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Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Report on the Examination

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GCE Physics, Specification A, PHYA4, Fields and further mechanics

General Comments

There were about 10,000 candidates entered for the unit 4 in January 2011. Section A originally consisted of 25 objective test questions (worth one mark each), but question 15 was discounted in fairness to the candidates because of a printing error in the equation for electric potential in the *Data and Formulae Booklet*. AQA regrets the presence of this error, and recognises the inconvenience to centres caused by having to bring the deletion of question 15 to the candidates' attention by an erratum notice. As usual, Section B was worth 50 marks and contained five questions.

The mean pre-test facility of the Section A test questions was slightly lower than those for the two 2010 objective tests, suggesting that this test was marginally more demanding. The mean point biserial value was practically identical to last year's values. The mean values of facility and discrimination index from the candidates' actual responses on Section A were in line with expectations.

In Section B, the examiners were again pleased to see excellent answers from some candidates, whilst it became evident that a small minority could achieve very little. This could be because they had been entered for the unit 4 examination prematurely, with insufficient time to consolidate their learning.

Section A

Keys to Objective Test Questions

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
B	A	C	D	C	C	C	B	D	B	B	A
13	**14**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
D	D	C	A	A	D	B	B	D	A	A	C

The *facility* of a question is a measure of all candidates attempting a question who choose the correct option. The mean facility of this paper was 63%. The facility for individual questions ranged from 86% for question 17 to 40% for question 21. For the purpose of monitoring standards over time, objective tests contain a proportion of questions that are re-banked after satisfactory use in an earlier examination. After question 15 had been excluded, this test contained six such questions, with a mean facility of 60% when last used. The eighteen new questions had all been pre-tested and had a mean pre-test facility of 46%. Candidates invariably produce higher facilities for the questions in a real examination than in the pre-testing situation. The improvement achieved on this paper for these questions on average was 16%. The mean facility of all of the re-banked questions also all improved, by an average of 6%.

The *point biserial index* of a question is a measure of how well the question discriminates between the most able and the least able candidates. The mean point biserial for this paper was 0.39. The new questions had a mean pre-test point biserial of 0.37, whilst the value for the re-banked questions was 0.45. Therefore, there was only a slight improvement in the discrimination of the questions; most of the re-banked questions gave very similar discrimination this time to that recorded when last used.

Eleven of the questions (questions 3, 5, 6, 7, 8, 13, 14, 17, 19, 23 & 25) proved to be easy, with facilities over 65%, whilst no question was found to be difficult.

Question 1 was a test of momentum and energy conservation laws for colliding trucks. Almost all candidates realised that momentum would be conserved in this situation. Two-thirds of candidates knew that kinetic energy would not be conserved and one third thought that it would be conserved.

Question 2 required candidates to find the linear speed of a point on the edge of a spinning disc. This is a two-stage calculation involving $\omega = \theta/t$ and $v = \omega r$. Candidates also had to appreciate that 30° is equivalent to $\pi/6$ rad, and that the radius of a disc is half of its diameter. 49% the candidates arrived at the correct response, whilst a quarter of them chose distractor B, indicating confusion between *d* and *r*.

Question 3 was the first of the re-banked questions from a previous examination. Three-quarters of the candidates were able to correctly combine $v = 2\pi f r$ with $E_k = ½ m v^2$ to arrive at the required algebraic result. Distractor D attracted one in eight responses, suggesting that the factor of ½ had been overlooked.

In **Question 4** candidates had to know how the acceleration-displacement relationship for a simple harmonic oscillator translates into a graph; linear but having a negative gradient. Slightly less than half of the candidates chose the correct response. Almost as many chose distractor A, which would be the potential energy-displacement graph.

Questions 5 and **6** were also concerned with simple harmonic motion. Candidates found question 5, which had appeared in a previous examination, slightly easier than last time; three-quarters of them successfully applied $a = (2\pi f)^2 A$ to give the correct answer. This was the most discriminating question in the examination. Question 6 was another easy question, the correct kinetic energy-time graph being recognised by over 80% of the candidates.

Calculation of the *additional* mass to be placed on a vertical spring in order to increase the period of oscillations by half was the task in **Question 7**. 66% of the candidates did this correctly. Distractor A (where the value was 0.25 kg instead of the correct 1.25 kg) was the most popular alternative; it was chosen by about one-sixth of candidates.

The next group of questions was on the topic of gravitation. **Question 8**, involving a rearrangement of the force equation from Newton's law, had a facility of 77%.

Question 9 was about the value of the gravitational field strength at the mid-point between two equal masses; surprisingly, only 60% of the candidates knew that this would be zero.

Question 10 was a re-banked question about the gravitational potential and angular velocity at two points whose height above the Earth's surface was different. The outcome was a very similar facility to that obtained on the previous occasion, with half of the candidates appreciating that the point at greater height would have greater V but the same ω. More than a quarter of responses were for distractor C (greater V, smaller ω) and almost a fifth for distractor A (both V and ω greater).

Question 11 required familiarity with the idea that a body appears to become weightless when its centripetal acceleration is just equal to the local value of the acceleration due to gravity. Hence, if this were to happen at the surface of the Earth, $\omega^2 R$ would have to equal 9.81 m s^{-2}. The question had a facility of 55%, but one in five candidates selected distractor A.

Question 12 had a very similar facility to question 11. It required candidates to select an *incorrect* statement about what would happen to a comet as it approached the Sun. Distractor C was chosen by 31% of the candidates; this suggests they thought that the comet would make a line-of-centres approach instead of looping around the Sun.

Almost three quarters of the candidates chose the correct answer in **Question 13**, which was a fairly direct test of Coulomb's inverse square law.

Question 14, requiring a combination of $F = EQ$ and $F = ma$, was the most discriminating question in the test; its facility was 67%.

Question 16, another reused question, combined Coulomb's law with Newton's law of gravitation and needed candidates to take data from the *Data and Formulae Booklet*. On this occasion, it proved to be only slightly more demanding than question 14 and it was almost as discriminating. The incorrect responses were distributed fairly evenly across the three remaining distractors.

Question 17 was the easiest question in the test, with a facility of 86%. The candidates were obviously competent when applying the equations $C = Q/V$ and $E = \frac{1}{2} C V^2$ to find the capacitance and energy stored from data on the graph of charge against pd.

Question 18 had been used in an earlier examination. Its facility of 58% this time was a slight improvement on that achieved previously. Either arithmetic errors, or failure to account for the 10% efficiency, were probably responsible for almost a quarter of the candidates choosing distractor C (0.50 m) rather than the correct 0.05 m.

Questions 19 and **20**, with facilities of 67% and 62% respectively, were both about charged particles moving at right angles to a magnetic field. Relatively few candidates chose any one of the incorrect responses in question 19, but distractor A (parabolic path) in question 20 attracted 29% of the responses.

The most demanding question in the test was **Question 21**, about the change in flux linkage when a coil is rotated in a magnetic field. 40% of the responses to this question were correct. Distractors C and D were each selected by almost a quarter of the candidates; this is probably because they considered the flux linkage to be zero when the plane of the coil was perpendicular to the magnetic field.

The most common incorrect response in **Question 22** was distractor C, which accounted for 25% of the answers. This wrong choice is likely to have been caused by trying to work out the emf across the wing tips of a moving aircraft using the equation $E = B L v$, rather than finding the *magnetic flux cut* by the wing of a moving aircraft, as required by the question. However, 59% of the candidates chose the correct answer. This question discriminated well between the most able and the least able candidates.

Question 23 had been used in a previous examination. Its facility in 2011 was 82%, an improvement on the previous result of over 10%. Evidently, the candidates this time readily recognised that the falling magnet would lose energy to the conducting ring only when the ring was complete, enabling the emf induced in it to cause a current.

Question 24 was a fairly demanding test of candidates' knowledge of transformers; slightly fewer than half of them selected the correct answer. Among the incorrect responses, distractor C was a common choice (23%), showing that the flux linkage ratio was better understood than the current ratio.

Transformers were also the subject under test in **Question 25**, where 68% of the responses were correct. This was a fairly straightforward calculation involving transformer efficiency.

Section B

General Comments

Candidates found it relatively easy to score marks in some sections of this paper, such as parts (a) and (b) (i) of question 2, parts (a) (i) and (ii) of question 4 and part (a) (i) of question 5. Their knowledge of basic definitions, uniform electric fields, and Fleming's left hand rule was therefore good. Their performance on calculations was more variable, ranging from excellent, in parts such as question 1 (a), to poor as exemplified by many responses to question 4 (b) (ii).

This paper contained more questions with a synoptic element than the corresponding paper in 2010. Unit 2 was revisited for the uniform acceleration equations in question 3 (a) and (b), for equilibrium conditions in question 4 (b), and for knowledge of stationary waves in question 5 (c). Many candidates were untroubled by these tests of their established knowledge.

On this occasion, examiners were pleased to see improved responses to the question where the quality of written communication was assessed (question 3 (a)). However, this may be partly due to the fuller guidance given in the question about the aspects to be addressed in candidates' answers.

Less able candidates continue to lose marks in calculations by presenting their answers in such a disorganised way that examiners are unable to follow their working. Once again, it is necessary to emphasise that marks are awarded for steps in the working of calculations; at this level, this ensures that partial credit can be given for incomplete or incorrect solutions to this type of question. Obviously no marks can be awarded when no working is shown.

Another ongoing problem concerns significant figures. The issue of using an appropriate number of significant figures is now addressed only in specific parts of a paper. Careless use of the number of figures written down in other questions can lead to unsatisfactory answers that cannot be rewarded. In particular, examiners have noticed a tendency by some candidates to limit their answer to **one** significant figure. This is not acceptable.

Question 1

This question as a whole was very rewarding for the candidates who were sufficiently familiar with the principles of gravitation to understand the mathematical conditions for a satellite in stable orbit, as required in part (b) (i). These candidates made good progress with all parts of the question, whereas many other candidates were only able to score well on parts (a) and (b) (ii). In part (a), the correct conversion of the orbital time of the Hubble satellite into seconds followed by correct use of $\omega = 2\pi/T$, with a correct unit for angular speed, brought full marks for the majority of the candidates. Confusion of angular speed ω with linear speed v continues to be a problem, and giving the unit of ω as $\mathrm{m\,s^{-1}}$ inevitably caused the loss of one mark.

Part (b) (i) required candidates to appreciate that the radius of the orbit of a satellite can be found from the orbit equation $GMm/r^2 = m\omega^2 r$. The angular speed ω had been determined in part (a), whilst the values for G and the Earth's mass M could be taken from the *Data and Formulae Booklet*. Because the question had indicated that the Hubble telescope is in orbit close to the Earth, some candidates assumed that the radius of its orbit would be that of the Earth, 6.37×10^6 m.

Another common unsuccessful response was to attempt to determine the answer using the orbit relationship T^2/r^3 = constant, incorrectly treating the surface of the Earth as a satellite orbit and using T = 24 hours and $r = 6.37 \times 10^6$ m.

Candidates who used $F = m\omega^2 r$, or $F = GMm/r^2$, had very little difficulty in part (b) (ii), where both marks were still accessible to those who had worked out wrong values for ω and/or r in the earlier parts of the question. Attempts at this part using $F = mv^2/r$ were often incorrect because of inability to correctly work out the linear speed, v.

Question 2

In this question candidates needed to appreciate the distinction between *momentum* and *change of momentum*. In part (a), for example, the force is not the momentum per second but the *change of* momentum per second. Parts (a) and (b) (i) were answered well. In (b) (i) either 'impulse' or 'change of momentum' were accepted as a correct answer, 'momentum' was not accepted because it would only be true for a body initially at rest.

In part (b) (ii), a great variety of methods were used to estimate the area under the force-time graph, and most candidates seemed able to work towards an acceptable value. Common errors were incorrect scaling factors when changing the number of counted squares into an impulse, and overlooking the 10^{-3} in milliseconds. The unit of impulse, which was required for the fourth mark, was less well known than that of angular speed in question 1 (a).

Part (b) (iii) required care over signs when calculating the change of momentum; since the ball was stated in the question to return along its approach path it follows that u and v are in opposite directions and take opposite signs. This difficulty caused a high proportion of candidates to end up with an incorrect value for v, typically $36\,\mathrm{m\,s^{-1}}$ instead of $16\,\mathrm{m\,s^{-1}}$. Examiners were expecting the final answer to be given to two significant figures, consistent with the data given in the question, but many candidates gave three.

Part (c), where candidates had to discuss the consequences of the same impulse on a higher approach speed, proved to be quite challenging. Some very good well-reasoned answers were seen. The principal conclusion, provided the ball still returns off the boot, had to be that its resulting speed would be lower. This is readily seen by realising that the initial momentum of the ball is greater but the change in momentum is the same. Credit was given for worthwhile principles in these answers, even if the wrong conclusion had been reached over the final speed. Examiners were pleased to see some rather profound answers which pointed out that, depending on how large the new approach speed, the ball could be stopped by the impulse or even continue in its original direction.

Question 3

Part (a), which was about a student's proposed experimental arrangement for measuring the acceleration of a cylinder down a slope, was also a test of candidates' quality of written communication. Answers were rather better than those on the quality of written communication questions in the 2010 unit 4 examinations. Perhaps this is because candidates now have a clearer idea about what is expected in this type of question and are making greater efforts to address these requirements, or perhaps this question may have been more accessible because it involved an experimental technique. The main errors saw candidates not answering the specific aspects posed in the question; what procedure should be followed, what measurements should be taken, and how would these measurements be used to calculate the acceleration? Less able candidates in particular, ended up writing much of their answer about how the circuit would work. Common misconceptions over measurements included the need to measure the mass of the cylinder, or the angle of the slope. Some candidates thought the time should be measured with a stopwatch rather than by the intended discharge circuit, whilst others thought there would be value in repeating the measurements for a different angle of slope. The best answers were usually brief and to-the-point, showing excellent understanding of what this experiment would involve.

The need to measure the distance from S_1 to S_2 was sometimes overlooked. The omission of any reference to the calculation of acceleration was a serious error and tended to limit the mark that examiners could award. Among the answers making an attempt to show how a could be determined, a frequent error was to suggest that this could be done by dividing the *average* speed by time rather than by dividing the *final* speed (ie twice the average speed) by time. The more successful answers were those using $s = ut + ½ at^2$, with u taken to be zero.

Many candidates achieved full marks in parts (b) (i) and (ii), showing confidence in solving an exponential equation to determine the time and then applying an appropriate uniform acceleration equation to calculate a. Some of the less convincing attempts to solve the exponential equation omitted the essential minus sign in $t = -RC \ln (V/V_0)$. A small proportion of the candidates used $\log_{10}$ rather than $\log_e$, therefore ending up with the incorrect answer. Many attempts at part (b) (ii) received no credit because the acceleration was found by dividing the *average* speed by the time of descent – the error already noted in part (a).

Question 4

Calculation of the electric field strength in a uniform field by using $E = V/d$ were known well in part (a) (i), as was finding the force on a charge using $F = EQ$ in part (a) (ii). Most candidates therefore achieved full marks in these parts. Answers to the force diagram in part (b) (i) were much less satisfactory. Examiners were expecting to see three clearly labelled force arrows, starting on the ball, showing the electrostatic force to the left, the weight of the ball downwards and the tension acting upwards along the thread. Careless drawing and inadequate labelling caused marks to be lost in a majority of answers. When labelling the downwards force, 'weight', '*W*' or '*mg*' were acceptable, whereas 'gravity', 'mass' or '*g*' were not. The tension force was often omitted, whilst additional horizontal forces such as 'centripetal force' were sometimes shown.

In part (b) (ii), some evidence was expected for the appearance of the equation $F = mg \tan \theta$. This could be from a consideration of the resolved components of the forces acting, or from a force diagram showing θ clearly. Many good answers were seen, but a large proportion of the candidates could make little or no progress.

Question 5

Most candidates were able to use Fleming's left hand rule in order to give the correct force direction in part (a) (i). Sometimes a candidate's answer was contradictory and went unrewarded, for example 'downwards towards the S pole'. Most answers to part (a) (ii) were reasonably good when explaining why the wire would vibrate, but rarely explained why these vibrations are *vertical*. An explanation by reference to the mutually perpendicular field, current and force directions was required in a complete answer. The reversal of force direction with change of current direction was well understood. Fewer candidates made reference to the continuous current reversals brought about by ac causing the process to repeat, or to the fact that the size of the current affects the magnitude of the magnetic force.

It was evident that a large number of candidates had made a second, more enlightened, attempt at part (b) once they had realised that direct substitution of $I = 2.4\,\text{A}$ into $F = BIL$ did not lead to the value of force (about 40 mN) they had been asked *to show*. Once they realised that the maximum force is caused by the peak current, it became a straightforward matter to secure three marks.

The final part of the question, part (c), involved the resonance effect observed when the wire is supplied with ac current at the frequency of its fundamental vibration. Resonance was usually mentioned, but fewer candidates used the values provided in the question together with $c = f\lambda$ to give a wholly convincing account of why the wire would vibrate in its fundamental mode at 80 Hz.

A large number of candidates had forgotten that the fundamental condition would be $L = \lambda/2$ (this should be studied in unit 2). After using $c = f\lambda$ with $\lambda = 0.40\,\text{m}$, they concluded that the frequency of waves on the wire would be 160 Hz. These candidates then attempted to argue that resonance would occur at 80 Hz because 80 is one half of 160, not understanding that if 160 Hz was the fundamental frequency, no frequency lower than 160 Hz could possibly set the wire into resonance.

Mark Ranges and Award of Grades

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