Current Electricity

Matthew Williams • Physics • May 20, 2026

Current Electricity

Electric Current

Electric current is the rate of flow of electric charge:

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

where I is current in amperes (A), Q is charge in coulombs (C), and t is time in seconds. One ampere equals one coulomb per second.

A current of 1 A means 6.24×10^{18} electrons pass a point each second.

Conductors, Insulators, and Semiconductors

Type	Description	Examples
Conductor	Has many free (conduction) electrons that can move through the material	Metals (copper, aluminium, silver), graphite
Insulator	Has very few free electrons; charge cannot flow easily	Rubber, plastic, glass, wood, dry air
Semiconductor	Conductivity between conductor and insulator; increases with temperature	Silicon, germanium

Conventional Current and Electron Flow

Conventional current flows from the positive terminal of a cell to the negative terminal, in the direction positive charges would flow. This convention was established before the electron was discovered.

Electron flow is in the opposite direction, from negative to positive. Electrons (negative charges) are repelled by the negative terminal and attracted to the positive terminal.

Both conventions describe the same physical process, but currents in circuit diagrams follow the conventional (positive to negative) direction.

EMF and Potential Difference

Electromotive force (EMF) is the energy transferred per unit charge by a source (cell, battery) as it drives charge around a complete circuit. Unit: volt (V).

Potential difference (p.d.) is the energy transferred per unit charge between two points in a circuit as charge flows between them. Unit: volt (V).

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

where W is energy in joules and Q is charge in coulombs. One volt = one joule per coulomb.

EMF is the p.d. across the source when no current flows. In a circuit, the p.d. across the source is slightly less than the EMF because some energy is lost inside the source (internal resistance).

Resistance

Resistance opposes the flow of current. For a given p.d., a higher resistance means less current flows.

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

Unit: ohm (Ω). One ohm = one volt per ampere.

Ohm's Law

For a metallic conductor at constant temperature, the current is directly proportional to the p.d. across it:

$$V = IR \quad \Longleftrightarrow \quad I = \frac{V}{R}$$

This holds for ohmic resistors, the resistance is constant regardless of the p.d. applied. Non-ohmic components (filament lamps, diodes) do not obey Ohm's Law because their resistance changes with temperature or other factors.

I-V Characteristics

A **current-voltage (I-V) graph** shows how current varies with the potential difference applied across a component.

<PlotlyGraph

data={[

{

x: [-6, -4, -2, 0, 2, 4, 6],

y: [-3, -2, -1, 0, 1, 2, 3],

type: 'scatter',

mode: 'lines',

name: 'Ohmic resistor',

line: {color: '#2563eb', width: 2.5},

},

{

x: [-6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6],

y: [-1.3, -1.2, -1.1, -1.0, -0.8, -0.5, 0, 0.5, 0.8, 1.0, 1.1, 1.2, 1.3],

type: 'scatter',

mode: 'lines',

name: 'Filament lamp',

line: {color: '#dc2626', width: 2.5, shape: 'spline'},

},

]}

layout={{
xaxis: {title: {text: 'Voltage / V'}},
yaxis: {title: {text: 'Current / A'}},
annotations: [
{x: -3.5, y: 2.2, text: 'Ohmic (straight line)', showarrow: false, font: {size: 10, color: '#2563eb'}},
{x: 3.5, y: 0.5, text: 'Lamp (flattens, R increases)', showarrow: false, font: {size: 10, color: '#dc2626'}},
],
}}
caption="I-V characteristics: the ohmic resistor gives a straight line through the origin (constant R). The filament lamp starts steep (cold, low R) and flattens at higher voltages as the filament heats up and resistance increases. Both curves are symmetric about the origin."
height={280}
/>

Current, charge, and energy, cellphone battery (2022 Paper 02, Q6)

A cellphone battery has a capacity of 9600 C. The charger delivers a current of 0.8 A. The power supply is 4.4 W.

Time to charge the battery:

$$t = \frac{Q}{I} = \frac{9\,600}{0.8} = 12\,000\text{s}$$

Voltage of the charger:

$$V = \frac{P}{I} = \frac{4.4}{0.8} = 5.5\text{V}$$

Work done to charge the battery:

$$W = QV = 9\,600 \times 5.5 = 52\,800\text{J}$$

📝 **Exam Tip**

Learn to rearrange $V = IR$: for the current, $I = V/R$; for resistance, $R = V/I$.

On I-V graphs: an ohmic conductor gives a straight line through the origin. A lamp gives a curve that flattens at higher voltages (resistance increases with temperature). A diode conducts in one direction only (covered separately).