YEAR 10 PHYSICS, AQA GCSE, LESSON 2 OF 12

# ELECTRIC CIRCUITS

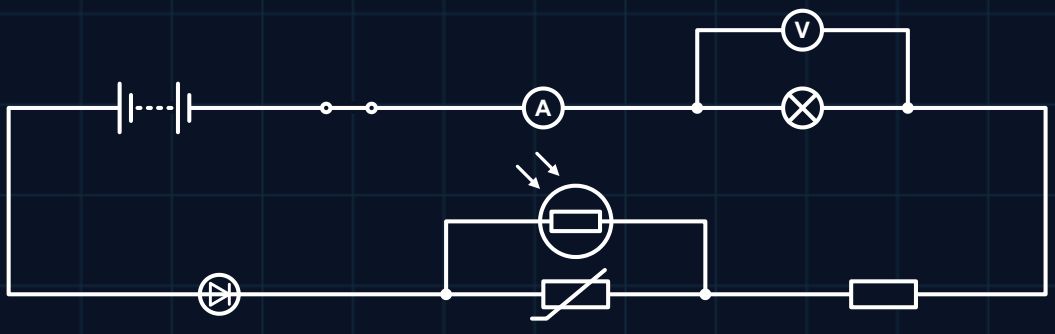
## LESSON 02 CURRENT AND CHARGE

Flick a switch and the lamp lights instantly, yet each electron drifts through the wire slower than a snail. How can both be true?

### IN THIS LESSON YOU WILL

- describe current as the rate of flow of charge
- use Q = I t, with time in seconds
- explain why the current is the same everywhere in a single loop

**ANSWER EDITION FOR TEACHERS AND SELF-MARKING**




NAME _____ CLASS _____

TEACHER _____ TARGET GRADE _____

START HERE

# HOW THIS BOOKLET WORKS

This is the booklet for **Lesson 2** of the Electric Circuits unit. It builds on the lessons before it; the “Do now” questions and the quick answers at the back help you check what you remember. Keep it: it is your classwork book *and* your revision guide.

**DO NOW**
Quick questions from earlier lessons. Remembering again is what makes it stick.

**LEARN IT**
The explanation, diagrams and worked examples. Read this again when you revise.

**TRY IT**
Practice that builds up: first with support, then on your own.

**LAB**
Record measurements from a virtual lab or a required practical.

**EXAM CORNER**
An AQA-style question with a tip on how the marks are given.

**REVISE IT**
Summary, cover-and-answer questions and an “I can” check to colour in.

! **Revising at home?** (1) Read the Learn it pages. (2) Cover them and answer the “Cover the page” questions in Revise it. (3) Check with the quick answers at the back.

## THE ROUTE THROUGH THE UNIT (THIS LESSON IS HIGHLIGHTED)


01 Complete circuits and symbols

**02 Current and charge**
Current as a rate of flow of charge, Q = I t, current is not used up

03 Potential difference

04 Resistance and V = I R

05 Resistance of a wire RP

06 Series and parallel circuits

07 Resistors in series and parallel RP

08 I–V graphs

09 Investigating I–V characteristics RP

10 Thermistors, LDRs and sensors

11 Power and energy transfer

12 Mains, safety and the National Grid

Lesson

# 02 CURRENT AND CHARGE

AQA Combined 6.2.1.2; Physics 4.2.1.2; Virtual Lab 1

**BIG QUESTION** **Flick a switch and the lamp lights instantly, yet each electron drifts through the wire slower than a snail. How can both be true?**

**BY THE END YOU CAN**

- describe current as the rate of flow of charge
- use Q = I t, with time in seconds
- explain why the current is the same everywhere in a single loop

charge (C) · current (A) · coulomb · ampere · electron · conventional current

RETRIEVE

## DO NOW

From earlier lessons. No notes!

**1**
Draw the symbols for a cell and a lamp.

**Cell: a long line and a shorter line (the long line is +). Lamp: circle with a cross.**

**2**
How must an ammeter be connected?

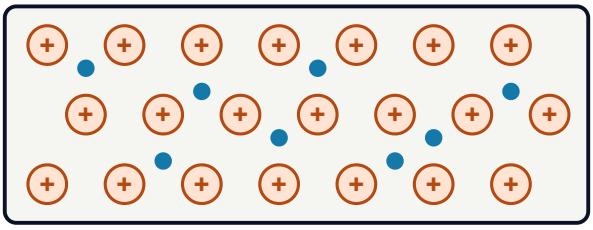
**In series (in the loop).**

**3**
Give two reasons why a lamp in a circuit might not light.

**Open switch; gap or loose wire; broken bulb; no cell.**

EXPLAIN

# WHAT IS FLOWING?




Inside a metal wire: fixed positive ions (orange) and free electrons (blue).

Metals contain **free electrons**: tiny particles with a negative charge that can move between the atoms. The wires are full of them *before* you switch on.

The cell pushes on all of them at once, so the whole loop starts moving together, just like the bike chain. The lamp lights straight away, even though each electron only drifts along at less than a millimetre per second.

Charge is measured in **coulombs (C)**. One electron has a tiny charge: it takes about $6 \times 10^{18}$ (six billion billion) electrons to make 1 C.

## CURRENT IS A RATE

**Current** is the **rate of flow of charge**: how many coulombs pass a point *each second*.

### THINK OF A TICKET BARRIER

Count the people going through a station barrier each second. The current is like the number of people *per second*, not the number of people in the station.

**Where the model breaks:** people can stop or change direction on their own; in a single loop all the charges move together.

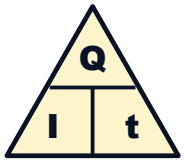
! **1 ampere = 1 coulomb per second.** A current of 0.5 A means 0.5 C of charge passes a point every second.

$$Q = I\,t$$

**charge flow = current × time**

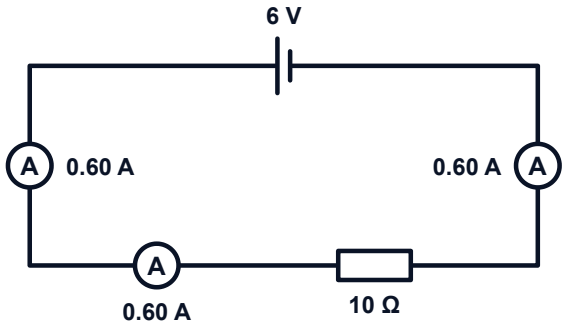
Q in coulombs (C), I in amperes (A), t in seconds (s)

Rearranged: I = Q ÷ t and t = Q ÷ I



| WORKED EXAMPLE | | YOUR TURN | |
|---|---|---|---|
| **A current of 0.40 A flows for 3.0 minutes. Calculate the charge that flows.** | | **A current of 0.50 A flows for 4.0 minutes. Calculate the charge that flows.** | |
| KNOW | I = 0.40 A, t = 3.0 × 60 = 180 s | KNOW | **I = 0.50 A, t = 240 s** |
| EQUATION | Q = I t | EQUATION | **Q = I t** |
| SUBSTITUTE | Q = 0.40 × 180 | SUBSTITUTE | **Q = 0.50 × 240** |
| ANSWER | **Q = 72 C** | ANSWER | **Q = 120 C** |

## CURRENT IS NOT USED UP




Three ammeters in one loop give the same reading.

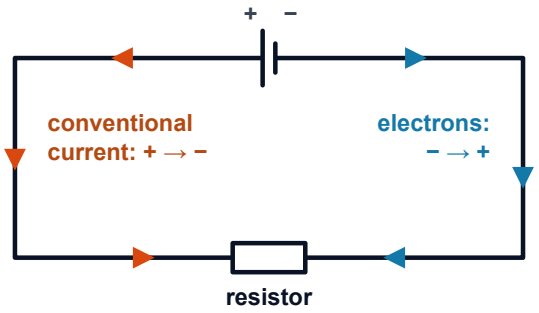
In a single loop, the current is **the same at every point**. Charge is not destroyed in a component: it carries on round the circuit. What the component takes is **energy** (Lesson 3).

> ! Charge goes round. Energy is transferred.

## WHICH WAY DOES CURRENT FLOW?

Outside the cell, electrons flow from the **negative (−)** terminal to the **positive (+)** terminal.

But circuit diagrams show **conventional current**, from + to −. This was agreed before electrons were discovered. Both describe the same current, and exam diagrams use conventional current.




Orange: conventional current (+ to −). Blue: electron flow (− to +). Same current, opposite arrows.

PRACTISE

# TRY IT

**1** Complete the sentences using the word bank.

Current is the rate of flow of **charge**. It is measured in **amperes (A)** using an **ammeter** connected in **series**. Charge is measured in **coulombs (C)**. A current of 2 A means **2** coulombs pass a point every **second**.

WORD BANK: **charge** | **series** | **ammeter** | **second** | **amperes (A)** | **coulombs (C)** | **2** | **parallel** | **volts**

**2** A current of 0.60 A flows in a circuit. Which statement is correct? Tick **one** box.

- ☐ There is 0.60 C of charge in the circuit.
- ☐ The lamp uses up 0.60 C each second.
- ☑ 0.60 C of charge passes any point each second.
- ☐ The current is 0.60 A only near the cell.

**3** SUPPORTED A current of 2.0 A flows for 30 s. Calculate the charge that flows.

| | |
|---|---|
| EQUATION | **Q = I t** |
| SUBSTITUTE | **Q = 2.0 × 30** |
| ANSWER | **60 C** unit: |

**4** SUPPORTED A current of 0.30 A flows for 5.0 minutes. Calculate the charge. *Convert the time first!*

| | |
|---|---|
| CONVERT | **t = 5.0 × 60 = 300 s** |
| EQUATION | **Q = I t** |
| SUBSTITUTE | **Q = 0.30 × 300** |
| ANSWER | **90 C** unit: |

**5** ON YOUR OWN 36 C of charge passes through a lamp in 12 s. Calculate the current.

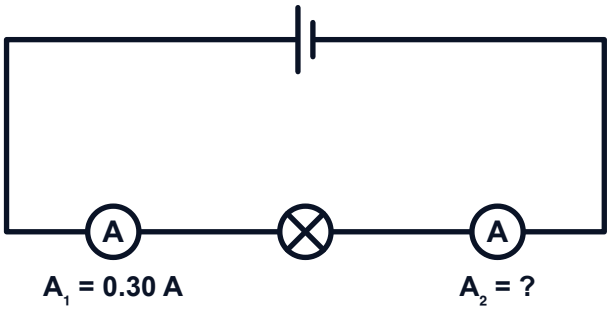
**I = Q ÷ t = 36 ÷ 12 = 3.0 A**

**6** **CHALLENGE** A phone charger supplies 0.80 A. How long does it take for 240 C to flow? Give your answer in seconds and in minutes.

**t = Q ÷ I = 240 ÷ 0.80 = 300 s = 5.0 minutes**

**7** Predict the reading on $A_2$. Explain why Mia is wrong.

**Mia:** The lamp uses up some current, so ammeter $A_2$ after the lamp will read less than $A_1$.




**$A_2$ = 0.30 A. It is a single loop, so the current is the same everywhere. Charge is not used up: the lamp transfers energy, not charge.**

INVESTIGATE

## VIRTUAL LAB 1: IS CURRENT USED UP?

PhET Circuit Construction Kit: DC → Lab. Full steps: Virtual Labs worksheet pp. 3–6.

Build one loop with a **6 V battery** and a **10 Ω resistor**. Use the non-contact ammeter to measure the current at three places.

**8** Record your readings.

| Position | Current / A | Current with 20 Ω / A |
|---|---|---|
| Before the resistor | 0.60 | 0.30 |
| After the resistor | 0.60 | 0.30 |
| Next to the battery | 0.60 | 0.30 |

**9** What do your readings show? Use numbers in your answer.

**All three readings are the same (0.60 A), so current is not used up. With 20 Ω the current halves (0.30 A) but is still the same everywhere.**

AQA-STYLE

## EXAM CORNER

Write in full sentences. Show every step of a calculation.

> **Get the marks:** Convert minutes to seconds before you substitute. The unit (C) is part of the answer.

**10** A motor draws a current of 0.60 A for 5.0 minutes. Calculate the charge that flows through the motor. **[3 marks]**

| | |
|---|---|
| EQUATION | **Q = I t, with t = 5.0 × 60 = 300 s** |
| SUBSTITUTE | **Q = 0.60 × 300** |
| ANSWER | **180 C** unit: |

**11** A student says the current leaving the motor is smaller than the current entering it. Explain why the student is wrong. **[2 marks]**

**The motor is in a single loop, so the current is the same everywhere (1). Charge is not used up; the motor transfers energy (1).**

REVIEW LATER

## REVISE IT

Use this box after the lesson and before tests.

### SUMMARY

- Current is the **rate of flow of charge**. In metal wires the charges are free electrons.
- Charge: coulombs (C). Current: amperes (A). 1 A = 1 C per second.
- **Q = I t**, with t in seconds.
- In a single loop, current is the same everywhere: charge is not used up.
- Conventional current: + to −. Electrons: − to +.

### COVER THE PAGE AND ANSWER

**1** What is current?

**2** What is the unit of charge?

**3** Write the equation linking charge, current and time.

**4** 0.2 A flows into a lamp. What current flows out?

### I CAN…

- describe current as the rate of flow of charge
- calculate charge, current or time using Q = I t
- convert minutes to seconds before calculating
- explain why current is not used up in a loop

REFERENCE

# EQUATION TOOLKIT

The equations you have met so far. You will meet these one at a time. Learn each equation **in words** as well as symbols: AQA gives you an equation sheet in the exam (it does not include $R_{total} = R_1 + R_2$), but knowing the equations by heart makes every question faster.

## Q = I t

Lesson 2

**charge flow = current × time**

C, A, s

Rearranged: I = Q ÷ t and t = Q ÷ I

## FOUR STEPS FOR EVERY CALCULATION

**1**
Write down what you know, with units. Convert units first (minutes → seconds, kW → W, mA → A).

**2**
Write the equation you will use, in symbols.

**3**
Substitute the numbers, then rearrange if needed.

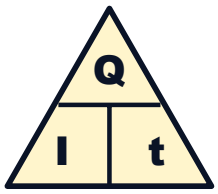
**4**
Give the answer with a unit. Ask: is it sensible?

| CONVERT | HOW | EXAMPLE |
|---|---|---|
| minutes → seconds | × 60 | 3.0 min = 180 s |
| hours → seconds | × 3600 | 2.0 h = 7200 s |
| milliamps (mA) → amps (A) | ÷ 1000 | 250 mA = 0.25 A |
| kilowatts (kW) → watts (W); kilohms (kΩ) → ohms (Ω) | × 1000 | 2.2 kW = 2200 W |
| kilovolts (kV) → volts (V) | × 1000 | 400 kV = 400 000 V |

## EQUATION TRIANGLES: HELP WITH REARRANGING

1. Cover the quantity you want to find.
2. The two left **side by side**? **Multiply** them.
3. One **above** the other? **Divide** the top by the bottom.

Example: to find I from Q = I t, cover I. Q is above t, so I = Q ÷ t. Triangles only help with rearranging: you still need to learn each equation.




$Q = I\,t$

$Q = I \times t$

$I = Q \div t$

$t = Q \div I$

REFERENCE

# KEY WORDS FROM THIS LESSON

Learn the meaning and spelling. In exams, precise words earn marks: say “p.d. across” and “current through”.

**Ampere (A)**: Unit of current. 1 A = 1 C per second.

**Charge (Q)**: Carried by particles such as electrons. Unit: coulomb (C).

**Conventional current**: The agreed direction of current: from + to −.

**Electron**: A tiny negatively charged particle. Free electrons carry the current in metals.

CHECK YOURSELF

# QUICK ANSWERS

Answers to the “Do now” and “Cover the page” questions, so you can check yourself when revising. Answers to the longer questions are in your teacher's answer edition.

### DO NOW

1. Cell: a long line and a shorter line (the long line is +). Lamp: circle with a cross.
2. In series (in the loop).
3. Open switch; gap or loose wire; broken bulb; no cell.

### COVER THE PAGE

1. The rate of flow of charge.
2. Coulomb (C).
3. $Q = I\,t$
4. 0.2 A