

## Core practical 3: Determine the emf and internal resistance of an electrical cell

### Objective

- To make measurements using an electrical circuit

### Safety

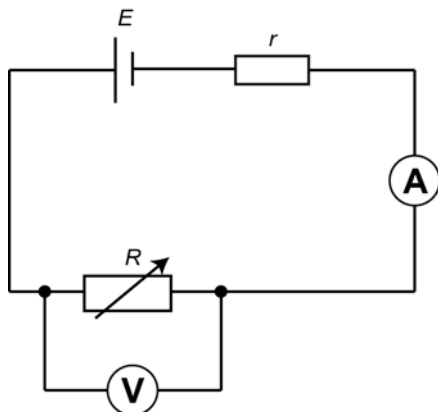
- Voltages and currents are small and so present no specific hazard.
- Normal laboratory safety procedures should be followed.

### Specification links

- Practical techniques 2, 6, 7
- CPAC 2a, 2b, 2d, 3a, 4b

### Procedure

- The cell and the resistor, labelled  $r$ , should be connected in series and used as a single circuit element. As a plan for this practical, draw a circuit that will connect the  $100\ \Omega$  variable resistor across the cell (and resistor  $r$ ) and measure the potential difference  $V$  across the variable resistance labelled  $R$  and the current  $I$  through it.



- Have your circuit design checked and, when your tutor or technician is happy, set it up on the bench. Have your circuit layout checked before you begin.
- Comment on how you will ensure the equipment is safely used and continues to function properly.
- Vary the resistance of the variable resistor and record values for  $V$  and  $I$ . Take readings for the whole range of the variable resistor.

### Notes on procedure

- Students should design a circuit and draw a diagram. Interpreting the instructions contributes well to CPAC 2. The students are asked to have their design and subsequent construction checked for safety (of the apparatus). This gives access to CPAC 3.
- Uncertainties are likely to be very small so this is not an experiment to practise the techniques. Comment could be made on how well the plots fit to the line of best fit. Students can measure the resistance of  $r$  with an ohmmeter to check their gradient value; they can quote this in their report with percentage difference.

### Answers to questions

- When a human body is connected across the terminals the resistance is about  $25\ \text{k}\Omega$ . If the internal resistance of the supply is  $5\ \text{M}\Omega$ , the terminal potential difference falls to a low value with very little current flowing, making it safe.
- There will be a very small potential difference across the ammeter. It is assumed to be so small that it can be ignored. This means that the potential difference across  $R$  and across the cell is the same.
- The voltmeter does not have an infinite resistance. Any small current will cause a pd across the internal resistance, reducing the terminal pd below the emf.
- The cell itself has an internal resistance but this is very small.

## Sample data

V/V	I/mA
1.60	0.0
1.30	13.1
1.14	20.0
0.96	28.2
0.80	35.2
0.65	41.5
0.49	48.8
0.38	53.4
0.23	60.3
0.10	66.0

Graph of  $V$  against  $I$  gives  $r = 22.7 \Omega$ .

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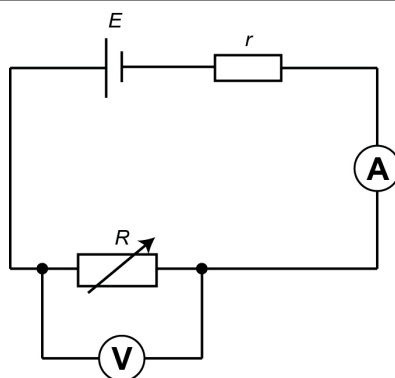
### All the maths you need

- The mathematical model for this circuit is  $E - Ir = V$ .
- Recognise and make use of appropriate units in calculations.
- Use an appropriate number of significant figures.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that  $y = mx + c$  represents a linear relationship.
- Determine the slope and intercept of a linear graph.

### Equipment

- electrical cell such as a 1.5 V cell
- resistor to act as internal resistance, labelled  $r$  in diagram
- 100  $\Omega$  variable resistor labelled  $R$
- voltmeter on 2 V range
- ammeter on 200 mA range
- 6 leads to make electrical connections

### Diagram



### Procedure

- The cell and the resistor, labelled  $r$ , should be connected in series and used as a single circuit element. As a plan for this practical, draw a circuit that will connect the 100  $\Omega$  variable resistor across the cell (and resistor  $r$ ) and measure the potential difference  $V$  across  $R$  and the current  $I$  through it.
- Have your circuit design checked and, when your teacher/technician is happy, set it up on the bench. Then, have your circuit layout checked before you begin.
- Comment on how you will ensure the equipment is safely used and continues to function properly.
- Vary the resistance of the variable resistor and record values for  $V$  and  $I$ . Take readings for the whole range of the variable resistor.

**Analysis of results**

1. The mathematical model for this circuit is  $E - Ir = V$ .
2. So  $V = -rI + E$ . A graph of  $V$  against  $I$  should give a straight line with gradient  $-r$ .
3. Measure the gradient of your graph and compare it with the manufacturer's value of the resistor  $r$ . Ensure you take account of the powers of 10 (prefix) in the measurement of current.
4. Justify the number of significant figures you use in your answer.
5. Comment on the likely accuracy of your values for  $E$  and  $r$ .

**Learning tips**

- It is not usually necessary to repeat readings from an electrical circuit such as this. There is very little random error and very little judgement is required when taking readings. For this reason, you should take more than the usual six readings so that you have more points on your graph. This will make it easier to recognise anomalies.

**Questions**

1. When the internal resistance is large in comparison to the external resistance, the terminal potential difference falls to a small value. This is used to make high voltage supplies safe for use in a laboratory. Explain how this makes the supply safe.
2. It should not matter whether the voltmeter is connected across  $R$  or across the cell. This is partly because of the low resistance of the ammeter. Explain why.
3. The intercept of your graph will be very close to the true value for the emf of the cell. Account for any difference.
4. Explain any difference between your value for  $r$  and the manufacturer's value.

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Objective	Safety
<ul style="list-style-type: none"> <li>To make measurements using an electrical circuit</li> </ul>	<ul style="list-style-type: none"> <li>Voltages and currents are small and so present no specific hazard.</li> <li>Normal laboratory safety procedures should be followed.</li> </ul>
Equipment per student/group	Notes on equipment
electrical cell such as a 1.5 V cell	Do not use a rechargeable cell. Mounted such that electrical connections can be easily made using standard connectors
resistor to act as internal resistance, labelled $r$ in diagram	22 $\Omega$ works well. Obscure the value with masking tape. Label resistor $r$ .
100 $\Omega$ variable resistor	A standard potentiometer using two terminals works well.
voltmeter on 2 V range	0–2 V range
ammeter on 200 mA range	0–200 mA range
6 leads to make electrical connections	
Notes	