

Electricity and resistivity

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Basics of electricity

Electric current: the rate of flow of charge through a conductor

$$I = \frac{\Delta Q}{\Delta t}$$

$$Q = n \times q$$

Net charge: the sum of charges in a body

$$Q = \pm ne$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$n = \text{integer}$$

Potential difference: the work done per unit charge

$$V = \frac{W}{Q}$$

Ohm's law: special case where $V \propto I$ if temperature and, therefore, resistance are kept constant

$$R = \frac{V}{I}$$

Moving charges

Electric current in metal: the flow of electrons

Conventional current: current from positive terminal to negative terminal

Electron flow: flow of electrons from negative to positive terminal

Electric current in electrolyte: the flow of ions

Current and potential difference are measured using ammeters and voltmeters. Ideal ammeters have zero resistance, while ideal voltmeters have infinite resistance.

Kirchhoff's laws

Conservation of charge: Electric charge cannot be created or destroyed – total current is constant.

Kirchhoff's first law: The sum of the current into any point in an electrical circuit is equal to the sum of currents out of the point.

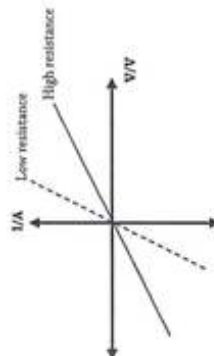


$$I_1 = I_2 + I_3$$

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

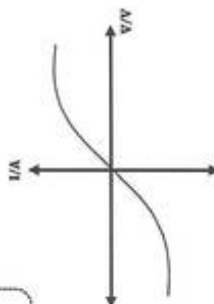
Current-voltage characteristics

Exam Tip!
Questions can be asked with I or V on the horizontal axis.



I-V graph for an Ohmic conductor

Semiconductors only conduct electricity over a certain threshold voltage. Below this voltage, the current cannot cross the potential difference gap set up within the diode.



I-V graph for a filament bulb

As the filament in the bulb carries higher amounts of current and heats up, the metal atoms vibrate and electrons cannot as easily pass through the filament. This increases the resistance of the filament.

Resistivity

Resistivity: a property of a material defined by the product of its resistance and its cross-sectional area divided by its length

$$\rho = \frac{RA}{L}$$

The resistivity of a wire can be determined by measuring the current through and potential difference across the wire, and plotting current against potential difference. The gradient of the graph will be the resistance of the wire.

The resistivity can then be found by using $R = \frac{\rho L}{A}$, with the length being measured using a ruler and the cross-sectional area measured using a micrometer.

The equation for resistivity tells us the following points:

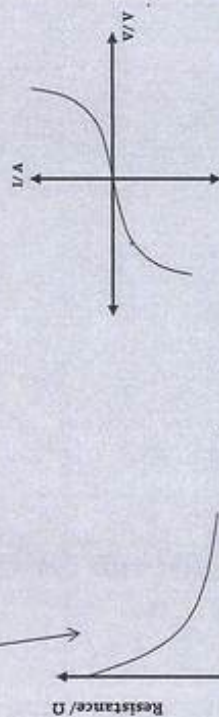
$$R \propto L$$

$$R \propto \frac{1}{A}$$

Temperature and resistance

Metal (conductor): As the temperature rises, the positive ions vibrate more vigorously and, therefore, the resistance in a metal increases.

Thermistor: An electrical component comprising of a semiconductor with a negative temperature coefficient, meaning that as temperature increases, the resistance of the component will decrease.



Temperature/°C

I-V graph for a thermistor

Applications of thermistors

- thermostats
- measuring temperature of electrical devices
- temperature sensors of computers and smartphones
- temperature sensors of mechanical engines

Superconductivity

Superconductivity is the phenomenon of resistivity of a material decreasing to zero when the material is cooled at or below the critical temperature.

Applications of superconductors:

- production of strong magnetic fields in particle accelerators
- reduction of energy loss in transmission of electric power