IGCSE PHYSICS • EXERCISE SHEET

4.2 Electrical quantities

Name: _____ Class: _____ Date: _____ **Total: 45 marks**

KEY WORDS resistance 电阻 • current 电流 • potential difference 电势差 • conductor 导体 • kilowatt-hour 千瓦时 • current 电流 • resistance 电阻 • volt 伏特 • electrical power 电功率 • electrical quantities 电学量

Objective

Build the skills to answer exam questions on **electrical quantities** 电学量: charge, current, e.m.f. and p.d., resistance, and electrical power and energy.

You must be able to:

- describe **charging by friction** 摩擦起电 and test whether an object is charged
- tell conductors from insulators, and explain the difference using electrons
- use $I = \dfrac{Q}{t}$, and choose the right range on an ammeter or a voltmeter
- define e.m.f. and p.d. and use $E = \dfrac{W}{Q}$ and $V = \dfrac{W}{Q}$
- measure resistance, use $R = \dfrac{V}{I}$, and say how length and thickness change it
- read current–voltage graphs for a resistor, a filament lamp and a diode
- use $P = IV$ and $E = IVt$, and work out a cost in kilowatt-hours

1 Worked examples

■ Charges, conductors and current

Rub a plastic rod with a cloth: **electrons** 电子 move from the cloth onto the rod. The rod is now negative and the cloth is positive. Only electrons move; the positive charge stays where it is. Like charges **repel** 排斥 and unlike charges **attract** 吸引. To test whether a rod is charged, hang it on a thread and bring another charged rod near it: **repulsion** 排斥力 is the only sure sign, because attraction also happens with an uncharged object.

A **conductor** 导体 (a metal) has free electrons that can move, so charge flows through it. An **insulator** 绝缘体 (plastic, rubber, glass) has no free electrons. To test a material, put it in a circuit with a cell and a lamp: the lamp lights only for a conductor.

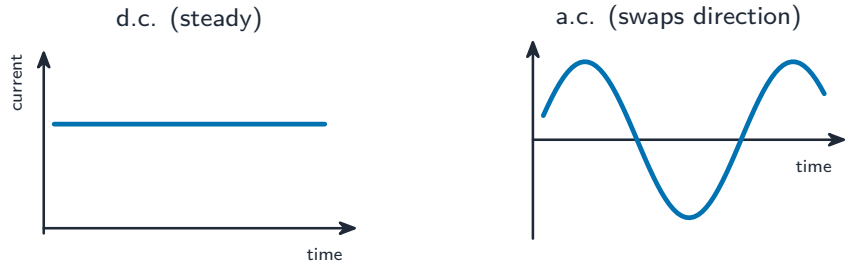
Current 电流 is the charge passing a point each second, measured in amperes (A):

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

Worked example 1. A current of 3.0 A flows in a lamp for 20 s. Find the charge that passes.

1. Write down what you know: $I = 3.0$ A and $t = 20$ s.
2. Rearrange $I = Q/t$ to give $Q = It$.
3. Substitute: $Q = 3.0 \times 20 = 60$ C.

Conventional current 常规电流 flows from + to − round the circuit; the electrons drift the other way. A **direct current** 直流电 (d.c.) always flows one way; an **alternating current** 交流电 (a.c.) keeps reversing.



d.c. flows one way; a.c. keeps reversing

Meters and their ranges

An **ammeter** 电流表 goes in series; a **voltmeter** 电压表 goes in parallel, across the component. Both may be **analogue** 模拟 (a needle on a scale) or **digital** 数字 (a number on a screen). Choose the **range** 量程 just above the biggest reading you expect: for a current of about 0.4 A use the 0–1 A range, not the 0–10 A range, because the needle moves further and the reading is more accurate.

E.m.f. and p.d.

The **e.m.f.** 电动势 of a cell is the work it does driving one coulomb of charge round the whole circuit. The **p.d.** 电势差 across a component is the work done by one coulomb passing through that component. Both are measured in volts (V):

$$E = \frac{W}{Q} \qquad V = \frac{W}{Q}$$

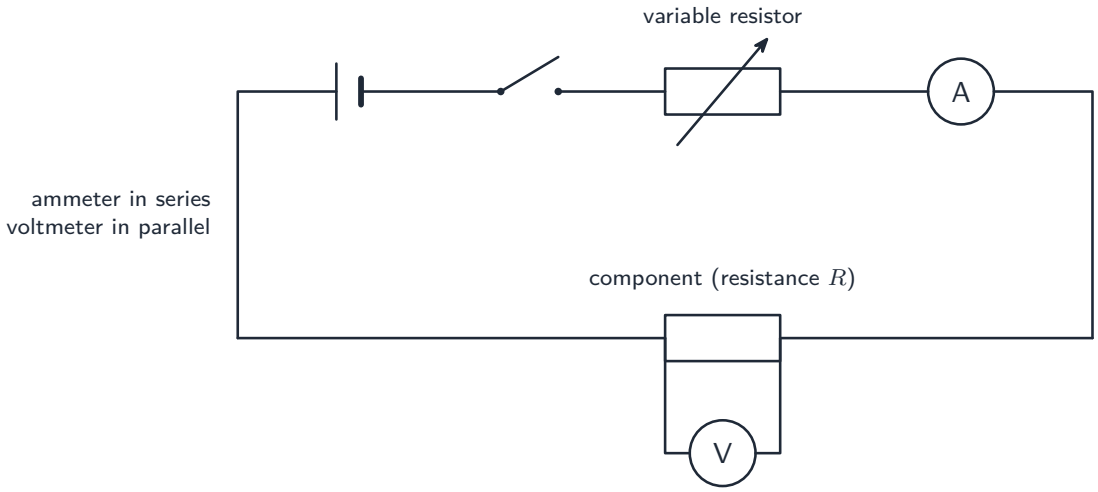
Worked example 2. A battery does 180 J of work moving 30 C of charge round a circuit. Find its e.m.f.

$$E = \frac{W}{Q} = \frac{180}{30} = 6.0 \text{ V}.$$

Measuring resistance

Resistance 电阻 measures how hard it is for current to flow:

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

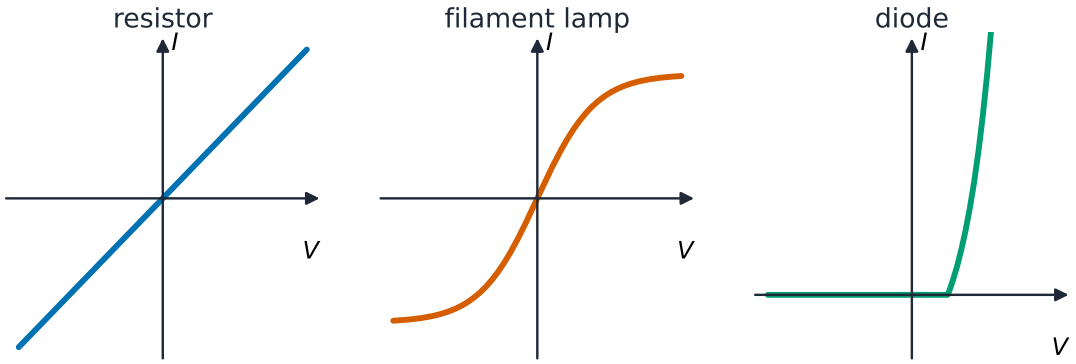


The circuit for measuring resistance: the ammeter is in series, the voltmeter is across the component, and the variable resistor changes the current

Worked example 3. In this circuit the voltmeter reads 4.8 V and the ammeter reads 0.20 A. Find the resistance of the component.

$R = \frac{V}{I} = \frac{4.8}{0.20} = 24\ \Omega$. In the experiment, change the variable resistor to get four or five pairs of readings. Then either find R for each pair and take the average, or plot V against I: the gradient of the straight line is R.

For a wire at constant temperature, a longer wire has more resistance ($R \propto l$) and a thicker wire has less ($R \propto 1/A$). Doubling the length doubles R; doubling the cross-sectional area halves it.



resistor (ohmic): $V = IR$ straight · filament: resistance rises with heat · diode: one-way

A resistor gives a straight line through the origin (constant R); a filament lamp curves as it heats up and its resistance rises; a diode conducts one way only

Power, energy and the kilowatt-hour

$$P = IV \qquad E = IVt$$

Worked example 4. A 230 V kettle takes a current of 8.0 A for 3.0 minutes. Find its power and the energy it transfers.

1. Power: $P = IV = 8.0 \times 230 = 1840$ W.
2. Time in seconds: $t = 3.0 \times 60 = 180$ s.
3. Energy: $E = Pt = 1840 \times 180 = 331\,000$ J $\approx 3.3 \times 10^5$ J.

Electricity bills use the **kilowatt-hour** 千瓦时 (kWh), the energy a 1 kW appliance uses in 1 hour:

$$E\ (\text{kWh}) = P\ (\text{kW}) \times t\ (\text{h}) \qquad \text{cost} = E\ (\text{kWh}) \times \text{price per kWh}$$

Worked example 5. A 2.0 kW heater runs for 2.5 hours. Electricity costs 0.60 yuan per kWh. Find the cost.

$E = 2.0 \times 2.5 = 5.0$ kWh, so the cost is $5.0 \times 0.60 = 3.0$ yuan.

2 Practice

2.1 A current of 2.0 A flows for 15 s. Find the charge that passes. [2]

2.2 A charge of 240 C passes through a motor in 4.0 minutes. Find the current. (Hint: change the time into seconds first.) [3]

2.3 A student wants to measure a current of about 0.25 A. Her ammeter has ranges of 0–100 mA, 0–1 A and 0–10 A. State which range she should use and explain why. [2]

2.4 A cell does 27 J of work moving 18 C of charge round a circuit. Find its e.m.f. [2]

2.5 A p.d. of 12 V across a heater drives a current of 0.50 A through it. Find its resistance. [2]

2.6 Wire P has a resistance of 6.0 Ω. Wire Q is made of the same metal and is the same thickness as P, but twice as long. Wire S is the same length as P but has twice the cross-sectional area. State the resistance of Q and of S. [2]

2.7 A 12 V motor draws a current of 2.5 A. Find its power, and the energy it transfers in 40 s. [3]

2.8 An electric oven is rated 3.0 kW. It is used for 1.5 hours each day for 10 days. Electricity costs 0.55 yuan per kWh. Find the cost. [3]

3 Exam-style questions

3.1 Two wires, X and Y, are made of the same metal at the same temperature. Y is twice as long as X and has half the cross-sectional area of X. The resistance of X is R. What is the resistance of Y? [1]

- **A** $R/4$
- **B** R
- **C** $2R$
- **D** $4R$

3.2 A charged rod is brought near a small ball hanging on a thread. The ball moves towards the rod. Which statement is correct? [1]

- **A** The ball must have the opposite charge to the rod.
- **B** The ball must be a conductor.
- **C** The ball may be uncharged.
- **D** The ball must have the same charge as the rod.

3.3 A phone charger is connected to the 230 V mains. It supplies a current of 2.0 A at a p.d. of 5.0 V to the phone for 30 minutes.

(a) Define the potential difference across the phone. [1]

(b) Calculate the charge that flows into the phone in the 30 minutes. [3]

(c) Calculate the energy transferred to the phone in this time. [2]

(d) The case of the charger is made of plastic. Explain, in terms of electrons, why the plastic case does not conduct. [2]

3.4 A student is given a length of resistance wire, a cell, a switch, an ammeter, a voltmeter and a variable resistor.

(a) Draw a labelled circuit diagram she could use to find the resistance of the wire. [3]

(b) Describe how she uses the circuit to obtain a reliable value for the resistance. [3]

(c) Her readings are $V = 3.0$ V and $I = 0.60$ A. Calculate the resistance of the wire. [2]

(d) She replaces the wire with a filament lamp and increases the current. State and explain how the resistance of the lamp changes. [2]

3.5 A 1.5 kW electric kettle and a 100 W lamp are each switched on for 20 minutes.

(a) Calculate the energy, in kWh, used by the kettle. [2]

(b) Calculate how many times longer the lamp would have to be on to use the same energy as the kettle. [2]

(c) The kettle is connected to the 230 V mains. Calculate the current in the kettle. [2]

Solutions

2.1 $Q = It = 2.0 \times 15 = 30$ C.

2.2 $t = 4.0 \times 60 = 240$ s; $I = \dfrac{Q}{t} = \dfrac{240}{240} = 1.0$ A.

2.3 The 0–1 A range. It is the smallest range above 0.25 A, so the needle moves well up the scale and the reading is more accurate; the 0–100 mA range would be overloaded and the 0–10 A range would read only coarsely.

2.4 $E = \dfrac{W}{Q} = \dfrac{27}{18} = 1.5$ V.

2.5 $R = \dfrac{V}{I} = \dfrac{12}{0.50} = 24\ \Omega$.

2.6 Q: twice the length, so 12 Ω. S: twice the area, so 3.0 Ω.

2.7 $P = IV = 2.5 \times 12 = 30$ W; $E = Pt = 30 \times 40 = 1200$ J.

2.8 $E = 3.0 \times 1.5 \times 10 = 45$ kWh; cost $= 45 \times 0.55 = 24.75 \approx 25$ yuan.

3.1 D. Twice the length doubles the resistance and half the area doubles it again, so $R_Y = 4R$. A takes both changes the wrong way, B assumes they cancel, and C counts only the length.

3.2 C. A charged rod attracts an uncharged object as well as an oppositely charged one, so attraction proves nothing; only repulsion is a sure test.

3.3 (a) The work done by a unit charge (one coulomb) passing through the phone.
(b) $t = 30 \times 60 = 1800$ s; $Q = It = 2.0 \times 1800 = 3600$ C.
(c) $E = IVt = 2.0 \times 5.0 \times 1800 = 18\,000$ J.
(d) Plastic has no free electrons; its electrons are held in their atoms, so charge cannot flow through it.

3.4 (a) Cell, switch, variable resistor and ammeter in series with the wire; voltmeter in parallel across the wire; correct symbols in a complete loop.
(b) Close the switch and read the ammeter and the voltmeter; adjust the variable resistor to obtain several pairs of readings; calculate $R = V/I$ for each pair and take the average, or plot V against I and use the gradient.
(c) $R = \dfrac{V}{I} = \dfrac{3.0}{0.60} = 5.0\ \Omega$.
(d) The resistance increases, because the filament gets hotter as the current rises.

3.5 (a) $E = 1.5 \times \dfrac{20}{60} = 0.50$ kWh.
(b) The lamp uses 0.10 kW, so it needs $\dfrac{0.50}{0.10} = 5.0$ h; 5.0 h ÷ 20 min = 15 times longer.
(c) $I = \dfrac{P}{V} = \dfrac{1500}{230} = 6.5$ A.