BRAC UNIVERSITY

Principles of Physics-II (PHY-112)

Department of Mathematics and Natural Sciences

Quiz: 3, **Section**: 30

Date: September 26, 2024

Duration: 30 Minutes | **Summer 2024 (10F-31C)** | Marks: 15

Name: Student ID:

Use SI Units only. Partial Marks will be given for partially correct answers ONLY.

1. Kirchoff's Junction Rule works in a closed loop due to the conservation of — **(1)**

   ◯ Energy ◯ Charge ✓ ◯ Current ◯ Potential

2. You turn on a switch for a light-bulb 20 m away. The electron drift speed in the circuit (diameter 1.0 mm) is 5.0 × mm s^{-1}. Which of the following generates a current in the wire? — **(1)**

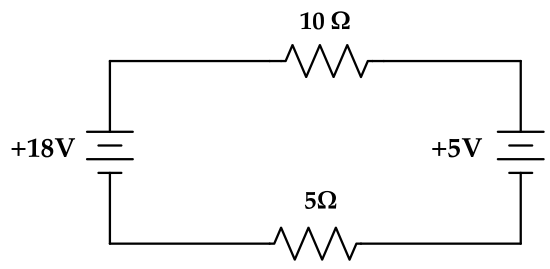
   ◯ Random motion of the free electrons ◯ Drift motion ✓ ◯ Current Density ◯ Positive charges

3. Find the voltage drop across the 5 Ω resistor and the direction of I in the circuit. Use only Kirchhoff's Loop rule to answer this. Mention travel directions and apply the sign convention accurately. **(4)**

   Apply KVL,

$$-I(10\,\Omega) - 5\,\text{V} - I(5\,\Omega) + 18\,\text{V} = 0$$
$$-I(15\,\Omega) + 13\,\text{V} = 0$$
$$I = \frac{13\,\text{V}}{15\,\Omega} = 0.867\,\text{A}.$$

   Thus, the voltage drop across the 5 Ω resistor is $5\,\Omega \times 0.867\,\text{A} = 4.335\,\text{V}$, and the current direction is clockwise.



4. What is the current produced by a 12 V car battery with an internal resistance of 0.025 Ω, attached to a resistance 10 Ω? How much power is supplied by the battery? How much power is supplied to the external circuit? **(3)**

   The current produced by the battery is:

$$I = \frac{\mathcal{E}}{R + r} = \frac{12}{10.025} \approx 1.197\,\text{A}$$

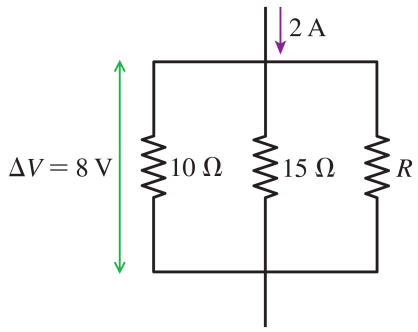
   The total power supplied by the battery is:

$$P_{\text{battery}} = I\mathcal{E} = 12 \cdot 1.197 \approx 14.364\,\text{W}$$

   The power supplied to the external circuit is:

$$P_{\text{external}} = I^2 \cdot R = (0.799)^2 \cdot 15 \approx 14.328\,\text{W}$$

5. What is the value of resistor R? [**Hint:** Use Parallel connection idea. No KCL is required.] **(3)**



For resistors in parallel, the total equivalent resistance is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

Use Ohm's law:

$$\frac{\Delta V}{R_{\text{total}}} = I = \frac{\Delta V}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R}}$$

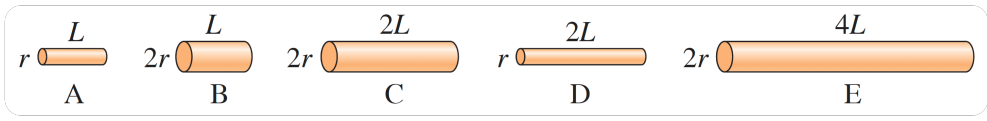
$$\frac{8\,\text{V}}{2\,\text{A}} = \left(\frac{1}{10\,\Omega} + \frac{1}{15\,\Omega} + \frac{1}{R}\right)^{-1}$$

$$\frac{1}{4}\,\Omega = 0.1\,\Omega + 0.067\,\Omega + \frac{1}{R}$$

$$\frac{1}{R} = 0.25\,\Omega - 0.167\,\Omega = 0.083\,\Omega.$$

$$R \approx 12\,\Omega.$$

6. The wires are all made of the same material. A fixed potential ΔV is applied across all wires. Rank in order, from largest to smallest, the currents I_A to I_E. **[Hint:** Use Ohm's Law.] **(3)**



Use Ohm's Law:

$$I = \frac{\Delta V}{R} = \frac{\Delta V A}{\rho L}.$$

Since all wires are made of the same material, the resistance R, by extension, the current depends on the geometry of the wires:

$$I \propto \frac{A}{L} = \frac{\pi r^2}{L}.$$

Check for the currents for all 5 cases:

$$I_A \propto \frac{\pi r^2}{L}, \quad I_B \propto \frac{\pi (2r)^2}{L} = 4I_A, \quad I_C \propto \frac{\pi (2r)^2}{2L} = 2I_A, \quad I_D \propto \frac{\pi (r)^2}{2L} = \frac{1}{2}I_A, \quad I_E \propto \frac{\pi (2r)^2}{4L} = I_A.$$

Ranking: $I_B > I_C > I_A = I_E > I_D$.

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1. Kirchoff's Loop Rule works in a closed loop due to the conservation of — **(1)**

   ◯ Energy ✓ ◯ Charge ◯ Current ◯ Potential

2. You turn on a switch for a light-bulb 2 m away. The electron drift speed in the circuit (diameter 1.0 mm) is 5.0 × mm s^{-1}. Which of the following generates a current in the wire? — **(1)**

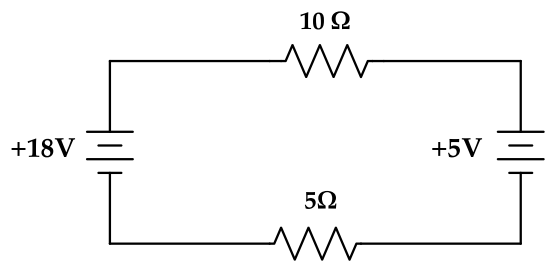
   ◯ Random motion of the free electrons ◯ Drift motion ✓ ◯ Current Density ◯ Positive charges

3. Find the voltage drop across the 10 Ω resistor and the direction of I in the circuit. Use only Kirchhoff's Loop rule to answer this. Mention travel directions and apply the sign convention accurately. **(4)**

   Apply KVL,

$$-I(10\,\Omega) - 5\,\text{V} - I(5\,\Omega) + 18\,\text{V} = 0$$
$$-I(15\,\Omega) + 13\,\text{V} = 0$$
$$I = \frac{13\,\text{V}}{15\,\Omega}$$
$$= 0.867\,\text{A}.$$

   Thus, the voltage drop across the 10 Ω resistor is $10\,\Omega \times 0.867\,\text{A} = 8.67\,\text{V}$, and the current direction is clockwise.



4. What is the current produced by a 12 V car battery with an internal resistance of 0.025 Ω, attached to a resistance 15 Ω? How much power is supplied by the battery? How much power is supplied to the external circuit? **(3)**

   The current produced by the battery is:

$$I = \frac{\mathcal{E}}{R + r} = \frac{12}{15.025} \approx 0.799\,\text{A}$$

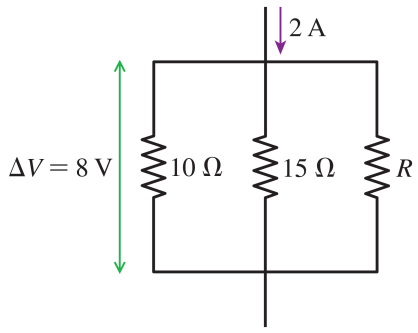
   The total power supplied by the battery is:

$$P_{\text{battery}} = I\mathcal{E} = 12 \cdot 0.799 \approx 9.59\,\text{W}$$

   The power supplied to the external circuit is:

$$P_{\text{external}} = I^2 \cdot R = (0.799)^2 \cdot 15 \approx 9.58\,\text{W}$$

5. What is the value of resistor R? [**Hint:** Use Parallel connection idea. No KCL is required.] **(3)**



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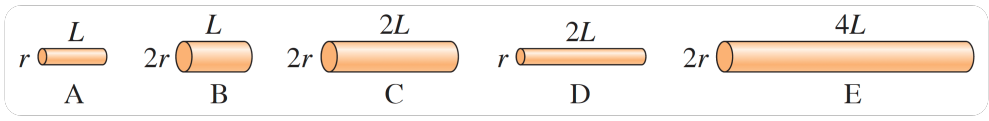

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Ranking: $I_B > I_C > I_A = I_E > I_D$.