

ELECTRIC CIRCUITS

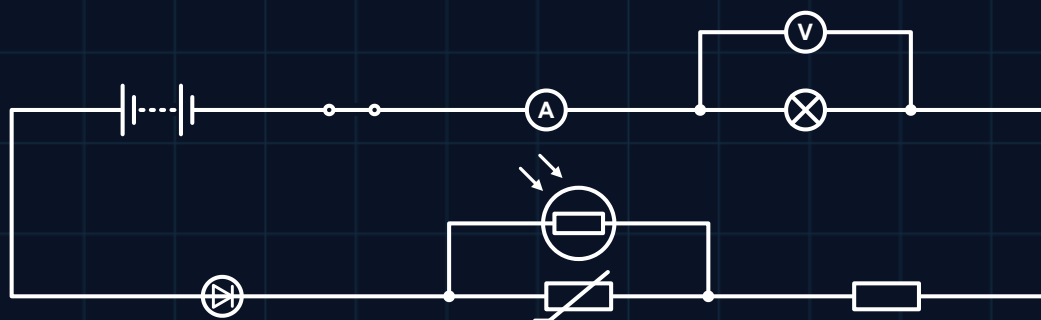
LESSON 12 MAINS, SAFETY AND THE NATIONAL GRID

Pylon cables carry up to 400 000 V. Why so high, and why do we only get 230 V at the plug?

IN THIS LESSON YOU WILL

- describe the difference between ac and dc
- state the UK mains values: 230 V, 50 Hz
- explain how the earth wire and fuse protect you
- explain why the National Grid uses very high p.d.s

ANSWER EDITION FOR TEACHERS AND SELF-MARKING



NAME

CLASS

TEACHER

TARGET GRADE

HOW THIS BOOKLET WORKS

This is the booklet for **Lesson 12** 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

03 Potential difference

05 Resistance of a wire **RP**

07 Resistors in series and parallel **RP**

09 Investigating I–V characteristics **RP**

11 Power and energy transfer

02 Current and charge

04 Resistance and $V = IR$

06 Series and parallel circuits

08 I–V graphs

10 Thermistors, LDRs and sensors

12 **Mains, safety and the National Grid**
ac and dc, 230 V 50 Hz mains, three-core cable, earthing, the National Grid

MAINS, SAFETY AND THE NATIONAL GRID

AQA Combined 6.2.3, 6.2.4.3; Physics 4.2.3, 4.2.4.3

BIG QUESTION Pylon cables carry up to 400 000 V. Why so high, and why do we only get 230 V at the plug?

BY THE END YOU CAN

- describe the difference between ac and dc
- state the UK mains values: 230 V, 50 Hz
- explain how the earth wire and fuse protect you
- explain why the National Grid uses very high p.d.s

alternating (ac)

direct (dc)

live

neutral

earth

fuse

National Grid

transformer



RETRIEVE

DO NOW

From earlier lessons. No notes!

1

A 230 V appliance draws 10 A. Calculate its power.

$$P = VI = 2300 \text{ W}$$

2

The current in a cable is halved. What happens to the heating ($P = I^2 R$)?

It falls to a quarter.

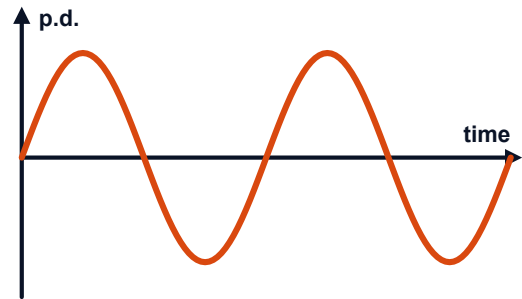
3

What is the unit of power?

Watt (W).

**DIRECT AND ALTERNATING P.D.**

dc from a cell or battery: the p.d. stays in one direction, so the current flows one way.



ac from the mains: the p.d. keeps reversing, so the current keeps changing direction.



UK mains: alternating current (ac), about **230 V**, frequency **50 Hz** (50 complete cycles every second).

INSIDE A PLUG CABLE

WIRE	COLOUR	JOB
Live	brown	carries the alternating p.d. from the supply (about 230 V)
Neutral	blue	completes the circuit; at or close to 0 V
Earth	green and yellow	safety wire at 0 V; only carries a current if there is a fault



 **Live** : brown

 **Neutral** : blue

 **Earth** : green & yellow

The outer sheath holds all three insulated wires together.

WHY THE LIVE WIRE IS DANGEROUS

Your body is at 0 V (the same as the earth). The live wire is at about 230 V. If you touch it, there is a p.d. across your body, so a current flows through you to earth: an **electric shock**, which can kill. This can happen even when the appliance is switched off, because the live wire is still connected to the supply.

■ HOW THE EARTH WIRE AND FUSE PROTECT YOU

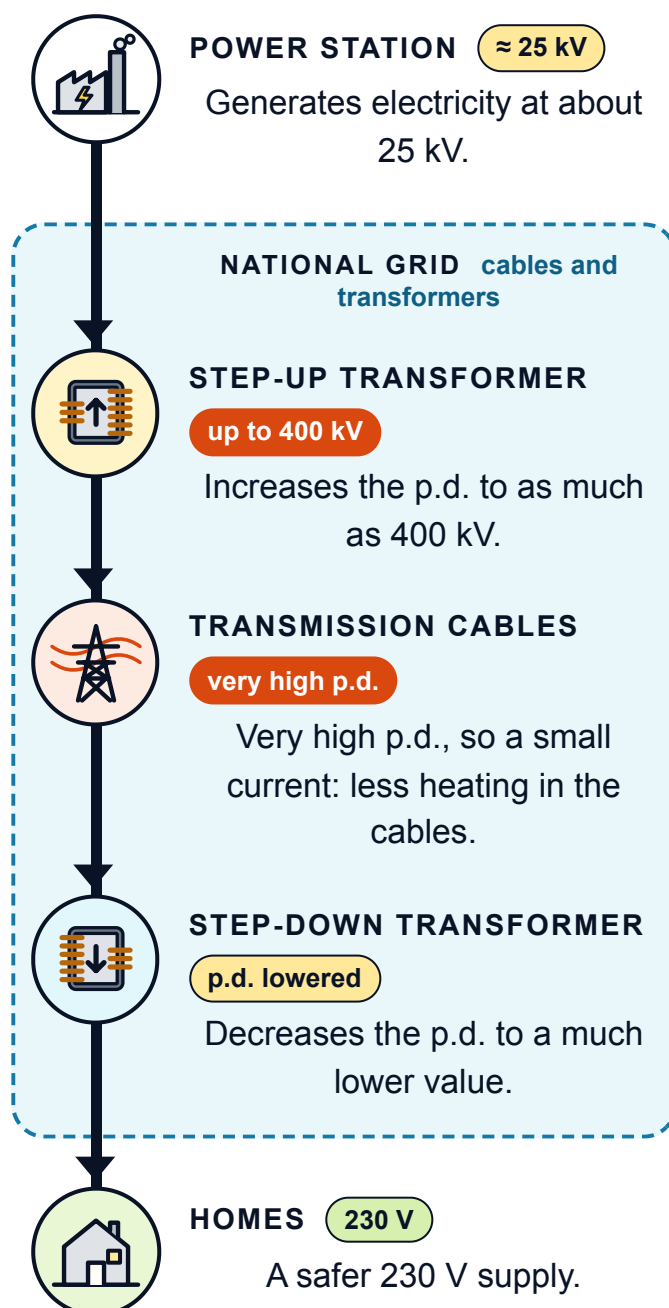
- 1 A fault makes the live wire touch the metal case.
- 2 The earth wire connects the case to earth through a very low resistance.
- 3 A very large current flows from the live wire, through the case and earth wire, to earth.
- 4 The large current melts the fuse (or trips the circuit breaker).
- 5 The live wire is disconnected, so the case is safe to touch.

■ THE NATIONAL GRID

The **National Grid** is a nationwide system of cables and transformers linking power stations to homes and businesses.

Step-up transformers raise the p.d. to as much as 400 kV. For the same power ($P = VI$), a higher p.d. means a **smaller current**. A smaller current means much less heating in the cables ($P = I^2 R$), so less energy is wasted: the grid is **efficient**.

Step-down transformers then lower the p.d. to 230 V, which is safer for homes.



$$V_p I_p = V_s I_s$$

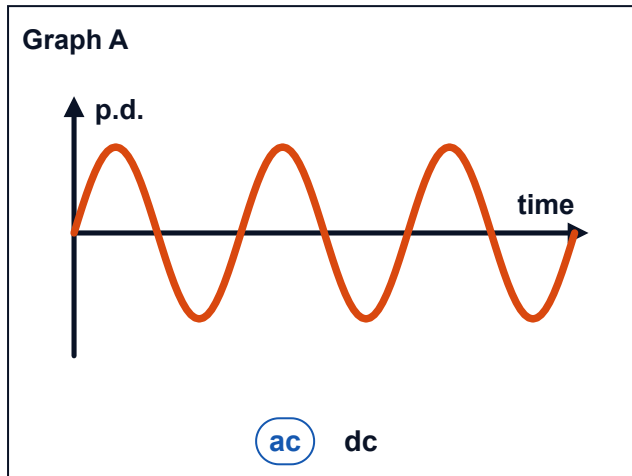
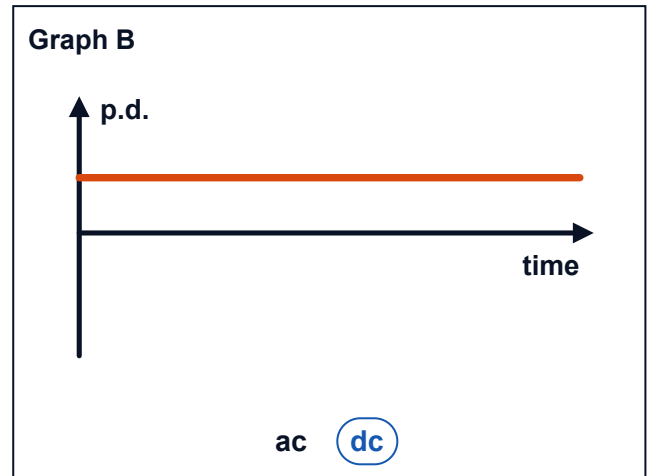
For an ideal transformer, power in = power out

p = primary (input) coil, s = secondary (output) coil



PRACTISE
TRY IT

- 1 Which graph shows ac and which shows dc? Circle one for each.



- 2 Complete the sentences.

UK mains electricity is alternating with a p.d. of about 230 V and a frequency of 50 Hz. The live wire is brown, the neutral wire is blue and the earth wire is green and yellow.

WORD BANK

alternating

direct

230

50

live

neutral

earth

- 3 Number the events 1–5 to show how an earthed metal case protects you.

3 | A large current flows through the earth wire

1 | The live wire touches the metal case

5 | The case is no longer live, so it is safe to touch

2 | The case is connected to earth by a low-resistance wire

4 | The fuse melts and breaks the circuit

- 4 Explain why Ava is wrong.

Ava

Touching the live wire is only dangerous when the appliance is switched on.

The live wire is still connected to the supply at about 230 V when the switch is off. Your body is at 0 V, so there is a p.d. across you and a current flows through you to earth: a shock.

- 5 A power station sends 1 000 000 W through the grid. Use $P = VI$ to find the current at 10 000 V and at 100 000 V. Then explain why the higher p.d. is better.

$I = P \div V = 1\,000\,000 \div 10\,000 = 100\text{ A}$; $1\,000\,000 \div 100\,000 = 10\text{ A}$. The current is 10 times smaller, so the heating in the cables ($I^2 R$) is 100 times smaller: much less energy is wasted.

- 6 An ideal transformer has 20 kV across the primary coil and 500 A in it. The p.d. across the secondary coil is 200 kV. Calculate the current in the secondary coil.

$$V_p I_p = V_s I_s: I_s = (20\,000 \times 500) \div 200\,000 = 50\text{ A}$$



Get the marks: Safety answers are sequences. Use cause → effect words: 'so', 'which means', 'therefore'.

- 7 A toaster has a metal case connected to the earth wire. A fault makes the live wire touch the case. Explain how the earth wire and the fuse protect someone who then touches the toaster. **[5 marks]**

The earth wire gives a low-resistance path from the case to earth (1). A very large current flows through the live and earth wires (1). This melts the fuse (1), which disconnects the live wire (1), so the case is not at a high p.d. and no current flows through the person (1).

- 8 Explain why the National Grid transmits electricity at a very high p.d., and why the p.d. is reduced before it reaches homes. **[4 marks]**

A step-up transformer increases the p.d. (1); for the same power, the current is smaller (1); a smaller current means less heating/energy loss in the cables, so it is more efficient (1); a step-down transformer reduces the p.d. to 230 V so it is safer in homes (1).

**SUMMARY**

- dc flows one way; ac keeps changing direction.
- UK mains: ac, 230 V, 50 Hz.
- Live (brown) ~230 V; neutral (blue) ~0 V; earth (green and yellow) safety wire.
- Earth wire + fuse: fault → big current → fuse melts → live disconnected.
- Grid: step up to high p.d. → small current → less heating ($I^2 R$) → efficient; step down to 230 V for safety.

COVER THE PAGE AND ANSWER

1 State the p.d. and frequency of UK mains.

2 What colour is the live wire?

3 When does the earth wire carry a current?

4 Why is a high p.d. used in the National Grid?

I CAN...

describe the difference between ac and dc



state the UK mains p.d. and frequency



name the three wires and their colours and jobs



explain how the earth wire and fuse protect a user



explain why the grid uses step-up and step-down transformers



EQUATION TOOLKIT

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 $R_{\text{total}} = R_1 + R_2$), but knowing the equations by heart makes every question faster.

$$Q = I t$$

Lesson 2

charge flow = current × time

C, A, s

Rearranged: $I = Q \div t$ and $t = Q \div I$

$$E = Q V$$

Lesson 3

energy transferred = charge ×
p.d.

J, C, V

Rearranged: $V = E \div Q$ and $Q = E \div V$

$$V = I R$$

Lesson 4

p.d. = current × resistance

V, A, Ω

Rearranged: $I = V \div R$ and $R = V \div I$

$$R_{\text{total}} = R_1 + R_2$$

Lesson 6

total resistance in series

Ω

Rearranged: (series only)

$$P = V I$$

Lesson 11

power = p.d. × current

W, V, A

Rearranged: $V = P \div I$ and $I = P \div V$

$$P = I^2 R$$

Lesson 11

power = current² × resistance

W, A, Ω

Rearranged: $R = P \div I^2$ and $I = \sqrt{(P \div R)}$

$$E = P t$$

Lesson 11

energy transferred = power ×
time

J, W, s

Rearranged: $P = E \div t$ and $t = E \div P$

$$V_p I_p = V_s I_s$$

Lesson 12

transformer: power in = power
out

V, A

Rearranged: $I_s = V_p I_p \div V_s$

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

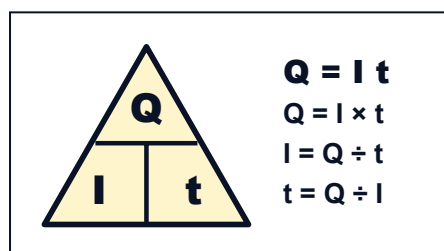
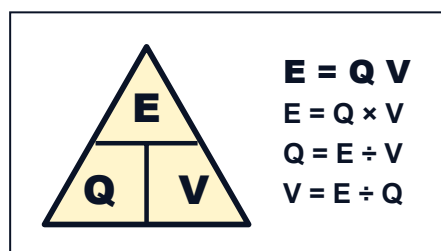
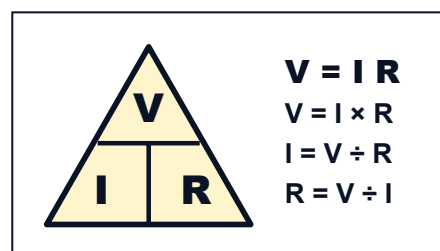
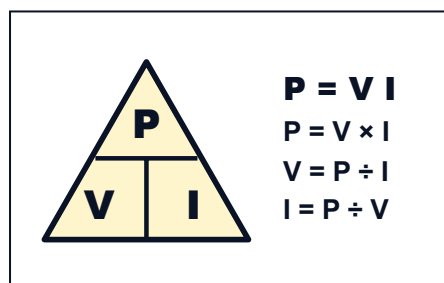
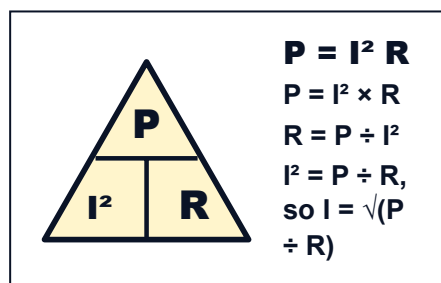
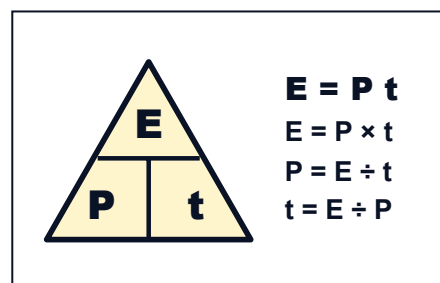
Give the answer with a unit. Ask: is it sensible?

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 $I = Q \div t$. Triangles only help with rearranging: you still need to learn each equation. For $P = I^2 R$, the triangle gives I^2 ; take the square root to find 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”.

Alternating current (ac): Current that keeps changing direction. UK mains is ac at 50 Hz.

Circuit breaker: A safety switch that cuts off the current if it gets too large.

Direct current (dc): Current that flows in one direction only, e.g. from a cell.

Earth wire: Green and yellow safety wire; carries a current only if there is a fault.

Fuse: A thin wire that melts and breaks the circuit if the current is too large.

Live wire: Brown wire at about 230 V; dangerous to touch.

National Grid: The system of cables and transformers linking power stations to consumers.

Neutral wire: Blue wire that completes the circuit; at or close to 0 V.

Transformer: Changes the size of an alternating p.d. (step-up or step-down).

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. $P = VI = 2300 \text{ W}$
2. It falls to a quarter.
3. Watt (W).

COVER THE PAGE

1. 230 V, 50 Hz.
2. Brown.
3. Only when there is a fault.
4. Smaller current, so less heating and energy loss in the cables.