

Exercise walk-through

11.5

Compound Direct Current Circuits

AP Physics C: Electricity and Magnetism

Electric current and Ohm's law

Rate of charge flow

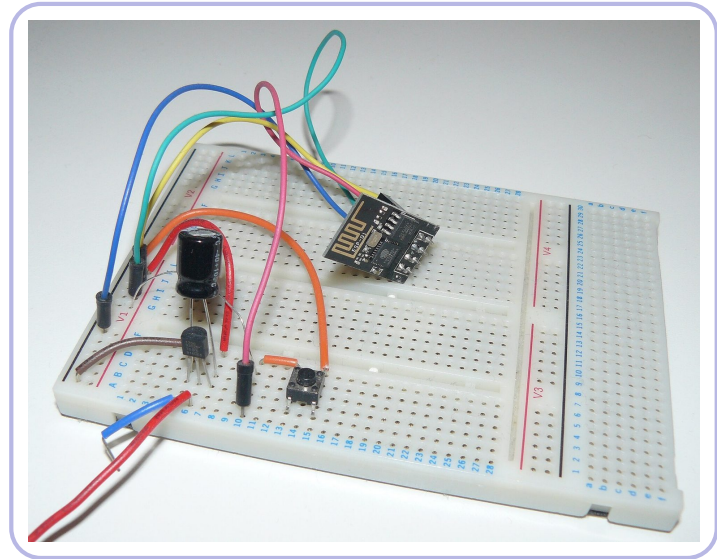
$$I = \frac{dQ}{dt}$$

Conventional current is opposite to the electron **drift**.

Ohm's law

$$V = IR, \quad R = \frac{\rho L}{A}$$

Resistivity ρ is a material property; R is the object's.



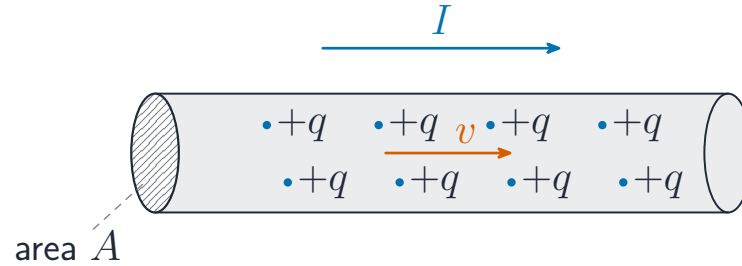
Breadboard

What a circuit is, and what Ohm's law claims

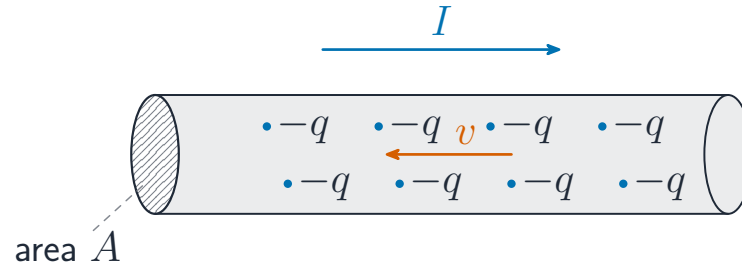
a circuit	closed loops of wires, batteries, resistors, bulbs, capacitors, inductors, switches and meters – charge flows only around a closed loop
steady state	current the same everywhere along one branch; nothing accumulates
Ohm's law	$I = \frac{\Delta V}{R}$ for an ohmic element – one whose R does not change with I
resistance	$R = \frac{\rho \ell}{A}$: material through ρ , and geometry through ℓ and A
ideal battery	maintains a fixed emf with zero internal resistance; a real one has r in series

Current is a **scalar** with a chosen direction, not a vector. Conventional current runs the way **positive** charge would move.

Electric Current



(a) positive carriers drift with I



(b) electrons drift against I

Charge carriers drift slowly through a conductor to make a current

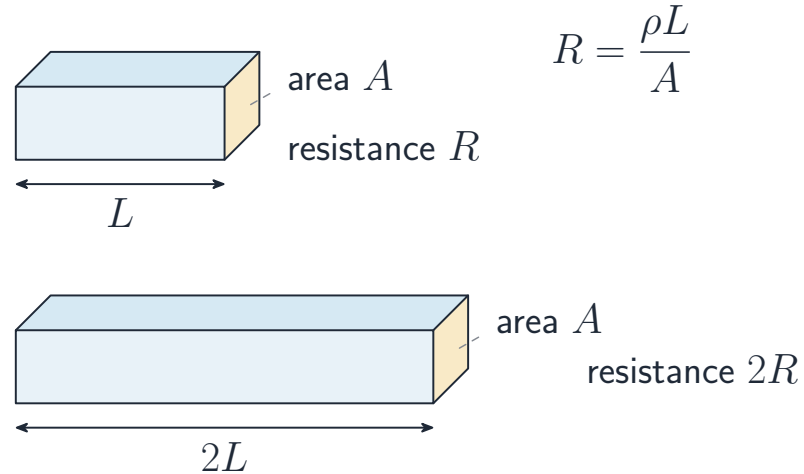
Worked example – how slowly electrons actually drift

A copper wire of area $1.0 \times 10^{-6} \text{ m}^2$ with $n = 8.5 \times 10^{28} \text{ m}^{-3}$ carries 1.7 A. Find the drift velocity .

$$\begin{aligned}
 \blacksquare \quad v_d &= \frac{I}{nqA} \\
 \blacksquare &= \frac{1.7}{(8.5 \times 10^{28})(1.6 \times 10^{-19})(1.0 \times 10^{-6})} \\
 \blacksquare &= 1.3 \times 10^{-4} \text{ m/s} - \text{about 0.5 m per hour}
 \end{aligned}$$

The *signal* travels near light speed; the electrons crawl. **Current density** $\vec{J} = nq\vec{v}_d$ is the same idea per unit **cross-sectional area**, tied to the field by $\vec{E} = \rho\vec{J}$, with $I = \int \vec{J} \cdot d\vec{A}$ in general.

Resistance, Resistivity, and Ohm's Law



twice the length $\Rightarrow$ twice the resistance

A longer conductor has more resistance; a wider one has less

Exercises 2.1-2.3

2.1 A battery of emf 9.0 V and internal resistance $1.0\ \Omega$ drives 2.0 A . Find the terminal voltage. [2]

2.2 Two $8.0\ \Omega$ resistors in parallel are in series with a $4.0\ \Omega$ resistor. Find the total resistance. [2]

2.3 State the difference between the emf and the terminal voltage of a battery. [1]

Exercises 2.1-2.3

2.1 A battery of emf 9.0 V and internal resistance $1.0\ \Omega$ drives 2.0 A. Find the terminal voltage. [2]

2.1

- $V = \varepsilon - Ir = 9.0 - 2.0(1.0) = 7.0\ \text{V}$

2.2 Two $8.0\ \Omega$ resistors in parallel are in series with a $4.0\ \Omega$ resistor. Find the total resistance. [2]

2.2

- parallel pair: $\frac{8.0}{2} = 4.0\ \Omega$; then $4.0 + 4.0 = 8.0\ \Omega$

2.3 State the difference between the emf and the terminal voltage of a battery. [1]

2.3

- the emf is the total energy per charge supplied; the terminal voltage is the smaller potential difference across the external circuit once Ir is lost internally

Exercises 3.1-3.2

3.1 A real battery is modelled as an ideal emf in series with

[1]

☐

A a capacitor

B an internal resistance

C an inductor

D nothing

3.2 The terminal voltage of a battery under load is

[1]

☐

A greater than the emf

B less than the emf

C equal to zero

D infinite

Exercises 3.1-3.2

3.1 A real battery is modelled as an ideal emf in series with

[1]

- ☐ **A** a capacitor
B an internal resistance
C an inductor
D nothing

3.1 B

- an internal resistance.

3.2 The terminal voltage of a battery under load is

[1]

- ☐ **A** greater than the emf
B less than the emf
C equal to zero
D infinite

3.2 B

- less than the emf.

Exercise 3.3 (a)

3.3 A 12 V battery of internal resistance $0.50\ \Omega$ is connected to a $5.5\ \Omega$ resistor.

(a) Find the current.

[2]

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3.3 A 12 V battery of internal resistance $0.50\ \Omega$ is connected to a $5.5\ \Omega$ resistor.

(a) Find the current.

[2]

(a)

- $$I = \frac{\varepsilon}{R + r} = \frac{12}{5.5 + 0.50} = 2.0\ \text{A}$$

Exercise 3.3 (b)

3.3 A 12 V battery of internal resistance $0.50\ \Omega$ is connected to a $5.5\ \Omega$ resistor.

(b) Find the terminal voltage.

[2]

Exercise 3.3 (b)

3.3 A 12 V battery of internal resistance $0.50\ \Omega$ is connected to a $5.5\ \Omega$ resistor.

(b) Find the terminal voltage.

[2]

(b)

- $V = \varepsilon - Ir = 12 - 2.0(0.50) = 11\ \text{V}$