Edexcel GCE

Teacher support materials

Edexcel AS/A GCE in Physics (8540/9540)

Book 2: guide to practical tests

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Success through qualifications

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Book 2: Guide to Practical Tests in AS/A GCE Physics

1 Introduction

The AS and A2 specifications require students to carry out experimental and investigative activities and indicate that these activities should be undertaken within the context of the specifications. The practical tests will assess the candidates' ability to:

- plan
- implement
- analyse and
- evaluate

by means of a number of practical tasks using basic laboratory apparatus. The test may also examine candidates' *knowledge* of more complex equipment, such as signal generators, oscilloscopes and data logging devices.

The purpose of these notes is not to provide a prescriptive guide to practical work as such, but to give an indication of the understanding, knowledge and skills that students will be expected to show in the practical tests. It is up to centres to devise and implement a suitable course of practical work in order that the students acquire these skills through their studies of AS and A2 Physics.

2 Planning

Students should be able to identify a problem and then determine a suitable procedure using appropriate apparatus.

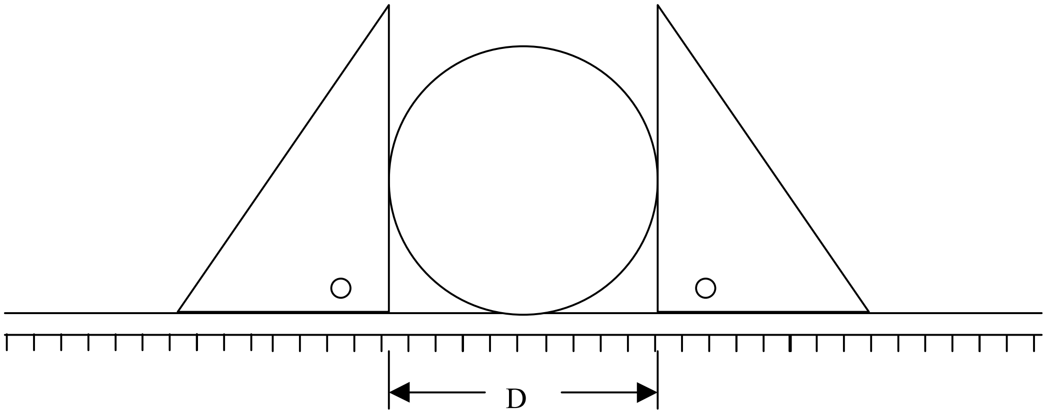
For example, an AS student might be asked to test the relationship for the acceleration of a ball rolling down a slope, $\rho ! = 0.71\, g \sin \rho$, where ρ is the angle of the slope. The student would be expected to:

- identify that s/he would need to find the acceleration for different angles of the slope and plot a graph of $\rho !$ against sin ρ
- recognise that a straight line through the origin of gradient 0.71 g should be obtained
- devise a suitable trigonometric method for determining ρ
- adopt suitable timing techniques to determine ρ, given that $\rho ! = 2x / t^2$ where t is the time to travel a distance x from rest the down the slope.

An A2 student might be asked to investigate the hypothesis that the period T of oscillations of a rule of length L on a cylinder of diameter D is given by $T^2 = kL^2 / D$ provided that the thickness of the rule is much less than D. Given a metre rule, half-metre rule several tin cans of different diameter, two set squares and a stopwatch, the student would be expected to:

- identify that s/he would need to find the period of oscillation of the metre rule for cans of different diameter, plot a graph of T^2 against $1 / D$ and then repeat this for the half-metre rule
- expect to get two straight lines through the origin, with the gradient for the metre rule being 4 times that of the half-metre rule

÷ determine a suitable method for finding the diameter of the cans, eg:



÷ find the period by timing a suitable number of oscillations

÷ consider the validity of assuming that the thickness of the rule *is* much less than the diameter of the cans.

An A2 student might be asked how s/he would test the hypothesis that the resonant frequency f is inversely proportional to the square root of the volume V of air in a conical flask. The student would be expected to:

÷ write down $f \alpha 1/\sqrt{V} \rightarrow f = kV^{-½}$

÷ consider a logarithmic approach of the form $\ln f = -½ \ln V + \ln k$

÷ identify that a graph of $\ln f$ against $\ln V$ would need to be plotted, the gradient of which should equal -½

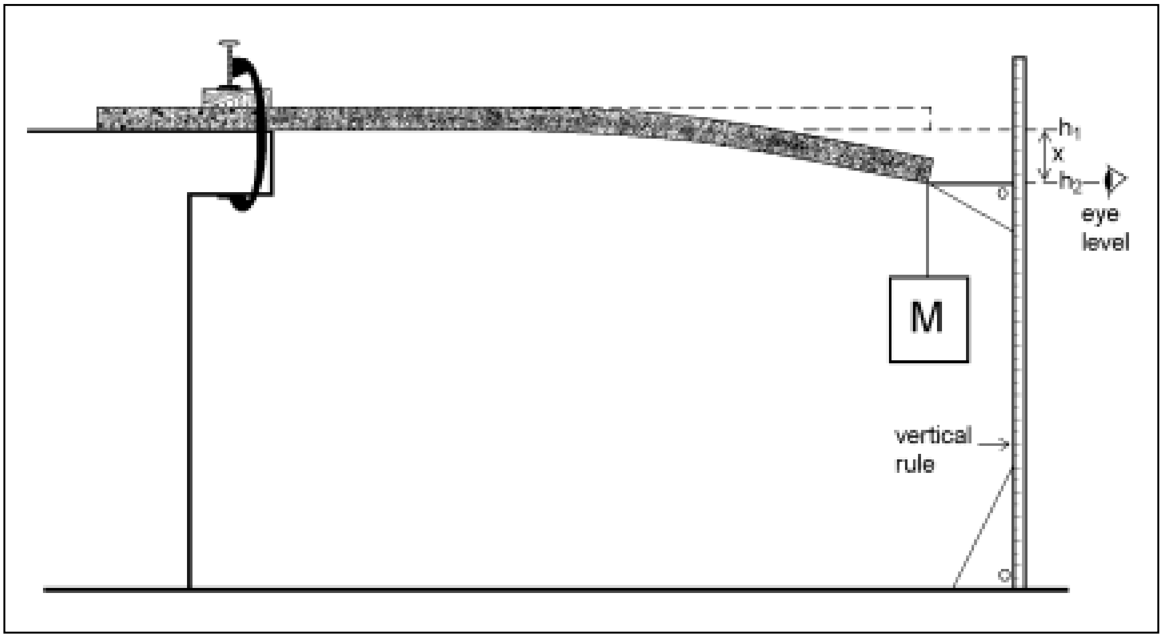
÷ describe a suitable technique for finding the volume of *air* inside the flask, given a measuring cylinder and a supply of water.

Students will be expected to set up electrical circuits. The circuit diagram may not be given in the question paper if it is a simple circuit, in which case students should be encouraged to draw a diagram of their proposed circuit before attempting to set it up. Students will be expected to be able to set up a potential divider circuit, where appropriate, to provide a continuously variable potential difference. They will be expected to choose the appropriate metre (eg ammeter or voltmeter) and set it on a suitable range for making measurements of p.d, current and resistance.

Teachers should emphasise the importance of safety in all practical work throughout the course as a matter of good practice. The attention of candidates will be drawn to any particular safety precautions in the practical test, eg they may be instructed to have their electrical circuit checked before connecting the power supply or warned that a component may get very hot during the course of the experiment. Candidates could be asked about safety in the practical test, eg 'why is it important to connect the capacitor the right way round?'

3 Implementing

Students should set up apparatus correctly and use it effectively, for example in determining the depression of a loaded cantilever students might be expected to set up (and draw) the following arrangement:



This experiment might also involve measuring the width and thickness of the rule. Students would be expected to use vernier callipers for the width and a micrometer for the thickness (or a suitable digital device for both). In both cases they would be expected to:

- check instruments for zero error (and record that this was done) and
- take repeat measurements in at least 3 places along the rule (recording all these measurements).

Students should be aware of the precision of instruments, in general:

mm scale	0.50 mm
vernier	0.10 mm
micrometer	0.01 mm

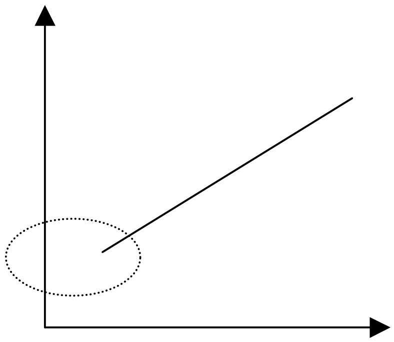
They should, however, recognise that if a measurement is the result of the difference of two readings (eg the depression of the cantilever in the above example), it would be unreasonable to quote an uncertainty of better than 1 mm (ie 0.5 mm for each reading).

Students should make and record sufficient relevant observations over a suitable range of values with appropriate precision. What is a 'sufficient' number of observations cannot be defined – it would depend on the nature and context of the experiment and is in itself a 'skill' which is acquired through experience. For example, for a mass oscillating on a spring with a period of about 1s it might be appropriate to time, say, 20 oscillations and then repeat. However, with a heavily damped motion it might not be possible to count more than a few oscillations, in which case it might be necessary to repeat 5 oscillations at least 4 times. Students should be prepared to modify their procedures in response to their experimental observations.

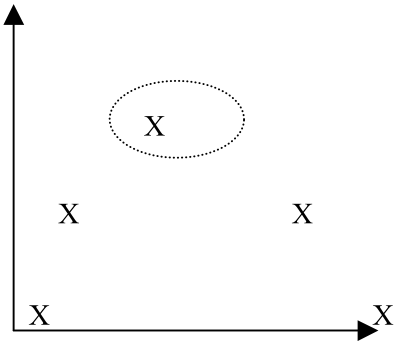
Where it is difficult to make a precise measurement, eg timing the ball rolling down the slope in the example given earlier (which is likely to be in the order of 2 seconds and subject to considerable subjective error) then several readings should be taken and averaged.

Students should be aware of the difference between the *accuracy* and *precision* of measurements, for example in the above situation they should understand that although the stopwatch can read to high *precision* (0.01 s) their timings will be subject to error because of their reaction time in starting and stopping the stopwatch. This will give rise to *random* errors, which can be reduced by taking several readings. A cheap stopwatch may well not be *accurate* eg when it reads 20.16 s, the actual time might only be 20.11 s. This would give rise to a *systematic* error of 0.05 s. Repeat readings cannot do anything about this – only a graphical method can help reduce such errors. Thermometers are notoriously inaccurate: although 0 – 100 ºC thermometers can be read (by interpolation) to a *precision* of 0.5 ºC or better they are unlikely to be *accurate* (due to their manufacture) to within 1 ºC, or even worse. This has less effect when measuring a temperature *difference* (eg determining the rise in temperature when a beaker of water is heated) and so students should still be trained to attempt readings to 0.5 ºC or better. Students should recognise that even though an instrument is capable of high *precision* (eg digital metre, electronic balance, digital stopwatch), its *accuracy* may well be in doubt (particularly if the student hasn't checked for any zero error) or there may be a further uncertainty due to human error.

Again, the number and range of values will depend on the outcomes expected. If a straight line graph is anticipated, it might be appropriate initially to take 6 measurements over as wide a range of values as possible. Having plotted the graph it might be necessary to take extra values, perhaps in a region where there is some doubt as to the nature of the line. This is particularly so in the case of a curve where more points are generally required, especially in the region of a maximum or minimum.



(i)



(ii)

Does graph (i) curve to the origin, or continue as a straight line and give an intercept? More readings would be needed (if possible) to decide. In graph (ii) extra readings in the region of the maximum would help to define its shape more precisely.

Students should realise that in some experiments (eg plotting a cooling curve) it is not possible to take extra measurements and should plan to take as many readings as possible at the first attempt (eg by taking readings every 30 seconds rather than every minute). It may actually be counter productive to take repeat readings in some cases, for example in an electrical experiment a component may heat up and so a repeat set of readings would be completely different.

Students should develop appropriate techniques to generate results which are as accurate and reliable as allowed by the apparatus. Some of these techniques have already been discussed and illustrated by examples, but the following list (which is by no means exhaustive) may be helpful as a summary:

- zero error checks
- repeat measurements (at different places if appropriate)
- difference methods (eg for extension of a spring)
- eye level to avoid parallax error
- use of marker at centre of oscillations to aid timing
- use of set square for checking vertical or horizontal arrangements
- interpolation of analogue scales
- trigonometric methods for measuring small angles.

In the practical tests marks will be awarded for employing and describing such techniques. Experience shows that candidates who do this are also more likely to gain higher marks for better results.

4 Analysing

Students should present work appropriately in written, graphical or other forms. In particular, results should be tabulated with data columns headed by the corresponding units with the data expressed to the appropriate precision, eg:

h_1 / mm	h_2 /mm	x/mm	$20T$ / s	$20T$ / s	T^2 / s ^{2}
327.5	321.0	6.5	19.52	19.64	0.96
327.5	314.5	13.0	27.64	27.50	1.90

All readings should be shown and recorded to the precision of the instrument. It is not essential to record 'intermediate' calculations (of for example the mean value of $20T$ and T), but the required quantity, T^2, should be expressed to a suitable number of significant figures. The number of significant figures is deemed to represent the precision of the value, eg 0.96 s ^{2} indicates a value of 0.96 ± 0.005 s ^{2}.

Graphs should be drawn having a large scale, but avoiding 'awkward' scales, particularly scales of 3. A rule-of-thumb definition of 'large' is that the points should occupy at least half the grid in both the x and y directions (or else the scale could be doubled!); this may include the origin if appropriate. The axes should be labelled with the quantity being plotted (or its symbol) and its units (if applicable), eg T^2 / s ^{2}, ln (V / cm ^{3}), 1 / D^2 / m $^{-2}$. Points should be plotted with precision (interpolating between grid lines) and denoted by a dot with small circle round it or a small cross. Error bars are not expected. Students should be taught to draw the line of best fit, whether it be a straight line or a *smooth* curve, preferably with a sharp pencil.

Students are expected to relate linear graphs to $y = mx + c$ and to understand that a straight line graph must *pass through the origin* to confirm a proportional relationship. They should, however, bear in mind that not all relationships in physics are linear! A2 candidates are expected to be able to plot logarithmic graphs in order to test for exponential relationships or power laws (as illustrated in the example earlier).

Students should be able to interpret information from a graph, allocating units where appropriate to the gradient, intercept and area under the curve where these represent physical quantities. When a gradient is being determined, whether from a straight line or by drawing a tangent at the appropriate point on a curve, as large a triangle as possible should be used and its co-ordinates should be recorded in the calculation of its value.

In analysing their observations students should be aware of the limitations of their experimental measurements. They should understand that certain types of measurement are more reliable than others. For example finding the period of a mass oscillating on a spring from 20 oscillations (say 20 s) should be a reliable, reproducible measurement, whereas the time for a ball to roll down a slope is likely to be fairly unreliable for a number of reasons: human error in measuring a time of about 2 s, the ball may not roll in a straight line and the ball might skid. Simple electrical measurements using digital metres should be reliable, whilst heat experiments may be less so due to heat losses and inaccurate and insensitive thermometers.

5 Evaluating

In drawing their conclusions students should be aware that as well as possible instrument errors (even with apparently 'accurate' devices such as digital metres and electronic balances), values stated on components (eg masses, resistors and especially capacitors) are only 'nominal' values, subject to manufacturers' tolerances.

They should also be aware of factors inherent within their apparatus or experimental arrangements which limit the reliability of their measurements, eg friction, air resistance, contact resistance, fluctuating power supplies, change of temperature during the experiment, etc.

They should understand how repeat measurements and graphical methods can reduce random and systematic errors and how such techniques can invariably improve the reliability of their data.

Students should assess the reliability of their data by considering the uncertainty of their measurements. In general terms this should be taken to be half the range of their measurements if several readings are taken or else the precision to which the instrument can be read if only a single reading is taken. However, if human error is likely to exceed this (eg reaction time starting and stopping a stopwatch) then this should be taken into consideration (eg although a stopwatch can read to 0.01 s precision, a more realistic uncertainty when using it to time oscillations might be 0.1 s to reflect reaction time). Uncertainties are usually of little value unless expressed as a percentage, eg a 0.1 s uncertainty in turning 20 oscillations (say 20 s) would give rise to a percentage uncertainty of only 0.5%, whereas a realistic uncertainly of 0.2 s in timing a ball rolling down a slope (say 2 s) would result in a 10% uncertainty.

Conclusions, wherever possible, should be based on *quantitative* evidence. For example, in the earlier experiment to test the relationship $\rho!= 0.71\, g \sin \rho$, the student might get a value for g of 10.4 ms^{-2}. A valid conclusion would be that the experiment confirms the relationship within experimental error because the value of g obtained is within about 4% of the accepted value and the experimental uncertainty is 10% from just the timing. Comments such as 'close to the right value' get no credit! The student's graph may not pass through the origin, from which s/he might infer that there could be a systematic error, eg the bench may not be horizontal, or there may be an additional constant term in the expression.

Finally, students need to apply their knowledge and understanding of physics, together with common sense. For example if in an experiment to determine a value for the density of a golf ball it was found it to be 140 kg m^{-3} they should stop and think 'but doesn't a golf ball sink in water?' A check of their calculations might enable them to discover, perhaps, that they had used the diameter of the ball instead of its radius and hence found a volume that was 8 times too large ('is the volume *really* 320 cm^3?'). If a careful check does not reveal such an error, then a suitable comment should be made to indicate that the student is somewhat surprised by the result.

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