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Report on the Examination

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GCE Physics, PHA3/B3/X, Investigative and Practical Skills in AS Physics

General Comments

The candidates found the demands of the new style paper much to their liking. The greater number of marks available compared to the outgoing legacy examinations usually made it possible to find merit in even the poorest scripts. There were very few low-scoring examples and it was unusual to find scripts in which any part had not been attempted.

Section A Task 1 and Section B discriminated well, the data analysis questions in the latter rewarding work that was clearly and logically set out. In Section A Task 2 there was rather less discrimination as so many candidates are well-versed in the conventions of data tabulation and graphical work, the general standard of which was good with more than half of the candidates scoring thirteen out of sixteen.

However, there were marks in each part that were hard to come by and these enabled the more able candidates to demonstrate their ability.

The proportion of the marks earned over both sections of the examination by candidates at the A/B and E/U borderlines was very similar; the A/B candidates were simply more efficient and careful in the way they managed their response to the test.

The work of the more able candidates was distinguished by their superior ability to explain experimental procedures, exemplified by their significantly better performance in Section B question 5, than the candidates at the E/U boundary. Likewise, the work done in Section A Task 2 and the analysis of the data in Section B questions 1 and 2 was another significant discriminator in favour of these candidates. More able candidates worked transparently, showing steps in their calculations in a manner that enabled them to review their work in the event that a suspicious result was produced. More able candidates appraised the outcome of their work – they returned to the apparatus and re-measured if an errant point was shown up and they took steps to guarantee the accuracy of their data, repeating readings when this was appropriate.

Less able candidates often stumbled when required to rearrange or even recall basic formulae. Their graphs often compressed one or both of the scales by the needless inclusion of an origin; this in turn compromised the gradient calculation. The reliability of their calculation work was frequently undermined by mixing units, leading to power of ten errors; an obvious example was in the calculation of the percentage error in *L*. Final answers for the volume of the stopper or the density of the rubber did not gain full credit due to the excessive use of significant figures. The steps in their calculations was not be set out distinctly and the answer to one part was immediately followed by another mathematical operation on the same line; the work seen in Section B question 4 was particularly poor in this respect.

The questions generally not answered well in Section A were Task 1 question 1 (a), where very few repeated their calliper measurements and Task 2 question 1 (a) (iii), where most gave one scale division for the uncertainty, ΔL, taking no account of the difficulty associated with making the measurement. In Section B question 1, most (correctly) recorded their result for *G* as a pure number but very few candidates seemed to be aware that $\frac{L}{G}$ required a unit. In question 5 (c), a bland response such as ‘take the reading at eye level to correct for parallax error’ was not sufficient to gain the mark.

Section A Task 1

Candidates were required to measure the volume of a rubber stopper by two different methods. The nature of these questions echoed those from the circus-style exercises from an earlier style of practical examination. Some of the hard-earned lessons of those times, eg the appropriate use of significant figures, have clearly been forgotten but there was no evidence seen to suggest that candidates were unable to perform the exercises. Task 1 has proved to be a good discriminator in favour of the better candidates and particularly so for those in the top 20% of the ability spectrum. Where different bungs were used the marking tolerances were adjusted so candidates would not be penalised.

Question 1

Most candidates provided readings that showed they knew how to use the callipers and it became quickly apparent if they had been provided with the smaller type 23 bung. Some clearly had been given digital callipers which read to 0.01 mm.

In part (a), candidates were clearly aware of the difficulty in making the diameter measurement, as their answer to part (c) showed, but it did not occur to many that they should repeat the measurement. Readings were usually consistently recorded and most got some credit for this part.

Despite the difficult appearance of the evaluation in part (b), the calculation of the volume using the directly-made measurements was done reliably by many and even when changing units into metres from the raw mm, most arrived at a satisfactory result. Some truncated their answer to two significant figures and those who gave excessive significant figures often repeated the mistake in their later calculations of density in 2 (b) and volume by the second method in 2 (c); only one mark per section was deducted for excessive use of significant figures. Candidates seemed to have unlearned the idea that to use more than four significant figures with final answers will be penalised, possibly because the legacy examinations present fewer opportunities to perform calculations of this sort.

In part (c), candidates were required to explain one property of the bung, to do with either the shape or the rigidity that made making the measurements difficult. Many said that when measuring the diameters they had difficulty avoiding a chord but this was not accepted; to measure a diameter the jaws of the callipers should lie in a direction perpendicular to the axis of the bung but some were clearly not doing this. A popular response was to explain that as the jaws closed the bung could deform and, providing the candidate explained that this affected the measurement, then credit was given. Answers outlining the difficulty of keeping the jaws in the same plane as the circular end of the bung were also accepted.

Candidates at the A/B boundary usually earned three or four out of five marks for this question while E/U candidates generally earned two.

Question 2

In all the scripts seen by the examiners, the candidates performed the exercise in part (a) reliably, with measurements of p, q and r of decreasing magnitude, except in isolated cases where the readings were taken using the wrong scale on the ruler. Marks were lost because the readings were not recorded to the nearest scale division or because the candidate unaccountably truncated a valid reading, eg 638 mm became 64 cm; if given in more than one form, the examiners will take the last of these as the candidate's intended answer.

Even with truncated data, most earned credit by deducing the mass of the bung to within 10% of the value supplied by the supervisor. In describing how they ensured the ruler was horizontal, a majority said they measured the vertical height of the ruler at each end but had also to add that they then ensured that these heights were the same. A popular idea that gained no credit was to place the set-square against the retort stand.

In (b) (ii), many instinctively wanted to convert p, q and r to metres when combining with ρ_W to find the density of the stopper and for less able candidates this sometimes became too much. Others either did not notice or realised this did not matter and progressed smoothly to a sensible result but despite a generous range of acceptable numerical answers, some did not gain credit. Good scripts showed the steps in the calculation in full. In (b) (iii), a majority were able to gain credit by explaining that the percentage error in r was greatest as this was the smallest measurement. Some had clearly been taught this idea very well, as exemplified by the candidate who wrote 'percentage uncertainty is inversely proportional to the magnitude of the measurement'. Those who calculated the percentage errors for each of p, q and r were not penalised.

For part (c), it was a surprise to find scripts in which candidates could not rearrange $\rho = \frac{m}{V}$ to make V the subject, or in some cases recall the equation accurately in the first place. A common error was to mix units by having ρ in kgm^{-3} and m in g, thus obtaining a result that was 10^3 too big. The impression gained was that most candidates had no feel for whether the result they had obtained was sensible or not and merely trusted the value shown on their calculator. The more confident used kg, m and s and used standard form to express their result but even so, perhaps only those who stuck to V in cm^3 could be really confident the order of magnitude was right. It seemed odd that few seemed to compare this answer with that for 1 (b).

Candidates at the A/B boundary usually earned between six and eight out of nine marks for this question while E/U candidates generally earned three or four.

Section A Task 2

Candidates were required to investigate the equilibrium conditions for a number of coplanar forces. This was quite a demanding manipulative exercise but the evidence seen in the scripts of candidates at both ends of the ability spectrum suggested that without the added pressure of a time limit, most took the problem in their stride and by simply observing the conventions of tabulation and graphical work most were able to obtain at least nine of the sixteen available marks.

In part (a), candidates gave answers for d and L that were almost universally of a suitable magnitude although some failed to give both to the mm precision expected. Part (iii) rarely attracted credit; some candidates made claims for the uncertainty, ΔL, of fractions of mm but the majority wrote 1 mm because this was the precision of the measuring instrument, an answer that was rejected on two counts. In order to make this measurement candidates had to judge the positions of the plumb line dropped from the horizontal rod and of point O against the horizontal scale on their ruler. As the uncertainty in a single reading was 1 mm, because *L* was the difference between two such readings, ΔL should be 2 mm. The difficulty involved in making the measurement should also be a factor in determining the candidates' decision so only answers for ΔL in the range 2 to 5 mm were accepted.

For part (b), the standard of the tabulation of the raw data was varied but the examiners usually found the evidence they required to award two marks. Some candidates eschew the use of the solidus separator between the variable and its unit both in the table headings and in the marking of the graph axes. Although the use of brackets around the units is reluctantly accepted, candidates should be told to use the solidus.

The award of both marks for recording the results was almost universal, the exceptions being where the independent variable was not recorded in the left-hand column of the table or where the candidates had recorded a total of five rather than five sets additional to the initial values of *m* and *d*.

In some isolated cases the candidate had recorded *d* using the wrong scale on the ruler, thus generating a graph with a negative gradient. Such candidates forfeited both the marks for results.

There was some discrimination in the award of the significant figure mark; those who gave *m* in kg sometimes recorded the data to the nearest 10 g although it was failure to record *d* consistently to the required mm precision that usually lost this mark.

The mark for quality, awarded if at least five of the six plotted points were within 2 mm of the best-fit line was earned by about 25% of the candidates. It was still possible for those candidates with backwards graphs to earn this mark.

In part (c), the marking of the axes and the choice of scales threw up the usual plethora of mistakes the most common being compressed scales due to the inclusion of an origin (although many who committed this error did so on the *d* axis and quite happily used the broken scale convention along the *m* axis). Candidates who used a broken scale but then marked an origin without using the broken scale convention were penalised because the markings on their axis suggested a non-linearity. A few candidates plotted the variables on the wrong axes.

Scales that used difficult intervals or were not marked with a frequency of 5 cm or less were also penalised. Poorly marked scales accounted for the majority of plotting errors seen and also made it difficult for the examiners to award full credit for the gradient calculation.

Some lost a mark because they did not show the $m = 100$ g set in their table, then forgot to plot this point on the graph. Plots were checked for accuracy and even if satisfactory could still fail to earn credit if poorly marked. The examiners will penalise points marked as blobs or as dots; it was usual to find some centres where significant numbers had been allowed to persist with this fault in the graphical work uncorrected. It is advantageous if candidates are taught to mark their points with + rather than ×.

Apart from poor scaling (usually in the vertical direction) the most common defect of the graphical work was the poor choice or marking of the best-fit line. Examiners were prepared to tolerate a smooth curve, without inflexion, if the distribution of points warranted this, although the majority of candidates generated data that suggested a straight line. However, there are some who cannot identify the position of a line that even approximately bisects the nonanomalous data and for those who included an origin the temptation to force their line through (0, 0) often proved irresistible.

Candidates at the A/B boundary usually earned between thirteen or fourteen out of sixteen marks for this question while E/U candidates generally earned nine or ten.

Section B

Candidates were required to perform further processing on their graphical work in Section A Task 2. They were then required to perform error calculations on the initial data from this exercise and to describe the procedure used to make the measurements. Other questions followed that involved two methods of determining the density of water that contained dissolved impurities and for many candidates these proved to be high-scoring answers.

Question 1

Far too many candidates did not show read offs either on the graph or as part of the working in their gradient calculation in part (a). The examiners are required to check that the read offs have been done accurately so unless clear evidence of working is seen full credit cannot be given. Candidates should also learn to set this part of the work out clearly for the purpose of error checking.

Gradient triangles must be of adequate step size and the read offs taken from their graph; many persist in using tabulated values that may not lie on the line of best fit.

Very few obtained even one of the two marks available to part (b). Many gave answers to more than four significant figures but the omission of the unit was just as prevalent. While candidates should be taught that no unit is given with the result of a gradient calculation, they should understand that if the result is used in a subsequent calculation, as was the case here, then the units marked with the variables on the axes must be taken into account. The result for $\frac{L}{G}$ gave the value of the concealed mass and only an answer in the range 200 ± 10 g could earn full credit.

Candidates at the A/B boundary usually earned one or two of the four marks for this question while E/U candidates generally earned one or zero.

Question 2

Most knew how to do part (a) and the mostly inappropriate ΔL data was not penalised. For a minority this mark was carelessly lost by mixing units for ΔL and L.

In part (b), there were two camps; those who knew straight away that they should multiply their 2 (a) answer by three (and earn the mark) and those who thought they should divide the percentage error in L by 2 × the percentage error in L thus obtaining 0.5%. The implausible nature of this result did not seem to occur to those who carried out this procedure, underlining once again the failure of the less able candidates to inspect their work or otherwise question the validity of what they are doing. A minority omitted to include × 100 in their calculation.

Candidates at the A/B boundary usually earned one or two out of two, while E/U candidates generally earned one or zero.

Question 3

For full credit candidates had to describe a valid procedure using both the plumb line and the set square. Successful answers described placing the ruler against the set-square having aligned this with the plumb line suspended from the horizontal rod. Many took advantage of the space provided for a sketch and saved the examiner the task of reading an often tortuous description of a fairly simple procedure.

Candidates at the A/B boundary usually earned one out of two while E/U candidates generally earned zero.

Question 4

In this question the examiners were looking for clarity of working and in the better scripts a simple and logical solution to the problem was easy to discern. Candidates were required to show (and not blandly state) the mass of water to be 26.05 g and the mass of liquid to be 27.13 g, then use the former result to deduce the volume enclosed by the bottle; credit was only given if this was to the correct order of magnitude. For such a 'show that' question, no penalty was extracted if the final answer was given to excessive significant figures and unless the calculated result was written down in full to at least four significant figures (and no valid method could lead to 1040 $kg\,m^{-3}$) one mark was withheld.

It was odd to find candidates truncating intermediate results in their work given that they had been provided with the four significant figure data in the first place.

An alternative and creditworthy solution seen in a few scripts involved using the density of water and the suggested density of the liquid to prove that the same volumes of water and liquid would fill the bottle.

Candidates at the A/B boundary usually earned four out of the five marks available while E/U candidates generally earned two or three.

Question 5

Part (a) proved to be very accessible and only those who did not understand that each 'set' of data was recorded in a 'row' of the table came unstuck.

In part (b)(i), having correctly identified which set of the Hare's apparatus data to disregard, many candidates elected to calculate the mean of the valid data in each column. Another method involved calculating the ratio of heights for each row of the table while others chose to calculate the density of each valid row of data and then determine the mean of these results. There were very few who could not make some progress towards a final answer and only those who had not made full use of the valid data failed to gain four marks.

The final mark was much more problematical and in contrast to the 'show that' problem set in question 4, final answers to more than four significant figures, of which there were many, were penalised.

A common mistake in part (b)(ii) was to state that 'h_W would be plotted against h_L' which it clearly transpired could mean different things to different candidates. Candidates were expected to make it clear which variable was plotted on which axis. Unless a clear explanation of how the gradient result would be combined with the density of water was given full credit was withheld.

Some candidates missed the point of part (b) (iii) and argued that they would identify anomalous data by circling the points on the graph, neglecting to explain how they would recognise that the points were anomalous in the first place. Reference to these points lying away from the line of best-fit was the expected answer although the many candidates who used the term ‘outlier’ were given credit.

In part (c), candidates were expected to refer to random error arising from poor technique in measuring the liquid heights and to explain how such errors could be overcome. The expected answers were the use of a non-vertical ruler, corrected for by the use of a set-square or plumb line alongside the ruler, or parallax error eliminated by some named procedure to ensure that the eye is level with the bottom of the meniscus. Many candidates stopped at the ‘get eye level’ idea without making some reference to the use of a plane mirror or looking along a set-square placed against the vertical ruler. The minority who took the ‘get ruler vertical’ approach were more successful but this part of the question was generally not answered well.

Candidates at the A/B boundary usually earned about nine out of the twelve marks available while E/U candidates generally earned four or five.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results statistics page of the AQA Website.