A-LEVEL PHYSICS • EXERCISE SHEET

10.3 Potential dividers

Name: ____________ Class: ________ Date: __________ **Total: 19 marks**

KEY WORDS null method 零点法 • potential divider 分压器 • galvanometer 检流计 • potentiometer 电位差计 • thermistor 热敏电阻

Objective

Build the skills to answer exam questions on **potential dividers** — the divider equation, the uniform wire, and sensor circuits.

You must be able to:

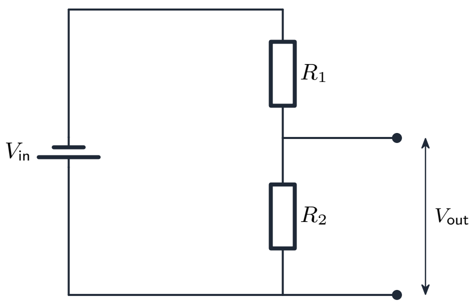
- use the **potential divider** equation
- explain why p.d. is proportional to **length** on a **uniform** wire ($V \propto L$)
- explain **thermistor** and **LDR** divider circuits, and the potentiometer null method

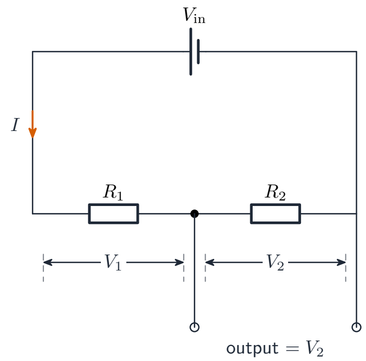
1 Worked examples

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.

Potential divider

Two resistors in series share V_{in} in proportion to their resistances. The output across R_2 is:





A potential divider splits the voltage

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}.$$

Worked example. 6.0 V across 2.0 kΩ + 4.0 kΩ, output across the 4.0 kΩ: $V_{out} = 6.0 \times \frac{4.0}{6.0} = 4.0$ V.

Uniform wire: $V \propto L$

A **uniform** resistance wire has the same resistance per unit length, so resistance is proportional to length ($R = \rho L/A$ with ρ, A constant). A length of wire is just a potential divider, so the **p.d. across a length is proportional to that length**:

$$V = V_{wire} \cdot \frac{L}{L_{total}}.$$

Worked example. A 2.0 V supply is across a uniform wire of length 100 cm. The p.d. across the first 30 cm is $V = 2.0 \times \frac{30}{100} = 0.60$ V. This $V \propto L$ rule is the basis of the **potentiometer**.

Sensor circuits

Replace a resistor with a **sensor**: a **thermistor** (R falls as temperature rises) or an **LDR** (R falls as light rises). The output voltage then changes with temperature or light, and can switch a load.

Potentiometer

A uniform wire with a sliding contact compares e.m.f.s by a **null method**: slide until a **galvanometer** reads **zero** (no current), so the balance lengths are in the ratio of the e.m.f.s.

2 Practice

Now apply the methods above.

2.1 State what a **potential divider** does. [1]

2.2 A 6.0 V supply is across a 2.0 kΩ and a 4.0 kΩ resistor in series. Find the p.d. across the 4.0 kΩ resistor. [2]

2.3 A uniform wire of length 80 cm has 4.0 V across its ends. Find the p.d. across the first 20 cm. [2]

2.4 State what happens to a **thermistor's** resistance as temperature rises. [1]

3 Exam-style questions

3.1 A 12 V supply is across $R_1 = 3.0$ kΩ and $R_2 = 1.0$ kΩ in series. Find V_{out} taken across R_2. [2]

3.2 A 6.0 V supply of negligible internal resistance is connected to a variable resistor R in series with a uniform resistance wire XY of resistance 8.0 Ω.

(a) R is adjusted so the p.d. across XY is 2.4 V. Calculate R. [3]

(b) Explain why the p.d. between any two points on wire XY is **proportional to the distance** between them. [2]

3.3 In a divider, a thermistor is in series with a fixed resistor and the output is taken across the **thermistor**. The temperature **rises**. Explain what happens to the output voltage. [3]

3.4 Explain how an **LDR** in a potential divider can be used to switch a lamp **on** when it gets dark. [3]

Solutions

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

2.1

- splits an input voltage into a chosen smaller output voltage, sharing it between resistors in proportion to their resistances

2.2

- $V_{\text{out}} = V_{\text{in}} \cdot R_2/(R_1 + R_2)$

$$V = (6.0\ \text{V}) \times \frac{4.0\ \text{k}\Omega}{2.0\ \text{k}\Omega + 4.0\ \text{k}\Omega} = \mathbf{4.0}\ \text{V}$$

2.3

- a uniform wire: $V \propto L$

$$V = (4.0\ \text{V}) \times \frac{20\ \text{cm}}{80\ \text{cm}} = \mathbf{1.0}\ \text{V}$$

2.4

- it **decreases**

3.1

- $V_{\text{out}} = V_{\text{in}} \cdot R_2/(R_1 + R_2)$

$$V_{\text{out}} = (12\ \text{V}) \times \frac{1.0\ \text{k}\Omega}{3.0\ \text{k}\Omega + 1.0\ \text{k}\Omega} = \mathbf{3.0}\ \text{V}$$

3.2

(a) the wire and R form a potential divider

$$V_{\text{XY}} = \varepsilon \cdot \frac{R_{\text{XY}}}{R + R_{\text{XY}}} \Rightarrow 2.4\ \text{V} = (6.0\ \text{V}) \times \frac{8.0\ \Omega}{R + 8.0\ \Omega}$$

$$R + 8.0\ \Omega = \frac{(6.0\ \text{V})(8.0\ \Omega)}{2.4\ \text{V}} = 20\ \Omega$$

- $R = 20\ \Omega - 8.0\ \Omega = \mathbf{12}$

(b) the wire is **uniform**, so its resistance is **proportional to length**

- the same current flows along it, so by $V = IR$ the p.d. across a length is proportional to that length

3.3

- as temperature rises, the thermistor's resistance **decreases**
- it now takes a **smaller share** of the total voltage
- so the output voltage across the thermistor **decreases**

3.4

- put the **LDR** in series with a fixed resistor and take the output across the **fixed resistor** (so the output rises in the dark)
- as it gets dark the LDR's resistance **rises**, so a larger share of the voltage is across the fixed resistor and the output **rises**
- the output crosses a **threshold** that switches the lamp on (e.g. via a transistor/comparator)