Version 1.0

General Certificate of Education (A-level)
June 2012

Physics PHA6/B6/X

Unit 6: Investigative and practical skills in A2 Physics

Report on the Examination

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

General Comments

The entry for the 2012 A2 EMPA was substantially up on the 2011 figure and the experiments used in this year's paper were easy to set up. All but one of the PSV exercises were involved in the test; of these the change in amplitude of a damped oscillator was that which students answered least well even though many will have tried the experiment in the 2011 paper about an air-damped pendulum. As in 2010, we asked about an aspect of data logging, this time to do with the use of a voltage sensor connected to a logger to monitor the discharge of a capacitor. It was clear that some students did not understand that it was the logger and not the sensor that sampled the data. We will continue to ask questions of this sort to encourage Centres to show students modern techniques for data acquisition.

It was encouraging to see that many students had prepared carefully for the test and absorbed some of the ideas in previous examinations. To confirm that the amplitude of the ruler in B4 decayed exponentially some measured the half life at several points while others calculated the decay constant; appreciating that their calculations would generate a range of results many evaluated the spread of these about the mean in order to justify their conclusion. Most of the solutions showing how the radius of the concave surface could be obtained from a graph of $(\text{period})^2$ against ball bearing radius were clearly and logically laid out. Some of the qualitative writing was well conceived: imaginative (and often successful) suggestions were seen about why the radii of the concave and convex surfaces would be different. But as ever there were parts that the students struggled with their explanations; in B2(a)(ii) most overlooked the fact that the voltmeter reading at which the watch should be stopped would never be displayed and in B2(a)(iii) many felt that uncertainty would be reduced because the rate at which the reading was falling was less.

In Section A Part 1 question 1 discriminated well between the students at the A and E boundaries, the better students showing the more methodical approach to parts (iii) and (iv). In question 2 all students were generally successful in (i) and (ii) but struggled with (v) so the mark ranges tended to be more compressed making it harder to distinguish between the differing abilities. Students at about A* standard were able to add the small but important detail to their answers to access the higher marks; they tended not to confuse diameter with radius when performing the calculation in 1(iii) and they did not fall back on generic responses in 2(v).

Section A Part 2 held few terrors for any student and even the weakest were capable of scoring well. E grade students typically gain up to 50% of their EMPA mark in this section of the test. Most repeated their half life timings and very few errant points were plotted; likewise there were comparatively few difficult scales used or badly marked points plotted on the graphs, mistakes which are much more frequent in the work of AS students. One recurring fault seen in the tabulation part stems from the insistence of some to write a description of the variable in the table heading (and in the labelling of the graph axes) rather than using the symbol identified in the question. The use of 'resistor' rather than 'resistance' was not accepted. A mark was withheld if the student recorded $\frac{R}{R + R_0}$ as $R/R + R_0$ (although the use of a bracket in the denominator sometimes saved the situation). It was by attention to these small details that the A grade students gained their superiority, typically losing 1 mark at most whereas the weaker students usually lost up to four.

In Section B, the distinctions between A* and A, and between A and E become more pronounced. The majority of the students earned full credit for their answers to B1(a) and it was rare to find a script where a wrong read off had been taken or where the x or y steps in the gradient calculation were too small. E grade students could make little progress with part (b) but the A* and some of the A grade students distinguished themselves by appreciating that R was the resistance in parallel with the $5600\,\Omega$ resistor, thus when T_0 was being measured R was infinite. In question 2 the distinction between A and E students was very marked, the former paying closer attention to the wording of the questions and framing their answer accordingly, e.g. in 2(a)(ii) where good students used numerical data from Figure 6 to illustrate their argument. In 2(a)(iii) very few E grade students saw that when the voltmeter reading had fallen by 75% two half lives had elapsed and 2(a)(iv) exposed poor understanding about the way a data logger gathered data; no credit was given for the idea that a data logger took continuous readings or for saying that the sensor had a very high sample rate. Good students made short work of parts (i) to (iii) in question 3 but most stumbled in (iv) where even the better students evaluated the uncertainty in T rather than in $10T$. Weaker students were only really secure with part (ii). Question 4 defeated most weak students who scored, if at all, on part (a) and made only a qualitative attempt at (b) which could get no credit. Many who were able to make a worthwhile attempt at (b) were often completely successful and this was an area where the A* students were able to clearly assert their ability.

The impression gained is that the better students are performing at about the same level as last year and the more accessible nature of Section A Part 2 helped all the students, resulting in a distribution that may be marginally more compressed than in 2011. The strongest students are very well prepared and they found plenty in these questions to show their capabilities. The number who gained at least 50 raw marks is significantly higher this year.

Section A Part 1

Question 1

Students investigated the oscillations of a ball bearing on the concave surface of a spherical mirror and used their measurements to determine the radius of curvature, R_1, of the mirror.

In part (i) students made measurements using a micrometer screw gauge to find the radius of the ball bearing. Most took the minimum of three repeats that we required but some did not convert the raw (diameter) readings to produce the radius, although this error was not penalised until part (iii). The central problem for some was taking the reading on the sleeve (fixed scale) part of the instrument; many students produced readings of a suitable precision but in error by 0.5 mm. A minority gave their readings to 0.005 mm (to the nearest half division on the scale) and these gained no credit. Some Centres provide digital micrometers that read to 0.001 mm and where it was clear that all the students were using these, credit was given. In future EMPAs Supervisors will be required to indicate on the Centre Declaration Sheet that such instruments have been used.

In part (ii) the short period of the motion contrasted with the much longer cycle time of the oscillating ruler in the next question and students had to judge the appropriate number of repeats in each experiment. Both motions were damped so the duration of timing was limited but most produced repeated readings of multiple cycles that were judged to be adequate; we required at least 30 cycles for the ball bearing and at least 10 for the ruler.

In part (iii) the variety of answers produced by different Centres was such that a result for R_1 (and for R_2 in Question 2) anywhere between 62 mm and 92 mm was accepted. Within Centres the range of values was much less diverse as might be expected for mirrors that had come from the same packet. The calculation could go wrong for two reasons: mixing units (ms^{-2} for g and mm for r) produced answers that fell well below the range allowed. Otherwise, the wrong substitution of diameter rather than radius pushed the result a little higher than expected, although usually not outside the range; in such cases one of the two marks available was deducted.

Students who failed to supply a unit with their working (or result) for T_1 in (ii) or for T_2 in Question 2(i) lost a mark. The failure to supply any unit for R_1 in (iii) or for R_2 in Question 2(ii) was similarly penalised.

Part (iv) produced many answers that earned two of the three marks available. Many saw that by squaring and then rearranging the formula for T_1 an expression in the form $y = mx + c$ could be produced and R_1 could be obtained by reading one or other of the intercepts. The better students saw that Figure 2 showed the line stopping short of each axis and said that they would extrapolate the line while most simply said they would ‘find’ the intercept. Very few saw that the x intercept gave the result directly but the majority were happy to use the y intercept and then, as required, rearrange the algebra to show how R_1 would be obtained.

Students at the A/B boundary typically earned 5 out of 8 marks while E/U students typically earned 2 or 3 marks.

Question 2

Students inverted the mirror and balanced a metre ruler on the convex surface. Setting the ruler oscillating and determining the period of the motion, they used their measurements to determine the radius of curvature, R_2, of the convex surface of the mirror.

Part (i) was almost universally successful and the answers for R_2 in (ii) were usually in close agreement with those for R_1. Students could usually show how they positioned the fiducial mark in their sketch to (iii) but those who were unwise enough to attempt a 3D view often lacked the artistic ability to provide the evidence the examiner was looking for. Very few thought that the mark should be placed other than in line with the ruler when at equilibrium but credit was only given if part of the mark was beyond the free end of the ruler. In justifying the positioning of the mark, phrases such as ‘the ruler always oscillated through this point’ kept cropping up but the answer we were looking for is that this is the point where the ruler is moving fastest (so the transit time is least). Thinking that the question was asking them to say why the mark was placed at the end of the ruler, some students said that this was the place where the amplitude of the ruler is greatest.

In (iv) one mark was gained for using the tabulated data to calculate the mean of $20T_2$ (or of T_2) and the uncertainty using half the range; the latter idea is one that some Centres are still not getting across to their students. The final answer expected was 3.35% but truncated final (or intermediate) results could lose one or both marks.

Part (v) attracted mixed responses but the popular answers, that the thickness of the mirror was bound to make R_2 greater than R_1, and the expression for R_2 assumed the ruler had no thickness, were given full credit. The idea that T_1 was much less than T_2 so the percentage uncertainties are very different was given no credit: a good experimenter would adjust the number of repeats and/or repetitions to take account of this. Generic answers such as ‘different instruments are used in each case’, or ‘the damping in each situation affected the oscillations differently’, attracted no credit. Valid reasons why either or both motions may not be truly simple harmonic could get credit but such responses were few and far between.

The chances of getting all the tricky parts of this question correct were slim and very few, even at A* standard, could get full marks. Students at the A/B boundary typically earned 4 or 5 out of 8 marks while E/U students typically earned 3 or 4.

Section A Part 2

Students investigated the discharge of a capacitor through different combinations of resistors.
While it is inevitable that we will continue to ask questions about capacitor discharge, offering as such questions do, the opportunity to challenge students about the mathematics of exponential decay, it is difficult to find ways of getting discrimination in the practical aspects of the experiments. Any A2 student should have the basic competence and necessary practical skills to produce the data to generate a successful graph and this was undoubtedly the case here. Thus it was in the questions we were able to ask in Section B about the experiment that the discrimination was to be found.

In part (a) there was little to go wrong unless, as in one or two cases only, the student decided to connect clip P to clip Q thus shorting out the 5600 □ resistor. Failure to repeat the T_0 measurement led to the loss of one mark in part (b) although students that made this mistake were also going to lose the mark for failing to repeat their readings for T. Inconsistent tabulation of the raw timings between parts (a) and (b) was penalised by the loss of the SF mark in (b). Otherwise the only reason why marks could be lost was where the student had decided not to head up their table using R/□ and T/s but had chosen instead to write out a description of the variables. This is not only clumsy it invites mistakes through inappropriate choice of phrase (‘time for voltmeter to fall by 50%’was seen more than once) and this practise should be discouraged. Students should also be aware that the use of ‘secs’ as an abbreviation for seconds is not tolerated.

In part (c) students were told to ‘calculate values of $\dfrac{R}{R+R_0}$ that correspond to each of your values of T’ and to ‘record these data below’. Those that left their T values in the table in part (b) lost the tabulation mark. The SF mark was almost universal; the students either gave all the $\dfrac{R}{R+R_0}$ data to 2 sf or all to 3 sf and it was very unusual to find any of these results to be wrongly recorded.

There is little to add to the comments already made about the graphs. Some students used a false origin on the *T* axis to spread the points out but at A2 hardly any fails to show the origin correctly (unlike at AS). It is worth reminding students that when a point doesn't follow the trend it is worth checking; either the calculated value is in error or (more likely) the point has been misplotted. Examiners will check every errant point for such mistakes. Where marks were lost it was generally for any point further than 2 mm from the best fit line (the Q mark) or for the incorrect inclusion of /□ with the label on the vertical axis. Errors in this part of the EMPA can have calamitous effects on the student's mark but the signs are that most Centres are well-versed in the expectations and prepare their students for this aspect of the work very thoroughly.

Students at the A/B boundary usually earned at least 15 out of 16 marks and E/U students generally earned 13.

Section B

Question 1

Since last year we have tightened the criteria for marking of gradient calculations. No credit is given in (a)(i) if either read off was incorrect and full credit was withheld if the steps were of insufficient size. Notwithstanding, the majority gained both marks with many either marking the read offs on the graph or showing these in the calculation. Not only does this make the work of the examiner much simpler, it helps the student guard against transcription errors.

In (a)(ii) many completely successful answers were seen although truncation to 2 sf or the incorrect inclusion of a unit cost marks.

In (b)(i) it was clear that many forgot that *R* was the resistance of the resistor placed in parallel with 5600 □. Many students gave 5600 □ as the value of R when $T = T_0$ although large numbers also gave 0 □.

All was not lost in (b)(ii) because it was possible to see that $\frac{R}{R+R_0}$ should be 1 when $T = T_0$ although how students reconciled this with their answer to (b)(i) is unclear.

Students at the A/B boundary usually earned 4 out of 6 marks and E/U students generally earned 2 or 3.

Question 2

Part (a)(i) was straightforward for most although credit was not given unless some reference was made to Figure 6 and some thought that the sample rate was the gradient of the graph.

Part (a)(ii) was a struggle for the students and often for the examiners who had to make sense of what they wrote. Some students thought the difficulty in measuring *T* was to do with the rate at which readings were changing, but this never varied from 2 Hz. Phrases such as the voltmeter readings 'are discrete' or 'become more precise as the readings get less' attracted no credit. The idea that the voltmeter reading only showed the true pd across the capacitor at the instant the sample was taken was only grasped by a few but it was these students who generally spotted that the 2.5 V reading that we needed to see in order to stop the watch was never shown in the sequence represented in Figure 6. Only students who included this quantitative detail, or said that the 2.5 V value occurred between 5.5 s and 6.0 s could gain both marks.

For full credit in part (iii) students had to explain how *T* could be obtained if the time for the voltmeter reading to fall by 75% was measured (this effectively measures two half lives) and explain why this reduced uncertainty (they needed to say that the measured time is now longer so the percentage uncertainty in the measurement (of 2*T*) or the (absolute) uncertainty in the result for *T* was reduced). Careful use of language was essential and students frequently made a slip that rendered their answer useless. Common errors were to say that the half life could be found by multiplying the time for the reading to fall by 75% by 2/3 and others said that uncertainty would be reduced because the rate at which the pd changed was less (after 2*T*) which made the voltmeter easier to read.

Part (b)(i) was more straightforward but there were still pitfalls, particularly for those who either had not seen data logging done, or had not had the process explained to them in enough detail. The common errors here were to say that the logger collected data continuously or to claim that the sensor had a sample rate.

Most gained the mark in (b)(ii) for saying the error was systematic (some even knew enough to say that it was a ‘percentage systematic error’ and ‘zero error’ was also accepted.

Answers in (b)(ii) could be spoiled by contradiction or evasion; unless they gave a definitive opinion about the suitability of their voltmeter, mentioning that their graph had a straight line like the high resistance meter in Figure 8, they could gain no credit. Several students thought they needed to make a comparison between the gradient of their line and that of the lines shown in Figure 8 so the statement that ‘my graph is like that of the high resistance voltmeter’ was not good enough.

Students at the A/B boundary usually earned between 4 or 7 out of 8 marks while E/U students could generally earn only 1 or 2.

Question 3

Part (i) was done well and many gave the required answer with a suitable unit, whether in m, mm or □m.

Part (ii) was even more successful although answers of more than 4 sf were penalised. Some gave 80.8 mm rather than the expected 80.6 mm; these were not accepted as the method of calculation involved a false step.

Part (iii) discriminated well in favour of those who knew the rule for combining percentage errors in the case of a product or quotient.

Part (iv) was generally unsuccessful, most students wrongly providing an answer in percentage terms or giving the uncertainty for T rather than for $10T$ as instructed.

Very few students could obtain the full 4 marks although this was not always because they failed in (iv).

Students at the A/B boundary usually earned 2 or 3 marks while E/U students generally earned 1or 2.

Question 4

As mentioned in the previous report students are still expected to apply the basic standards and conventions applied in Section A Part 2 whenever graphical skills are required in other parts of the paper.

In part (a) two smooth curves, continuous through each set of five points were expected (although a few drew two straight lines); many drew these curves without care, either missing points or using thick or hairy lines. Centres should be aware that the art of curve drawing is a skill that we will continue to examine. The equilibrium position could be deduced from the median line between the curves but it was surprising to see how many could not draw this, either parallel to the grid lines or at a required position (15.7 ± 0.1 cm) for credit to be given.

For some part (b) was a step too far and for those providing no quantitative working, offering instead statements like ‘both curves tend towards the asymptote’, there was no credit. However, the many able students who knew how to proceed often distinguished themselves and this part of the paper provided excellent discrimination. Clear working based on the use of amplitudes rather than the positions y_t or y_b, were expected and a number of valid solutions were seen, although these had to provide consistent and valid proof that the amplitude of the oscillations decayed exponentially.
The A* students would frequently earn 4 or 5 marks while students at the A/B boundary usually earned at least 2 marks (although these students were also well represented at each of the higher marks). E/U students generally earned 1 and sometimes 2.

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