IGCSE PHYSICS 0625 · CHAPTER 9 NOTES · ~13 MIN READ

Electricity & circuits

Charge, current, voltage and resistance made simple — then series and parallel circuits, power, cost of electricity and plug safety.

Static charge | Current & charge | e.m.f. & p.d. | Resistance & V = IR | I–V graphs | Series & parallel | Potential divider | Power & kWh

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Current** is the flow of charge (amperes). **Voltage (p.d.)** is the energy given to each coulomb. **Resistance** (ohms) opposes the current.
- **V = IR**, so R = V ÷ I. A steeper I–V line means a smaller resistance.
- **Series:** one loop, same current, voltages add, resistances add. **Parallel:** branches, same voltage, currents add.
- **P = IV** and **E = IVt**. Cost = kWh × price per kWh.
- Fuse and switch go in the **live** wire; metal cases are **earthed**.

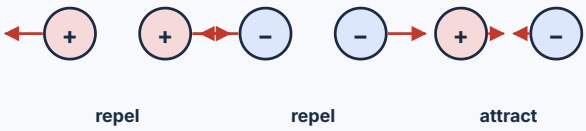
BY THE END YOU CAN

- Explain static charge and the electron model of current.
- Use V = IR, I = Q ÷ t EXT, P = IV and E = IVt.
- Draw circuits and solve series and parallel problems, including a potential divider. EXT
- Sketch I–V graphs for a resistor, a filament lamp and a diode. EXT
- Calculate the cost of electricity and choose a fuse.

1 Static charge and current

Static electricity

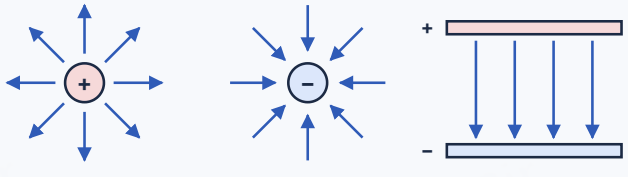
- There are two kinds of electric charge, **positive** and **negative**. **Like charges repel, unlike charges attract.**



like charges repel · unlike charges attract

Like charges repel; unlike charges attract.

- **Charging by friction:** when you rub two insulators together only **electrons** move. The one that gains electrons becomes negative; the one that loses them becomes positive. Protons never move.
- A charged object attracts small neutral things such as scraps of paper. A charged balloon will stick to a wall.
- **Conductors** (metals, graphite) have free electrons so charge can flow. **Insulators** (plastic, glass, rubber) have none, so charge stays where it is.
- EXT Charge is measured in **coulombs (C)**.



positive charge field points away | **negative charge** field points in | **parallel plates** uniform field

field direction = direction of the force on a + charge

EXT An electric field is a region where a charge feels a force. Its direction is the direction of the force on a positive charge. The field around a point charge is radial; between two parallel plates it is uniform.

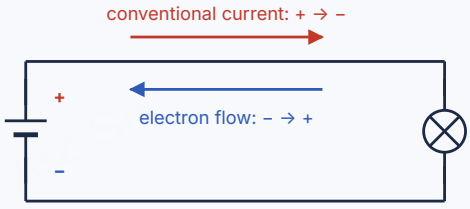
Electric current

Current — the rate of flow of electric charge. It is measured in amperes (A) with an **ammeter in series**.

EXT $$I = \frac{Q}{t}$$

charge Q (C) = current I (A) × time t (s)

- In metals the charge carriers are **free electrons**, which drift through the metal when a p.d. is applied.



electrons are negative, so they drift
the opposite way to conventional current

Conventional current is drawn from + to −. Electrons are negative, so they actually drift from − to +.

- **d.c.** (direct current) always flows one way. **a.c.** (alternating current) keeps reversing direction, like the mains supply.
- Analogue meters have a needle; digital meters show numbers. Choose a suitable range.

WORKED EXAMPLE

EXT **A current of 0.50 A flows for 2.0 minutes. How much charge passes through the circuit?**

1. t = 2.0 × 60 = 120 s
2. Q = It = 0.50 × 120
3. **= 60 C**

e.m.f. and potential difference

e.m.f. — the electrical work done by a source in driving one coulomb of charge round a complete circuit. Measured in volts (V).

Potential difference (p.d.) — the work done (energy transferred) per coulomb as charge moves through a component. Measured in volts (V), with a **voltmeter in parallel**.

EXT $$V = \frac{W}{Q}$$

also E = W ÷ Q for a source · 1 volt = 1 joule per coulomb

PICTURE IT

Compare with a water circuit: the cell is the pump that lifts each bit of water to a higher energy (the e.m.f.), and a resistor is a narrow pipe where each bit gives up energy (the p.d.).

WORKED EXAMPLE

EXT **A 12 V battery moves 5.0 C of charge round a circuit. How much energy does it transfer?**

1. W = QV = 5.0 × 12
2. **= 60 J**

2 Resistance

Resistance and Ohm's law

Resistance — how much a component opposes the current. Measured in ohms (Ω).

$$R = \frac{V}{I}$$

V = I R and I = V ÷ R · V in volts, I in amps, R in ohms

- A higher resistance means a smaller current for the same p.d.
- **To measure R:** put an ammeter in series and a voltmeter in parallel with the component, read V and I, then R = V ÷ I. Repeat with different p.d.s.

WORKED EXAMPLE

A lamp has 6.0 V across it and a current of 0.25 A flowing through it. Find its resistance.

1. R = V ÷ I = 6.0 ÷ 0.25
2. **= 24 Ω**

WORKED EXAMPLE

A 12 Ω resistor carries 0.50 A. Find the p.d. across it.

1. V = IR = 0.50 × 12
2. **= 6.0 V**

- **Wires:** a longer wire has more resistance and a thicker wire (bigger cross-section) has less.
- EXT Resistance is directly proportional to length and inversely proportional to cross-sectional area. Doubling the length doubles R; doubling the area halves R.

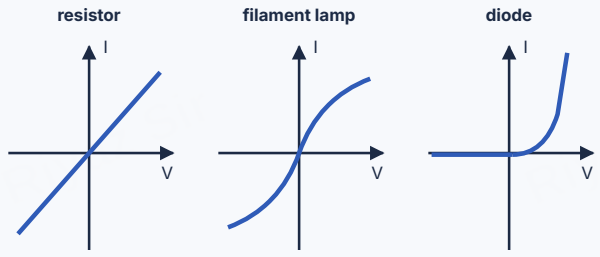
WORKED EXAMPLE

EXT **A wire has resistance 4.0 Ω. A wire of the same material is twice as long and has four times the cross-sectional area. Find its resistance.**

1. Twice the length: × 2
2. Four times the area: ÷ 4
3. **R = 4.0 × 2 ÷ 4 = 2.0 Ω**

I–V graphs

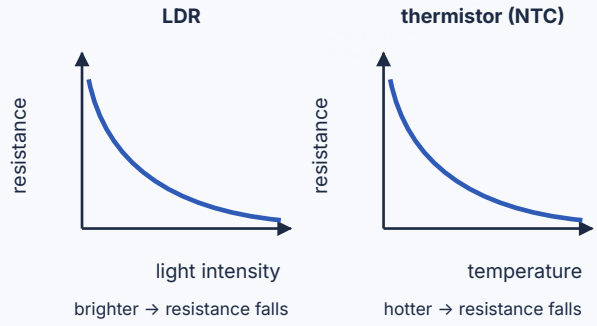
EXTENDED



Resistor: a straight line through the origin, so R is constant. Filament lamp: the curve flattens as the filament gets hot and its resistance rises. Diode: current flows in one direction only.

- On an I–V graph a **steeper line means a smaller resistance**.
- **Filament lamp:** more current heats the filament, the atoms vibrate more, and the resistance rises.
- **Diode:** conducts only in the forward direction. An **LED** is a diode that lights up when current flows through it.

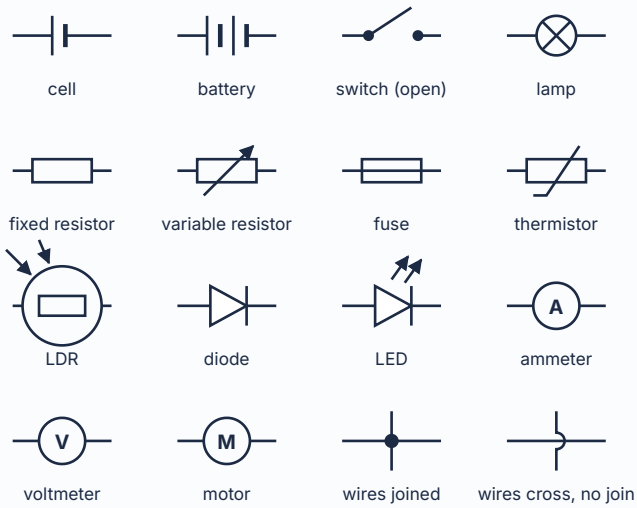
Resistors that change



LDR: the brighter the light, the lower the resistance. NTC thermistor: the hotter it gets, the lower the resistance.

- Uses: an LDR in automatic street lights; a thermistor in fire alarms, thermostats and electronic thermometers.

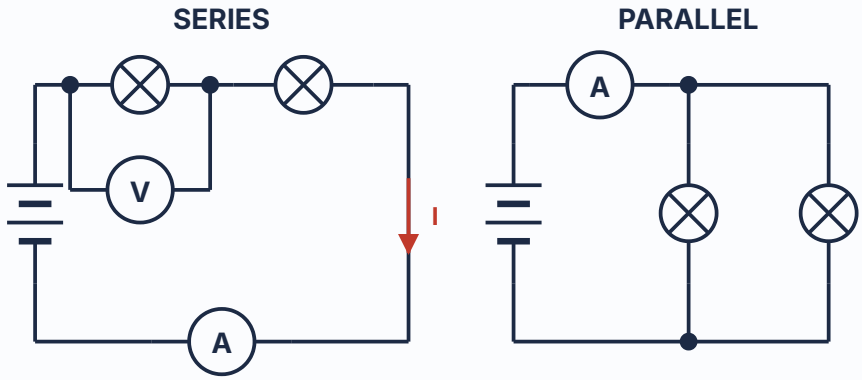
Circuit symbols



The standard symbols. Learn to draw all of them.

- Also needed: **heater** (resistor symbol), **transformer** (two coils on an iron core) and **relay** (a coil that switches a second circuit).
- An **ammeter** goes in series (low resistance). A **voltmeter** goes in parallel (high resistance).

Series and parallel



one loop: same current everywhere
voltages add up to the supply
if one lamp breaks, all go out

branches: each gets the full voltage
currents in the branches add up
if one lamp breaks, the other stays on

ammeter in SERIES (in the loop) · voltmeter in PARALLEL (across the part)

In series, the same current flows through every part. In parallel, each branch gets the full supply voltage.

	Series	Parallel
current	same everywhere	branch currents add up to the supply current
p.d.	shared: the p.d.s add up to the supply voltage	the same across every branch
resistance	$R = R_1 + R_2 + R_3$	combined R is less than the smallest
one lamp breaks	all go out	the others stay on

- **Cells in series:** the e.m.f.s add up.
- At a **junction** the total current going in equals the total current going out. EXT
- Lamps in a house are in **parallel**, so each gets the full voltage, can be switched on separately, and keeps working if one fails.

EXT $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

two resistors in parallel, or $R = R_1R_2 \div (R_1 + R_2)$

WORKED EXAMPLE

Two resistors of 4.0 Ω and 8.0 Ω are in series across a 12 V supply. Find the current and the p.d. across each resistor.

1. R = 4.0 + 8.0 = 12 Ω
2. I = V ÷ R = 12 ÷ 12 = **1.0 A**
3. V_1 = IR = 1.0 × 4.0 = **4.0 V**
4. **V_2 = 1.0 × 8.0 = 8.0 V, and 4.0 + 8.0 = 12 V**

WORKED EXAMPLE

EXT **A 6.0 Ω and a 3.0 Ω resistor are in parallel across 12 V. Find each branch current, the total current and the combined resistance.**

1. I_1 = V ÷ R_1 = 12 ÷ 6.0 = **2.0 A**
2. I_2 = 12 ÷ 3.0 = **4.0 A**
3. Total current = 2.0 + 4.0 = **6.0 A**
4. **Combined R = V ÷ I = 12 ÷ 6.0 = 2.0 Ω**

EXAM TIP

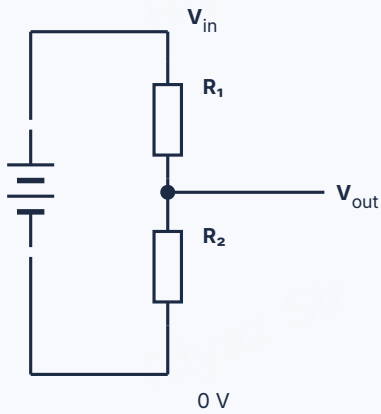
Check: the combined resistance in parallel must be **smaller than the smallest branch**. 2.0 Ω is below 3.0 Ω, so it passes.

COMMON MISTAKE

Using the series formula for resistors that are in parallel.

Potential divider

EXTENDED



Vout = Vin × R_2 ÷ (R_1 + R_2)

Two resistors in series share the supply voltage. The bigger resistor takes the bigger share.

EXT $\frac{R_1}{R_2} = \frac{V_1}{V_2}$

or $V_{out} = V_{in} \times R_2 \div (R_1 + R_2)$

- A **variable potential divider** has a sliding contact, so the output voltage can be adjusted. Putting an LDR or thermistor in place of one resistor makes a light or temperature sensor.

WORKED EXAMPLE

EXT **A 9.0 V supply is connected across a 2.0 kΩ and a 1.0 kΩ resistor in series. Find the p.d. across the 1.0 kΩ resistor.**

1. Total resistance = 3.0 kΩ
2. $V_2 = V_{in} \times R_2 \div (R_1 + R_2) = 9.0 \times 1.0 \div 3.0$
3. **= 3.0 V**

4 Electrical energy and power

Power, energy and cost

$$P = I\,V$$

power (W) = current (A) × p.d. (V)

$$E = I\,V\,t$$

energy (J) = current × p.d. × time (s), or E = P t

WORKED EXAMPLE

An electric kettle takes 10 A from 230 V mains. Find its power and the energy it transfers in 3.0 minutes.

1. P = IV = 10 × 230 = **2300 W**
2. t = 3.0 × 60 = 180 s
3. **E = Pt = 2300 × 180 = 414 000 J**

Kilowatt-hour (kWh) — the energy used by a 1 kW appliance in 1 hour. 1 kWh = 3.6 million joules.

$$\text{energy (kWh)} = \text{power (kW)} \times \text{time (h)}$$

then cost = energy (kWh) × price per kWh

WORKED EXAMPLE

A 2.0 kW heater runs for 3.0 hours. Electricity costs 20 cents per kWh. Find the cost.

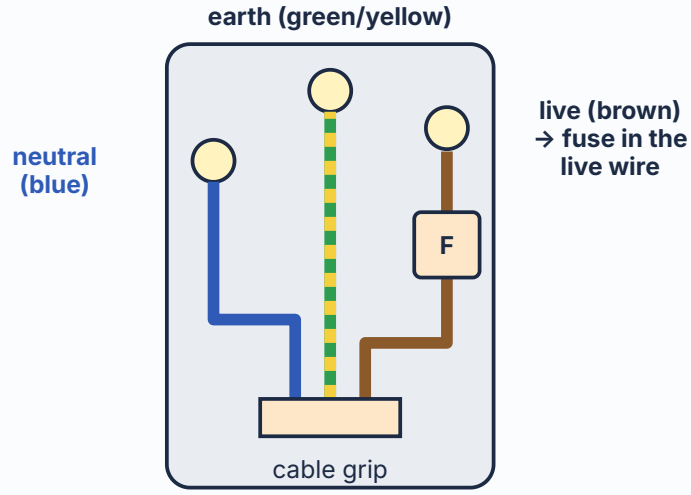
1. Energy = 2.0 × 3.0 = 6.0 kWh
2. **Cost = 6.0 × 20 = 120 cents ($1.20)**

COMMON MISTAKE

Not converting: watts ÷ 1000 to get kW, and minutes ÷ 60 to get hours.

5 Electrical safety

The three-pin plug and fuses



earth → metal case · fuse → live wire · switch → live wire

The wire colours. The fuse and switch are always in the live wire.

- **Hazards:** damaged insulation, overheated cables, damp conditions (water conducts) and overloaded sockets.
- **Live** (brown) carries the voltage. **Neutral** (blue) completes the circuit. **Earth** (green and yellow) connects the metal case to the ground.
- The switch is in the **live** wire so that the appliance is not live when switched off.
- A **fuse** is a thin wire that melts if the current gets too high, breaking the circuit. Choose a fuse rating just above the normal current: a 690 W appliance on 230 V draws 3.0 A, so use a 5 A fuse.
- A **trip switch** (circuit breaker) uses an electromagnet to switch off when the current is too high. It can be reset.
- **Earth wire:** if a fault makes the live wire touch the metal case, a large current flows to earth and blows the fuse, so the case never stays live.
- **Double-insulated** appliances have a plastic case, so no earth wire is needed. The fuse still protects the circuit and cabling.

COMMON MISTAKE

Putting the fuse in the neutral wire. If it blows, the appliance would still be live.

6 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Which particles move when an insulator is charged by friction?
2. A lamp has 12 V across it and a current of 3.0 A. What is its resistance?
3. A 60 W bulb is on for 5.0 hours. How much energy is that in kWh?
4. Name the wire that the fuse is placed in.
5. Should an ammeter be connected in series or parallel?
6. What is the resistance of 5.0 Ω and 10 Ω in series?

EXAM-STYLE

7. Resistors of 6.0 Ω and 12 Ω are connected in parallel to a 12 V battery. Find (a) the current in each, (b) the total current, (c) the combined resistance. EXT
8. A 3.0 kW shower is used for 10 minutes. Electricity costs 25 cents per kWh. Find the cost.
9. EXT Describe and explain the shape of the I–V graph for a filament lamp. [3]
10. Explain how the earth wire protects the user. [3]
11. EXT A current of 3.0 A flows for 20 s. How much charge flows?

Show answers

1. electrons
2. 12 ÷ 3.0 = 4.0 Ω
3. 0.060 × 5.0 = 0.30 kWh
4. live
5. series
6. 15 Ω
7. (a) 12 ÷ 6.0 = 2.0 A and 12 ÷ 12 = 1.0 A
   (b) 2.0 + 1.0 = 3.0 A
   (c) R = 12 ÷ 3.0 = 4.0 Ω
8. energy = 3.0 × 10 ÷ 60 = 0.50 kWh
   cost = 0.50 × 25 = 12.5 cents
9. The graph is a curve that flattens as the p.d. increases
   the filament gets hotter as more current flows
   so its resistance rises
10. It connects the metal case to the ground
    if the live wire touches the case, a large current flows to earth
    this blows the fuse and disconnects the appliance
11. Q = It = 3.0 × 20 = 60 C

Stuck on a question?

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