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Report on the Examination

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GCE Physics, PHA6/B6/X, Investigative and Practical Skills in A2 Physics

General Comments

Although it will have struck the candidates that this paper presented a much more severe test than the EMPA they saw at AS level last summer, most acquitted themselves very well. As in the 2010 AS paper, it was obvious where centres had taken note of the PSV exercises in the preparation of the candidates; one of these was the determination of the period of an oscillator performing shm and this was the focus of question 1 of Section A Part 1. The use, by many, of the simple pendulum equation later in the question, further confirmed that most candidates were well prepared.

The use of log theory to reveal the nature of a power law was widely understood although a majority missed the significance of the term, integer, mentioned in the question. To a few of the candidates the concept of inverse proportion, tested in question 2 (b) (iii), means no more than 'as variable *x* increases, variable *y* decreases' but an encouraging number could perform a valid test on their data to confirm the relationship. Here, and in question 1 (c), some candidates rejected the obvious approaches but found inventive alternative solutions that gained full credit.

The initial measuring in Section A Part 2 required the candidates to work carefully and apply standard precautions to reduce uncertainty; but they also had to improvise when the need arose. Many did all the right things in determining the length of a paperclip but then truncated the final answer and there remains a cohort that struggle to read an analogue micrometer screw gauge. Graphing the profile of the paperclip chain was done well although some disregarded the instruction to make measurements to the junctions between the clips and others measured to the wrong side of the centre.

Most of Section A discriminated well and this was also generally true of Section B, with the exception of question 1. Even some of the more able candidates missed out on question 1 (a) because they substituted, wrongly, the number of paperclips provided to determine the mean length, *c*, and not the number (24) used in the chain used in part (c). Others gave answers to (b) (ii) and (b) (iii) that took no account of the instruction that they should refer to, or use, the data in Table 1 in formulating their answer. In question 2, there were very few wrongly calculated gradients but several using tangents placed at the wrong junction on Figure 4. Many candidates lost the mark in 2 (b) because they did not take account of possible units or significant figures in their results but many gained full credit for question 2 (c). Question 3 showed that a worrying number positioned their fiducial mark behind the oscillating chain and not below the chain when in the equilibrium position; relatively few can explain why the fiducial mark should be so positioned. Question 4 part (b) exposed the candidates who did not understand that uncertainty is half the range and part (c) showed that many did not really grasp the graphical representation of what they had seen in Section A Part 1 that was illustrated in Figure 5.

As detailed in the PSV exercises, it was expected that candidates had been given experience of data logging and in Question 4 (d) they were given an opportunity to write at length about this. While many could make a sensible statement or two, eg eliminating human error or readily transferring data to a spreadsheet, few used technical vocabulary correctly when explaining these advantages. The biggest confusion was between the terms *accuracy* and *precision*; many seem to use these words interchangeably and see no clear distinction between them.

Section A Task 1

Candidates were required (in question 1) to investigate the oscillations of a paperclip chain of variable length and then deduce the form of a suggested power law linking the number of clips in the chain with the period of the oscillation. They then made measurements (in question 2) of the time for energy transfer between pendulums coupled by a fine thread from which was suspended a small number of paperclips. They were required to use their measurements to test the suggestion that the time for energy transfer between the pendulums was inversely proportional to the number of paperclips suspended from the coupling thread.

The candidates seemed to have little difficulty in carrying out either experiment and the good quality of the measuring done by most became apparent in the subsequent analysis.

Question 1

Candidates were required to determine the period of the oscillations from (the sum of) at least 20 cycles; many did this and repeated the process, thus taking account of both random and systematic error, which is good practise. Unfortunately, a few forgot to divide their timing by the number of cycles and some others gave these raw readings in an inconsistent fashion, some to 0.1 s and the rest to 0.01 s, otherwise there were few scripts in which marks were dropped in part (a).

In part (b), many candidates clearly understood how log theory could be used to identify the integer *x* in the suggested relationship, $n \propto T^x$, linking the number of clips, *n*, to the period, *T* and all but a handful of these produced a relevant graph. It was common to find the data plotted on the grid had not been tabulated which made it difficult for the examiners to give full credit for the work. Even where the log values were tabulated, it was frequently found that the number of decimal places was less than the minimum (3) required. It is apparent that many candidates do not appreciate that the place holder in the log of a number is not significant and the need to give the result to at least three decimal places was missed by many. Another common error was the poor scaling of the graph and/or the use of a small triangle to determine the gradient. Where candidates had plotted log *T* on the vertical axis, the gradient result (about 0.5) led to confusion about what *x* should be, but even those that plotted the data the other way round generally ignored the information that *x* was an integer.

The use of $T = 2\pi\sqrt{\frac{l}{g}}$ with an appropriate value inserted for *l* was the required method in 1 (c) and a significant number were successful in showing that the outcome was inconsistent with their measured result. Some candidates slipped up by using 9.81 for *g* but inserting a value for *l* in centimetres. Rather than following the instruction to 'show that…' some discussed how the paperclip chain had widely distributed mass and so could not behave like a simple pendulum; such answers could gain no credit. Some inventive solutions were seen in which candidates read the intercept on their log graph, manipulated the result then combined this with the length of a paperclip before showing that the outcome was incompatible with $\frac{4\pi^2}{g}$.
Candidates at the A/B boundary usually earned six or seven out of nine marks for this question while E/U candidates generally earned four.

Question 2

Some will have realised that the coupled oscillator experiment in the Specimen question paper was very similar to that in question 2 of Section A Part 1 and very few were unable to produce a convincing set of measurements for the energy transfer times. It was immediately obvious where the candidate had measured the time for energy transfer from one pendulum to the other (ie $\frac{\tau}{2}$) but where the procedure had been carried out as intended the result was nearly always in agreement with the values supplied by the Supervisor. Part (b) (iii) was a good discriminator that generated a variety of approaches, the most common of which was to compare values of $\eta\tau$ for the three different coupling arrangements. Many produced values of $\eta\tau$ that were within 5% of the mean and happily concluded that the inverse relationship was established but others, who found less close agreement, could not decide what to make of their results. If any $\eta\tau$ value was further than 10% of the mean the examiners expected the candidate to reject the inverse proportion theory; for any result between 5% and 10% of the mean the candidate could either accept or reject the theory. Some very good answers were seen where candidates calculated the mean and computed the deviation of each $\eta\tau$ value to justify their decision.

The least successfully answered part was (c). Candidates were expected to say that with fewer than four clips on the thread the transfer time would become so large that one pendulum would appear to be at rest for a long period, so it would be difficult to know when to start or stop the watch. Many realised this and phrased their answer in terms of the long time that 'the amplitude was (approximately) zero' but some said that it would be hard to see 'when the displacement was zero', which was not accepted. Ideas that the experiment would become too time consuming or that the tension in the thread would be too small to facilitate energy transfer were not accepted.

Section A Task 2

Candidates were required to investigate the profile of a paperclip chain arranged to hang as a catenary.

The initial measurements made in parts (a) and (b) discriminated well. Why so many truncated their result for *c*, the length of one paperclip, remains a mystery. Perhaps these candidates were confused into thinking that the raw measurement (across several clips) and the result (for one clip) should be given to the same number of decimal places, but this rather flies in the face of logic; the same students had happily given the period of the paperclip chain to three or four significant figures in Part 1.

The micrometer readings were done well by a majority (it was clear to the examiners when the centre had provided digital instruments) and most candidates generated a result from repeated readings. Common errors were to misread the sleeve reading so that, for example, a reading of 1.07 mm was given as 1.57 mm.

The tabulation of the raw data in part (c) was good, the mark available being almost universally awarded, but the three marks for recording the data were less accessible. Some candidates lost all of these for measuring the wrong half of the chain or for displacing the *xy* origin from the desk to the lowest point on the chain. Others ignored the instruction that they should measure to the junctions between paperclips and this tended to produce more scatter on the graph. A common error was the omission of the $x = 0$ set or failure to comply with the instruction about the required separation of the ends of the chain so that the largest tabulated *x* value fell outside the range, 355 mm to 380 mm, for which credit could be given. Very few candidates did not measure sufficient data points (a minimum of ten were required).

The significant figure mark often came into play where candidates had tabulated their *xy* data in centimetres. While most of the data points were recorded to the nearest 0.1 cm, as required, the $x = 0$ value was not recorded as '0.0'. Such inconsistencies attract a penalty; there is nothing magical about reading zero from a scale – it is simply just another graduated point and subject to the same uncertainty as any other.

The graphical work was of good quality and very few lost marks for errant or missing labels or reversed axes. The message about avoiding difficult scales has still not reached every centre and examiners will continue to punish intervals based around 3, etc. However, very few were penalised for making insufficient use of the page and most mark the points clearly. It was clear when candidates had followed the instruction to make their measurements to the junctions between paperclips because the points would be evenly spaced along the best fit line. Errant points are always checked for accuracy of plotting and it is very often the case that these turn out to have been marked at the wrong place on the grid; candidates should check such points before handing in their Section A Part 2 script. Only where insufficient points had been plotted or the candidate had been really careless in their measuring was it necessary to withhold the quality mark.

The most discriminating aspect of part (d) was the quality of the best fit line. Although there were plenty of data points some candidates feel obliged to make the line pass through each often leading to points of inflexion. Curves that had not been drawn in one continuous movement could be sketchy and this too was penalised by the examiners.

Parts (a) and (b), the results/significant figure marks in part (c) and the line mark in (d) provided good discrimination in the question.

Section B

Question 1

This was probably the least successful question in providing discrimination; many candidates were not careful enough in their reading of the question and either substituted wrong data ((a)) or gave information that was not required ((b)(iii)). Some gave their final answer to part (a) with excessive significant figures. Candidates enjoyed mixed success in part (b); in (b)(i) they were required to give two sensible statements that either separately, or together, would explain why the percentage difference between the approximate and true values for the length of the paperclip chain increased with the number of paperclips. Many wrote that as the chain became longer percentage difference increased because there were more junctions, but did not explain that the difference between approximate and true values (as a fraction of the true value) increases. In (b)(ii) candidates were required to explain the general trend illustrated by the data in Table 1; credit could be gained if they explained that as *n* increased the percentage difference increased at a decreasing rate, or that (as *n* increased) the difference between values of percentage difference became less. Some knew what they wanted to say but were not careful in their choice of words, saying that as *n* increased percentage difference decreased. Others simply quoted percentage difference values for a small value and for a large value of *n* without establishing the way that the percentage difference varied between these values. More able candidates noted that as *n* doubled percentage difference approximately halved, speculating (correctly) that the relationship between the variables was a form of exponential growth.

In (b) (iii) it was suggested that candidates drew a sketch to illustrate how they would use the data in Table 1 to determine the largest value of *n* for which percentage difference is less than 4%. As before, many overlooked the integer idea (*n* = number of paper clips) and others chose to describe an experimental technique which took no account of how the data in the Table could be used. It was expected that candidates drew a sketch graph depicting the data and showed a read off where potential difference = 4%; very few thought to add 'then round down to find *n*'. Very few took note of the question that asked them to explain how to reduce uncertainty in the result.

Question 2

For part (a) all candidates drew tangents but not always at the correct point on the curve. The other key error was in failing to make the step sizes in the gradient calculation large enough; even on the restricted grid they were supplied with in Figure 4 they should have used at least 8 cm in each direction. Very few gave incorrect calculations but some unaccountably gave a unit with the result.

In part (b) only those who kept their wits about them were able to score the available mark. Candidates were required to give each answer to three or four significant figures, *p* to be supplied with a unit but *q* without.

Many obtained success in part (c) for their numerical answer. There was no penalty for a missed unit if, as was frequently the case, no unit had been given with the result for *p* in (b) (i).

Question 3

Nearly all knew the fiducial mark was for assistance in judging when to start and stop the watch and that it should be placed at the centre of the oscillations, as shown in nearly all the sketches seen. However, a small minority think the mark is to ensure that the chain is given the same initial displacement. The candidates' sketches also revealed that many had placed the mark too high so that it was behind part of the chain that was moving slowly. Candidates were also expected to justify their positioning of the mark by saying that this was where the transit time is least (or this is where the chain is moving with maximum speed) so a sketch showing the mark placed too high (losing the first mark) ensured that they could they made no useful attempt at earning the second mark.

Question 4

In parts (a) and (b) candidates were required to complete Table 2 which gave data from an energy transfer experiment like that performed in Section A Part 1. While virtually all managed part (a) without a hitch, the answers in part (b) were very variable. Some did not know that the uncertainty is half the range but a more costly error proved to be the truncation of the result for the uncertainty when *n* = 3 from 2.30 to 2.3. Inconsistency in significant figures between (b) (i) and (b) (ii) was penalised.

Part (c) was a good discriminator and really tested whether the candidates could see how the displacement-time graph shown in Figure 5 tied in with their observations of the coupled pendulums. Many confused the period with the time for energy transfer between the pendulums.

In part (d), many candidates incorrectly used the term accuracy to describe the improvement obtained when human error is overcome. Credit was earned when candidates said that precision improved because of the greater sensitivity and high sample rates that can be achieved with data loggers. Other valid ideas were that capturing information in digital form allowed it to be readily processed using computers, saving the time and effort of the experimenter.

Mark Ranges and Award of Grades

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