Cambridge Assessment International Education

Practical booklet 8

Investigating how the force between magnetic poles depends on their separation

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

Using a log-log graph to investigate the relationship between two variables.

Outcomes

Syllabus sections 1.2e, 2.1a, 22.1a

Skills included in the practical

A Level skills	How learners develop the skills
Analysis	Investigate a relationship by drawing a log-log graph
Conclusions	Determine and interpret the gradient of a graph

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

	How learners develop the skills
MMO collection	Measure lengths using a micrometer Measure force using a newton-meter (force meter)
MMO values	
MMO quality of data	
ACE limitations	Identify the limitations of the experimental procedure
ACE improvements	Identify possible improvements to the experimental procedure

Learners will be familiar with the inverse square law that applies to forces between point masses (syllabus 8.2b) and point charges (syllabus 17.3b).

If the force of attraction F between two magnets depends on their separation d according to

$$F = kd^n$$

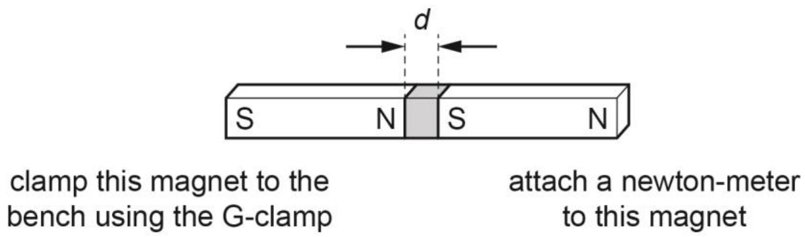
and the inverse square law is obeyed then $n = -2$.

Since $\lg F = n \lg d + \lg k$, a graph of $\lg F$ against $\lg d$ has a gradient of n.

The y-intercept is $\lg k$ so $k = 10^{y\text{-intercept}}$.
Values of n and k can be used to find the force at a distance outside the experimental range, e.g. for $d = 20$ cm.

The uncertainty about the existence and location of a 'point magnetic pole' means that the situation is more complicated than it is for electric and gravitational forces.

Method



- Learners set up the magnets as above, using the cards to separate the magnets and then measure the distance *d* of that separation.
- They then gently pull the newton-meter (force meter) until the magnets separate and record the maximum reading *F* on the newton-meter.
- This is repeated for different separations.

Results

Learners record all of their results in a table, such as that below.

d/m	*F*/N	lg(*d*/m)	lg(*F*/N)

Interpretation and evaluation

With the results, learners plot a graph of lg *F* on the *y*-axis against lg *d* on the *x*-axis to find the gradient = *n*.

A more sensitive method might use a precision digital balance that can measure to 0.1 g or 0.01 g.

One magnet is fixed vertically on the balance and the other magnet is clamped vertically above it with a known separation. This time the magnets repel so that the two magnets do not come into contact.
Readings from the balance indicate the force of repulsion and can be converted from g to N.

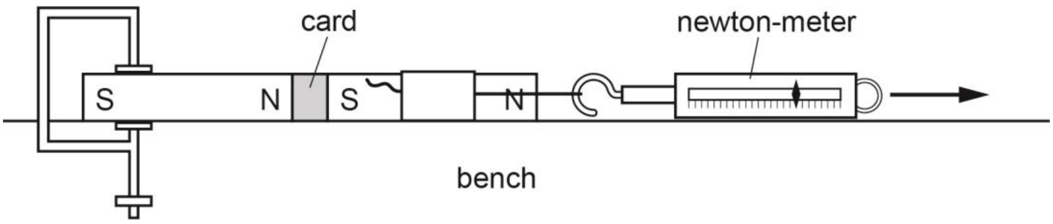
The power law governing the force and the separation varies for different regions of separation.

Technician's notes

Each learner will require:

- 2 × bar magnets
- 1 × newton meter (force meter)
- access to a micrometer screw gauge
- 6 × cards 2cm × 2cm × 1mm
- string
- 1 × G-clamp
- adhesive tape
- log-log graph paper

Equipment set-up



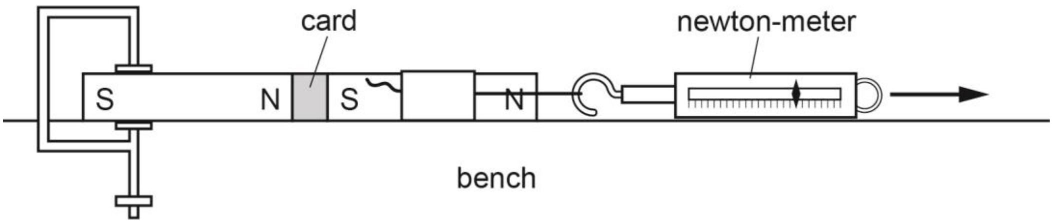
Learner worksheet

Aim

Using a log-log graph to investigate the relationship between two variables.

Method

1. Use the micrometer screw gauge to measure the thickness *d* of one of the cards.
2. Clamp one of the magnets to the bench.
3. Use string and tape to attach a newton-meter (force meter) to the other magnet.
4. Place the card between the magnets.
5. Gently pull the newton-meter until the magnets separate.
6. Read the maximum value of force *F* at separation.
7. Change the separation using more cards.
8. Repeat for further values of *d* and *F*.



Results

Record all of your results

d/m	*F*/N	lg (*d*/m)	lg (*F*/N)

Interpretation and evaluation

Investigate the relationship $F = kd^n$ ($\lg F = n \lg d + \lg k$).

1. Plot a graph with $\lg F$ on the y-axis against $\lg d$ on the x-axis.
2. The gradient = n.
3. The y-intercept = $\lg k$ so $k = 10^{y\text{-intercept}}$.
4. Use your values of n and k to calculate F when d = 20 cm.
5. Describe the main sources of uncertainty in this investigation.
6. Describe how you could improve this investigation.

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