Instructor's Solutions Manual to Accompany Circuit Analysis: Theory and Practice, 5e

Allan H. Robbins
Wilhelm C. Miller

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Chapter 1

Introduction

1.3 Converting Units

1. a. $27\ \cancel{\text{min}} \times (60\ \text{s}/\cancel{\text{min}}) = 1620\ \text{s}$

   b. $0.8\ \cancel{\text{h}} \times (3600\ \text{s}/\cancel{\text{h}}) = 2880\ \text{s}$

   c. $\left(2\cancel{\text{h}} \times \frac{3600\ \text{s}}{\cancel{\text{h}}}\right) + \left(3\ \cancel{\text{min}} \times \frac{60\ \text{s}}{\cancel{\text{min}}}\right) + 47\ \text{s} = 7427\ \text{s}$

   d. $35\ \cancel{\text{hp}} \times (746\ \text{W}/\cancel{\text{hp}}) = 26\ 110\ \text{W}$

   e. $1827\ \cancel{\text{W}} \times \frac{1\ \text{hp}}{746\ \cancel{\text{W}}} = 2.45\ \text{hp}$

   f. $23\ \cancel{\text{rev}}. \times 360^\circ/\cancel{\text{rev}} = 8280^\circ$

3. a. $1.2\ \text{m} \times 70\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}} = 0.84\ \text{m}^2$

   b. $\frac{1}{2}\left(25\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right)(0.5\ \text{m}) = 0.0625\ \text{m}^2$

   c. $\left(10\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right)\left(25\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right)$
   $\left(80\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right) = 0.02\ \text{m}^3$

   d. $\frac{4\pi}{3}\left(10\ \cancel{\text{in}} \times \frac{2.54\ \cancel{\text{cm}}}{\cancel{\text{in}}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right)^3 = 0.0686\ \text{m}^3$

5. $\frac{15\ \text{parts}}{12\ \cancel{\text{s}}} \times \frac{3600\ \cancel{\text{s}}}{\text{h}} = 4500\ \text{parts/h}$

7. $\frac{27\ \cancel{\text{mi}}}{\cancel{\text{gal}}} \times \frac{1.609\ \text{km}}{\cancel{\text{mi}}} \times \frac{1\ \cancel{\text{gal}}}{3.785\ \text{liters}} = 11.5\ \text{km/liter}$

9. $\frac{18\cancel{^\circ}}{0.02\ \cancel{\text{s}}} \times \frac{1\ \text{rev}}{360\cancel{^\circ}} \times \frac{60\ \cancel{\text{s}}}{1\ \text{min}} = 150\ \text{rpm}$

11. $\frac{60\ \text{mi}}{\cancel{\text{h}}} \times 500\ \cancel{\text{s}} \times \frac{1\ \cancel{\text{h}}}{3600\ \cancel{\text{s}}} = 8.33\ \text{mi}$

13. $\frac{2000\ \cancel{\text{yd}}}{\cancel{\text{h}}} \times \frac{0.914\ \text{m}}{\cancel{\text{yd}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 0.508\ \text{m/s}$

15. $\frac{3\ \text{km}}{\text{h}} \times \frac{8}{60}\ \text{h} + \frac{5\ \text{km}}{\text{h}} \times 1.25\ \text{h} + \frac{4\ \text{km}}{\text{h}} \times \frac{12}{60}\ \text{h} = 7.45\ \text{km}$

17. $\frac{2\ \text{km}}{\text{h}} \times \frac{15}{60}\ \text{h} + \frac{5\ \text{km}}{\text{h}} + \frac{18\ \text{h}}{60}\ \text{h} + \frac{2.5\ \text{km}}{\text{h}} \times t_3 = 2.85\text{km}$

    Thus, $t_3 = 0.34\text{h} = 20.4$ minutes.

19. Machine 1: $\frac{\$0.43}{\text{min}} \times \frac{60\ \text{min}}{\text{h}} = \$25.80/\text{h}$

    Machine 2: $\frac{\$200}{8\ \text{h}} = \$25.00/\text{h}$ (This one is cheaper to operate. Buy it.)

1.4 Power of Ten Notation

21. a. 8.675×10^3

    b. 8.72×10^{-3}

    c. 1.24×10^3

    d. 3.72×10^{-1}

    e. 3.48×10^2

    f. 2.15×10^{-7}

    g. 1.47×10^1

23. a. $\frac{1.25 \times 10^2}{1 \times 10^3} = 1.25 \times 10^{-1}$

    b. $\frac{8 \times 10^4}{1 \times 10^{-3}} = 8 \times 10^7$

    c. $\frac{3 \times 10^4}{1.5 \times 10^6} = 2 \times 10^4 \times 10^{-6} = 2 \times 10^{-2}$

    d. $\frac{(16)(21.8) \times 10^{-7} \times 10^6}{(14.2)(12) \times 10^{-5}} = 2.05 \times 10^4$

25. a. $(4 \times 10^3)(5 \times 10^{-2})^2 = (4 \times 10^3)(25 \times 10^{-4})$
    $= 100 \times 10^{-1} = 10$

    b. $(4 \times 10^3)(-5 \times 10^{-2})^2 = (4 \times 10^3)(25 \times 10^{-4}) = 10$

    c. $\frac{(6 \times 10)^2}{(10 \times 10^{-1})} = \frac{36 \times 10^2}{1} = 3.6 \times 10^3$

    d. $\frac{(50)^{-2}(2.5 \times 10^6)(6 \times 10^3)}{(1 \times 10^3)(2 \times 10^{-1})^2} = \frac{(2.5)(6) \times 10^6 \times 10^3}{(5 \times 10)^2(1 \times 10^3)(4 \times 10^{-2})}$

    $= \frac{15 \times 10^9}{25 \times 10^2 \times 10^3 \times 4 \times 10^{-2}} = \frac{15 \times 10^9}{100 \times 10^3}$

    $= 0.15 \times 10^6 = 15 \times 10^4$

    e. $\frac{(-0.027)^{1/3}(-0.2)^2}{(24)^\circ \times 10^{-3}} = \frac{(-0.3)(-2 \times 10^{-1})^2}{1 \times 10^{-3}}$

    $= \frac{(-0.3)(4 \times 10^{-2})}{1 \times 10^{-3}} = -12$

27. i. $(8.42 \times 10^2)(1.4 \times 10^{-3}) = 11.79 \times 10^{-1} = 1.179$

ii. $\dfrac{3.52 \times 10^{-2}}{7.91 \times 10^{-3}} = 0.445 \times 10^1 = 4.45$

Direct computation for these examples is less work.

29. 6.24×10^{18}

31. $\dfrac{6.24 \times 10^{18} \text{ electrons}}{1 \text{ s}} \times 10.03 \times 10^3 \text{ s}$

$= 62.6 \times 10^{21}$ electrons

33. $t = \dfrac{3.47 \times 10^5 \text{ km}}{299\ 792.458 \text{ km/s}} = 1.16 \text{ s}$

35. $\dfrac{3.73 \times 10^4 \text{ m}^3}{1 \text{ s}} \times \dfrac{3600 \text{ s}}{1 \text{ h}} \times \dfrac{1 \text{ liter}}{1 \times 10^{-3} \text{ m}^3}$

$= 13.4 \times 10^{10}$ liters/h

1.5 Prefixes

37. a. kilo, k
    b. mega, M
    c. giga, G
    d. micro, μ
    e. milli, m
    f. pico, p

39. a. 1.5 ms
    b. 27 μs
    c. 350 ns

41. a. 150×10^3 V; 0.15×10^6 V
    b. 0.33×10^{-3} W; 33×10^{-5} W

43. a. 330 V + 150 V + 200 V = 680 V
    b. 60 W + 100 W + 2.7 W = 162.7 W

45. $1500 \text{ W} = 1.5 \times 10^3 \text{ W} = 1.5 \text{ kW}$

47. $I_3 = I_1 + I_2 + I_4 = 12 \text{ A} + 150 \text{ A} + 25 \text{ A} = 187 \text{ A}$

49. $39 \text{ mmfd} = 39\mu\mu\text{F} = 39 \times 10^{-6} \times 10^{-6} = 39 \times 10^{-12}\text{F}$
$= 39 \text{ pF}$

51. Radio signal: $t = \dfrac{5000 \text{ km}}{299\ 792.458 \text{ km/s}} = 16.68 \text{ ms}$

Telephone signal: $t = \dfrac{5000 \times 10^3 \text{ m}}{150 \text{ m/}\mu\text{s}} = 33.33 \text{ ms}$

$\therefore$ Radio signal arrives first by 16.65 ms.

53. a. $R = \dfrac{V}{I} = \dfrac{50 \text{ V}}{24 \text{ mA}} = 2.083 \text{ k}\Omega$. (Since V and I are specified as exact, you can use as many digits as you like.)

b. $R_{\text{max}} = \dfrac{V_{\text{max}}}{I_{\text{min}}} = \dfrac{50.1 \text{ V}}{23.9 \text{ mA}} = 2.096 \text{ k}\Omega = 2.10 \text{ k}\Omega$

when rounded to 3 digits

$R_{\text{min}} = \dfrac{V_{\text{min}}}{I_{\text{max}}} = \dfrac{49.9 \text{ V}}{24.1 \text{ mA}} = 2.071 \text{ k}\Omega = 2.07 \text{ k}\Omega$

when rounded to 3 digits.

The actual value of R lies somewhere between 2.07 kΩ and 2.10 kΩ.

55. See CD in the back of the book.

1.6 Circuit Diagrams

57. Same as Figure 1–7(a) of the text.

Chapter

2

Voltage and Current

2.1 Atomic Theory

1. There are of the order of 10^{23} free electrons per cm^3 at room temperature in copper.

a. $1 \text{ m}^3 = (100 \text{ cm})^3 = 10^6 \text{ cm}^3$. Thus, the number of electrons is

$$N = \frac{10^{23} \text{ electrons}}{\cancel{\text{cm}}^3} \times 10^6 \cancel{\text{cm}}^3 = 10^{29} \text{ electrons}$$

b. Volume =

$$\frac{\pi d^2}{4} \times l = \frac{\pi}{4}(0.163 \text{ cm})^2(500 \text{ cm}) = 10.4 \text{ cm}^3$$

$$N = \frac{10^{23} \text{ electrons}}{\cancel{\text{cm}}^3} \times 10.4 \cancel{\text{cm}}^3$$

$$= 10.4 \times 10^{23} \text{ electrons}$$

3. Original: $F_1 = k\dfrac{Q_1 Q_2}{r_1^2}$

New: $F_2 = \dfrac{k(2Q_1)(3Q_2)}{\left(\dfrac{r_1}{2}\right)^2} = \dfrac{(2)(3)}{\left(\dfrac{1}{2}\right)^2}\left[k\dfrac{Q_1 Q_2}{r_1^2}\right] = 24\, F_1$

$\therefore$ Force increases by a factor of 24.

5. a. It has a lot of free electrons. This results from having few (e.g., 1) electrons in its valence shell

b. Inexpensive and easily formed into wires.

c. Has a full valence shell. Therefore, no free electrons.

d. The electrical force is so great that electrons are torn from their parent atoms. This movement of electrons constitutes a current. We see the effect as a lightning discharge.

2.2 The Unit of Electrical Charge: The Coulomb

7. a. $F = \dfrac{9 \times 10^9 (1 \times 10^{-6} \text{ C})(7 \times 10^{-6} \text{ C})}{(10 \times 10^{-3})^2}$

$= 630$ N (repulsive)

b. $F = \dfrac{9 \times 10^9 (8 \times 10^{-6})(4 \times 10^{-6})}{(0.12)^2}$

$= 20$ N (attractive)

c. $F = \dfrac{9 \times 10^9 (1.602 \times 10^{-19})^2}{(12 \times 10^{-8})^2}$

$= 1.60 \times 10^{-14}$ N (replusive)

d. $F = \dfrac{9 \times 10^9 (1.602 \times 10^{-19})^2}{(5.3 \times 10^{-11})^2}$

$= 8.22 \times 10^{-8}$ N (attractive)

e. Neutron is uncharged $\therefore F = 0$

9. $180 \text{ N} = \dfrac{9 \times 10^9 (4 \times 10^{-6}) Q_2}{(2 \times 10^{-2})^2}$ $\therefore Q_2 = 2\mu\text{C}$ (Attractive)

11. $0.02 \text{ N} = \dfrac{9 \times 10^9 Q_1 (5\, Q_1)}{(0.5)^2}$

$0.02 = 180 \times 10^9\, Q_1^2$

$\therefore Q_1 = 0.333\, \mu$C and $Q_2 = 1.67\, \mu$C, both (+) or both (–).

13. 19×10^{13} ~~electron~~ $\times 1.6 \times 10^{-19}$ coulomb/~~electron~~ $= 30.4\, \mu$C

15. $Q_1 = -(14.6 \times 10^{13} \times 1.60 \times 10^{-19}) = -23.4\, \mu$C

$Q_2 = 1.3\, \mu$C

$Q_{\text{final}} = Q_{\text{initial}} + Q_1 + Q_2$

$5.6\, \mu\text{C} = Q_{\text{initial}} - 23.4\, \mu\text{C} + 1.3\, \mu\text{C}$

$\therefore Q_{\text{initial}} = 27.7\, \mu$C (positive)

2.3 Voltage

17. $V = \dfrac{W}{Q} = \dfrac{360 \text{ J}}{15 \text{ C}} = 24 \text{ V}$

19. $V = \dfrac{W}{Q} = \dfrac{1200 \text{ J}}{0.5 \text{ C}} = 2400 \text{ V}$

21. $W = QV = (0.5 \times 10^{-6} \text{ C})(8.5 \times 10^3 \text{ V}) = 4.25$ mJ

23. $Q = \dfrac{W}{V} = \dfrac{57 \text{ J}}{12 \text{ V}} = 4.75 \text{ C}$

2.4 Current

25. $$I = \frac{Q}{t} = \frac{250\ \mu\text{C}}{5\text{ ms}} = 50\text{ mA}$$

27. $Q = It = (16.7\text{ mA})(20\text{ ms}) = 334\ \mu\text{C}$

29. $Q = (93.6 \times 10^{12})(1.6 \times 10^{-19}) = 15\ \mu\text{C}$

$$I = \frac{Q}{t} = \frac{15 \times 10^{-6}\text{ C}}{5 \times 10^{-3}\text{ s}} = 3\text{ mA}$$

31. At $t = 0$, $q_0 = 20$ C. At $t = 1$ s, $q_1 = 100$ C.

$$I = \frac{\Delta q}{\Delta t} = \frac{100\text{ C} - 20\text{ C}}{1\text{ s}} = \frac{80\text{ C}}{1\text{ s}} = 80\text{ C/s} = 80\text{ A}$$

33. $$Q = \frac{47 \times 10^{19}\text{ electrons}}{6.24 \times 10^{18}\text{ electrons/C}} = 75.3\text{ C}$$

$$V = \frac{W}{Q} = \frac{1353.6\text{ J}}{75.3} = 18.0\text{ V}$$

$$I = \frac{Q}{t} = \frac{75.3\text{ C}}{78\text{ s}} = 0.966\text{ A}$$

.

2.5 Practical DC Sources

35. a. $E_T = 1.47 + 1.61 + 1.58 = 4.66$ V
    b. $E_T = 1.47 + 1.61 - 1.58 = 1.50$ V

37. $$\text{Life} = \frac{\text{capacity}}{\text{drain}} = \frac{1400\text{ mAh}}{28\text{ mA}} = 50\text{ h}$$

39. From Figure 2-15, capacity at 5˚C is 90% of its value MAX at 25˚C. Therefore, capacity = 0.9 Max = 81 Ah. Thus, Max = 81/0.9 = 90 Ah. At –15˚C, capacity = 0.65 Max = 0.65 (90) = 58.5 Ah. Thus, life ≈ 58.5 Ah/5 A = 11.7 h.

2.6 Measuring Voltage and Current

41. Both

43. The voltmeter and ammeter are interchanged.

45. Meter 1: Reading is 7 A, Meter 2: Reading is –7 A

2.7 Switches, Fuses, and Circuit Breakers

47. When a fuse “blows,” it becomes an open circuit with source voltage across it. The voltage rating tells you how much voltage you can use the fuse with so that it does not arc over when it blows.

Chapter

3

Resistance

3.1 Resistance of Conductors

1. a. $$R = \frac{(2.825 \times 10^{-18}\ \Omega \cdot \text{m})(100\ \text{m})}{\pi(0.5 \times 10^{-3}\ \text{m})^2} = 3.60\ \Omega$$

b. $$R = \frac{2.825 \times 10^{-8}\ \Omega \cdot \text{m})(100\ \text{m})}{\pi(1.0 \times 10^{-3}\ \text{m})^2} = 0.900\ \Omega$$

c. $$R = \frac{(2.825 \times 10^{-8}\ \Omega \cdot \text{m})(100\ \text{m})}{\pi(0.005 \times 10^{-3}\ \text{m})^2} = 36.0\ \text{k}\Omega$$

d. $$R = \frac{(2.825 \times 10^{-8}\ \Omega \cdot \text{m})(100\ \text{m})}{\pi(0.05 \times 10^{-2}\ \text{m})^2} = 36.0\ \text{m}\Omega$$

3. $$L = 250\ \text{ft} = 250\ \text{ft}\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 76.2\ \text{m}$$

$$A = \frac{\rho L}{R} = \frac{(1.723 \times 10^{-8}\ \Omega \cdot \text{m})(76.2\ \text{m})}{0.02\ \Omega}$$

$$= 6.56 \times 10^{-5}\ \text{m}^2$$

$$\text{w} = 0.25\ \text{inch} = 0.25\ \text{inch}\left(\frac{2.54 \times 10^{-2}\ \text{m}}{1\ \text{inch}}\right)$$

$$= 0.00635\ \text{m}$$

$$h = \frac{A}{\text{w}} = \frac{6.56 \times 10^{-5}\ \text{m}^2}{0.00635\ \text{m}} = 0.0103\ \text{m} = 0.407\ \text{inch}$$

5. $$R = \frac{\rho L}{A} \qquad L = \frac{RA}{\rho}$$

$$= \frac{(10.3\ \Omega)(\pi)(0.40 \times 10^{-3}\ \text{m})^2}{1.723 \times 10^{-8}\ \Omega \cdot \text{m}}$$

$$L = 300\ \text{m}$$

$$L = 986\ \text{ft}$$

7. $$R = \frac{\rho L}{A} \qquad \rho = \frac{RA}{L}$$

$$= \frac{(3.0\ \Omega)(\pi)(0.25 \times 10^{-3}\ \text{m})^2}{6.00 \times 10^{-2}\ \text{m}}$$

$$= 982 \times 10^{-8}\ \Omega \cdot \text{m}$$

Resistivity is less than ρ for carbon.

9. $$R = \frac{\rho L}{A} \qquad \rho = \frac{R \cdot A}{L}$$

$$= \frac{(32\ \Omega)(\pi)(0.75 \times 10^{-3}\ \text{m})^2}{2500\ \text{m}}$$

$$= 2.26 \times 10^{-8}\ \Omega \cdot \text{m}$$

This alloy is not as good a conductor as copper.

3.2 Electrical Wire Tables

11. $$\text{AWG 22}: R = (300\ \text{ft})\left(\frac{16.2\ \Omega}{1000\text{ft}}\right) = 4.86\ \Omega$$

$$\text{AWG 19}: R = (300\ \text{ft})\left(\frac{8.05\ \Omega}{1000\ \text{ft}}\right) = 2.42\ \Omega$$

Diameter of AWG 19 is 1.42 times the diameter of AWG 22.

The resistance of AWG 19 is $\frac{1}{2}$ the resistance of AWG 22.

13. From Table 3-2, AWG 22 can handle about 2 A of current. Since AWG 19 is 3 sizes larger, it should handle about 4 A of current.

Since AWG 30 is ten sizes smaller than AWG 20 (which can handle 3 A), AWG 30 can handle about 0.30 A.

15. $$R = \left(\frac{415\ \Omega}{1000\ \text{ft}}\right)L = 550\ \Omega$$

$$L = (550\ \Omega)\left(\frac{1000\ \text{ft}}{415\ \Omega}\right) \approx 1330\ \text{ft} \approx 405\ \text{m}$$

3.3 Resistance of Wires—Circular Mils

17. a. $D = 0.016$ in $= 16$ mil

$A = 16^2 = 256$ CM

b. $$D = 2.0\ \text{mm} = 2.0\ \text{mm}\left(\frac{1\ \text{in}}{25.4\ \text{mm}}\right) = 0.0787\ \text{in}$$

$$= 78.4\ \text{mil}$$

$A = 78.4^2 = 6200$ CM

c. $A = (0.25\text{in})(6.0\text{in})$

$= (250\text{mil})(6000\text{mil})A$

$= 1.50 \times 10^6 \text{sq mil}$

$A = 1.91 \times 10^6 \text{CM}$

$= 1910$ MCM

19. a. $$R = \frac{\rho M}{A} = \frac{\left(1036 \frac{\text{CM} \cdot \Omega}{\text{ft}}\right)(400 \text{ ft})}{256 \text{ CM}} = 16.2\ \Omega$$

b. $$R = \frac{\left(1036 \frac{\text{CM} \cdot \Omega}{\text{ft}}\right)(400 \text{ ft})}{6200 \text{ CM}} = 0.668\ \Omega$$

c. $$R = \frac{\left(1036 \frac{\text{CM} \cdot \Omega}{\text{ft}}\right)(400 \text{ ft})}{1.91 \times 10^{6} \text{ CM}} = 2.17 \times 10^{-3}\ \Omega$$

21. a. $$R = \frac{\rho L}{A}$$

$$A = \frac{\left(10.36 \frac{\text{CM} \cdot \Omega}{\text{ft}}\right)(200 \text{ ft})}{0.5\ \Omega} = 4144 \text{ CM}$$

$$A = 4144 \text{ CM}\left(\frac{\pi}{4} \frac{\text{sq mil}}{\text{CM}}\right) = 3255 \text{ sq mil}$$

b. $D = \sqrt{A} = 64.4 \text{ mil} = 0.0644 \text{ in}$

23. $D = 0.040 \text{ in} = 40 \text{ mil}$

a. $A = D^2 = 1600 \text{ CM}$

$$A = 1600 \text{ CM}\left(\frac{\pi}{4} \frac{\text{sq mil}}{\text{CM}}\right) = 1260 \text{ sq mil}$$

b. $$R = \frac{\rho L}{A} \quad L = \frac{R \cdot A}{\rho} = \frac{(12.5\ \Omega)(1600 \text{ CM})}{\left(10.37 \frac{\text{CM} \cdot \pi}{\text{ft}}\right)} = 1930 \text{ ft}$$

25. *At T = –30°C:*

$$R = \frac{-30^\circ - (-236^\circ)}{20^\circ - (236^\circ)}(50\ \Omega) = 40.2\ \Omega$$

At T = 0°C:

$$R = \frac{0^\circ - (-236^\circ)}{20^\circ - (-236^\circ)}(50\ \Omega) = 46.1\ \Omega$$

At T = 200° C:

$$R = \frac{200^\circ - (-236^\circ)}{20^\circ - (-236^\circ)}(50\ \Omega) = 85.2\ \Omega$$

27. a. Positive temperature coefficient since as temperature increases, resistance also increases.

b. $R_2 = R_1[1 + \alpha_1(T_2 - T_1)]$

$$\alpha_1 = \frac{\left(\frac{R_2}{R_1} - 1\right)}{T_2 - T_1} = \frac{\left(\frac{25\ \Omega}{20\ \Omega} - 1\right)}{85^\circ\text{C} - 20^\circ\text{C}} = 0.00385(^\circ\text{C})^{-1}$$

c. Temperature intercept:

$$\frac{20^\circ - \text{T}}{20\ \Omega} = \frac{85^\circ - 20^\circ}{25\ \Omega - 20\ \Omega}$$

$$\text{T} = -\frac{20\ \Omega(85^\circ - 20^\circ)}{25\ \Omega - 20\ \Omega} + 20^\circ = -240^\circ\text{C}$$

At T = 0°C:

$$R = \frac{100^\circ - (-240^\circ)}{20^\circ - (-240^\circ)}(20\ \Omega) = 18.5\ \Omega$$

At T = 100°C:

$$R = \frac{100^\circ - (-240^\circ)}{20^\circ - (-240^\circ)}(20\ \Omega) = 26.2\ \Omega$$

29. $$R = \frac{260^\circ - (-2270^\circ)}{20^\circ - (-2270^\circ)}(15.2\ \Omega) = 16.8\ \Omega$$

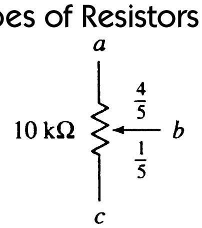
31. $$\text{m} = \frac{70\ \Omega}{140^\circ\ \text{C}} = 0.5\ \Omega/^\circ\text{C}$$

$$\text{R} = (0.5\ \Omega/^\circ\text{C})\text{T} + 130\ \Omega$$

$$\text{T} = \frac{-130\ \Omega}{0.5\ \Omega/^\circ\text{C}} = -260^\circ\text{C}$$

3.5 Types of Resistors

33.



a. $R_{ab} = 10\ \text{k}\Omega \quad R_{bc} = 0$

b. $R_{ab} = 8\ \text{k}\Omega \quad R_{bc} = 2\text{k}\Omega$

c. $R_{ab} = 2\text{k}\Omega \quad R_{bc} = 8\ \text{k}\Omega$

d. $R_{ab} = 0 \quad R_{bc} = 10\ \text{k}\Omega$

3.6 Color Coding of Resistors

35. a. $15 \times 10^4 \pm 10\% = 150\ \text{k}\Omega \pm 10\% = 150\ \text{k}\Omega \pm 15\ \text{k}\Omega$

b. $28 \times 0.1 \pm 5\% = 2.8\ \Omega \pm 5\%$

$= 2.8\ \Omega \pm 0.14\ \Omega$

(with a reliability of 0.001%)

c. $47 \times 10^6 \pm 5\% = 47\ \text{M}\Omega \pm 5\% = 47\ \text{M}\Omega \pm 2.4\ \text{M}\Omega$

d. $39 \times 10^0 \pm 5\% = 39\ \Omega \pm 5\%$

$= 39\ \Omega \pm 2\Omega$

(with a reliability of 0.1%)

3.7 Measuring Resistance—The Ohmmeter

37. Connect the ohmmeter between the two terminals of the light bulb. If the resistance is measured to be low (about 0 Ω), the bulb is functional. If the ohmmeter indicates an open circuit, the light bulb is burned out.

39. AWG 24 has a resistance of 25.7 Ω/1000 ft (Table 3-2)

Measure the resistance between the two ends of the wire. Calculate the approximate length (in feet) from:

$$L = \frac{R}{0.0257} \quad (L\text{–in feet})$$

3.8 Thermistors

41. a. At $T = 20^\circ\text{C}$, $R \cong 380\ \Omega$

b. At $T = 40^\circ\text{C}$, $R \cong 150\ \Omega$

c. The thermistor has a negative temperature coefficient since resistance decreases as temperature is increased.

3.11 Conductance

43. a. $$G = \frac{1}{R} = \frac{1}{0.25\ \Omega} = 4.0\ \text{S}$$

b. $$G = \frac{1}{500\ \Omega} = 2.0\ \text{mS}$$

c. $$G = \frac{1}{250\ \text{k}\Omega} = 4.0\ \mu\text{S}$$

d. $$G = \frac{1}{12.5\ \text{M}\Omega} = 0.08\ \mu\text{S}$$

45. $$R = (1000\ \text{m})\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)\left(\frac{104\ \Omega}{1000\ \text{ft}}\right) = 341\ \Omega$$

$$G = \frac{1}{341\ \Omega} = 2.93\ \text{mS}$$

Chapter

4

Ohm's Law, Power, and Energy

4.1 Ohm's Law

1. a. $I = \dfrac{E}{R} = \dfrac{40 \text{ V}}{20\ \Omega} = 2 \text{ A}$

b. $\dfrac{35 \text{ mV}}{5 \text{ m}\Omega} = 7.0 \text{ A}$

c. $\dfrac{200 \text{ V}}{40 \text{ k}\Omega} = 5 \text{ mA}$

d. $\dfrac{10 \text{ V}}{2.5 \text{ M}\Omega} = 4\mu\text{A}$

e. $\dfrac{7.5 \text{ V}}{2.5 \times 10^3\ \Omega} = 3 \text{ mA}$

f. $\dfrac{12 \times 10^3 \text{ V}}{2 \times 10^6\ \Omega} = 6 \text{ mA}$

3. a. $V = I\,R = (1 \times 10^{-3} \text{ A})(40 \times 10^3\ \Omega) = 40 \text{ V}$

b. $(10 \times 10^{-6} \text{ A})(30 \times 10^3\ \Omega) = 0.3 \text{ V}$

c. $(10 \times 10^{-3} \text{ A})(4 \times 10^4\ \Omega) = 400 \text{ V}$

d. $(12 \text{ A})(3 \times 10^{-2}\ \Omega) = 0.36 \text{ V}$

5. $R = \dfrac{E}{I} = \dfrac{120 \text{ V}}{1.25 \text{ A}} = 96\ \Omega$

7. $V = I\,R = (50 \times 10^{-3} \text{ A})(560\ \Omega) = 28 \text{ V}$

9. $I = G\,E = (0.2 \text{ S})(30 \text{ V}) = 6 \text{ A}$

11. $R = \dfrac{V}{I} = \dfrac{33 \text{ V}}{15 \text{ mA}} = 2.2 \text{ k}\Omega$

$\therefore$ Color code is Red, Red, Red

13. From its color code, $R = 22\ \Omega$. Fuse blows at 1 A.
This corresponds to $V = I\,R = (1 \text{ A})(22\ \Omega) = 22 \text{ V}$.

15. $\ell = (800 \text{ t})(3 \text{ inches/t}) = 2400 \text{ in} = 200 \text{ ft}$.
From the wire table (Chapter 3), resistance is 104 Ω/1000 ft. Thus, $R = (0.2)\ (104\ \Omega) = 20.8\ \Omega$ at 20°C.

a. At 20° C, $I = \dfrac{48 \text{ V}}{20.8\ \Omega} = 2.31 \text{ A}$

b. At 40°C, (using the method of Chapter 3),
$R = \left(\dfrac{274.5}{254.5}\right)(20.8\ \Omega) = 22.43\ \Omega$
Thus, $I = \dfrac{48 \text{ V}}{22.43\ \Omega} = 2.14 \text{ A}$

17. $R = \rho\dfrac{\ell}{A} = \dfrac{(2.825 \times 10^{-8})(100 \text{ m})}{\frac{\pi}{4}(0.5 \times 10^{-3} \text{ m})^2} = 14.39\ \Omega$

$E = I\,R = (200 \times 10^{-3} \text{ A})(14.39\ \Omega) = 2.88 \text{ V}$

19. This is a linear graph. Therefore, choose any *V-I* point, for example, 80 V and 20 A. Thus,
$R = \dfrac{V}{I} = \dfrac{80 \text{ V}}{20 \text{ A}} = 4\ \Omega$

21. $I_{\text{old}} = \dfrac{100 \text{ V}}{R} \qquad I_{\text{new}} = 2\,I_{\text{old}} = 2\left(\dfrac{100 \text{ V}}{R}\right)$

Also: $I_{\text{new}} = \dfrac{E_{\text{new}}}{2\,R}$

$\therefore\ \dfrac{2(100 \text{ V})}{R} = \dfrac{E_{\text{new}}}{2\,R}$

Cancel R. $\therefore\ E_{\text{new}} = 400 \text{ V}$

23. $A = \dfrac{\pi d^2}{4} = \dfrac{\pi}{4}(0.1 \times 10^{-3})^2 = 0.7854 \times 10^{-8} \text{ m}^2$

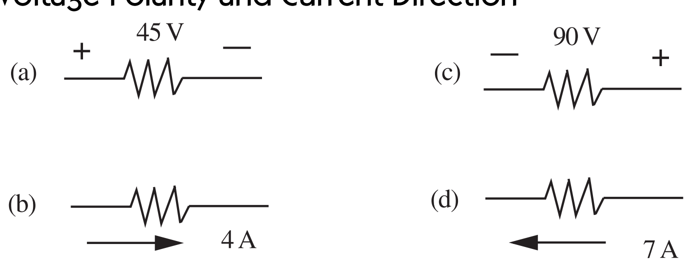
$\rho = 99.72 \times 10^{-8} \quad \Omega - \text{m}$

$R = \dfrac{\rho\ell}{A} = \dfrac{(99.72 \times 10^{-8})(25)}{0.7854 \times 10^{-8}} = 3174\ \Omega$

$I = \dfrac{12 \text{ V}}{3174\ \Omega} = 3.78 \text{ mA}$

4.2 Voltage Polarity and Current Direction

25.



4.3 Power

27. $P = \dfrac{W}{t} = \dfrac{723\text{ J}}{227\text{ s}} = 3.19\text{ J/s} = 3.19\text{ W}$

29. $P = EI = (12\text{ V})(3\text{ A}) = 36\text{ W}$

31. $P = I^2R$

$I^2 = \dfrac{P}{R} = \dfrac{1200\text{ W}}{6\ \Omega} = 200$

$\therefore I = \sqrt{200} = 14.1\text{ A}$

33. $P = \dfrac{V^2}{R} \therefore V^2 = PR$

$V^2 = (752\text{ W})(3\ \Omega) = 2256$

$V = 47.5\text{ V}$

35. $R = 10\,000\ \Omega$

$I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{0.25\text{ W}}{10\,000\ \Omega}} = 5\text{ mA}$

$V = \dfrac{P}{I} = \dfrac{0.25\text{ W}}{0.005\text{ A}} = 50\ V$

37. $I = \dfrac{P}{V} = \dfrac{445\text{ W}}{12\text{ V}} = 37.9\text{ A}$

39. $P = (3.56\text{ hp})(746\text{ W/hp}) = 2656\text{ W}$

41. $V = \sqrt{PR} = \sqrt{(2\text{ W})(270\ \Omega)} = 23.2\text{ V}$

$I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{2\text{ W}}{270\ \Omega}} = 86.1\text{ mA}$

43. $V_{min} = 95\text{ V};\ V_{max} = 105\text{ V}$

$\therefore P_{min} = \dfrac{(95\text{ V})^2}{25\ \Omega} = 361\text{ W}$

$P_{max} = \dfrac{(105\text{ V})^2}{25\ \Omega} = 441\text{ W}$

4.4 Power Direction Convention

45. a. $P = (12\text{ V})(4\text{ A}) = 48\text{ W} \rightarrow$

b. $P = (15\text{ V})(2\text{ A}) = 30\text{ W} \leftarrow$

c. $P = (8\text{V})(16\text{ A}) = 128\text{ W} \leftarrow$

d. $P = (30\text{ V})(8\text{ A}) = 240\text{ W} \rightarrow$

4.5 Energy

47. a. $W = Pt = (40\text{ W})\ (9\ \cancel{\text{h}} \times 3600\text{ s/}\cancel{\text{h}})$
$= 1.296 \times 10^6\text{ W– s} = 1.296 \times 10^6\text{ J}$

b. $W = (40\text{ W})(9\text{ h}) = 360\text{ Wh}$

c. Cost = (0.360 kWh)($0.08/kWh) = 2.88 cents

49. $W = (900)\left(\dfrac{5}{60}\right) + (120)(8)(1.7) +$

$(1100)\left(\dfrac{36}{60}\right) + \dfrac{(120)^2}{288}\left(\dfrac{24}{60}\right) = 2.387\text{ kWh}$

Cost = (2.387)($0.11) = $0.26

51. Per day: $W = (200\text{ W} \times 24\text{ h}) + (4000\text{ W})(24\text{ h}) + (3600\text{ W})(12\text{ h}) = 144\text{ kWh}$

Per year: $W_T = 365 \times 144\text{ kWh} = 52\,560\text{ kWh}$

Cost at $0.10/kW = $5256

53. It takes 12 (1.75 min) = 21 minutes to toast the loaf.

$W = (1100\text{ W})\left(\dfrac{21}{60}\right) = 385\text{ Wh} = 0.385\text{ kWh}$

Cost = (0.385)($0.13) = $0.05 = 5 cents

4.6 Efficiency

55. $P_{in} = \dfrac{P_{out}}{\eta} = \dfrac{50\text{ kW}}{0.97} = 51.5\text{ kW}$

57. $P_{out} = P_{in} - P_{loss} = 1100\text{ W} - 190\text{ W} = 910\text{ W}$

$\eta = \dfrac{P_{out}}{P_{in}} \times 100\% = \dfrac{910\text{ W}}{1100\text{ W}} \times 100\% = 82.7\%$

59. $P_{in} = (120\text{ V})(15\text{ A}) = 1800\text{ W}$

$P_{out} = (0.89)(1800\text{ W}) = 1602\text{ W}$

$P_{out} = 1602\text{ W/(746 W/hp)} = 2.15\text{ hp}$

61. $\eta_T = \eta_1 \times \eta_2 = (0.95)(0.80) = 0.76$

$P_{in} = (48\text{ V})(180\text{ A}) = 8640\text{ W}$

$P_{out} = \eta_T\, P_{in} = (0.76)(8640\text{ W}) = 6566\text{ W}$

$\therefore P_{out} = \dfrac{6566\text{ W}}{746\text{ W/hp}} = 8.8\text{ hp}$

63. $1600\text{ W} \longrightarrow \boxed{\eta_1} \xrightarrow{P_m} \boxed{0.75} \longrightarrow 1100\text{ W}$

$P_m = \dfrac{1100\text{ W}}{0.75} = 1467\text{ W} = \dfrac{1467}{746} = 1.97\text{ hp}$

65. $W_{out} = Pt = (35\text{ kW})(24\text{ h}) = 840\text{ kWh}$

$W_{in} = \dfrac{W_{out}}{\eta} = \dfrac{840\text{ kWh}}{0.55} = 1527\text{ kWh}$

Cost = (1527 kWh)($0.09/kWh) = $137.45

4.7 Nonlinear and Dynamic Resistances

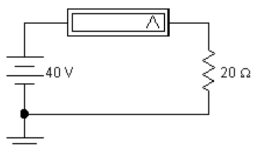
67. a. From the graph, $I = 2.5$ A $\therefore R_{dc} = \dfrac{25\text{ V}}{2.5\text{ A}} = 10\ \Omega$

b. From the graph, $I = 4.5$ A $\therefore R_{dc} = \dfrac{60\text{ V}}{4.5\text{ A}} = 13.3\ \Omega$

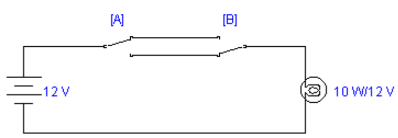
c. Because, for this resistor, R varies with current.

4.8 Computer-Aided Circuit Analysis

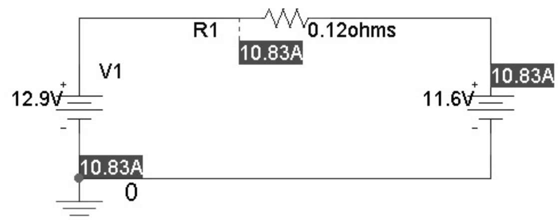
69. Use the following circuit. Set the source voltage and resistance as shown. Click the power ON/OFF switch and read the ammeter.



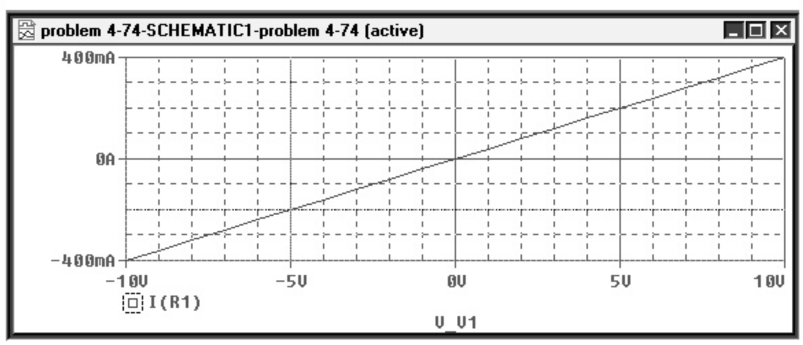
71. Click the power ON/OFF switch to the ON position, then operate switches A and B.

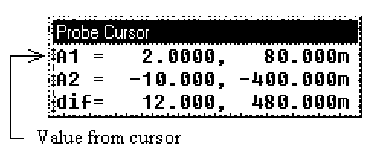


73. Following the procedure outlined in the text, build the circuit on the screen. Double-click the default voltage value beside the V1 source symbol and change it to 12.9 V, then click OK. Similarly, set V2 to 11.6 V. Double-click the 1k default resistance value and set it to 0.12 ohm. Click the New Simulation Profile icon, enter a name, click Create, select Bias Point Analysis and click OK. Click the Run icon and when simulation is complete, close the inactive window that appears. Click the Bias Point Current Display icon to read the current—see below.



75. See below.





Chapter

5

Series Circuits

5.2 Kirchhoff's Voltage Law

1. a. $V = +(3\text{ A})(10\ \Omega) = +30\text{ V}$

   b. $V = -(6\text{ A})(15\ \Omega) = -90\text{ V}$

3. a. $V = +(3\text{ A})(15\ \Omega) = +45\text{ V}$

   b. $V = +(-4\text{ A})(15\ \Omega) = -60\text{ V}$

   c. $V = +(6\text{ A})(15\ \Omega) = +90\text{ V}$

   d. $V = +(-7\text{ A})(15\ \Omega) = -105\text{ V}$

5. a. $V_1 = 33\text{ V} - 16\text{ V} - 10\text{ V} = 7\text{ V}$

   b. $V_2 = \dfrac{12\text{ W}}{3\text{ A}} = 4\text{ V}$

   $V_1 = 6\text{ V} - 9\text{ V} + 3\text{ V} + 4\text{ V} = 4\text{ V}$

7. $V_3 = \dfrac{36\text{ W}}{3\text{ A}} = 12\text{ V}$

   $V_4 = 24\text{ V} - 10\text{ V} - 12\text{ V} = 2\text{ V}$

5.3 Resistors in Series

9. a. $R_T = 3\text{ k}\Omega + 2\text{ k}\Omega + 5\text{ k}\Omega = 10\text{ k}\Omega$

   b. $R_T = 360\text{ k}\Omega + 580\text{ k}\Omega + 2000\text{ k}\Omega$
   $= 2940\text{ k}\Omega$
   $= 2.94\text{ M}\Omega$

   c. $R = 3900\ \Omega$

   $R_T = 6(3900\ \Omega) = 23\,400\ \Omega = 23.4\text{ k}\Omega$

11. a. $R_T = 200\ \Omega + 400\ \Omega + 1000\ \Omega + 50\ \Omega = 1650\ \Omega$

    $I = \dfrac{10\text{ V}}{1.65\text{ k}\Omega} = 6.06\text{ mA}$

    b. $R_T = 1.2\text{ k}\Omega + 3.3\text{ k}\Omega + 5.6\text{ k}\Omega + 0.82\text{ k}\Omega + 2.2\text{ k}\Omega + 0.33\text{ k}\Omega + 4.7\text{ k}\Omega = 18.15\text{ k}\Omega$

    $I = \dfrac{300\text{ V}}{18.15\text{ k}\Omega} = 16.5\text{ mA}$

13. a. $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{100\text{ mW}}{1\text{ k}\Omega}} = 10\text{ mA}$

    b. $R_T = \dfrac{130\text{ V}}{10\text{ mA}} = 13\text{ k}\Omega$

    c. $R = 13\text{ k}\Omega - (3\text{ k}\Omega + 4\text{ k}\Omega + 1\text{ k}\Omega) = 5\text{ k}\Omega$

    d. $V_{3\text{ k}\Omega} = (3\text{ k}\Omega)(10\text{ mA}) = 30\text{ V}$

    $V_{4\text{ k}\Omega} = 40\text{ V}$

    $V_{1\text{ k}\Omega} = 10\text{ V}$

    $V_R = 50\text{ V}$

    e. $P_T = (130\text{ V})(10\text{ mA}) = 1300\text{ mW}$

    $P_{3\text{ k}\Omega} = (10\text{ mA})2(3\text{ k}\Omega) = 300\text{ mW}$

    $P_{4\text{ k}\Omega} = 400\text{ mW}$

    $P_R = 500\text{ mW}$

    $P_T = 300\text{ mW} + 400\text{ mW} + 100\text{ mW} + 500\text{ mW}$
    $= 1300\text{ mW}$ (as required.)

15. a. $I = \dfrac{4\text{ V}}{100\ \Omega} = 0.04\text{ A} = 40\text{ mA}$

    b. $V_{R_1} = (300\text{ W})(0.04\text{ A}) = 12\text{ V}$

    $V_{R_3} = (250\text{ W})(0.04\text{ A}) = 10\text{ V}$

    c. $V = 12\text{ V} + 4\text{ V} + 10\text{ V} = 26\text{ V}$

17. a. $V_{R_2} + V_{R_3} = 16\text{ V} - 7.5\text{ V} = 8.5\text{ V}$

    $V_{R_2} = \dfrac{4.7\text{ k}\Omega}{4.7\text{ k}\Omega + 3.6\text{ k}\Omega}(8.5\text{ V}) = 4.81\text{ V}$

    $V_{R_3} = \dfrac{3.6\text{ k}\Omega}{4.7\text{ k}\Omega + 3.6\text{ k}\Omega}(8.5\text{ V}) = 3.69\text{ V}$

    b. $I = \dfrac{8.5\text{ V}}{(4.7\text{ k}\Omega + 3.6\text{ k}\Omega)} = 1.02\text{ mA}$

    c. $R_1 + \dfrac{7.5\text{ V}}{1.02\text{ mA}} + 7.32\text{ k}\Omega$

19. a. $R_T = 120\ \Omega + 39\ \Omega + 78\ \Omega + 220\ \Omega = 457\ \Omega$

    b. $I = \dfrac{36\text{ V}}{457\ \Omega} = 0.0788\text{ A} = 78.8\text{ mA}$

    c. $V_1 = (120\ \Omega)(0.0788\text{ A}) = 9.45\text{ V}$

    $V_2 = 3.07\text{ V}$

    $V_3 = 6.14\text{ V}$

    $V_4 = 17.33\text{ V}$

    d. $V_T = 9.45\text{ V} + 3.07\text{ V} + 6.14\text{ V} + 17.33\text{ V}$
    $= 35.99\text{ V} \cong E$

    e. $P_1 = (0.0788\text{ A})^2(120\ \Omega) = 0.745\text{ W}$

    $P_2 = 0.242\text{ W}$

    $P_3 = 0.484\text{ W}$

    $P_4 = 1.365\text{ W}$

    f. $R_1 : 1\text{ W}$

    $R_2 : \dfrac{1}{4}\text{ W}$

    $R_3 : \dfrac{1}{2}\text{ W}$

    $R_4 : 2\text{ W}$

g. $P_T = (36\text{ V})(0.0788\text{ A})$
$= 2.836\text{ W}$
$= 0.745\text{ W} + 0.242\text{ W} + 0.484\text{ W} + 1.365\text{ W}$

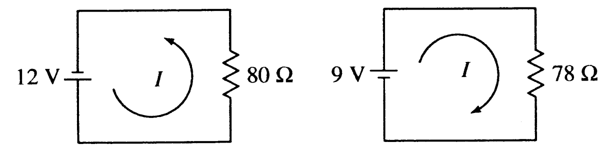
5.5 Interchanging Series Components

21. $R = \dfrac{E - V_F}{I_F}$

$= \dfrac{24\text{ V} - 3.8\text{ V}}{10\text{ mA}}$

$= 2.02\text{ k}\Omega$

23.



Circuit 1: $I = \dfrac{12\text{ V}}{80\ \Omega} = 0.15\text{ A}$

Circuit 2: $I = \dfrac{9\text{ V}}{78\text{ k}\Omega} = 0.115\text{ mA}$

5.6 Voltage Divider Rule

25. Circuit 1:

$R_T = 24\ \Omega$

$V_{6\ \Omega} = \left(\dfrac{6\ \Omega}{24\ \Omega}\right)24\ \Omega = 6\text{ V}$

$V_{3\ \Omega} = 3\text{ V}$

$V_{5\ \Omega} = 5\text{ V}$

$V_{8\ \Omega} = 8\text{ V}$

$V_{2\ \Omega} = 2\text{ V}$

$V_T = 6\text{ V} + 3\text{ V} + 5\text{ V} + 8\text{ V} + 2\text{ V} = 24\text{ V} = E$

Circuit 2:

$R_T = 4.3\text{ k}\Omega + 2.7\text{ k}\Omega + 7.8\text{ k}\Omega + 9.1\text{ k}\Omega = 23.9\text{ k}\Omega$

$V_{4.3\text{ k}\Omega} = \left(\dfrac{4.3\ \Omega}{23.9\text{ k}\Omega}\right)(120\text{ V}) = 21.6\text{ V}$

$V_{2.7\text{ k}\Omega} = 13.6\text{ V}$

$V_{7.8\text{ k}\Omega} = 39.2\text{ V}$

$V_{9.1\text{ k}\Omega} = 45.7\text{ V}$

$V_T = 21.6\text{ V} + 13.6\text{ V} + 39.2\text{ V} + 45.7\text{ V} = 120.1\text{ V}$
$\cong (170\text{ V} - 50\text{ V})$
$= E_T$

27. a. circuit (a)

$R_T = \dfrac{24\text{ V}}{20\text{ mA}} = 1.2\text{ k}\Omega = R_1 + R_2 + R_3$

$R_1 + 3.5\,R_1 + 2(3.5\,R_1) = 1.2\text{ k}\Omega$

$R_1 + 0.104\text{ k}\Omega$

$R_2 = 0.365\text{ k}\Omega$

$R_3 = 0.730\text{ k}\Omega$

b. $V_1 = \left(\dfrac{0.104\text{ k}\Omega}{1.2\text{ k}\Omega}\right)24\text{ V} = 2.09\text{ V}$

$V_2 = 7.30\text{ V}$

$V_3 = 14.61\text{ V}$

c. $P_1 = (20\text{ mA})2(0.104\text{ k}\Omega) = 41.7\text{ mW}$

$P_2 = 146.1\text{ m}\Omega$

$P_3 = 292.2\text{ m}\Omega$

a. circuit (b)

$V_2 = \dfrac{R_2}{R_1 + R_2 + R_3}(50\text{ V}) = \dfrac{R_2}{8\,R_2}(50\text{ V}) = 6.25\text{ V}$

$R_2 = \dfrac{V_2^2}{P_2} = \dfrac{(6.25\text{ V})^2}{0.160\text{ W}} = 244\ \Omega$

$R_1 = 4(244\ \Omega) = 977\ \Omega$

$R_3 = 3(244\ \Omega) = 732\ \Omega$

b. $V_2 = 6.25\text{ V}$

$V_1 = 25.0\text{ V}$

$V_3 = 8.75\text{ V}$

c. $P_1 = \dfrac{(25.0\text{ V})^2}{977\ \Omega} = 640\text{ mW}$

$P_3 = 480\text{ mW}$

$P_2 = 160\text{ mW}$ (given)

29. a. $R_T = 24(25\ \Omega) = 600\ \Omega$

$I = \dfrac{120\text{ V}}{600\ \Omega} = 0.2\text{ A}$

b. $V = \left(\dfrac{25\ \Omega}{600\ \Omega}\right)120\text{ V} = 5.0\text{ V}$

c. $P = \dfrac{(5\text{ V})^2}{25\ \Omega} = 1\text{ W}$

d. $R_T = 22(25\ \Omega) = 550\ \Omega$

$I = \dfrac{120\text{ V}}{550\ \Omega} = 0.218\text{ A}$

$V = \left(\dfrac{25\ \Omega}{550\ \Omega}\right)120\text{ V} = 5.45\text{ V}$

$P = \dfrac{(5.45\text{ V})^2}{25\ \Omega} = 1.19\text{ W}$

e. Since each of the remaining bulbs now dissipates 20% more power, the life expectancy will decrease.

5.8 Voltage Subscripts

31. circuit (a)

$V_{ab} = V_1 + V_2 = 2.09\text{ V} + 7.30\text{ V} = 9.39\text{ V}$

$V_{bc} = V_3 = 14.61\text{ V}$

circuit (b)

$V_{ab} = 25.0\text{ V}$

$V_{bc} = 6.25\text{ V}$

33. circuit (a)

$$I = \frac{54\text{ V}}{3\text{ k}\Omega + 9\text{ k}\Omega + 6\text{ k}\Omega} = 3\text{ mA}$$

$V_{3\text{ k}\Omega} = (3\text{ mA})(3\text{ k}\Omega) = 9\text{ V}$

$V_{9\text{ k}\Omega} = 27\text{ V}$

$V_{6\text{ k}\Omega} = 18\text{ V}$

$V_a = +(3\text{ mA})(9\text{ k}\Omega + 6\text{ k}\Omega) = 45\text{ V}$

circuit (b)

$E_T = 6\text{ V} + 3\text{ V} = 9\text{ V}$

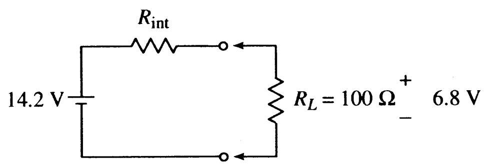
$$V_{330\ \Omega} = \left(\frac{330\ \Omega}{330\ \Omega + 670\ \Omega}\right)9\text{ V} = 2.97\text{ V}$$

$V_{670\ \Omega} = 6.03\text{ V}$

$V_a = 6.03 - 3\text{ V} = 3.03\text{ V}$

5.9 Internal Resistance of Voltage Sources

35.



a. $V_R = 14.2\text{ V} - 6.8\text{ V} = 7.4\text{ V}$

$$I = \frac{6.8\text{ V}}{100\ \Omega} = 0.068\text{ A}$$

$$R_{\text{int}} = \frac{7.4\text{ V}}{0.068\text{ A}} = 109\ \Omega$$

b. $$V_L = \left(\frac{200\ \Omega}{(109\ \Omega + 200\ \Omega)}\right)14.2\text{ V} = 9.20\text{ V}$$

5.10 Ammeter Loading Effects

37. circuit (a)

$$I_{\text{actual}} = \frac{15\text{ V}}{(10\text{ k}\Omega + 12\text{ k}\Omega + 18\text{ k}\Omega)} = 0.375\text{ mA}$$

$$I_{\text{measured}} = \frac{15\text{ V}}{(10\text{ k}\Omega + 12\text{ k}\Omega + 18\text{ k}\Omega + 0.050\text{ k}\Omega)} = 0.374532\text{ mA}$$

$$\text{loading error} = \left(\frac{0.375\text{ mA} - 0.374532\text{ mA}}{0.375\text{ mA}}\right)\times 100\% = 0.125\%$$

circuit (b)

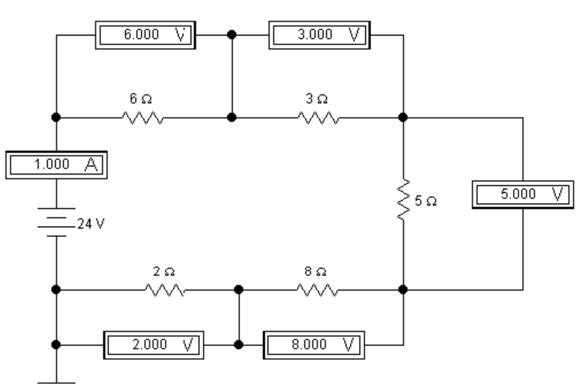
$$I_{\text{actual}} = \frac{0.15\text{ V}}{(100\ \Omega + 120\ \Omega + 180\ \Omega)} = 0.375\text{ mA}$$

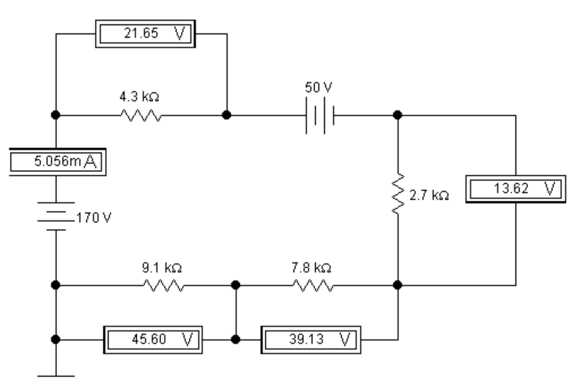
$$I_{\text{measured}} = \frac{0.15\text{ V}}{(100\ \Omega + 120\ \Omega + 180\ \Omega + 50\ \Omega)} = 0.333\text{ mA}$$

$$\text{loading error} = \frac{(0.375\text{ mA} - 0.333\text{ mA})}{0.375\text{ mA}}\times 100\% = 11.1\%$$

5.11 Circuit Analysis Using Computers

39.





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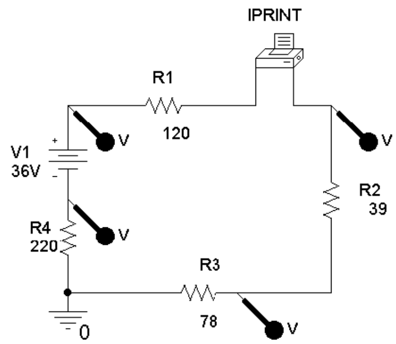


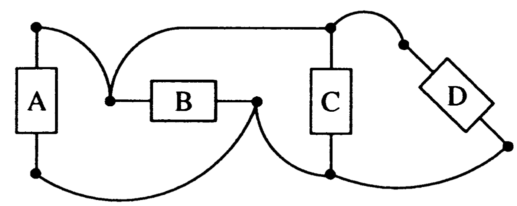
Chapter

6

Parallel Circuits

6.1 Parallel Circuits

1. a. A and B are in series
   D and E are in series
   C and F are in parallel
   b. B, C, and D are in parallel
   c. A and B are in parallel
   D and F are in parallel
   C and E are in series
   d. A, B, C, and D are in parallel

3. 

6.2 Kirchhoff's Current Law

5. a. $I_1 = 5\text{ A} - 2\text{ A} = 3\text{ A}$ (downward)
   $I_2 = 4\text{ A} - 3\text{ A} = 1\text{ A}$ (left)
   b. $I_1 = 6\text{ A} + 1\text{ A} = 7\text{ A}$ (right)
   $I_2 = 7\text{ A} - 2\text{ A} - 3\text{ A} = 2\text{ A}$ (upward)
   $I_3 = 4\text{ A} + 3\text{ A} = 7\text{ A}$ (downward)
   c. $I_1 = 15\text{ mA} - 5\text{ mA} - 6\text{ mA} = 4\text{ mA}$ (right)
   $I_2 = 5\text{ mA} + 4\text{ mA} + 6\text{ mA} + 7\text{ mA} - 2\text{ mA}$
   $= 20\text{ mA}$ (right)

7. a. $I_1 = \dfrac{50\text{ V}}{40\ \Omega} = 1.25\text{ A}$
   $I_2 = \dfrac{5\text{ V}}{60\ \Omega} = 0.0833\text{ A}$
   $I_3 = 1.25\text{ A} - 0.0833\text{ A} = 1.167\text{ A}$
   $I_4 = 0.0833 + 1.167\text{ A} = 1.25\text{ A}$
   b. $R_3 = \dfrac{5\text{ V}}{1.167\text{ A}} = 4.29\ \Omega$

9. a. $I_1 = 500\text{ mA} - 200\text{ mA} - 100\text{ mA} = 200\text{ mA}$
   $I_2 = 500\text{ mA}$
   $I_3 = 200\text{ mA} - 50\text{ mA} = 150\text{ mA}$
   $I_4 = 200\text{ mA}$
   b. $V = (25\ \Omega)(100\text{ mA}) = 2500\text{ mV}$
   $= 2.5\text{ V}$
   c. $R_1 = \dfrac{2.5\text{ V}}{200\text{ mA}} = 12.5\ \Omega$
   $R_3 = \dfrac{2.5\text{ V}}{150\text{ mA}} = 15.7\ \Omega$
   $R_4 = \dfrac{2.5\text{ V}}{50\text{ mA}} = 50\ \Omega$

6.3 Resistors in Parallel

11. a. $R_T = \dfrac{(4\ \Omega)(6\ \Omega)}{4\ \Omega + 6\ \Omega} = 2.4\ \Omega$
    b. $R_T = \dfrac{1}{\dfrac{1}{480\ \Omega} + \dfrac{1}{240\text{ k}\Omega} + \dfrac{1}{40\text{ k}\Omega}} = 32\text{ k}\Omega$
    c. $R_T = \dfrac{1}{\dfrac{1}{8.2\text{ k}\Omega} + \dfrac{1}{10\text{ k}\Omega} + \dfrac{1}{39\text{ k}\Omega}} = 4.04\text{ k}\Omega$

13. a. $\dfrac{1}{R} = \dfrac{1}{400\text{ k}\Omega} - \dfrac{1}{500\text{ k}\Omega} = 0.5\ \mu\text{S}$
    $R = 2.0\text{ M}\Omega$
    b. $\dfrac{1}{R} = \dfrac{1}{30\Omega} - \left(\dfrac{1}{50\Omega} + \dfrac{1}{90\Omega}\right) = 2.22\text{ mS}$
    $R = 450\ \Omega$

15. a. $\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{4R_1} + \dfrac{1}{\dfrac{R_1}{5}} = \dfrac{6.25}{R_1} = \dfrac{1}{200}\ \Omega$
    $R_1 = 1250\ \Omega$
    $R_2 = 5000\ \Omega$
    $R_3 = 250\ \Omega$

b. $$I_{R_1} = \frac{2\text{ A}}{5} = 0.40\text{ A}$$

$$I_{R_2} = \frac{2\text{ A}}{(5)(4)} = 0.10\text{ A}$$

c. $I = 0.40\text{ A} + 0.10\text{ A} + 2.0\text{ A} = 2.5\text{ A}$

17. a. $V_{R_1} = V_{R_2} = (2\text{ mA})(450\ \Omega) = 900\text{ mV}$

b. $$I_2 = \frac{900\text{ mV}}{200\ \Omega} = 4.5\text{ mA}$$

19. a. $$R_T = \cfrac{1}{\cfrac{1}{600\ \Omega} + \cfrac{1}{800\ \Omega} + \cfrac{1}{800\ \Omega}} = 240\ \Omega$$

b. $$R_T = \cfrac{1}{\cfrac{1}{27\text{ k}\Omega} + \cfrac{1}{33\text{ k}\Omega} + \cfrac{1}{56\text{ k}\Omega} + \cfrac{1}{47\text{ k}\Omega}} = 9.392\text{ k}\Omega$$

c. $R_{T_1} = 6\text{k}\Omega \| 3\text{ k}\Omega = 2\text{ k}\Omega$

$R_{T_2} = 9\text{ k}\ \Omega \| 9\text{ k}\Omega \| 9\text{ k}\Omega = 3\text{ k}\Omega$

$$R_T = \frac{(2\text{ k}\Omega)(3\text{ k}\Omega)}{2\text{ k}\Omega + 3\text{ k}\Omega} = 1.2\text{ k}\Omega$$

21. $$I_T = \frac{32\text{ V}}{16\text{ k}\Omega} = 2.0\text{ mA}$$

$I_1 + 3I_1 + 1.5(3I_1) = 2.0\text{ mA}$

$I_1 = 0.2353\text{ mA}$

$I_2 = 0.7059\text{ mA}$

$I_3 = 1.0589\text{ mA}$

$$R_1 = \frac{32\text{ V}}{0.2353\text{ mA}} = 136\text{ k}\Omega$$

$$R_2 = \frac{32\text{ V}}{0.7059\text{ mA}} = 45.3\text{ k}\Omega$$

$$R_3 = \frac{32\text{ V}}{1.0589\text{ mA}} = 30.2\text{ k}\Omega$$

23. a. $R_T = 12.5\text{ k}\Omega$

b. $R_T = 0\ \Omega$ (short circuit)

c. $R_T = 75\ \Omega$

25. $R_T \cong 30\ \Omega \| 30\ \Omega = 15\ \Omega$

6.4 Voltage Sources in Parallel

27. $$I = \frac{20\text{ V}}{100\ \Omega} = 0.2\text{ A}$$

$$I_1 = \frac{0.2\text{ A}}{2} = 0.1\text{ A} = I_2$$

6.5 Current Divider Rule

29. a. $$I_1 = \left(\frac{2\ \Omega}{2\ \Omega + 8\ \Omega}\right)(10\text{ A}) = 2\text{ A}$$

$$I_2 = \left(\frac{8\ \Omega}{2\ \Omega + 8\ \Omega}\right)(10\text{ A}) = 8\text{ A}$$

b. $$I_1 = \left(\frac{1\text{ k}\Omega}{1\text{ k}\Omega + 3\text{ k}\Omega}\right)(16\text{ mA}) = 4\text{ mA}$$

$$I_2 = \left(\frac{3\text{ k}\Omega}{1\text{ k}\Omega + 3\text{ k}\Omega}\right)(16\text{ mA}) = 12\text{ mA}$$

31. a. $$R_T = \cfrac{1}{\cfrac{1}{4.7\text{ k}\Omega} + \cfrac{1}{3.3\text{ k}\Omega} + \cfrac{1}{1.0\text{ k}\Omega} + \cfrac{1}{2.2\text{ k}\Omega}}$$

$= 0.508\text{ k}\Omega$

$$I_1 = \left(\frac{0.508\text{ k}\Omega}{4.7\text{ k}\Omega}\right)60\text{ mA} = 6.48\text{ mA}$$

$$I_2 = \left(\frac{0.508\text{ k}\Omega}{3.3\text{ k}\Omega}\right)60\text{ mA} = 9.23\text{ mA}$$

$I_3 = 30.45\text{ mA}$

$I_4 = 13.84\text{ mA}$

b. $$R'_T = \cfrac{1}{\cfrac{1}{200\ \Omega} + \cfrac{1}{400\ \Omega} + \cfrac{1}{600\ \Omega}} = 109.1\ \Omega$$

$$I_4 = \left(\frac{109.1\ \Omega}{109.1\ \Omega + 300\ \Omega}\right)150\text{ mA} = 40\text{ mA}$$

$$I_5 = \left(\frac{300\ \Omega}{109.1\ \Omega + 300\ \Omega}\right)150\text{ mA} = 110\text{ mA}$$

$$I_1 = \left(\frac{109.1\ \Omega}{200\ \Omega}\right)110\text{ mA} = 60\text{ mA}$$

$$I_2 = \left(\frac{109.1\ \Omega}{400\ \Omega}\right)110\text{ mA} = 30\text{ mA}$$

$$I_3 = \left(\frac{109.1\ \Omega}{600\ \Omega}\right)110\text{ mA} = 20\text{ mA}$$

33. $$\left(\frac{R_1}{R_1 + R}\right)90\text{ mA} = 60\text{ mA}$$

$$\left(\frac{24\ \Omega}{24\ \Omega + R}\right)90\text{ mA} = 60\text{ mA}$$

$$24\ \Omega + R = \frac{(24\ \Omega)(90\text{ mA})}{60\text{ mA}}$$

$R = 36\ \Omega - 24\ \Omega = 12\ \Omega$

35. a. $R_T = 24\ \Omega \| 48\ \Omega \| 16\ \Omega = 8\ \Omega$

b. $$I = \frac{12\text{ V}}{8\ \Omega} = 1.50\text{ A}$$

c. $$I_1 = \left(\frac{8\ \Omega}{24\ \Omega}\right)1.50\text{ A} = 0.50\text{ A}$$

$$I_2 = \frac{I_1}{2} = 0.25\text{ A}$$

$$I_3 = \left(\frac{8\ \Omega}{16\ \Omega}\right)1.50\text{ A} = 0.75\text{ A}$$

d. $\sum I_{in} = 1.50\text{ A}$

$\sum I_{out} = 0.50\text{ A} + 0.25\text{ A} + 0.75\text{ A} = 1.50\text{ A}$

$\sum I_{in} = \sum I_{out}$

6.6 Analysis of Parallel Circuits

37. a. $R_T = 60\Omega \| 100\ \Omega \| 75\ \Omega = 25\ \Omega$

b. $I = \dfrac{240\text{ V}}{25\ \Omega} = 9.60\text{ A}$

$I_1 = \dfrac{240\text{ V}}{60\ \Omega} = 4.0\text{ A}$

$I_2 = \dfrac{240\text{ V}}{100\ \Omega} = 2.40\text{ A}$

$I_3 = \dfrac{240\text{ V}}{75\ \Omega} = 3.20\text{ A}$

$I_4 = 2.40\text{A} + 3.20\text{ A} = 5.60\text{ A}$

c. $\sum I_{in} = 9.60\text{ A}$

$\sum I_{out} = 4.0\text{ A} + 2.40\text{ A} + 3.20\text{ A} + 5.60\text{ A} = 9.60\text{ A}$

$\sum I_{in} = \sum I_{out}$

d. $P_1 = (4.0\text{ A})^2(60\ \Omega) = 960\text{ W}$

$P_2 = (2.40\text{ A})^2(100\ \Omega) = 576\text{ W}$

$P_3 = (3.20\text{ A})^2(75\ \Omega) = 768\text{W}$

$P_T = (240\text{ V})(9.60\text{ A}) = 2304\text{ W}$

$P_T = P_1 + P_2 + P_3$

39. a. $I_1 = \dfrac{20\text{ V}}{20\ \Omega} = 1.00\text{ A}$

$I_2 = 2.0\text{ A}$

$I_3 = 5.0\text{ A}$

$I_4 = 4.0\text{ A}$

b. $I = 1.0\text{ A} + 2.0\text{ A} + 5.0\text{ A} + 4.0\text{ A} = 12.0\text{ A}$

c. $P_1 = 20\text{ W}$

$P_2 = 40\text{ W}$

$P_3 = 100\text{ W}$

$P_4 = 80\text{ W}$

41. a. $R_3 = \dfrac{48\text{ V}}{12\text{ mA}} = 4\text{ k}\Omega$

$R_4 = \dfrac{48\text{ V}}{(50\text{ mA} - 30\text{ mA} - 12\text{ mA})} = 6\text{ k}\Omega$

$R_1 = \dfrac{V^2}{P} = \dfrac{(48\text{ V})^2}{1.152\text{ W}} = 2\text{ k}\Omega$

$R_T = \dfrac{48\text{ V}}{50\text{ mA}} = 0.96\text{ k}\Omega$

$R_2 = \dfrac{1}{\dfrac{1}{0.96\text{ k}\Omega} - \dfrac{1}{4\text{ k}\Omega} - \dfrac{1}{6\text{ k}\Omega} - \dfrac{1}{2\text{ k}\Omega}} = 8\text{ k}\Omega$

b. $I_{R_1} = \dfrac{1.152\text{ W}}{48\text{ V}} = 24\text{ mA}$

$I_{R_2} = 30\text{ mA} - 24\text{ mA} = 6\text{ mA}$

$I_{R_4} = 50\text{ mA} - 30\text{ mA} - 12\text{ mA} = 8\text{ mA}$

c. $I_1 = 12\text{ mA} + 8\text{ mA} = 20\text{ mA}$

$I_2 = 20\text{ mA} + 24\text{ mA} + 6\text{ mA} = 50\text{ mA}$

d. $P_2 = (6\text{ mA})(48\text{ V}) = 288\text{ mW}$

$P_3 = (12\text{ mA})(48\text{ V}) = 576\text{ mW}$

$P_4 = (8\text{ mA})(48\text{ V}) = 384\text{ mW}$

43. $I_1 = \dfrac{1000\text{ W}}{120\text{ V}} = 8.33\text{ A}$

$I_2 = \dfrac{120\text{ V}}{24\ \Omega} = 5.00\text{ A}$

$I_3 = \dfrac{120\text{V}}{48\ \Omega} = 2.50\text{ A}$

$I_4 = 7.50\text{ A}$

$I_T = 15.83\text{ A}$

The rated current of the fuse will be exceeded; the fuse will "blow" open.

6.7 Voltmeter Loading Effects

45. a. $V_{meas} = \left(\dfrac{\text{M}\Omega}{1\text{ M}\Omega + 0.5\text{ M}\Omega}\right)30\text{ V} = 20\text{ V}$

b. $V_{ab} = 30\text{ V}$

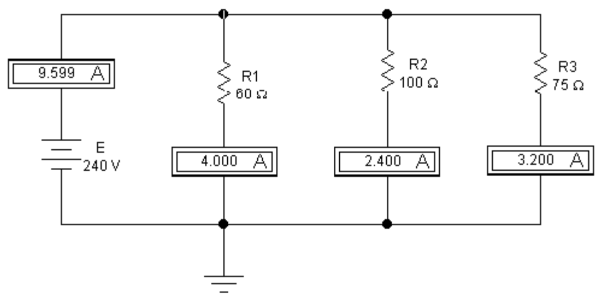
$\text{loading effect} = \dfrac{30\text{ V} - 20\text{ V}}{30\text{ V}} \times 100\% = 33.3\%$

47. $1.2\text{ V} = \left(\dfrac{50\text{ k}\Omega}{50\text{ k}\Omega + 1000\text{ k}\Omega}\right)E$

$E = 25.2\text{ V}$

6.8 Computer Analysis

49.



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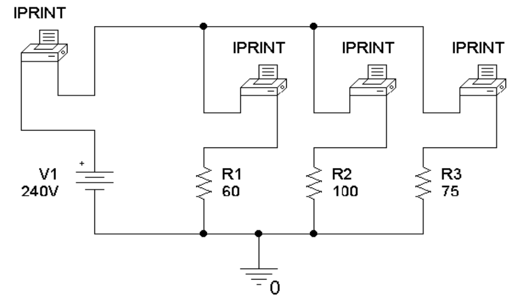

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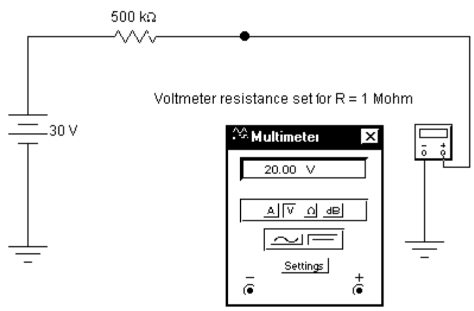


Chapter

7

Series-Parallel Circuits

7.1 The Series-Parallel Network

1. a. $R_T = R_1 + R_5 + [(R_2 + R_3)\|R_4]$

   b. $R_T = (R_1\|R_2) + (R_3\|R_4)$

3. a. $R_{T_1} = R_1 + [(R_3 + R_4)\|R_2] + R_5$

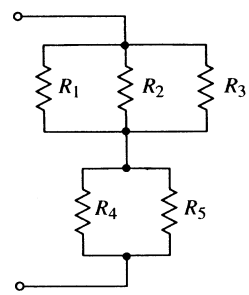
   $R_{T_2} = R_5$

   b. $R_{T_1} = R_1 + (R_2\|R_3\|R_5)$

   $R_{T_1} = R_5\|R_3\|R_2$

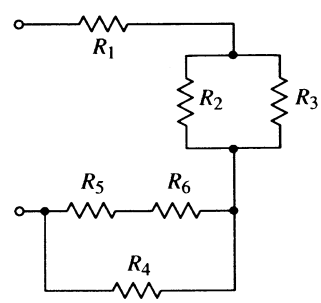
   (R_4 is shorted)

5. a.



(one possible solution)

   b.



(one possible solution)

7.2 Analysis of Series-Parallel Circuits

7. a. $R_T = 300\ \Omega + [4\ \text{k}\Omega\|(200\ \Omega + 300\ \Omega + 500\ \Omega)] + 400\ \Omega = 1500\ \Omega$

   b. $R_T = 5.1\ \text{k}\Omega\|[1.2\ \text{k}\Omega + \{4.7\ \text{k}\Omega\|(3.3\ \text{k}\Omega + 5.6\ \Omega)\}] = 2.33\ \text{k}\Omega$

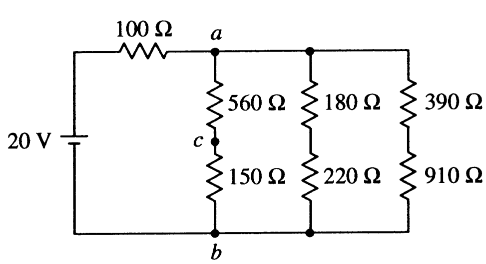
9. $R_{ab} = 80\ \Omega + 40\ \Omega + [60\ \Omega\|60\ \Omega\|(10\ \Omega + 20\ \Omega + 30\ \Omega] = 140\ \Omega$

   $R_{cd} = 10\ \Omega\|[20\ \Omega + 30\ \Omega + (60\ \Omega\|60\ \Omega)] = 8.89\ \Omega$

11. a. $R_T = 100\ \Omega + [(560\ \Omega + 150\ \Omega)\|(180\ \Omega + 220\ \Omega\|(390\ \Omega + 910\ \Omega)]$

   $= 100\ \Omega + 710\ \Omega\|400\ \Omega\|1300\ \Omega$

   $= 313.78\ \Omega \cong 314\ \Omega$



   b. $$I_T = \frac{20\ \text{V}}{314\ \Omega} = 63.7\ \text{mA}$$

$$I_1 = \left(\frac{213.78\ \Omega}{560\ \Omega + 150\ \Omega}\right)63.7\ \text{mA} = 19.2\ \text{mA}$$

$$I_2 = 63.7\ \text{mA} - 19.2\ \text{mA} = 44.5\ \text{mA}$$

$$I_3 = \left(\frac{213.78\ \Omega}{180\ \Omega + 220\ \Omega}\right)63.7\ \text{mA} = 34.1\ \text{mA}$$

$$I_4 = \left(\frac{213.78\ \Omega}{390\ \Omega + 910\ \Omega}\right)63.7\ \text{mA} = 10.4\ \text{mA}$$

   c. $V_{ab} = +(34.1\ \text{mA})(180\ \Omega + 220\ \Omega) = 13.6\ \text{V}$

   $V_{bc} = -(19.2\ \text{mA})(150\ \Omega) = -2.88\ \text{V}$

13. a. $R_T = 1\text{ k}\Omega + 2\text{ k}\Omega + 5\text{ k}\Omega \| [1\text{ k}\Omega + \{6\text{ k}\Omega \| (3\text{ k}\Omega + 6\text{ k}\Omega)\}] = 5.396\text{ k}\Omega$

$$I_1 = \frac{28\text{ V}}{5.396\text{ k}\Omega} = 5.\overline{189}\text{ mA}$$

$$I_2 = \left(\frac{5\text{ k}\Omega}{5\text{ k}\Omega + 4.6\text{ k}\Omega}\right)5.\overline{189}\text{ mA} = 2.\overline{702}\text{ mA}$$

$$I_3 = \left(\frac{6\text{ k}\Omega}{6\text{ k}\Omega + 3\text{ k}\Omega + 6\text{ k}\Omega}\right)2.\overline{702}\text{ mA} = 1.\overline{081}\text{ mA}$$

$I_4 = 5.\overline{189}\text{ mA} - 2.\overline{702}\text{ mA} = 2.\overline{486}\text{ mA}$

$I_5 = 2.\overline{702}\text{ mA} - 1.\overline{081}\text{ mA} = 1.\overline{621}\text{ mA}$

$I_6 = 2.\overline{702}\text{ mA}$

b. $V_{ab} = +(5\text{ k}\Omega)(2.\overline{486}\text{ mA}) = 12.\overline{432}\text{ V}$

$Vcd = +(6\text{ k}\Omega)(1.\overline{621}\text{ mA}) = 9.\overline{729}\text{ V}$

c. $P_T = (28\text{ V})(5.\overline{189}\text{ mA}) = 145.3\text{ mW}$

$P_1 = 26.9\text{ mW}$ $P_5 = 15.8\text{ mW}$

$P_2 = 7.3\text{ mW}$ $P_6 = 7.0\text{ mW}$

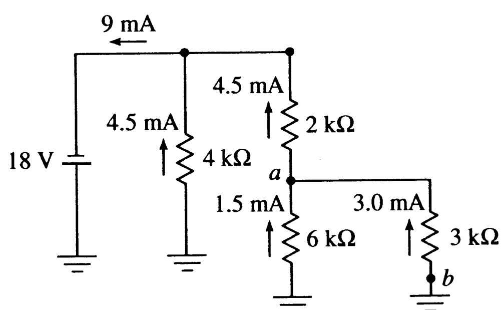
$P_3 = 3.5\text{ mW}$ $P_7 = 53.9\text{ mW}$

$P_4 = 30.9\text{ mW}$

$$P_T = \sum_{n=1}^{7} P_n = 145.3\text{ mW}$$

15. circuit (a)

a.



$R_T = 4\text{ k}\Omega \| (2\text{ k}\Omega + 6\text{ k}\Omega \| 3\text{ k}\Omega = 2\text{ k}\Omega$

$$I_T = \frac{18\text{ V}}{2\text{ k}\Omega} = 9.0\text{ mA}$$

$$I_2 = \frac{18\text{ V}}{4\text{ k}\Omega} = 4.5\text{ mA}$$

$$I_1 = \frac{18\text{ V}}{2\text{ k}\Omega + (6\text{ k}\Omega \| 3\text{ k}\Omega)} = 4.5\text{ mA}$$

$$I_3 = \left(\frac{3\text{ k}\Omega}{6\text{ k}\Omega + 3\text{ k}\Omega}\right)4.5\text{ mA} = 1.5\text{ mA}$$

b. $V_{ab} = -(1.5\text{ mA})(6\text{ k}\Omega) = -9.0\text{ V}$

c. $$P_T = \frac{(18\text{ V})^2}{2\text{ k}\Omega} = 162\text{ mW}$$

$P_{6\text{k}\Omega} = (1.5\text{ mA})2(6\text{ k}\Omega) = 13.5\text{ mW}$

$P_{3\text{k}\Omega} = (3.0\text{ mA})2(3\text{ k}\Omega) = 27.0\text{ mW}$

$P_{2\text{k}\Omega} = (4.5\text{ mA})2(2\text{ k}\Omega) = 40.5\text{ mW}$

$P_{4\text{k}\Omega} = (4.5\text{ mA})2(4\text{ k}\Omega) = 81.0\text{ mW}$

$$P_T = \sum_{n=1}^{4} P_n = 162\text{ mW}$$

15. circuit (b)

a. $R_T = 10\ \Omega + 16 \| [5\ \Omega \| (8\ \Omega + 4\ \Omega)] = 15.76\ \Omega$

$$I_T = I_1 = \frac{12\text{V} - 3\text{ V}}{15.76\ \Omega} = 0.571\text{ A}$$

$$I_2 = \left(\frac{16\ \Omega}{16\ \Omega + 9\ \Omega}\right)0.571\text{ A} = 0.365\text{ A}$$

$$I_3 = \left(\frac{6\ \Omega}{6\ \Omega + 12\ \Omega}\right)0.365\text{ A} = 0.122\text{ A}$$

$I_4 = 0.471\text{ A} - 0.122\text{ A} = 0.449\text{ A}$

b. $V_{ab} = -(0.365\text{ A})(5\ \Omega) = -1.827\text{ V}$

c. $P_T = (9\text{ V})(0.571\text{ A}) = 5.14\text{ W}$

$P_{10\Omega} = (0.571\text{ A})^2\,(10\ \Omega) = 3.26\text{ W}$

$P_{16\Omega} = (0.206\text{ A})^2(16\ \Omega) = 0.68\text{ W}$

$P_{5\Omega} = (0.365\text{ A})^2(5\ \Omega) = 0.67\text{ W}$

$P_{6\Omega} = (0.244\text{ A})^2(6\ \Omega) = 0.36\text{ W}$

$P_{8\Omega} = (0.122\text{ A})^2(8\ \Omega) = 0.12\text{ W}$

$P_{4\Omega} = (0.122\text{ A})^2(4\ \Omega) = 0.06\text{ W}$

$$P_T = \sum_{n=1}^{6} P_n = 5.15\text{ W}$$

7.3 Applications of Series—Parallel Circuits

17. Zener is on:

$V_1 = 14.0\text{ V}$

$$I_1 = \frac{24\text{ V} - 10\text{ V}}{150\ \Omega} = 93.3\text{ mA}$$

$V_2 = 2.06\text{ V}$

$V_3 = 7.94\text{ V}$

$$I_2 = I_3 = \frac{10\text{ V}}{39\ \Omega + 150\ \Omega} = 52.9\text{ mA}$$

$I_Z = 93.3\text{ mA} - 52.9\text{ mA} = 40.4\text{ mA}$

$P_T = (24\text{ V})(93.3\text{ mA}) = 2240\text{ mW}$

$P_Z = 404.2\text{ mW}$

$P_1 = 1306.7\text{ mW}$

$P_2 = 109.2\text{ mW}$

$P_3 = 419.9\text{mW}$

19. R_{min}:

$$V_L = \left(\frac{R}{R + 80\ \Omega}\right) 20\text{ V} = 5.6\text{ V}$$

$(20\text{ V})R = (5.6\text{ V})R + 448\text{ V} \cdot \Omega$

$$R_{\text{min}} \frac{448\text{ V} \cdot \Omega}{14.4\text{ V}} = 31.\bar{1}\ \Omega$$

R_{max}:

$$I_1 = \frac{20\text{ V} - 5.6\text{ V}}{80\ \Omega} = 180\text{ mA}$$

$$I_{Z(\text{max})} = \frac{1\text{ W}}{5.6\text{ V}} = 178.57\text{ mA}$$

$I_{L(\text{min})} = 1.43\text{ mA}$

$$R_{\text{max}} = \frac{5.6\text{ V}}{1.43\text{ mA}} = 3.92\text{ k}\Omega$$

$R = 31.1\ \Omega \rightarrow 3900\ \Omega$

21. Using KVL: $(750\ \Omega)I_E + 0.6\text{ V} + (7.5\text{ k}\Omega)I_B - 2\text{ V} = 0$

But $I_E \cong 100\ I_B$

$(750\ \Omega)(100I_B) + (7.5\text{ k}\Omega)I_B = 1.4\text{ V}$

$$I_B = \frac{1.4\text{ V}}{82.5\text{ k}\Omega} = 17.0\ \mu\text{A}$$

$I_E \cong 1.70\text{ mA} \cong I_C$

$V_B = (7.5\text{ k}\Omega)(17.0\ \mu\text{A}) - 2.0\text{ V} = -1.87\text{ V}$

$V_{CE} = -16\text{ V} + (3.9\text{ k}\Omega)(1.7\text{ mA}) + (0.75\text{ k}\Omega)(1.7\text{ mA}) = -8.10\text{ V}$

23. a. $I_D = 3.6\text{ mA}$

$V_S = -(-2.0\text{ V}) = 2.0\text{ V}$

b. $$R_S = \frac{2.0\text{ V}}{3.6\text{ mA}} = 0.556\text{ k}\Omega = 556\ \Omega$$

c. $V_{DS} = 15\text{ V} - (3.6\text{ mA})(1.5\text{ k}\Omega + 0.556\text{ k}\Omega) = +7.6\text{ V}$

25. $$V_B = \left(\frac{4\text{ k}\Omega}{4\ \Omega + 32\text{ k}\Omega}\right)(18\text{ V}) = 2.00\text{ V}$$

$V_E = 2.00 - 0.7\text{ V} = 1.30\text{ V}$

$$I_E = \frac{1.30\text{ V}}{0.4\text{ k}\Omega} = 3.25\text{ mA} \cong \text{I}_\text{C}$$

$V_{CE} = 18\text{ V} - 3.25\text{ mA}\ (2.40\text{ k}\Omega + 0.40\ \text{k}\Omega) = 8.90\text{ V}$

7.4 Potentiometers

27. a. For $R_2 = 0\ \Omega$: $V_{bc} = V_L = 0\text{ V}$

For $R_2 = 10\text{ k}\Omega$:

$$V_{bc} = V_L = \left(\frac{10\text{ k}\Omega \| 10\text{ k}\Omega}{20\text{ k}\Omega + 10\text{ k} \| 10\text{ k}\Omega}\right) 36\text{ V} = 7.2\text{ V}$$

$V_L = 0 \rightarrow 7.2\text{ V}$

b. $$V_L = \frac{(2.5\text{ k}\Omega \| 10\text{ k}\Omega)}{(2.5\text{ k}\Omega \| 10\text{ k}\Omega) + 20\text{ k}\Omega + (10\text{ k}\Omega - 2.5\text{ k}\Omega)} \times 36\text{ V} = 2.44\text{ V}$$

If R_L is removed:

$$V_{ab} = \frac{7.5\text{ k}\Omega}{20\text{ k}\Omega + 10\text{ k}\Omega} = 9.0\text{ V}$$

29. $R_T = (200\ \Omega \| 50\ \Omega) + (800\ \Omega \| 100\ \Omega) = 40\ \Omega + 88.\bar{8}\ \Omega = 128.\bar{8}\ \Omega$

$$V_{bc} = \frac{50\ \Omega \| 200\ \Omega}{128.\bar{8}\ \Omega} \times 24\text{ V} = 7.45\text{ V}$$

$V_{ab} = 24\text{ V} - 7.448\text{ V} = 16.6\text{ V}$

31. a. $V_{out(min)} = 0\text{ V}$

$$V_{out(max)} = \left(\frac{(10\text{ k}\Omega \| 10\text{ k}\Omega)}{(10\text{ k}\Omega \| 10\text{ k}\Omega) + (R_{10}\text{ k}\Omega) + 10\text{ k}\Omega}\right.120\text{ V} = 40\text{ V}$$

b.
$$V_{out} = \frac{R_2 \| 10\text{ k}\Omega}{(R_2 \| 10\text{ k}\Omega) + (R_1 10\text{ k}\Omega) + 10\text{ k}\Omega} \times 120\text{ V}$$

But $R_1 = 10\text{ k}\Omega - R_2$

$$20\text{ V} = \frac{\dfrac{(R_2)(10\text{ k}\Omega)}{R_2 + 10\text{ k}\Omega} \times 120\text{ V}}{\dfrac{(R_2)(10\text{ k}\Omega)}{R_2 + 10\text{ k}\Omega} + \dfrac{10\text{ k}\Omega - R_2)(10\text{ k}\Omega)}{10\text{ k}\Omega\ R_2 + 10\text{ k}\Omega}} + 10\text{ k}\Omega$$

$R_2 = 3.82\text{ k}\Omega$

33. $R_L = 0\ \Omega$: $V_{out} = 0\text{V}$

$R_L = 250\ \Omega$:

$$V_{out} = \frac{(250\ \Omega \| 100\ \Omega)(20\text{ V})}{(250\ \Omega \| 100\ \Omega) + 100\ \Omega} = 8.33\text{ V}$$

$R_L = 500\ \Omega$:

$$V_{out} = \frac{(500\ \Omega \| 100\ \Omega)(20\text{ V})}{(500\ \Omega \| 100\ \Omega) + 100\ \Omega} = 9.09\text{ V}$$

7.5 Loading Effects of Instruments

35. a.
$$5.0\text{ V} = \frac{750\text{ k}\Omega \| 200\text{ k}\Omega}{750\text{ k}\Omega \| 200\text{ k}\Omega + 200\text{ k}\Omega} \times E = 0.4412E$$

$E = 11.\overline{3}\text{ V}$

b. Unloaded voltage:

$$V_{NL} = \frac{750\text{ k}\Omega}{750\text{ k}\Omega + 200\text{ k}\Omega} \times 11.\overline{3}\text{ V} = 8.95\text{ V}$$

c.
$$\text{Loading effect} = \frac{8.95\text{ V} - 5.00\text{ V}}{8.95\text{ V}} \times 100\% = 44.1\%$$

d.
$$V = \left(\frac{200\text{ k}\Omega \| 200\text{ k}\Omega}{(200\text{ k}\Omega \| 200\text{ k}\Omega) + 750\text{ k}\Omega}\right) 11.\overline{3}\text{ V} = 1.33\text{ V}$$

37. a. Break the circuit between the 5.6 Ω resistor and the voltage source. Insert the ammeter at the break, connecting the red (+) lead of the ammeter to the positive terminal of the voltage source and the black (–) lead to the 5.6 Ω resistor.

b. Measuring I_1

$$I_1(\text{loaded}) = \frac{0.2\text{ V}}{2\ \Omega + 5.6\ \Omega + 6.8\ \Omega \| 3.9\ \Omega}$$
$$= 19.84\text{ mA}$$

Measuring I_2

$$I_1(\text{loaded}) = \frac{0.2\text{ V}}{5.6\ \Omega + (6.8\ \Omega + 2\ \Omega) \| 3.9\ \Omega}$$
$$= 24.09\text{ mA}$$

$$I_2(\text{loaded}) = \left(\frac{3.9\ \Omega}{3.9\ \Omega + 6.8\ \Omega + 2\ \Omega}\right)(24.1\text{ mA}$$
$$= 7.40\text{ mA}$$

Measuring I_3

$$I_1 = \frac{0.2\text{ V}}{5.6\ \Omega + 6.8\ \Omega \| (3.9\ \Omega + 2\ \Omega)} = 22.83\text{ mA}$$

$$I_3(\text{loaded}) = \left(\frac{6.8\ \Omega}{3.9\ \Omega + 6.8\ \Omega + 2\ \Omega}\right) 22.83\text{ mA}$$
$$= 12.22\text{ mA}$$

c.
$$I_{1(NL)} + \frac{0.2\text{ V}}{5.6\ \Omega + 6.8\ \Omega + 3.9\ \Omega} = \frac{0.2\text{ V}}{8.0785\ \Omega}$$
$$= 24.76\text{ mA}$$

$$I_{2(NL)} = \left(\frac{3.9\ \Omega}{2.9\ \Omega + 6.8\ \Omega}\right) 24.76\text{ mA} = 9.02\text{ mA}$$

$$I_{3(NL)} + \left(\frac{6.8\ \Omega}{3.9\ \Omega + 6.8\ \Omega}\right) 24.76\text{ mA} = 15.73\text{ mA}$$

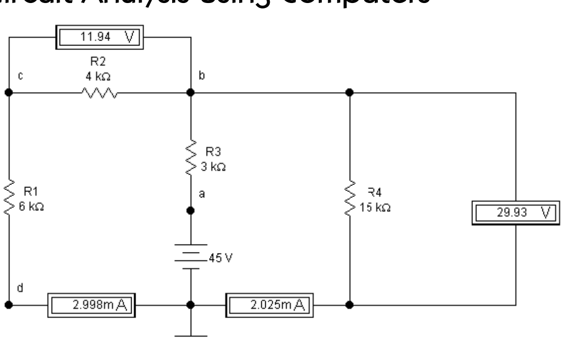
Loading(I_1) =19.9%

Loading(I_2) = 18.0%

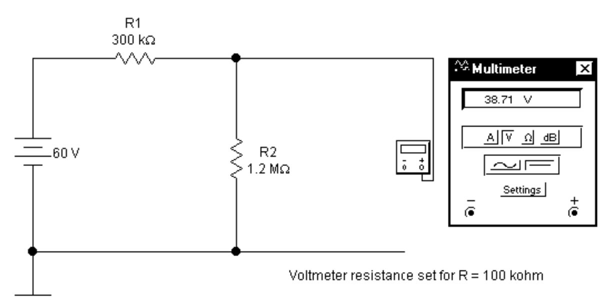
Loading(I_3) = 22.3%

7.6 Circuit Analysis Using Computers

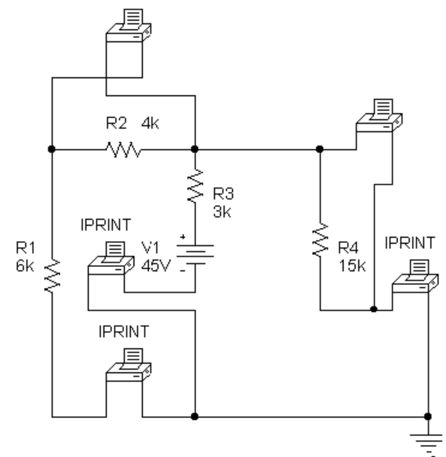
39.



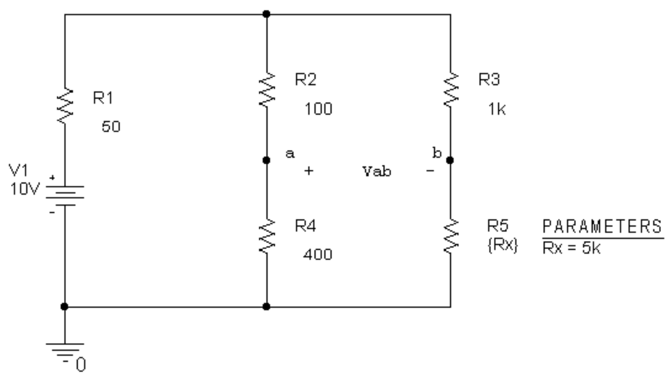
41.

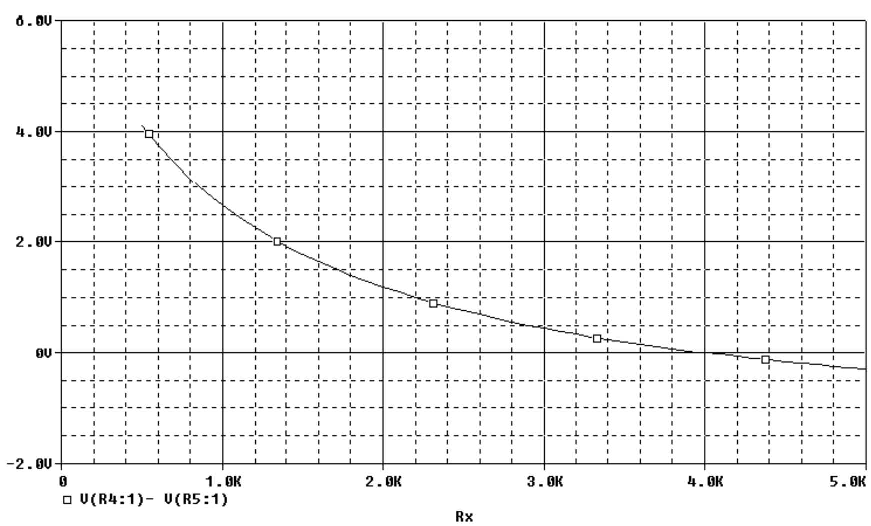


43.


R2 4k
R3
3k
IPRINT
R1
6k
V1
45V
R4
15k
IPRINT
IPRINT

45.


R1
50
R2
100
R3
1k
V1
10V
a
+
Vab
b
-
R4
400
R5
{Rx}
PARAMETERS
Rx = 5k
0


6.0V
4.0V
2.0V
0V
-2.0V
0
1.0K
2.0K
3.0K
4.0K
5.0K
V(R4:1)- V(R5:1)
Rx

Chapter

8

Methods of Analysis

8.1 Current Sources

1. $V_S = 18\text{ V} + 20\text{ V} = 38\text{ V}$

3. a. $$I_3 = \left(\frac{300\ \Omega}{200\ \Omega + 300\ \Omega}\right)20\text{ mA} = 12\text{ mA}$$

   b. $V_S = (20\text{ mA})(0.1\text{ k}\Omega) + (12\text{ mA})(0.2\text{ k}\Omega) = 4.4\text{ V}$

   $V_1 = (20\text{ mA})(0.1\text{ k}\Omega) = 2.0\text{ V}$

5. $$I_{50\text{k}\Omega} = \frac{15\text{ V}}{50\text{ k}\Omega} = 300\ \mu\text{A}$$

   $$I_{150\text{k}\Omega} = \frac{15\text{ V}}{150\text{ k}\Omega} = 100\ \mu\text{A}$$

   $I_1 = 300\ \mu\text{A} + 100\ \mu\text{A} = 400\ \mu\text{A}$

   $I_2 = 400\ \mu\text{A} + 100\ \mu\text{A} = 500\ \mu\text{A}$

7. Power provided by voltage source:

   $P = (15\text{ V})(500\ \mu\text{A}) - 7.5\text{ mW}$

   Power dissipated by resistors:

   $P_{150\text{k}\Omega} = (300\ \mu\text{A})^2 50\text{ k}\Omega = 4.5\text{ mW}$

   $P_{150\text{k}\Omega} = (100\ \mu\text{A})^2 150\text{ k}\Omega = 1.5\text{ mW}$

   Power absorbed by current source:

   $P = (0.1\ \mu\text{A})(15\text{ V}) = 1.5\text{ mW}$

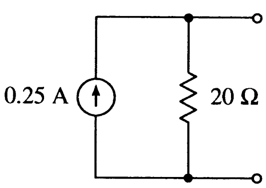
   $P_{\text{in}} = 7.5\text{ mW} = \sum P_{\text{out}}$

   Note:

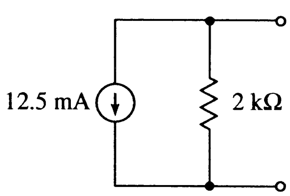
   The current source is taking energy from the circuit rather than providing energy.

8.2 Source Conversions

9. a.



   b.

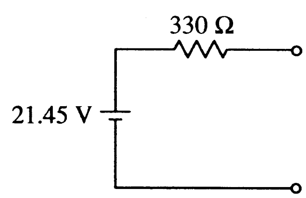


11. a. $$I_L = \left(\frac{450\ \Omega}{450\ \Omega + 50\ \Omega}\right)8\text{ A} = 7.2\text{ A}$$

    b. $E = (8\text{ A})(450\ \Omega) = 3600\text{ V}$

    $$I_L = \frac{3600\text{ V}}{450\ \Omega + 50\ \Omega} = 7.2\text{ A}$$

13. a.



    b. $$I = \frac{21.45\text{ V} - 16\text{ V}}{330\ \Omega + 470\ \Omega + 100\ \Omega} = 6.0\overline{5}\text{ mA}$$

    c. $V_{ab} = (6.0\overline{5})\text{ mA})(0.1\text{ k}\Omega) = 0.60\overline{5}\text{ V}$

8.3 Current Sources in Parallel and Series

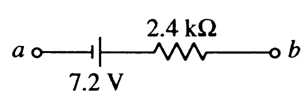
15. $I_T = 100\text{ mA} - 50\text{ mA} = 50\text{ mA (down)}$

    $R_T = 3\text{ k}\Omega \| 6\text{ k}\Omega \| 8\text{ k}\Omega = 1.6\text{ k}\Omega$

    $V_2 = -(50\text{ mA})(1.6\text{ k}\Omega) = -80\text{ V}$

    $$I_1 = -\left(\frac{1.6\text{ k}\Omega}{3\text{ k}\Omega}\right)50\text{ mA} = -26.7\text{ mA}$$

17.



    $E = (3\text{ mA})(2.4\text{ k}\Omega) = 7.2\text{ V}$

    $$I_3 = \frac{8\text{ V} - 7.2\text{ V}}{2.4\text{ k}\Omega + 1.6\text{ k}\Omega + 2.0\text{ k}\Omega} = 0.133\text{ mA}$$

    $V_{ab} = -7.2\text{ V} - (0.133\text{ mA})(2.4\text{ k}\Omega) = -7.52\text{ V}$