GCE

Physics A

Advanced GCE **H558**

Advanced Subsidiary GCE **H158**

OCR Report to Centres June 2015

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

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This report on the examination provides information on the performance of candidates which it is hoped will be useful to teachers in their preparation of candidates for future examinations. It is intended to be constructive and informative and to promote better understanding of the specification content, of the operation of the scheme of assessment and of the application of assessment criteria.

Reports should be read in conjunction with the published question papers and mark schemes for the examination.

OCR will not enter into any discussion or correspondence in connection with this report.

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OCR REPORT TO CENTRES

G481 Mechanics

General Comments:

The marks for this paper ranged from 0 to 60 and the mean mark was about 31. Most candidates made excellent use of their time to tackle most of the questions in the paper. There were no significant omissions of specific questions.

Centres have continued to make good use of past papers, mark schemes and examiners reports. Most candidates showed good analytical skills and a decent command of technical language. Some descriptive responses lacked structure and knowledge of basic physics. Very few candidates took advantage of expressing their ideas in the form of bullet points. On some scripts, potentially good answers were marred by premature rounding of numbers and erroneous transfer of data between questions. Generally, candidates made good use of their calculators and often wrote the final answers in scientific notation. Numerical answers must not be left as fractions or as surds. It is important that the final numerical answer conveys the significant figures used in the question.

There were some very good scripts with clearly laid out physics and well presented calculations. The comments that follow tend to relate mainly to the opportunities that were missed by the candidates.

Comments on Individual Questions:

Question	Comments
1(a)	Candidates answered this opening question extremely well by correctly labelling the axes as velocity and time. A very small number of candidates had the labels either as speed and time or distance and time. Any units, whether correct or not, were ignored by the examiners.
1(b)	There were very few incorrect answers. Most candidates correctly labelled the vertical axis as stress and the horizontal axis as strain.
1(c)	Most candidates struggled to gain a mark in this question. There were no problems identifying force or tension for the vertical axis, but the horizontal axis was frequently stated as extension rather than length of the wire. Even better candidates struggled with this question.
2(a)	The majority of candidates gained a mark for stating two scalar quantities that shared the same unit. The correct pairings were often stress and pressure, and torque and moment. Some candidates misread the question and gave two vector quantities instead. Correct answers from other units were allowed; these included frequency and decay constant. About 1 in 10 candidates omitted this question altogether.
2(b)(i)	The correct values for the *x*-component and *y*-component of the force **B** were 6.0 N and 2.0 N respectively. One significant figure answers were allowed. The majority of the candidates scored a mark for values lying within $\pm$ 0.1 N. A small number of candidates opted for a longer route. They measured the angle θ made by the force with the *x*-axis and the magnitude of the force F directly from Fig.2.1 and then used $F\cos\theta$ and $F\sin\theta$. No mark was awarded for swapping the component values.

2(b)(ii) This was a discriminating question, with many of the best candidates gaining full marks. There were a few different methods that could have been used to determine the resultant force. Most candidates used Pythagoras' theorem with the magnitude of the sides of the triangle being 8.0 N and 5.0 N. Some used Fig.2.1 to carry out the vector addition. A few used the cosine rule having calculated the individual magnitudes of the forces **A** and **B**.
The most frequent incorrect answers were:

- determining the magnitude of the vector from the end of **A** to the end of **B;**
- adding the magnitudes of the force **A** and force **B;**
- just quoting the magnitude of the force **A.**

2(c)(i) Most candidates gained a mark for stating the direction as 'down'. The most frequent incorrect answers were: vertical, right and horizontal.

2(c)(ii) Many candidates would have benefitted from concise answers in bullet form. The majority of the candidates scored either one or two marks. The horizontal component of the velocity remains the same. The reason why this is the case eluded some candidates. Examiners were looking for the idea that there is no 'horizontal force' on the water. There were some flawless answers such as '*the component of the weight horizontally is zero because mgcos90° = 0*'. A small number of candidates thought that the horizontal component of the velocity remains the same because '*the hose stops providing a horizontal force'* or '*there was no drag*'.

2(c)(iii) This proved to be a more challenging question with many candidates demonstrating a poor knowledge of projectiles and kinematics. It was difficult to make sense of sentences such as '*the velocity decelerates from **X** to **Y***' or '*the water floats at* **Y**'. Candidates in the upper quartile had no problems and gave eloquent description of the variation of the vertical component of the velocity. Many of these candidates knew that the vertical component of the velocity decreased in magnitude from **X** to **Y**, increased in magnitude from **Y** to **Z** and was zero at **Y**.

3(a)(i) Most of the candidates scored either two or three marks. The length from **A** to **B** was 8.0 cm. A tolerance of ± 0.1 cm was allowed. This gave a displacement of magnitude 400 km and an average velocity of 270 m s^{-1}. Some candidates, incorrectly used Pythagoras' theorem to determine the length **A** to **B**; the angle between the two displacements was 100° and not 90°. However, examiners gave credit leading to a maximum of two marks as long as the value of the length **A** to **B** was used to determine the average velocity. There was no credit at all for determining the average **speed** from the total distance travelled by the aircraft. A very small number of candidates lost a mark for not converting the distance from km to m.

3(a)(ii) The majority of the candidates simply described the differences between scalar and vector quantities. The Examiners were looking for the idea that distance is used to determine speed and displacement for velocity and that distance is not the same as the magnitude of the displacement. Correct answers such as '*distance is longer than displacement, therefore the average velocity is smaller than the average speed*' were rare, especially in the lower quartile.

3(b)(i) The majority of the candidates gave well-structured answers. It was good to see the pattern of equation, correct substitution and correct answer to two significant figures. The most common errors were:

- determining the speed by dividing the radius by the period;
- using $\underline{\pi r^2}$ instead of $\underline{2\pi r}$ when calculating the distance travelled.

3(b)(ii) Once again, most candidates provided well-structured analytical answers. The most popular route was using the equation of motion $v^2 = u^2 + 2as$. A small number of candidates had problems rearranging this equation or forgot to square the initial velocity. It was clear that candidates were competent at using the equations of motion.

4(a) Many candidates gave good answers by making reference to either 'height' or 'position' of an object in a gravitational field. Some candidates gave vague answers in terms of energy transfers. Generally, candidates gained a mark for this question.

4(b)(i) Candidates either used their knowledge of kinematic or the idea of conservation of energy to calculate the speed of the ball just before impact with the ground. Generally the answers showed progression and clarity. A small number of candidates decided to use $v^2 = 2gh$ and totally ignored the initial downward velocity of 15 m s^{-1}. There was no credit for this.

4(b)(ii) Most candidates scored a mark for calculating the kinetic energy of the ball either just before impact with the ground or after hitting the ground. The energy transferred to the ground presented a few challenges for the candidates in the lower quartile. Many assumed that the transfer of energy was equal to the difference between the kinetic energies linked to speeds of 15 m s^{-1} and 12 m s^{-1}. Others assumed that the energy transfer could be calculated by determining the square of the difference of the speeds 16.7 m s^{-1} and 12 m s^{-1}. Unambiguous answers were presented by the best candidates.

4(b)(iii) This proved to be a challenging question for many candidates. The success in this question relied on understanding that velocity is a vector and the change in velocity of the ball was '16.7 + 12 = 28.7 m s^{-1}' and not '16.7 - 12 = 4.7 m s^{-1}'.

5 This question produced a good spread of marks. Candidates who read the question carefully and focused on the key requirements of the question generally did well. There were two easy marks for correctly identifying the instrument used to measure the physical quantities. Many gained two marks for '*use a stop-clock for timing the mass over a fixed distance and measure the distance with a ruler'*. A variety of timing methods were allowed by the Examiners.
Determining the input power to the motor presented some challenges. This required a clear description of how the output **power** was determined. A disturbing number of candidates saw no difference between 'energy' and 'power'; this prevented them from securing the last two marks. In short, there were some missed opportunities in this question.

6(a) This was a discriminating question. Most candidates scored a mark for either stating the base units for force or the base units for speed and area. The manipulation of units presented problems for some candidates. A small number of candidates thought that *k* was density and therefore concluded the unit kg m^{-3} must be right.

6(b)(i) About a third of the candidates correctly drew an arrow opposite to the direction of *D*. Most candidates drew an arrow in the direction of the resultant force of the weight and drag.

6(b)(ii) A pleasing number of candidates realised that for terminal velocity, the drag had to be opposite in direction to the weight. For some candidates, the answer was much simpler - '*there is a non-zero resultant force on the ball'*. Sadly, some candidates thought that the ball was travelling at its terminal velocity because drag and weight had the same magnitude.

6(b)(iii) This proved to be a challenging question, with many candidates not realising that the ball had to be travelling vertically upwards. A significant number of candidates had the ball accelerating vertically downwards because the direction of the resultant force. Some candidates had the ball '*decelerating slowly'*; this does not make much sense. A small number of candidates saw no difference between 'velocity' and 'acceleration'.

6(c) This question produced a good range of marks, with most scoring two or more marks. Many candidates knew that the initial acceleration of the DVD was g or 9.81 m s^{-2} because there was no drag. Many also realised that drag increased as the speed of the falling DVD increased and that the decreasing magnitude of the resultant force led to a decreasing acceleration. A small number of candidates spoilt their answers by suggesting that the DVD was '*decelerating as it fell towards the ground'*.

7(a)(i) Generally this was well answered with most candidates correctly using the equations for density and weight. Some candidates stopped after calculating the mass of the concrete block, perhaps thinking that this was the '*weight'* of the block.

7(a)(ii) Most candidates gained two marks for determining the pressure. Only a very small number of candidates used the incorrect value for the cross-sectional area.

7(b)(i) The majority of the candidates gained a mark here for stating the principle of moments or simply writing '*net moment = 0*'.

7(b)(ii) Most candidates scored one mark for knowing that the force at wall **X** would decrease. The explanation was not always successful. Those who attempting to answer in terms of moments about the opposite wall did generally well.

8(a) Most candidates were aware of the elastic properties the material, and hence secured the QWC mark. A pleasing number of candidates knew that the area enclosed between the loading and the unloading sections of the graph was related to the energy 'lost'. The majority of candidates also scored a mark for stating that the material did not obey Hooke's law. Some candidates spoilt their answers by suggesting that the material became plastic at large stress values or by using terms such as malleable and ductile in their descriptions. This question produced a good range of marks.

8(b)(i) The more able candidates performed well in this question. Responses from these candidates were logically set out. There were no problems with powers of ten or manipulating equations. Some candidates managed to pick up marks for correctly calculating the stress and strain values. The majority of the candidates gave a plausible assumption. The most frequent one being '*the material obeys Hooke's law'*.

8(b)(ii) About a quarter of the candidates omitted this question. A small number of candidates correctly calculated the breaking force using the ratio of cross-sectional areas or by repeating the stress and strain calculations.

G482 Electrons, Waves and Photons

General Comments:

Candidates scored across the range from zero to 99%. Papers ranged from excellent to many lacking basic GCSE knowledge. There was no evidence that candidates were pressed for time and they were therefore able to answer the paper fully within the time limit. Candidates scored freely in questions where the exercise was mainly substituting into formulae. These questions were the ones where weaker candidates gained the majority of their marks. Where explanations were required the answers proved to be more discriminating, especially in Q4 and Q5. Good candidates were able to demonstrate their knowledge on the wide range of topics covered. Weaker candidates appeared to find most of the paper accessible. There were very few unattempted sections.

Many candidates have little understanding of how to set out their calculations so that these can be read and understood by a third party. This was especially important in Q1c, 2c and 3c. In Q3c it was necessary to explain why the calculation was being undertaken and what conclusion was reached by doing it. The explanation was often omitted, leaving just a string of numbers.

Candidates should be reminded that the Examiner has to read their answers on a computer screen. Often they write down the side of the page, into the next section or at the base of the page instead of using the extra sheets for this purpose at the end of the paper.

It was evident that many candidates had studied last year's paper closely as the knowledge and correct use of the potential divider in Q2 and Q3 was extensive. It was also detrimental in Q3b where many circuit diagrams contained a lamp and/or a limiting resistor. Rote learning was also evident in the correct analysis being given following the description of a different experiment.

There are still major misunderstandings in the such terms as *path* and *phase* difference; for example a phase difference of $\lambda/2$, and *displacement* and *amplitude*.

Candidates often are not diligent in reading the question carefully, which is usually designed to lead the candidate. For example in Q6b a particular scenario was given about the effect of blue and red light on a clean metal surface. Many answers just included a general description of the photoelectric effect rather than addressing the particular situation.

Comments on Individual Questions:

Question No.

1a Most candidates were able to complete this section successfully with the majority scoring full marks. Only the weakest stumbled here.

1b This was a more searching and discriminating question. Most arranged three components in parallel with the supply but failed to place the switches correctly. Some then lost the final mark by not labelling the heaters.

1c Part (i) was to focus candidates on the relationships between P, R and A; most scored full marks. In part (ii) few stated that P is proportional to A or that RA is constant but calculated the resistance of the second heater followed by the diameters of the two wires. It was intended that this should be a quick calculation taking the square root of the ratio of the given powers. Only the best candidates solved the problem in a few lines using ratios.

1d This question about fuses was successful in being more discriminating than many in the past. Candidates were given full credit if they forgot to include the fan in any otherwise correct calculations here.

1e In the definition of 1KWh there was confusion between power and energy. The majority forgot to include the fan in the cost of using the heater, giving an answer of 108 p.

2a About half of the candidates completed both symbols correctly and another third only one.

2b Parts (i) and (ii) were almost universally correct with most completing (iii) successfully too. In (iv) R was read correctly from the graph with about a third then justifying the voltage using a potential divider calculation.

2c This question discriminated well with the top third scoring full marks; a few candidates failed to indicate which was the ON and which the OFF position reversing their answers. About half had failed to grasp the clues from the earlier parts and tried to include the value of current from b(ii); hence failing to score any marks.

3a The calculation of part (i) was done well with the unit being universally known; weaker candidates failed through being unable to convert 4 hours and 40 minutes into seconds. In part (ii) the understanding of the role of a battery charger was poor and the convention for current flow frequently not known. Very few appreciated that the voltage across the charger terminals had to be greater than he emf of the cell. In comparison, section 4 was answered well.

3b Only a small percentage of candidates appeared to be familiar with this straightforward experiment. These usually scored full marks. It was a common misconception for two voltmeters to be included, one to measure the terminal p.d. and the other to measure the e.m.f., where in fact both would measure the same quantity. Few, who attempted to measure the e.m.f. directly using a voltmeter, realised that the cell had to be on open circuit to obtain a correct value.

3c Many candidates approached this question using power calculations, failing to realise that some power is dissipated in the internal resistance. This leads to calculations of the power provided by the cell not the power dissipated by the lamp. Most of those who assumed that the cell could provide the required current to light the lamp to normal brightness successfully justified the number of cells necessary to do so. A common error was to calculate 6/18 as 0.3 instead of 0.33 leading to significant inaccuracies in further calculations.

4a The basic definitions on waves in part (i) were often imprecise. A typical example for *frequency* is *the amount of waves in a second*. For *phase difference* most compared two different waves rather than referring to two points on the same wave. In part (ii) many confused a progressive wave with a stationary wave so only about one third of the candidates scored both marks.

4b In part (i) many candidates gave only the characteristics of a stationary wave failing to give the comparison property for a progressive wave. Part (ii) was answered well by all. In part (iii) most candidates were aware that all points oscillated with the same frequency but failed to give enough detail to score further marks. In part (iv) many candidates did not notice the request for frequency values . It was apparent that few candidates had an understanding of harmonics. About half of the candidates gave at least one correct frequency but the explanation for the choice was often not convincing.

5a More than half of the candidates are aware that coherence requires a constant phase difference. Interference is related to the principle of superposition of waves and the sum of displacements at the point(s) where the waves meet. Many candidates refer to *amplitudes* and to the waves *colliding*, etc. There is only a small selection of words that are accepted to describe the word *interference*.

5b Well answered by most. The common error was to insert MHz for GHz in the calculation.

5c The meanings of *phase* and *path length* and their role in interference were often not well understood leading to confusion when movements of the detector or transmitter were made. Many failed to realise in part (ii) that the distances of the detector from the two transmitters remain equal. Energy was often lost rather than spreading out. Few seemed to be aware of the inverse square law. Most answered part (iii) well especially those in terms of path length rather than phase difference.

5d There were many good answers to part (i). In part (ii) some students failed to recognise that the question related to polarisation but most scored some marks.

6a Almost 100% success for *photoelectric effect.*

6b There were many good answers but some candidates were side-tracked into writing about the gold-leaf electroscope experiment losing sight of the original question. Some also failed to refer to the blue and red photons in the stem of the question.

6c These calculations were usually well answered with many weak candidates scoring full marks. In part (i) separation of the work function from the rest of Einstein's equation was often not clear i.e. by stating that the kinetic energy is zero. The KE term just disappeared. Also in part (ii) a few students failed to subtract the work function from the photon energy.

6d In part (i) about half of the candidates scored full marks for satisfactory descriptions of evidence. Some candidates referred to Young's double slit or similar experiments being performed on an atomic scale with electrons. Others knew of a suitable experiment but were too vague in presenting their evidence. The majority scored full marks for the final part. There were more power of ten and rounding errors here than anywhere else in the paper. Overall these were very few.

G483 Practical Skills in Physics 1

General Comments

Teachers and technicians in Centres are thanked for once again for their hard work in organising the practical skills assessment. The successful assessment of practical skills relies very much on the care and attention to detail that the individual Centres put into the process.

The purpose of the moderation process is to confirm the marks awarded by a Centre and to ensure consistency between Centres. It is essential that the mark schemes are followed and Centres must annotate candidates' scripts either to justify the award of a mark or to indicate why a mark has not been awarded. It was clear from the moderation process that the majority of Centres marked the tasks carefully and there were many helpful annotations. There were, however, still a significant number of Centres where the marking of B1.2 in the Qualitative Tasks and C4.1 and C4.2 in the Evaluative Tasks failed to include clearly the numerical marking point as well, e.g. C4.1-2 for the second marking point for C4.1. The questions at the end of the Qualitative Tasks and the Evaluative Tasks are 'high demand' questions and thus Centres should not credit trivial answers. Additional guidance is given in the mark schemes and Centres are welcome to contact OCR for further guidance. Centres do need to be careful about giving 'benefit of doubt' marks. If a Centre is to award a mark which is 'benefit of doubt' then the script must be annotated with reasoning. The same candidate should not then be awarded another benefit of doubt mark.

The majority of larger Centres had carried out appropriate internal moderation. Centres must ensure that the final agreed marks awarded are clearly indicated on the scripts. For large Centres it is important that marks agreed at internal moderation meetings are then applied consistently across all the candidates in the Centre.

Candidates should be reminded of the need to show all the steps clearly when carrying out calculations; this particularly applies to the end of the quantitative tasks and when determining uncertainties in gradients or *y*-intercepts in the evaluative tasks. In addition, candidates should be encouraged to include greater detail in their answers to descriptive type questions, giving reasons where necessary.

Centres are reminded that the only help to be given to candidates is clearly indicated in the 'instructions for teachers'. Any help given must be recorded on the front of the appropriate task. Under no circumstances should help be given in the construction of the table of results, the graph or the analysis parts of the quantitative tasks. Centres must ensure that the guidance within marks schemes remains confidential at all times.

Administration

Centres are advised to check that they are using the latest assessment material from 'Interchange'. Before marking a task, 'Interchange' should be checked. Centres are advised to sign-up to the email update process.

A small number of Centres did not include the candidate numbers (or used incorrect numbers) on the work that was submitted. The cover sheet is a useful sheet to include with each candidate's work which is sent to the Moderator. The cover sheet is available from and the spreadsheet from 'interchange. There is also a useful spreadsheet.

Centres should ensure that the marks are submitted to OCR and the Moderator by 15th May. Small Centres should also submit all their candidates' work in line with the moderation instructions directly to the Moderator and not wait to hear from the Moderator. Larger Centres should wait for the automated email from OCR. If a Centre has not heard from OCR by the end of May then the OCR contact Centre should be either telephoned or emailed. Where work is submitted late, the candidates' marks may not be ready for the publication of results.

It was very helpful where Centres enclosed with their paperwork any correspondence with OCR including copies of emails and coursework consultancies.

The Centre Authentication Form must be completed and sent to the Moderator. Moderators had to ask a small number of Centres to supply this form. Copies of this form are available from the OCR website.

Re-submitting Tasks

A number of Centres did not always follow the rule on resubmitting tasks correctly. As the 'Frequently Asked Questions' on 'Interchange' indicates, candidates wishing to improve their mark by re-sitting this unit can re-submit one or two Tasks (from any of the Qualitative, Quantitative or Evaluative Tasks) plus one (or two) of the new available Tasks **OR** complete three new Tasks (from the selection available for assessment on Interchange clearly marked with the current assessment year).

When a candidate re-sits this unit and uses up to two tasks from the previous session, the marks confirmed by the original Moderator in the previous session cannot be 'carried forward'; the re-submitted tasks should be reviewed in the light of the Moderator comments and Teachers are advised to re-mark the Task in light of any comments made by the original Moderator (the Archive Mark Schemes are available on Interchange for this purpose) and it will be re-moderated when it is re-submitted. Thus the Centre must include one Qualitative, one Quantitative and one Evaluative Task for each candidate in the sample.

Where a candidate has not made any improvements to their marks on a 'new' task, they should not be entered (or if they have been entered, they must be withdrawn). Centres should ensure that the candidate number is the same on each piece of work that is submitted. The Cover sheet also allows for additional information to be given to the Moderator, for example indicating that a task was previously submitted.

A number of Centres did not have available the work of candidates from the previous year. If a candidate is to resubmit work next year, then the candidate's work from this year must be kept securely. It is important that Centres review their procedures with regard to storing the work for next year.

Qualitative Tasks

Generally these tasks were marked to the published mark schemes. The marking criteria that were generously awarded were A1.2, B1.1 and B1.2.

For A1.2, candidates' responses must be detailed and the additional guidance given in the mark schemes should be followed. Annotation is helpful.

Where graphical work is requested in the Qualitative Tasks, candidates are not being assessed on the size of the graph or the labelling of the scales since this is assessed in the Quantitative Tasks. The graph may be used to judge the quality of an experiment. In addition, candidates may be assessed on their drawing of a straight line of best-fit or a smooth curve. This latter marking point was again generously awarded. There should be a balance of points about the line and 'hairy' lines should be penalised. Further guidance is given in the Practical Skills Handbook.

As has been stated in previous reports, for B1.2 candidates' answers must be detailed and explanations must be thorough – the guidance given in the mark scheme should be followed. It is very helpful to indicate where the mark is awarded with an indication to the corresponding point in the additional guidance. Again Centres are welcome to email OCR for additional guidance or confirmation of marks awarded.

Quantitative Tasks

The mark schemes for the quantitative tasks are generic in nature and very much reflect good practical skills which candidates should develop throughout the course. To accurately mark these tasks, markers must check carefully the table of results, the graph and the various calculations towards the end of the task.

Centres are able to help candidates in setting up the apparatus (as indicated in the mark schemes), any help given must be recorded in the box on the front of the Task. Under no circumstances may Centres assist candidates in the construction of graphs or in the analysis section. Most candidates were able to set up the apparatus in the tasks without help. Centres that did provide help clearly indicated it; this was very helpful to the moderation process.

Results tables were generally well presented. The majority of candidates labelled the columns with both a quantity and the appropriate unit although weaker candidates often did not score this mark with the more complicated units. It is expected that there should be a distinguishing mark between the quantity and the unit. Index notation should be encouraged, e.g. $1/t^2$ / s^{-2} or t^{-2} / s^{-2} are encouraged.

All raw data should be included in a table of results and given consistently. Common errors in this part were to have inconsistent readings e.g. distances not measured to the nearest millimetre when using a metre rule or not using a suitable full range. Often candidates recorded distances to the nearest centimetre although a small number added zeros so as to indicate that they had measured distances to the nearest 0.1 mm. When significant figures are assessed in the table, the guidance in the mark schemes must be followed. There still appears to be some confusion by candidates regarding the difference between decimal places and significant figures

Graphical work was generally done well. When a candidate asks for another sheet of graph paper, a similar sheet should be issued. Weaker candidates often used less than half of the graph grid for their points. On the graph paper provided, it is expected that the points should occupy four large squares horizontally and six large squares vertically when the graph paper is portrait. When the graph paper is landscape the points should occupy four large squares vertically and six large squares horizontally. Centres should ensure that the graph paper is clear before giving the task to candidates. If it is not appropriate, then another similar sheet should be used perhaps downloaded from the task individually.

Points were usually plotted accurately to within half a square. Often mis-plotted points were very obviously wrong; candidates should be encouraged to check points like this as they finish plotting graphs. The mark schemes very clearly state that "two suspect plots" should be checked and that these plots must be circled. The majority of candidates drew their line of best-fit with a fair balance of points. For the award of this mark there must be at least five trend plots. Centres were sometimes generous in awarding this mark.

Candidates will normally need to determine the gradient and/or the *y*-intercept of their line of best fit. It is expected that the gradient should be calculated from points on their best-fit line which are at least half the length of their line apart. Weaker candidates often lost marks either by using triangles that were too small or by working out $\Delta x/\Delta y$. Good candidates indicate clearly the points that they have used and show their calculation. Where candidates have used data from their table that does not lie on the line of best-fit, then this mark should be penalised. Centres should check the calculation. The plots selected must be accurate within half a small square and the calculation must be checked. Where candidates are not able to read off the *y*-intercept directly, it is expected that they should substitute a point on their line into the equation $\underline{y = mx + c}$. Guidance is clearly given in the Practical Skills Handbook. Gradient/*y*-intercept values do not need units. Centres are asked to ignore both incorrect units and significant figures at this stage – candidates will invariably be penalised in C2.2.

Candidates are then required to use either their gradient or their *y*-intercept to determine another quantity. It is essential that candidates show their working. Candidates who do not use their gradient and/or *y*-intercept values cannot score C2.2 marks. The C2.2 marks are awarded for candidates who have used the gradient/*y*-intercept and given their answer to an appropriate number of significant figures and the second mark is awarded for the quantity being within a specified range with a consistent unit having used the gradient/*y*-intercept. It is at this stage that a power of ten (POT) errors would be penalised.

The final mark for the quantitative task (C2.3) is awarded for justifying the number of significant figures. The phrase “raw data” is not explicit enough; candidates must explicitly quote the quantities that have actually been used. Thus, where a candidate states “I quoted my answer to 2 significant figures because that was the least number of significant figures in my data”, the mark should not be awarded.

Evaluative Tasks

Again the Evaluative Tasks were where weak candidates had greatest difficulty. There are a large number of high demand marks in these tasks and Centres should not give credit for weak or vague answers. It is important that the additional guidance in the mark schemes is carefully followed

The initial part of the task requires candidates to determine percentage uncertainties. When marking this part, significant figures should not be penalised. Centres were sometimes generously awarding the uncertainty in a measurement; it is important that the mark scheme is applied consistently.

Where candidates are asked to determine a percentage uncertainty in a quantity requiring the use of the gradient and/or *y*-intercept then the worst acceptable line should be drawn. In many cases, the worst acceptable line was generously credited for lines which often did not follow the original trend. It is expected that candidates will determine the gradient and *y*-intercept correctly for the award of this mark; small triangles, incorrect read-offs and incorrect calculations should be penalised.

In C3.2, there continues to be confusion between the terms *accuracy* and *reliability*. A number of Centres were generous in awarding marks for a single sentence with ambiguous phrasing. It is suggested that candidates be encouraged to approach each term independently and allotting each a separate sentence. When candidates are discussing reliability they are expected to make a relevant point regarding the scatter of points about the straight line of best-fit. For the award of the accuracy, comments such as “it is close to the accepted value” is not good enough for a mark – the answer need to be more detailed with reference to the percentage uncertainty determined earlier.

For C4.1 and C4.2, the mark schemes allow for “one other detailed correctly identified limitation” and a corresponding improvement to this limitation. Again it was most helpful where Centres annotated the work with the actual marking point awarded e.g. C4.1 – 3 for the third limitation point. Weak candidates are still often describing the procedure they followed. Some candidates wrote very little of substance. Good candidates scored well by describing relevant problems and suggesting specific ways to overcome them. Vague suggestions without explanation did not gain credit. Centres should ensure that they credit detailed answers at this stage – candidates should clearly explain the limitations and not just list points. For example, a common answer from candidates is ‘parallax’ without indicating how the ‘parallax’ occurs. Other examples include ‘light gates’ or ‘motion sensors’ without explanation; credit must not be given. Centres should ensure that they follow the mark schemes carefully. Centres should not be awarding ‘benefit of doubt marks’. If a Centre wishes to gain further clarification then advice should be sought either by both email or by using the coursework consultancy service.

The last part of each Evaluative Task (C4.3) requires candidates to identify one source of uncertainty and indicate the likely effect that this uncertainty would have on the quantity determined. Candidates should use a step-by-step approach and include the effect on the gradient and/or *y*-intercept. The reasoning by candidates must be consistent and correct for the award of this mark. Vague answers should not be credited.

Finally

Centres should receive an individual report from the moderator. This will be available from interchange – the Centre’s Examination Officer should be able to access the report.

Centres are always welcome to email OCR for clarification. There is also a coursework consultancy service available – further information is available from ‘Interchange’. It would be helpful if Centres could submit coursework consultancies as they mark the tasks and preferably by the end of the Spring term so that feedback can be given in good time before the 15^{th} May deadline.

Finally this year’s and the previous years’ tasks, instructions and mark schemes continue to remain confidential. Furthermore candidates’ work from this year (and previous years) also continues to remain confidential. If there is a possibility of a candidate re-submitting the work, then the Centre must keep the work securely, otherwise the work should be destroyed securely in line with OCR’s policy for controlled assessment.

G484 The Newtonian World

General Comments:

The marks for this paper ranged from 0 to 60 and the mean mark was about 34. The majority of the candidates made good use of their time and completed the paper in the scheduled time of 1hour and 15 minutes. Most candidates made an attempt to answer all questions.

Centres have continued to make good use of past papers, mark schemes and Examiners reports. Most candidates showed a good understanding of significant figures and rounding of numbers. However, candidates are reminded that it is poor practice to round numbers up or down in the middle of calculations. It is best to carry forward calculator values to at least four significant figures. Examiners were generous this session, but this poor technique will be penalised in the future.

Candidates scored freely in questions involving substituting into formulae but there were fewer opportunities to do this than in recent papers. Where explanations were required the answers proved to be more discriminating, especially in questions 5 and 6. Many candidates unfortunately did not read these questions carefully and merely stated rather than gave reasons for their comments.

There were some very good scripts with clearly laid out physics and well-presented calculations. However, a significant minority of the scripts were poorly set out. This was particularly noticeable in the calculation parts of questions 1, 2 and 5. This made it very difficult for examiners to follow the logical steps and award compensatory marks. A minority of scripts suffered, once again, from poorly formed digits particularly in indices. The clarity of written work in some scripts made it difficult for Examiners to follow the candidate’s argument and inevitably this led to a loss of marks. Candidates are also reminded that it is not good practice to overwrite when changing their answers.

The comments that follow tend to relate mainly to the opportunities that were missed by the candidates.

Comments on Individual Questions:

Question No.

1(a)(i) This question was designed to allow students to demonstrate their understanding of Newton’s third law. Although many were able to quote the law accurately, few were able to apply it correctly. Only a minority of candidates scored any marks at all, usually for stating that the pair forces must be of the same type and *N* and *W* were not. It was particularly disappointing to see the large number of misconceptions offered such as ‘Newton’s laws only apply on Earth’, ‘*N* and *W* should be applied at the same point’ and ‘There is no gravity on the Moon’. Newton’s third law continues to present a challenge to the majority of candidates.

1(a)(ii) This was a discriminating question with the more able candidates performing well. Many candidates attempting the question failed to read the word ‘*location’* and gave answers referring to just the magnitude and direction of the force.

1(b) This largely synoptic question seemed to cause problems for all but the more able candidates. Few realised the need to resolve the velocity of the ball into horizontal and vertical components. Of the few, who attempted to resolve, the majority applied the equation $\underline{v^2 = u^2 + 2}\ as$ incorrectly. The Examiners rewarded those who indicated a need to resolve provided that it was clear that the acceleration acted only in the vertical direction. A small minority determined correctly the time to reach maximum height but forgot to double their value to obtain the total flight time. It was, however, pleasing to see some well-set out solutions from able candidates.

2(a)(i) Most candidates were able to score the mark for dividing the molar mass of xenon by Avogadro's number. A small number, however, obtained answers which were many orders of magnitude greater than the required value. Candidates are advised to ask themselves the simple question 'Is this a reasonable answer' before moving on to the next question. This check often suggests an error has occurred which may hopefully be found and corrected thus avoiding an unnecessary loss of marks.

2(a)(ii) There were three stages to this calculation: firstly, the determination of the mass of xenon ejected per second which most were able to complete successfully; secondly, the application of Newton's second law to determine the force on the xenon ions and hence, by Newton's third law, the force on the spacecraft; finally, the acceleration which could be calculated from Newton's second law. The majority of candidates followed this process through accurately and presented their working logically. The most common error, made by weaker candidates, was the use of the spacecraft's mass to determine the force on the xenon. This resulted in excessively high acceleration.

2(a)(iii) The mark scheme was made particularly flexible here in order to reward candidates for accurately quoting either of Newton's second and third laws or a statement of conservation of linear momentum. This ensured that most candidates were in a position to score the mark. A significant number of candidates lost this mark by not making it clear that Newton's second law refers to the **resultant** force acting on the system.

2(a)(iv) Most candidates realised that the mass of the spacecraft would decrease as xenon is ejected and this would cause an increase in acceleration. Only a minority were aware that this conclusion required the force on the spacecraft to be constant and correctly drew attention to this fact. On the whole this question discriminated well across the range of candidates.

2(b)(i) Very many candidates realised that this question required them to calculate the impulse by finding the area under the curve. A wide variety of methods were seen but the poor layout made it difficult to follow the logic and identify specific errors. A significant number calculated this value by counting squares for the entire shape which inevitably consumed an excess of their time. The expected method of calculating the area of the trapezium from 0-12 ms at a height of 1000 N together with a rectangle from 4 to 9 ms of height 200 N using formulae, was not commonly seen. This method reduced the counting to a few small squares at the top of the graph.

To reflect the time required to obtain a reasonably accurate area the examiners decided to award a maximum of 2 marks, dependent upon the accuracy of the value obtained. The candidate's area was then used to determine the change in velocity with error carried forward. This application resulted in good discrimination with about 75% scoring 2 or more marks. A small minority used the maximum force of 1300 N acting over a time of 12 ms; this approach received no credit.

2(b)(ii) In this question it was common to see the phrase '*rate of acceleration'* used when clearly what was meant was '*acceleration'.* Candidates should note that 'rate of acceleration' is the 'jerk' experienced and this is the gradient of an acceleration against time graph. It is also inappropriate to talk of *'acceleration slowing down'*. For the first marking point credit was only given if the candidate identified the **increase** in acceleration and stated that this occurred **linearly** between 0 and 3 ms. A small latitude was allowed on the upper limit of this range of times but a significant number lost this mark through inaccurate reading of the scale on the graph. The second mark was awarded for candidates correctly identifying the period from 6.5 ms as one in which the acceleration **decreased** without specifying the manner of the changes. Unfortunately many incorrectly associated the negative gradient with negative acceleration or deceleration rather than negative jerk and lost the second mark.

3(a)(i) Most candidates did well and secured two marks for drawing a straight line through the origin with negative gradient. Most of these graphs were carefully drawn and were consequently easy to mark. A wide variety of incorrect graphs were drawn ensuring that the question differentiated across the entire spectrum of abilities.

3 (a)(ii) Almost half of the candidates gave good answers correctly related to their acceleration against displacement graph plotted in (i). Since the graph was drawn through the origin, examiners allowed use of a point taken from the straight line as an alternative to the expected gradient. A significant number clearly knew how to get the frequency but failed to score the second mark by stating '*transpose the equation to get frequency'* rather than quoting a formula with frequency as the subject. A small number also lost this mark as a result of imprecisely drawing their square root sign so that the division by 2π was incorrectly shown.

3 (b)(i) Most candidates recognised the need to use $v_{max} = 2\pi f A$ to obtain the amplitude. On the whole the calculation was carefully done and the answer correctly rounded to at least two significant figures. A surprisingly large number of candidates misread the v scale as 0.9 at maximum and lost one mark. It was pleasing to note that few candidates attempted to answer this question using 'suvat' equations.

3 (b)(ii) Given the application of error carried forward from (i) most candidates scored full marks; choosing the $a_{max} = (2\pi f)^2 A$ approach. A small number of candidates used a graphical method most of which showed a clear tangent at one of the v = 0 points. The scale of the graph did not allow for great accuracy using this method and marks were awarded for obtaining an answer in a fairly wide range. A minority of candidates unwisely used two points positioned on the curve to determine the gradient usually resulting in a substantial error.

3 (c) The examiners recognised that it was difficult to accurately draw the required curve and focused their attention on two features:

- The points at which the curve crossed the time axis
- The height of the positive peaks.

A wide range of curves were seen; many of them were carefully drawn and easily meeting the two criteria. A common error seen was a graph of correct frequency but with constant maximum velocity. The question succeeded in discriminating across the entire spectrum.

3(d) The majority of candidates did well in this question and scored two or more marks. A significant minority did not realise that the question was about resonance and wrote, sometimes at length, about frequencies, phase and even wavelength. None of these answers could be awarded any marks. Those drawing resonance curves generally produced reasonable diagrams with good labelling which was appreciated by the Examiners.

4(a) Most candidates did well and secured the mark for an accurate statement or word equation. The common errors seen were a definition of gravitational field strength, omission of square and taking the sum of masses.

4(b) Candidates were well prepared in this area and answered this question well; many scoring full marks. In general the derivation was clearly set out and the logic was easy to follow. In a few scripts candidates omitted a square but managed to correct this at a later stage. The small minority who were unable to complete the derivation, wisely looked up the formula in the Data, Formulae and Relationship Booklet and quoted this accurately thus earning a single mark for recognition.

4(c)(i) Just over half of the candidates gave a full correct answer to this question on Kepler's law. The most common error was a failure to mention that the graph passed through the origin. This feature is critical to the conclusion that $\underline{r^3}$ is proportional to $\underline{T^2}$.

4(c)(ii) Candidates generally coped very well with this slightly less familiar setting to Kepler's law and scored highly on the question across a wide range of the ability spectrum. This clearly reflects a thorough preparation in Centres for this important topic. A small number of candidates lost marks through poor transposition of formulae which is still fairly common in questions generally. There was a slight increase in the number of errors seen involving powers of ten, usually as a result of misreading the scales on the graph. Candidates are advised to pay particular attention to the scales on graphs.

5(a) This question was specifically included to give a hint as to the method to be used in (b). The question was written in a 'show' format to enable candidates to answer (b) even if they could not recall this area of synoptic work. However this did mean that all working, including substitution, had to be shown and this did result in a small number losing the mark.

5(b) Again this question had three distinct strands to the physics. The vast majority of candidates were capable of determining the correct mass and thermal energy required to raise the temperature of the titanium. A small number of errors were seen in these two strands however: mainly in transposition of the density formula and converting temperature changes incorrectly to kelvin scale. The final stage to determine the time was less confidently handled with transposition errors and some strange manipulation of the equations which usually resulted in the reciprocal of the correct answer. Perhaps the very small time involved in this form of welding surprised a few candidates.

5(c) The answers given for this question were disappointing. All too often the only factor quoted was the vague '*heat lost to the surroundings'.* A significant number of candidates scored one mark by identifying the loss of thermal energy to the non-shaded volume of titanium. Only a tiny minority realised that some photons would be reflected from the metal surface. Other suggestions such as *'photons are absorbed in the air', 'photons would miss the target', 'not all photons have the same energy', 'the laser needs to heat up as well'* were not given any credit. Marks for this discriminating question were mostly awarded only to the more able candidates.

5(d) This question discriminated across the entire spectrum of ability, largely as a result of candidates writing about the lack of a temperature change rather than focusing on what actually happened to the energy supplied at this stage. Many answers were merely statements lacking in the vital explanation. It was, however, encouraging to see that the physics involved in this unfamiliar situation was broadly understood by the candidates.

6(a) Although the term 'extrapolate' was not commonly seen, most candidates understood the need to extend the line back until it cut the temperature axis in order to justify their comments about negative volumes and the temperature scale. Many referred to 'zero' or 'minimal volume' and this was credited by Examiners. A significant number of candidates talked about the kinetic energy and velocity of molecules in their answers and only loosely related this to the question. This was most unfortunate given that the graph given involved volume rather than either of these terms.

6(b)(i) This standard definition was poorly answered by many candidates. Candidates did not seem to be aware that a precise definition was required. Many candidates lost the mark as a result of omitting to specify that the energies were associated with the **molecules** of the gas and that the distributions were **random**, both of which are important features of internal energy. Since the question did not specify that the gas was ideal it was appropriate to include potential energy even though it is small for gases under 'normal' conditions.

6(b)(ii) Although this was a topic that was well understood in general it was not common to see both marks scored. In most cases this was because only the most able candidates linked the kinetic energy of the molecules to temperature. Some candidates didn't distinguish clearly enough in their answers which phase had the higher internal energy by ambiguous use of 'it'.

6(c)(i) This calculation was very well answered, with only a small minority using temperature on the celsius scale. As in previous years the penalty of this serious error in physics was fairly high in this question.

6(c)(ii) Weaker students struggled with this question frequently managing only to score the mark for the number of moles of helium added. The most common error was to assume that the volume remained the same. Very few candidates attempted to solve the problem by using partial pressures and, of those who did, most only scored one mark, usually for determining the partial pressure of one of the gases. In some case it appeared that, although the calculation gave a correct partial pressure and consequently received a mark, the candidates were not actually aware that this could lead to the required total pressure value. A small minority attempted to use $\underline{p_1V_1 / T_1 = p_2V_2 / T_2}$ apparently unaware that this formula is only applicable to situations in which the mass or number of molecules of gas is constant. In order to prevent an excessive penalty for the use of celsius temperatures in gas calculations on this paper Examiners ignored the use here, if it had been previously penalised.

6(c)(iii) This was another case where it was clear that the majority of candidates knew the answer but almost half failed to score the mark because they did not make clear that volume must remain constant for the pressure to be proportional to the absolute temperature.

G485 Fields, Particles and Frontiers of Physics

General Comments:

The paper worked well to differentiate candidates of differing abilities. The marks for this paper ranged from 0 to 96. The mean mark of about 55 was similar to recent sessions. There was no evidence of candidates running out of time. There were no specific questions with aberrant omission rates. Candidates who used the additional space on page 26 did so for extra extended writing for questions 5(a) and 11(c).

The spread of responses and variety of techniques used showed that candidates had been well prepared to tackle the complexities of the examination and the better candidates were able to use their physics and mathematical skills with confidence.

Generally, candidates took much more care with significant figures and there were fewer errors with rearranging equations. However, a significant number of candidates did lose marks for inappropriate rounding of numbers within calculations. Candidates are once again reminded that it is good practice to use calculator values throughout calculations and then to write the final answer to an appropriate number of significant figures.

The legibility of a very small number of candidates remains a serious concern. Generally, candidates were making good use of command terms when answering questions. Technical terms were generally used appropriately, but some terms such as '*mass defect'* and '*binding energy'* continue to baffle some candidates. As mentioned before, some candidates would have benefited from writing their answers as bullet points rather than in continuous prose.

There were some very good scripts with clearly laid out physics and well-presented answers. The comments that follow tend to relate mainly to the opportunities that were missed by the candidates.

Comments on Individual Questions:

Question	Comments
1(a)	There were very few correct answers in this opening question, with many candidates either defining electric field **strength** or mentioning that electric fields were created by charged objects. The marking scheme was made flexible to allow a range of answers that hinted the idea that this was a region where a charged particle experiences a force. Most candidates gained a mark.
1(b)	The majority of the candidates gained two marks. Most candidates were aware that gravitational force or field was always attractive and that electric force or field can either be attractive or repulsive depending on the charge creating the electric field. Most candidates wrote the similarity as either '*both obey inverse square law'* or '*both create radial fields*'.
1(c)	This was a discriminating question, with many of the best candidates gaining full marks. The most important point was to deduce that plate **A** was positively charged and plate **B** was negatively charged and this meant that the electron will experience a force to the left. The electron decelerated in the uniform electric field, stopped after travelling a distance equal to two-thirds the separation between the plates and then reversed direction of travel. A good number of candidates even reasoned that the electron would travel back through the hole with kinetic energy of 4.0 eV. About a third of the candidates scored no marks because they had the electron accelerating between the plates and hitting plate **B** with kinetic energy of 10 eV.

1(d)(i) Most candidates scored two marks in this question. Answers were generally well-structured and prefixes correctly identified. The majority of the answers were written in scientific notation. A pleasingly number of candidates derived an expression for the force and then substituted the values. A small number of candidates used a separation of 12.5 cm to determine the electric field strength. This gave an answer of 7.2×10^{-8} N. On the basis of error-carried-forward rules, Examiners awarded one mark for this incorrect answer.

1(d)(ii) This was a challenging question requiring synoptic knowledge of equations of motion and dynamics. Many candidates scored a mark for either calculating the horizontal acceleration of the charged particle or the time it took to fall between the parallel plates. Further success in the question hinged on how effectively the question was scrutinised. Top-end candidates effortlessly calculated the horizontal displacement to be 0.051 m. However, many candidates ignored that the charged particle was falling vertically at a constant speed and attempted to determine the time of fall using an equation of motion with 9.81 m s^{-2}. A very small number of candidates in the lower quartile attempted to use either Coulomb's law or triangle of forces to determine the displacement.

2(a)(i) Most candidates gained two marks for determining the current. Only a very small number of candidates forgot to convert the 1.0 cm length into metres.

2(a)(ii) This was a low-scoring question with only a small number of candidates realising that the force experienced by the current-carrying cable would be changing direction.

2(b)(i) The majority of the candidates did extremely well in this question. The physics was clear and the manipulation of the equations was easy to follow. It was rare to see an incorrect answer. Examiners did not award any marks for just quoting the final equation $\underline{r = mv/BQ}$ without any working.

2(b)(ii) This was a discriminating question, with many best candidates gaining full marks. The answers showed careful reasoning and good algebraic skills. The crucial step towards the correct answer was realising that $\underline{v \propto r}$ and hence kinetic energy $\underline{\propto r^2}$. About half of the candidates did not make good use of their equation from **(b)(i)** and incorrectly arrived at answers such as 0.0625, $\sqrt{2}$, 2 and 4.

3(a) The majority of the candidates knew that protons and neutrons were not fundamental particles because they are composed of quarks. A small number of candidates gave incorrect or incomplete answers such as:

- *Protons and neutrons are hadrons.*
- *Neutrons and protons have other particles inside.*
- *Protons and neutrons can be broken down.*

3(b) This was a well answered question with a correct pair from the family of leptons. Although not in the specification, it was good to see muon and tau particles mentioned. A very small number of candidates had '*electrons and mesons*'.

3(c)(i) This was another success for the candidates with most gaining two marks. Those who made mistakes did so with the proton or nucleon numbers for the calcium nucleus and the incorrect symbol for the electron. Some antineutrino symbols looked deceptively like the Greek gamma.

3(c)(ii) Many candidates lost marks for being imprecise with their physics. The term *mass defect* was used by many candidates to mean 'change in mass Δm'. This was overlooked as long as candidates knew that there was a decrease in the mass of the system and this led to energy being released in accordance with Einstein's mass-energy equation. Some candidates decided to answer the question in terms of binding energies. Such answers often led to no marks because the candidates had the binding energy of the calcium nucleus as being **less** than that of the potassium nucleus. Some of the most frequent incorrect answers were:

- *Energy is given out because the mass of the particles changes.*
- *Energy is released as kinetic energy of the beta particle.*
- *Energy released is equal to the mass defect.*

3(c)(iii) This question produced a range of marks. Better candidates gave immaculate answers. Many candidates gained a mark for correctly calculating the decay constant for the potassium isotope. Determining the number of potassium nuclei proved to be fairly challenging with many candidates not knowing what to do with the 0.012% or how to use Avogadro constant. A very small number of candidates had the decay constant equal to the half-life. The modal mark for this question was three.

4(a)(i) Although the majority of the candidates were awarded a mark, the sketch graphs were generally of poor quality. The curves were often thick and levelled off inappropriately.

4(a)(ii) A good number of candidates sketched a graph showing a smaller time constant. A significant number of candidates drew a curve assuming the resistance of the thermistor had increased. A very small number of candidates drew straight lines.

4(a)(iii) Most candidates either gave a definition for time constant or half-life. About a third of the candidates, mainly in the upper quartile, gave perfect answers in terms of constant ratio of potential difference $\underline{V}$ for fixed intervals of time $\underline{t}$. The most common answer was '*After one half life the p.d. decreases to V/2, then after another half life to V/4, then V/8, and so on....*'

4(b)(i) Almost all candidates attempted this question, with most gaining a mark for the correct value for the time constant. There were fewer errors with powers of ten. Very few candidates calculated the total capacitance of the capacitors using the reciprocal equation.

4(b)(ii) This was an unfamiliar question and the success hinged on doing exactly what was stated in the second sentence of the question. A good number of candidates correctly calculated the total charge stored by the capacitors. In order to calculate the average current, this charge had to be divided by the time between each throws; 0.0083 s or simply 1/120 s. This is where many candidates slipped. They divided by time constant or half the time between each throws. Some candidates calculated the maximum power dissipated in the resistor or the maximum current in the 240 Ω resistor. About a quarter of the candidates, mainly in the upper quartile, gained full marks.

4(b)(iii) Most candidates struggled here. Those who scored one mark did so for stating that the '*capacitors cannot fully discharge'*.

5(a) There was a good spread of marks, with most candidates gaining the QWC mark for clearly linking the observations with the conclusions. The answers showed a good understanding of the scattering experiment. The modal mark for this question was three.

5(b)(i) This was another well answered question with most candidates describing and explaining the motion of the aluminium nucleus in terms of repulsive electrostatic force or conservation of momentum. A small number of candidates tried to explain the fate of the aluminium nucleus in terms of the strong nuclear force.

5(b)(ii) Most candidates scored full marks for calculating the speed of the alpha-particle. Many candidates knew how to convert the kinetic energy of 8.0 MeV into joules. The most frequent errors were:

- Forgetting to square root the final answer.
- Using the mass of an electron instead of the alpha-particle.
- Using 8.0×10^{6} J as the kinetic energy of the alpha-particle.

5(b)(iii) This was a well-answered question with the majority of candidates correctly using the equation for Coulomb's law to calculate the distance $\underline{r}$. Only a small number of candidates used the incorrect values for the charge of the aluminium nucleus and the alpha-particle. It was good to see many candidates rearranging the equation first, then substituting the values and finally writing the answer to the correct number of significant figures.

5(b)(iv) The modal mark for this question was one. This mark was scored by candidates for recognising that the strong force was either attractive at long distances or repulsive at very close distances. Only a small number of candidates were successful in discussing the effects of the strong nuclear force and the electrostatic force on the resultant force on the alpha-particle.

6(a) Most candidates gave an adequate definition for binding energy of a nucleus. Vague answers such as '*it is energy that holds the nucleons together*' or '*the energy required to break the nuclear bonds*' were unacceptable.

6(b) The modal mark for this question was one. The majority of the candidates dividing 4.53×10^{-12} J by the nucleon number of 4. A small number of candidates divided the energy released by the proton number of 2.

6(c) Many candidates struggled to give a decent explanation. The focus was on the higher binging energy or the greater mass of the helium nucleus, rather than the greater charge and greater electrostatic repulsion. Higher temperature was necessary to give the helium nuclei greater kinetic energy and hence a greater chance of getting close enough for the attractive strong nuclear force to trigger fusion.

6(d) The answers to this question were generally well-structured and easy to follow. Most candidates were familiar with the equation $\underline{E_k = 3kT/2}$. A small number of candidates scored no marks for using either using 4.53×10^{-12} J or 1.13×10^{-12} J as the mean kinetic energy of the helium nuclei. The modal mark for this question was two.

7(a) The majority of the candidates gave a decent definition of the photon and gave one of its main properties. The most common properties listed were '*photon has no mass*' and '*photon can travel in a vacuum*'.

7(b)(i) Most candidates scored a mark for dividing 4.8×10^{-3} by 1.6×10^{-19}. A small number used a slightly longer route to show that the number of electrons incident at the anode was 3.0×10^{16} s^{-1}. They calculated the total power dissipated using the potential difference and current and then divided the power by the energy gained by each electron (2.4×10^{-14} J).

7(b)(ii) The answers were generally easy to follow. The modal range for this question was two to three marks. The best candidates gave brief and flawless answers. Some candidates lost a mark for

- premature rounding of numbers within the calculation;
- failing to convert the mass into kg;
- subtracting 273 K from the correct answer.

7(b)(iii) The more able candidates performed well in this question. The energy of a single photon was equal to the maximum kinetic energy of a single electron. The omission rate was noticeably high for candidates in the lower quartile. The most common errors made were using $\underline{mc^2}$, 1.6×10^{-19} J and 720 J as the energy of the photon. A small number of candidates tried to use the de Broglie equation to determine the shortest wavelength of the X-rays.

7(c) Most candidates did manage to score one or two marks for this question. Instead of injecting a contrast material (iodine) into the patient, some candidates opted for using barium and sometimes even boron. Most candidates did know that a contrast material had a greater number of electrons (high Z) or that it had a greater attenuation coefficient compared with the tissues of the heart and blood vessels.

8(a) Most candidates knew about the ionising and penetrating properties of the radiations from the two types of tracers. The answers were generally easy to follow and there were fewer convoluted answers.

8(b) This question produced a range of marks. The principles of a CAT scanner were understood and the answers were generally well-structured. A small number of candidates spoilt their answers by mixing together different types of scanners, which included MRI and PET scanners.

9(a) Most candidates showed a decent understanding of Doppler effect. However, there were missed opportunities from some candidates for not mentioning either the source or the observer. The '*change in the wavelength of a wave reflected off a moving object'* was allowed.

9(b) Most candidates scored two or three marks. There were some excellent answers with the transducer placed at an angle to the artery, ultrasound being reflected off blood cells and the change in the wavelength being proportional to the speed of the blood. It was good to see many candidates quoting the correct equation for the change in frequency of the ultrasound ($\underline{\Delta f = 2fv\cos\theta/c}$). There was no credit for using the incorrect equation $\underline{\Delta f = fv/c}$. A small number of candidates thought that the wave equation $\underline{v = f\lambda}$ could be used to determine the speed of the blood.

9(c)(i) Generally this was well answered with most candidates correctly using the equation for acoustic impedance. Some candidates incorrectly used the value for the speed of light $\underline{c}$ in the equation $\underline{Z = \rho c}$.

9(c)(ii) Most candidates gained a mark for calculating the wavelength of ultrasound. Only a small number of candidates failed to get a mark because of transfer error with the speed (1500 m s^{-1} instead of 1570 m s^{-1}) or omitting the mega prefix.

9(d) The answers to this question were well-structured and easy to follow. Most candidates wrote the answer as 36%, but this was the percentage of ultrasound intensity reflected at the muscle-bone boundary. A pleasing number of candidates got the correct value of 64%.

9(e) Almost all candidates were familiar with the use a coupling gel. The answers were generally very good and most candidates managed to score full marks. One of the marks was dependent on stating that the acoustic impedance of the gel and skin were similar, so this meant very little reflection of the ultrasound at the gel-skin boundary.

10(a) Only about a third of the candidates gave the correct answer in terms of the evolutionary stage of a low-mass star. Many candidates lost a mark for writing correct things about a white dwarf but failing to answer the question. Many candidates did not appreciate that the white dwarf was the remnant core of a low-mass star after the red giant phase.

10(b) About half of the candidates scored full marks for using $\underline{d = p^{-1}}$ and then converting the distance into light years. A significant number of candidates had the skill and competence to apply trigonometry to a triangle with base of length 1 AU. Some even managed to correctly recall the astronomical unit is metres. The most common error was:

- $d = 0.0059 \times 3.26 = 0.019$ *ly*

10(c)(i) Most candidates correctly defined intensity as power divided by area. A small number of candidates defined intensity incorrectly as '*energy divided by area'*.

10(c)(ii) This was a good discriminating question that required careful execution. Most candidates in the upper quartile scored four or more marks. Their answers showed good development and errors were minimised. Most candidates in the lower quartile managed to get at least one mark. Candidates at this end struggled with writing the correct expressions for surface area and volume of the star. Sadly, for a significant number of candidates, the volume $\underline{V}$ of a star was given by the expression $\underline{V = 4\pi \boldsymbol{r}^2/3}$. A significant number of candidates confused the terms 'power' and 'intensity' and ended up calculating the ratio of intensities instead.

11(a) The majority of the candidates gave a correct statement of Hubble's law. It was important that **galaxy** was mentioned in the answer. For a disturbing number of candidates, this law applied to planets and stars in our galaxy.

11(b)(i) The correct value for the cell for $\underline{v}$ was 1010 or 1014. A range of values were allowed for the distance $\underline{d}$. The modal mark for this question was two.

11(b)(ii) This was generally a well-answered question with many knowing the value for the age of the universe. The gradient of the best-fit straight line was often calculated correctly and errors in powers of ten were rare. The conversion of the age of the universe from seconds to years was done correctly. A small number of candidates used a data point to determine the age, There was a penalty of one mark for such an approach.

11(c) There were exuberant answers to this question, with many candidates scoring at least two marks. Candidates were often using the additional pages provided to provide a robust answer. It was good to see that many candidates were familiar with the existence of primordial helium (and other 'lighter' elements) in the early stages of the universe. Almost all candidates gave a decent explanation of the big bang and knew about the existence of the cosmic microwave background radiation or the temperature of about 3 K. Some candidates gave elaborate, but unnecessary description of Olbers' paradox. The omission rate for this question was very low indeed.

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