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General Certificate of Education

Physics 2450

Specification A

PHYA4 Fields and Further Mechanics

Report on the Examination

2010 examination - June series

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GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

General Comments

This is the first June test of Unit 4 of the present Physics A specification. Section A (on which candidates are advised to spend around 45 minutes) consists of 25 objective test questions worth 1 mark each. Section B (on which candidates are advised to spend around 1 hour) is worth 50 marks and on this occasion contained 5 questions.

In Section A, the objective test containing 25 multiple choice questions, the mean pre-test facility was slightly lower than that for the January test paper. This indicates that the test was a little harder.

In Section B, some competent work was seen, but candidates' answers on descriptive questions were often disappointing. Most found it much easier to score marks on calculations, where the main failings were careless working and the inadequate presentation of intermediate steps.

Section A

Keys to Objective Test Questions

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
C	B	D	A	D	B	B	A	A	D	B	D	A

14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
C	B	C	C	D	B	D	D	C	B	A	A

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 59%. The facility for individual questions ranged from 88% for question 6 to 28% for question 14. 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. This test contained seven such questions, with a mean facility of 63% when last used. In the June 2010 test their mean facility was 65%. 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, causing the mean facility of the new questions to rise to 57%.

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 0.44. These statistics show that there was no discernable improvement in the discrimination of the questions. All of the re-banked questions actually produced inferior discrimination this time to that recorded when last used.

Eight of the questions (Questions 3, 6, 10, 11, 15, 17, 20, and 23) proved to be easy, with facilities over 65%. One question alone (Question 14) was found to be difficult because its facility was less than 35%.

Question 1 was a test of the 'impulse = change of momentum' relationship. Almost two-thirds of the candidates selected the correct response. Nevertheless, 25% of candidates chose distractor A, showing a failure to understand the distinction between a change and a rate of change. This error was even more evident in Question 5 of Section B, which involved the laws of electromagnetic induction.

The surprising outcome of **Question 2** was that just as many candidates chose the wrong answer as the right one. This seems to have been caused by careless working. Forgetting that the mass of the glider was 2000 kg could have led candidates to the conclusion that its velocity would be 100 m s^{-1} (distractor D) instead of 50 m s^{-1}, or perhaps they forgot the factor of ½ when finding the area of the triangle under the graph line. The facility of this question was 40%.

Question 3 tested the change of momentum of a gas molecule making an elastic collision with the walls of its container. Misunderstanding the vector nature of momentum, and therefore of the change of momentum, was responsible for the 21% of candidates who chose distractor A. Their reasoning is likely to have been that $mv - mv = 0$, rather than the correct $mv - (-mv) = 2mv$, which 69% of the candidates selected.

Question 4 was the first of a pair of questions on circular motion, both of which had appeared in previous examinations. The main failing exhibited in the responses was the fact that the ball, once it had broken away from the string, would fall under gravity. Only answer D offered the possibility of some vertical motion and it was chosen by 40% of the candidates. Distractors A and C each attracted 28% of the answers. Candidates found the quantitative content of **Question 5** on circular motion more to their liking, because 63% of them chose the correct answer. Both of these questions gave statistics which were very similar to those obtained when last used.

The next three questions were on simple harmonic motion. At first sight, **Question 6** does not appear to be easy – albeit it that a correct answer only requires care when working out the result from three values substituted into $v = \pm 2\pi f\,(A^2 - x^2)$. Yet, as on the previous occasion when this question was used, it turned out to have the highest facility on the paper – it was 88% this time. In **Question 7**, 64% of the responses were for the correct shape of E_k against x curve. By selecting distractor B, 25% of the candidates showed that they understood the trend of the E_k behaviour but not the exact form of it. Knowledge of both the simple pendulum and the mass-spring system was required in **Question 8**. Application of the time period formulae should have led students to conclude that, since under the new conditions $T_{pendulum} = 2T_{spring}$, the new pendulum length should be four times greater than the new mass on the spring. 62% of the candidates made this correct choice, but (like the preceding question) this question did not discriminate well between the candidates.

Questions 9 and **10**, involving gravitational fields, were reused questions from previous examinations. The candidates in 2010 found Question 9 to be slightly easier than their predecessors, with the facility advancing from 55% to 59%. One in four candidates demonstrated their confusion with magnetic fields by opting for distractor C, where the force was perpendicular to the field. Question 10 was a direct test of the equation connecting field strength and potential gradient, $g = -\Delta V/\Delta r$. The outcome from this question was very similar to when it was last used; the facility was 72% and there were no particularly strong distractors.

In **Question 11**, equating the centripetal force on a satellite with the gravitational force on it should lead easily to a correct algebraic expression for the speed. Two thirds of candidates were successfully able to do this.

Question 12 represented a slightly unfamiliar situation for the students. Normally they would be much more accustomed to dealing with the force between point charges than with the force between a point charge and a charged plate. The clue to a correct answer came from the equation representing Coulomb's law, $F = Q_1Q_2/4\pi\varepsilon_0 r^2$. 64% of candidates spotted this.

Question 13 required candidates to appreciate that, for the total potential to be zero at the chosen point, the magnitude of V due to the +4 μC charge should be the same as the magnitude of V due to the –16 μC charge. This required (Q/r) to be the same and should give a distance ratio of 1:4. 58% of the candidates were able to work this out correctly, which is 5% lower than when this question was last used in an examination. Almost one in four of the candidates chose distractor B, suggesting that the distance ratio would be 1:2. Question 13 was the worst discriminator in this examination.

There is no doubt that **Question 14** made appreciable mathematical demands, but it is surprising that the facility declined from 38% when pretested to 28% in this examination. This made it the most demanding question on the paper. Candidates should have seen that the contributions to V from the charges at top left and bottom right would effectively cancel. This then meant that the total potential would be double that due to one of the remaining charges. Application of Pythagoras leads to the distance r being $\sqrt{2}\,a$. Guesswork is probably the explanation for as many as 32% of the responses being for distractor D, which was no more than the simple potential equation $V = Q/4\pi\varepsilon_0 r$ with $r = a$.

Question 15 had appeared in a previous examination paper. Students now appear to be much more confident when dealing with a capacitor that is charged by a constant current, and so the facility of 73% was 13% higher than when the question last appeared. The constant current idea also cropped up in **Question 16**, which was rather more demanding. Combining $Q = CV$ with $Q = I\,t$, and appreciating that Q will fall by 10% when V falls by 10%, ought to have brought a satisfactory outcome. Just about half of the candidates succeeded with this, and wrong answers were mostly split between distractors B and C.

Questions 17 and **18** were about capacitor discharge through a resistive circuit. The first of these was answered correctly by 66% of the candidates. The most popular incorrect response was distractor B, which showed the correct shape for the discharging section but had the wrong shape for the charging section. Question 18 was the best discriminator on this paper. Its facility was 59%. Satisfactory answers required the equation $0.5 = e^{-10/RC}$ to be solved for RC. Not even confusion with 'half life' could account for the 26% of candidates who chose option B, 5 s.

The remaining questions all tested various aspects of electromagnetism. **Question 19** involved a basic current balance and assumed familiarity with $F = B\,I\,l$. The simple idea here was that reversing the current and doubling it would produce a force in the opposite direction that would be twice the original. This eluded so many of the candidates that only 41% of them could select the correct response, whilst many of them chose distractors C or D. The principles of the magnetic deflection of an electron beam by a magnetic field were well understood in **Question 20**, where 73% of the candidates made the correct choice. Almost one in five candidates chose distractor D, an obvious confusion over the shape of the curved path.

Question 21 could be answered by applying Fleming's left hand rule to a beam of positive ions. Around half of the responses were correct, but a quarter were for distractor A (which was upwards, instead of downwards). **Question 22** contained a synoptic element, because two of the unit combinations quoted were mechanical. The facility of the question was 44%. Overlooking the word *not* in the stem of the question presumably caused 34% of the candidates to choose distractor A, where $F = B\,I\,l$ ought to have shown that A T m is a *correct* unit of force.

Question 23 was easy, with a facility of 73%. It was a direct test of $\varepsilon = N\,(\Delta\Phi/\Delta t)$ in a graphical context. The most common incorrect answer was distractor A. A coil which was rotating in a magnetic field was the subject being tested in **Question 24**. This was successfully answered by 57% of the candidates. Incorrect answers were almost equally divided between distractors A and B, with very few for distractor D.

Knowledge of the efficiency of a transformer was tested in **Question 25**, which had a facility of 58%. The output power from the transformer must have been 60 W, because the lamp was lit at its normal brightness. The turns ratio indicated that the primary voltage was 23 V, whilst the question stated that the primary current was 2.7 A. Hence the input power could be found using 2.7 × 23 = 62.1 W. 25% of the candidates chose the incorrect distractor B.

Section B

The general comments made at the start of the report on Section B of the January 2010 Unit 4 test remain just as valid in relation to candidates' attempts at this second test of the new specification. Answers to numerical sections were usually approached much more confidently, and completed much more competently, than those to parts requiring description, explanation, or even straightforward recall.

Mathematical errors soon emerged in the work of less able candidates. Examiners were surprised by the large number of candidates in the final year of an A level course who could not successfully rearrange a simple equation such as $E = V/d$, who could not use a calculator to arrive at a correct numerical answer, or who set out their work in such a disorganised manner that their working could not be followed.

Working remains an essential part of most calculations. When candidates' ideas are set out clearly and logically, examiners are often able to give some credit for their attempts, even when the final answer goes wrong. When no working is shown, this is not possible and generally candidates do not gain credit for their responses.

The use of an appropriate number of significant figures is now tested in specific answers and on a limited number of occasions (just one in this paper). Unfortunately, this has tempted many students to quote 8 or 10 figures in some other final answers. Although this does not affect candidates marks on particular questions it is worth pointing out to candidates that they are wasting precious examination time by writing down so many unnecessary numbers. At the opposite extreme, other candidates reduced their final answer to just *one* significant figure. When this was equivalent to an arithmetical mistake, by taking the answer outside acceptable limits, no credit was given for the answer. It is important to encourage students to write down their final answers to at least two, but usually no more than three, significant figures.

Part (a) of Question 3 was used to assess the quality of candidates' written communication according to a new framework which was adopted for this new specification. Evidence, from both the January and June sittings of Unit 4, shows that students have difficulty in satisfying the requirements of the scheme. Perhaps time pressure in the examination is a contributory factor, but the majority do not seem able to organise their ideas sufficiently well to be able to express scientific ideas clearly and coherently. The new assessment method was introduced to try to address the common complaint that scientists cannot communicate effectively. Answers seen thus far from many of the students taking Unit 4 lend much credence to the complaint.

Question 1

Many correct statements of Newton's law of gravitation were seen in part (a). Some candidates referred to just one aspect of the law ($\propto M_1M_2$, *or* $\propto 1/r^2$, not both together) and only received one mark. A reference to point masses – which helps when explaining the meaning of r – was not common. In fact a clear understanding of the meaning of r was expected in satisfactory answers. The common inadequate responses, when neither was more fully explained, were 'radius' and 'distance'. Candidates who tried to rely simply on quoting $F = GM_1M_2/r^2$ were awarded a mark only when the terms in the equation were correctly identified; a further mark was available to them if they gave a clear definition of r or referred to the nature of the force as attractive.

Part (b) (i) could be approached using either 'mass = volume × density' or 'mass $\propto r^3$'. The first method was far more common, and most answers were satisfactory. On this paper, this was the first example of a question requiring candidates to 'show that…' Convincing answers to this type of question should include the fullest possible working, in which the final answer is quoted to one more significant figure than the value given in the question. Here, for example, a value of 47.3 kg was convincing. Part (b) (ii) also proved to be very rewarding for most candidates. Common errors here were failing to square the denominator, or to assume that surfaces in contact meant that $r = 0$ (whilst still arriving at a finite numerical answer!).

Whilst many correct and well argued answers were seen in part (c), it was clear that some candidates had not read the question with sufficient care. Two requirements for a satisfactory answer ought to be clear from the wording of the question: the need to give a *quantitative* answer, and to confine the answer to *the effect on the calculations in part (b)*. 'Calculations' (plural) was a strong hint that the mass of both spheres would be affected, but there were many answers in which it was assumed that the masses would not be changed. This meant that a maximum mark of 1 out of 4 could be awarded, for the $1/r^2$ relationship alone. The incorrect use of language sometimes also limited the mark that could be awarded for the answers here: candidates who stated that doubling the separation would reduce the force '*by* one quarter' could not be credited with a mark.

Question 2

Far fewer correct answers were seen to part (a) (i) than might have been expected. Deducing the correct direction for the electric field involved spotting that the electrostatic force on the sphere acted upwards, and that the sphere carried a negative charge. The vast majority of answers to part (a) (ii) showed that students had not forgotten Hooke's law from Unit 2 of AS Physics; 0.24 × 0.018 readily gave 4.32×10^{-3} N. Part (a) (iii) was also well answered, either by combining $F = EQ$ and $E = V/d$ before inserting numbers, or by working out E, and then d, separately.

Attempts to answer both sections of part (b) showed that many candidates had little understanding of what would happen when switch S was moved to position **Y**. The fact that the immediate effect would be to short out the plates, causing them to discharge and therefore reduce the field strength to zero, escaped a very large number of candidates. Common answers to part (b) (i) were that the field was reversed, or that the field became an alternating one. Answers which suggested that an electric force would still be acting received no further credit in part (b) (ii). What was required here was an understanding that, when the field was removed, the sphere would fall under its own weight, extending the spring downwards. The resultant force on the sphere would be proportional to the change in the extension of the spring, producing an acceleration that was proportional to the displacement from equilibrium but acted in the opposite direction to the displacement ie the condition for shm.

Question 3

It was evident from their attempts at part (a) that during their courses many candidates had considered the application of conservation of momentum to events involving an explosion. It was less clear that they had ever considered an explosion that takes place in a moving object, or considered how conservation of energy applies in an explosion. Consequently, part (a) of the question proved to be difficult, not least because it was unfamiliar territory for so many. Part (b), which was formulaic and involved much less original thinking, brought much more success for the majority.

In part (a) only a very small proportion of the candidates were able to produce answers that were well organised, coherent, detailed and contained correct physics to merit a 'high level' mark of five or six. More answers fell into the 'intermediate level' (three or four marks) and even more into the 'low level' (one or two marks). A major failing in most answers was to overlook the question's requirement to address the two conservation laws '*in this instance*'. For a high level answer, it was necessary to consider *an explosion on a moving space vehicle travelling in a straight line in deep space.* All of the italicised section is significant. The system has momentum before exploding (unlike a straightforward recoil example); this momentum has to be conserved because there are no external forces in deep space. Hence the probe speeds up and the capsule must be ejected along the original line of movement (although it may not be possible to tell that this is 'backwards' until the calculation has been done). Forces between probe and capsule during the explosion are equal and opposite, but they are internal forces for the system. When considering momentum, it was common for candidates to conclude that 'momentum must be conserved because momentum is always conserved'.

In the explosion, chemical energy is converted into kinetic energy; this increases the total kinetic energy of the system, which is shared between probe and capsule. Examiners saw many very weak answers that showed total confusion – such as momentum being converted into energy, mass being converted into energy, or energy not being conserved. A serious omission in many answers was that of the word 'kinetic' before 'energy', whilst many answers referred to the event as an 'inelastic collision'. There was seldom any reference to conservation of the total energy of the system taken as a whole.

Most candidates recovered from their poor attempts at part (a) to gain all three marks for the calculation in part (b)(i). There were also many awards of full marks in part (b)(ii), where the main mistake was to calculate only the kinetic energy of the system (probe + capsule) after the explosion, and to regard this as the answer to the question. Apparently, the candidates who did this had not realised that the system had an initial kinetic energy.

Question 4

In part (a) the correct application of Fleming's left hand rule to moving electrons was a much sterner test than it ought to have been for A2 candidates. It seemed that responses were distributed almost randomly between the six alternative directions. Part (b) was the familiar test of whether candidates understood the significance of the directional nature of velocity for a particle moving in a circle. The expected approach was to point out that a change in direction shows that velocity is changing, and that acceleration involves a change in velocity. Alternatively, it could be argued that the force on the electron always acts at right angles to its velocity, thus changing the electron's direction of travel and causing it to accelerate. Candidates with a superficial acquaintance with this situation tended to refer to centripetal force in their answers, without conveying any proper understanding of the directional nature of velocity.

As suggested by the question, the starting point for successful answers to part (c) (i) was the equation $BQv = mv^2/r$. Most candidates arrived at a correct result for the speed of the electron, by substituting either the separate values for e and m_e, or for the specific charge e/m_e, from the *Data and Formulae Booklet*. Calculation of the angular speed in part (c) (ii) usually caused little difficulty, but its unit was not always known: m s^{-1} was often written down. Those who had quoted m s^{-1} usually then got into difficulty in part (c) (iii), because they tried to find the orbital period by dividing the circumference of the circle by their value for ω/m s^{-1}. A particularly worrying error by many candidates in this part was a calculator error when trying to divide ω (= 7.55×10^7 rad s^{-1}) by 2π. This led to a final incorrect answer of 7.1×10^9 revolutions per minute, which appeared in a large number of scripts. The error appears to have been caused by an incorrect sequence of division and multiplication operations on calculators.

Question 5

A large proportion of the answers to part (a) were completely correct and quoted to the expected two significant figures. The most common error was to apply the principles correctly, but to give three significant figures in the final answer. Other frequent mistakes were to use sin 35° instead of cos 35°, to calculate cos 35 in radians instead of degrees, or to omit the cos 35° factor completely.

The confusion between flux linkage and rate of change of flux linkage was so widespread that the answers to part (b) were usually very poor. In part (b) (i), a majority of the candidates seemed to prefer to draw a cosine graph rather than the required sine (or – sine) curve. Responses to part (b) (ii) were split fairly evenly between zero and 2.66×10^{-3}. In part (b) (iii), the candidates who had drawn a cosine graph in part (i) could only refer usefully to the induced emf being proportional to the rate of change of flux linkage; everything else in their answers was nonsensical because of the wrong graph. Good, fully-reasoned answers, that referred to the changing flux linkage as the coil rotated and to the correct angles at which the rate of change would be maximised, were remarkably rare. Even when a sine curve had been drawn, examiners frequently came across a statement that ‘the emf is greatest when the coil is perpendicular to the magnetic field’. In truth, the emf is greatest when the *plane of* the coil is *parallel* to the magnetic field.

Mark Ranges and Award of Grades

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