4.3 Electric circuits

Name: _____ Class: _____ Date: _____ **Total: 28 marks**

0 Vocabulary

Word	Example
ammeter /ˈæmiːtə/ 电流表	Connect the **ammeter** in series. 把**电流表**串联在电路中。
electromotive force 电动势 /ɪˌlektrəʊˈməʊtɪv fɔːs/	The battery has an **electromotive force** of 9 V. 电池的**电动势**是 9 V。
circuit /ˈsɜːkɪt/ 电路	A closed **circuit** lets steady current flow through the lamp. 闭合的**电路**能让稳定的电流流过灯泡。
potential difference 电势差 /pəˈtenʃl ˈdɪfrəns/	The **potential difference** across the lamp is 6 V. 灯泡两端的**电势差**是 6 V。
voltmeter /ˈvəʊltmiːtə/ 电压表	Connect the **voltmeter** across the lamp. 把**电压表**并联在灯泡两端。
resistance /rɪˈzɪstəns/ 电阻	A thin wire has a high **resistance**. 细导线的**电阻**很大。
ohm /əʊm/ 欧姆	The **ohm** is the unit of resistance. **欧姆**是电阻的单位。
variable resistor 可变电阻器 /ˈveərɪəbl rɪˈzɪstə/	A **variable resistor** changes the current in a circuit. **可变电阻器**可以改变电路中的电流。
directly proportional 成正比 /daɪˈrektli prəˈpɔːʃənl/	Current is **directly proportional** to voltage for a resistor. 对于一个电阻器，电流与电压**成正比**。
inversely proportional 成反比 /ɪnˈvɜːsli prəˈpɔːʃənl/	Pressure is **inversely proportional** to volume. 压强与体积**成反比**。
resistor /rɪˈzɪstə/ 电阻器	The **resistor** limits the current. **电阻器**限制电流。
filament lamp 灯丝灯泡 /ˈfɪləmənt læmp/	A **filament lamp** gets hot when it lights up. **灯丝灯泡**发光时会变热。
diode /ˈdaɪəʊd/ 二极管	The **diode** stops current flowing the wrong way. **二极管**阻止电流反向流动。

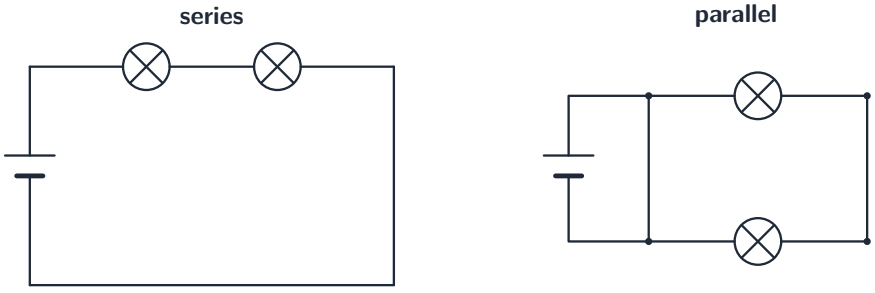
Word	Example
cell /sel/ 电池	One **cell** gives 1.5 V. 一个**电池**提供 1.5 V 的电压。
battery /'bætəri/ 电池组	A **battery** is two or more cells joined together. **电池组**由两个或更多电池连接而成。
power supply /'paʊə sə'plaɪ/ 电源	The **power supply** gives 6 V. **电源**提供 6 V 的电压。
thermistor /'θɜ:mɪstə/ 热敏电阻	A **thermistor** measures the temperature. **热敏电阻**测量温度。
light-dependent resistor 光敏电阻 /laɪt dɪ'pendənt rɪ'zɪstə/	A **light-dependent resistor** has a low resistance in bright light. **光敏电阻**在强光下的电阻值很小。
light-emitting diode 发光二极管 /laɪt ɪ'mɪtɪŋ 'daɪəʊd/	A **light-emitting diode** glows when current flows the right way. 电流沿正确方向流过时，**发光二极管**会发光。
bell /bel/ 电铃	An electric **bell** rings when you press the button. 按下按钮时，**电铃**会响。
series /'sɪəri:z/ 串联	Springs in **series** stretch more than one spring. **串联**的弹簧比单个弹簧伸长得更多。
parallel /'pærəlel/ 并联	Two springs side by side, in **parallel**, are stiffer. 两个弹簧并排**并联**时，整体更硬。
total resistance 总电阻 /'təʊtl rɪ'zɪstəns/	Two 5 Ω resistors in series have a **total resistance** of 10 Ω. 两个 5 Ω 的电阻串联后，**总电阻**为 10 Ω。
junction /'dʒʌŋkʃn/ 节点	At a **junction**, the current splits. 电流在**节点**处分流。
potential divider 分压器 /pə'tenʃl dɪ'vaɪdə/	Two resistors in a **potential divider** share the voltage. **分压器**中的两个电阻分担电压。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

Series and parallel rules

	series	parallel
current	the same everywhere	splits; branch currents add to the total
p.d.	shared; the p.d.s add to the supply	the same across every branch
resistance	$R = R_1 + R_2$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$; less than the smallest
e.m.f. of cells	e.m.f.s add	(identical cells) the same as one cell



Series: same current, shared p.d., $R_{total} = R_1 + R_2$. Parallel: same p.d., split current, smaller total R

Worked example 1: a parallel pair

A 6 Ω and a 3 Ω resistor are in parallel across a 6.0 V supply. Find the total resistance and the supply current.

1. Parallel resistors: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$.

$$\frac{1}{R} = \frac{1}{6\ \Omega} + \frac{1}{3\ \Omega} = \frac{1}{2\ \Omega},\ \text{so}\ R = \mathbf{2}\ \Omega$$

2. Current from $V = IR$, so $I = \frac{V}{R}$:

$$I = \frac{V}{R} = \frac{6.0\ \text{V}}{2\ \Omega} = \mathbf{3.0}\ \text{A}$$

Check: 2 Ω is less than the smaller resistor, 3 Ω, as it must be.

Worked example 2: a potential divider

A 1.0 kΩ resistor and a variable resistor R are in series across 6.0 V. Find the output p.d. across R when $R = 2.0$ kΩ.

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1. The same current flows through both, so the supply p.d. divides in the ratio of the resistances: $V_{\text{out}} = \dfrac{R}{R_1 + R} \times V$.
2. $$V_{\text{out}} = \frac{R}{R_1 + R} \times V = \frac{2.0\ \text{k}\Omega}{1.0\ \text{k}\Omega + 2.0\ \text{k}\Omega} \times 6.0\ \text{V} = \mathbf{4.0}\ \text{V}$$

Increasing R increases its share of the p.d. A thermistor (resistance falls as it gets hotter) or an LDR (resistance falls in brighter light) in place of R makes V_{out} respond to temperature or light.

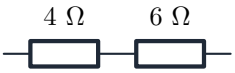
■ **Worked example 3: an unknown resistor**

A 9.0 V battery drives 1.5 A through a resistor Q in series with two 4.0 Ω resistors in parallel. Find the resistance of Q.

1. Total resistance from $R = \dfrac{V}{I}$:
$$R = \frac{V}{I} = \frac{9.0\ \text{V}}{1.5\ \text{A}} = 6.0\ \Omega$$
2. The parallel pair: $\dfrac{1}{R_p} = \dfrac{1}{4.0\ \Omega} + \dfrac{1}{4.0\ \Omega}$, so $R_p = 2.0\ \Omega$.
3. Series parts add: $R = R_Q + R_p$, so $R_Q = 6.0\ \Omega - 2.0\ \Omega = \mathbf{4.0}\ \Omega$.

2 Practice

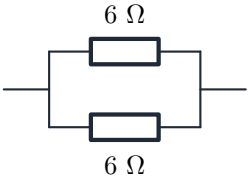
2.1 Two resistors of 4 Ω and 6 Ω are in series. Find the total resistance. [1]



2.2 State how the current behaves at every point in a series circuit. [1]

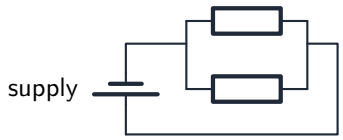


2.3 Two 6 Ω resistors are connected in parallel. Find their combined resistance. [2]



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2.4 State how the potential difference across each branch of a parallel circuit compares with the supply p.d. [1]



3 Exam-style questions

3.1 Compared with the smallest single resistor, two resistors in parallel give a total resistance that is: [1]



- ☐ **A** larger
- **B** smaller
- **C** the same
- **D** zero

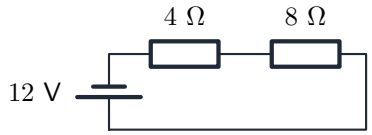
3.2 A student has a 2.0 Ω resistor and a 40 kΩ resistor. Which statement is correct? [1]



- ☐ **A** In parallel, their combined resistance is just under 2.0 Ω.
- **B** In parallel, their combined resistance is about 20 kΩ.
- **C** In series, their combined resistance is 42 Ω.
- **D** In series, their combined resistance is just under 2.0 Ω.

3.3 A 12 V supply is connected to a 4 Ω and an 8 Ω resistor in series.

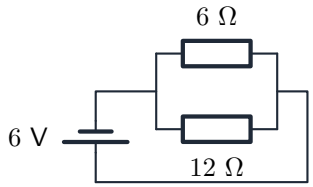
(a) Find the total resistance and the current. [3]



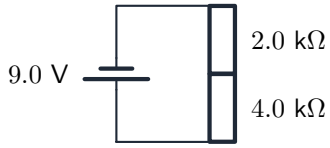
(b) Find the p.d. across the 8 Ω resistor. [2]

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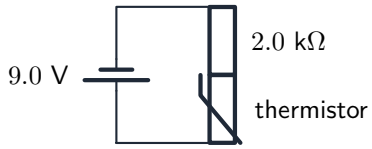
3.4 A 6 Ω and a 12 Ω resistor are connected in parallel across a 6 V supply. Find the total resistance and the total current from the supply. [4]



3.5 A potential divider is made from a 2.0 kΩ resistor and a 4.0 kΩ resistor in series across a 9.0 V supply. Find the p.d. across the 4.0 kΩ resistor. [3]



3.6 The 4.0 kΩ resistor in **3.4** is replaced by a thermistor. The temperature rises and the resistance of the thermistor decreases. State and explain what happens to the p.d. across the thermistor. [2]

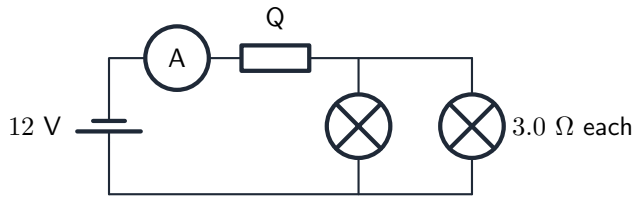


3.7 A 12 V battery is made of identical cells, each of e.m.f. 1.5 V, connected in series. The battery is connected to a resistor Q in series with two identical lamps in parallel. Each lamp has a resistance of 3.0 Ω. An ammeter in the battery lead reads 2.4 A.

(a) Determine the number of cells in the battery. [1]

(b) Calculate the total resistance of the circuit. [2]

(c) Calculate the resistance of Q. [2]



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(d) Calculate the power supplied to one lamp. [2]

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Solutions

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

2.1

- series: $R = 4\ \Omega + 6\ \Omega = \mathbf{10}\ \Omega$

2.2

- the current is the same at every point

2.3

- parallel: $1/R = 1/R_1 + 1/R_2$

$$\frac{1}{R} = \frac{1}{6\ \Omega} + \frac{1}{6\ \Omega} = \frac{2}{6\ \Omega} \Rightarrow R = \mathbf{3}\ \Omega$$

2.4

- it is the same as the supply p.d. (each branch has the full p.d.)

3.1 B

- two resistors in parallel give a total smaller than the smaller one

3.2 A

- in parallel the total is less than the smaller resistor, and the 40 kΩ branch carries almost no current, so the total is just under 2.0 Ω; in series it would be about 40 kΩ

3.3

(a) series: $R = 4\ \Omega + 8\ \Omega = 12\ \Omega$

- $I = V/R$

$$I = \frac{12\ \text{V}}{12\ \Omega} = \mathbf{1.0}\ \text{A}$$

(b) $V = IR$

$$V = (1.0\ \text{A})(8\ \Omega) = \mathbf{8.0}\ \text{V}$$

3.4

- parallel: $1/R = 1/R_1 + 1/R_2$

$$\frac{1}{R} = \frac{1}{6\ \Omega} + \frac{1}{12\ \Omega} = \frac{1}{4\ \Omega} \Rightarrow R = 4\ \Omega$$

- $I = V/R$

$$I = \frac{6\ \text{V}}{4\ \Omega} = \mathbf{1.5}\ \text{A}$$

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3.5

- series: $R = R_1 + R_2$

$$R = 2.0\ \text{k}\Omega + 4.0\ \text{k}\Omega = 6.0\ \text{k}\Omega$$

- the p.d. divides in the ratio of the resistances: $V_2 = \dfrac{R_2}{R_1 + R_2} \times V$

$$V_2 = \frac{4.0\ \text{k}\Omega}{6.0\ \text{k}\Omega} \times 9.0\ \text{V} = \mathbf{6.0}\ \text{V}$$

3.6

- the p.d. across the thermistor **decreases**
- its share of the total resistance is smaller, so it takes a smaller share of the 9.0 V

3.7

(a)

- e.m.f.s in series add: $\dfrac{12\ \text{V}}{1.5\ \text{V}} = \mathbf{8}$ cells

(b)

- $V = IR$, so $R = \dfrac{V}{I}$

$$R = \frac{V}{I} = \frac{12\ \text{V}}{2.4\ \text{A}} = \mathbf{5.0}\ \Omega$$

(c)

- two equal lamps in parallel: $\dfrac{1}{R_p} = \dfrac{1}{3.0\ \Omega} + \dfrac{1}{3.0\ \Omega}$, so $R_p = 1.5\ \Omega$
- series parts add: $R_Q = R - R_p = 5.0\ \Omega - 1.5\ \Omega = \mathbf{3.5}\ \Omega$

(d)

- the 2.4 A splits equally between the identical lamps: 1.2 A each; power $P = I^2R$

$$P = I^2R = (1.2\ \text{A})^2(3.0\ \Omega) = \mathbf{4.3}\ \text{W}$$

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