**Investigating circuits with more than one source of e.m.f.**

**Introduction**

In this practical activity students will be measuring the potential difference and current for each component in a circuit, and then using this to substantiate Kirchhoff’s first and second laws. They should already be aware of the difference between e.m.f. and potential difference and have an understanding of internal resistance and how to determine this.

**Aims and skills covered**

* To draw circuit diagrams and make circuits from circuit diagrams.
* To measure values within the circuit
* To observe whether Kirchhoff’s laws are substantiated, within experimental uncertainty

**Links to Specifications**

**Physics A**

* 4.1.1(g) Kirchhoff’s first law; conservation of charge.
* 4.2.1(a)(b) circuit diagrams using circuit symbols
* 4.2.2(a) potential difference and the unit *volt*
* 4.2.2(b) electromotive force (e.m.f.) of a source such as a cell or a power supply
* 4.2.2(c) distinction between e.m.f. and p.d. in terms of energy transfer
* 4.3.1(a) Kirchhoff’s second law; the conservation of energy
* 4.3.1(b) Kirchhoff’s first and second laws applied to electrical circuits
* 4.3.1(e) analysis of circuits with components including both series and parallel
* 4.3.1(f) analysis of circuits with more than one source of e.m.f.
* 4.3.2(a) source of e.m.f.; internal resistance
* 4.3.2(b) terminal p.d.; 'lost volts'
* 4.3.2(c)(i) the equations **E** *= I*(*R + r*) and **E** = *V* + *Ir*
* 4.3.2(c)(ii) techniques and procedures used to determine the internal resistance of a chemical cell or other source of e.m.f.

**Physics B**

* 3.1.2a(iii) resistance, including series and parallel combinations
* 3.1.2a(iv) the effect of internal resistance and the meaning of e.m.f.
* 3.1.2a(vii) action of a potential divider
* 3.1.2a(i) the terms: e.m.f, potential difference, current, charge, resistance, conductance, series, parallel, internal resistance, load, resistivity, conductivity, charge carrier number density
* 3.1.2b(ii) recognise standard circuit symbols
* 3.1.2c(ii) use formulae for resistors in series and parallel, and for e.m.f. and internal resistance
* 3.12d(v) determining the internal resistance of a chemical cell or other source of e.m.f.

**Practical Skills**

* 1.2.1(b) safely and correctly use a range of practical equipment and materials
* 1.2.1(c) follow written instructions
* 1.2.1(d) make and record observations/measurements
* 1.2.1(e) keep appropriate records of experimental activities
* 1.2.1(f) present information and data in a scientific way
* 1.2.1(j) use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification
* 1.2.2(b) use of appropriate digital instruments including electrical multimeters to measure resistance
* 1.2.2(f) correctly constructing circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components
* 1.2.2(g) design, construct and check circuits using DC power supplies and a range of circuit components.

**CPAC**

* (1) Follows written procedures
* (3) Safely uses a range of practical equipment and materials
* (4) Makes and records observations

**Mathematical skills**

* M0.1 Recognise and make use of appropriate units in calculations
* M0.3 Use ratios, fractions and percentages
* M1.1 Use an appropriate number of significant figures
* M2.3 Substitute numerical values into algebraic equations using appropriate units for physical quantities
* M2.4 Solve algebraic equations

**Equipment (per learner or group)**

* 3 D cells in holders (use standard D cells only, not high power or high capacity cells)
* voltmeter
* ammeter
* multimeter reading in milliamps
* various resistors in the range 10Ω to 100Ω.

**Health and safety**

* Safe use of electrical circuits
* Note that some cheap cell holders can scratch the plastic insulation from the side of the cell resulting in a short circuit

Before carrying out any experiment or demonstration based on this guidance, it is the responsibility of teachers to ensure that they have undertaken a risk assessment in accordance with their employer’s requirements, making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.

**Notes**

* These practical activities are not controlled assessments, should not be carried out in exam conditions and can be adapted by the centre. Students can collaborate during the activities which should take place as part of the normal teaching sequence. They are intended to be formative with students acquiring and practising skills throughout the course.
* To achieve a pass in the Practical Endorsement each student is required to demonstrate competence in all the skills, apparatus and techniques listed in section 1.2 of the specification and assessed against the Ofqual Common Practical Assessment Criteria (CPAC) at the end of the course.
* The skills, apparatus and techniques can be demonstrated during any practical work undertaken during the A Level course whether an OCR practical activity or not.
* It is suggested that support is given to remind students that the internal resistance can be deduced from the “lost volts” at the terminals of the cell and the current delivered by the cell. This theory can be left available on the board, as the task is designed to assess practical skills and techniques.
* Whilst using a multimeter may appear very simple, students are often confused by the ranges. They should be taught to start on higher range and increase sensitivity until they have an appropriate reading. Some multimeters will be auto-ranging, but still cause problems giving 0 or E readings for out of range which also happens when leads or connections are faulty.

CLEAPSS document R151 “*Ammeters,Voltmeters etc,for Class Use*” and the Laboratory Handbook sections 12.3.1 “*DMMs compared to analogue meters*”, 12.3.2 “*Provision of digital multimeters*” and 12.3.3 “*Which DMMs to buy*”, contain useful information on selection and use of digital multimeters

* Observant students may notice that there is a deficit of potential difference between the sum of pds across the resistors and the output of the cells. This is normally accounted for within the leads and connections.
* Students may also notice in step 8 of the procedure that the potential difference across the two cells in series drops as more current is delivered to the circuit, and may link this to internal resistance.

**Recording**

* Learners should not need to re-draft their work but rather keep all their notes as a continuing record of Practical Activity.
* As evidence for the Practical Endorsement learners should have the data collected in a clear and logical format.

In addition, to support the assessment of practical work in the written examinations:

* Learners should have clearly sketched their circuit diagrams
* Learners should have tabulated or annotated their diagrams with the appropriate readings from the meters
* Learners should have evidence of their multimeter readings
* Learners should annotate their work if discrepancies are noted or errors are made and corrected to support the use of the lab book as a contemporaneous record
* Learners should have drawn conclusions consistent with the evidence obtained
* Learners should have made a valid consideration of uncertainty, potential sources of error and improvements..