Cambridge Assessment International Education

Practical booklet 11

Making and using a thermocouple

Cambridge International AS & A Level

Physics 9702

Version 0.1

Cambridge Pathway

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Introduction

Practical work is an essential part of science. Scientists use evidence gained from prior observations and experiments to build models and theories. Their predictions are tested with practical work to check that they are consistent with the behaviour of the real world. Learners who are well trained and experienced in practical skills will be more confident in their own abilities. The skills developed through practical work provide a good foundation for those wishing to pursue science further, as well as for those entering employment or a non-science career.

The science syllabuses address practical skills that contribute to the overall understanding of scientific methodology. Learners should be able to:

1. plan experiments and investigations
2. collect, record and present observations, measurements and estimates
3. analyse and interpret data to reach conclusions
4. evaluate methods and quality of data, and suggest improvements.

The practical skills established at AS Level are extended further in the full A Level. Learners will need to have practised basic skills from the AS Level experiments before using these skills to tackle the more demanding A Level exercises. Although A Level practical skills are assessed by a timetabled written paper, the best preparation for this paper is through extensive hands-on experience in the laboratory.

The example experiments suggested here can form the basis of a well-structured scheme of practical work for the teaching of AS and A Level science. The experiments have been carefully selected to reinforce theory and to develop learners' practical skills. The syllabus, scheme of work and past papers also provide a useful guide to the type of practical skills that learners might be expected to develop further. About 20% of teaching time should be allocated to practical work (not including the time spent observing teacher demonstrations), so this set of experiments provides only the starting point for a much more extensive scheme of practical work.

Guidance for teachers

Aim

To establish a temperature scale and use it to estimate an unknown temperature.

Outcomes

Syllabus sections 1.2e, 2.1a, 11.2a

Skills included in the practical

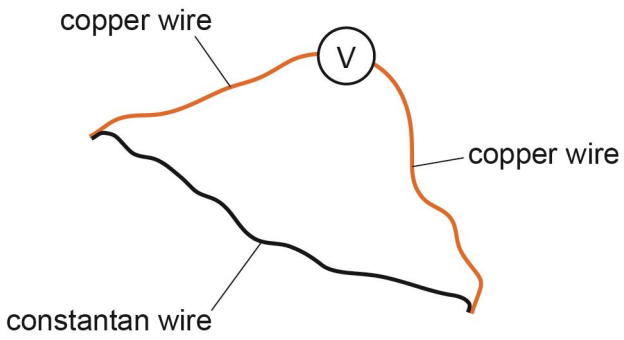
A Level skills	How learners develop the skills
Planning	Plan and then carry out an experiment
Analysis	Collect and record data in a table
Conclusions	Determine and interpret the gradient and *y*-intercept of a graph Use the results of the experiment to estimate an unknown temperature

This practical provides an opportunity to build on essential skills introduced at AS Level.

AS Level skills	How learners develop the skills
MMO collection	Measure temperature using a thermometer Use a voltmeter with an appropriate scale
MMO values	
MMO data	
ACE limitations	Identify the limitations of the experimental procedure

Theory

The e.m.f. of the thermocouple circuit shown depends on the temperature difference $(\theta - \theta_0)$ between the two metal junctions.



$V = a(\theta - \theta_0) + b$ where a and b are constants

Method

Learners are given the circuit diagram and equation above, and should plan and then carry out an experiment to determine the constants *a* and *b* in the equation.

The planning of the experiment should follow the principles assessed in Paper 5, i.e. considering the experimental procedure, the measurements to be taken, the control of variables, the analysis of the data and any safety precautions to be taken.

The expected experimental procedure is:

- Learners construct a thermocouple as shown above.
- Room temperature θ_0 is measured using the mercury-in-glass thermometer.
- One junction is kept at room temperature while the other is placed in boiling (or very hot) water.
- As the water cools, readings of water temperature θ and the voltmeter V are recorded.

Learners' proposed experimental procedures should be checked before they attempt to carry out the experiment, paying particular attention to safety.

Results

All water temperature θ and voltmeter V readings should be recorded.

θ /°C	V/mV	$(\theta - \theta_0)$ /°C

Interpretation and evaluation

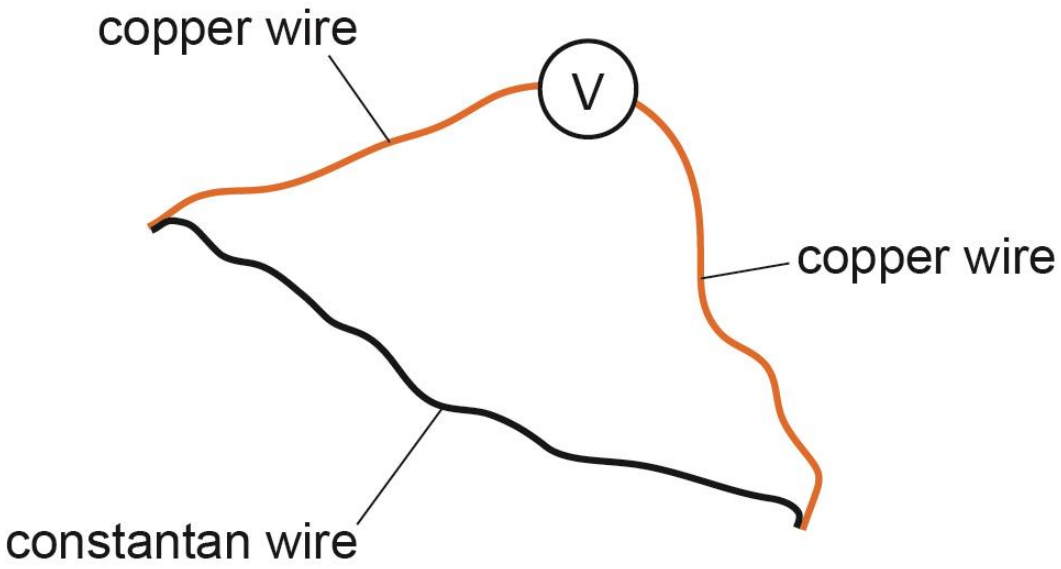
- Using $V = a(\theta - \theta_0) + b$ the values of a and b are determined from a graph of V against $(\theta - \theta_0)$.
- The results are used to estimate the temperature of a lit match.
- Learners should be encouraged to question this method of temperature measurement or temperature estimate. Some issues for discussion are:
    - the expansion of mercury is not uniform
    - the graph should go through (0,0) and not have an intercept. When both junctions are at room temperature the voltmeter reading is zero.

Technician's notes

Each learner will require:

- 1 × liquid-in-glass 0–100°C thermometer reading to the nearest 1°C
- 1 × digital voltmeter set to 0–200 mV scale reading to the nearest 0.1 mV
- 1 × bare 26 swg constantan wire of length 50 cm
- 2 × bare 26 swg copper wires each of length 50 cm. One end of each wire should have a 4 mm plug attached
- 1 × beaker
- source of boiling water
- box of matches

Equipment set-up



Learner worksheet

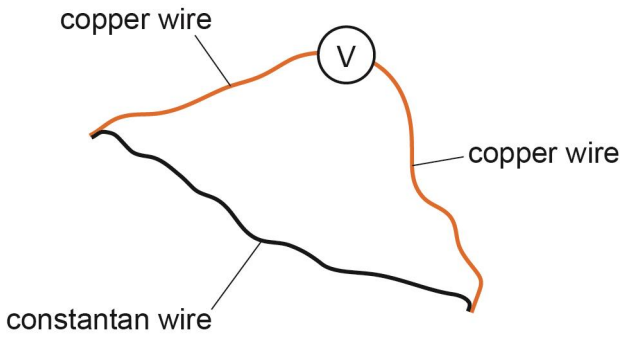
Aim

To establish a temperature scale and use it to estimate an unknown temperature.

Method

A thermocouple thermometer can be created by connecting metals of different types. Copper wire and constantan wire are available.

Connect the circuit shown below. The junctions should be formed by twisting the ends of the wire together. The length of each junction should be about 2 cm and it must not be possible to separate the wires by gentle pulling.



The e.m.f. V measured by the voltmeter is given by:

$V = a(\theta - \theta_0) + b$

where θ and θ_0 are the temperatures of the two junctions of the thermocouple.

Using the apparatus provided, plan an experiment to test the relationship between V and θ, and determine values for a and b.

Check with your teacher that your planned experiment is appropriate, and then carry out the experiment.

Results

Draw a table of results with appropriate column headings and use it to record your results.

Interpretation and evaluation

1. Determine the values of *a* and *b* from your experiment. This will require plotting a graph.
2. Use your results to estimate the temperature of the flame from a lit match.
3. State two sources of uncertainty.

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