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Specification A

PHYA4 Fields and Further Mechanics

Report on the Examination

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General Comments

This first January sitting for the unit 4 test of the Physics A specification was taken by more than 9000 candidates. Under this new 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 four questions.

Section A followed in the tradition of previous objective tests, although the number of questions has been increased from the 15 used latterly in the previous unit 4 tests. The mean pre-test facility and point biserial values for this test were closely similar to those for recent objective tests on the legacy Physics A specification. The mean values of facility and discrimination index from the candidates' responses on Section A were in line with expectations.

In Section B, the examiners were pleased to see some competent work from many of the candidates. Good work was well rewarded and the average mark for each section of the test was highly satisfactory. There was evidence that some candidates found the overall test demanding and were short of time towards the end of Section B.

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 64%. The facility for individual questions ranged from 87% for question 4 to 35% 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. This test contained eight such questions, with a mean facility of 50% when last used. The eighteen new questions had all been pre-tested and had a mean pre-test facility of 54%. Candidates invariably produce higher facilities for the questions in a real examination than in the pre-testing situation. The mean facility of all of the re-banked questions also all improved, by an average of 10%.

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 0.41. Therefore there was no discernable improvement in the discrimination of the questions; in fact most of the re-banked questions gave inferior discrimination this time to that recorded when last used.

Thirteen of the questions (questions 1, 3, 4, 9, 12, 13, 14, 18, 19, 20, 24 and 25) proved to be easy, with facilities over 65%, whilst no question was found to be difficult.

Question 1, on factual knowledge of the impulse – momentum relationship, was an easy starter with a facility of 85%.

Question 2 required candidates to determine the momentum of the water flowing out of a garden hose in one second. This called for mathematical application as well as knowledge and it was therefore much more demanding. 41% of the candidates selected the correct answer, and the question was not a strong discriminator. The most popular incorrect distractor, chosen by 28%, was C (0.20). This numerical value could be found by multiplying the density of water by the flow rate, ignoring the cross-sectional area value given in the question.

Like the first question, **Question 3** was a straightforward test of candidates' knowledge. It required candidates to decide whether or not mass, momentum, kinetic energy and total energy would be conserved in an inelastic collision. 85% of the candidates appreciated that everything except kinetic energy would be conserved. Incorrect responses were fairly evenly spread around the other three distractors.

Question 4 proved to be the easiest question, with a facility of 87%. Application of $\omega = 2\pi/T$ with T equal to the period of Earth's rotation readily gave the correct answer.

Question 5 asked candidates to identify a situation in which centripetal force would **not** be involved, so they ought to have known to look for the answer that did not involve circular motion. 61% realised that this was the α particle in an electric field, where the trajectory would be parabolic rather than circular. However, 30% of the candidates chose distractor C, where the α particle was in a magnetic field.

Question 6, about phase differences in shm, had a facility of 72% but did not discriminate very well. 17% chose distractor A ($\pi/4$ instead of $\pi/2$); this may have been caused by a misunderstanding of the radian to degree conversion.

Question 7 was concerned with the amplitude and period of a mass-spring system. The facility was 63%, but one in five of the candidates selected distractor A – where the amplitude was correct but the period was 1.0s instead of 2.0s. Answers in Section B also showed that there was widespread misunderstanding of what is meant by the time taken for *one oscillation*.

Question 8, on forced vibrations, had a facility of 59% and did not discriminate very well. Distractor B, where a phase relation was involved, attracted 23% of the candidates. This again may be an indication of a misunderstanding of phase angles, because the angle in the situation described is 90°, not 180°.

Questions 9 and 10 were about gravitational forces. Application of the inverse square law was completed successfully by 70% of the candidates in the former question. In Question 10, candidates had to appreciate that the condition described would be met when the centripetal force acting on material is just equal to its weight, so $\omega^2 R = GM/R^2$. Only 48% of them were successful, but the question discriminated very well.

The correct algebraic rearrangement of $g = GM/R^2$ would deliver a correct answer in **Question 11**, achieved by 62% of the candidates. The unit of gravitational potential was known correctly by 71% of them in **Question 12**. However, one in five selected distractor C – $\mathrm{N\,kg^{-1}}$ – which is the unit of gravitational field strength.

Coulomb's law had to be applied in **Question 13**. 66% of the candidates realised that doubling the separation would have the effect of reducing the force by a factor of four, whilst the changes to the charges would mean that they would become $+2Q$ and $-Q$, so that the force would remain one of attraction. Distractor C was selected by 22% of candidates; this could be because they thought that $F \propto 1/r$ instead of $F \propto 1/r^2$.

Question 14, about a charged particle moving in an electric field, had a facility of 66% and was a good discriminator. Incorrect responses were almost equally distributed between the incorrect distractors.

Question 15 required candidates to apply $F = EQ$ in a charged parallel plate situation. 58% of them appreciated that the separation of the plates was d and that the field strength E would be V/d. However, 29% chose distractor A, for which the field strength must have been interpreted as $V \div (d/2)$.

Question 16, also on electrostatics, was concerned with field strength and potential. This was the worst discriminator in the test, and only 43% of candidates selected the correct response. A principal reason for as many as 24% of them choosing distractor A (potential is a scalar) must be that they had failed to notice that the question asked for the *incorrect* statement.

The statement that is incorrect was also to be chosen in **Question 17**, about the energy of an α particle during a head-on encounter with a gold nucleus. The facility of this question was 62%, the most common incorrect choice being distractor D (19%).

Question 18 was a test of $C = Q/V$ in a graphical application. Because Q is on the x-axis and V on the y-axis, the gradient is $1/C$ (answer D). The majority of candidates recognised this, making the 72%. It may not be surprising that distractor A was the most popular incorrect response, chosen by 15%, since this suggests that the gradient would be C. This question was another good discriminator.

78% of candidates were not troubled by the constant charging current of the capacitor in **Question 19**, because they chose the correct answer. This question required $Q = I\,t$ to be combined with $C = Q/V$. **Question 20** was also a test of $C = Q/V$, but in combination with $E = \frac{1}{2}CV^2$. Candidates found this question also to be relatively easy, for the facility was 72% – but it was the most discriminating question in the test.

Question 21 was the most demanding question, with a facility of 35%. It required a fundamental understanding of charge flow in conductors and the magnetic force equations. The required average force per electron could be found by dividing the force on the whole section of conductor ($F = B\,I\,L$) by the number of electrons in it (volume $\times\ 8.0 \times 10^{28}$). This was another question that discriminated well.

The magnetic force on a moving electron was also tested in **Question 22**, but this time qualitatively instead of quantitatively. Since this electron was moving anti-parallel to the magnetic field through which it was travelling, it would experience no magnetic force. Therefore, its motion would not be affected by the B field. 45% of candidates appreciated this (answer C), but 21% thought it would grind to a halt and set off in the opposite direction (distractor B) whilst 18% thought it would accelerate in its original direction (distractor D). Confusion with the effects of electric fields is evident in these incorrect responses.

Question 23 looked at factors that might increase the radius of curvature of charged particles following a circular arc in a B field. The facility of this question was 63%, and incorrect responses were fairly equally spread.

Question 24 moved on to electromagnetic induction and tested $E = N\,\Delta\Phi/\Delta t$ for a uniform rate of change of magnetic flux. 72% of the responses were correct. Like questions 22 and 23, this question was a very good discriminator.

The uniform rate of change of flux experienced by an aircraft wing in steady horizontal flight, leading to an emf across the wing tips, was considered in **Question 25**. This had a facility of 71%. No doubt arithmetical errors were the cause of 13% of the candidates choosing distractor B, and 11% choosing distractor C.

Section B

The questions provided good coverage of the specification and gave candidates ample opportunities to show what they had learned. It was pleasing to see many good answers to questions which required fairly demanding mathematics, such as the solution of exponential equations by logarithms in question 2. The specification for this test includes a requirement for some of the content to be synoptic. A topic which comes into this category is cost of energy calculations (question 4 (b) (iv)) and this caused much difficulty for many of the candidates.

When marking all parts of the paper, there were examples of candidates who had not read the questions sufficiently carefully to be able to answer them properly. This was particularly evident in descriptive parts. In the answers to question 1 (a), for example, many answers were encountered which did not even contain the word *energy*. The most important advice to candidates for this paper, as always, is therefore to read the questions thoroughly before attempting to answer them.

Several of the calculations were answered competently, but less able candidates often presented their working in such a disorganised manner that examiners had great difficulty in interpreting their thinking. Candidates need to be informed that working is expected to be shown in calculations, and that specific marking points are often available for working. This enables examiners to award marks for partially correct calculations, where the final answer may well be wrong as a consequence of an arithmetic slip.

Question 4 (a) (ii), on energy losses in transformers, was used to assess candidates' quality of written communication by a method new to A2 level. Most answers were only partly satisfactory for one reason or another, one of the main ones being a lack of familiarity with and/or understanding of the subject matter. Although this topic is new to this specification at this level, it did once occupy a prominent place in most GCSE specifications.

Question 1

In part (a), the award of the full two marks was comparatively rare. Most answers were incomplete because candidates had not addressed the need to describe the energy changes of the bob '*over one complete oscillation, starting at its maximum displacement*'. A large proportion of candidates confined their attention to the first half of the oscillation, which limited them to half marks. Another error was a reluctance to refer to the potential energy as *gravitational*. Some candidates missed the point of the question completely, and wrote about velocity and acceleration in shm.

Calculation of the period of the swing in part (b) (i) was straightforward, and proved to be rewarding for most candidates. Those who confused period with frequency gained little credit, except for the mark for giving a final answer to an appropriate number of significant figures. Using the given data, the answer for the length was 1.948 m, when calculated to four significant figures. Final answers of 2.0 m (rather than 1.9 m) were therefore regarded as incorrect.

The solution to part (b) (ii), where the maximum E_k of the girl was needed, came readily from 'E_k gained = gravitational E_p lost'. Equating this result to $\frac{1}{2}mv^2$ then led to a neat solution to part (b) (iii), to find the maximum speed of the girl. Many candidates attempted much more tortuous routes to parts (ii) and/or (iii), using $v_{max} = 2\pi fA$. The principal downfall of this method (quite apart from its relative difficulty) was the adoption of 250 mm for the amplitude, A. Some successful solutions by the method were seen, however, where the correct value for A had been found by Pythagoras, or some equivalent calculation.

Many reasonable graphs were drawn in part (c), where the E_k against t graph was required, starting at maximum displacement. The majority of answers recognised that E_k would be zero at t = 0, T/2 and T. On most answers there were also correct maxima, of similar amplitude, within one square of T/4 and 3T/4 on the graph. The most demanding aspect was the shape of the graph; 'half wave rectified' waveforms tended to dominate, whilst triangular waveforms were by no means uncommon. Correct ($\sin^2$) shapes were comparatively rare, but credit was given for any shape which showed appropriately curved characteristics.

Question 2

Most candidates were able to calculate the initial discharge current successfully in part (a) (i). The common approaches to finding the time constant in part (a) (ii) were reading from the graph at the point where the pd had fallen to 6.0/e, or solving the exponential equation $V = V_0 e^{-t/RC}$ for corresponding V and t values. It was expected that candidates would know that a time constant is measured in s; the unit ΩF was not accepted. The principal difficulty experienced by some candidates in part (a) (iii) was not spotting that the capacitance value had to be expressed in μF. Answers of 2.2×10^{-4} μF were clearly wrong and caused this mark to be lost.

A wide variety of approaches could be adopted when answering part (a) (iv). Most candidates attempted to answer the question 'in reverse', by showing that after 25 s the energy lost would be 90% of the original; this was acceptable. Some lost the third mark when using this method by failing to link the two energies (calculated correctly) to the 90% value for the loss. A neat and concise solution was seen in a few cases, where candidates reasoned that, since $E \propto V^2$, the percentage loss of energy would be $[1 - (V/V_0)^2] \times 100$.

In part (b) (i) one mark was awarded for a correct consequence of the increased charging pd, and one mark for an explanation. The fact that $E \propto V^2$ was quite well known, and it was expected that candidates would realise that doubling the pd would *quadruple* the energy stored: to state just that the energy stored would 'increase' was too simplistic to deserve this mark. Candidates who resorted to $E = \frac{1}{2} QV$ almost invariably reached the wrong conclusion, because they thought that the energy stored would *double*.

In part (b) (ii) the one available mark was given for a correct consequence *together with* an acceptable explanation. Relatively few candidates were able to state that the time taken for 90% of the energy to be lost would be unchanged because the time constant had not altered.

Question 3

Many very good answers were seen in part (a) (i), expressed either fully in words or simply by quoting $E_p = mV$. The corresponding equation for an incremental change, $\Delta E_p = m\Delta V$, was also acceptable but mixed variations on this such as $E_p = m\Delta V$ (which showed a lack of understanding) were not. The consequences of doubling m were generally well understood in part (a) (ii), where most candidates scored highly, but some inevitably thought that E_p would be unchanged whilst V would double.

Candidates who were not fully conversant with the metric prefixes used with units had great difficulty in part (b), where it was necessary to know that 1 MJ $=10^6$ J, 1 GJ $=10^9$ J, and (even) 1 km = 10^3 m. Direct substitution into $V = (-)\ GM/r$ (having correctly converted the value of V to J kg^{-1}) usually gave a successful answer for the radius of orbit **A** in part (b) (i). A similar approach was often adopted in part (b) (ii) to find the radius of orbit **B**, although the realisation that $V \propto 1/r$ facilitated a quicker solution. Some candidates noticed that $V_{\mathbf{B}} = 3\ V_{\mathbf{A}}$ and guessed that $r_{\mathbf{B}} = r_{\mathbf{A}}/3$, but this was not allowed when there was no physical reasoning to support the calculation.

Part (b) (iii) caused much difficulty, because candidates did not always appreciate that the centripetal acceleration of a satellite in stable orbit is equal to the local value of g, which is equal to GM/r^2. This value turns out to equal to V/r, which provided an alternative route to the answer. Many incredible values were seen, some of them greatly exceeding 9.81 m s^{-2}.

Part (c) was generally well understood, with some very good and detailed answers from the candidates. Alternative answers were accepted: either that *g* is not constant over such large distances, or that the field of the Earth is radial rather than uniform.

Question 4

In part (a) (i), the requirement that $N_P > N_S$ was regarded as fundamental for the first mark; the second mark was awarded for either a core linking the coils or an ac supply. Some candidates missed the point of the question completely by writing about how transformers change voltages rather than concentrating on their essential features.

Most attempts to answer part (a) (ii) fell well short of examiners' expectations. In many cases the principal cause of this was a lack of detailed knowledge or confused understanding. When this kind of question is employed to assess the quality of candidates' written communication, it will be expected that a good answer will be structured: well organised, and coherent. This was another general error, because candidates often presented answers that rambled on without general direction.

Successful answers were primarily expected to address **two** (and only two) causes of energy loss; four causes are commonly identified by the standard sources that deal with this topic, so asking for two was not unduly demanding. For each cause that was identified, there was a requirement to discuss how the loss could be reduced by suitable features and materials.

Answers that could be placed in the 'good to excellent' category (five or six marks) should have backed up this factual knowledge with some physical reasoning. Very few answers addressed these requirements sufficiently successfully to deserve the award of full marks. It seemed that most of the candidates had heard about eddy currents, but not all of them knew exactly what they are or where they occur. Many answers showed considerable confusion; 'eddy currents caused by the coils can be stopped by using a soft iron core', 'heat losses from the currents can be reduced by using smaller currents', and 'energy losses from re-magnetising the core can be cut down by laminating it' were typical of the confused responses seen.

A proportion of the candidates evidently mixed up the principles of energy loss reduction in transformers with the principles involved in reducing power losses from transmission cables, because there were frequent references to using higher voltages in the transformers in order to reduce the currents causing the heating.

The calculations in parts (b) (i) and (ii) were usually correct, with $P = I V$ and the transformer efficiency equation being successfully applied. Almost all of the answers to part (b) (iii) were incorrect, because candidates did not realise that when on standby the transformer, as well as the load, continues to waste energy. Consequently, the power wasted on standby was 3.0 W, not 2.7 W.

This error did not prevent candidates from accessing both available marks in part (b) (iv), provided they correctly applied the physical principles there. In this part, relatively few completely correct answers were seen, largely because the candidates were unable to convert an energy value from J to kWh.

In part (c) it was usual to award both marks; most candidates knew that it takes an appreciable time for a computer to boot up and this would therefore be a disadvantage of switching off. For the advantage, a more specific point than 'saves energy' was being looked for, because this response does little more than re-state the question.

Mark Ranges and Award of Grades

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