5.10: Current and Resistance (Answers)

Conceptual Questions

1. If a wire is carrying a current, charges enter the wire from the voltage source's positive terminal and leave at the negative terminal, so the total charge remains zero while the current flows through it.

3. Using one hand will reduce the possibility of "completing the circuit" and having current run through your body, especially current running through your heart.

5. Even though the electrons collide with atoms and other electrons in the wire, they travel from the negative terminal to the positive terminal, so they drift in one direction. Gas molecules travel in completely random directions.

7. In the early years of light bulbs, the bulbs are partially evacuated to reduce the amount of heat conducted through the air to the glass envelope. Dissipating the heat would cool the filament, increasing the amount of energy needed to produce light from the filament. It also protects the glass from the heat produced from the hot filament. If the glass heats, it expands, and as it cools, it contacts. This expansion and contraction could cause the glass to become brittle and crack, reducing the life of the bulbs. Many bulbs are now partially filled with an inert gas. It is also useful to remove the oxygen to reduce the possibility of the filament actually burning. When the original filaments were replaced with more efficient tungsten filaments, atoms from the tungsten would evaporate off the filament at such high temperatures. The atoms collide with the atoms of the inert gas and land back on the filament.

9. In carbon, resistivity increases with the amount of impurities, meaning fewer free charges. In silicon and germanium, impurities decrease resistivity, meaning more free electrons.

11. Copper has a lower resistivity than aluminum, so if length is the same, copper must have the smaller diameter.

13. Device B shows a linear relationship and the device is ohmic.

15. Although the conductors have a low resistance, the lines from the power company can be kilometers long. Using a high voltage reduces the current that is required to supply the power demand and that reduces line losses.

17. The resistor would overheat, possibly to the point of causing the resistor to burn. Fuses are commonly added to circuits to prevent such accidents.

Problems

21. a. $v=4.38\times 10^5\frac{m}{s}$;

b. $\Delta q=5.00\times 10^{-3}C$,no. of protons=$3.13\times 10^{16}$

23. $I=\frac{\Delta Q}{\Delta t}$, $\Delta Q=12.00C$, no. of electrons=7.46×10^{19}

25. $I(t)=0.016\frac{C}{s^4}t^3-0.001\frac{C}{s}$ $I(3.00s)=0.431A$

27. $I(t)=-I_{max}sin(\omega t+\phi)$

29. $|J|=15.92A/m^2$

31. $I=3.98\times 10^{-5}A$

33. a. $|J|=7.60\times 10^5\frac{A}{m^2}$;

b. $v_d=5.60\times 10^{-5}\frac{m}{s}$

35. $R=6.750k\Omega$

37. $R=0.10\Omega$

39. $R=\rho\frac{L}{A}$; $L=3cm$

41. $\frac{R_{Al}/L_{Al}}{R_{Cu}/L_{Cu}} = \frac{\rho_{Al}\frac{1}{\pi(\frac{D_{Al}}{2})^2}}{\rho_{Cu}\frac{1}{\pi(\frac{D_{Cu}}{2})^2}} = \frac{\rho_{Al}}{\rho_{Cu}}(\frac{D_{Cu}}{D_{Al}})^2 = 1, \frac{D_{Al}}{D_{Cu}} = \sqrt{\frac{\rho_{AI}}{\rho_{Cu}}}$

43. a. $R = R_0(1+\alpha\Delta T), 2 = 1+\alpha\Delta T, \Delta T = 256.4^\circ C, T = 276.4^\circ C$;

b. Under normal conditions, no it should not occur.

45. $R = R_0(1+\alpha\Delta T)\ \ \alpha = 0.006^\circ C^{-1}$, iron

47. a. $R = \rho\frac{L}{A}, \rho = 2.44\times 10^-8\Omega\cdot m$, gold; $R = \rho\frac{L}{A}(1+\alpha\Delta T)$

b. $R = 2.44\times 10^{-8}\Omega\cdot m(\frac{25m}{\pi(\frac{0.100\times 10^{-3}m}{2})^2})(1+0.0034^\circ C^{-1}(150^\circ C - 20^\circ C))R = 112\Omega$

49. $R_{Fe} = 0.525\Omega, R_{Cu} = 0.500\Omega, \alpha_{Fe} = 0.0065^\circ C^{-1}, \alpha_{Cu} = 0.0039^\circ C^{-1}, R_{Fe} = R_{Cu}, R_{0Fe}(1+\alpha_{Fe}(T-T_0))$
$= R_{0Cu}(1+\alpha_{Cu}(T-T_0)), \frac{R_{0Fe}}{R_{0Cu}}(1+\alpha_{Fe}(T-T_0)) = 1+\alpha_{Cu}(T-T_0), T = 2.91^\circ C$

51. $R_{min} = 2.375\times 10^5\Omega, I_{min} = 12.63\mu A$

$R_{max} = 2.625\times 10^5\Omega, I_{max} = 11.43\mu A$

53. $R = 100\Omega$

55. a. $I = 2mA$;

b. $P = 0.04mW$;

c. $P = 0.04mW$;

d. It is converted into heat.

57. $P = \frac{V^2}{R}, R = 40\Omega, A = 2.08mm^2, \rho = 100\times 10^{-8}\Omega\cdot m, R = \rho\frac{L}{A}, L = 83m$

59. $I = 0.14A, V = 14V$

61. a. $I \approx 3.00A + \frac{100W}{110V} + \frac{60W}{110V} + \frac{3.00W}{110V} = 4.48A$

$P = 493W$

$R = 9.91\Omega,$

$P_{loss} = 200.W$

b. $P = 493W$

$I = 0.0045A$

$R = 9.91\Omega$

$P_{loss} = 201\mu W$

Additional Problems

69. $dR = \frac{\rho}{2\pi rL}dr$

$R = \frac{\rho}{2\pi L}ln\frac{r_o}{r_i}$

$R = 2.21\times 10^{11}\Omega$

71. a. $R_0 = 0.003\Omega$;

b. $T_c = 37.0^\circ C\ R = 0.00302\Omega$

73. $\rho = 5.00 \times 10^{-8} \Omega \cdot m$

75. $\rho = 1.71 \times 10^{-8} \Omega \cdot m$

77. $a.\ V = 6000V;$

b. $V = 60V$

79. $P = \dfrac{W}{t}, W = 8.64J$

Challenge Problems

81. $V = 7.09cm^3\ n = 8.49 \times 10^{28} \dfrac{electrons}{m^2}\ \ v_d = 7.00 \times 10^{-5} \dfrac{m}{s}$

83. a. $v = 4.38 \times 10^7 m/s;$

b. $v = 5.81 \times 10^{13} \dfrac{protons}{m^3};$

c. $1.25 \frac{electrons}{m^3}$

85. $E = 75kJ$

87. a. $P = 52W\ R = 36\Omega;$

b. $V = 43.54V$

89. a. $R = \dfrac{\rho}{2\pi L} ln(\dfrac{R_0}{R_i});$

b. $R = 2.5m\Omega$

91. a. $I = 0.870A;$

b. $\#\text{electrons} = 2.54 \times 10^{23}$

c. $R = 132\Omega;$

d. $q = 4.68 \times 10^6 J$

93. $P = 1045W, P = \dfrac{V^2}{R}, R = 12.27\Omega$

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