 W**

11. a. the most: R_3, the least: R_1

b. R_3, $R_T = 1.2\ \text{k}\Omega + 6.8\ \text{k}\Omega + 82\ \text{k}\Omega =$ **90 kΩ**

$$I_s = \frac{E}{R_T} = \frac{45\ \text{V}}{90\ \text{k}\Omega} =$$ **0.5 mA**

c. $V_1 = I_1R_1 = (0.5\ \text{mA})(1.2\ \text{k}\Omega) =$ **0.6 V**, $V_2 = I_2R_2 = (0.5\ \text{mA})(6.8\ \text{k}\Omega) =$ **3.4 V**, $V_3 = I_3R_3 = (0.5\ \text{mA})(82\ \text{k}\Omega) =$ **41 V**, results agree with part (a)

d. $P_s = EI_s = (72\ \text{V})(1.8\ \text{A}) =$ **129.6 W**

e. $P_{18\ \Omega} = V_3I_3 = (32.4\ \text{V})(1.8\ \text{A}) =$ **58.32 W**

12. a. $R_T = 12\ \text{k}\Omega + 4\ \text{k}\Omega + 6\ \text{k}\Omega = 22\ \text{k}\Omega$

$E = IR_T = (4\ \text{mA})(22\ \text{k}\Omega) =$ **88 V**

b. $R_T = 12\ \Omega + 22\ \Omega + 82\ \Omega + 10\ \Omega = 126\ \Omega$

$E = IR_T = (500\ \text{mA})(126\ \Omega) =$ **63 V**

13. I. a. $$I = \frac{V}{R} = \frac{5.2\ \text{V}}{1.3\ \Omega} =$$ **4 A**

b. $E = IR_T = (4\ \text{A})(9\ \Omega) =$ **36 V**

c. $R_T = 9\ \Omega = 4.7\ \Omega + 1.3\ \Omega + R$, $R =$ **3 Ω**

d. $V_{4.7\ \Omega} = (4\ \text{A})(4.7\ \Omega) =$ **18.8 V**

$V_{1.3\ \Omega} = (4\ \text{A})(1.3\ \Omega) =$ **5.2 V**

$V_{3\ \Omega} = (4\ \text{A})(3\ \Omega) =$ **12 V**

II. a. $$I = \frac{V}{R} = \frac{6.6\ \text{V}}{2.2\ \text{k}\Omega} =$$ **3 mA**

b. $V_{3.3\ \text{k}\Omega} = (3\ \text{mA})(3.3\ \text{k}\Omega) = 9.9\ \text{V}$

$E = 6.6\ \text{V} + 9\ \text{V} + 9.9\ \text{V} =$ **25.5 V**

c. $$R = \frac{V}{I} = \frac{9\ \text{V}}{3\ \text{mA}} =$$ **3 kΩ**

d. $V_{2.2\ \text{k}\Omega} =$ **6.6 V**, $V_{3\ \text{k}\Omega} =$ **9 V**, $V_{3.3\ \text{k}\Omega} =$ **9.9 V**

14. a. $$I_m = \frac{E}{R_T} = \frac{36\ \text{V}}{4.4\ \text{k}\Omega} =$$ **8.18 mA**, $$V_m = \frac{1}{2}E = \frac{1}{2}(36\ \text{V}) =$$ **18 V**

b. $R_T = 1\ \text{k}\Omega + 2.4\ \text{k}\Omega + 5.6\ \text{k}\Omega = 9\ \text{k}\Omega$

$$I_m = \frac{E}{R_T} = \frac{22.5\ \text{V}}{9\ \text{k}\Omega} =$$ **2.5 mA**, $V_m = 2.5\ \text{mA}(2.4\ \text{k}\Omega + 5.6\ \text{k}\Omega) =$ **20 V**

c. $$\boldsymbol{V}_{3.3\ \text{k}\Omega} = \frac{3.3\ \text{k}\Omega(12\ \text{V})}{4.5\ \text{k}\Omega} = 8.8\ \text{V}$$

$V_m = 12\ \text{V} - 8.8\ \text{V} =$ **3.2 V**

$$I_m = \frac{12\ \text{V}}{4.5\ \text{k}\Omega} =$$ **2.67 mA**

15. a. $I = \dfrac{10\text{ V}}{30\ \Omega} = \mathbf{0.333\ A}$

$V = 0$ V

b. $I = 0$ A, $V = IR = \dfrac{80\text{ V}}{60\ \Omega} = \mathbf{5.33\ V}$

16. a. $R_T = 3\ \text{k}\Omega + 1\ \text{k}\Omega + 2\ \text{k}\Omega = \mathbf{6\ k\Omega}$

$I_s = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{6\ \text{k}\Omega} = \mathbf{20\ mA}$

$V_{R_1} = (20\text{ mA})(3\ \text{k}\Omega) = \mathbf{60\ V}$

$V_{R_2} = (20\text{ mA})(1\ \text{k}\Omega) = \mathbf{20\ V}$

$V_{R_3} = (20\text{ mA})(2\ \text{k}\Omega) = \mathbf{40\ V}$

b. $P_{R_1} = I_1^2 R_1 = (20\text{ mA})^2 \cdot 3\ \text{k}\Omega = \mathbf{1.2\ W}$

$P_{R_2} = I_2^2 R_2 = (20\text{ mA})^2 \cdot 1\ \text{k}\Omega = \mathbf{0.4\ W}$

$P_{R_3} = I_3^2 R_3 = (20\text{ mA})^2 \cdot 2\ \text{k}\Omega = \mathbf{0.8\ W}$

c. $P_T = P_{R_1} + P_{R_2} + P_{R_3} = 1.2\text{ W} + 0.4\text{ W} + 0.8\text{ W} = \mathbf{2.4\ W}$

d. $P_T = EI_s = (120\text{ V})(20\text{ mA}) = \mathbf{2.4\ W}$

e. the same

f. R_1 – the largest

g. dissipated

h. R_1: 2 W, R_2 : 1/2 W, R_3: 1 W

17. $P = 21\text{ W} = (1\text{ A})^2 \cdot R$, $R = \mathbf{21\ \Omega}$
$V_1 = I_1R_1 = (1\text{ A})(2\ \Omega) = \mathbf{2\ V}$, $V_2 = I_2R_2 = (1\text{ A})(1\ \Omega) = \mathbf{1\ V}$
$V_3 = I_3R_3 = (1\text{ A})(21\ \Omega) = \mathbf{21\ V}$
$E = V_1 + V_2 + V_3 = 2\text{ V} + 1\text{ V} + 21\text{ V} = \mathbf{24\ V}$

18 $P = 8\text{ W} = I^2 \cdot 1\ \Omega$, $I = \sqrt{8} = \mathbf{2.828\ A}$
$P = 16\text{ W} = I^2R_1 = (2\ .828\text{ A})^2R_1$, $R_1 = \mathbf{2\ \Omega}$
$R_T = 32\ \Omega = 2\ \Omega + R_2 + 1\ \Omega = 3\ \Omega + R_2$, $R_2 = \mathbf{29\ \Omega}$
$E = IR_T = (2.828\text{ A})(32\ \Omega) = \mathbf{90.5\ V}$

19. a. $R_T = NR_1 = 8\left(28\frac{1}{8}\,\Omega\right) = 225\ \Omega$

$$I = \frac{E}{R_T} = \frac{120\ \text{V}}{225\ \Omega} = \mathbf{0.53\ A}$$

b. $$P = I^2R = \left(\frac{8}{15}\,\text{A}\right)^2\left(28\frac{1}{8}\,\Omega\right) = \left(\frac{64}{\cancel{225}}\right)\left(\frac{\cancel{225}}{8}\right) = \mathbf{8\ W}$$

c. $$V = IR = \left(\frac{\cancel{8}}{15}\,\text{A}\right)\left(\frac{225}{\cancel{8}}\,\Omega\right) = \mathbf{15\ V}$$

d. All go out!

20. $P_s = P_{R_1} + P_{R_2} + P_{R_3}$

$E \cdot I = I^2R_1 + I^2R_2 + 24$

$(R_1 + R_2)I^2 - E \cdot I + 24 = 0$

$6I^2 - 24\,I + 24 = 0$

$I^2 - 4\,I + 4 = 0$

$$I = \frac{-(-4) \pm \sqrt{(-4)^2 - 4(1)(4)}}{2(1)} = \frac{4 \pm \sqrt{16 - 16}}{2} = \frac{4}{2} = 2\ \text{A}$$

$$P = 24\ \text{W} = (2\ \text{A})^2R, \quad R = \frac{24\ \Omega}{4} = \mathbf{6\ \Omega}$$

21. a. $V_{ab} + 4\ \text{V} + 9\ \text{V} - 12\ \text{V} = 0$, $V_{ab} = -13\ \text{V} + 12\ \text{V} = \mathbf{-1\ V}$

b. $V_{ab} + 4\ \text{V} + 8\ \text{V} - 4\ \text{V} = 0$, $V_{ab} = 4\ \text{V} - 12\ \text{V} = \mathbf{-8\ V}$

c. $V_{ab} + 12\ \text{V} - 5\ \text{V} + 6\ \text{V} - 12\ \text{V} = 0$, $V_{ab} = -18\ \text{V} + 17\ \text{V} = \mathbf{-1\ V}$

22. a. $E_T = 8\ \text{V} - 32\ \text{V} + 20\ \text{V} = \mathbf{-4\ V}$, $I = \frac{4\ \text{V}}{10.3\ \Omega} = \mathbf{388.3\ mA}$

b. $E_T = -4\ \text{V} + 10\ \text{V} - 12\ \text{V} = \mathbf{-6\ V}$, $I = \frac{16\ \text{V}}{11.5\ \Omega} = \mathbf{1.39\ A}$

23. a. $$P = 8\ \text{mW} = I^2R, \quad R = \frac{8\ \text{mW}}{I^2} = \frac{8\ \text{mW}}{(2\ \text{mA})^2} = \mathbf{2\ k\Omega}$$

$$I = \frac{E}{R_T} = \frac{20\ \text{V} - E}{3\ \text{k}\Omega + 2\ \text{k}\Omega} = 2\ \text{mA (CW)}, \quad E = \mathbf{10\ V}$$

b. $$I = \frac{16\ \text{V}}{2\ \text{k}\Omega} = 8\ \text{mA}, \quad R = \frac{V}{I} = \frac{12\ \text{V}}{8\ \text{mA}} = \mathbf{1.5\ k\Omega}$$

$$I = \frac{E}{R_T} = \frac{E - 4\ \text{V} - 10\ \text{V}}{2\ \text{k}\Omega + 1.5\ \text{k}\Omega} = \frac{E - 14\ \text{V}}{3.5\ \text{k}\Omega} = 8\ \text{mA (CCW)}$$

$E = \mathbf{42\ V}$

24. a. $-6\ \text{V} + 4\ \text{V} - 12\ \text{V} - V = 0$, $V = -18\ \text{V} + 4\ \text{V} = \mathbf{-14\ V}$

b. $+30\text{ V} - 7\text{ V} - 8\text{ V} - V = 0$, $V = 30\text{ V} - 15\text{ V} = \mathbf{15\text{ V}}$

c. $-14\text{ V} - 22\text{ V} - V_1 + 12\text{ V} = 0$, $V_1 = -36\text{ V} + 12\text{ V} = \mathbf{-24\text{ V}}$
$V_1 - V_2 - 12\text{ V} = 0$, $V_2 = V_1 - 12\text{ V} = -24\text{ V} - 12\text{ V} = \mathbf{-36\text{ V}}$

25. a. $I = \dfrac{12\text{ V}}{8\ \Omega} = \mathbf{1.5\text{ A}}$

b. $\boldsymbol{V}_2 = IR = (1.5\text{ A})(2\ \Omega) = \mathbf{3\text{ V}}$

c. $60\text{ V} - 12\text{ V} - V_1 - 3\text{ V} = 0$
$V_1 = 60\text{ V} - 15\text{ V} = \mathbf{45\text{ V}}$

26. a. $+10\text{ V} - V_2 = 0$
$V_2 = \mathbf{10\text{ V}}$
$+10\text{ V} - 6\text{ V} - V_1 = 0$
$V_1 = \mathbf{4\text{ V}}$

b. $+24\text{ V} - 10\text{ V} - V_1 = 0$
$V_1 = \mathbf{14\text{ V}}$
$+10\text{ V} - V_2 + 8\text{ V} = 0$
$V_2 = \mathbf{18\text{ V}}$

27. a. $\boldsymbol{V}_{1.8\,\Omega} = IR = (3\text{ A})(1.8\ \Omega) = 5.4\text{ V}$
$24\text{ V} - V_1 - 10\text{ V} - 5.4\text{ V} = 0$, $V_1 = 24\text{ V} - 15.4\text{ V} = \mathbf{8.6\text{ V}}$
$V_{2.7\,\Omega} = IR = (3\text{ A})(2.7\ \Omega) = 8.1\text{ V}$
$10\text{ V} - 8.1\text{ V} - V_2 = 0$
$V_2 = 10\text{ V} - 8.1\text{ V} = \mathbf{1.9\text{ V}}$

b. $+ 10\text{ V} - V_1 + 6\text{ V} - 2\text{ V} - 3\text{ V} = 0$, $V_1 = \mathbf{11\text{ V}}$
$+10\text{ V} - V_2 - 3\text{ V} = 0$, $V_2 = \mathbf{7\text{ V}}$

28. $\dfrac{1\text{ V}}{2\ \Omega} = \dfrac{50\text{ V}}{R_2}$, $R_2 = \dfrac{(50\text{ V})(2\ \Omega)}{1\text{ V}} = \mathbf{100\ \Omega}$

$\dfrac{1\text{ V}}{2\ \Omega} = \dfrac{100\text{ V}}{R_3}$, $R_3 = \dfrac{(100\text{ V})(2\ \Omega)}{1\text{ V}} = \mathbf{200\ \Omega}$

29. a. **10 kΩ**
b. V_3: $V_2 = 10\text{ k}\Omega\text{:}1\text{ k}\Omega = \mathbf{10:1}$
V_3: $V_1 = 10\text{ k}\Omega\text{:}100\ \Omega = \mathbf{100:1}$
c. $V_3 = \dfrac{R_3 E}{R_T} = \dfrac{(10\text{ k}\Omega)(60\text{ V})}{0.1\text{ k}\Omega + 1\text{ k}\Omega + 10\text{ k}\Omega} = \mathbf{54.05\text{ V}}$
d. $V' = \dfrac{(R_2 + R_3)E}{R_T} = \dfrac{(1\text{ k}\Omega + 10\text{ k}\Omega)(60\text{ V})}{11.1\text{ k}\Omega} = \mathbf{59.46\text{ V}}$

30. a. $V = \dfrac{40\ \Omega(30\text{ V})}{40\ \Omega + 20\ \Omega} = \mathbf{20\text{ V}}$

b. $V = \dfrac{(2\text{ k}\Omega + 3\text{ k}\Omega)(40\text{ V})}{4\text{ k}\Omega + 1\text{ k}\Omega + 2\text{ k}\Omega + 3\text{ k}\Omega} = \dfrac{(5\text{ k}\Omega)(40\text{ V})}{10\text{ k}\Omega} = \mathbf{20\text{ V}}$

c. $\dfrac{(1.5\ \Omega + 0.6\ \Omega + 0.9\ \Omega)(0.72\ \text{V})}{(2.5\ \Omega + 1.5\ \Omega + 0.6\ \Omega + 0.9\ \Omega + 0.5\Omega)} = \dfrac{(3\ \Omega)(0.72\ \text{V})}{6\ \text{k}\Omega} = \mathbf{0.36\ V}$

31. a. $\dfrac{V_1}{1.2\ \Omega} = \dfrac{20\ \text{V}}{2\ \Omega}$, $V_1 = \dfrac{(1.2\ \Omega)(20\ \text{V})}{2\ \Omega} = \mathbf{12\ V}$

$\dfrac{V_2}{6.8\ \Omega} = \dfrac{20\ \text{V}}{2\ \Omega}$, $V_2 = \dfrac{(6.8\ \Omega)(20\ \text{V})}{2\ \Omega} = \mathbf{68\ V}$

$E = V_1 + 20\ \text{V} + V_2 = 12\ \text{V} + 20\ \text{V} + 68\ \text{V} = \mathbf{100\ V}$

b. $120\ \text{V} - V_1 - 80\ \text{V} = 0$, $V_1 = \mathbf{40\ V}$

$80\ \text{V} - 10\ \text{V} - V_3 = 0$, $V_3 = \mathbf{70\ V}$

32. a. $\dfrac{1000\ \text{V}}{100\ \Omega} = \dfrac{V_2}{68\ \Omega}$, $V_2 = \dfrac{68\ \Omega(1000\ \text{V})}{100\ \Omega} = \mathbf{680\ V}$

$\dfrac{1000\ \text{V}}{100\ \Omega} = \dfrac{V_1}{2\ \Omega}$, $V_1 = \dfrac{2\ \Omega(1000\ \text{V})}{100\ \Omega} = \mathbf{20\ V}$

$E = V_1 + V_2 + 1000\ \text{V}$

$= 20\ \text{V} + 680\ \text{V} + 1000\ \text{V}$

$= \mathbf{1700\ V}$

b. $V_1 = \mathbf{0\ V}$

$V_2 = \dfrac{10\ \text{k}\Omega(50\ \text{V} - 30\ \text{V})}{10\ \text{k}\Omega + 3.3\ \text{k}\Omega + 4.7\ \text{k}\Omega}$

$= \dfrac{10\ \text{k}\Omega(20\ \text{V})}{18\ \text{k}\Omega} = \mathbf{11.11\ V}$

$V_x = E_1 - V_{3.3\ \text{k}\Omega}$

$V_{3.3\ \text{k}\Omega} = \dfrac{3.3\ \text{k}\Omega(20\ \text{V})}{18\ \text{k}\Omega}$

$= 3.67\ \text{V}$

$V_x = 50\ \text{V} - 3.67\ \text{V} = \mathbf{46.33\ V}$

33. $\dfrac{2\ \text{V}}{1\ \text{k}\Omega} = \dfrac{V_2}{2\ \text{k}\Omega}$, $V_2 = \dfrac{2\ \text{k}\Omega(2\ \text{V})}{1\ \text{k}\Omega} = \mathbf{4\ V}$

$\dfrac{2\ \text{V}}{1\ \text{k}\Omega} = \dfrac{V_4}{3\ \text{k}\Omega}$, $V_4 = \dfrac{3\ \text{k}\Omega(2\ \text{V})}{1\ \text{k}\Omega} = \mathbf{6\ V}$

$I = \dfrac{2\ \text{V}}{1\ \text{k}\Omega} = \mathbf{2\ mA}$

$E = 2\ \text{V} + 4\ \text{V} + 12\ \text{V} + 6\ \text{V} = \mathbf{24\ V}$

34. a. $4\text{ V} = \dfrac{R(20\text{ V})}{2.2\text{ k}\Omega + 1.8\text{ k}\Omega + R}$

$4(4\text{ k}\Omega + R) = 20R$

$16\text{ k}\Omega + 4R = 20R$

$16R = 16\text{ k}\Omega$

$R = \dfrac{16}{16}\text{k}\Omega = \mathbf{1\ k\Omega}$

b. $110\text{ V} = \dfrac{(6\text{ M}\Omega + R)(140\text{ V})}{6\text{ M}\Omega + R + 3\text{ M}\Omega}$

$110(9\text{ M}\Omega + R) = 840\text{ M}\Omega + 140R$

$990\text{ M}\Omega + 110R = 840\text{ M}\Omega + 140R$

$30R = 150\text{ M}\Omega$

$R = \dfrac{150}{30}\text{ M}\Omega = \mathbf{5\ M\Omega}$

35. a. $R_{\text{bulb}} = \dfrac{8\text{ V}}{50\text{ mA}} = 160\ \Omega$

$V_{\text{bulb}} = 8\text{ V} = \dfrac{R_{\text{bulb}}(12\text{ V})}{R_{\text{bulb}} + R_x} = \dfrac{160\ \Omega(12\text{ V})}{160\ \Omega + R_x}$, $R_x = \mathbf{80\ \Omega}$ in series with the bulb

b. $V_R = 12\text{ V} - 8\text{ V} = 4\text{ V}$, $P = \dfrac{V^2}{R} = \dfrac{(4\text{ V})^2}{80\ \Omega} = 0.2\text{ W}$, $\mathbf{\therefore 1/4\ W\ okay}$

36. $V_{R_1} + V_{R_2} = 72\text{ V}$

$\dfrac{1}{5}V_{R_2} + V_{R_2} = 72\text{ V}$

$V_{R_2}\left[1 + \dfrac{1}{5}\right] = 72\text{ V},\ V_{R_2} = \dfrac{72\text{ V}}{1.2} = 60\text{ V}$

$R_2 = \dfrac{V_{R_2}}{I_{R_2}} = \dfrac{60\text{ V}}{4\text{ mA}} = \mathbf{15\ k\Omega},\ R_1 = \dfrac{V_{R_1}}{I_{R_1}} = \dfrac{72\text{ V} - 60\text{ V}}{4\text{ mA}} = \dfrac{12\text{ V}}{4\text{ mA}} = \mathbf{3\ k\Omega}$

37. $R_T = R_1 + R_2 + R_3 = 2R_3 + 7R_3 + R_3 = 10R_3$

$V_{R_3} = \dfrac{R_3(60\text{ V})}{10R_3} = \mathbf{6\ V},\ V_{R_1} = 2V_{R_3} = 2\ (6\text{ V}) = \mathbf{12\ V},\ V_{R_2} = 7V_{R_3} = 7(6\text{ V}) = \mathbf{42\ V}$

38. a. $V_{R_3} = 4V_{R_2} = 4(3V_{R_1}) = 12V_{R_1}$

$E = V_{R_1} + 3V_{R_1} + 12V_{R_1}\ \therefore R_T = R_1 + 3R_1 + 12R_1 = 16R_1 = \dfrac{64\text{ V}}{10\text{ mA}} = 6.4\text{ k}\Omega$

$R_1 = \dfrac{6.4\text{ k}\Omega}{16} = \mathbf{400\ \Omega}$, $R_2 = 3R_1 = \mathbf{1.2\ k\Omega}$, $R_3 = 12R_1 = \mathbf{4.8\ k\Omega}$

b. $R_T = \dfrac{64\text{ V}}{10\,\mu\text{A}} = 6.4\text{ M}\Omega$, $R_1 = \dfrac{6.4\text{ M}\Omega}{16} =$ **400 kΩ**, $R_2 =$ **1.2 MΩ**, $R_3 =$ **4.8 MΩ**

$\dfrac{I_1}{I'} = \dfrac{10\text{ mA}}{10\,\mu\text{A}} =$ **10^3** and $\dfrac{R_1'}{R_1} = \dfrac{400\text{ k}\Omega}{400\ \Omega} =$ **10^3** also

39. a. $V_a = 12\text{ V} + 5\text{ V} =$ **17 V**
$V_b = 5\text{ V} + 16\text{ V} =$ **21 V**
$V_{ab} = 17\text{ V} - 21\text{ V} =$ **−4 V**

b. $V_a =$ **−6 V**
$-6\text{ V} + 6\text{ V} + 10\text{ V} - V_b = 0$, $V_b =$ **10 V**
$V_{ab} = V_a - V_b = -6\text{ V} - 10\text{ V} =$ **−16 V**

c. $-8\text{ V} + 3\text{ V} - V_a = 0$, $V_a =$ **−5 V**
$V_b =$ **−8 V**
$V_{ab} = V_a - V_b = -5\text{ V} - (-8\text{ V}) = -5\text{ V} + 8\text{ V} =$ **+3 V**

40. a. $I\downarrow = \dfrac{60\text{ V} + 20\text{ V}}{18\ \Omega + 82\ \Omega} = \dfrac{80\text{ V}}{100\ \Omega} =$ **0.8 A**
$V_a = 60\text{ V} - I(18\ \Omega) = 60\text{ V} - (0.8\text{ A})(18\ \Omega) = 60\text{ V} - 14.4\text{ V} =$ **45.6 V**

b. $\overrightarrow{\text{I}} = \dfrac{100\text{ V} - 60\text{ V}}{4(2\text{ k}\Omega)} = \dfrac{40\text{ V}}{8\text{ k}\Omega} =$ **5 mA**
$V_a - I(2\text{ k}\Omega) + 100\text{ V} = 0$
$V_a = (I)(2\text{ k}\Omega) - 100\text{ V} = (5\text{ mA})(2\text{ k}\Omega) - 100\text{ V} = 10\text{ V} - 100\text{ V} =$ **−90 V**

41. $I = \dfrac{47\text{ V} - 20\text{ V}}{2\text{ k}\Omega + 3\text{ k}\Omega + 4\text{ k}\Omega} = \dfrac{27\text{ V}}{9\text{ k}\Omega} = 3\text{ mA (CCW)}$
$V_{2\text{k}\Omega} = 6\text{ V}$, $V_{3\text{k}\Omega} = 9\text{ V}$, $V_{4\text{k}\Omega} = 12\text{ V}$

a. $V_a =$ **20 V**, $V_b = 20\text{ V} + 6\text{ V} =$ **26 V**, $V_c = 20\text{ V} + 6\text{ V} + 9\text{ V} =$ **35 V**
$V_d =$ **−12 V**, $V_e =$ **0 V**

b. $V_{ab} =$ **−6 V**, $V_{dc} =$ **−47 V**, $V_{cb} =$ **9 V**

c. $V_{ac} =$ **−15 V**, $V_{db} = -47\text{ V} + 9\text{ V} =$ **−38 V**

42. $I_{R_2} = \dfrac{4\text{ V} + 4\text{ V}}{8\ \Omega} = \dfrac{8\text{ V}}{8\ \Omega} = 1\text{ A}$, $R_1 = \dfrac{V_{R_1}}{I} = \dfrac{12\text{ V} - 4\text{ V}}{1\text{ A}} = \dfrac{8\text{ V}}{1\text{ A}} =$ **8 Ω**,
$R_3 = \dfrac{V_{R_3}}{I} = \dfrac{8\text{ V} - 4\text{ V}}{1\text{ A}} = \dfrac{4\text{ V}}{1\text{ A}} =$ **4 Ω**

43. $V_{R_2} = 48\text{ V} - 12\text{ V} = 36\text{ V}$

$$R_2 = \frac{V_{R_2}}{I} = \frac{36\text{ V}}{16\text{ mA}} = \mathbf{2.25\ k\Omega}$$

$V_{R_3} = 12\text{ V} - 0\text{ V} = 12\text{ V}$

$$R_3 = \frac{V_{R_3}}{I} = \frac{12\text{ V}}{16\text{ mA}} = \mathbf{0.75\ k\Omega}$$

$V_{R_4} = 20\text{ V}$

$$R_4 = \frac{V_{R_4}}{I} = \frac{20\text{ V}}{16\text{ mA}} = \mathbf{1.25\ k\Omega}$$

$V_{R_1} = E - V_{R_2} - V_{R_3} - V_{R_4}$

$= 100\text{ V} - 36\text{ V} - 12\text{ V} - 20\text{ V} = 32\text{ V}$

$$R_1 = \frac{V_{R_1}}{I} = \frac{32\text{ V}}{16\text{ mA}} = \mathbf{2\ k\Omega}$$

44. a. $V_a = -8\text{ V} + 14\text{ V} = \mathbf{+6\ V}$, $V_b = \mathbf{14\ V}$

$\boldsymbol{V}_c = +I(10\ \Omega) - 6\text{ V}$ with

$$I = \frac{14\text{ V} + 6\text{ V}}{10\ \Omega + 10\ \Omega} = \frac{20\text{ V}}{20\ \Omega} = 1\text{ A}$$

Therefore, $V_c = (1\text{ A})(10\ \Omega) - 6\text{ V} = 10\text{ V} - 6\text{ V} = \mathbf{4\ V}$

$V_d = \mathbf{0\ V}$

b. $V_{ab} = V_a - V_b = 6\text{ V} - 14\text{ V} = \mathbf{-8\ V}$

$V_{cb} = V_c - V_b = 4\text{ V} - 14\text{ V} = \mathbf{-10\ V}$

$V_{cd} = V_c - V_d = 4\text{ V} - 0\text{ V} = \mathbf{4\ V}$

c. $V_{ad} = V_a - V_d = 6\text{ V} - 0\text{ V} = \mathbf{6\ V}$

$V_{ca} = V_c - V_a = 4\text{ V} - 6\text{ V} = \mathbf{-2\ V}$

45. $V_0 = \mathbf{0\ V}$, $V_4 = (2\text{ k}\Omega)(6\text{ mA}) + 3\text{ V} = 12\text{ V} + 3\text{ V} = \mathbf{15\ V}$, $V_7 = \mathbf{4\ V}$

$V_{10} = V_1 - V_0 = 12\text{ V} - 0\text{ V} = \mathbf{12\ V}$, $V_{23} = V_2 - V_3 = 4\text{ V} - (-8\text{ V}) = 4\text{ V} + 8\text{ V} = \mathbf{12\ V}$

$V_{30} = V_3 - V_0 = -8\text{ V} - 0\text{ V} = \mathbf{-8\ V}$, $V_{67} = V_6 - V_7 = 4\text{ V} - 4\text{ V} = \mathbf{0\ V}$

$V_{56} = V_5 - V_6 = 3\text{ V} - 4\text{ V} = \mathbf{-1\ V}$, $I\uparrow = \dfrac{4\text{ V} + 8\text{ V}}{4\ \Omega} = \dfrac{12\text{ V}}{4\ \Omega} = \mathbf{3\ A}$

46. $V_0 = \mathbf{0\ V}$, $V_{03} = V_0 - V_3 = 0\text{ V} - 0\text{ V} = \mathbf{0\ V}$, $V_2 = (3\text{ mA})(3.3\text{ k}\Omega) = \mathbf{9.9\ V}$

$V_{23} = V_2 - V_3 = 9.9\text{ V} - 0\text{ V} = \mathbf{9.9\ V}$, $V_{12} = V_1 - V_2 = 20\text{ V} - 9.9\text{ V} = \mathbf{10.1\ V}$

$\Sigma I_i = \Sigma I_o$

$I_i = 4\text{ mA} + 3\text{ mA} + 10\text{ mA} = \mathbf{17\ mA}$

47. a. $V_L = I_L R_L = (2\text{ A})(28\ \Omega) = 56\text{ V}$
$V_{\text{int}} = 60\text{ V} - 56\text{ V} = 4\text{ V}$
$R_{\text{int}} = \dfrac{V_{\text{int}}}{I} = \dfrac{4\text{ V}}{2\text{ A}} = \mathbf{2\ \Omega}$

b. $VR = \dfrac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% = \dfrac{60\text{ V} - 56\text{ V}}{56\text{ V}} \times 100\% = \mathbf{7.14\%}$

48. a. $V_L = \dfrac{3.3\ \Omega(12\text{ V})}{3.3\ \Omega + 43\ \text{m}\Omega} = \dfrac{39.6\text{ V}}{3.343\ \Omega} = \mathbf{11.85\text{ V}}$

b. $VR = \dfrac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% = \dfrac{12\text{ V} - 11.85\text{ V}}{11.85\text{ V}} \times 100\% = \mathbf{1.27\%}$

c. $I_s = I_L = \dfrac{11.85\text{ V}}{3.3\ \Omega} = 3.59\text{ A}$
$P_s = EI_s = (12\text{ V})(3.59\text{ A}) = \mathbf{43.08\text{ W}}$
$P_{\text{int}} = I^2 R_{\text{int}} = (3.59\text{ A})^2\ 43\ \Omega = \mathbf{0.554\text{ W}}$

49. a. $I = \dfrac{E}{R_T} = \dfrac{12\text{ V}}{2\ \text{k}\Omega + 6.8\ \text{k}\Omega} = \dfrac{12\text{ V}}{8.8\ \text{k}\Omega} = \mathbf{1.36\text{ mA}}$

b. $I = \dfrac{E}{R_T} = \dfrac{12\text{ V}}{8.8\ \text{k}\Omega + 0.25\ \text{k}\Omega} = \dfrac{12\text{ V}}{9.05\ \text{k}\Omega} = \mathbf{1.33\text{ mA}}$

c. not for most applications.