PHY-112

Principles of Physics-II

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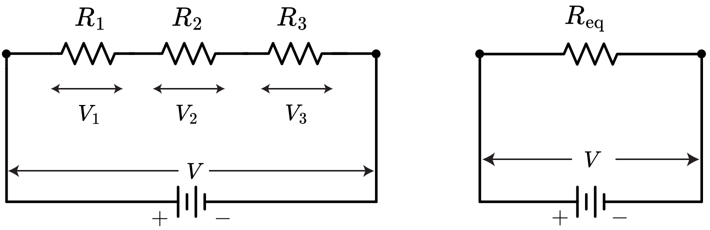
Spring-24 | Class-16

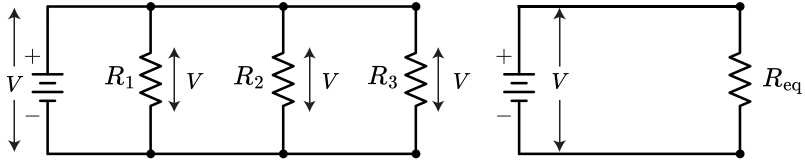
Combinations of Resistors: Series

The voltage across each resistor is not the same. The total voltage across the series combination equals the sum of the voltages across each resistor.



$$R_{\text{eq}} = R_1 + R_2 + R_3 = \sum_{i}^{n} R_i$$

The voltage across each resistor is the same. The total current through the parallel combination is the sum of the currents through each individual resistor.

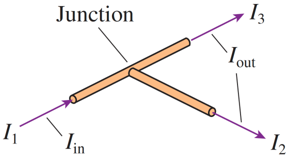


$$\frac{1}{R_{\mathrm{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \sum_i^n \frac{1}{R_i}$$

Kirchhoff's Two Rules for Circuits

Because **electric charge is conserved**, the total current into the junction must equal the total current leaving the junction. That is,

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

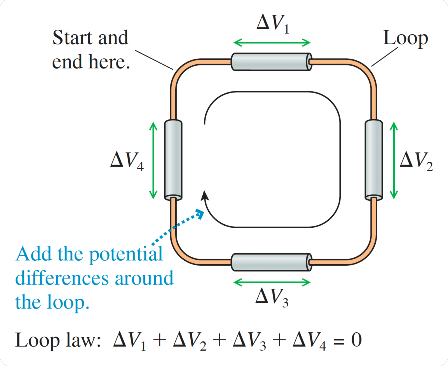


Junction law: $I_1 = I_2 + I_3$

Kirchhoff's 2nd Rule: Voltage Rule or Loop Rule

Because **energy is conserved**, a charge that moves around a closed path has $\Delta U_{\text{elec}} = 0$. In a circuit, the algebraic sum of all potential differences sum to zero.

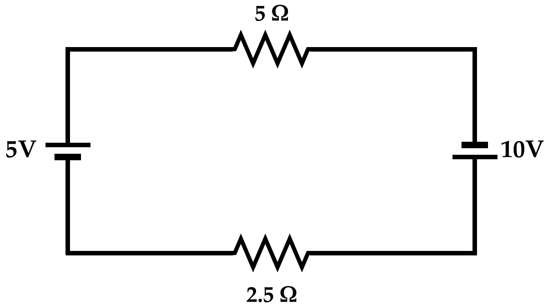
$$\Delta V_{\text{loop}} = \sum_i (\Delta V)_i = 0$$



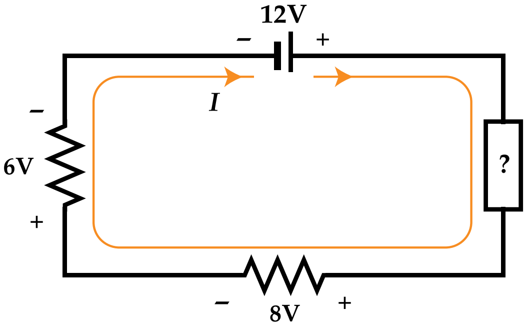
How to use Kirchhoff's 2ⁿᵈ Rule: Convention

- **Draw a circuit diagram**: Label all known and unknown quantities.
- **Assign a direction to the current**: Draw and label a current arrow I to show your choice.
- ***Travel* around the loop**: Choose any direction.
  Resistance Rule: For a move through resistance in the direction of the current, the change in potential is $-iR$; in the opposite direction, it is $+iR$.
  EMF Rule: For a move through an ideal EMF device in the direction of the EMF arrow ($-$ to $+$), the change in potential is $+\mathcal{E}$; in the opposite direction, it is $-\mathcal{E}$.
- **Apply the loop law**: $\sum(\Delta V_i) = 0$.

Q: Find the current and potential differences across each resistor.

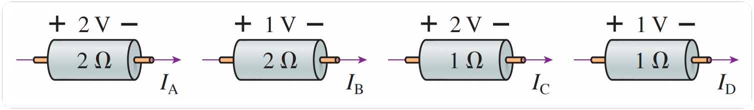


Q: What is ΔV across the unspecified circuit element? Does the potential increase or decrease when traveling through this element in the direction assigned to I?

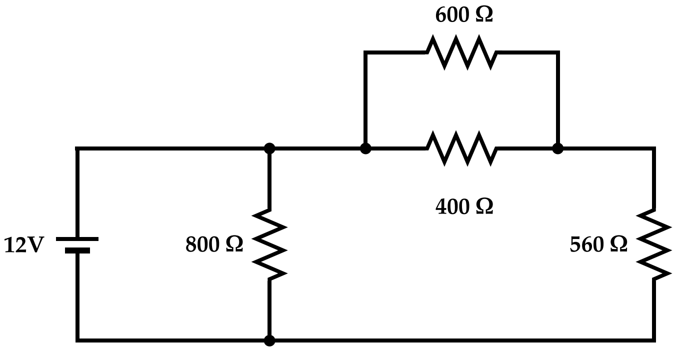


Testing Concepts (3)

Q: Rank in order, from largest to smallest, the currents I_A to I_D through the four resistors.



Q: Find the current through and the potential difference across each of the four resistors in the circuit.



Energy Dissipation in Resistors:

$$E_{\text{chemical}} \to U \to K \to E_{\text{thermal}}$$

The battery's chemical energy is transferred to the thermal energy of the resistors, raising their temperature.
Energy exchanged per unit time is **Power**.

Power delivered by the EMF:

$$P_{\text{battery}} = \frac{\Delta U}{\Delta t} = \frac{\Delta q}{\Delta t}\mathcal{E} = I\mathcal{E}.$$

It is measured in $\mathrm{J\,s^{-1}}$, or commonly, W.

For example, a $120\,\mathrm{V}$ battery that generates $2\,\mathrm{A}$ of current is delivering $240\,\mathrm{W}$ of power to the circuit.

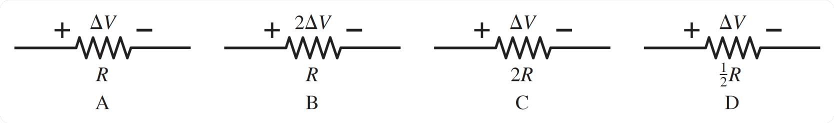
Power dissipation through Resistors:

$$P_R = \frac{\Delta U}{\Delta t} = \frac{\Delta q}{\Delta t} V_R = I \Delta V_R = I^2 R = \frac{(\Delta V)^2}{R}.$$

It is also measured in $\mathrm{J\,s^{-1}}$, or commonly, W.

Electric Bills are measured in terms of Kilowatt hours (kW h).

Q: Rank in order, from largest to smallest, the powers P_A to P_D dissipated in resistors A to D.



Q: A $6\,\Omega$ flashlight bulb is powered by a $3\,\mathrm{V}$ battery with an internal resistance of $1\,\Omega$. What are the power dissipation of the bulb and the terminal voltage of the battery?

Electric Bills are measured in terms of Kilowatt hours (kW h).

$$E_{\text{thermal}} = P_R \Delta t.$$

With great power comes massive electricity bills!