

Exercise walk-through

# 10.3.1

## The potentiometer and the null method

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A-Level Physics

## Sheet 10.3.1 – what you need to know

### You must be able to:

- explain why the p.d. along a uniform wire is proportional to its length
- compare two e.m.f.s from their **balance lengths**
- explain a **null method**, and why it measures an e.m.f.
- say why the driver cell must have the larger e.m.f.

### What the exam asks

“Explain what is meant by a null method.” [1]

“Explain why the potential difference  $V$  between any two points on wire  $XY$  is proportional to the distance  $L$  between those points.” [2]

“Calculate the e.m.f. of cell  $X$ .” [2]

*Practise on exercise sheet 10.3.1, then try the real exam questions on past-paper sheet 10.3.1.*

## A uniform wire is a potential divider

A uniform wire has  $R = \frac{\rho L}{A}$  with  $\rho$  and  $A$  fixed, so  $R \propto L$ .

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

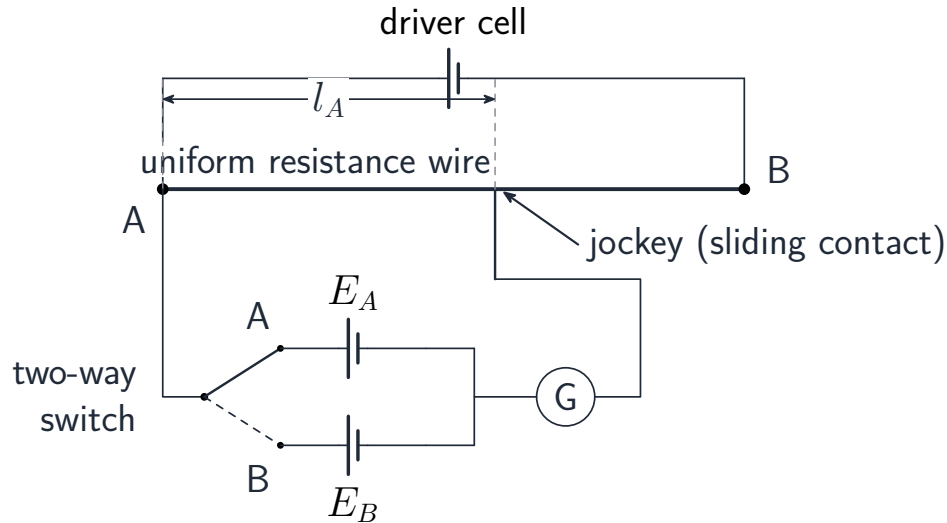
$$V = V_{\text{wire}} \times \frac{L}{L_{\text{total}}}$$

**2.0 V across 100 cm of uniform wire**

the p.d. across the first 30 cm:

$$V = V_{\text{wire}} \times \frac{L}{L_{\text{total}}} = 2.0 \text{ V} \times \frac{30 \text{ cm}}{100 \text{ cm}} = 0.60 \text{ V}$$

# Potentiometer – the null method



Slide the contact until the **galvanometer** reads **zero**:

$$\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}.$$

At balance no current flows, so the cell's internal resistance does not matter.

## Comparing two e.m.f.s

**A 1.02 V standard cell balances at 51.0 cm; a second cell at 75.0 cm**

at balance each e.m.f. equals the p.d. across its balance length, so

$$\frac{E_2}{E_1} = \frac{\ell_2}{\ell_1}$$

$$E_2 = E_1 \times \frac{\ell_2}{\ell_1} = 1.02 \text{ V} \times \frac{75.0 \text{ cm}}{51.0 \text{ cm}} = 1.50 \text{ V}$$

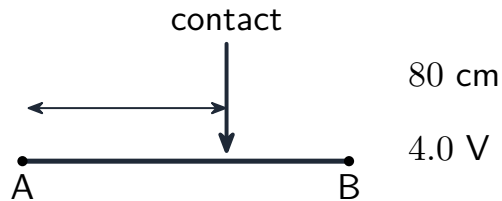
At balance **no current** flows in the cell, so there is no *Ir*: the balance measures the **e.m.f.**, which no real voltmeter can.

The driver cell needs a **larger** e.m.f. than the cells it measures, or there is no balance point.

## Exercise 2.1

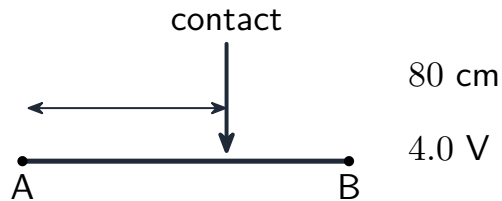
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**2.1** A uniform wire of length 80 cm has 4.0 V across its ends. Find the p.d. across the first 20 cm. [2]



## Exercise 2.1

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**2.1**

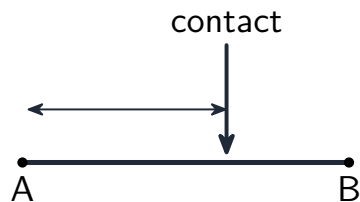
- a uniform wire:  $V \propto L$

$$V = V_{\text{wire}} \times \frac{L}{L_{\text{total}}} = 4.0 \text{ V} \times \frac{20 \text{ cm}}{80 \text{ cm}} = \mathbf{1.0 \text{ V}}$$

## Exercise 2.2

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**2.2** Explain why the p.d. across part of a uniform resistance wire is proportional to the length of that part. [2]



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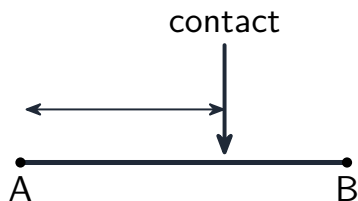
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## Exercise 2.2

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**2.2**

- for a uniform wire  $R = \frac{\rho L}{A}$  with  $\rho$  and  $A$  constant, so resistance is proportional to **length**
- the whole wire carries the same current, so the p.d. across a part is  $IR$ , which is therefore proportional to that part's length

## Exercise 2.3

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**2.3** Explain what is meant by a **null method**, and name the instrument used in one. [2]

null method

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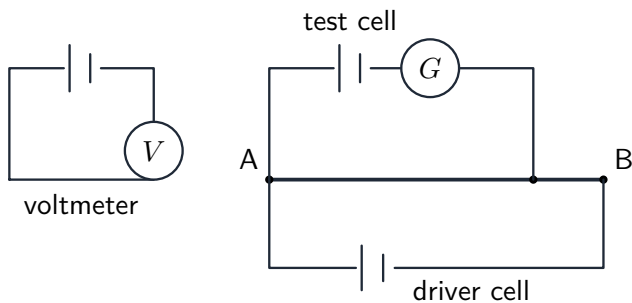
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**2.3**

- a null method adjusts the circuit until an instrument reads **exactly zero**, and the measurement is taken at that setting
- the instrument is a **galvanometer**, which is a sensitive centre-zero ammeter

## Exercise 2.4

**2.4** Explain why a potentiometer measures the **e.m.f.** of a cell, while a voltmeter connected across its terminals does not. [3]



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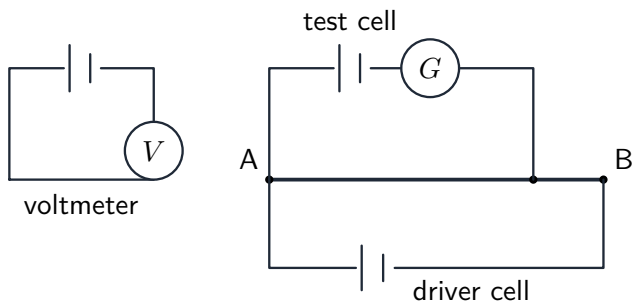
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## Exercise 2.4

2.4 Explain why a potentiometer measures the **e.m.f.** of a cell, while a voltmeter connected across its terminals does not. [3]



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2.4

- at the balance point the galvanometer reads zero, so **no current flows** through the cell being measured
- with  $I = 0$  there is no p.d.  $Ir$  across its internal resistance, so the p.d. being balanced is the full **e.m.f.**
- a voltmeter always draws **some** current, so there is always a small  $Ir$  inside the cell and it reads the **terminal p.d.**, which is slightly less than the e.m.f.

## Exercise 3.1

**3.1** In a potentiometer experiment the galvanometer reads zero. At that moment the current through the cell being measured is [1]

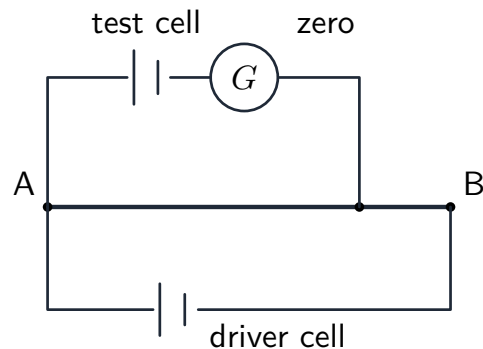
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**A** zero.

**B** equal to the current through the driver cell.

**C** equal to the full-scale current of the galvanometer.

**D** impossible to determine.



## Exercise 3.1

**3.1** In a potentiometer experiment the galvanometer reads zero. At that moment the current through the cell being measured is [1]

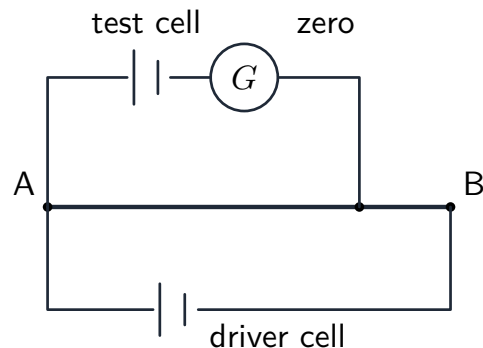
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A zero.

B equal to the current through the driver cell.

C equal to the full-scale current of the galvanometer.

D impossible to determine.



**3.1 A**

- a zero reading on the galvanometer means **no current** flows in that branch, which is the whole point of the method

## Exercise 3.2

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**3.2** A uniform potentiometer wire is 1.00 m long with a p.d. of 2.0 V across it. A cell balances at 0.70 m. What is the e.m.f. of the cell? [1]

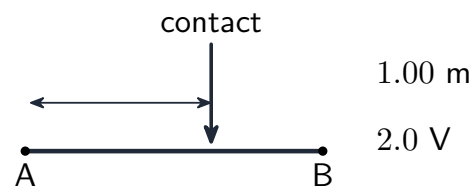
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**A** 0.70 V

**B** 1.4 V

**C** 2.0 V

**D** 2.9 V



## Exercise 3.2

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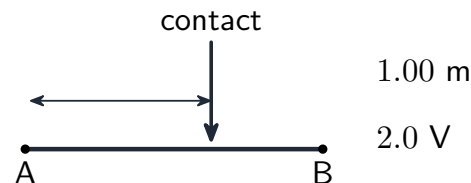
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A 0.70 V

B 1.4 V

C 2.0 V

D 2.9 V



**3.2 B**

- the p.d. along a uniform wire is proportional to length, and at balance the e.m.f. equals the p.d. across the balance length

$$E = V_{\text{wire}} \times \frac{\ell}{L} = 2.0 \text{ V} \times \frac{0.70 \text{ m}}{1.00 \text{ m}} = 1.4 \text{ V}$$

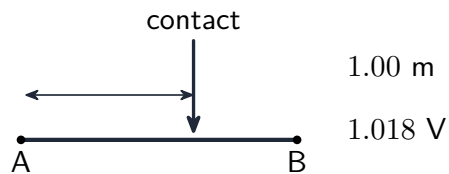
- D divides by 0.70 instead of multiplying

## Exercise 3.3 (a)

**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(a) Calculate the e.m.f. of the second cell.

[2]

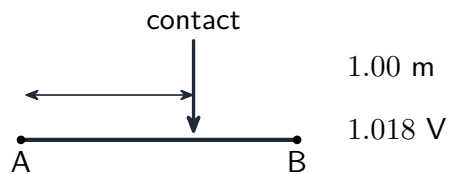


## Exercise 3.3 (a)

**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(a) Calculate the e.m.f. of the second cell.

[2]



(a)

- the e.m.f. is proportional to the balance length

$$E_2 = E_1 \times \frac{\ell_2}{\ell_1} = 1.018 \text{ V} \times \frac{78.0 \text{ cm}}{62.5 \text{ cm}} = \mathbf{1.27 \text{ V}}$$

## Exercise 3.3 (b)

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**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(b) Explain why the driver cell must have an e.m.f. greater than that of either cell being measured. [2]

## Exercise 3.3 (b)

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**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(b) Explain why the driver cell must have an e.m.f. greater than that of either cell being measured. [2]

(b)

- the p.d. available along the whole wire is set by the driver cell
- if the cell being measured had a larger e.m.f., no length of wire would have a p.d. big enough to balance it and there would be **no balance point**

## Exercise 3.3 (c)

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**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(c) State **two** advantages of this method over measuring the e.m.f. with a voltmeter. [2]

## Exercise 3.3 (c)

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**3.3** A potentiometer wire AB is 1.00 m long. A standard cell of e.m.f. 1.018 V gives a balance point 62.5 cm from A. A second cell, connected in its place, balances at 78.0 cm from A.

(c) State **two** advantages of this method over measuring the e.m.f. with a voltmeter. [2]

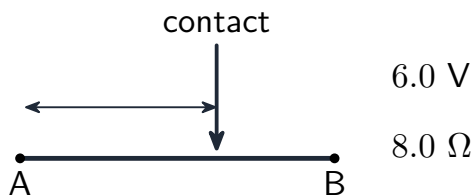
(c)

- any **two** of: at balance **no current** is drawn from the cell, so the **e.m.f.** is measured rather than the terminal p.d.; the galvanometer only has to detect **zero**, so its calibration does not matter; the result depends on a **length**, which can be measured very precisely

## Exercise 3.4 (a)

**3.4** A  $6.0\text{ V}$  supply of negligible internal resistance is connected to a variable resistor  $R$  in series with a uniform resistance wire  $XY$  of resistance  $8.0\ \Omega$ .

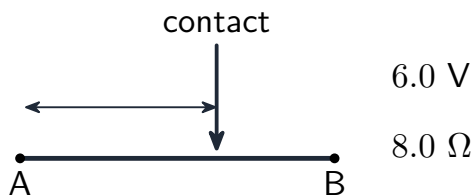
(a)  $R$  is adjusted so the p.d. across  $XY$  is  $2.4\text{ V}$ . Calculate  $R$ . [3]



## Exercise 3.4 (a)

**3.4** 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  $R$ . [3]



(a) the wire and  $R$  form a potential divider, so use the output form

$$V_{XY} = \varepsilon \times \frac{R_{XY}}{R + R_{XY}}$$

## Full solution 3.4 (a)

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(a) the wire and  $R$  form a potential divider, so use the output form

$$V_{XY} = \varepsilon \times \frac{R_{XY}}{R + R_{XY}}$$

- rearranged for the total resistance

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

- take away the resistance of the wire

$$R = (R + R_{XY}) - R_{XY} = 20 \text{ } \Omega - 8.0 \text{ } \Omega = \mathbf{12 \text{ } \Omega}$$

## Exercise 3.4 (b)

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**3.4** 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  $8.0\ \Omega$ .

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

## Exercise 3.4 (b)

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**3.4** 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  $8.0\ \Omega$ .

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