Physics
DC Circuits

Batteries and Kirchhoff's Laws

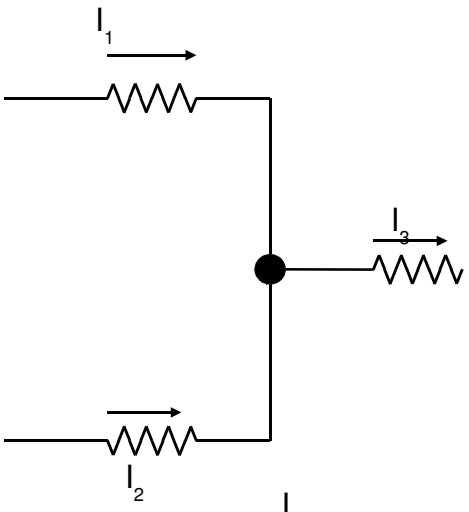
Part One: Emf, Terminal Voltage and Internal Resistance

1. A 9-V battery has an internal resistance of 1 Ω. If the battery delivers 3 A to the external circuit, what is the terminal voltage of the battery?
2. A battery with an internal resistance of 1.5 Ω is connected across a load consisting of two resistances, 3.0 Ω and 3.5 Ω in series. The potential difference across the 3.0-Ω resistance is 9.0 V. What is the emf of the battery?
3. A battery provides an emf of 3.1 V. When a load of 5.8 Ω is connected across the battery an ammeter in the external circuit reads 0.50 A. Find the internal resistance of the battery.
4. A battery has an emf of 16.0 V and internal resistance 0.80 Ω. The external resistance is 2 Ω. Calculate the total resistance of the circuit, the current in the external circuit and the terminal voltage.
5. The terminal voltage of a 24-V battery is 22.0 V and the current in the circuit is 4.00 A. What are the internal resistance of the battery and the resistance of the circuit resistor?
6. A dry cell has an emf of 1.60 V and an internal resistance of 0.02 Ω. If the terminal voltage is 1.5 V, what current is delivered to the external circuit?
7. A 65.0-Ω resistor is connected to the terminals of a battery whose emf is 12.0 V and whose internal resistance is 0.500 Ω. Calculate (a) the current in the circuit, (b) the terminal voltage of the battery, and (c) the power dissipated in the resistor and in the battery's internal resistance.
8. The internal resistance of a dry cell increases gradually with age, even though the cell is not used. The emf, however, remains fairly constant at about 1.5 V. Dry cells may be tested for age at the time of purchase by connecting an ammeter directly across the terminals of the cell and reading the current. The resistance of the ammeter is so small that the cell is practically short circuited. (a) The short-circuit current of a fresh dry cell (1.50-V emf) is 25.0 A. What is the internal resistance? (b) What is the internal resistance if the short-circuit current is only 10.0 A?

Part Two: Kirchhoff's First Law

Use Kirchhoff's first law to write an equation for each diagram below.

9.



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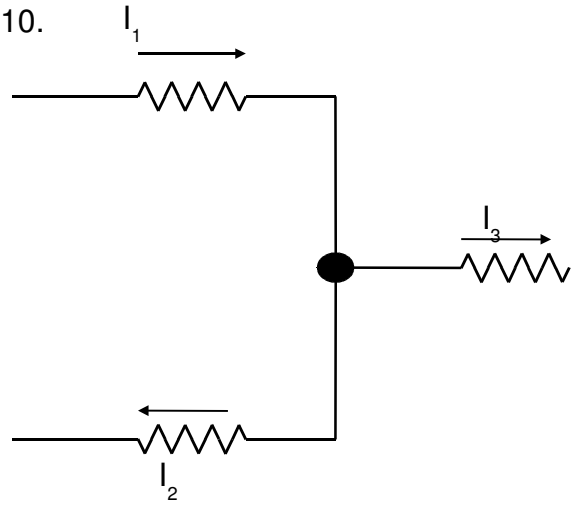

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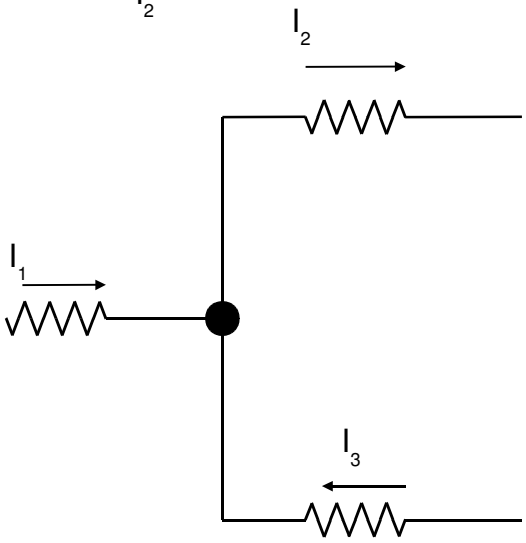

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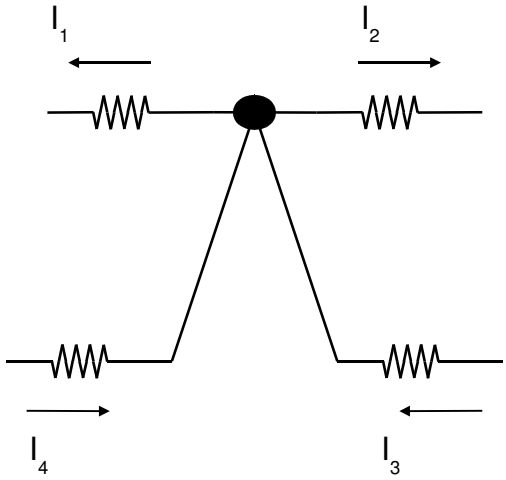

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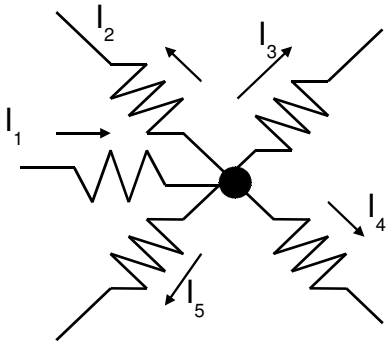

Part Three: Kirchhoff's Second Law

Apply Kirchhoff's second law to each circuit below. Write the loop equations.

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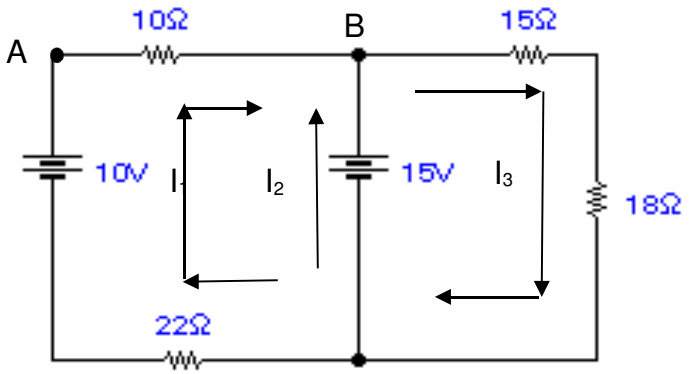

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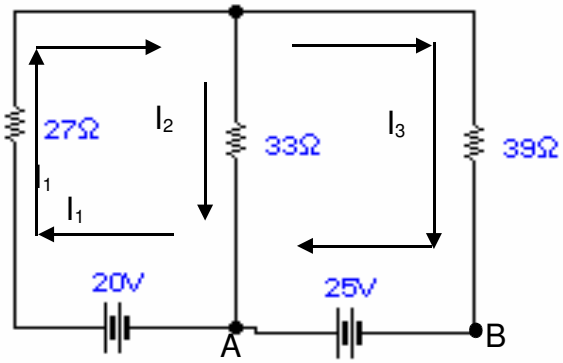

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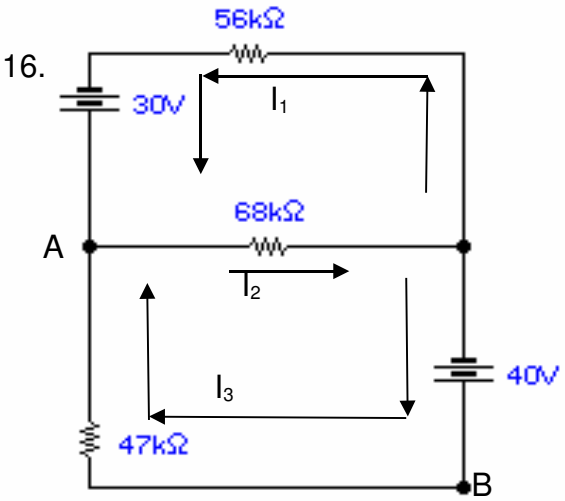

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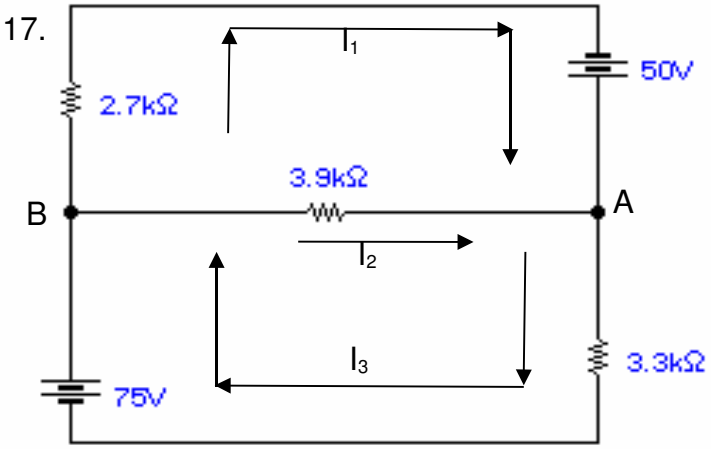

Answers to the Odd Numbered Problems:

1. 6 V
3. 0.4 Ω
5. 0.500 Ω; 5.50 Ω
7. (a) 0.183 A; (b) 11.9 V; (c) 2.18 W, 0.0168 W
9. $I_1 + I_2 = I_3$
11. $I_1 + I_3 = I_2$
13. $I_1 = I_2 + I_3 + I_4 + I_5$
15. Loop 1 - Start at point A and trace loop cw.
    $+20 - 27\ I_1 - 33\ I_2 = 0$
    Loop 2 - Start at point B and trace the loop cw.
    $+25 + 33\ I_2 - 39\ I_3 = 0$
17. Loop 1 - Start at point B and trace the loop cw.
    $-2700\ I_1 + 50 + 3900\ I_2 = 0$
    Loop 2 - Start at point A and trace the loop cw.
    $-3300\ I_3 + 75 - 3900\ I_2 = 0$