RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE **H558**

Advanced Subsidiary GCE **H158**

Examiners' Reports

January 2011

HX58/R/11J

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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.

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EXAMINERS' REPORTS

Chief Examiner's Report

Centres have once again made good use of previous examiners' reports and examination papers. A significant number of candidates improved their final AS and A2 UMS marks by re-sitting the AS unit papers.

The quality of analytical work showed some improvement. The recall of definitions remains a cause for concern in all unit papers. The marking of definitions was tighter this session and we hope to continue this practice in the future.

All examination scripts are electronically scanned before being marked by examiners. Most candidates wrote their answers within the scanned zones for each question. As commented last session, the legibility of a small minority of candidates was extremely poor. Examiners cannot award marks if they cannot make out what the candidates have written.

Candidates continue to make sensible use of the error carried forward rule when tackling analytical questions. Candidates scored acceptable marks for questions requiring extended writing. However, taken as a whole, the answers often lacked organisation and the use of scientific vocabulary was weak. Candidates are once again reminded to carefully examine the questions before putting pen to paper.

A handful of Centres entered their students for the G485 paper this session rather than in June 2011. It was clear that the candidates were inadequately prepared to tackle the complexities of this A2 paper. The omission rate for some of the questions was uncharacteristically high. Extended answers lacked robustness and clarity. Unit G485 is designed to be taken in the summer with only resit candidates attempting the paper in the winter.

As always, experienced teams of examiners provided accurate and efficient marking. On screen marking of the four theory papers allowed analysis of the performance of the papers at a question-by-question level. The Principal Examiners' reports reflect this detailed analysis.

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.

The report for each unit of the January 2011 examination series is given below.

G481 Mechanics

General Comments

The mark for this paper ranged from 2 to 59 and the mean score was about 32. Most candidates used their time efficiently and the omission rate for the questions was very low.

It is clear that Centres are making good use of past papers, marking schemes and examiner's reports. In line with previous sessions, candidates did marginally better with definitions and their answers to analytical questions showed more organisation. Once again, there has been an improvement in the comprehension of key command terms (eg *define*, *explain*, etc.). However, there is still concern with a significant cohort of candidates who were overwhelmed by simple arithmetic and algebra and who consistently made poor use of the Data, Formulae and Relationships Booklet.

It appears that a small number of candidates had been entered prematurely, with little grasp of the basics and unprepared for the transition from GCSE Science. Confusion between powers of ten and physical quantities such as pressure p and density ρ suggest that such candidates regard physics as superficial arrangement of letters to be memorised rather than concepts to be understood.

As mentioned in previous reports, candidates need to be extra careful with their writing. Sadly, examiners were once again struggling to decipher some scripts.

Comments on Individual Questions

Question One

Most candidates made a good start by scoring more than five marks in this opening question.

(a) The majority of candidates scored full marks by correctly identifying the units of the three quantities given in the table. Almost all candidates knew the unit for density and a very small number of candidates got the units for stress and work done mixed up.

(b)(i) Sadly, about a fifth of the candidates failed to identify weight of the object as the force acting on the table. Two of the most popular incorrect answers were '*mass*' and '*pressure*'. The term '*gravity'* was not allowed by the examiners.

(b)(ii) This was designed to be a straight forward question about pressure. Sadly, a third of the candidates only managed to score one mark. A disappointing number of candidates calculated the density of the block because of the similarity between the 'p' and 'ρ' and a few decided to use the mass of the block instead of its weight.

(b)(iii) All candidates wrote something down for this question. Error-carried-forward rule was applied for the last statement. About a third of the candidates, mainly at the top end, scored full marks for writing down the numbers 8, 4 and 2. The factor for the mass caused the most problems and that for the area the least. The use of the factor zero in a small minority of cases was somewhat disturbing.

Question Two

This question produced a range of marks with most candidates scoring more than nine marks.

(a) There is no excuse for getting definitions wrong, especially when the same question has been asked before. More than half of the candidates could not sensibly define *thinking distance*. Incorrect answers such as '*distance travelled as the driver thinks'* and '*the time taken for the driver to apply his brakes'* were too frequent.

(b) Almost all candidates recognised that the area under the velocity against time graph was equal to distance or displacement. A few candidates thought the area represented the acceleration of the car and then proceeded to secure full marks for **(c)**.

(c)(i) The vast majority of candidates correctly determined the thinking distance by multiplying 20 m s^{-1} by 5.0 s. About one in twenty candidates misread the time axis and quoted 20 m as the thinking distance.

(c)(ii) Most of the candidates scored full marks by determining '$\frac{1}{2}\times 20\times 3.5$'. However, a significant number of candidates used 4.0 s instead of 3.5 s or ignored the factor of a half. Examiners awarded one mark if the candidate had quoted the stopping distance of 45 m on the answer line.

(d)(i) This was well answered with most candidates scoring full marks. Candidates either determined the gradient of the velocity against time graph or used an equation of motion to calculate the deceleration of the car. A small number of candidates had a jumble of numbers but still managed to score one mark for correctly identifying the physics via '*acceleration = gradient*'.

(d)(ii) This was an accessible question with most candidates multiplying the mass of the car by their answer from **(d)(i)**.

(e) Most candidates opted for the incorrect physics '*distance is proportional to speed*' and hence scored nothing. Some candidates misinterpreted the term 'factor' and went on to describe road conditions and the subsequent fate of the braking distance. A third of the candidates scored one or two marks. It was good to see some candidates using work done and energy argument to score full marks. Answers such as '*work done = Fx = ½ mv*^{2}*, therefore distance increases by a factor of 4*' were rare but delightful to see.

(f) Full marks were rare but most candidates managed to score two or more marks for their extended writing. The idea of stopping time or the stopping distance was increased by the use of an air bag seemed to be known by most candidates. Most answers went on to link this to a reduction in the magnitude of the deceleration. Most candidates referred to an accelerometer triggered by '*rapid'* deceleration of the car. Examiners did not give any credit because '*quick deceleration'* makes little physics sense. Too many candidates used inappropriate scientific vocabulary. Sadly answers such as '*the air bags absorb the force*' and '*the air bags cushion the driver and absorb his energy*' were quite frequent.

Question Three

All candidates attempted this question but disappointingly only about a fifth of the candidates scored five or more marks.

(a) Only a third of the candidates gave a correct definition for work done by a force – '*work done = force × distance moved in the direction of the force*'. Most candidates lost a mark for failing to mention '*moved*' and or '*in the direction of the force*' in their definitions. A small number of candidates defined the joule.

(b)(i) Most candidates produced elaborate and convoluted answers to this simple question. The net force on the car had to be zero because it was travelling at a constant velocity. Sadly candidates resolved the 300 N force or the weight in random directions to answer the question. A disappointing number of candidates confused force and velocity by mentioning that the '*net force was equal to 18 m/s*'.

(b)(ii) Only a third of the candidates managed to correctly resolve the weight down the slope. A disappointing number of candidates drew incorrect triangles to determine the component of the weight. The most common errors were:

- net force = 9000/sin 7°
- net force = 9000 cos 7°
- net force = 9000/cos 7°

(b)(iii) Most candidates were baffled by this question. A disappointing number of candidates used the weight of the car rather than the resistive force of 300 N.

(b)(iv) This was a low-scoring question with about a fifth of the candidates omitting the question altogether. Only the top scoring candidates appreciated the role of **(b)(ii)** in determining the power developed by the car. Some candidates merely repeated their answer to **(b)(iii)** but otherwise it was difficult to unscramble the thinking involved in many of the answers.

G482 Electrons, Waves and Photons

General Comments

The majority of the 2900 candidates were retaking this examination. Only a few candidates did not attempt all sections in every question. All appeared to have sufficient time to complete the paper. There was more use made of the last blank three pages on the paper to complete or rewrite answers. However not all candidates who did so indicated in the body of their script that the answer was continued on page 18. This would be most helpful to the examiner. Most candidates managed to attempt to answer most sections in every question. Many candidates continue to have problems when describing basic electrical circuits. It is common to see 'potential difference through' and 'current flows through' rather than 'potential difference across' and 'current in'. In a potential divider circuit containing a variable resistor many candidates refer to the current in the circuit being 'constant' to explain how the voltages across the components change rather than using the correct explanation that the current is the 'same' in each component. There were fewer problems with transposition and powers of ten in calculations than in previous papers. However many descriptive responses still lacked structure and careful argument, often containing contradictions. Some candidates are failing to gain full marks when asked to show that a quantity has a given approximate value, eg Q6bii and 8bi, because they either do not state the accurate value to 2 or more significant figures, or do not show the full substitution into the equation.

Comments on Individual Questions

Q1(a)(b) These introductory questions were well answered by almost all of the candidates.

(c)(i) Many attempted this correctly as expected using the series then parallel formulae for resistors. One common error in the algebra was to use equals signs in the wrong places between steps in the calculations. A method using a power argument, assuming 0.5 W, was not accepted.

(ii) Candidates scored the marks either by using 20 V for one resistor, or 40 V for the network of 4 resistors. Many scored zero for using 0.5 W without proof.

(d)(i) Most candidates showed the required relation but explanations were often rather vague and circuitous. Those who argued that the area of cross-section doubled scored zero.

(ii) This question was a good discriminator between the average and good candidates. Few appreciated IX=IY. Many candidates did not quote an expression for power and the majority of those that did used P α 1/R and concluded Y dissipated the greater power.

Q2(a) Most answered parts (i) and (iii) correctly but often failed to give positive ions or cations for part (ii).

(b)(i) Many gave internal resistance as an answer without explaining its effect clearly. Those who mentioned the connecting leads gained credit for this.

(ii) Many did not start by quoting the expected formula, but just wrote a numerical equation. Another unexpected route was to find the external and total resistances leading to the value of internal resistance.

(iii) Almost every candidate did this correctly.

(c)(i) Most were able to link the increased resistance with temperature rise but many implied that the resistance rise was caused by an increase in current rather than the heating effect of a current. Those who then realised that the current dropped as the resistance increased became very confused. Those who failed to mention temperature increase or heating effect scored zero.

(ii) Few realised that the two bulbs were in parallel and so the current was double. Very few candidates mentioned an initial high current. Some believed that fuses only exist for 3, 5 or 13 A so chose 13 as 5 was too close to 4.5 A, giving an acceptable answer for the wrong reason.

(iii) Most candidates gave very bland responses, eg different fuses are needed for different circuits, with little physics shown. It was hoped that candidates would contrast the two circuits discussed in the question, namely the starter motor and lighting circuits.

Q3(a) Most candidates answered this correctly.

(b) These questions were usually done correctly but sometimes the total resistance was given as the final answer in (i) and then ecf was applied to (ii). Other common errors were to substitute incorrectly into the potential divider equation or to calculate the current assuming 6 V across the 560 ohm resistor.

(c)(i),(ii) Most correctly read the graph and then started the explanation with the resistance decreasing. Many then used V α R to conclude that the voltmeter reading falls. However, a significant number of candidates gave a good analysis scoring full marks.

(iii) Many did not see the change in resistance with temperature to be the important factor. Also although some understood the function of the sensor and the relevance of sensitivity, many thought that the thermistor would be used directly in the oven or fridge power circuit so thought that a low and constant R would be better.

Q4(a) Almost all candidates gave correct answers. A few confused displacement and amplitude.

(b) Many correctly picking out the constant phase difference. However some thought the π phase difference was a reason for incoherence; others that either equal amplitudes or zero phase difference is a condition for coherence.

(c) The numbers were usually correctly found from the graph but there were many instances of T = 3s forfeiting one mark.

(d) The most common error was to give the answer for x2 as 1 instead of 1.0.

(e) Some stated that the intensity was proportional to amplitude 2 and were able to derive the 3/2 and 9/4 correctly. However this knowledge was rarely carried forward to give a correct answer in (ii) where many added 2.25 + 1 to give 3.25I instead of adding amplitudes and squaring.

(f)(i) The correct value was often stated, but the justification, the need for movement by λ/2, was not so common. Another confusion was to state that a phase difference of λ/2 was required.

(ii) Many scored the first mark but some implied that the main reason for the increased intensity was the fact that the speaker was now nearer to the microphone. Few mentioned that the intensity increased to a maximum, the detail required for the second mark.

Q5(a) Most stated the laws correctly. A significant number omitted the conservation laws or stated them as conservation of current and voltage. Only a very few reversed the two laws.

(b) Only a few candidates scored no marks at all. Most had at least a reasonable grasp of this topic. Frequently mentioned points were electron emission, conservation of energy, idea of threshold frequency/work function and Einstein's equation. Some mentioned the one-to-one interaction between photon and electron. Few defined work function correctly in terms of minimum energy and not many defined the terms in Einstein's equation. Many focused too heavily on the gold leaf experiment, so scoring few marks.

Q6(a) The value in joules was usually correct but few candidates gave a satisfactory definition.

(b)(i) Applying the principle stated in part (a) proved more challenging and there were many incorrect answers. Some reversed the two answers. Others tried to work backwards from the information given in part (ii).

(ii) Mainly well done, using the correct value for E even where the answer to part (i) was incorrect. Some marks were forfeited by not stating the answer to 2 or more significant figures or by not showing the full substitution.

(c)(i) Very few explained that the electron had wave properties. Most could quote $\lambda=h/mv$ but not all defined the terms.

(ii) Mainly well done although some weaker candidates tried to use $E = hc/\lambda$.

Q7(a) Most gave an adequate description of a photon but few appreciated that a continuous spectrum contains all wavelengths or colours.

(b)(i) Many correctly identified infra red, but many chose UV and some 'visible'. A very significant number stated a numerical value read from the graph. Only a few mentioned the idea of heat; most answers related to the position of the peak on the graph.

(ii) Most gained at least the first mark for working out the 5% value. This was often done correctly or not at all.

(c)(i) Correct answers were in the minority. Where the correct colours were chosen they were usually in the reverse order. Many chose various adjacent colours in the spectrum.

(ii) Most candidates were unable to calculate the correct value of d. However they usually stated the correct equation and then gained a mark for some correct working using their wrong value of d.

Q8(a) There were many correct arrows, but some pointed down whilst others rose only to the second or other intermediate level. Even so the minimum energy was often given correctly. Occasionally the powers of 10 factor was forgotten.

(b) The calculation to show the approximate energy change was usually done correctly but only a minority drew a correct arrow, even amongst those who answered (a)(i) correctly.

(c) The phenomenon of absorption spectra appeared to be poorly understood. There were some excellent answers but some confused this process with the photoelectric effect. A significant number used the term 'ionised' or 'partly ionised' instead of 'excited' when referring to the promotion of electrons to higher energy levels.

G484 The Newtonian World

General Comments

The majority of candidates had been well prepared for this examination and there were very few extremely weak scripts. The exam paper provided ample opportunity for candidates to demonstrate their knowledge and understanding of the specification content. There was no evidence of candidates being short of time to complete the paper.

Some candidates provided excellent responses but generally the answers to straightforward definitions and laws (conservation of momentum and Boyle's law for example) were disappointing. Many candidates offered vague statements and omitted the detail that was required to score full marks. There was a significant number of lower attaining candidates who simply wrote down equations from the formula sheet but then made incorrect substitutions of values into them. They clearly misunderstood what the symbols represented thereby revealing a severe lack of understanding.

Comments on Individual Questions

Q1(a)(i) Most candidates managed to score one mark by explaining the principle of conservation of linear momentum, but less than half of the candidates gave sufficient information to score both marks. Many failed to refer to the 'total' momentum and/or the requirement for 'no external forces'.

(a)(ii) Most candidates knew there was a loss of kinetic energy in an inelastic collision, however, there were too many vague answers where candidates referred merely to a loss of energy. A significant minority of candidates incorrectly added that in this type collision momentum was not conserved.

(a)(iii) 1 The majority of candidates were able to calculate the correct final velocity but some added together the initial momentum of each object even though they were travelling in opposite directions.

(a)(iii) 2 It seemed as if candidates could either calculate kinetic energies very easily or else they found it virtually impossible. Consequently most candidates seemed to score either two or no marks. Some also subtracted the initial KE values implying that they thought KE was a vector quantity.

(b)(i) Most candidates were able to calculate the mass of air, although some engaged in quite tortuous routes to get their answer. Some had clearly forgotten the formula for the volume of a cylinder; which is included in the datasheet.

(b)(ii) 1, 2, 3 Most candidates had little difficulty in calculating the momentum of the air, the force provided by the helicopter blades and the mass of the helicopter. However, a significant minority tried to use the formula for circular motion when calculating the force, but, with 'error carried forward' they still could get a mark for the mass of the helicopter.

Q2 (a)(i) Marks were unexpectedly low in what was thought to be a straightforward opening part of the question. This was due to predominantly vague answers that did not use a word such as "resultant" in their answer.

(a)(ii) Generally, candidates' explanations of the cause and direction of the acceleration were done more satisfactorily.

(b) About half the candidates had no problems calculating the radius of the orbit. However, a significant number of candidates failed to score any marks here and in the subsequent calculation in part **(c)(ii).** They often assumed either that the satellite had an orbital period of one day, or one year, or that the acceleration due to gravity was 9.81 at the satellite's location.

(c)(i) Fewer than half the candidates knew what was required to decelerate the satellite, but in many cases their answers were again too vague. A surprising number of candidates suggested either increasing the mass of the satellite or increasing the air resistance!

Q3(a)(i) A disappointing number of candidates were able to explain the meaning of the kilowatt-hour. Many incorrectly started their explanation with the words "the power needed.to…...".

(a)(ii) Many candidates also had difficulty calculating the cost. There were plenty of careless errors made in calculating the number of hours in a week or converting pence into pounds.

(b)(i), (ii) The calculations of heat energy, and its rate of removal were generally done well with a large majority of candidates scoring full marks.

(c) Most candidates scored at least two marks for their graph. The most common error being ignoring the horizontal line during the change of state. Most candidates recognised that the line for the frozen milk needed to be steeper.

Q4(a)(i) More than half the candidates could answer this satisfactorily. However, a large number of candidates gave unsatisfactory explanations regarding the mean position. A significant minority described "displacement" as the distance moved in a particular direction and made no reference to the mean position. Only a tiny number of candidates were unable to spell "maximum".

(a)(ii) Most candidates could explain frequency but less than half knew the meaning of angular frequency.

(b)(i),(ii),(iii) Allowing for error carried forward, most candidates were able to complete the calculations of amplitude, frequency and maximum speed satisfactorily. However, most candidates forgot to include the amplitude in their final expression for the value of the depth '*d*'.

Q5(a)(i) Most candidates were able to correctly describe the behaviour of the smoke particles.

(a)(ii) Very few candidates scored more than one mark for linking the observation of the smoke particles to the behaviour of gas molecules. Most commonly, the mark was gained for saying they move randomly. A lot of candidates focused on the behaviour of gas molecules according to the kinetic theory of gases. Whilst a lot of correct physics was written very few marks were scored because candidates failed to read the question carefully enough. As a result they failed to answer the question set.

(b) Only a minority of candidates were able to complete the calculation correctly. Either they introduced 298K as room temperature or else they ignored the square term in velocity, as if they were using conservation of momentum.

Q6(a)(i),(ii) Candidates who knew Boyle's law went on to complete the graphs correctly. However, the conditions under which Boyle's law applies were not always fully given with no mention of a fixed mass of gas and/or the need for the temperature to be constant.

(b)(i),(ii) Both parts of the calculation were generally done very well but a few candidates used 15° C. Those candidates who attempted to use $pV = NkT$ generally became confused between moles and molecules and lost marks. Some candidates attempted the last part of the question by using pV = const, even though gas had leaked from the container. Some candidates calculated correctly the remaining mass, but not the loss of mass, again failing to read the question carefully.

G485 Fields, Particles and Frontiers of Physics

General Comments

The marks for this paper ranged from 4 to 86 and the mean score was about 45. Most candidates managed to finish the paper in the allotted time. Sadly, the omission rate was significantly high for questions on nuclear physics and medical physics. A handful of Centres had entered their students for this large unit in the January session rather than in the June session. The responses from such candidates lacked robustness, depth and scientific maturity that characterises A2 candidates. It was also clear that the preparation of some topics were rushed with many tougher questions omitted by the candidates. Centres are advised to enter their candidates for this paper in the summer.

Many candidates disadvantaged themselves with answers showing weak organisation. Answers were not always laid out clearly and the writing of some candidates is giving serious cause for concern. Analytical work often showed missed opportunities. Candidates are reminded not to round their answers in the middle of a long calculation. Candidates generally struggled with questions requiring extended writing. In order to maximise marks and to focus on key points, candidates can present their answers in bullet points. This would have been an excellent approach for Q6(a) where candidates had to describe the formation and the evolution of a star. About half of the candidates were resit candidates. It is good to report that there was a slight improvement in their average attainment.

Comments on Individual Questions

Question One

Most candidates made a decent start in this opening question and scored four or more marks.

(a)(i) This was a well answered question with most candidates scoring full marks. Most candidates decided to determine the electric field strength followed by $F = EQ$. A small number of candidates incorrectly used Coulomb's law to determine the magnitude of the force experienced by the electron. It is good to report that almost all candidates correctly converted the separation from millimetres to metres.

(a)(ii) Surprisingly, about half of the candidates were baffled by this synoptic question. Some decided to use $KE = \frac{1}{2}mv^2$ with *v* equal to the speed of light. The success in this question was very much Centre-dependent. The correct answers were either via $KE = VQ$ or $KE = Fx$.

(a)(iii) A significant number of candidates wrote the equation for kinetic energy and then stopped. A good number of candidates successfully gained a mark through the rule of error-carried-forward. A disappointing number of candidates struggled to rearrange the equation for kinetic energy or quoted the value for speed^2.

(b) This was a challenging question that suited candidates at the top end of ability. Some of the answers were elegant with candidates realising that the gain in the kinetic energy of the electron was the same because both *V* and *Q* were constants in the equation $KE = VQ$. The vast majority of the answers were either contradictory or too superficial.

Question Two

This was a fairly accessible question with marks ranging from zero to nine. The modal mark was six with most candidates showing a decent understanding of capacitors.

(a) The definition for the farad was disappointing across the ability spectrum. The vast majority of the candidates scored zero for their answers. Candidates cannot be expected to score a mark for a clumsy response such as '*it is the unit for capacitance*'. Some candidates mixed quantities and units, eg '*coulomb per p.d*' and '*charge per unit volt*'. Examiners allowed the answer '1F = 1 C V^{-1}', they would have preferred '*coulomb per* (unit) *volt*'.

(b)(i) The answers to this question were very disappointing. Too many candidates mentioned charges moving in the circuit without ever mentioning the electrons. The plates were mysteriously charged. Candidates showed poor understanding of how the plates A and B acquired opposite charges. Less than a tenth of the candidates mentioned electrons travelling in a clockwise direction with plate A gaining electrons and plate B losing electrons. Candidates are advised to carefully examine the question before putting pen to paper.

(b)(ii) Most candidates correctly determined the charge stored by the capacitor and the energy stored by the capacitor. A few candidates lost a mark for assigning an incorrect value for the nano prefix.

(c)(i) Most candidates did well in this *show* question. A small number of candidates failed to gain a mark because their answer did not show all the steps in the calculation, eg '$12 = 3.24R$, hence R = 3.7 MΩ'.

(c)(ii) This was a challenging question, with most candidates making a good start with either a correct value for the time constant or a correct exponential decay equation. Sadly, many lost a valuable mark for quoting the current in amperes rather than in microamperes.

(d) Almost three quarters of the candidates scored zero. The most common error was to assume that the total resistance of the circuit was doubled (rather than halved). This led to incorrect reasoning with doubling of the time constant and hence a lower rate of discharge. Some candidates gave qualitative responses to this quantitative question.

Question Three

Most candidates had a decent knowledge of particles moving in a uniform magnetic field. The majority of candidates scored at least four marks.

(a) The answer to this question was simple; the magnetic flux density was perpendicularly out of the plane of the paper. Some candidates were obviously rushing because their answers made reference to the direction of the force on the protons. Too many scripts mentioned '*centripetal force*', which had nothing at all to do with the question. Disappointingly, only a third of the candidates scored a mark for this straight forward question.

(b) The answers to this question were pleasing. Candidates clearly showed how the relationship $\frac{mv^2}{R} = BQv$ led to the final equation $v = \frac{BQR}{m}$.

(c) A small number of candidates determined the speed of the proton by dividing the radius by the orbital period. Examiner's allowed error forward if the magnetic flux density was subsequently correctly determined. Most candidates correctly determined the speed of the protons and then used $B = \frac{vm}{QR}$. It was rare to find candidates deriving an equation for the magnetic flux density from first principles and then substituting the values.

(d) Most candidates scored nothing for their elaborate responses. Very few candidates appreciated that the component of the force on the proton in the direction of motion was zero and hence there was no work done on the particle.

Question Four

The enthusiasm of candidates for cosmology was clear to see from their scripts. Sadly, some of the responses lacked the depth expected at this level. Most candidates managed to score at least four marks for this question on Hubble law and the big bang.

(a) The examiners were disappointed with the countless incorrect statements for Hubble's law. Some candidates mentioned Olbers' paradox. Others thought it was something to do with the reciprocal of the Hubble constant. A disappointing number of candidates mentioned '*recessional velocity of <u>planets</u>*'. This was definitely a missed opportunity for most candidates.

(b)(i) Candidates struggled to make sense of the information given in the question. The answer was quite simple; multiply the speed of light by a factor of 0.15. Many candidates tried to use the Hubble constant to answer the question.

(b)(ii) Too many candidates struggled to get a decent answer to this question. About a quarter of the candidates simply omitted the question. Most candidates were overwhelmed by the unit of 'km s^{-1} Mpc^{-1}' for the Hubble constant. Candidates in the upper quartile showed excellent comprehension of this topic and picked up two valuable marks.

(b)(iii) The answers to this question were once again very much Centre-dependent. Almost all candidates were familiar with the idea that the age of the age was equal to the reciprocal of the Hubble constant. The conversion of the km s^{-1} and the Mpc was simply too daunting for most of the candidates. Some candidates also fell at the last hurdle when converting the time from seconds into years.

(c) Candidates wrote enthusiastically about the big bang. Most candidates were aware of the current temperature of the universe or the existence of the microwave background radiation. Some even mentioned the existence of the primordial helium as the supporting evidence for the big bang. Examiners enjoyed marking this question.

Question Five

This question was badly answered with only the more able candidates obtaining the marks.

(a) Candidates struggled to define the parsec. The diagram lacked precision and had too many omissions. The terms stellar parallax and arc seconds were randomly sprinkled on the examination paper with candidates showing very little knowledge of this topic. Once again, it was candidates in the upper quartile that gave elegant and complete answers.

(b)(i) The answers here were very disappointing. Some candidates unsuccessfully tried using their diagrams in (a) and tan (1/3600) to determine the distance of Tau Ceti in parsec. The answer was fairly straight forward; distance = 1/0.275 = 3.64 pc.

(b)(ii) An equal number of candidates got full marks and zero. A significant number of candidates successfully recalled that 1 pc = 3.26 ly.

Question Six

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

(a)(i) Candidates enjoyed writing about the formation of a star from a dust cloud and its eventual demise into a white dwarf. Most candidates correctly sequenced the processes. However, some of the answers were vague. For example, candidates were referring to '*fusion of hydrogen into helium'* when it should have been '*fusion* of *protons or hydrogen* <u>*nuclei*</u> *into helium* <u>*nuclei'*</u>. A disturbing number of candidates thought that the star expanded into a red giant and this then imploded into a white dwarf. It seems that candidates were unaware of the outer shells of the star responsible for the formation of the red giant and gravitational collapse of the core creating a white dwarf.

(a)(ii) Most candidates provided comprehensive answers here. The evolution of the massive star into a super red giant followed by a supernovae and neutron star or black hole was known by almost all candidates.

(b)(i) About half of the candidates failed to score any marks. A significant number of candidates did not appreciate that this question required knowledge of Einstein's mass-energy equation. A disturbing number of candidates completely ignored the reference to the one millionth mass of the Sun. Candidates who managed to determine the time in seconds (4.74×10^{14} s) were awarded two marks out of three.

(c)(i) The majority of the candidates scored two marks for knowing that fusion took place at high pressures and temperatures within the core of a star. Very few candidates mentioned the repulsive electrical forces between the hydrogen nuclei and the role of the strong nuclear force in the fusion process.

(c)(ii) The majority of the candidates secured a mark for mentioning kinetic energy. Only a small number of candidates mentioned electromagnetic waves or gamma photons. The most popular incorrect answers were '*heat energy*' and '*light*'.

(c)(iii) The concept of binding energy per nucleon remains enigmatic for many candidates. One mark was awarded for the correct conversion of 7.2 MeV into joules. Only a quarter of the candidates got the correct answer of 4.6×10^{-12} J.

Question Seven

This proved to be a challenging question on ultrasound. About half of the candidates managed to score at least seven marks.

(a) The marking of this question was generous. Candidates were on the whole familiar with the idea that the piezoelectric film produced an e.m.f. when it was strained.

(b) The answers for A-scan and B-scan lacked clarity. Too many candidates failed to mention that '*pulses of ultrasound are sent into the body*' and that these are reflected at the interface between different tissues. Many candidates also failed to mention that in a B-scan the transducer is moved around the patient or several transducers are used to create a three-dimensional image.

(c)(i) It was great to see a good understanding of how units are derived. Most candidates gave well presented solutions.

(c)(ii) Most of the candidates effortlessly calculated the fraction of the reflected intensity to be 0.37. A percentage answer was allowed. A small number of candidates incorrectly substituted the densities or the speeds rather than the acoustic impedances.

(c)(iii) Candidates showed a good understanding of acoustic impedance matching and were aware of the reasons for using the gel.

(c)(iv) Most candidates correctly used the wave equation to determine the wavelength of the ultrasound. Inevitably, a small number of candidates quoted their final answer in metres rather than millimetres. Most candidates successfully converted the megahertz into hertz.

(c)(v) Not many candidates were familiar with the idea that shorter wavelengths produced better quality images. Sadly, the modal mark for this question was zero.

Question eight

Most candidates struggled with this question on X-rays.

(a) Most candidates concentrated their efforts on the contrast media rather the image intensifiers. Barium meals were known to most candidates. A good number of candidates mentioned their '*high Z values*' or '*large attenuation coefficients*'. Very few candidates mentioned anything useful about image intensifiers.

(b) Only candidates at the top end made sense of this demanding question.

(c)(i) The focus of this question was on the <u>production</u> of a CAT scan image and simple X-ray image. Most candidates managed to score at least one mark for mentioning multiple detectors in a CAT scanner.

(c)(ii) The majority of the candidates were aware that CAT scan images could be processed into three-dimensional images. Once again, it was the most able candidates that picked up maximum marks.

Question nine

This was a high scoring question with a significant proportion of the candidates gaining maximum marks. It was good to see candidates demonstrating a decent understanding of particle physics.

(a)(i) Candidates did really well to recall the quark composition of the neutron and the proton. Almost all candidates correctly identified the charged on these two particles. For the charge on the proton, an answer of +1 and +*e* were both allowed.

(a)(ii) Almost three quarters of the candidates correctly identified the charge and strangeness of the up quark and the charge and baryon number for the down quark.

(b)(i) Most of the candidates managed to score at least one mark for the decay equation. A correct word equation for the decay was awarded full marks by the examiners. The most common errors were incorrect subscript and superscript for the proton and swapping the antineutrino for either a gamma photon or a neutrino.

(b)(ii) Half of the candidates correctly identified the '*weak interaction*' as the force responsible for the decay of a neutron and the other half incorrectly opted for either the *'strong nuclear force'* or the bemusing comment '*beta decay*'.

(b)(iii) Most candidates effortlessly categorised the electrons and neutrons into the correct groups of leptons and hadrons (or baryons).

Question ten

Most candidates scored at least four marks for this demanding question on radioactivity.

(a) It was difficult to decipher candidates' responses. Most candidates saw no difference between the terms spontaneous and random and ended up scoring no marks.

(b) Middle and low scoring candidates confused the decay constant with activity. Few candidates knew that the decay constant was the probability of decay of a nucleus per unit time. On this occasion, examiners allowed the equation $\lambda = \frac{A}{N}$, as long as all the terms were correctly defined.

(c) Half of the candidates showed superficial knowledge of carbon dating and scored no marks. All candidates had to do was to look at **(d)** for inspiration. It was difficult to make sense of statements that did not mention carbon-14 nuclei. The technique was quite often misunderstood and there were too many bland comments such as *'you can find the age from the amount of carbon in the sample'* and *'the age can be found because the half life of carbon is known'*.

(d)(i) Most candidates correctly determined the decay constant from the half-life of the carbon-14 isotope. A small number of candidates decided to convert the half-life into seconds but then struggled to convert the decay constant into year-1. A pleasing number of candidates managed to correctly substitute values into the decay equation $A = A_0 e^{-\lambda t}$ but then struggled to determine the age of the dead wood.

(d)(ii) Most candidates struggled here. Examiners only awarded a mark if candidates mentioned the random nature of the radioactivity or the very low activity of the sample.

(d)(iii) The key point that the activity would be masked by the background radiation was missed out by the majority of the candidates.

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