1. Definition of Electric Current

(a) Three identical wires are connected in parallel between the terminals of a battery, as in the circuit shown below. The current is known to be steady and is known in one wire to be equal to $I_1 = 2 \, \text{A}$. At the end of 20 sec., how much charge has been delivered from one terminal of the battery to the other? Key 21. HQ 7.

(b) A typical automobile battery can deliver 100 amp-hours of charge without recharging. How many coulombs is this? How many electrons? Assuming each of these electrons is associated with only one atom in the battery’s internal chemistry, how many moles of atoms are involved? Key 12. HQ 4.

2. Ohm’s Law for Simple Circuits

(a) A lamp is rated to draw 100 W at 110 V. What current will flow through it, and what is the lamp’s resistance? Key 11. HQ 12. HQ 3.

(b) Two lamps, one rated at 100 W at 110 V and one at 60 W at 110 V, are connected in parallel to a 110 V supply. What current is drawn from the supply line? Key 14. HQ 2.
3. Household Circuits

(a) A 110 V household circuit contains a fuse that burns out when a 20 A current flows through it. What is the maximum number of 100 W lamps that can be connected to this circuit?  

(b) A traveler goes to Europe and takes his electric shaver. This shaver is designed for a 110 V outlet, and has a power rating of 15 W. On his arrival in Europe, he discovers that all the outlets are 220 V. A Physics 102 graduate, he improvises, deciding to put a light bulb in series with his shaver to avoid overloading it. What wattage bulb should he choose? (Remember, the bulbs are designed for 220 V!)

4. One-Loop Circuit Analysis
(a) What is the equivalent resistance of $R_1$ and $R_2$? \hfill \text{Key 27.}

(b) What is the total circuit resistance? \hfill \text{Key 6.}

(c) What is the equivalent battery voltage (that is, the potential difference $V_a - V_d$)? \hfill \text{Key 23. HQ 1. HQ 9.}

(d) What is the current flowing from c to d? \hfill \text{Key 1.}

(e) What is the voltage across the parallel resistors (i.e., $V_a - V_b$)? \hfill \text{Key 8. HQ 10.}

(f) What are the currents in $R_1$ and $R_2$? \hfill \text{Key 9.}

(g) What is the voltage drop across $R_3$ (i.e., $V_b - V_c$)? \hfill \text{Key 17.}

(h) The symbol near the point b means that this point is grounded. Then one takes $V_b = 0$ by convention. Using the answers to 4c, 4e, and 4g, find $V_a$, $V_c$, and $V_d$. \hfill \text{Key 2.}

(i) How much power is dissipated in $R_3$? \hfill \text{Key 7.}

5. \textbf{Resistivity of Copper Wire}

(a) Calculate the resistance of a copper wire of cross sectional area 1.0 mm$^2$ and length 1.0 m, at 20° C. \hfill \text{Key 26. HQ 11.}

(b) What is the resistance at 20° C of a hollow, cylindrical copper wire of length 1.0 m, inner radius $r = 1$ mm, and outer radius $r' = 3$ mm? \hfill \text{Key 15.}
Helping Questions

1. What is the potential difference between the negative terminal of the left battery and the positive terminal of the right battery? Key 25.

2. What current does the 100 W lamp draw? The 60 W lamp? Key 30.

3. What is the relation between the potential drop across a resistor, the current through it, and its resistance? Key 24.

4. If one has \( N \) atoms, how many moles of atoms does one have? Key 19.

5. What is the relationship between power, voltage, and resistance? Key 28.

6. What is the maximum power that can be spent in this circuit? Key 18.

7. What is the value of \( I_2 \) and \( I_3 \)? Of \( I \)? How many amp-sec equals one coulomb? Key 10.

8. How many 100 W lamps are needed to spend 2200 W? Key 20.

9. What are the potential differences \( V_a - V_p \) and \( V_p - V_d \) where \( p \) is a point between the two batteries? Key 13.

10. If the equivalent resistance between two points \( p \) and \( q \) in a circuit is \( R_e \), and the current going from \( p \) towards \( q \) is \( I \), what is \( V_p - V_q \) (assuming there are no sources of potential between \( p \) and \( q \))? Key 29.

11. What is the relation between the resistance of a resistor, its cross-sectional area, and its length and the resistivity of the resistor material? Key 3.

12. What is the relation between power, voltage, and current? Key 4.

13. How should the resistance of the bulb compare to the resistance of the shaver in order to produce a 110 V drop across the shaver? Key 5.
Solutions

1. \( I = \frac{V_{\text{eff}}}{R_{\text{tot}}} = 2 \text{ A.} \)

2. \( V_a = 8.0 \text{ V}; \) \( V_c = -16 \text{ V}; \) \( V_d = -16 \text{ V.} \)

3. \( R = \frac{\rho l}{A}. \)

4. \( P = VI. \)

5. They should be the same.

6. \( R_{\text{tot}} = R_3 + \frac{R_1 R_2}{R_1 + R_2} = 12 \Omega. \)

7. \( P = I^2 R = 32 \text{ W}. \)

8. \( V_b - V_a = IR = 8 \text{ V}. \)

9. \( I_1 = \frac{V}{R_1} = 1.33 \text{ A}; \) \( I_2 = \frac{V}{R_2} = 0.67 \text{ A}. \)

10. \( I_1 = I_2 = I_3 = 2 \text{ A}; \) \( I = I_1 + I_2 + I_3 = 6 \text{ A}; \) 1 amp-sec = 1 C.

11. \( I = \frac{P}{V} = 0.91 \text{ A}; \) \( R = \frac{V}{I} = 121 \Omega. \)

12. \( Q = 3.6 \times 10^5 \text{ C} = 2.25 \times 10^{24} \text{ electrons} = 3.74 \text{ moles}. \)

13. Each voltage drop is 12 V.

14. \( I = \frac{P_{\text{tot}}}{V} = 1.5 \text{ A}. \)

15. \( R = \frac{\rho l}{\pi (r'^2 - r^2)} = 6.7 \times 10^{-4} \Omega. \)

16. \( P = 60 \text{ W}. \)

17. \( IR = 16 \text{ V}. \)

18. \( P = IV = 2200 \text{ W}. \)

19. \( N/N_0 \) moles, where \( N_0 \) is Avogadro’s number.

20. 22 lamps.

21. \( Q = I \Delta t = 120 \text{ C}. \)

22. \# of bulbs is \( VI/P = 22. \)

23. \( V_{\text{eff}} = V_1 + V_2 = 24 \text{ V}. \)

24. \( V = IR. \)
25. $\Delta V = 0$.

26. $R = \rho l / A = 1.7 \times 10^{-2} \Omega$.

27. $R = R_1 R_2 / (R_1 + R_2) = 4 \Omega$.


29. $V_p - V_q = I R_e$.

30. $I = P / V = 0.91 \text{ A for the 100 W lamp, 0.55 A for the 60 W lamp.}$