Exercise walk-through

Potential dividers ▪ 10.3

eXercise

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

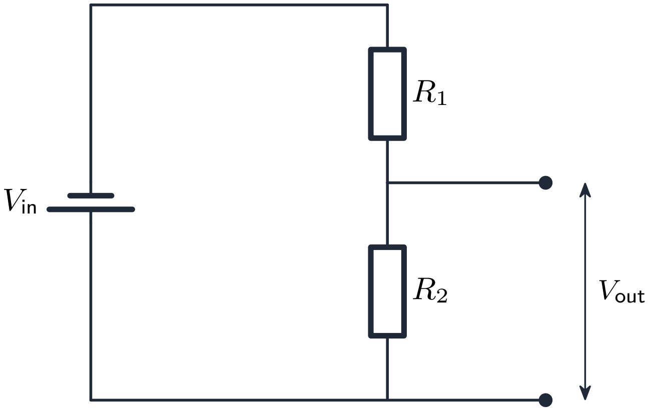
Method — Potential divider

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

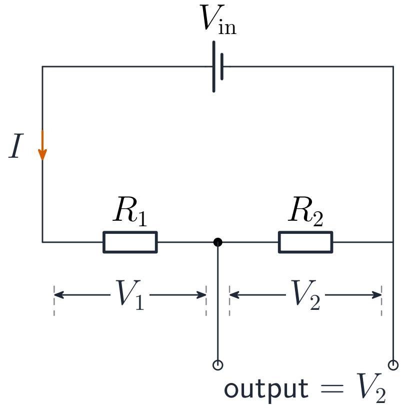
$$V_{\text{out}} = V_{\text{in}} \cdot \frac{R_2}{R_1 + R_2}.$$

Worked example. 6.0 V across $2.0\ \text{k}\Omega + 4.0\ \text{k}\Omega$, output across the $4.0\ \text{k}\Omega$:
$V_{\text{out}} = 6.0 \times \dfrac{4.0}{6.0} = 4.0$ V.

Method — Potential divider



Method — Potential divider



A potential divider splits the voltage

Method — 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**:

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

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 $V = 2.0 \times \dfrac{30}{100} = 0.60$ V. This $V \propto L$ rule is the basis of the **potentiometer**.

Method — 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.

Method — 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.

Practice 2.1 ▪ 1 mark

State what a **potential divider** does.

Solution 2.1

Worked steps

Splits an input voltage into a chosen smaller output voltage, sharing it between resistors in proportion to their resistances B1.

Practice 2.2 ▪ 2 marks

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.

Solution 2.2

Method: Potential divider

Worked steps

$$V = 6.0 \times \frac{4.0}{2.0 + 4.0} = 4.0\ \mathrm{V} \quad \text{M1}\ \text{A1}.$$

Practice 2.3 ▪ 2 marks

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

Solution 2.3

Method: Uniform wire: $V \propto L$

Worked steps

$V = 4.0 \times \frac{20}{80} = 1.0\ \text{V}$ **M1** **A1**.

Practice 2.4 ▪ 1 mark

State what happens to a **thermistor's** resistance as temperature rises.

Solution 2.4

Method: Sensor circuits

Worked steps

It **decreases** B1.

Exam-style 3.1 ▪ 2 marks

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.

Solution 3.1

Method: Potential divider

Worked steps

$$V_{\text{out}} = 12 \times \frac{1.0}{3.0 + 1.0} = 12 \times 0.25 = 3.0 \text{ V} \quad \textbf{M1}\,\textbf{A1}.$$

Exam-style 3.2 ▪ 3 marks

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 $8.0\ \Omega$.

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

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

Solution 3.2

Method: Uniform wire: $V \propto L$

Worked steps

(b) The wire is **uniform**, so its resistance is **proportional to length** B1; the same current flows along it, so by $V = IR$ the p.d. across a length is proportional to that length B1.

Exam-style 3.3 ▪ 3 marks

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.

Solution 3.3

Worked steps

As temperature rises, the thermistor's resistance **decreases** B1; it now takes a **smaller share** of the total voltage B1; so the output voltage across the thermistor **decreases** B1.

Exam-style 3.4 ▪ 3 marks

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

Solution 3.4

Worked steps

Put the **LDR** in series with a fixed resistor and take the output across the **fixed resistor** (so the output rises in the dark) B1; 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** B1; the output crosses a **threshold** that switches the lamp on (e.g. via a transistor/comparator) B1.