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Physics **PHA3/B3/X**

Unit 3: Investigative and practical skills in AS Physics

Report on the Examination

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

General Comments

Electrical experiments are not always popular but many candidates acquitted themselves well, despite the unorthodox nature of some of the tasks. Compared to this year's questions, the 2010 experiments were much simpler to carry out but took the candidates to parts of the specification where their understanding of the physics may not have been completely secure. In contrast, the 2011 paper did not stray far from investigating how the physical dimensions of a conductor affected the electrical properties but the manipulative demands had greater depth and variety. The idea of producing a calibration curve (Section A, Part 1, question 2) was new but most grasped the concept and scored well.

Compared to last year, there was more numerical work and rather less continuous writing and this may have contributed to the improved mark in Section A, Part 1. While this might be expected to work in the candidate's favour, there was a sting in the tail for those who took insufficient care with use of significant figures or with the need to show units with their answers; it was rare to see a script where the attention to detail was sufficient to avoid some penalty of this sort.

The graphical challenges were also more varied; in Section A, Part 1 candidates produced a curving calibration graph and, as was found last year, many struggled to produce a smooth continuous line that met expectations. The graphical work seen in Section A, Part 2 was usually good with two well defined linear regions that most drew with the aid of a ruler. As mentioned in last year's *Report on the Examination*, plotting errors often coincided with the use of difficult scales and in both graphs there were the usual quota of thick or hairy lines that attracted no credit.

The experiment in Part 2 produced outcomes that the majority found easy to identify and this led to many making a good start in Section B where candidates analyse the quantitative aspects of their experiment. Opportunities this year to earn marks through continuous writing did not include experimental design, of which there were two opportunities in 2010. But in making predictions about alternative outcomes (B2), discussing contrasting approaches to reducing uncertainty (B3) or discussing experimental procedures (B4) the candidates had ample opportunities to demonstrate their command of scientific vocabulary. It is inevitable that in some of this style of question the candidates have to improvise answers but this works to the advantage of those who are good at problem-solving in a practical physics context.

The general impression gained was that candidates seemed well prepared and there is clear evidence that some very able candidates are being entered for the EMPA. Once again, it seemed apparent that centres had taken note of the PSV exercises when preparing their candidates.

Section A Part 1

Question 1

In question 1, candidates were required to measure the diameter of a wire using a micrometer then determine the resistance per unit length of the wire. Using these two pieces of evidence they then had to identify the material from which the wire was made.

Using the micrometer in part (a), very few candidates did not produce at least one reading of about the right magnitude. An occasional error was due to taking the thimble reading to be ten times too small and very few could not deduce the SWG number correctly. For full credit repeat readings were required and these had to be all to the same precision. Some centres clearly provided digital micrometers which could read to 0.001 mm. It was usually clear when all the candidates had been given these instruments, but we will ask in future that centres make it clear which type of micrometer their candidates will use.

The voltmeter readings in (b)(i) and (b)(ii) were generally given with appropriate and consistent precision and with unit but some clearly thought that consistency in significant figures was expected. For raw readings such as these it is decimal places that must be consistent. The expected ratio between the readings (V_1 in the range $4V_2$ to $6V_2$) was met by those who had attached the clips a... directed, close to each of the round terminals, as shown in Figure 2.

In (b)(iii), it was expected that the candidates used the graduations on the ruler to which the wire was attached to determine x, the distance between the clips. Some gave values of close to 400 mm which suggested that they had not measured between the inside edges of the clips while others gave readings that were much less than 300 mm; in each case, no credit was given although the most significant reason why the mark was withheld was that raw readings were not given to the nearest mm. Very few scripts were seen where this mark was awarded.

In (c) some showed through their working that they thought 10 mV was 0.001 V but the majority of withheld marks were due to one significant figure answers for the percentage uncertainties.

There was mixed success in (d) but earlier errors did not prevent those who added 5% to the sum of their previous answers earning credit.

Constantan was correctly identified by the majority but the noteworthy thing here was how many lacked the confidence to simply divide their answer to (b)(iv) by that for (b)(iii) to calculate the resistance per unit length and there were many convoluted approaches of a style which is hardly ever seen in A2 scripts.

Candidates at the A/B boundary usually earned at least six out of nine marks for this question while E/U candidates generally earned three. There were very few scripts that earned full marks, the majority did not score in (b)(iii).

Question 2

Candidates used a rotary potential divider to balance the pd across a potential divider circuit. This pd changed as candidates connected different known resistors in the potential divider. By plotting a calibration graph to show how resistance connected in the potential divider affected the position of the control knob on the rotary potential divider, the candidates were able to determine the resistance of another resistor, the value of which was concealed.

In part (a) many missed the unit with θ_0, instantly forfeiting a mark. Table 3 was generally completed appropriately, with ascending readings for the pointer position and the values for $\theta - \theta_0$ computed correctly. Some candidates re-measured θ_0 for each row of the table and if these values were found to vary, no credit was given. If the potentiometer had been wired up backwards the readings decreased but candidates could still go on to correctly deduce R_U; since this was not the candidate's fault they were not penalised. If θ_0 had been set just below 360°/0° some candidates, not appreciating that they were computing the difference between two pointer positions, produced negative values for $\theta - \theta_0$; this approach earned no credit.

In (b), most vertical scales were continuous down to zero, otherwise candidates used a false origin; where such an approach is used and the point of intersection of the axes is not labelled (and therefore assumed to represent zero), the broken scale convention must be shown. Difficult scales were given no credit and these often went hand-in-hand with plotting errors. Badly marked points or poorly drawn lines (particularly poor was the section between R = 5.6 kΩ and 15 kΩ) were other frequent reasons why full credit was not earned.

In (c) most saw the need to subtract θ_0 from θ_U before locating R_U but the range of acceptable results was from 8.1 kΩ to 10.1 kΩ hence a bland result of 10 kΩ gained no credit.

Candidates at the A/B boundary usually earned four or five out of seven marks for this question while E/U candidates generally earned three. Many scripts did not get one or both marks in (c).

Section A Part 2

Candidates were required to investigate the variation in potential difference along a conductive paper strip of two different widths.

The mark for $\frac{V_{260}}{V_{20}}$ in (a) was rarely awarded and probably accounts, in itself, for the marginally lower success of the candidates this year compared with last for this question. Candidates had to get a lot of things right to earn this mark; numerically the result had to fit into a narrow range and be given to the same precision as the raw data. Additionally, there had to be a minus sign and no unit and all of this defeated all but the most careful.

Having thus identified the dependent variable as 'potential difference' in the stem of the question, the use of 'voltmeter reading' as a label in the tabulation (or on the graph axis) was not accepted. The insistence of many candidates to write out the name of the variables in full, rather than use the identifying symbols given in the question, is frequently their undoing.

Unlike 2010 there was no necessity for candidates to produce derived values using their raw data but this simplification was more than offset by making the candidates decide how many additional data points to tabulate in (b). It was rare to find the additional values of *x* given to a frequency other than 20 mm earning both marks for raw results; those who went for 30 mm steps forfeited one of these marks. Significant figure errors were similarly rare although inconsistencies between (a) and (b) were penalised.

In (c) the graph was generally done to a good standard, and only exceptionally were marks lost for poorly labelled axes or using inappropriate scales; however some failed to choose scales that accommodated their V_{20} and/or V_{260} data. The complication for the candidates that their V data fell both sides of the horizontal axis led to some plotting errors and contributed in Section B to errors in the gradient calculation.

Candidates should check any errant point and not assume that the examiner will not; there is no limit to the number of points the examiners will check if they have any doubts about the legitimacy of the graph. For this experiment it was very easy to hold the page to eye level to see instantly whether there is any point, legitimately plotted, that would cost the Q (quality) mark (comparatively few cases were seen where the Q mark was not awarded). So it is also easy to pick out any point that might not have been legitimately plotted; if a point is further than one millimetre from where it should be will cost a mark. Likewise, points marked as dots or as blobs or with a thick cross will be penalised.

One continuous line consisting of two linear regions, drawn with the aid of a ruler and a sharp pencil, earned the line mark. Candidates should use pencil for graphs (except to label the axes and mark the graduations) and erase any error carefully and thoroughly. The standard of graphical work is improving but, because the EMPA is marked by a team of examiners who can apply the same standard consistently, candidates must expect to receive full credit only if they produce graphical work of the highest standard.

Candidates at the A/B boundary usually earned between twelve and thirteen out of fifteen marks for this question while E/U candidates generally earned nine or ten. As pointed out in last year's *Report on the Examination*, a poor performance in this part of the EMPA will significantly affect the chance of overall success.

Section B

Question 1

In question 1, the candidates were required to read and record V_0 and V_{280} and many struggled to earn this mark. If the line did reach these points on the grid, candidates were expected to use algebra to locate the values and any extrapolation of the line into the margin was given no credit. Candidates given a fresh sheet of graph paper to redraw the graph were not given credit. The value of *x* where the line crossed the horizontal axis was also required and candidates were more successful in determining this, although the margin of acceptable error was one millimetre.

The same margin applies to the gradient read offs; good candidates show these in their working but the message seems to be getting lost about making the size of the steps sufficiently large. There were some ridiculously small triangles used by some candidates and these offered very little chance of a successful outcome in the ensuing calculation.

The evaluation was successful for many although some mixed up units having evaluated the gradient using metres for the horizontal step.

Candidates at the A/B boundary generally earned three out of six marks for this question while E/U candidates typically earned one.

Question 2

In part (a) there was some guesswork going on among the less able candidates but there were many more that could deduce the right answers correctly, although in (b) the explanations often fell short. The idea being tested, that some changes are incremental shifting the intercept but not changing the gradient, while there are also proportional changes where the gradient changes and the intercept does not, was one that the more able candidates grasped easily. As with questions of this sort, the careful and accurate use of language is the key to success.

Candidates at the A/B boundary generally earned two out of three marks for this question while E/U candidates typically earned one.

Question 3

Many correctly said in (a) that the point where the conductive paper becomes narrower could be identified by the point on the graph where the gradient changed.

Part (b) proved much more challenging. Candidates could support either suggestion providing they could assemble convincing supporting arguments. Additionally, they could earn a mark for supporting the suggestion that was confirmed by their own graph; student A is saying that the graph has a knee, like a diode characteristic, so examiners looked for a brief curve joining the two linear sections of the candidate's graph. Student B is saying that the gradient changes at a point so the candidate's graph should consist of two straight lines meeting at a point.

Candidates at the A/B boundary generally earned two out of three marks for this question while E/U candidates typically earned one.

Question 4

In (i) the idea that the wire had a non-uniform cross section occurred to many candidates but some talked about the wire being dirty or kinked.

In (ii) those who had mentioned a dirty wire often carried on in the same vein and this gained no credit. Marks were awarded for saying that the diameter should be measured at different points along the wire and then calculating an average.

In (iii) the phrase 'check for zero error' could attract the mark but otherwise the candidate had to describe how this was done and frequently they overlooked the need to close the jaws before inspecting the scale. There were many who said only that they would 'zero the micrometer'. Unsuccessful answers confused random and systematic errors or talked about checking the calibration of the instrument.

Candidates at the A/B boundary generally earned two out of four marks and E/U candidates typically earned one.

Question 5

In (i) the 3° uncertainty was almost universal.

In (ii) a good sketch could earn both marks, otherwise the candidate had to mention the (very) shallow gradient leading to the large uncertainty in R_U to earn both marks. Once again, careful writing did the trick but poor ideas such as 'small scale' in the vertical axis attracted no credit.

This was the most successful question for most candidates in Section B and candidates at the A/B boundary generally earned two out of three marks while E/U candidates typically earned one.

Question 6

This proved to an accessible problem and generally the highest scoring answer in this section of the script.

In (a) many evaluated $\frac{R}{L^2}$ for each row of data in Table 4 to three significant figures and went on to say that the consistency in the results confirmed the theory being proposed. If all the evaluations were done to two significant figures, one mark was withheld and if all were evaluated as 0.07 then only one of the three marks could be awarded. Instances where reverse working was done could also attract credit.

In (b) answers in the range 7.4 cm to 7.6 cm earned a mark but for full credit it had to be clear that the candidate was using the average of their $\frac{R}{L^2}$ values in the calculation.

Candidates at the A/B boundary generally earned three out of five marks and E/U candidates typically earned two.

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