A-LEVEL PHYSICS • EXERCISE SHEET

10.3 Potential dividers

Name: ______________ Class: __________ Date: ____________ **Total: 18 marks**

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:

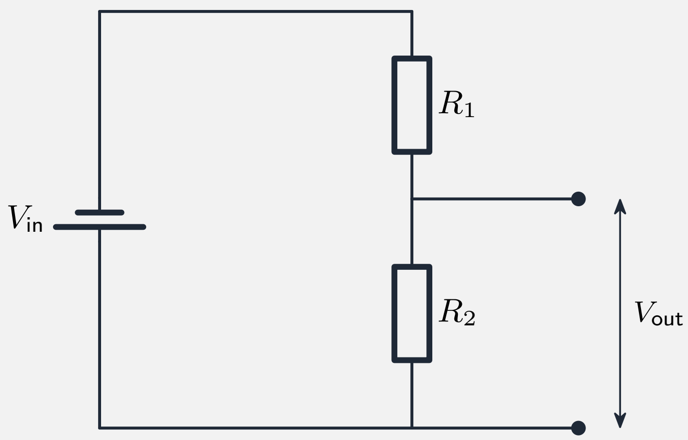
- use the **potential divider** equation
- explain why p.d. is proportional to **length** on a **uniform** wire ($V \propto L$)
- explain **thermistor** and **LDR** divider circuits, and the potentiometer null method

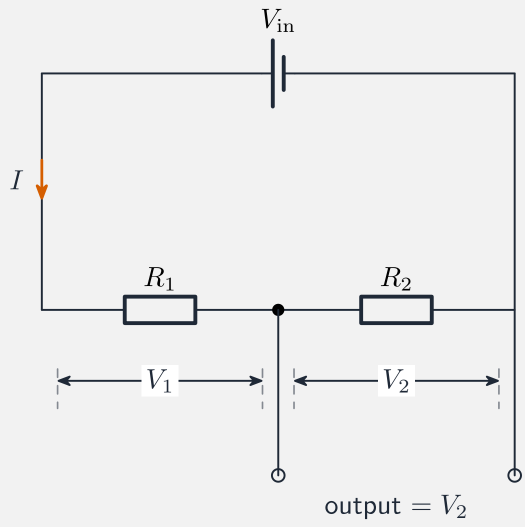
1 Worked examples

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]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **10.3 Potential dividers** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/21 N25 —Q5 (uniform wire as a potential divider)
- 9702/22 J25 —Q6 (potential divider, structured)
- 9702/24 J25 —Q6 (potential divider, calculation)
- 9702/12 N25 —Q35 (potential divider, multiple choice)
- 9702/14 J25 —Q36 (potential divider, multiple choice)

Solutions

2.1 Splits an input voltage into a chosen smaller output voltage, sharing it between resistors in proportion to their resistances.

2.2 $V = 6.0 \times \dfrac{4.0}{2.0 + 4.0} = 4.0$ V.

2.3 $V = 4.0 \times \dfrac{20}{80} = 1.0$ V.

2.4 It **decreases**.

3.1 $V_{\text{out}} = 12 \times \dfrac{1.0}{3.0 + 1.0} = 12 \times 0.25 = 3.0$ V.

3.2 (a) The wire and R form a potential divider: $V_{\text{XY}} = \varepsilon \cdot \dfrac{R_{\text{XY}}}{R + R_{\text{XY}}}$, so $2.4 = 6.0 \times \dfrac{8.0}{R + 8.0}$; $R + 8.0 = \dfrac{6.0 \times 8.0}{2.4} = 20$; $R = 12\ \Omega$.

3.2 (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).