

ELECTRIC CIRCUITS

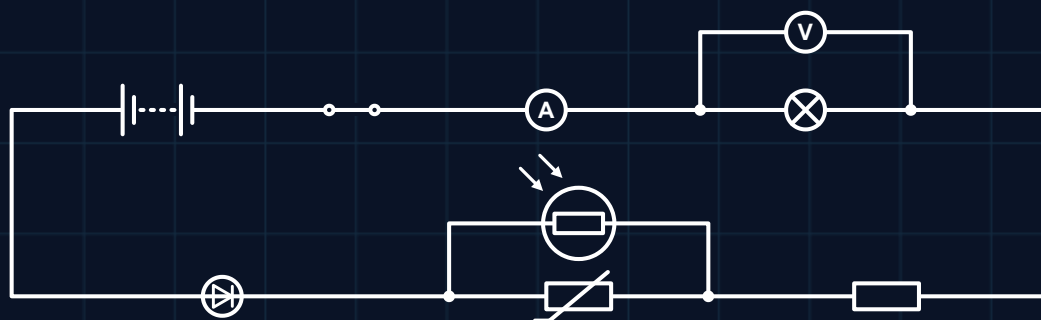
LESSON 11 POWER AND ENERGY TRANSFER

Which transfers more energy: a 3 kW kettle boiling for 3 minutes, or a 10 W LED lamp left on for 5 hours?

IN THIS LESSON YOU WILL

- describe power as the energy transferred per second
- use $E = P t$, $P = V I$ and $P = I^2 R$ with the right units
- describe the energy transfers in everyday appliances
- choose the right equation for a question

ANSWER EDITION FOR TEACHERS AND SELF-MARKING



NAME

CLASS

TEACHER

TARGET GRADE

HOW THIS BOOKLET WORKS

This is the booklet for **Lesson 11** 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**

Power, $E = P t$, $P = V I$, $P = I^2 R$, energy transfers in appliances

02 Current and charge

04 Resistance and $V = I R$

06 Series and parallel circuits

08 I–V graphs

10 Thermistors, LDRs and sensors

12 Mains, safety and the National Grid

POWER AND ENERGY TRANSFER

AQA Combined 6.2.4.1–6.2.4.2; Physics 4.2.4.1–4.2.4.2

BIG QUESTION Which transfers more energy: a 3 kW kettle boiling for 3 minutes, or a 10 W LED lamp left on for 5 hours?

BY THE END YOU CAN

- describe power as the energy transferred per second
- use $E = P t$, $P = V I$ and $P = I^2 R$ with the right units
- describe the energy transfers in everyday appliances
- choose the right equation for a question

power

watt (W)

kilowatt (kW)

energy transferred

power rating



RETRIEVE

DO NOW

From earlier lessons. No notes!

1

5.0 C passes through a 12 V lamp. How much energy is transferred?

$$E = Q V = 60 \text{ J}$$

2

2.0 A flows for 1 minute.
How much charge flows?

$$Q = 2.0 \times 60 = 120 \text{ C}$$

3

What is the resistance of a heater with 230 V across it and 5.0 A through it?

$$R = 230 \div 5.0 = 46 \Omega$$



EXPLAIN

HOW FAST IS ENERGY TRANSFERRED?

Power is the **energy transferred per second**. It is measured in **watts (W)**: 1 W = 1 J per second. A 2000 W (2 kW) kettle transfers 2000 J of energy every second.

APPLIANCE	TYPICAL POWER	ENERGY TRANSFERRED EACH SECOND
LED lamp	10 W	10 J
Laptop	60 W	60 J
Hairdryer	1.2 kW = 1200 W	1200 J
Kettle	2.2 kW = 2200 W	2200 J
Electric shower	9 kW = 9000 W	9000 J

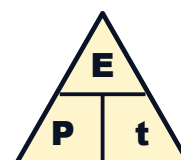
Every appliance transfers energy electrically from the mains to other energy stores: a kettle to the **thermal store** of the water; a hairdryer's fan to **kinetic** energy and its heater to thermal; a phone charger to the **chemical store** of the battery.

$$E = P t$$

energy transferred = power × time

E in joules (J), P in watts (W), t in seconds (s)

Convert kW → W (× 1000) and minutes or hours → seconds first.



WORKED EXAMPLE

A 2.0 kW kettle is on for 3.0 minutes.
Calculate the energy transferred.

KNOW $P = 2000 \text{ W}$, $t = 180 \text{ s}$

EQUATION $E = P t$

SUBSTITUTE $E = 2000 \times 180$

ANSWER $E = 360\,000 \text{ J}$

YOUR TURN

A 1.2 kW hairdryer is used for 10 minutes.
Calculate the energy transferred.

KNOW $P = 1200 \text{ W}$, $t = 600 \text{ s}$

EQUATION $E = P t$

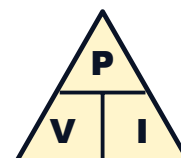
SUBSTITUTE $E = 1200 \times 600$

ANSWER $E = 720\,000 \text{ J}$

$$P = V I$$

power = p.d. × current

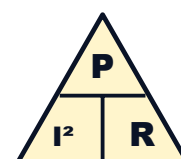
P in watts (W), V in volts (V), I in amperes (A)



$$P = I^2 R$$

power = current² × resistance

P in watts (W), I in amperes (A), R in ohms (Ω)



WORKED EXAMPLE

A heater on the 230 V mains draws a current of 4.0 A. Calculate its power.

EQUATION $P = VI$

SUBSTITUTE $P = 230 \times 4.0$

ANSWER $P = 920 \text{ W}$

YOUR TURN

A current of 3.0 A flows through a 20 Ω resistor. Calculate the power.

EQUATION $P = I^2 R$

SUBSTITUTE $P = 3.0^2 \times 20 = 9.0 \times 20$

ANSWER $P = 180 \text{ W}$

! In $P = I^2 R$, **square the current first**. Doubling the current makes the heating **four times** bigger: that is why cables carrying big currents get hot.

IF YOU KNOW...	USE
p.d. and current	$P = VI$
current and resistance	$P = I^2 R$
power and time	$E = Pt$
charge and p.d.	$E = QV$
current and time	$Q = It$



PRACTISE
TRY IT

1 Answer the big question. Show both calculations.

Kettle: $E = 3000 \times 180 = 540\,000 \text{ J}$. **LED:** $t = 5 \times 3600 = 18\,000 \text{ s}$, $E = 10 \times 18\,000 = 180\,000$

J. The kettle transfers 3 times as much energy.

2

SUPPORTED A 12 V car headlamp draws a current of 5.0 A. Calculate its power.

EQUATION $P = VI$

SUBSTITUTE $P = 12 \times 5.0$

ANSWER **60 W**

unit:

3

SUPPORTED A 9.0 kW electric shower runs for 8.0 minutes. Calculate the energy transferred in joules.

CONVERT $P = 9000 \text{ W}, t = 480 \text{ s}$

EQUATION $E = Pt$

SUBSTITUTE $E = 9000 \times 480$

ANSWER **4 320 000 J**

unit:

4

ON YOUR OWN A current of 2.0 A flows through a 10Ω resistor. Then the current is increased to 4.0 A. Calculate the power each time. What happens to the power when the current doubles?

$P = 2.0^2 \times 10 = 40 \text{ W}; P = 4.0^2 \times 10 = 160 \text{ W}$. The power is 4 times bigger.

5

ON YOUR OWN A device transfers 240 J of energy when 40 C of charge flows through it. Calculate the p.d. across it.

$V = E \div Q = 240 \div 40 = 6.0 \text{ V}$

6

CHALLENGE A lamp is rated 60 W, 230 V. Calculate the current through it and its resistance.

$I = P \div V = 60 \div 230 = 0.26 \text{ A}$. $R = V \div I = 230 \div 0.26 \approx 880 \Omega$.



Get the marks: Write the power in watts before you substitute: $2.2 \text{ kW} = 2200 \text{ W}$. Give answers to a sensible number of significant figures.

7

A 2.2 kW kettle runs on the 230 V mains. (a) Calculate the current [6 marks]
through the kettle. (b) Calculate the energy transferred in 150 s. (c) A heater draws
twice this current through the same resistance. How does its heating power
compare?

(a) $P = 2200 \text{ W}$ (1); $I = P \div V = 2200 \div 230$ (1) = 9.6 A (1). (b) $E = P t = 2200 \times 150$ (1) =
 $330\,000 \text{ J}$ (1). (c) $P = I^2 R$, so it is 4 times the power (1).

**SUMMARY**

- Power is energy transferred per second. $1 \text{ W} = 1 \text{ J/s}$.
- $E = P t$ (P in W, t in s).
- $P = V I$ and $P = I^2 R$.
- Doubling the current through a resistor makes the heating 4 times bigger.
- Appliances transfer energy electrically to thermal, kinetic or chemical stores.

COVER THE PAGE AND ANSWER**1** What is power?

.....

3 Write two equations for electrical power.

.....

2 Convert 3.5 kW into watts.

.....

4 Write the equation linking energy, power and time.

.....

I CAN...

describe power as energy transferred per second

use $E = P t$ with unit conversionsuse $P = V I$ and $P = I^2 R$ 

choose the right equation from the data given



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 $R_{\text{total}} = R_1 + R_2$), 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 $t = E \div P$

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

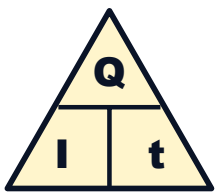
Give the answer with a unit. Ask: is it sensible?

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 .

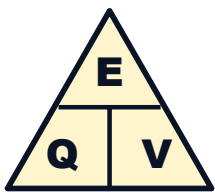


$$Q = I t$$

$$Q = I \times t$$

$$I = Q \div t$$

$$t = Q \div I$$

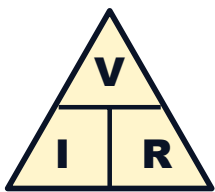


$$E = Q V$$

$$E = Q \times V$$

$$Q = E \div V$$

$$V = E \div Q$$

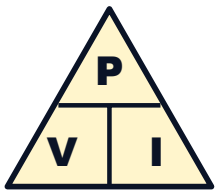


$$V = I R$$

$$V = I \times R$$

$$I = V \div R$$

$$R = V \div I$$

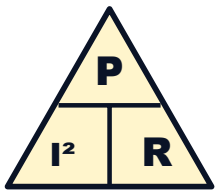


$$P = V I$$

$$P = V \times I$$

$$V = P \div I$$

$$I = P \div V$$



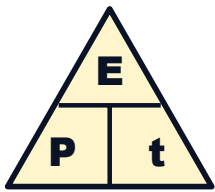
$$P = I^2 R$$

$$P = I^2 \times R$$

$$R = P \div I^2$$

$$I^2 = P \div R,$$

$$\text{so } I = \sqrt{(P \div R)}$$



$$E = P t$$

$$E = P \times t$$

$$P = E \div t$$

$$t = E \div P$$

REFERENCE

KEY WORDS FROM THIS LESSON

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

Power (P): Energy transferred per second. Unit: watt (W).

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. $E = Q V = 60 \text{ J}$
2. $Q = 2.0 \times 60 = 120 \text{ C}$
3. $R = 230 \div 5.0 = 46 \Omega$

COVER THE PAGE

1. Energy transferred per second.
2. 3500 W
3. $P = V I$ and $P = I^2 R$
4. $E = P t$