CCEA GCE - Physics
Summer Series 2016

Chief Examiner's Report

physics

Foreword

This booklet outlines the performance of candidates in all aspects of CCEA's General Certificate of Education (GCE) in Physics for this series.

CCEA hopes that the Chief Examiner's and/or Principal Moderator's report(s) will be viewed as a helpful and constructive medium to further support teachers and the learning process.

This booklet forms part of the suite of support materials for the specification. Further materials are available from the specification's microsite on our website at www.ccea.org.uk

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GCE PHYSICS

Chief Examiner's Report

General Observations

Poor handwriting continues to be a problem. Sometimes it is not possible to read what has been written – a problem that penalises candidates on occasions when misread numerical data is used in later parts of unstructured calculations.

Online marking of A2 1 and A2 2 (and AS 1 and AS 2) introduced further issues. Candidates are strongly advised to score out work they do not want considered and to rewrite their new response – candidates should never overwrite a response. On scanned responses it is very difficult to establish what the candidate intends to be assessed.

In questions requiring extended writing, candidates frequently provide superfluous information. This indicates poor answering technique in that candidates are not customising their responses to the specifics of the question. Secondly, it often means that the responses extend beyond the area allocated on the paper for the answer. Given the nature of the online marking system, those responses continued on other parts of the question/answer booklet may not be assessed and consequently credit not awarded.

I do stress that examiners will always try to find a candidate's complete response and mark it accordingly.

Candidates should be reassured that in numerical problem questions, examiners will award full marks for an answer consistent with correct physics. That is, variations in the final answer based on the rounding of intermediate values will not cost a candidate marks.

Candidates are advised that answers should be given as a decimal fraction expressed to an appropriate number of significant figures.

Assessment Unit AS 1 Forces, Energy and Electricity

Q1 Almost all candidates responded positively to this question.

(a) Only a small number of candidates failed to score less than three of the four marks available. The most common mistakes made by candidates were with regard to volume. Some candidates confused this concept with that of amount of substance and gave the mole as the S.I. unit. Others confused base units and derived units and stated the metre as the S.I. unit of volume. Candidates are advised to write clearly so that examiners can distinguish units, for example, the lower case 'k' in kg from the upper case 'k' in K (kelvin).

(b) Most candidates correctly expressed power in its base units. Candidates are advised that a linear format should be used to express (base) units. That is, there should be no solidus.

Q2 This question was well answered.

(a) Almost all candidates appreciated the use of the equation $s=ut+½at^2$ in calculating a value for the acceleration of freefall. Most candidates correctly performed the calculation with each set of data and took an average. However, those candidates who did the calculation with just one set of data were penalised one mark for not following the instruction to use all the data. Those candidates who averaged the distance fallen and separately averaged the time for the fall were also penalised a mark as this procedure is considered to be flawed. A third approach was to consider the data as two points on an s against t^2 graph and perform a calculation to determine the gradient which was then doubled. This method yielded a relatively poor answer because the imaginary best-fit line was based on only two data points; consequently partial credit only was awarded for this method.

(b) Majority of candidates obtained the mark for this question. Candidates are advised to select data appropriate to the context. In this question the greatest distance to be measured was just less than one metre and a measuring instrument capable of measuring up to a metre had to be specified in the answer.

(c) The most common reason for not awarding the mark in this question was a lack of specificity in the response. As in the previous question, many candidates produced generalised statements about measurement of distance or time. The examiners expect to see such comments made specific to the context of the question.

Q3 The mathematics involved in this question proved challenging for many candidates.

(a) In Part (i), many candidates struggled to find a time expression for the vertical component of the projectile's motion. Some failed to double the time taken to reach the maximum height and others didn't consider the vertical component of the velocity. Scoring in Part (ii) of this question for most candidates was dependent on Part (i). However the mark scheme allowed partial credit for those candidates who realised the initial velocity of the ball was determined by equating the expressions for time in Part (i). A number of candidates recalled the range equation for projectiles from which they were able to determine the initial velocity and were awarded full credit.

(b) The single mark available for this question was essentially a quality mark. No error carried forward was applied here and so only those candidates sure of their physics and accurate in its application received the mark.

Q4 This question was generally well answered.

(a) Candidates' statements of Newton's second law of motion often lacked precision. Since momentum is not on the AS course, definitions involving the variation of acceleration with force and mass were common and could receive full marks. Candidates are advised that the expression 'indirect' proportion is ambiguous and that they should use 'inverse' proportion when referring to, for example: $a \propto \frac{1}{m}$ that is, acceleration is inversely proportional to mass. Furthermore, candidates are encouraged to indicate the correct causal relationship. In the previous example, the acceleration of an object depends on the mass of the object. The mass, however, is independent of the acceleration.

(b) Part (i) of this question was well answered and most candidates obtained the single mark available for determining the woman's weight and realising the reaction force must equal the weight according the Newton's third law of motion. Part (ii) was less well done. Most candidates realised the total acceleration of the woman must be considered but many failed to correctly combine the acceleration of freefall with that of the lift. Candidates are advised to consider how reasonable their numerical answers are. Here, despite being asked to calculate the maximum reaction force, many candidates wrote down values that were smaller than that given in Part (i).

(c) This question was poorly answered. Most candidates' responses didn't relate weightlessness to the reaction force from the lift floor and frequently failed to state the acceleration, (magnitude and direction) of the lift required to cause the sensation of weightlessness.

Q5 A significant number of candidates found aspects of this question challenging.

(a) The application of the Principle of Moments to Part (i) of this question eluded a number of candidates. Most, however, were able to successfully calculate the maximum weight of the gymnast. In Part (ii), a minority of candidates didn't understand that the upward force provided by the support must be equal to the total downward force.

(b) Poor candidate answering technique was largely responsible for the loss of marks in this question. Most candidates correctly indicated that the supports should be moved further apart and gained a mark. Some candidates provided explanations that gained another mark but very few responses were worthy of both explanation marks.

Q6 Many candidates were challenged by parts of this question.

(a) Part (i) of this question was generally well answered with most candidates correctly calculated the kinetic energy of the javelin. Part (ii) was less well answered. A large number of candidates knew that the javelin would also have some gravitational potential energy but were unable to apply the conservation principle and realise that the release height of the javelin should be used rather than the maximum height acquired by the javelin. The mark scheme allowed for the candidate calculating 92% of any total energy value and this enabled most candidates to receive at least one mark.

(b) Somewhat surprisingly, this question was poorly answered. Only the best candidates realised that the work done by the frictional force must equal the kinetic energy of the javelin as it entered the soil and went on to correctly determine the average force. Others obtained the correct answer by a more circuitous route; they calculated the impact velocity from the kinetic energy, used that to determine the deceleration and from that calculated the force – full credit was given to these candidates.

Q7 This question was well answered.

(a) Almost all candidates drew diagrams that contained the salient information. However, the general standard of diagrams was poor. Candidates are advised to take care with their diagrams so that all important aspects can be clearly identified by the examiners. A number of candidates lost partial credit for indicating that the extension was determined using a length of wire less than half that available.

(b) Majority of candidates are familiar with this experiment but many are less than clear on the details. Candidates lost credit for not stating that the basic procedure required the determination of extension for a range of tensile forces. Many responses were too general and not specific to the context of the experiment. For example; failing to identify a distance measuring instrument capable of reaching at least one metre was penalised, as was the measurement of radius or cross-sectional area which can only be calculated from measurements of diameter.

(c) It is pleasing that most candidates opted for the graphical determination of the Young modulus. Most were awarded full marks in this question. Candidates are advised that a graphical solution offers advantages over multiple calculations and averaging, and for this reason the latter approach could not be awarded all three marks.

The standard of written communication among this cohort was high. Almost all responses were relevant and well structured. Some errors in spelling, punctuation and grammar were evident but were, generally, not such as to suggest a weakness. Attention must be drawn to continued deterioration in the standard of handwriting. Candidates are advised that it is in their best interests to maintain a reasonable standard of handwriting.

Q8 Majority of candidates found this question accessible.

(a) Part (i) of this question was well answered. Almost all candidates appreciated that current is the rate of flow of charge. Part (ii) was less well done. Some candidates did not appreciate that potential difference is the energy transfer per coulomb of charge. Of those who did, some either ignored the nature of the energy change or got the energy change wrong; in both cases a mark was lost.

(b) The calculation of charge, in Part (i), was well done. Very few candidates failed to convert two minutes into seconds correctly. Part (ii) of this question was also very well done.

Q9 Some candidates experienced difficulty with parts of this question.

(a) Statements of Ohm's law were not as good as expected. As has been mentioned elsewhere in this report, candidates are asked to consider the causal relationship. Current and voltage are proportional (assuming constant conditions) and current is proportional to voltage; however, voltage is independent of current.

(b) Part (i) of this question was relatively straight forward and most candidates were awarded the mark. However, Part (ii) proved to be much more challenging. Many candidates struggled to perform the algebra required to obtain an expression for the total resistance of the network in terms of R and so were unable to ascertain the value of R.

Q10 This question was well answered by many candidates.

(a) An enabling mark scheme allowed many candidates to access full marks here. Candidates were required to state the resistivity equation and insert the equation for circular area in terms of diameter into the resistivity equation. There was no requirement to rearrange the equation to make resistivity the subject. This question was well answered by the majority of candidates.

(b) Part (i) of this question proved problematic for a small number of candidates. Almost all candidates appreciated that the way to identify the material used in the experiment was to determine the cross-sectional area and hence the diameter of a wire made from each material and then to identify which was most likely. Very few candidates used the gradient of the graph in their calculations, preferring instead to select a length and corresponding resistance to substitute into their equations. Both methods were considered equally acceptable in terms of the mark scheme but candidates are, once again, advised that the graphical route offers advantages over other methods. Part (ii) again indicated a weakness in the answering technique of a significant number of candidates who indicated that goggles must be worn, or hair to be tied back or stools placed under benches. These generic safety precautions have no significant relevance to this experiment and so gained no credit.

Q11 Majority of candidates found this question accessible.

(a) Candidates appeared familiar with superconductivity, some lost marks because they did not refer to the 'critical' or 'transition' temperature or incorrectly referred to the 'curie' temperature. Others lacked the conviction that the resistance fell to zero below this temperature, stating that it almost became zero.

(b) Most sketches were ruled, accurately drawn and accompanied by appropriate labelling.

(c) Almost all candidates were able to name and briefly describe an application of superconductors.

Assessment Unit AS 2 Waves, Photons & Medical Physics

Q1 Most candidates performed well in this question.

(a) Almost all candidates correctly identified the regions of the electromagnetic spectrum to which waves with the given frequencies belonged. Most, but not all, went on to state a correct typical wavelength. However, many candidates chose to recall a typical wavelength rather than calculate one using $c = f\lambda$.

(b) Explanations of phase difference, in Part (i), were generally poor; few candidates identified that it was the fraction of the cycle/wavelength/period by which one wave (or particle) leads the other. However, in Part (ii), majority of candidates were able to calculate the phase angle correctly.

Q2 This question was very well answered by candidates.

(a) The descriptions of the experiment were generally excellent. Almost all the diagrams produced contained the necessary apparatus and were awarded the mark. However, candidates are advised that it is in their best interests to produce diagrams of good quality so that their physics knowledge and understanding can be fully appreciated by the examiner and marks awarded accordingly. A small number of candidates failed to label their diagrams and forfeited a mark. Candidate descriptions of the procedure tended to be very good and were awarded full marks here. In the measurements section, most candidates correctly outlined a graphical method for determining the refractive index and awarded full marks. In an effort to encourage the graphical analysis of experimental results, those candidates who opted to calculate multiple values for the refractive index and find their mean were penalised a single mark. The majority of candidates described an experiment using a rectangular transparent block while others described an experiment using a semi-circular block. Both options were equally well described.

The general standard of written communication was high. Almost all responses were relevant and well structured. However, the standard of handwriting in some cases was very poor to the extent that it disrupted the understanding of the passage. Candidates are advised that it is in their best interests to maintain a reasonable standard of handwriting.

(b) Most candidates were able to determine the critical angle of the impure crown glass but for many that was as far as they progressed in the calculation. A large number of candidates were unable to combine the critical angle with the geometry of the equilateral prism to determine the incident angle that just caused total internal reflection to occur.

Q3 Most candidates responded positively to this question.

(a) The ray diagrams produced by most candidates were good. Some candidates lost marks because the lens wasn't identified as concave (diverging) and/or rays lacked direction arrows and/or virtual rays/images were not dashed. A minority of candidates thought that a convex lens was used which prevented them accessing marks.

(b) In Part (i) of this question, the diagrams produced by candidates contained the necessary information. A number of candidates did not fully label their diagram and forfeited a mark. Candidates are again advised to produce good quality diagrams. In Part (ii), a majority of candidates realised that the inverse of the gradient was the focal length of the lens. However, the algebra required to show this result was poorly demonstrated by most candidates. In this question, candidates were guided to start from $1/u + 1/v = 1/f$; many failed to comply and so forfeited a mark.

Q4 The majority of candidates found this question accessible.

(a) Candidates lost marks because they were imprecise in their use of technical terms. For example, they stated the vector sum of the amplitudes rather than the vector sum of the displacements. Omitting the vector nature of the displacement addition and the notion that the waves must meet or interact also cost candidates credit.

(b) Most candidates indicated that they were able to apply the superposition principle (even if they couldn't state it). Candidates lost marks for careless drawing.

(c) Part (i) of this question was generally well answered. However, a number of candidates lost marks by writing an incorrect equation, for example: $v = fL$. The candidate incorrectly identifies the wavelength as L and will forfeit a mark because of that. But, if they had written $v = f\lambda$ and stated $\lambda = L$ separately they may have picked up a mark for an error carried forward for a wrong wavelength. In Part (ii), candidates did not identify that resonance at 168 Hz indicated the third mode of vibration and subsequently lost credit. In contrast, almost all candidates correctly identified a node and antinode on their diagrams, as required in Part (iii) of this question.

Q5 Most candidates found this question challenging.

(a) In Part (i), very few candidates simply stated that a constant phase difference explained coherent sources. Most supplemented this response with other information some of which was neutral (like same wavelength and frequency) and were duly awarded the mark and some of which was wrong (like same amplitude) and these candidates lost the mark. In Part (ii), the conditions for observable interference, other than the waves having the same amplitude, were poorly known.

(b) In Part (i), a majority of candidates did not respond to the terms of this question. Specifically, they did not use the concept of path difference. Candidates who did use the concept experienced difficulty in conveying the idea that a path difference equal to an odd number of half wavelengths was required for destructive interference. The calculation in Part (ii) of this question saw only those candidates who had a complete understanding of the physics achieve any credit and full credit went only to those candidates who were able to accurately complete the calculation.

Q6 Many candidates failed to score well in one or both parts of this question.

(a) The ability of most candidates to explain the relative effect of sound and light diffraction through an open door was not good, even though most possessed a reasonable appreciation of diffraction as a phenomenon. Many candidates completely ignored the light and consequently forfeited some credit. Frequently, responses lacked a specific physics basis and did not include a comparison between wavelength and doorway width. Unfortunately, some candidates incorrectly described diffraction as the bending of waves rather than the spreading of wave fronts.

(b) Many candidates correctly determined the periodic time from the frequency, from which most were able to ascertain the time interval represented by one centimetre on the oscilloscope screen. Whilst most candidates went on to identify the correct time base setting, many of them introduced a power-of-ten error and ticked the wrong setting.

Q7 This question was generally well answered.

(a) Many candidates offered confused, inaccurate or incomplete descriptions of x-ray production and a small, but significant, number described the process of x-ray imaging. Few candidates were awarded the mark for explaining 'bremmstrahlung'. The marks for explaining the production of the characteristic x-rays were more frequently awarded.

(b) In Part (i) of this question most candidates recalled accurately that CT stood for computed tomography. In Part (ii), not all candidates were able to state that the x-ray beam and detector are stationary throughout a conventional x-ray scan but that the x-ray beam rotates around the patient in CT scans. In Part (iii) a large majority of candidates appreciated that CT scans exposed the patients to a higher dose of x-rays than the conventional scanning technique.

Q8 Parts of this question challenged many candidates.

(a) Candidate statements of the conditions under which photoelectric emission occurs typically failed to attract full credit. Responses in which the candidate compared the photon energy with the threshold frequency and vice versa were common. Such comparisons were not considered to be worthy of credit. Another frequent omission was in failing to indicate how the electron obtained the energy required to escape from the metal.

(b) Many candidates performed this calculation very well and were awarded full marks.

(c) In Part (i), most candidates appreciated that increasing the intensity of the incident radiation alone would have no effect on the kinetic energy of the emitted electrons. In Part (ii), a larger majority appreciated that the number of photoelectrons emitted per second would increase if the intensity of the incident radiation increases.

Q9 This question was poorly answered by many candidates.

(a) In Part (i), the term 'population inversion' and the electron arrangement it describes (more electrons in an excited state than in the ground state) were unknown by large numbers of candidates. In Part (ii), there were few correct responses, indicating that a photon with energy equal to the energy gained by the excited electrons passing the excited electrons caused them to relax.

(b) In Part (i), few candidates explained why electron energy levels in atoms have negative values. However, in Part (ii), most candidates correctly identified the transition made by an electron to emit a photon with that energy and many went on to correctly draw the arrow on Fig 9.1, as required in Part (iii).

Q10 Many candidates coped well with this question.

(a) The calculation of the de Broglie wavelength was very well done. Some candidates selected the wrong value for the mass from the Data and Formulae Sheet while a few made mistakes in converting the wavelength to nanometre; both mistakes were penalised.

(b) Many candidates failed to logically explain the effect of increasing the accelerating potential on the de Broglie wavelength of the electrons and/or to describe how the diffraction pattern was affected as a result of this wavelength change.

Assessment Unit AS 3 Practical Techniques

The general standard of performance in this module continues to be very strong.

Heads of Physics departments are instructed to use equipment/apparatus that conforms to that indicated in the Apparatus and Materials List provided and to check the operation/performance of all experiments in advance of the examination for the benefit of the candidates from their centre.

Q1 This question was well answered by most candidates.

(a) In Part (i), almost all candidates correctly manipulated the apparatus and obtained an accurate refracted ray. Most went on to measure angle θ between 29° and 31° (34° and 36° Session 2) and angle *a* between 48° and 52° (57° and 61° Session 2). However, some candidates measured the glancing angle rather than the refraction angle and forfeited one mark. Other candidates recorded non-integer angles and were penalised for this. Candidates are advised that no standard protractor can measure accurately to a tenth of a degree which is what is implied if an angle given to one decimal place is recorded. In Part (ii), a large number of candidates calculated the inverse of the refractive index of the material from which the block was made and consequently received no credit.

(b) The apparatus was generally well manipulated by candidates, many of whom continued to measure a value for the critical angle between 40° and 44° and duly received full marks if they had also marked the correct angle on their diagram.

(c) Theory indicates that constant K (in both sessions) ought to have a value of 1. However, as so many candidates calculated their refractive index incorrectly in (a)(ii), full credit was awarded for a value of K consistent with earlier measurements. The initial intention had been to use this part as a quality mark awarded only to those candidates whose value of K lay between 0.9 and 1.1.

Q2 Many candidates found parts of this question challenging.

(a) Most candidates used the ohmmeter correctly and obtained accurate values for the three resistances. Some candidates introduced power-of-ten errors whilst others recorded values that appeared random.

(b) Almost all candidates were able to populate the results table. However, some candidates did not adjust their power supply so that the supply voltage lay within the range indicated. A failure to record all values to two decimal places was also penalised.

(c) In Part (i), most candidates performed the calculation accurately and recorded values for R1 consistent with their results (200 **Ω** Session 1 and 300 **Ω** Session 2). In Part (ii), the candidate had to state whether or not they considered their results reliable. The mark for this question was based on the candidate commenting on the spread of R1 values calculated. Candidates are advised to repeat calculations, particularly if a result fails to conform to a trend. Many candidates felt the result was unreliable because there were no repeat measurements!

Q3 Aspects of this question challenged many candidates.

(a) In this question candidates were asked to consider the uncertainties in the length of a straightened paper clip. In Part (i), the mark was awarded for the candidate writing a value and uncertainty both expressed to the nearest millimetre. In Part (ii), the rationale behind the candidate's uncertainty magnitude was explored. Almost all candidates correctly identified that the uncertainty in using the rule had to be doubled but very few candidates obtained the mark here as most omitted to mention the kinks and bends in the straightened paper clip.

(b) This part was generally well answered. Most candidates measured multiple diameters from which they found a mean. Some candidates recorded their mean diameter in millimetres to an impractical number of decimal places and were penalised. Others misread their micrometer screwgauge by 0.50 mm and were also penalised.

(c) Most candidates correctly determined a percentage uncertainty consistent with their diameter and doubled it to get the percentage uncertainty in the wire's cross-sectional area. A minority of candidates calculated minimum and/or maximum values and/or most probable values of the wire's cross-sectional area and from these calculated the percentage uncertainty; this method attracted full marks if accurately executed.

Q4 This question was generally well done.

(a) In this question there were five instructions to the candidate and two marks available for total compliance. Candidates are advised to read all parts of the question carefully and apply what they know and understand to the specific context of the question parts. Almost all candidates recorded three masses with the second and third recorded being approximately 500g larger than the previous mass and were awarded the first mark. However, many candidates did not receive the second mark; usually because they didn't record their frictional forces in newton to one decimal place and sometimes because there were fewer than three trials recorded.

(b) Mean frictional forces were accurately determined by almost all candidates, but many recorded the mean force in newton to more than one decimal place which is not appropriate in this context and so forfeited the mark.

(c) Theory indicates that there is a proportional relationship between the object's mass and the frictional force and so candidates identifying Equation 4.2 (Equation 4.1, Session 2) received the first mark as a quality mark. The second mark was for the candidate's justification of their selection. In this question the ideal answer is to compute values for β from each set of data for each equation and show by a percentage difference for example that the values of β for the chosen equation are more constant. Responses based on logic were usually only successful in eliminating the inversely proportional relationship.

Q5 Many candidates found parts of this question challenging.

(a) In Part (i) of this question, two major issues prevented candidates receiving full marks. The requirement to quote values to three significant figures was ignored by some and imprecisely done by others. Many candidates introduced power-of-ten errors as they didn't convert the diameter of the copper wire to metre. In Part (ii), the axes suggested by most candidates were usually accompanied by consistent gradients and gradient units.

(b) Almost all candidates had a current scale to facilitate the drawing of a graph with an appropriate spread of accurately plotted points. Best fit lines were also accurately drawn by most candidates.

(c) Part (i) of this question required candidates to determine the gradient of their graphs. A large majority of the candidature performed this task in an exemplary fashion. The major source of lost credit was in matching the unit to the gradient calculated. The cumbersome nature of the axis units created problems for many candidates. The power-of-ten error introduced in the first part was carried into Part (ii) where a second power-of-ten error was commonly introduced as the mass of one mole of copper atoms was not converted into kilogram. The responses of many candidates failed to show a logical progression through this calculation. Candidates are advised that it is in their best interests to work neatly and logically through calculations as examiners try to understand the candidate's thought process in order that intermediate credit can be awarded if appropriate. In addition, candidates should consider how reasonable their numerical answer is as unexpected answers may indicate an error in calculation or method.

Assessment Unit A2 1 Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

Q1 This question was answered very well by the majority of candidates.

(a) Almost all candidates were able to state that momentum was the product of an object's mass and velocity.

(b) In Part (i) of this question a number of candidates were unable to convert the rugby player's running speed from 28.8 km h^{-1} to 8 m s^{-1}. An error carried forward from Part (i) into Part (ii) meant that almost all candidates were able to pick up marks for their application of momentum conservation to the rugby context of this question. In answering Part (iii) most candidates offered a reasoned approach but some opted for a more mathematical approach; both options were equally successful on most occasions.

Q2 Aspects of this question challenged some candidates.

(a) In Part (i), most candidates adequately described a method for obtaining the data required to establish Boyle's law. However, many responses failed to clearly establish how the experimental arrangement meant that the volume of the gas was proportional to the length of the gas column. The experimental detail, required in Part (ii), regarding the maintenance of a constant gas temperature was very well answered.

The quality of written communication demonstrated by almost all candidates was very high. There were, however, two main issues: first, the relevance of those responses in which the apparatus was described in unnecessary detail and secondly, the poor hand writing of some candidates was sufficiently intrusive to disrupt the understanding of the passage and these candidates were penalised.

(b) In Part (i), the calculation of the air pressure in the tyre after the journey was well answered by many candidates. There were two common mistakes made by candidates here; some omitted to convert the gas temperatures to kelvin while others did not identify the air pressure in the tyre as the sum of 102 kPa and 190 kPa. Most candidates found the calculation in Part (ii) challenging. Very few candidates attempted the ratio method to answer this question. Most candidates attempted to obtain values for the mean molecular kinetic energy at each temperature and to work from there. It was common to see answers in which the square root was taken at the wrong stage in the calculation and also to see data regarding the higher temperature as the denominator.

Q3 The application of the physics of circular motion to this question was beyond many candidates.

(a) The relationship between linear velocity, angular velocity and radius was well known.

(b) Many candidates confused the physics at positions A and C. The generous mark scheme allowed for candidates restating the phrases "maximum bar deformation" from the question as "force is maximum", in Part (i), and "no deformation" as "zero force", in Part (ii), allowed many candidates to access some marks. The calculation of angular velocity was done surprisingly well given the explanations offered earlier in the question.

Q4 This question on oscillations was successfully completed by many candidates.

(a) The motion analysis in terms of acceleration and kinetic energy (velocity) was well answered by most candidates. There were some candidates who misused the terms 'displacement' and 'amplitude' here.

(b) The majority of candidates' responses about the oscillating pendulum were correct. In Part (iii), a sizeable minority of candidates incorrectly stated that the comment about energy conversion was false. It is unlikely that these candidates spent much time considering the energy conservation principle in the context of the oscillating pendulum.

Q5 Most candidates were able to respond positively to parts of this question.

(a) The observations from the alpha scattering experiments were well known.

(b) Only a small number of candidates were able to explain that the backscattered alpha particles could only be explained by the alpha particles encountering an object that had a high positive charge density and a high mass density.

(c) This calculation was done well by most candidates. Some candidates, however, inadvertently substituted inconsistent mass and volume data while others omitted to convert their mass into kilogram.

Q6 This question was well answered.

(a) Almost all candidates correctly deduced the number of protons and neutrons in the rhenium nucleus.

(b) In Part (i), acceptable definitions of half-life were supplied by most candidates. Candidate descriptions, in Part (ii), tended to be good and many candidates picked up full marks here.

Q7 There were aspects of this question that challenged some candidates.

(a) Einstein's mass-energy equation was very well known.

(a) In Part (i), many candidates calculated the mass defect of the nucleus rather than the atom. In Part (ii), the conversion of the mass defect to its energy equivalence was generally well done although the conversion from unified atomic mass units to kilograms and joules to megaelecton-volts caused some problems. Responses to Part (iii) were generally good. However, the question context was the entire atom and not just the nucleus: few candidates answered accordingly. No penalty was applied to candidates who missed this point.

(c) This 'stretch and challenge' question was poorly answered. Many candidates did not appreciate that the kinetic energy of the neutron must do the work in dissociating the atom and so be equal to the value calculated in (b)(ii).

Q8 Most candidates performed well in this question.

(a) Descriptions of nuclear fusion were generally good.

(b) In Part (i), only a small number of candidates did not know the deuterium-tritium reaction. In Part (ii), most candidates responded appropriately. However, there were some candidates who misinterpreted this question and provided responses outlining the advantages of nuclear fusion.

(c) In Part (i) of this question almost all candidates appreciated that the reactants required a kinetic energy large enough to overcome the electrostatic repulsion but not all of them responded well enough to be awarded both marks. Part (ii) required the candidate to identify that the reactants, being charged, could be controlled by magnetic fields that were generated by current carrying coils of wire. Many candidates were unable to write a response that would attract all three marks.

Q9 This data analysis question was very well answered by most candidates.

(a) The graphical requirements for proportionality are well known.

(b) Almost all candidates correctly mapped the equation to that of a linear graph.

(c) In Part (i), the vast majority of candidates calculated D2 correctly and expressed their answer to an appropriate number of significant figures. The graph plotting required in Part (ii) posed few problems. The scales chosen by some candidates contradicted our normal rules but in this particular application they were deemed appropriate. In Part (iii), constant c was generally found from widely separated points from a good best-fit line. In Part (iv), a large minority of the candidature did not realise that an extreme-fit line was required and forfeited all the marks for this part. Of candidates who did draw an extreme-fit line, many went on to secure all three marks.

Assessment Unit A2 2 Fields and their Applications

Q1 This question was very accessible to most candidates.

(a) Statements of Newton's law of universal gravitation, in Part (i) of this question, were generally very good. In Part (ii), most candidates successfully showed that Newton's universal gravitation was consistent with Kepler's 3rd law of planetary motion. The most common loss of credit here was in not using the symbols given in the question: that is, in using 'r' rather than 'd' for the orbital radius.

(b) In Part (i) of this question, many candidates struggled to select the correct data in order to calculate the orbital period. Some candidates added the radius of both Rhea and Saturn to the distance 5.27 x 105 km even though the question stated this was the average separation of "their centres of mass". There were many who failed to accommodate the distances in kilometres. Conversions from seconds to days were generally very well done. Part (ii) of this question was usually well answered.

Q2 This question was very well answered.

(a) Almost all candidates were able to correctly determine the electric field strength, however, the data provided in the question meant that power-of-ten errors were commonly introduced.

(b) This straightforward question was successfully answered by most candidates. The calculation of force between two point charges caused few difficulties but, a minority of candidates incorrectly identified the direction in which the force acted.

A number of candidates used the Boltzmann constant in the context of this question; confusing it with $\frac{1}{4\pi\varepsilon_0}$.

Q3 Most candidates responded well to this question.

(a) In Part (i) of this question, the circuit diagrams produced tended to be correct but the penmanship offered by some candidates was very poor. Some candidates included bulbs "to check the circuit was working" despite the question stating discharge "through a fixed resistance" – these candidates forfeited a mark. The crux to answering Part (ii) was to identify a suitable sampling rate given the discharge curve in Fig 3.1 and most candidates did so.

(b) The deduction of the capacitor time constant in Part (i) was very well done. Most responses were well laid out and most candidates went on to use Fig 3.1 to obtain a value between 56 s and 64 s for full credit. The extension of this question into Part (ii) was well handled by most candidates, a minority of candidates combined the three series capacitors incorrectly.

Q4 This question revealed weaknesses in many candidates.

(a) As in previous questions, candidates struggled to select the correct data to use in the calculation with most choosing the wrong flux density from Table 4.1. Candidates also failed to realise that the phrase "at the face" corresponded to a distance from the magnet of 0 mm.

(b) Candidates completed Part (i) of this question well. However, some candidates did not appreciate the difference between flux density and field strength whilst others couldn't recall the correct equation to use. Part (ii) was quite well answered with most candidates being able to explain how Fleming's left hand rule applies in this context.

Q5 Candidates found parts of this question challenging.

(a) Responses here tended to be poor. Most candidates appreciated that they were required to calculate the rate of change in flux linkage but this was often the only mark to be accessed. The context of this question seemed to prevent most candidates from identifying that $N = 1$, and the area swept out by the tether every second was the product of tether length and tether velocity.

(b) In Part (i) of this question few candidates experienced any difficulty in using the turns ratio equation to calculate the output p.d. across the secondary coil of the transformer. Greater difficulty was experienced in Part (ii) when calculating the efficiency of the transformer with a large number of candidates finding the ratio of the potential differences or currents.

Q6 Most candidates were able to respond positively to all parts of this question.

(a) The naming of CRO components in Part (i) was well done. However, a sizeable number of candidates unnecessarily described the function sometimes instead of providing the component name and were duly penalised. Part (ii) was not well answered. Many candidates struggled to convey that the vertical height of the trace was required while others could not recall a suitable name for the y-amp gain.

(b) This calculation was very well handled by the majority of candidates. Despite the lack of structure given, most candidates successfully determined the transit time and the electric field strength, determined the acceleration experienced by the electron from the field strength and went on to determine the displacement. The mark scheme incorporated an error carried forward (ECF) protocol within the question which allowed candidates to accrue more of the five marks available.

Q7 This question was generally well answered.

(a) This part posed few problems. Candidates' most common mistake was in failing to express the particles' masses in unified atomic mass units. Failure to include the negative sign of the electron charge was another common omission.

(b) The basic operating principles of the cyclotron were well known. The most commonly lost mark here was for not stating that the a.c. potential difference between the dees had a fixed frequency.

The quality of written communication displayed by most candidates was good enough to gain both marks. However, the poor standard of handwriting by some candidates meant that the illegibility of some words and phrases was sufficiently intrusive to disrupt the understanding of the passage – these candidates were penalised.

(c) Part (i) of this question had two parts, a fact picked up by most candidates who went on to address both parts and score accordingly. A minority did not address both parts. In Part (ii), the use of Einstein's mass-energy relationship was apparent to most candidates. However, many candidates obtained an energy value for the gamma photon that was twice the size it ought to be as they didn't factor in that two photons were emitted – information that was given to the candidate in the stem of the question.

Q8 This question was well answered.

(a) The majority of candidates answered both parts of this question well to show the conservation of charge (Part (i)) and lepton number (Part (ii)). In Part (i), some candidates reduced the hadrons to their quark structure and were able to achieve full credit if they clearly showed that the total charge of the reactants was the same as the total charge of the products.

(b) Almost all candidates knew that the non-leptons were hadrons and, specifically, baryons. However, many lost credit for not indicating that the hadrons had a quark structure and so were not fundamental, like the leptons.

(c) In Part (i) of this question, it was a common mistake to state the exchange particle responsible for β- decay to be the W or Z bosons. A few candidates identified the W- boson as the specific exchange particle responsible. In Part (ii) some candidates didn't realise that the W- boson decays into the electron and the electron anti-neutrino.

Q9 Aspects of this question challenged many candidates.

(a) This question, in Part (i), on modes of vibration on stretched strings was done well by some candidates while others groped for the method. As has been stated in previous Chief Examiner Reports, this type of question requires candidates to provide explicit evidence of the logic behind their response. That is, candidates should provide equations, they should show all substitutions into those equations and, if a number is required, ideally provide a value to a greater number of significant figures that can be shown to round off to the value they have to show. In this case, the candidate has to show that the lawnmower engine is turning over at 3600 rpm. The best way to tackle this is to show how the data on the standing wave pattern can be used to calculate this value. The responses of many candidates had a variety of calculations dotted around the available answer space. It is incumbent on candidates to show logically their working out as all values are given. In Part (ii) candidates were asked to apply their understanding of harmonic motion to determine the maximum force acting on the piston. Many candidates executed this calculation accurately. However, there were frequent concerns over the use of incorrect physics in the context; many candidates attempted to use circular motion to answer this question. The use of the error carried forward protocol in the mark scheme allowed candidates who couldn't determine the angular frequency to access later marks.

(b) This question tested candidates' knowledge of the AS electricity course. The stem of the question provided the candidates with lots of information about the spark produced by a spark plug. As has been mentioned previously, some candidates found it difficult to select the data relevant to the two parts of this question.

(c) Candidates' understanding of sound intensity and sound intensity level was tested in this final part of the paper. Many candidates coped very well and obtained a correct value for the new intensity level.

Assessment Unit A2 3 Practical Techniques

Q1 The majority of candidates completed this question successfully.

(a) Almost all candidates measured and recorded values for the lengths l1 and l2 of the string-spring system that increased with the load and angles that decreased with the load. Some candidates appeared to measure only the length of the string and were penalised. Since a metre rule was provided, it was expected that values be recorded in centimetre to one decimal place and most candidates conformed. A small number of candidates forfeited marks for quoting angles to one decimal place. This is considered to be wrong as it is not possible to measure angles, using standard protractors, to one tenth of a degree.

(b) In Part (i) of this question, almost all candidates successfully found the average of l1 and l2 (Session 1) or the sum of l1 and l2 (Session 2). In Part (ii), a large number of candidates incorrectly incorporated degrees into the unit for $\frac{m}{\text{Cos}\left[\frac{\theta}{2}\right]}$ and forfeited a mark. Other candidates did not follow the instruction to give their value to three significant figures and were duly penalised. In Part (iii), most candidates demonstrated their mastery of graph drawing as good scaling, accurate plotting and well considered best-fit line positioning were the norm. A small number of candidates appeared unfamiliar with the phrase "graph L against " $\frac{m}{\text{Cos}\left[\frac{\theta}{2}\right]}$ as meaning that 'L' should be plotted on the y-axis. Candidates who did invert their axes were penalised just one mark. However, these candidates often forfeited marks later on in the question for their analysis.

(c) In Part (i), the calculation of gradient was generally very well done. Almost all candidates selected points from their best-fit line that were far apart. It is evident that some candidates force their best-fit line through points from their results table (usually the first and last) in order that they may use these when calculating gradient. Candidates are advised that this is not good scientific practice and adopting this practice risks losing the mark for the quality of the best-fit line. The application of error carried forward here allowed most candidates to access the mark for unit of gradient. In Part (ii), most candidates realised that their gradient was equal to $\frac{1}{2k}$ (in Session 1) and $\frac{1}{k}$ (in Session 2) and almost all then proceeded to find a value for k consistent with their graph. However, the physical interpretation of constant P, required in Part (iii) of the question, was recognised by only a few candidates.

Q2 Almost all candidates responded well to this question.

(a) Majority of all candidates were able to obtain useful data on the transmission of light through different thicknesses of glass. Candidates are advised that values measured using the same measuring instrument should be recorded to the same number of decimal places. Some candidates amended the column heading to record current in amperes – an action that was considered to be suitable in this context.

(b) In Part (i) of this question, most candidates correctly showed the logarithmic form of the equation and went on to correctly map it to a linear form. A number of candidates used logarithms to base ten and were penalised. In Part (ii), headings involving logarithms posed problems for some candidates. Candidates are advised that logarithmic values have no unit but it is useful to indicate the physical quantity and unit of the number the logarithm of which has been taken, in this case, current measured in milliampere and that is why the column (or axis) heading is ln(I/mA). Another frequent mistake was to express values to something other than two decimal places, as was required by the question. In Part (iii), the graphs drawn by candidates tended to attract most of the marks. A sizeable minority of candidates missed the scaling on the x-axis (in landscape view) for 'N'. These candidates were penalised. A significant number of candidates chose an inappropriate scale for the ln(I/mA) axis which resulted in an almost horizontal best-fit line; these candidates were also penalised.

(c) In Part (i) of this question, candidates were credited for appreciating that P was a positive constant and for obtaining a gradient consistent with their graph. In Part (ii), most candidates appreciated that constant I_0 was related to the intercept of their graph. For those who used the scale provided for N, the intercept was, normally, correctly read from the y-axis and a consistent value for I_0 obtained. Those candidates who did not use the N scale provided usually had to calculate a value for the intercept by substituting the value of the gradient and the co-ordinates of a point on the line into y=mx+c. Full credit could be accessed but much more work was required to achieve it. Furthermore, this part of the question also required candidates to draw an extreme-fit line from which to establish a value for the uncertainty in I_0. Many candidates did not realise an extreme-fit line had to be drawn and forfeited the three marks available. Of those who did draw an extreme fit line, two main approaches were observed: some candidates calculated the co-ordinates of a centroid and used it while others considered only the plotted points. A very generous approach was taken to the assessment of extreme-fit lines. Those candidates who drew an extreme-fit line usually went on to determine a value for the absolute uncertainty in I_0 consistent with their graph. Part (iii) challenged the candidates to interpret I_0 and P by sketching a graph on the axes of Fig 2.2. Many candidates successfully had graphs of the same gradient and a larger I_0 (smaller I_0 in Session 2). Candidates are advised to label lines on their graphs. Almost all graphs had at least two lines, most had three lines and some even had four lines; it is in the candidate's interest to make clear to the examiner what each of these lines represents.

Q3 Most parts of this question were accessible to all candidates.

(a) In Part (i) of this question, almost all candidates calculated a value for the acceleration of freefall that was consistent with the results. Some candidates introduced power-of-ten errors when they failed to convert the radii to metre. Part (ii) was surprisingly poorly answered. A significant number of candidates did not appreciate that the absolute uncertainty in (R – r) was the sum of their absolute uncertainties. In Part (iii), many candidates correctly calculated the percentage uncertainty in the value for freefall. The most common mistake made by candidates was in failing to double the percentage uncertainty in the periodic time because it is squared in the relationship.

(b) In Part (i) of this question, most candidates correctly calculated a value for constant k but some candidates had difficulty establishing its unit. In Part (ii), most candidates responded with excellent descriptions of a procedure to be followed that would facilitate the acquisition of data, thereby enabling an accurate and reliable value for the radius of curvature of any bowl to be determined.

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