

ELECTRIC CIRCUITS

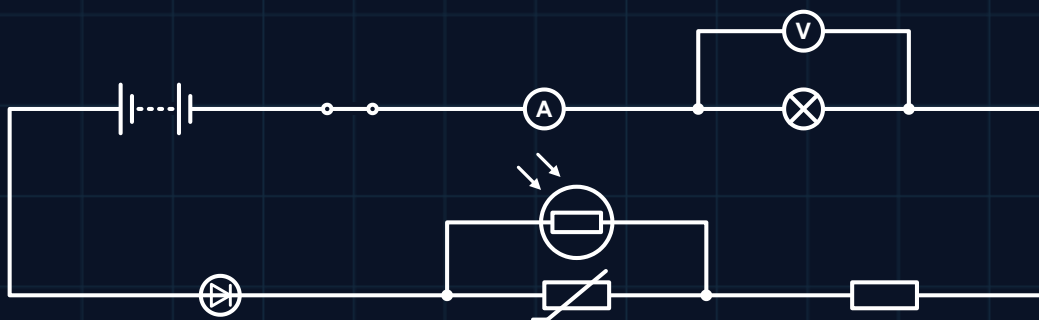
LESSON 03 POTENTIAL DIFFERENCE

An AA battery says 1.5 V. A car battery says 12 V. What is that number actually telling you?

IN THIS LESSON YOU WILL

- explain p.d. as the energy transferred per coulomb
- connect a voltmeter in parallel across a component
- use $E = QV$
- explain why the p.d.s in a loop add up to the supply p.d.

ANSWER EDITION FOR TEACHERS AND SELF-MARKING



NAME

CLASS

TEACHER

TARGET GRADE

HOW THIS BOOKLET WORKS

This is the booklet for **Lesson 3** 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

p.d. as energy per coulomb, voltmeters, $E = QV$, p.d.s add in series

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

POTENTIAL DIFFERENCE

AQA Combined 6.2.1.3, 6.2.4.2; Physics 4.2.1.3, 4.2.4.2; Virtual Lab 2

BIG QUESTION An AA battery says 1.5 V. A car battery says 12 V. What is that number actually telling you?

BY THE END YOU CAN

- explain p.d. as the energy transferred per coulomb
- connect a voltmeter in parallel across a component
- use $E = QV$
- explain why the p.d.s in a loop add up to the supply p.d.

potential difference (p.d.)

volt (V)

voltmeter

parallel

energy

joule (J)



RETRIEVE

DO NOW

From earlier lessons. No notes!

1

What is current?

The rate of flow of
charge.

2

0.50 A flows for 20 s. How much charge flows?

$Q = 0.50 \times 20 = 10 \text{ C}$

3

Does a lamp use up current? Explain.

No. The current is the
same all round the loop;
the lamp transfers energy.



EXPLAIN

ENERGY CARRIED BY CHARGE

The cell does not make charge: the charge was already in the wires. The cell gives **energy** to the charge. When the charge passes through a component such as a lamp, energy is transferred to it, so the lamp lights up and gets hot.

THINK OF DELIVERY VANS

Each coulomb of charge is a delivery van on a circular route. The battery loads each van with energy. At the lamp the van drops its energy off, then drives on, empty, back to the battery to reload. The vans (charge) are never used up; only the parcels (energy) are delivered.

Where the model breaks: real charges do not carry parcels, and energy reaches the lamp as soon as the switch closes, not after a slow journey.

WHAT A VOLT MEANS

Potential difference (p.d.) is the **energy transferred per coulomb** of charge between two points. It is measured in **volts (V)**. People often call it 'voltage'.

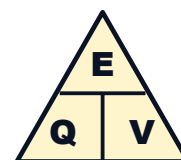
! **1 volt = 1 joule per coulomb.** A p.d. of 6 V across a lamp means 6 J of energy is transferred to the lamp by every 1 C of charge that passes through it.

$$E = QV$$

energy transferred = charge × potential difference

E in joules (J), Q in coulombs (C), V in volts (V)

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



WORKED EXAMPLE

6.0 C of charge passes through a lamp with 12 V across it. Calculate the energy transferred.

KNOW $Q = 6.0 \text{ C}, V = 12 \text{ V}$

EQUATION $E = QV$

SUBSTITUTE $E = 6.0 \times 12$

ANSWER $E = 72 \text{ J}$

YOUR TURN

A heater transfers 360 J while 30 C passes through it. Calculate the p.d. across it.

KNOW $E = 360 \text{ J}, Q = 30 \text{ C}$

EQUATION $V = E \div Q$

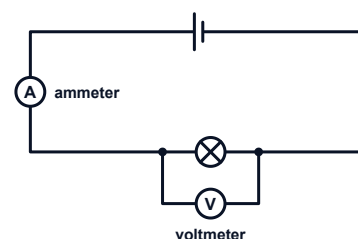
SUBSTITUTE $V = 360 \div 30$

ANSWER $V = 12 \text{ V}$

MEASURING P.D.: THE VOLTMETER

A p.d. is always *between two points*, so a **voltmeter** is connected **across** a component, with one lead on each side. This is connecting it **in parallel**.

Say 'the p.d. **across** the lamp' and 'the current **through** the lamp'.



Ammeter in series (in the loop).
Voltmeter in parallel (across the lamp).

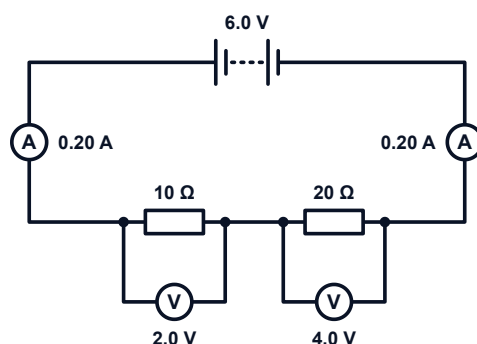
	CURRENT	POTENTIAL DIFFERENCE
What it is	rate of flow of charge (coulombs per second)	energy transferred per coulomb (joules per coulomb)
Unit	ampere, A	volt, V
Measured with	ammeter, in series	voltmeter, in parallel
Say	current <i>through</i>	p.d. <i>across</i>

ENERGY IN = ENERGY OUT

In a single loop, the p.d.s across the components **add up to the p.d. of the supply**.

Here each coulomb gets 6 J from the battery and hands over all 6 J on the way round: 2 J in the $10\ \Omega$ resistor and 4 J in the $20\ \Omega$ resistor.

Energy is conserved.



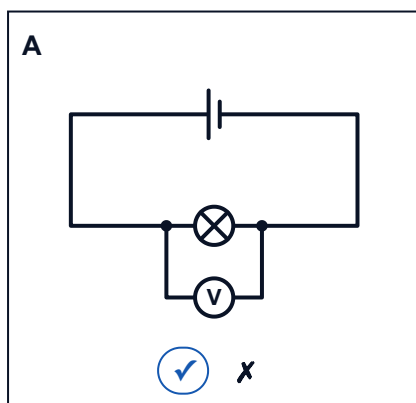
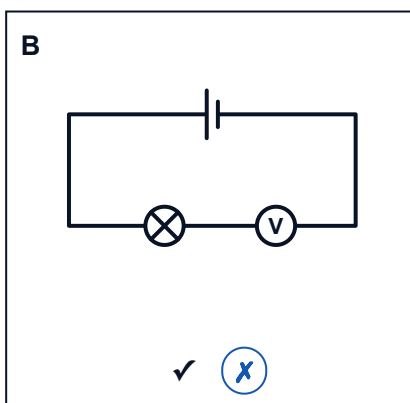
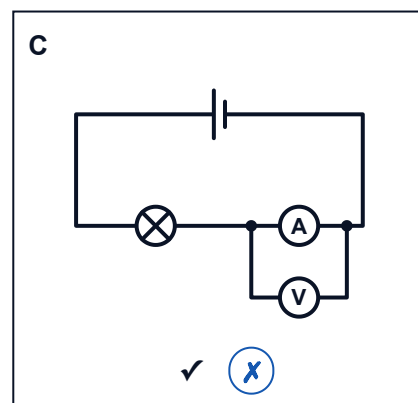
Series: the same current everywhere; $2.0\text{ V} + 4.0\text{ V} = 6.0\text{ V}$.



PRACTISE

TRY IT

1 Which circuit measures the p.d. across the lamp correctly? Circle ✓ or ✗ for each.



A only. In B the voltmeter is in series; in C it is across the ammeter, not the lamp.

2 Complete the sentences.

A p.d. of 9 V across a resistor means 9 J of energy is transferred to the resistor for every coulomb of charge. A voltmeter is connected across a component, in parallel.

WORD BANK

9

coulomb

second

across

parallel

series

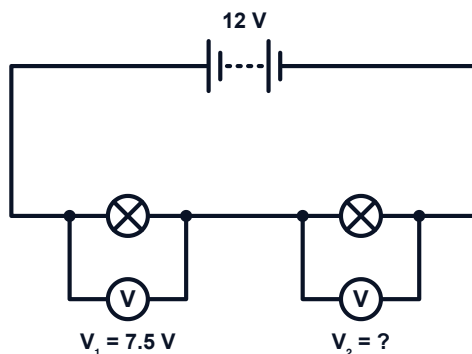
3 **SUPPORTED** 25 C of charge passes through a resistor with 4.0 V across it. Calculate the energy transferred.

EQUATION	$E = Q V$	
SUBSTITUTE	$E = 25 \times 4.0$	
ANSWER	100 J	unit:

4 **ON YOUR OWN** A kettle element transfers 23 000 J of energy when 100 C of charge flows through it. Calculate the p.d. across the element.

$$V = E \div Q = 23\,000 \div 100 = 230\text{ V}$$

5 (a) What does voltmeter V_2 read? (b) How much energy does each coulomb transfer in the second lamp?



(a) $12 - 7.5 = 4.5\text{ V}$. (b) 4.5 J per coulomb.

- 6 Explain what is wrong with Leo's idea.



A 9 V battery pushes the charges faster than a 1.5 V battery. That's what volts measure.

Volts measure energy transferred per coulomb, not speed. A 9 V battery gives each coulomb 9 J of energy; a 1.5 V battery gives each coulomb only 1.5 J.



INVESTIGATE

VIRTUAL LAB 2: WHAT DOES A VOLT MEAN?

Full steps: Virtual Labs worksheet
pp. 7–10.

Use one **10 Ω** resistor. At each battery setting, measure the p.d. across the resistor. Then calculate the energy transferred when 2 C passes.

- 7 Record and calculate.

Battery setting / V	p.d. across resistor / V	Energy for 2 C / J
3	3.0	6.0
6	6.0	12
9	9.0	18

- 8 Add a second 10 Ω resistor in series (6 V battery). Measure the p.d. across each resistor. What do you notice?

About 3.0 V across each; $3.0 \text{ V} + 3.0 \text{ V} = 6.0 \text{ V}$, the battery p.d. The energy from the battery is shared between the resistors.



Get the marks: Explaining a p.d. needs two ideas: energy (joules) and per coulomb of charge.

- 9** A 9.0 V battery moves 20 C of charge around a circuit. Calculate the energy transferred by the battery. **[2 marks]**

EQUATION	$E = Q V$	
SUBSTITUTE	$E = 20 \times 9.0$	
ANSWER	180 J	unit:

- 10** A voltmeter connected across a resistor reads 3.0 V. Explain what this reading means. **[2 marks]**

3.0 J of energy is transferred (1) to the resistor for every coulomb of charge passing through it (1).

**SUMMARY**

- p.d. is the **energy transferred per coulomb**: $1 \text{ V} = 1 \text{ J/C}$.
- A voltmeter goes **across** a component (in parallel).
- $E = Q V$**
- Charge is not used up; energy is transferred.
- In a series loop, the component p.d.s add up to the supply p.d.

COVER THE PAGE AND ANSWER

1 What is potential difference?

.....

2 How is a voltmeter connected?

.....

3 Write the equation linking energy, charge and p.d.

.....

4 A 6 V battery; one of two series lamps has 2 V across it. What does the other have?

.....

I CAN...

explain p.d. as energy transferred per coulomb



connect a voltmeter in parallel



use $E = Q V$ and its rearrangements



use 'p.d.s add up' in a series loop



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 $Q = E \div V$

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

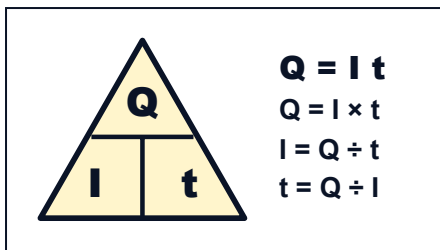
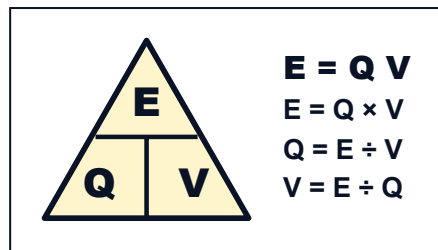
Give the answer with a unit. Ask: is it sensible?

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.



REFERENCE

KEY WORDS FROM THIS LESSON

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

Parallel: Components on separate branches. A voltmeter is connected in parallel.

Potential difference (V): Energy transferred per unit charge between two points. Unit: volt (V).

Volt (V): Unit of p.d. $1 \text{ V} = 1 \text{ J per C}$.

Voltmeter: Measures p.d. Connected in parallel, across a component.

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. The rate of flow of charge.
2. $Q = 0.50 \times 20 = 10 \text{ C}$
3. No. The current is the same all round the loop; the lamp transfers energy.

COVER THE PAGE

1. Energy transferred per coulomb of charge.
2. In parallel, across the component.
3. $E = Q V$
4. 4 V