GCE

Physics A

Advanced GCE **H558**

Advanced Subsidiary GCE **H158**

OCR Report to Centres

January 2013

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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.

CONTENTS

Advanced GCE Physics A (H558)

Advanced Subsidiary GCE Physics (H158)

OCR REPORT TO CENTRES

Overview

Most Centres have once again made excellent use of past papers, marking schemes and previous examiners' reports. The quality of analytical work at both AS and A2 levels showed marginal improvement. Rearranging of equations continues to be an obstacle for some AS candidates. The recall of definitions continues to be a problem for a significant number of candidates across the ability spectrum.

There was not much improvement in the quality of written answers. A significant number of candidates showed a poor comprehension of technical terms. As mentioned in previous reports, candidates must closely examine questions before answering. Using bullet points should also help candidates focus on sequencing ideas in a logical manner.

Centres are reminded that copies of the Data, Formulae and Relationships Booklets are despatched to Centres with the general stationery prior to the examination series. Examination Officers should ensure that copies of this booklet are available for candidates in the examination.

All examination scripts are scanned electronically before being marked by examiners. Most candidates wrote their answers within the scanned zones for each question. As always, experienced teams of Examiners provided accurate and efficient marking of the four theory papers. On-screen marking of these papers allowed analysis of the performance of the candidates at a question-by-question level. The Principal Examiners' reports reflect this detailed analysis. The report for each Unit of the January 2013 examination series is given below.

G481 Mechanics

General comments

The marks for this paper ranged from 0 to 59 and the mean score was about 32. The omission rate was once again quite low and the majority of the candidates managed to complete the paper in the allotted time of 1 hour.

The majority of the candidates were well prepared to tackle the complexities of this paper. Definitions were learnt well and analytical solutions were succinctly presented. A small number of candidates were losing marks unnecessarily by incorrectly rounding numbers at intermediate stages of a calculation. This is illustrated in the examples below for Question **2(b)**.

Incorrect method:
distance = $2 \times \pi \times 0.60 = 3.77 =$ **3.7**
speed = $\frac{3.7}{12} = 0.308$ m s^{-1} ✓ (ecf)

Ideal method:
distance = $2\pi r = 2 \times \pi \times 0.60$
speed = $\frac{\text{distance}}{\text{time}} = \frac{2\pi \times 0.60}{12} = 0.314 \approx 0.31$ m s^{-1} ✓ ✓

The quality of written work was variable with a significant number of candidates struggling with spellings. Many descriptive responses still lacked organisation and reasoning. In some cases written answers were spoilt by candidates using inappropriate technical vocabulary such as the use of '*gravity*' rather than '*weight*' or '*force of gravity*'. In Questions **4(c)(i)**, **5(b)** and **5(c)(ii)**, the incorrect use of the term '*rate*' by candidates across the ability spectrum demonstrated poor understanding of this mathematical term. Further details on this are given later in this report. Candidates were making better use of the Data, Formulae and Relationships Booklet in this paper. As mentioned in previous reports, the legibility of some candidates remains a cause for concern.

Comments on Individual Questions

Question 1

Surprisingly few candidates managed to score two marks in this opening question on units. Most of the candidates were able to correctly identify the unit for density, but the majority were unable to do the same for pressure and power.

Question 2

This question produced a good range of marks with most candidates scoring 5 or more marks.

(a) The majority of the candidates showed excellent knowledge of vectors and scalars and secured two marks. The most frequently mentioned difference was that a '*vector has direction'* and the two most frequently mentioned similarities were that '*speed and velocity both have magnitudes'* and '*they have the same unit*'. A small number of candidates reversed their answers and hence scored no marks.

(b)(i) The answers for the speed of the locomotive were mostly correct and well-structured. As mentioned earlier, some low-scoring candidates lost a mark for premature rounding of numbers. Amongst the occasional errors seen was the use of πr^2 instead of $2\pi r$ for the circumference of the circle. Another common error was to quote the final speed to one significant figure.

(b)(ii) This question discriminated well, with most candidates in the upper quartile securing two marks. A small number of candidates struggled with the concepts of displacement and distance. The usual cause of failure was to divide the circumference of the circle by a factor of four.

(b)(iii) The explanations of why the average velocity was zero after 12 s were varied. Most candidates understood that the locomotive returned to the same point and therefore had a net displacement equal to zero. A small number of candidates tried their luck with a statement such as '*the average velocity is zero because velocity is positive and then negative and hence they cancel each other*'.

(b)(iv) The majority of the candidates appreciated the vector nature of velocity and gave clear explanations of why the velocity changed as the locomotive went round the track.

Question 3

All candidates attempted this question and scored marks covering the entire range. Most candidates scored 6 or more marks. A significant number of candidates struggled to give reasoned descriptions in **(c)**.

(a) Calculating the value for the deceleration of the car was an easy task for most candidates. A few candidates divided the mass of the car by the braking force.

(b) The majority of the candidates correctly used either $v^2 = u^2 + 2as$ or $\frac{1}{2}mv^2 = Fs$ to determine the braking distance of the car. The solutions were often well-structured using the approach:

equation $\rightarrow$ substitution $\rightarrow$ rearranging $\rightarrow$ answer.

The two most common errors in this question were

- omitting the negative sign for acceleration *a* when using $s = ut + \frac{1}{2}at^2$
- using 'distance = 18 $\times$ 6.0 = 108 m'.

(c) Most candidates were able to identify that the distance travelled by the car down the slope was greater than their answer in **(b)**. Very few candidates, even at the top of the distribution, secured full marks. Explanations lacked clarity and statements were often contradicted. Too many candidates were using '*gravity*' to either mean '*weight'* or '*acceleration of free fall*'. The pivotal point that the component of the weight of the car reduces the net force down the slope eluded most candidates. Some candidates erroneously argued for a longer braking distance by suggesting that the net force down the slope was much greater than before.

(d) Most candidates had some understanding of GPS devices and showed familiarity with the term '*trilateration*'. Some answers were truly extraordinary with correct accounts of synchronised clocks, pulses of coded microwaves signals sent by satellites and General Relativity. However, for significant number of candidates the role of the satellites remains a mystery. For them, satellites 'bounced *off signals and knew the position of cars'*. Too many candidates were using the term *signals* rather than microwaves or radio waves. There was considerable confusion over the '*delay time'* of the microwave signal sent from the satellite to the GPS device in the car. Many candidates would have benefitted by giving their reasoned answers in bullet points.

Question 4

In this question most candidates scored 5 or more marks. The descriptive answers in **(c)(i)** showed poor understanding of the term '*rate'* but the analytical answers to **(c)(ii)** were well laid out.

(a) Almost all candidates correctly defined acceleration. Those who lost a mark was because of the inappropriate use of the term '*per'* at the end of a viable definition (e.g. *acceleration is the rate of change of velocity per unit time*) or using speed instead of velocity. A good number of candidates gave a word equation (e.g. *acceleration = change in velocity/time*) which was acceptable.

(b) A significant number of candidates failed to mention '*mass'* and '(*net*) *force'* as the two factors. Some candidates provided a long list of factors that included terms such as drag, time, cross-sectional area, weight, etc.

(c)(i) The expected answers for the two stages of the journey of the rocket were '*constant acceleration'* followed by '*constant deceleration'*. The descriptions from candidates were often difficult to decipher. Many candidates thought that the rocket was falling towards the ground after 5.0 s rather than still gaining height. This also had a direct impact on their calculation for the maximum height reached by the rocket in **(c)(ii)**. A few candidates recognised that the rocket was momentarily at rest at its maximum height at 25 s. There was an excessive use of the term '*rate'*. Velocity and acceleration were often confused with each other. The list below shows some of the common errors.

- *The rocket moves at a constant rate.*
- *The rocket has a constant rate of acceleration between 0 and 5.0 s.*
- *The rocket has a constant acceleration and moves with constant velocity*

Some credit was given for responses such as '*speed increases between 0 and 5.0 s*' and '*speed decreases after 5.0 s'*.

(c)(ii) The most common answer was '$\frac{1}{2} \times 200 \times 5.0 = 500$ m'. About a third of the candidates recognised that the rocket was at its maximum height at 25 s and they correctly determined the total area under the velocity-time graph from 0 to 25 s. A significant number of candidates used the equations of motion to calculate the distance travelled from 0 to 5.0 s and from 5.0 s to 25 s.

(c)(iii) Very few candidates gained any credit for their explanation of why the rocket had a speed greater than 200 m s^{-1} when it hits the ground. Most candidates did attempt this question, but generally the answers were vague. Many candidates gave the explanation that the rocket was falling as a result of gravity, had an acceleration of 9.81 m s^{-2} or its mass was less because of all the fuel used.

Question 5

AS Physics candidates often struggle with questions requiring extended writing. Writing answers in bullet points can help candidates focus on salient points. It also helps to have a good understanding of technical concepts and terms. The term '*gravity'* must be used with caution. It is not the same as weight. Its excessive and inappropriate use in **(b)** and **(c)(ii)** made descriptions nebulous.

(a) The idea that greater speed meant greater resistive force acting on the object was obvious to almost all candidates. It was good to see many scripts with a clear statement such as '*drag is proportional to speed squared*'.

(b) Most candidates gave a decent description of Galileo's experiments. Many candidates focussed on different mass balls dropped from a tall tower and noticing that the time of fall was independent of the mass. Rolling similar size but different mass balls from ramps was also outlined by many candidates. The conclusion from such experiments lacked finesse. No credit could be given for statements such as '*the objects of different mass fall at the same rate'* or '*different-mass objects have the same rate of acceleration'*. A small number of candidates thought that '*Galileo found that objects of different mass have different terminal velocities*'. Many candidates also ignored Aristotle's views on the motion of falling objects.

(c)(i) Most candidates realised that the two forces were drag and weight and that they were equal and opposite at terminal velocity. A few candidates spoilt their answers by misusing terms such as '*equilibrium'* and '*balance'*.

(c)(ii) This was a poorly answered question. Many candidates had little to say about how the magnitude of the deceleration varied as the velocity fell from 50 m s^{-1} to 4.0 m s^{-1}. The answers concentrated more on the reasons for the skydiver reaching a terminal velocity rather than answering the question set. The modal mark for this question was one. Most candidates did realise that opening the parachute led to a greater upward drag. The descriptions thereafter were disjointed and lacked physics. Once again, the misuse of the term '*rate'* prevented many candidates from gaining more marks. A statement such as '*falling at a quicker rate'* does not make much sense. Even top-grade candidates were struggling to gather 3 or more marks in this question.

Question 6

This question was generally answered well. The omission rate for this question was zero. Candidates excelled in **(a)** and **(b)(i)**.

(a) The majority of the candidates gave a flawless definition for work done by a force. Some inevitably lost a mark for omitting '*moved'* or '*in the direction of the force'* in the definition.

(b)(i) The majority of the candidates produced clear and correct answers for the kinetic energy of the person. The conversion of weight to mass was usually taken into account and.it was very pleasing for the examiners to see a concise solution such as

$$\text{kinetic energy} = \tfrac{1}{2}\times\left(\frac{700}{9.81}\right)\times 15^2 = 8.0\times 10^3\ \text{J}$$

Making errors with rounding numbers is definitely minimised by the solution above.

(b)(ii) This question favoured top-grade candidates. Such candidates realised that the work done by the resistive force was the difference between the initial gravitational potential energy and the final kinetic energy of the person. Some candidates unsuccessfully tried to use the ideas of kinematics to solve this problem.

Question 7

This question was a high-scoring question with most candidates showing a good understanding of moments.

(a) This was a well reasoned and answered question. Almost all candidates recognised that the object would move into region 3. Most candidates deduced that there was a net downward force of 2 N and a net force of 1 N to the left.

(b) Candidates were only given a mark for a complete definition of the principle of moments. A significant number of candidates defined moment of a force instead.

(c) This question was well-answered by candidates in the upper quartile. The principle of moments was used effectively to determine the weight of the suitcase. Some candidates lost marks because of incorrect perpendicular distance between the 50 N force and the wheels of the suitcase. Some candidates converted some of the distance to metres and not others giving rise to powers of ten errors.

Question 8

This question produced a good range of marks with most candidates scoring 4 or more marks.

(a) Hooke's law was familiar to most candidates. A few candidates lost the mark for using the symbol for proportional rather than the word. Full credit was given to candidates who recognised that the graph was a '*straight line passing through the origin*'. It is worth reminding some candidates that a straight line on its own does not imply proportionality between two quantities; the line must also pass through the origin.

(b) Most candidates realised that the gradient of the line represented the force constant of the wire. Examiners also allowed '*spring constant*' and '*stiffness*'. The most common incorrect answers were Young modulus, work done, stress and strain.

(c) Almost all candidates attempted this question. Various data points on the straight-line graph of Fig. 8.1 were used to determine the values of stress and strain. These were then generally used correctly to determine the value of Young modulus. The most common error in this question was to use $2\pi r$ to determine the cross-sectional area of the wire. A few candidates omitted the 10^{-3} factor for extension which led to errors in powers of ten. A good number of candidates quoted the equation $E = \frac{FL}{Ax}$ and used it correctly to determine the Young modulus. Those who misquoted the equation (by swapping length *L* and extension *x*) scored no marks.

(d) The answers to this question lacked quantitative rigour. A common misconception was that Young modulus for the material was not a constant. There was also confusion with whether the gradient of the line increased or decreased. Even candidates in the upper quartile struggled to give reasoned answers.

(e) This proved to be a challenging question, but high-scoring candidates did manage to make a good start with $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$. Some candidates found the algebra too much of a challenge and attempted to cancel the *m* and the *k,* ending up with $v = x$. Many candidates quoted $\frac{1}{2}Fx = \frac{1}{2}mv^2$ and ended with the incorrect conclusion $x \propto v^2$.

G482 Electrons, Waves and Photons

General comments

Most candidates appeared to have been well prepared for the examination, being familiar with the style of question and the quality of answer expected from them.

Good candidates were able to demonstrate their knowledge on the wide range of topics covered. Weaker candidates appeared to find the paper accessible resulting in few candidates scoring much below 40%.

On average the definitions of quantities were known better. However there is still some confusion about when to use the words *displacement* or *amplitude*. There are still some very common but incorrect descriptions, for example, in the description of the motion of particles in a sound wave in a tube, Q4. There is also confusion in the understanding of the difference between a wave and an oscillation, Q4. In electricity topics too many candidates still write about *current across* and *voltage through* showing a lack of basic understanding of these words. *Voltage* and *p.d*. are still equated to *energy* and *force* in sentences where it would not happen when written in mathematical equation form.

There was sufficient time to complete the paper and weaker candidates managed to attempt to answer almost all sections in every question. Candidates scored freely in questions where the exercise was mainly substituting into formulae and managing powers of ten. Where explanations were required the answers proved to be more discriminating, especially in Q3 and Q4.

Most of the mathematical sections were well laid out. Significant figures were more important than usual in this paper and most candidates were able to write the correct number where necessary. However some of the handwriting was difficult to decipher, often in cases where it was very small.

Comments on Individual Questions

Question 1

(a) Many candidates wrote answers involving resistance. Many indicated that they believed that resistance is related to the gradient of the line. However a majority scored both marks and very few failed to score one.

(b) A common error was to include a variable resistor in series, rather than to use a potential divider to vary the p.d. across the lamp. Almost all scored the mark for correctly positioning the two meters. Most descriptions of the experiment were adequate.

(c) The majority were able to find the current in at least one of the branches. A minority calculated the combined resistance and then the total current.

(d) Most drew a straight line to (6, 300) but a common error was to draw the line to (6, 250). Very few understood how to attempt the second part being unable to apply both circuit conditions relating to current and voltage together. Most considered only one or the other.

Question 2

(a) Many scored full marks but a common error was to consider only the heater resistance in the first part. All were able to apply one of the formulae to calculate the power dissipated; most with success. The majority followed the instructions and gave an answer to three significant figures. Almost all scored the mark for a suitable value for the fuse

(b) Most candidates were able to calculate the cost successfully.

(c) All accessed the correct formula but a sizeable minority failed to substitute the correct resistance value.

(d) It was realised that the resistance of thinner wires is greater but many did not pursue this to a full conclusion. Some just stated that the current decreased, others that the wires were heated.

Question 3

(a) The majority of candidates scored at least one mark for the definition of *e.m.f.* However the meaning of internal resistance was not explained clearly. The common answer was to refer to the wires, terminals or electrolyte rather than a voltage drop across the terminals when a current is drawn from the battery.

(b) Candidates were able to add two resistors in parallel. However some became confused when calculating the p.d. across the thermistor using the thermistor resistance rather than the combined resistance. Others applied the potential divider formula using the values of the two parallel resistors. Almost all realised that the resistance of the thermistor decreased with temperature but only the better candidates argued correctly how and why the p.d. and current varied.

(c) Part **(i)** was the most accessible question on the paper with a large number of candidates scoring full marks. However part **(ii)** divided the candidates equally with more than 40% of candidates gaining full marks and the same number failing to score.

Question 4

(a) Almost all candidates scored full marks in this part.

(b) Most drew a suitable sinusoidal curve with the correct phase. A minority only drew the curve starting from zero displacement at 0.5 ms.

(c) The common approach was to discuss the phase difference between two waves rather than between the oscillations at two points on the same wave. It is important to be able to distinguish between a displacement–position graph at one time and a displacement-time graph at one position and the descriptions associated with each graph.

(d) All realised that the displacement would have a greater amplitude but although many also quoted that intensity is proportional to amplitude squared they then squared the amplitude rather than increasing it by 1.4.

(e) A significant number falsely believe that the end of the tube must be closed for the incident wave to be reflected. This did not lose them any marks for describing how a stationary wave can be set up in a tube but they heavily penalised themselves in **(ii)** thinking that Q is a node and P an antinode. Few stated that the molecules oscillated only that they moved. Most used the word displacement instead of amplitude in this context. Some still believe that the air molecules oscillate across the tube rather than along it.

Question 5

(a) Many candidates tried to restrict the categories of waves to which the principle applies, referring to, for example, coherent or travelling in opposite directions. Here the word amplitude was often used for displacement and many used general terms like constructive and destructive interference. On average this was poorly answered.

(b) Coherent was correctly explained by the majority of better candidates. A majority also gave a correct value for the path difference; a few writing an algebraic expression rather than a value. All selected the equation for fringe separation and the only mistakes were in powers of ten.

Candidates who used the equation to state and explain the changes to the fringe pattern in different conditions scored high marks. Others gave contradictory statements or incomplete reasoning. There was some confusion mixing the conventional assignment of the symbols *a* and *x*.

Question 6

(a) A significant number labelled the diagram with violet having the greatest diffraction and red the least. Most gave a sufficient explanation as to why the central beam was white and were also able to calculate the wavelength in **(iii)**.

(b) Most scored the three marks here, all choosing the appropriate formula.

(c) Almost all chose the correct line for green with the majority also making the upper spectral line red.

Question 7

(a) Few appreciated that an answer in terms of energy of electron equals energy of photon was expected and most wrote out the equation in words rather than in symbols. Some of those who discussed energy were confused thinking it must be in electron volts.

(b) Few wrote a bullet by bullet type account of how to do the experiment but instead wrote vague statements about what had to be measured rather than how to do it.

(c) The common error in completing the graph was not to draw it through the origin. The final mark was scored for the correct gradient of the line that was drawn by the candidate. In **(iii)** it was expected that the candidate should use his/her gradient not the approximate value given in the question. In **(ii)** the answer was meant to be an algebraic manipulation and a statement as to which terms were the gradient of the line. Many did not do this but calculated the value of *hc/e* which was effectively the same calculation that was then repeated in **(iii)**.

G484 The Newtonian World

General Comments

The marks for this paper ranged from 0 to 59 and the mean score was almost 34. Most candidates used their time efficiently and were able to attempt all sections of the paper.

It is clear that Centres are making good use of past papers, marking schemes and examiner's reports. Candidates did marginally better with definitions and short written answers. Unfortunately this improvement was not evident in answers involving extended writing where many candidates disadvantaged themselves with answers showing weak organisation.

One significant feature this session was a lack of clarity in candidate's handwriting. In too many cases this made it difficult to determine keywords to the point that marks could not be awarded. This trend was also evident in calculations where candidates were sometimes unable to read their own digits, particularly in powers of ten, resulting in unnecessary arithmetical errors.

Another feature of calculations that is giving serious cause for concern is the growing trend to omit indices in the middle of a calculation. Examiners noted a significant number of scripts in which the formula had been quoted correctly, then correct values assigned to the symbols, only for the substitution mark to be lost because a quantity had not been squared, cubed or square rooted. One example of this, from question 4b(i), is shown below

$v = 0.188$

Kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2} \times 0.40 \times 0.188$

Unfortunately this error cost some candidates several marks in otherwise good answers.

The data in all questions on this paper were given to two significant figures. Examiners therefore expected candidates to carry at least three significant figures in their working and intermediate answers in order to ensure that the final answer could be confidently rounded to two significant figures. It was not uncommon to see intermediate values being round to two or even one significant figure. This resulted in an inaccurate final answer and an unnecessary loss of marks.

Comments on Individual Questions

Question 1

(a) Most candidates managed to score one mark by stating Newton's second law correctly but less than half of the candidates gave sufficient information to score both marks. Occasionally 'rate of' was omitted from the change in momentum and in a small number of scripts the definition was in terms of acceleration so the mark was lost. The second mark was only awarded if it was clear that the force and the change of momentum were in the same direction.

(b) **(i)** This was usually well answered. Infrequent errors were the failure to give a minus sign for the velocity of B and failure to divide the total initial momentum of A and B by the total mass.

(ii) This proved to be much more difficult and only the more able candidates were able to give convincing answers worthy of both marks. The concept of impulse being the change in momentum of one of the masses was not appreciated by many candidates and common errors were the use of the combined mass for the final momentum.

Those who did the calculation successfully generally understood the directional aspect and were able to score the final mark.

(iii) Most candidates were able to state Newton's third law, but were unable to show that the two impulses would also be equal and opposite. At A2 candidates are expected to understand and state that the two forces referred to in Newton's third law act on different bodies so a bald statement 'action and reaction are equal and opposite' received no credit. Some candidates realised that the forces would act for the same length of time, but forgot to identify impulse as the product of force and time.

Question 2

(a) **(i)** Candidates were generally able to determine the correct velocity by using the orbital radius but it was rare to see this done in the simplest way. Many calculated the mass of the Earth and then *v* unfortunately these calculations increased the risk of arithmetic errors and all too often marks were lost. This was one of several instances where the omission of indices was a common cause of errors.

(ii) Most candidates used the T^2 approach given on the mark scheme, with fair success, although errors in the value of r used and omissions of the cube and square root were commonly seen.

(b) **(i)** This was generally well answered by candidates using either the approach given on the mark scheme or the reverse argument.

(ii) This stretch and challenge question was highly discriminating and only the most able candidate found it possible to score more than one mark. The majority of candidates found the surface area of the Earth and then divided this by an area derived from the width of the photograph overlooking the fact that there would be considerable overlap at high latitudes. Only a small number realised that the satellite crossed the equator twice in each orbit.

(c) Generally well answered by most candidates.

Question 3

(a) Generally well answered although a few weaker candidates defined *r* as the radius rather than the distance between centres of the bodies. A significant minority, unfortunately, misused the term **sum** in their definition.

(b) **(i)** A relatively straight forward calculation which produced a wide range of answers largely as a result of forgetting to convert the time period to seconds or the omission of powers already noted. Many of these answers were unrealistic and candidates should perhaps have realised that an error had occurred.

(ii) Very few candidates realised that this could be solved by the ratio method given on the mark scheme and resorted to a length calculation using their mass from **(i)**; success was largely dependent on whether they managed to remember to square the radius of the orbit of Megaclite.

(iii) Like **(ii)** the ratio method was ignored by all but a few able candidates. Most preferred to use the Kepler formula. This was successfully completed by many although a significant minority either forgot to square root the value of T^2 or failed to notice that the answer was required in hours rather than seconds.

Question 4

(a) The first and last marking points were commonly scored in this familiar experiment. A few candidates tried to manually count the number of oscillations in a short set time and a similar number did not make it sufficiently clear that they were conducting the measurements with several different masses.

The determination of the relationship between f and m was less well done. Most used the graphical method but a disappointingly large number failed to point out that to establish proportionality the straight line graph must pass through the origin.

The product method was rarely described with sufficient clarity.

(b) (i) Answers were generally good apart from a significant number of errors in converting 36 mm to metres and the careless dropping of the square in the kinetic energy formula.

(ii) Candidates generally had more success with this calculation.

(c) This question was poorly answered by most candidates. They clearly understood the relationship between kinetic energy and gravitational potential energy in an oscillating simple pendulum and were determined to apply this relationship to the vertically oscillating spring. The associated curved graphs for simple pendulum were commonly seen in answers. Most candidates did not separated the potential energy into its two parts, gravitational and elastic, and consequently restricted themselves to one mark for correctly identifying the values of kinetic energy at three key positions in the motion. Only a minority of these candidates stated that the kinetic energy was zero rather than a minimum at the amplitude positions. Of the minority realising that potential energy could take two forms a significant number were under the misconception that elastic potential energy decreased to zero at the midpoint and then increased again as the mass went up.

Overall it appeared that few candidates had studied this type of oscillation in any depth.

Question 5

(a) (i) Generally well answered. A common error was to confuse *N* with Avogadro's constant. At A2 candidates should be encouraged to use correct scientific terminology, as no credit was given for the imprecise term particles.

(ii) Candidates seemed to experience some difficulty in deciding what was required in this question, consequently there were few good clear answers. Many were unable to specify the constant quantities in Boyle's Law. It was rare to see the fixed mass of gas linked to a constant value for *n* or *N*. Explanations were generally weak or nonexistent.

(iii) On the whole this was well answered by the majority of candidates.

(b) (i) Again many candidates were unsure how to tackle this question. Only the better candidates realised that they were expected to calculate values from the graph to establish *pV* was a constant. It was disappointing to see A2 students misunderstanding the scale on the horizontal axis by introducing $\times 10^{-3}$ to the *1/V* values. A significant number of candidates believed that the required proportionality was obvious since the graph was a straight line without reference to whether it passed through the origin or not.

(ii) Most candidates successfully calculated the number of moles from the given data and used it to determine a temperature in Kelvin. A significant number unfortunately had power of ten errors in their values which consequently produced an unrealistic temperature. Sadly they seemed to be unaware of this problem and did not correct their working. Many candidates did not convert their temperature into ºC.

Question 6

(a) **(i)** Many candidates realised the atoms would be vibrating in a solid, but several appeared to contradict themselves by adding ‘they are not moving’ without specifying that they meant ‘translational movement’.

(ii) Most candidates gave a colloquial answer rather than using scientific terminology. Since the model is a mass vibrating in classical harmonic motion the examiners expected candidates to link the energy increase to frequency and/or amplitude.

(iii) Most candidates gave good responses to this question, although a few thought that the kinetic energy increased when the substance changed state.

(b) **(i)** This slightly more involved heat calculation was generally answered fairly well by the majority of candidates. Only the weaker candidates failed to appreciate that the insulation reduced the thermal energy input to the metal block. The use of electrical power in the calculation was well handled by most.

(ii) This question was intended to be a highly discriminating stretch and challenge question and consequently the mark scheme was particularly tight. Candidates were expected to realise that even with insulation present some heat would be lost from the apparatus to the surroundings. The examiners insisted that this distinction should be clear in all answers. Many answers were unfortunately lacking in precision in this respect and marks were lost. Only the most able candidates were able to link the increased heat losses to an increase in the calculated value for specific heat capacity with adequate reasoning.

G485 Fields, Particles and Frontiers of Physics

General comments

The marks for this paper ranged from 0 to 97 and the mean score was about 63. Very few parts of the questions were left unanswered and the majority of the candidates finished the paper in the allotted time of 2 hours.

The quality of both written and analytical work was marginally better than previous sessions. Candidates demonstrated a good understanding of physical principles. Analytical solutions were generally well presented and showed a good understanding of significant figures and powers of ten. Candidates were making better use of the Data, Formulae and Relationships Booklet in this paper. Most candidates showed that they could cope adequately with synoptic questions. A small but significant number of candidates were not ready to tackle the range and diversity of this A2 paper in this January session. Their scripts were often sprinkled with comments such as '*have not done this topic yet*'.

Comments on Individual Questions

Question 1

This was a well answered question with most candidates scoring 8 or more marks.

(a)(i) Most candidates scored two marks by correctly identifying the direction of electron flow and explaining how the plate **Y** became negatively charged by gaining electrons (or plate **X** by losing electrons). Only a few candidates gave an explanation of how the capacitor plates acquired equal but opposite charge. A small number of candidates confused conventional current and the direction of electron flow.

(a)(ii) Most candidates correctly calculated the value of the capacitance. The answers were well-structured using the equations $Q = It$ and $Q = VC$. Some candidates attempted to use $V = IR$ and $\tau = CR$ to calculate the value of the capacitance. This approach was flawed because the resistance *R* in the circuit was not a constant. The majority of the candidates managed to secure one mark for drawing a graph on Fig. 1.2 that started from the origin and had a positive gradient. Candidates in the upper quartile drew a straight line graph passing through the origin and the coordinates 100 s, 1.6 V. About a quarter of the candidates drew an exponentially decreasing *V*-*t* graph starting from 1.6 V.

(b)(i) This was a well answered question with most of the candidates showing a good understanding of natural logarithms. A few candidates could only manage to calculate the time constant of the circuit.

(b)(ii) Almost all candidates managed to calculate the speed of the bullet by dividing 0.10 m by their answer from **(b)(i)**.

Question 2

This question produced a good range of marks with most candidates scoring 10 or more marks. The synoptic questions **(c)(ii)** and **(c)(iii)** discriminated well and suited the candidates in the upper quartile.

(a) The majority of the candidates made an excellent start by correctly recalling the definition for electric field strength. A small number of candidates incorrectly gave the definition as '*voltage divided by distance*'.

(b)(i) Many candidates struggled to give a decent answer. The most common answers were '*the electric field is different*' and '*the separation of the field lines is different*'. Less than half of the candidates realised that it was the directions of the electric field at points **B** and **C** that were different. An answer such as '*the electric field is up at B and to the left at C*' was acceptable.

(b)(ii) Most candidates managed to correctly determine the electric field strength at point **C**. The most common incorrect answer was 4.0×10^5 N C^{-1} which was derived from the flawed relationship $E \propto r^{-1}$.

(c)(i) The answers to this question were well-structured with most candidates substituting correct values into the equation $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$. The most frequent errors were using 2*e* instead of the product *Qq,* forgetting to square the separation *r* and calculating the electric field strength rather than the electrical force between the particles.

(c)(ii) This question discriminated well, with most candidates in the upper quartile securing two marks. Such candidates used the correct masses of the particles from the Data, Formulae and Relationships Booklet. A significant number of the low-scoring candidates were not familiar with the equation $F = \frac{GMm}{r^2}$ and tried their luck with $F = mg$.

(c)(iii) This was a challenging question with a significant number of candidates not knowing the de Broglie equation. Some attempted to use $p = mv$ with a value for the speed equal to the speed of light. A small number of candidates used $F = \frac{mv^2}{r}$, $p = mv$ and their value for the electrical force in **(c)(i)** to calculate the momentum of the electron. In doing so, they did not answer the question but they were given some credit for the efforts. Many candidates successfully determined the kinetic energy of the electron. The two most frequent mistakes were using $E = mc^2$ and $E = \frac{hc}{\lambda}$ to calculate the kinetic energy of the electron.

Question 3

All candidates attempted this question and scored marks covering the entire range. Most candidates scored 7 or more marks. Most of the answers to **(c)** were logical and easy to follow.

(a) Almost all candidates scored one mark for mentioning either the '*left-hand rule*' or the '*motor rule*'.

(b) Most candidates appreciated that the force acting on the ions was perpendicular to their velocity and hence no work was done. A disappointing number of candidates attempted to answer the question in terms of the uniform magnetic field. The range of strange answers showed that many candidates still struggle with the conceptual aspects of circular motion.

(c)(i) Most candidates effortlessly calculated the force acting on the lithium-7 ion. A few candidates lost a mark for forgetting to square the speed after correctly quoting the equation $F = \frac{mv^2}{r}$.

(c)(ii) This was another success for most candidates. Candidates either used $F = BQv$ or $B = \frac{mv}{Qr}$ to calculate the magnetic flux density *B.*

(c)(iii) Almost three quarters of the candidates correctly calculated the number of lithium-7 ions reaching the detector per second to be 3.0×10^{10} s^{-1}.

(d) Many candidates gave verbose answers but failed to explain the significance of the 'height' and position of the smaller peak on Fig. 3.2. Many candidates were aware that the height of the peak was indicative of the abundance of the ions but failed to give definitive answers. Candidates in the upper quartile had no problems gathering two marks with succinct answers such as '*the smaller height implies less abundance and its position means that the ions have smaller mass*'. About one in ten candidates decided to omit this question.

Question 4

In this question most candidates scored 6 or more marks. Candidates particularly enjoyed extending the diagram for the chain reaction in **(a)(ii)**.

(a)(i) Most candidates made a good start by correctly stating one quantity conserved in the fission reaction. The most popular answers were momentum, mass-energy, proton number and nucleon number. Mass or energy on its own was not allowed.

(a)(ii) The labelling of all particles in Fig. 4.1 and the diagram illustrating chain reaction were a pleasure to mark. Many candidates demonstrated an excellent understanding of chain reaction.

(b)(i) A pleasing number of candidates scored full marks. The change in mass Δ*m* was carefully calculated and then substituted into the mass-energy equation $\Delta E = \Delta mc^2$. The list below summarises the most common errors made in this question.

- Rounding all the masses given to 2 or 3 significant figures.
- Using 3.**43** × 10^{-27} kg for the mass of the $^{2}_{1}$H nucleus rather than 3.**343** × 10^{-27} kg.
- Forgetting to square the speed of light term in the mass-energy equation.
- Using the mass of one $^{2}_{1}$H nucleus rather than two of these nuclei when calculating the change in mass.
- Calculating the mass defect of either the $^{2}_{1}$H nucleus or the $^{3}_{1}$He nucleus using the masses of proton and neutron given in the Data, Formulae and Relationships Booklet.

(b)(ii) The majority of candidates simply wrote '*kinetic*' as the one word answer to this question. The most frequent incorrect answers were heat, light and sound.

(b)(iii) The omission rate for this question part was high at about one in ten candidates. It was clear from the scripts that a significant number of candidates had not come across the physics of ideal gases. The equation $E = \frac{3}{2}kT$ was not familiar with a significant number of candidates using *k* = 1. A small number of candidates even tried using $E = \frac{1}{2}mv^2$ with *v* =*c*.

(b)(iv) Candidates struggled to give a plausible answer to this question. Only a small number of candidates appreciated the spread of kinetic energies of the nuclei that were being modelled as an ideal gas.

Question 5

A2 Physics candidates often struggle with questions requiring extended writing. Writing answers in bullet points can help candidates focus on salient points. Most candidates scored 8 or more marks in this question.

(a) Most candidates scored full marks for calculating the decay constant of F-18. The answers were once again nicely presented and easy to follow.

(b) This was successfully tackled by most candidates. Those candidates who forgot to convert the mega prefix into 10^6 did so hurriedly at the end of their working in this 'show' question.

(c) This was a challenging question for most candidates, but a good number of candidates in the upper quartile picked up 3 valuable marks for calculating the initial mass of fluorodeoxyglucose (FDG). Many candidates struggled with the idea of molar mass and the percentage mass of fluorine-18 in FDG.

(d) The majority of the candidates successfully used $A = A_0 e^{-\lambda t}$ to determine the activity of FDG after a time of 20 minutes. A small number of candidates failed to convert the time *t* in seconds; their incorrect answer of 249 was awarded 1 mark.

(e) The principles of PET were generally well understood. Many candidates tried to illustrate their answers with annotated diagrams. Such diagrams were often superfluous because all the important physics had already appeared in textual form. Most candidates scored either 3 or 4 marks. Most of them were familiar with the idea of electron-positron annihilation and the production of two identical gamma photons travelling in opposite directions. It was also good to see that many candidates were aware of how the difference in the detection times of the two photons was used to locate the position of the annihilation event. The most common error was that positrons are fired from an external source into the patient. From the complex answers presented by many candidates it was clear that Centres had thoroughly discussed PET scanners.

Question 6

This question produced a range of marks with many candidates scoring 7 or more marks. The description of the Compton Effect in **(b)** and the operation of the CAT scanner in **(d)** lacked precision.

(a) Most candidates adequately described how X-rays were produced by colliding high-speed electrons at a metal target and the loss of kinetic energy of the electrons resulted in the production of X-ray photons. Some candidates gave description in terms of 'line spectrum' with the removal of electrons from the innermost shells and electron transitions from higher energy levels. Such descriptions were awarded full marks.

(b) Many candidates correctly described the Compton Effect in terms of an X-ray photon interacting with an orbital electron of an atom and the scattering of the photon. However, there were some missed opportunities here. The list below illustrates some of the most common errors.

- The X-ray photon interacted with the nucleus of the atom or just '*the material*'.
- The electron was not liberated but moved to a higher energy level.
- The scattered X-ray photon had a reduced speed.

(c)(i) Most candidates made a good start with the equation $I = I_0 e^{-\mu x}$. Many candidates used trial and error techniques to get to the correct answer in this 'show' question. The solution below typifies the most frequent error with a mismatch of units for the attenuation coefficient μ and thickness *x* of the tissue.

$I = 3.0 \times 10^9 \times e^{-(0.065 \times 0.017)}$

$I = 50000$ W m^{-2}

(c)(ii) This was a good discriminating question. Surprisingly, many candidates got muddled with converting the cross-sectional area into square metres. Instead of using 5×10^{-6} m^2, candidates were using $(5 \times 10^{-3})^2$ m^2. There was also considerable confusion about the actual energy required from the X-ray beam to destroy the malignant cells of the tumour; a significant number of candidates used 20 J instead of 2000 J. Candidates were given equal credit for using either 5×10^4 W m^{-2} or their calculated value from **(c)(i)**.

(d) The idea of an X-ray beam transmitted through the patient from various angles was well known but often not expressed clearly. Imprecise statements such as '*X-rays are taken from many angles*' were quite common. Only a small number of candidates mentioned a **thin** beam of X-rays from the source. For one of the main advantages of a CAT scan image over a conventional X-ray image the most common answers were '*a CAT scan image is 3D*' and '*CAT scan image shows good contrast between soft tissues*'. Regrettably, some candidates, small in numbers, gave descriptions of PET scanner and MRI scanner.

Question 7

This question produced a decent range of marks with most candidates scoring 5 or more marks. Once again, some candidates struggled with their descriptions. Scientific terms were used with lack of basic understanding.

(a) The marks gained in this question were proportionate to the overall marks scored by the candidates. Good answers were often presented as bulleted points. The answers ranged from jumbled up concepts to exceptional understanding and clarity. Most candidates were aware of '*spin*' or '*magnetic moment*' of protons or nuclei. Precession of protons was not communicated effectively. Low-scoring candidates confused precession and resonance. The role of the radio waves in the resonance of the protons was adequately portrayed. A good number of candidates showed decent understanding of relaxation times.

(b) Most candidates gave a long list of viable disadvantages and advantages of MRI scans. For disadvantage, the most common answer was '*cannot scan patients with pacemakers*' and for advantage, the two most common responses were '*it is non-invasive technique*' and '*it is non-ionising and therefore safe*'. No credit was given for '*images are 3D*' because this was already mentioned at the start of **(a)**.

Question 8

A2 Physics candidates are passionate about Cosmology and this definitely came across with the diverse and complete answers to **(a)**. Most candidates were scoring 5 or more marks for this question.

(a) This was a well answered question with almost all candidates scoring full marks. Candidates started with the gravitational collapse of the gas cloud and finished off with a stable star producing energy by fusing hydrogen nuclei into helium nuclei.

(b)(i) Most candidates wrote copiously about white dwarfs with many scoring full marks. Most candidates were aware that a white dwarf was extremely dense and hot. Some went beyond the confines of the specification and wrote about Fermi pressure and Chandrasekhar limit; marks were always awarded for correct physics.

(b)(ii) Most candidates struggled to pick up marks here. Those who identified the red giant phase and explained how its immense surface area led to enormous emission of energy were awarded full marks.

Question 9

Most candidates scored 8 or more marks. The analytical solutions to **(c)(i)** were particularly well presented and showed an excellent grasp of the Hubble constant.

(a) Candidates enjoyed writing about Olbers' paradox. Most candidates confidently started off with the statement that the '*night sky should be bright*'. Many were also aware that this was based on incorrect supposition that the Universe was '*static and infinite*'. A number of candidates fused together Olbers' assumptions with those of the Cosmological principle. Examiners decided to condone this because a lot of current literature available to candidates on Olbers' paradox does the same.

(b) Most candidates wrote confidently about Hubble's law and gave decent explanations of how Olbers' paradox was resolved. Sadly some candidates made reference to '*receding stars or planets'* rather than '*receding galaxies'*.

(c)(i) This was quite a success with most candidates scoring at least 2 marks for their calculation of the Hubble constant. The correct unit was often quoted as s^{-1}. A small number of candidates decided to give the answer in km s^{-1} Mpc^{-1}; there was no penalty for this alternative approach.

(c)(ii) This last question proved to be a good discriminator. Many candidates correctly determined the age of the Universe in years. A very small number of candidates guessed the answer as 12 billion years without showing any supportive calculations – the correct answer based on the data provided was 13 billion years. It was mainly candidates in the upper quartile that had the poise to calculate the maximum observable distance from the Earth.

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