4.2 Electrical quantities

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

0 Vocabulary

Word	Example
charging by friction 摩擦起电 /ˈtʃɑːdʒɪŋ baɪ ˈfrɪkʃn/	**Charging by friction** happens when you rub a balloon on your hair. 用气球摩擦头发时会发生**摩擦起电**。
ion /ˈaɪɒn/ 离子	An **ion** is an atom that has gained or lost electrons. **离子**是得到或失去电子的原子。
electric current 电流 /ɪˈlektrɪk ˈkʌrənt/	An **electric current** flows when the switch is closed. 开关闭合时，就有**电流**流过。
analogue /ˈænəlɒg/ 模拟	An **analogue** signal changes smoothly. **模拟**信号连续平滑地变化。
digital /ˈdɪdʒɪtl/ 数字	A **digital** signal uses only 0 and 1. **数字**信号只使用 0 和 1。
ranges /ˈreɪndʒɪz/ 量程	Choose meter **ranges** large enough for your readings. 选择足够大的仪表**量程**，以便测量读数。
free electrons /friː ɪˈlektrɒnz/ 自由电子	**Free electrons** carry current in a metal wire. **自由电子**在金属导线中传导电流。
conventional current 常规电流 /kənˈvenʃənl ˈkʌrənt/	**Conventional current** flows from + to −. **常规电流**的方向是从 + 到 −。
alternating current 交流电 /ˈɔːltəneɪtɪŋ ˈkʌrənt/	The mains gives **alternating current**. 市电提供**交流电**。
energy /ˈenədʒi/ 能量	Food gives your body the **energy** it needs to move. 食物为你的身体提供运动所需的**能量**。
cross-sectional area 横截面积 /krɒs ˈsekʃənl ˈeərɪə/	A thick wire has a large **cross-sectional area**. 粗金属丝的**横截面积**大。
kilowatt-hour /ˈkɪləwɒt ˈaʊə/ 千瓦时	One **kilowatt-hour** is the energy a 1 kW heater uses in one hour. 一**千瓦时**是一台 1 kW 加热器在一小时内消耗的能量。

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heater /ˈhiːtə/ 加热器	The **heater** warms the water. **加热器**给水加热。

1 Key knowledge and worked examples

■ Charges, conductors and current

Rub a plastic rod with a cloth: **electrons** 电子 move from the cloth onto the rod. For this assumed electron transfer, the rod becomes negative and the cloth positive. The ions remain in the solid. 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.

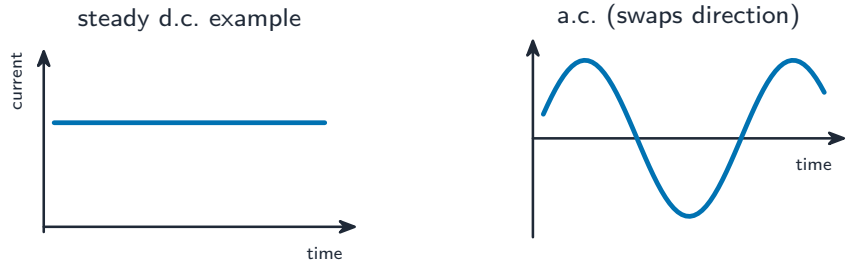
Current 电流 is the charge passing a point each second, measured in amperes (A):

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

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

Rearrange $I = Q/t$ to give $Q = It$, then substitute: $Q = 3.0 \times 20 = 60\,\text{C}$.

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 a **range** 量程 that includes the expected reading with useful resolution: about 0.4 A fits the 0–1 A range. Start high if the current is

unknown, then reduce safely. A finer scale improves reading resolution, not necessarily calibration accuracy.

■ 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):

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

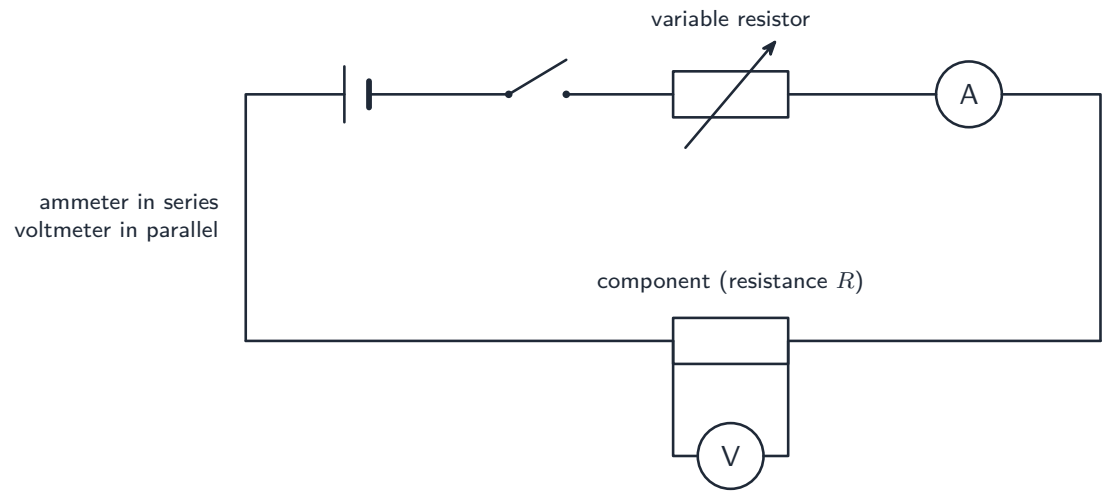
Worked example 2. A battery does 180 J of work moving 30 C of charge round a circuit. Find its e.m.f.

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

■ Measuring resistance

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

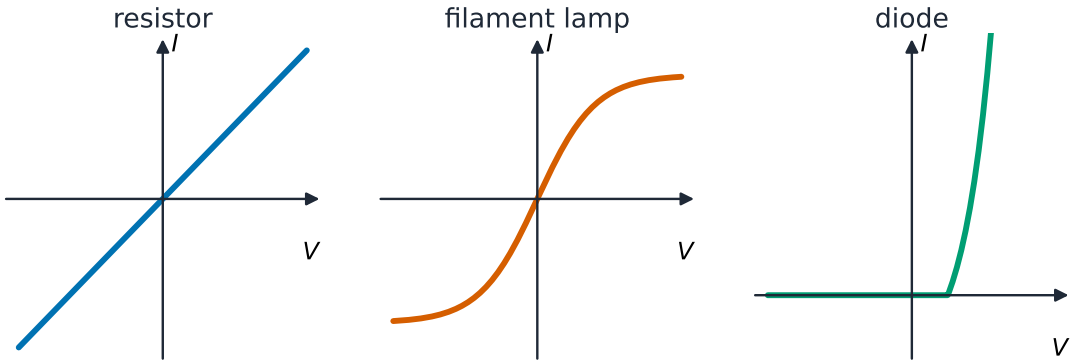
$$R = \frac{V}{I}$$



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.

$R = \dfrac{V}{I} = \dfrac{4.8}{0.20} = 24\ \Omega$. At approximately constant temperature, obtain several V, I pairs. For an ohmic component, plot V against I: its straight-line gradient is R. Do not assume a filament lamp has constant resistance as it heats.

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: $E = Pt = 1840 \times 180 = 331\,200$ 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:

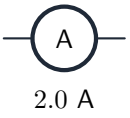
$$E \text{ (kWh)} = P \text{ (kW)} \times t \text{ (h)} \qquad \text{cost} = E \text{ (kWh)} \times \text{price per kWh}$$

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]



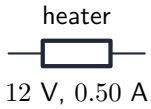
2.3 A student wants to measure a current of about 0.25 A. Her ammeter has ranges of 0–100 mA, 0–1 A and 0–10 A. State which range she should use and explain why. [2]

0–100 mA 0–1 A 0–10 A

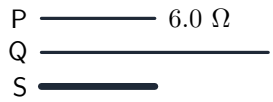
2.4 A cell does 27 J of work moving 18 C of charge round a circuit. Find its e.m.f. [2]



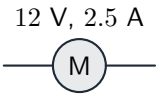
2.5 A p.d. of 12 V across a heater drives a current of 0.50 A through it. Find its resistance. [2]



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]



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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]



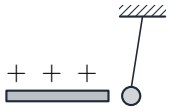
3 Exam-style questions

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]

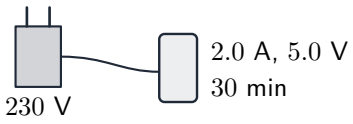


☐ **A** The ball must have the opposite charge to the rod.
B The ball must be a conductor.
C The ball may be uncharged.
D The ball must have the same charge as the rod.

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]



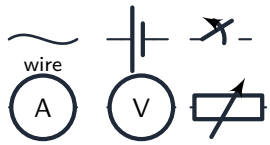
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(c) Calculate the energy transferred to the phone in this time. [2]

(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]

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(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]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- $Q = It$

$$Q = It = (2.0\text{ A})(15\text{ s}) = \mathbf{30}\text{ C}$$

2.2

- $t = 4.0 \times 60\text{ s} = 240\text{ s}$
- $I = Q/t$

$$I = \frac{Q}{t} = \frac{240\text{ C}}{240\text{ s}} = \mathbf{1.0}\text{ A}$$

2.3

- the 0–1 A range
- it is the smallest range above 0.25 A, so the needle moves well up the scale; the 0–100 mA range would be overloaded and the 0–10 A range would read only coarsely

2.4

- $E = W/Q$

$$E = \frac{W}{Q} = \frac{27\text{ J}}{18\text{ C}} = \mathbf{1.5}\text{ V}$$

2.5

- $R = V/I$

$$R = \frac{V}{I} = \frac{12\text{ V}}{0.50\text{ A}} = \mathbf{24}\ \Omega$$

2.6

- Q: twice the length, so **12** Ω
- S: twice the area, so **3.0** Ω

2.7

- $P = IV$

$$P = IV = (2.5\text{ A})(12\text{ V}) = \mathbf{30}\text{ W}$$

$$E = Pt = (30\text{ W})(40\text{ s}) = \mathbf{1200}\text{ J}$$

2.8

- $E = Pt$ in kWh

$$E = nPt = (3.0\text{ kW})(1.5\text{ h}) \times 10 = \mathbf{45}\text{ kWh}$$

- cost $= 45 \times 0.55 = 24.75 \approx \mathbf{25}$ yuan

3.1 D

- twice the length doubles the resistance and half the area doubles it again, so $R_\text{Y} = 4R$

- **A** takes both changes the wrong way; **B** assumes they cancel; **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) $t = 30 \times 60 \text{ s} = 1800 \text{ s}$

- $Q = It$

$$Q = It = (2.0 \text{ A})(1800 \text{ s}) = \mathbf{3600} \text{ C}$$

(c) $E = IVt$

$$E = IVt = (2.0 \text{ A})(5.0 \text{ V})(1800 \text{ s}) = \mathbf{18\,000} \text{ J}$$

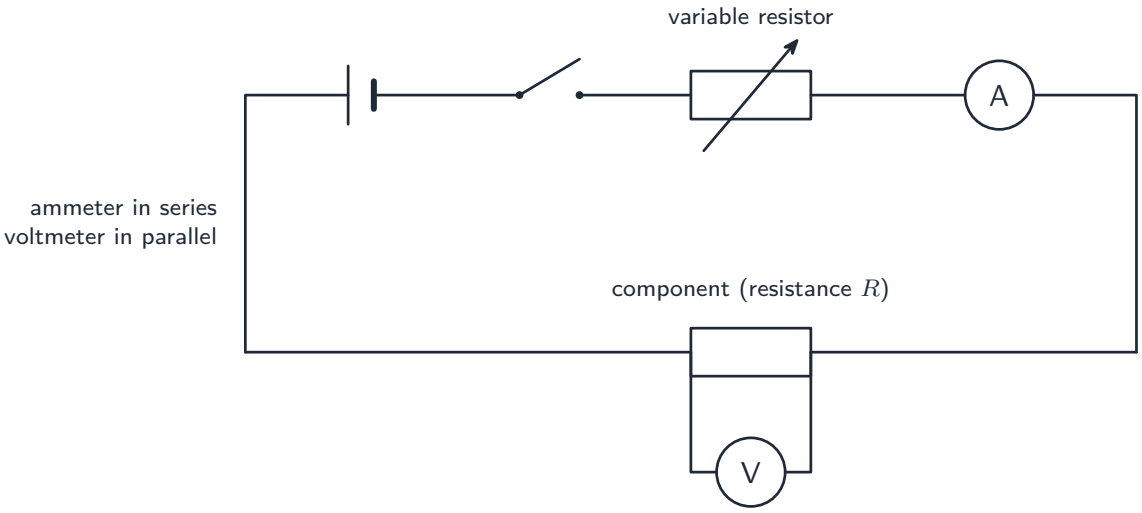
(d) plastic has no free electrons

- 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

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(c) $R = V/I$

$$R = \frac{V}{I} = \frac{3.0\text{ V}}{0.60\text{ A}} = \mathbf{5.0}\ \Omega$$

(d) the resistance increases

- because the filament gets hotter as the current rises

3.5

(a) $E = Pt$

$$E = (1.5\text{ kW}) \times \frac{20}{60}\text{ h} = \mathbf{0.50}\text{ kWh}$$

(b) the lamp uses 0.10 kW, so it needs $0.50/0.10 = 5.0$ h

- 5.0 h ÷ 20 min = **15** times longer

(c) $I = P/V$

$$I = \frac{P}{V} = \frac{1500\text{ W}}{230\text{ V}} = \mathbf{6.5}\text{ A}$$

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