CHAPTER 3
OHM'S LAW, ENERGY, AND POWER

BASIC PROBLEMS

SECTION 3-1 Ohm's Law

1. *I* is directly proportional to *V* and will change the same percentage as *V*.
   (a) $I = 3(1\text{ A}) = \mathbf{3\ A}$
   (b) $I = 1\text{ A} - (0.8)(1\text{ A}) = 1\text{ A} - 0.8\text{ A} = \mathbf{0.2\ A}$
   (c) $I = 1\text{ A} + (0.5)(1\text{ A}) = 1\text{ A} + 0.5\text{ A} = \mathbf{1.5\ A}$

2. (a) When the resistance doubles, the current is halved from 100 mA to **50 mA.**
   (b) When the resistance is reduced by 30%, the current increases from 100 mA to $I = V/0.7R = 1.429(V/R) = (1.429)(100\text{ mA}) \cong \mathbf{143\ mA}$
   (c) When the resistance is quadrupled, the current decreases from 100 mA to **25 mA**.

3. Tripling the voltage triples the current from 10 mA to 30 mA, but doubling the resistance halves the current to **15 mA.**

SECTION 3-2 Application of Ohm's Law

4. (a) $I = \dfrac{V}{R} = \dfrac{5\text{ V}}{1\ \Omega} = \mathbf{5\ A}$ (b) $I = \dfrac{V}{R} = \dfrac{15\text{ V}}{10\ \Omega} = \mathbf{1.5\ A}$

   (c) $I = \dfrac{V}{R} = \dfrac{50\text{ V}}{100\ \Omega} = \mathbf{0.5\ A}$ (d) $I = \dfrac{V}{R} = \dfrac{30\text{ V}}{15\text{ k}\Omega} = 2\ \mathbf{mA}$

   (e) $I = \dfrac{V}{R} = \dfrac{250\text{ V}}{4.7\text{ M}\Omega} = \mathbf{53.2\ \mu A}$

5. (a) $I = \dfrac{V}{R} = \dfrac{9\text{ V}}{2.7\text{ k}\Omega} = \mathbf{3.33\ mA}$ (b) $I = \dfrac{V}{R} = \dfrac{5.5\text{ V}}{10\text{ k}\Omega} = \mathbf{550\ \mu A}$

   (c) $I = \dfrac{V}{R} = \dfrac{40\text{ V}}{68\text{ k}\Omega} = \mathbf{588\ \mu A}$ (d) $I = \dfrac{V}{R} = \dfrac{1\text{ kV}}{2\text{ k}\Omega} = \mathbf{500\ mA}$

   (e) $I = \dfrac{V}{R} = \dfrac{66\text{ kV}}{10\text{ M}\Omega} = \mathbf{6.60\ mA}$

6. $I = \dfrac{V}{R} = \dfrac{12\text{ V}}{10\ \Omega} = \mathbf{1.2\ A}$

7. (a) $I = \frac{V}{R} = \frac{25\text{ V}}{10\text{ k}\Omega}$ = **2.50 mA** (b) $I = \frac{V}{R} = \frac{5\text{ V}}{2.2\text{ M}\Omega}$ = **2.27 μA**

(c) $I = \frac{V}{R} = \frac{15\text{ V}}{1.8\text{ k}\Omega}$ = **8.33 mA**

8. Orange, violet, yellow, gold, brown ≡ 37.4 Ω ± 1%

$I = \frac{V_S}{R} = \frac{12\text{ V}}{37.4\ \Omega}$ = **0.321 A**

9. $I = \frac{24\text{ V}}{37.4\ \Omega} = 0.642\text{ A}$

0.642 A is greater than 0.5 A, so **the fuse will blow.**

10. (a) $V = IR$ = (2 A)(18 Ω) = **36 V** (b) $V = IR$ = (5 A)(47 Ω) = **235 V**
(c) $V = IR$ = (2.5 A)(620 Ω) = **1550 V** (d) $V = IR$ = (0.6 A)(47 Ω) = **28.2 V**
(e) $V = IR$ = (0.1 A)(470 Ω) = **47 V**

11. (a) $V = IR$ = (1 mA)(10 Ω) = **10 mV** (b) $V = IR$ = (50 mA)(33 Ω) = **1.65 V**
(c) $V = IR$ = (3 A)(4.7 kΩ) = **14.1 kV** (d) $V = IR$ = (1.6 mA)(2.2 kΩ) = **3.52 V**
(e) $V = IR$ = (250 μA)(1 kΩ) = **250 mV** (f) $V = IR$ = (500 mA)(1.5 MΩ) = **750 kV**
(g) $V = IR$ = (850 μA)(10 MΩ) = **8.5 kV** (h) $V = IR$ = (75 μA)(47 Ω) = **3.53 mV**

12. $V = IR$ = (3 A)(20 mΩ) = **60 mV**

13. (a) $V = IR$ = (3 mA)(27 kΩ) = **81 V** (b) $V = IR$ = (5 μA)(100 MΩ) = **500 V**
(c) $V = IR$ = (2.5 A)(47 Ω) = **117.5 V**

14. (a) $R = \frac{V}{I} = \frac{10\text{ V}}{2\text{ A}}$ = **5 Ω** (b) $R = \frac{V}{I} = \frac{90\text{ V}}{45\text{ A}}$ = **2 Ω**

(c) $R = \frac{V}{I} = \frac{50\text{ V}}{5\text{ A}}$ = **10 Ω** (d) $R = \frac{V}{I} = \frac{5.5\text{ V}}{10\text{ A}}$ = **0.55 Ω**

(e) $R = \frac{V}{I} = \frac{150\text{ V}}{0.5\text{ A}}$ = **300 Ω**

15. (a) $R = \frac{V}{I} = \frac{10\text{ kV}}{5\text{ A}}$ = **2 kΩ** (b) $R = \frac{V}{I} = \frac{7\text{ V}}{2\text{ mA}}$ = **3.5 kΩ**

(c) $R = \frac{V}{I} = \frac{500\text{ V}}{250\text{ mA}}$ = **2 kΩ** (d) $R = \frac{V}{I} = \frac{50\text{ V}}{500\ \mu\text{A}}$ = **100 kΩ**

(e) $R = \frac{V}{I} = \frac{1\text{ kV}}{1\text{ mA}}$ = 1 **MΩ**

16. $R = \frac{V}{I} = \frac{6\text{ V}}{2\text{ mA}}$ = **3 kΩ**

17. (a) $R = \frac{V}{I} = \frac{8\text{ V}}{2\text{ A}}$ = **4 Ω**

(b) $R = \frac{V}{I} = \frac{12\text{ V}}{4\text{ mA}}$ = **3 kΩ**

(c) $R = \frac{V}{I} = \frac{30\text{ V}}{150\,\mu\text{A}}$ = 0.2 MΩ = **200 kΩ**

18. $I = \frac{V}{R} = \frac{3.2\text{ V}}{3.9\ \Omega}$ = **0.82 A**

SECTION 3-3 Energy and Power

19. $P = \frac{W}{t} = \frac{26\text{ J}}{10\text{ s}}$ = **2.6 W**

20. Since 1 watt = 1 joule, *P* = 350 J/s = **350 W**

21. $P = \frac{W}{t} = \frac{7500\text{J}}{5\text{ h}}$

$\left(\frac{7500\text{J}}{5\text{ h}}\right)\left(\frac{1\text{ h}}{3600\text{s}}\right) = \frac{7500\text{J}}{18{,}000\text{s}}$ = 0.417 J/s = **417 mW**

22. (a) 1000 W = 1 × 10^3 W = **1 kW**

(b) 3750 W = 3.750 × 10^3 W = **3.75 kW**

(c) 160 W = 0.160 × 10^3 W = **0.160 kW**

(d) 50,000 W = 50 × 10^3 W = **50 kW**

23. (a) 1,000,000 W = 1 × 10^6 W = **1 MW**

(b) 3 × 10^6 W = **3 MW**

(c) 15 × 10^7 W = 150 × 10^6 W = **150 MW**

(d) 8700 kW = 8.7 × 10^6 W = **8.7 MW**

24. (a) 1 W = 1000 × 10^{-3} W = **1000 mW**

(b) 0.4 W = 400 × 10^{-3} W = **400 mW**

(c) 0.002 W = 2 × 10^{-3} W = **2 mW**

(d) 0.0125 W = 12.5 × 10^{-3} W = **12.5 mW**

25. (a) 2 W = **2,000,000 μW**

(b) 0.0005 W = **500 μW**

(c) 0.25 mW = **250 μW**

(d) 0.00667 mW = **6.67 μW**

26. (a) 1.5 kW = 1.5 × 10^3 W = **1500 W**

(b) 0.5 MW = 0.5 × 10^6 W = **500,000 W**

(c) 350 mW = 350 × 10^{-3} W = **0.350 W**

(d) 9000 μW = 9000 × 10^{-6} W = **0.009 W**

27. $P = \frac{W}{t}$ in watts

$V = \frac{W}{Q}$

$I = \frac{Q}{t}$

$P = VI = \frac{W}{t}$

So, (1 V)(1 A) = 1 W

28. $P = \frac{W}{t} = \frac{1\text{ J}}{1\text{ s}} = 1\text{ W}$

1 kW = 1000 W = $\frac{1000\text{ J}}{1\text{ s}}$

1 kW-second = 1000 J

1 kWh = 3600 × 1000 J

1 kWh = 3.6 × 10^6 J

SECTION 3-4 Power in an Electric Circuit

29. $P = VI$ = (5.5 V)(3 mA) = **16.5 mW**

30. $P = VI$ = (115 V)(3 A) = **345 W**

31. $P = I^2R = (500\text{ mA})^2(4.7\text{ k}\Omega)$ = **1.18 kW**

32. $P = I^2R = (5.0\text{ A})^2(20 \times 10^{-3}\ \Omega)$ = **500 mW**

33. $P = \frac{V^2}{R} = \frac{(60\text{ V})^2}{620\ \Omega}$ = **5.81 W**

34. $P = \frac{V^2}{R} = \frac{(1.5\text{ V})^2}{56\ \Omega}$ = 0.0402 W = **40.2 mW**

35. $P = I^2R$

$R = \frac{P}{I^2} = \frac{100\text{ W}}{(2\text{ A})^2}$ = **25 Ω**

36. 5×10^6 watts for 1 minute = 5×10^3 kWmin

$$\frac{5\times10^3 \text{ kWmin}}{60 \text{ min/1 hr}} = \textbf{83.3 kWh}$$

37. $$\frac{6700 \text{ W/s}}{(1000 \text{ W/kW})(3600 \text{ s/h})} = \textbf{0.00186 kWh}$$

38. (50 W)(12 h) = **600 Wh**
50 W = 0.05 kW
(0.05 kW)(12 h) = **0.6 kWh**

39. $$I = \frac{V}{R_L} = \frac{1.25 \text{ V}}{10\ \Omega} = 0.125 \text{ A}$$

$P = VI = (1.25 \text{ V})(0.125 \text{ A}) = 0.156 \text{ W} = \textbf{156 mW}$

40. $$P = \frac{W}{t}$$

$$156 \text{ mW} = \frac{156 \text{ mJ}}{1 \text{ s}}$$

$W_{\text{tot}} = (156 \text{ mJ/s})(90 \text{ h})(3600 \text{ s/h}) = \textbf{50,544 J}$

SECTION 3-5 The Power Rating of Resistors

41. $P = I^2R = (10 \text{ mA})^2(6.8 \text{ k}\Omega) = 0.68 \text{ W}$
Use the next highest standard power rating of **1 W**.

42. If the 8 W resistor is used, it will be operating in a marginal condition.
To allow for a **safety margin of 20%**, use a **12 W** resistor.

SECTION 3-6 Energy Conversion and Voltage Drop in a Resistance

43. (a) + at top, – at bottom of resistor (b) + at bottom, – at top of resistor

(c) + on right, – on left of resistor

SECTION 3-7 Power Supplies and Batteries

44. $V_{\text{OUT}} = \sqrt{P_L R_L} = \sqrt{(1 \text{ W})(50\ \Omega)} = \textbf{7.07 V}$

45. Ampere-hour rating = (1.5 A)(24 h) = **36 Ah**

46. $I = \dfrac{80\,\text{Ah}}{10\,\text{h}}$ = **8 A**

47. $I = \dfrac{650\,\text{mAh}}{48\,\text{h}}$ = **13.5 mA**

48. $P_{LOST} = P_{IN} - P_{OUT}$ = 500 mW – 400 mW = **100 mW**
$$\%\ \text{efficiency} = \left(\frac{P_{OUT}}{P_{IN}}\right)100\% = \left(\frac{400\,\text{mW}}{500\,\text{mW}}\right)100\% = \mathbf{80\%}$$

49. P_{OUT} = (efficiency)P_{IN} = (0.85)(5 W) = **4.25 W**

SECTION 3-8 Introduction to Troubleshooting

50. The 4th bulb from the left is open.

51. If should take **five** (maximum) resistance measurements.

ADVANCED PROBLEMS

52. Assume that the total consumption of the power supply is the input power plus the power lost.
P_{OUT} = 2 W
$$\%\ \text{efficiency} = \left(\frac{P_{OUT}}{P_{IN}}\right)100\%$$
$$P_{IN} = \left(\frac{P_{OUT}}{\%\ \text{efficiency}}\right)100\% = \left(\frac{2\ \text{W}}{60\%}\right)100\% = 3.33\ \text{W}$$
The power supply itself uses
$P_{IN} - P_{OUT}$ = 3.33 W – 2 W = 1.33 W
Energy = $W = Pt$ = (1.33 W)(24 h) = 31.9 Wh ≅ **0.032 kWh**

53. $R_f = \dfrac{V}{I} = \dfrac{120\,\text{V}}{0.8\,\text{A}}$ = **150 Ω**

54. Measure the current with an ammeter connected as shown in Figure 3-1. Then calculate the unknown resistance with the formula, $\boldsymbol{R = 12\ \mathrm{V}/I}$.

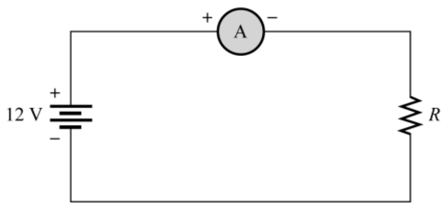

Figure 3-1

55. Calculate I for each value of V:

$$I_1 = \frac{0\ \mathrm{V}}{100\ \Omega} = \mathbf{0\ A} \qquad I_2 = \frac{10\ \mathrm{V}}{100\ \Omega} = \mathbf{100\ mA}$$

$$I_3 = \frac{20\ \mathrm{V}}{100\ \Omega} = \mathbf{200\ mA} \qquad I_4 = \frac{30\ \mathrm{V}}{100\ \Omega} = \mathbf{300\ mA}$$

$$I_5 = \frac{40\ \mathrm{V}}{100\ \Omega} = \mathbf{400\ mA} \qquad I_6 = \frac{50\ \mathrm{V}}{100\ \Omega} = \mathbf{500\ mA}$$

$$I_7 = \frac{60\ \mathrm{V}}{100\ \Omega} = \mathbf{600\ mA} \qquad I_8 = \frac{70\ \mathrm{V}}{100\ \Omega} = \mathbf{700\ mA}$$

$$I_9 = \frac{80\ \mathrm{V}}{100\ \Omega} = \mathbf{800\ mA} \qquad I_{10} = \frac{90\ \mathrm{V}}{100\ \Omega} = \mathbf{900\ mA}$$

$$I_{11} = \frac{100\ \mathrm{V}}{100\ \Omega} = \mathbf{1\ A}$$

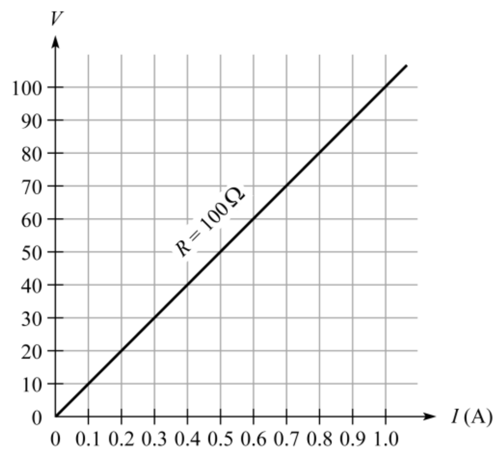

Figure 3-2

The graph is a straight line as shown in Figure 3-2. This indicates a *linear* relationship between I and V.

56. $R = \dfrac{V_S}{I} = \dfrac{1\text{ V}}{5\text{ mA}}$ = **200 Ω**

(a) $I = \dfrac{V_S}{R} = \dfrac{1.5\text{ V}}{200\ \Omega}$ = **7.5 mA**

(b) $I = \dfrac{V_S}{R} = \dfrac{2\text{ V}}{200\ \Omega}$ = **10 mA**

(c) $I = \dfrac{V_S}{R} = \dfrac{3\text{ V}}{200\ \Omega}$ = **15 mA**

(d) $I = \dfrac{V_S}{R} = \dfrac{4\text{ V}}{200\ \Omega}$ = **20 mA**

(e) $I = \dfrac{V_S}{R} = \dfrac{10\text{ V}}{200\ \Omega}$ = **50 mA**

57. $R_1 = \dfrac{V}{I} = \dfrac{1\text{ V}}{2\text{ A}}$ = **0.5 Ω** $R_2 = \dfrac{V}{I} = \dfrac{1\text{ V}}{1\text{ A}}$ = **1 Ω** $R_3 = \dfrac{V}{I} = \dfrac{1\text{ V}}{0.5\text{ A}}$ = **2 Ω**

58. $\dfrac{V_2}{30\text{ mA}} = \dfrac{10\text{ V}}{50\text{ mA}}$

$V_2 = \dfrac{(10\text{ V})(30\text{ mA})}{50\text{ mA}}$ = 6 V **new value**

The voltage decreased by 4 V, from 10 V to 6 V.

59. The current increase is 50%, so the voltage increase must be the same; that is, the voltage must be increased by (0.5)(20 V) = **10 V**.

The new value of voltage is V_2 = 20 V + (0.5)(20 V) = 20 V + 10 V = **30 V**

60. Wire resistance: $R_W = \dfrac{(10.4\text{ CM}\cdot\Omega/\text{ft})(24\text{ ft})}{1624.3\text{ CM}}$ = 0.154 Ω

(a) $I = \dfrac{V}{R + R_W} = \dfrac{6\text{ V}}{100.154\ \Omega}$ = **59.9 mA**

(b) V_R = (59.9 mA)(100 Ω) = **5.99 V**

(c) V_{R_W} = 6 V – 5.99 V = 0.01 V

For one length of wire, $V = \dfrac{0.01\text{ V}}{2}$ = **0.005 V**

61. 300 W = 0.3 kW
30 days = (30 days)(24 h/day) = 720 h
Energy = (0.3 kW)(720 h) = **216 kWh**

62. $\dfrac{1500\text{ kWh}}{31\text{ days}}$ = 48.39 kWh/day

$P = \dfrac{48.39\text{ kWh/day}}{24\text{ h/day}}$ = **2.02 kW**

63. The minimum power rating you should use is **12 W** so that the power dissipation does not exceed the rating.

64. (a) $P = \frac{V^2}{R} = \frac{(12\text{ V})^2}{10\ \Omega}$ = **14.4 W**

(b) $W = Pt$ = (14.4 W)(2 min)(1/60 h/min) = **0.48 Wh**

(c) Neither, the power is the same because it is not time dependent.

65. $V_{R(\text{max})}$ = 120 V – 100 V = 20 V

$I_{\text{max}} = \frac{V_{R(\text{max})}}{R_{\text{min}}} = \frac{20\text{ V}}{8\ \Omega}$ = 2.5 A

A fuse with a rating of less than 2.5 A must be used. **A 2 A fuse is recommended.**

66. $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{0.5\text{ W}}{0.030\ \Omega}}$ = **4.08 A**

67. Power will increase by four times.

66. The materials required for the Load Test Box are as follows:

Item	Component	Qty
1	Resistor: 5.0 Ω, 10 W	1
2	Resistor: 16 Ω, 5 W	1
3	Resistor: 100 Ω, 2.0 W	1
4	Resistor: 150 Ω, 3.0 W	1
5	1 pole, 4 position rotary switch	1
6	Knob	1
7	Enclosure (4” x 4” × 2” Al)	1
8	Banana plug terminals	2
9	Fuse (1.5 A) and fuse holder	1
10	PC board (etched with pattern)	1
11	Screws, washers, nuts	4
12	Standoffs	4

69. See Figure 3-3.

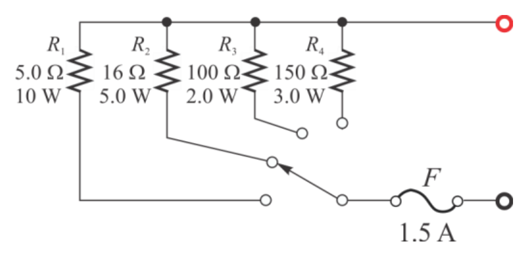

Figure 3-3

Multisim Troubleshooting Problems

70. *R* is open.

71. No fault

72. R_1 is shorted.

73. Lamp 4 is shorted.

74. Lamp 6 is open.