RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE **7883**

Advanced Subsidiary GCE **3883**

Report on the Units

January 2009

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Oxford Cambridge and RSA Examinations

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Advanced Subsidiary GCE Physics (3883)

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2821 Forces and Motion

General Comments
The general impression of the Examiners who marked the paper for this module was that the level of difficulty of the questions was appropriate for the candidates for whom it was intended.

The paper consisted of a wide range of questions covering a large proportion of the Specification. The candidates produced a very wide range of responses and the majority of questions provided good differentiation. There was an almost complete range of marks. There were more candidates with less than 10 and fewer candidates with a total of greater than 50 this year. This was expected as this was a legacy paper taken by candidates who were in the main re-sitting the module. The range of marks obtained suggests that the paper contained sufficient material to test the most able candidate. The well prepared candidates were able to show their knowledge and understanding and obtain a grade appropriate to their ability. There were a significant number of candidates with less than 20 that is below the pass mark for this paper. Those candidates with less than 20 were often unable to give acceptable definitions, used inappropriate formulae in their calculations and gave low-level responses in their explanations. Basic understanding and recall was absent and suggested that these candidates had not prepared much of the content of the course. The weaker candidates scored poorly in parts of questions where explanations were required. In 'show that' situations they were also prone to omit the statement of the formula for a calculation and therefore were more in danger of losing marks if later work was unclear. Many errors were the result of untidy presentation of work.

There were many scripts showing a high level of competence, especially with the numerical work. The mean mark for candidates in this session was 30.2, which was 1.6 marks lower than the mean mark obtained in the January session in 2008. All the questions except question 2 provided the opportunity for the weaker candidates to score some marks, and each question had at least one part in which the more able candidates were able to show their understanding of the subject.

There was a good range of responses to the majority of questions and so differentiation was achieved. The responses differed widely depending on the amount of preparation of the candidate and the Centre. There were many centres whose candidates had clearly been very well prepared but equally there were a number of centres where the candidates had a very poor understanding of the concepts involved. The lack of precision, poor use of English, basic errors in calculations and the failure to read the question carefully reduced the marks of many candidates of the full range of abilities. Many candidates struggled with basic mathematical procedures such as manipulating simple equations. The overall presentation of mathematical writing was often untidy and unclear. The parts of questions that required descriptive work and the precise statement of a definition were poor generally. However, the majority of candidates were able to give good answers to some parts of every question. The most able candidates scored highly in all the questions on the paper. It was thought that many of the less-able candidates could have gained higher marks with a better quality of written presentation and clearer mathematical working.

The length of the paper was considered to be about correct with the vast majority of the candidates finishing the paper in the required time. There were however, a number of examples of blank sections in question 6 to suggest that some candidates had insufficient time to complete the paper or were not prepared for this particular topic. The standard of written communication was generally adequate with many candidates scoring at least one of the marks available for written communication. Marks were lost by a significant number of candidates who failed to describe the terms required in a logical and organised order.

Comments on Individual Questions

1 This question produced very good differentiation across the full ability range.

(a)(i) The good candidates scored full marks for this part. However, a significant number of candidates omitted the terms velocity, speed and acceleration in their answers. The use of the word motion and not the technical terms required meant that these candidates failed to score any marks.

(ii) The majority of calculations were correct. A significant number used equations of constant acceleration rather than determining the distance from the area under the graph.

(b) This part was meant to be a high demand question and this was shown by the marks obtained. The description of the difference between scalar and vector was often given without reference to the motion of the projectile. The explanation of the displacement of the projectile was poorly given by the vast majority of the candidates.

(c) (i) This part was well answered by the majority of candidates.

(ii) A large number of candidates used Pythagoras correctly and scored the first two marks for the magnitude of the velocity. However, a significant number of candidates assumed the angle for the velocity at this point in the path of the projectile was still 53 degrees. Many candidates used a scale diagram and scored full marks.

(iii) Many candidates gave an answer of zero for the velocity of the projectile at its maximum height.

(d) The majority of candidates scored at least two marks out of three for this section. A significant minority gave a positive gradient for the velocity - time graph. In some cases it was difficult to see the candidate's answer on Fig. 1.2. The marking of scripts on line requires a clearly drawn line on graphs for it to be seen on the scanned version.

2 This question was found to be difficult by the majority of candidates. There was good differentiation between the average and the very good candidates.

(a) Many candidates scored the first mark for stating the correct equation and giving $u = 0$. However, very few candidates were able to transform the equation and compare it with $y = mx$ to give the correct gradient for the graph in Fig. 2.2.

(b)(i) The gradient calculation did not prove to be that straightforward to many candidates. Careless misreading of the scale values was often the main mistake with only a small minority finding the inverse of the gradient. The majority did score at least one mark.

(ii) Very few candidates related the acceleration to 2 / gradient. However, many candidates were able to take readings from the graph and substitute them into a suitable equation. There was evidence of a significant minority simply quoting 9.81 or 10 without any working. The mark scheme covered this response adequately.

(c) This part of the question was poorly answered with many only scoring the charity mark of air resistance. The answer that results could not be obtained for a distance of zero due to the trapdoor not opening indicated a lack of understanding of graph work associated with experimental results. Very few answers referred to the time delay due to the electromagnet. There were many comments concerning reaction time causing an error. However, the diagram clearly shows the time being measured by electrical means.

3 This question differentiated between the average and the very good candidates.

(a)(i) This definition was known correctly by the majority of candidates. The mark was often lost by the omission that the unit measured 'force' and caused an acceleration of one metre per second squared.

(ii) This definition was known correctly by the majority of candidates. The mark was often lost by the omission of the phrase 'in the direction of the force'.

(b)(i) The vast majority of candidates correctly gave the equations in this part.

(ii) Very few candidates were able to use the equations given in part(i) to show that the work done was equivalent to the change of kinetic energy. The vast majority of candidates scored zero or one for this part.

(iii) There were many vague statements given for this relationship and the vast majority did not obtain this mark. The distance increasing with the velocity or proportional to the velocity were the most common answers that were not accepted.

(c)(i) This part was answered well by the good candidates. However, the majority followed a two step approach and calculated the acceleration first rather than relating the work done to the change in kinetic energy. The below average candidates found the processes required too difficult to complete.

(ii) A significant minority obtained the correct answer for the distance even though they had not been able to state the relationship for part (b)(iii). There were many candidates that calculated a value for the distance giving a result to four or five significant figures without seeing the relationship between the distance for the speed of 13.3 m per s and the speed of 26.6 m per s. Others calculated values that were either less than 25 m or very large values without any comment.

4 This question was well answered by the average to below average candidates.

(a)(i) This part was well done by the vast majority of candidates.

(ii) This part was well done by the vast majority of candidates.

(b)(i) This part was well done by the vast majority of candidates.

(ii) The calculation of pressure proved a good discriminator in this question and indicated whether the candidate had a good understanding of the physics involved.

(iii) This part was only answered correctly by a minority of candidates. The majority thought that the area was the critical variable in the resulting pressure.

5 This question produced very good differentiation across the full ability range.

(a) The definition was generally given correctly. The main mistakes were either to use the term mass instead of weight or to omit the required statement that it was the 'point' where the weight seems to act.

(b)(i) The vast majority of candidates failed to score the mark for this part. The answers were generally too vague with comments such as all the forces are balanced not scoring at this level. The resultant moment and resultant force being zero were rarely given together. Only a very small minority used the idea of zero acceleration or constant velocity to score the mark.

(ii) A good majority scored both marks. Marks were lost for giving the wrong unit or using the wrong distance of the weight from the turning point.

(iii) The majority of candidates were unable to solve this straight forward moment calculation although they had often completed part (ii) correctly.

(iv) The use of error carried forward in the marking of this part enabled the majority to get a mark for this calculation. Parts (iii) and (iv) were often left with no response by the average to weaker candidates.

(v) The good candidates were able to complete this part without any difficulty. The average candidate often knew the correct formula but had difficulty substituting the correct value for the force. The weaker candidate could get no further than quoting the expression for power as work done / time or left the part with no response.

(c) The average to good candidate understood what was required for this section and obtained the mark.

6 This question produced good differentiation across the full ability range.

(a) The explanation of the behaviour of a spring was generally described correctly in terms of Hooke's law. However, very few candidates explained the term extension. The behaviour of the spring after the elastic limit was exceeded was poorly described with very few candidates stating that the spring would not return to its original length after the force was removed or that it would be permanently deformed. The majority of candidates scored at least two of the three marks available.

(b) There was a full range of marks for this part with the majority scoring three or more marks. The loss of marks was generally due to candidates giving explanations involving combinations of the terms or describing specific metals or materials. The weaker candidates tended to score marks for merely quoting the Young modulus and / or stress and strain. The main confusion shown was to describe and compare all the terms asked for by the value of the Young modulus; for example comparing a ductile material and a brittle material on the basis of their Young modulus value.

At least one of the marks for QWC was not gained because of the general poor spelling, sentence construction and organisation in the candidate's answers.

2822 Electrons and Photons

General comments
As this was a legacy paper the entry was slightly smaller than would usually be expected. However, the range of marks obtained was similar to the range obtained during the last examination session. The standard of the paper was about the same as previous papers.

There were some admirable scripts from candidates who had obviously been well taught and thoroughly prepared for the examination by the use of past papers and mark schemes. There were some candidates that seemed never to have seen a past paper and were unaware that good examination answers require the inclusion of key points of physics and the correct use of technical vocabulary. The presentation of some of the scripts left a lot to be desired. Untidy writing that collapsed into illegibility made it impossible for some marks to be awarded with certainty. Examiners should not be required to guess the word from its context. Numerical skills were varied, but once again marks were regularly lost because of problems with powers of 10 and the poor understanding of significant figures. . Centres must remind candidates that scripts are now scanned and marked electronically and that answers should be kept within the scanned regions of the paper. Extra sheets can be attached as they are scanned and sent electronically at the same time as the paper.

There was no evidence that candidates found time to be a problem, with incomplete scripts usually being from weaker candidates who missed questions from various parts of the paper.

Comments on individual questions

Question one

(a) Many candidates answered this question correctly. A common error was to define resistance or even to write Ohm's law. Candidates need to know the difference between a quantity and a unit. A few used sentences such as 'voltage per unit amperage' and would be best advised to strike them from their vocabulary.
(b)(i) Whilst many candidates got both the marks, a significant minority suggested that the resistance increased at a uniform rate for the fixed resistor and at a non-uniform rate for the lamp. Some thought the resistance was given by the gradient and that the decreasing gradient for the curve showed that the resistance of the lamp decreased with potential difference. A few candidates confused 'directly proportional to' with 'constant'.
(b)(ii) The vast majority of the candidates identified 7V as the correct answer. Something around 3.5V was the most common incorrect answer, often justified with reference to gradient. Many did not earn the second mark because they did not specify that both the current and the p.d. were the same for both or to give the equation for resistance. A minority gave the answer as 0V.
(b)(iii) Many candidates completed this calculation correctly. The most common error was candidates progressing as far as the formula for resistors in parallel, and then forgetting to invert their final answer. Disappointingly, a large number of candidates are still writing equations such as $R = 1/R_1 + 1/R_2$, even though they then went on to get the correct answer. Most candidates realised they had to use 4V but, a significant number used their value from the previous part of the question.

Question two

(a) & (b) This was mostly answered correctly. A very small number of candidates did not draw arrows on the diagram, suggesting they did not realise there was a question to be answered.
(c) Many candidates were able to do this, giving a good explanation of the process they were using. However, in the minority of cases it seemed as if the numbers were juggled until the correct answer could be obtained.

This was actually tackled in a variety of ways, as well as the way suggested in the mark scheme. For example, a significant number of candidates calculated the current for the flow of one electron in the time given and then multiplied by the total number of electrons.
(d) About a third of the candidates got this right. Many candidates drew a straight line of either increasing or decreasing gradient. It should be noted that '*it doesn't vary*' is one possible correct answer to the question 'how does it vary?' There were some very unusual curves drawn, including parabolas.
(e) Most candidates gave the correct answer. The better candidates wrote the equation, substituted the values and then wrote their answer. Such good practice needs to be adopted by more candidates. The use of $W = IVt$ was a common mistake.

Question three

(a) Many candidates correctly distinguished between e.m.f and p.d. The most common error was to simply state that energy was being gained or lost without specifying that it was charge that was gaining and losing the energy. Some wrote that charge was being gained or lost.
(b) Most candidates correctly identified the unit as the similarity and a very small number wrote that both quantities involved energy per unit charge. Some candidates wrote that they were both voltages.
(c)(i) Whilst many candidates correctly identified that there is a p.d across the internal resistance, many simply wrote 'the battery has an internal resistance'. Incorrect answers often focused on the resistance of the circuit wires rather than the internal resistance.
(c)(ii) The majority of candidates were able to calculate the p.d. across the wire. In many cases, no working was provided. A significant number of candidates calculated the p.d. across the wire X and were penalised accordingly.
(c)(iii) Most candidates correctly identified wire Y and stated that it had the lower resistance. Only the better candidates scored the second mark by linking the resistance to any of the equations for electrical power.

Question 4

(a) Most candidates gave the correct equation. Those that had the wrong answer at this stage generally lost many marks on this question.
(b) The majority of candidates scored both marks on this question. A few failed to correctly square 0.5 and a minority cubed it. Some candidates penalised themselves by not reducing the fraction from $0.5/0.5^2$ to 2 or at least 1/0.5.
(c)(i) Again, many candidates got this mark. A sizable minority lost the mark because they did not show that the **area** was as given. They did not rearrange the equation and left it with volume as the subject.
(c)(ii) This question was generally well answered.
(d) Very few candidates indeed realise that resistivity was a property of the material and would therefore remain constant. They gave very convoluted explanations, which ended with either resistivity increasing or decreasing, depending on how their argument had been constructed. Sadly resistivity was frequently confused with resistance.

Question five

Few candidates scored all 4 marks available for Kirchhoff's laws. Many omitted key words such as 'sum', 'loop' or 'point'. A significant number of candidates thought that current and voltage were the quantities conserved.

The question on the photoelectric effect was reasonably answered by many candidates. It was obvious which candidates had been prepared for the examination using past examination papers. These candidates wrote the key points succinctly. Marks were lost because some candidates tried to discuss the photoelectric effect without mentioning photons or by mixing up frequency and energy. Many candidates wrote that the frequency (of the photon) had to exceed the work function energy of the metal. Most candidates scored the QWC marks; where they lost a mark it was invariably for poor spelling. Even though Kirchhoff was given in the stem of the question, spelling it correctly in their answer proved beyond many candidates.

Question six

(a) Most candidates scored two marks for writing the equation in words. A few lost their marks by using the words 'directly proportional to' instead of 'equals'.
However, there is still confusion between the size of the particle and its de Broglie wavelength. Many thought the electrons were diffracted because they are the same size as the gaps they pass through. Candidates also lost marks by not specifying that the gap the electron diffracts through relates to the atoms/atomic lattice of the graphite. Only a minority of candidates explained why the ball would not exhibit diffraction. Candidates again concentrated on the size of the ball rather than its wavelength. Some candidates came close to earning the mark by commenting that the wavelength of the ball was different from the size of the window, but this was not specific enough to earn the mark.
(b) Most candidates were able to calculate the speed correctly and proceed from this point to get full marks. Where of course they calculated the speed incorrectly, they still could proceed correctly. The most common error was taking 97.5% of the speed of light. In some cases, they ended up with a speed greater than that of light.

Question seven

(a) The majority ticked the correct box. A few ticked two boxes.
(b) Candidates were very vague when explaining what else was wrong with a given magnetic field pattern. In many cases candidates, even though they were told the direction of a magnetic field pattern was wrong, focused on the direction of the current and commented that that was wrong. Other answers which were too vague were for example, that '*the field lines were wrong'*, or even that the '*field lines should be concentric*'. Often the way they expressed themselves was insufficiently clear and it was felt that they might well have drawn the shape correctly but were unable to convey their ideas in a coherent sentence.
(c)(i) Many candidates answered this correctly. Some incorrectly rearranged $F = BIL$ to $B = FIL$. A few made power of ten errors.
(c)(ii) The separation between the two wires was calculated correctly by most candidates with an error carried forward for magnetic flux density. The most common error was quoting the answer to one significant figure without having quoted a value to more significant figures previously.

Question eight

(a) Most candidates were able to give at least one correct property of the photon. Many got both marks. A minority wrote that the photon had mass and that it was charged. They might have been confused between the photon and the proton. Some concentrated on the wave properties of electromagnetic radiation and earned no marks.
(b)(i) Most candidates gave correct answers here. Many started with the correct equation and went on to secure both marks. A few candidates tried to include the area and radiant power data.
(b)(ii) This was a more demanding question and was correctly answered by about a third of the candidates. A few earned just the first mark by correctly calculating the power radiated from the Sun.
(b)(iii) Infra red was the most popular answer but a few thought it might be radio waves and some went to the short wavelength end of the electromagnetic spectrum and wrote either u.v. or gamma. A minority wrote '*infa red*' – they were awarded a BOD (benefit of doubt) mark.

2823/01 Wave Properties

General Comments

The general standard of work was slightly better than last year with very few candidates scoring less than 50%. Candidates showed better proficiency in the numerical questions than in those requiring a written response. The paper provided ample opportunity for candidates to demonstrate their knowledge and understanding of the module content and there was no evidence of candidates being short of time.

Comments on Individual Questions

Q1. A surprising number of candidates overlooked the opening part of the question which asked for the angles of incidence and refraction to be shown on the diagram provided. As a result many lost this very easy mark. Teachers should remind their students to read each question carefully to ensure that all parts are answered. The remainder of the question was generally answered well with high marks being gained.

Q2. The *principle of superposition* is understood well by the majority of candidates and many scored full marks for part (a). Some again lost a mark by referring to amplitude instead of displacement in their definition. In part b(ii) some candidates lost marks by writing incorrect algebraic expressions for the path difference. For destructive interference, for example, some would write $(n/2)\lambda$ instead of $(n+½)\lambda$ for the required path difference. Full marks were very common for the calculation of the slit separation in part (c) but some lost a mark for failing to convert 2.4 mm into metres.

Q3 Most candidates showed good understanding of optic fibres and the concept of *total internal refraction*. The majority scored full marks for correctly using the formula $n = 1/\sin C$ in part (b). Part (c) attracted some very good answers with candidates being able to give full explanations of why a large critical angle will reduce the amount of *multipath dispersion.*

Q4. This proved to be the lowest scoring question on the paper. Many offered vague and ambiguous answers in parts (a) and (b) with many having difficulty in explaining the differences between stationary and progressive waves. Many candidates provided fully correct answers to parts (c) and (d) but a significant number appeared to have no idea of how nodes and antinodes are formed in open and closed air columns.

2823/02 & 2826/02 Principal Moderator's Report

There is little new to say about this legacy examination. The number taking the coursework option, in this session, remained about the same and a full range of results was obtained. As always the housekeeping of entering the correct code, to signify that the candidate was carrying forward a previous mark, was a little approximate. Overall, the standard was a little higher on AS than last year showing the number of re-sit candidates trying to improve their grades. I have given a full report as last year so that centres will not need to look at archive material to get any help they may require in the summer.
The comments on the individual descriptors are the same as in previous awards and my reports from earlier years remain relevant.

There is rarely any point in repeating investigations e.g. the resistivity of a range of materials or finding "*g*" in several ways, the full range of descriptors can be covered with one in-depth study. Briefly the main features of each skill are as follows.

Planning
A preliminary experiment should be carried out to guide the final investigation, rather than be an early run of exactly the same work. The range, scales, safety and equipment choice should be influenced by this preliminary work. One or two detailed references to books or internet sites are needed at level 7, it would be good if these were taken into account in the body of the work, rather than just used as a means of securing the mark.

Equipment should be chosen taking into account precision and reliability rather than just offering a list of the equipment used, with little justification as to why these particular instruments or methods have been chosen.

Some good science should be shown, to allow the higher descriptors to be met.
With 2826, reference must be made to other areas of the specification. There should be an appreciation that Physics is about simple ideas applied to differing areas of study and that similarities occur based on theses simple rules. Annotation to show where other areas of the specification are brought into the work would greatly aid the moderation process.
The use of the 8 mark should be reserved for really excellent work making the investigation a truly first class study; the mark should be awarded very sparingly. Where a candidate is given the top mark it should be supported by annotation showing exactly why the marker felt it was worthy of full marks.

Implementing
It is important to watch for consistency of observations carried out. They must be to the precision of the measuring device e.g. 10cm. in a table of results is not to the same precision as 14.1cm.The readings should always be to the maximum precision available with the apparatus used.

The "a" descriptors can only be judged by the centre. A good table of results with consistent readings, repeats and correct units is all that is needed to score up to I7b.

Analysing
Good graphical work is needed with gradients and intercepts taken and used for the award of A5a and A5b. Science of a high level and the correct use of significant figures in the final quoted result are needed for the level 7 descriptors. Again linkage to other parts of the specification is required for A2.

It is difficult to gain high marks here if the investigation does not lead to a straight-line relationship. The careful use of statistics and IT should be encouraged bearing in mind that the final answer should be given with significant figures correctly based on the experimental observations.

Again the award of 8 marks should be viewed very carefully and annotated in detail where the centre feels it is valid.

Evaluating
An objective discussion is needed with identification of where uncertainties lie and how they might be overcome. The identified sources of uncertainty need to be looked at in terms of the numerical effect that they have on the final result. That final result should be given in the form a +/- b, with correct significant figures for both the result and the uncertainty and with the correct units. Improvements should be offered to the procedures to increase the reliability of the results, with the maximum effort being expended on the data with highest uncertainty. A treatment similar to that found in the appendix of “Physics 1” will yield all the “b” descriptors here.

The idea that error is the difference between the observed result and a book value must be avoided.

2823/03 Practical Examination 1

General Comments
The general standard of the work done by candidates was again similar to previous years. Candidates continue to find the analysis section in question one and the evaluation section in question two the most difficult parts of the paper.

All Centres appeared to have the appropriate equipment for the practical examination.

Candidates appeared to complete the paper within the necessary time allocation and most candidates were able to complete question one and two without help from the supervisor. Plans were again very Centre dependent.

Candidates should be encouraged to show all the steps clearly when carrying out calculations. In addition candidates should be encouraged to include greater detail in their answers to descriptive type questions, giving reasons where necessary.

Comments on Individual Questions

Plan

Candidates were required to plan an experiment to investigate how the resistance of a wire varies with temperature.

The majority of the plans were about an appropriate length. Interestingly part **(b)** asked for the range and precision of any instruments that would be used and part **(c)** asked for the factors that needed to be controlled to ensure that it is a valid test – plans often omitted these parts.

Candidates were expected to draw a workable diagram of the apparatus. The examiners expected to see a workable circuit diagram using the correct symbols to measure resistance. This mark was sometimes not scored because candidates proposed connecting power supplies with ohmmeters or did not use a voltmeter. Candidates were also expected to explain their procedure. In this case it was expected that candidates would make it clear that the resistance would be determined at different temperatures. Some candidates scored an additional mark for suggesting that the wire length should be very long so as to have a more measurable resistance.

Most candidates suggested methods of achieving the temperature range required; pleasingly very few candidates suggested using a bunsen burner. There was also a mark available for an appropriate method to determine the temperature. Sadly few candidates discussed waiting for the temperature of the wire to stabilise.

There was one mark available for a relevant safety precaution related to either hot or cold temperatures. Weak candidates often listed standard laboratory rules or were vague.

A large number of candidates mentioned the need to keep the cross-sectional area or length or type of wire constant.

There were four marks available for extra detail e.g.
Wire must not have kinks
Typical resistance very low or quotes resistivity value
Determination of typical resistance of wire
Check diameter of wire using micrometer in different places

Take several readings of temperature to ensure that temperature is constant
Calculation of range of meter
Use of a protective resistor
Calculation of protective resistor
Prevent wire shorting
Use of insulated wire
Use of remote measuring devices
Use of I-V or V-I characteristics to determine resistance at each temperature
Detailed explanation of bridge methods
Explanation for use of insulated wire within water
Evidence of preliminary investigation in the laboratory.

In the notes for guidance for the plan it is stated that candidates should list clearly the sources that have been used. Two marks were available for evidence of the sources of the researched material. Detailed references should have page or chapter numbers or be internet pages. Two or more detailed references score two marks. Two or more vague references scored one mark.

Most of the more able candidates were able to score two marks for the quality of written communication which were awarded for the organisation and sentence construction of the Plan. Plans that were too long did not score both marks.

1 This question asked candidates to investigate how the current in a circuit depends on the resistance of the circuit.

Candidates were initially asked to set up the circuit. Very few candidates needed help; if help was given, one mark was deducted.

Part **(c)** asked candidates to justify the number of significant figures that were used for *V*. Good candidates referenced their answers to the number of significant figures in both *I* and *R*.
Results tables were generally well presented. The majority of candidates labelled the columns with both a quantity and the appropriate unit. It is expected that there should be a distinguishing mark between the quantity and the unit. It is expected that all raw data should be included in a table of results. All the raw data should be given consistently. Some candidates did not calculate *R* correctly. Calculated quantities should have been given to an appropriate number of significant figures.

Graphical work was generally done well. Points were usually plotted accurately to the nearest half square. Mis-plotted points were very obviously wrong; candidates should be encouraged to check points like this as they finish plotting graphs. The majority of candidates drew their line of best-fit with a fair balance of points. There was also a mark for the quality of the experimentation – in this practical five good trend plots were expected.

It is expected that the gradient should be calculated from points on their best-fit line which are at least half the length of their line apart. Weaker candidates often lost marks either by using triangles that were too small or by working out $\Delta x/\Delta y$. Good candidates clearly indicate the points that they have used and show their calculation. The gradient had to be negative. Where candidates could not read off the *y*-intercept, it is expected that they should substitute a point on their line into the equation $y = mx + c$.

In part **(g)** candidates were asked to determine values for *E* and *F*. Weak candidates did not use their answers for the gradient and *y*-intercept; failure to use these values prevented candidates gaining four marks. Determining the units was generally good and answers were normally given to an appropriate number of significant figures

Part **(h) (i)** asked candidates to determine whether the value for *F* was in range. This was answered well with some clear working shown. Part **(h) (ii)** asked candidates to explain whether their results indicated random errors. Examiners expected the scatter of points on the graph would be described to explain whether random error existed. Too often candidates answers lacked clarity and thus did not score marks.

2 In this question candidates were required to investigate how the extension of a spring system depends on the load submerged in water and then write an evaluation of the procedure.

In part **(b) (iii)** most candidates determined *e* correctly although a number of candidates lost this mark since they did not record the distances to the nearest millimetre.

Part **(c)** confused a number of candidates. Many candidates did not use an appropriate uncertainty estimate of 0.1 cm to 0.5 cm while other candidates did not use *L* in the ratio.

In part **(d)** it was expected that candidates would gain a larger value for *e*.

In part **(e)** candidates were asked whether their results supported the relationship that *e* is directly proportional to the total mass added, explaining their reasoning clearly. No marks were awarded without reasoning. Weak candidates were often very vague with their reasoning and a number of candidates were confused with the total mass added. Good candidates calculated a constant of proportionality for both sets of results. It is expected that candidates will then draw a conclusion based on their results.

In part **(f)** weak candidates are still evaluating experiments by describing the procedure they followed. Some candidates wrote very little of substance. Good candidates scored well by describing relevant problems and suggesting specific ways to overcome them. Vague suggestions without explanation did not gain credit. In particular human error without explanation did not score.

Credit worthy problems:
Difficultly in measuring *L*,
Difficultly in ensuring the same amount of mass holder is submerged or masses may have different values,
Spring system oscillates,
Two readings of are not enough to verify the suggestion.

Credit worthy solutions:
Use of a marker at the top and bottom of the springs or clamp the ruler
Use vernier callipers or a travelling microscope,
Mark the mass holder
Wait for some time for the oscillations to stop or use a wider mass holder to increase the damping
Use of reference mark/slow motion video playback
Use many different masses <u>and</u> plot a graph relating *e* and total mass added.

Two marks were available for spelling, punctuation and grammar in this part. These marks were not scored as well this year as in previous years. Often weak candidates did not use capital letters at the start of sentences and there were many spelling errors.

2824 Forces, Fields and Energy (Written Examination)

General Comments

This paper seemed to produce a wider spread of marks than usual with many more candidates being able to show a reasonable basic knowledge of the topics; possibly the candidates found this a more straightforward paper than in previous years. No one question stood out as being beyond the reach of most candidates; however the first three questions produced the best marks for many candidates. Very few candidates made no attempt at q7 and most appeared to have sufficient time to write all they wanted. Those who managed only a few sentences usually still gained several marks.

The impression is that the standard of presentation from candidates who are in their final year has deteriorated. Numbers appeared all over the page and the standard of spelling in some cases was very poor. Many candidates were handicapped by not being able to handle the basic mathematical manipulations of proportion in a clear and logical manner. Overall the presentation of calculations and mathematical argument was poorer than on previous papers.

Comments on Individual Questions

Q1 (a) Candidates lost marks in this introductory part by failing to answer the question. The answer required was ‘to find the area under the graph’ for 1 mark with justification as the second mark. Again in (ii) it was vital to show the method to gain the mark as the answer was given. Many failed to do so satisfactorily. Two straight lines on the diagram to indicate the triangles used were quite adequate. Most managed to find the speed of the ball and to read the graph correctly to calculate its maximum acceleration. The most common error was to forget to change the mass of the ball to kilograms.

(b) Those who failed to add the velocities to find the change in momentum of the ball often lost only one mark in this part of the question. Those who subtracted the velocities and then squared the result to find the change in kinetic energy and those who added the squares of the velocities both lost rather more marks. The mean force calculation was done well.

Q2 (a) Most candidates were able to state the meanings of the terms. The two common errors were to forget to state that the temperature in the absolute or thermodynamic temperature – it was adequate to say temperature in K – and to just call *R* a *constant*, i.e. leaving out the word *gas* ,*gas constant* being the minimum description that was accepted.

(b) Good candidates gained full marks easily but others lost marks through their inability to make their methods clear or to show calculations in a logical order. Too many are still using temperature in degrees Celsius where kelvins are needed.

(c) This section was answered well by all but the weakest with almost all scoring the last three marks.

Q3 (a) The majority of the answers to this question showed that less than half of the candidates have much real understanding of the dynamics of circular motion. A centripetal force was added correctly to the first diagram by almost all candidates but then a significant minority added a centrifugal force to the second diagram causing them to forfeit the marks for this subsection. Few were unable to substitute the correct figures into the correct formula to score the marks in part (ii). Almost all realised that the medallion moved to a greater angle to the vertical when the car travelled faster around the bend but few were able to explain clearly that the tension increased to *provide* the larger centripetal force. The better candidates appreciated that the vertical component of the tension was unchanged and only the horizontal component increased.

(b) Almost all candidates were able to score at least half of the marks for this section. Apart from careless errors, marks were only lost by not giving a sufficient description of a resonance phenomenon. Very few candidates did not recognise that this was a resonance situation.

Q4 (a) The drawing of field lines was often not accurate enough to gain both marks. The lines had to equally spaced, starting and stopping normally at the surfaces of the plates. Many added the arrows towards the zero plate

(b) There was some confusion between force and electric field strength and a minority tried to use formulae for point charges. Otherwise most were successful until part (iii). Here a common error was to calculate the initial kinetic energy of the electrons rather than the loss of kinetic energy. Very few were able to complete the last subsection correctly. The most common error was to equate the loss of kinetic energy to $\frac{1}{2}m\Delta v^2$ instead of $\frac{1}{2}m(u^2 - v^2)$.

(c) Many used Fleming's left hand rule without thinking about the sign of the charge carrier, leading to a force towards P. This made it difficult to give a satisfactory answer to part (ii). In fact part (ii) was poorly answered by most candidates as was part (iii). Here a common error was to equate *Bev* to the formula for centripetal force. Another common error was to misinterpret *v* as *V* and substitute 36 instead of 4.0×10^6, again showing no understanding of the situation. The unit of magnetic field density was well known.

Q5 (a) There was much confusion in the series arrangement of capacitors. The most popular approach was to state that the voltage across the larger capacitor was 6.0 V. In many cases this just lost the candidate two marks and further errors using this incorrect assumption were not penalised. a less common error was to share the 9.0 V equally across the two capacitors in parallel.

(b) Very few failed to gain the mark for $Q = VC$ and the majority gained all three marks here.

(c) Incorrect or incomplete units for quantities in the middle of any analysis in this part were ignored. Usually any inconsistencies cancelled out when taking the ratio. Some candidates achieved the correct answer using incorrect physics either by confusing the quantities *Q* and *C* or by giving incorrect formulae for the stored energy or both. Many candidates scored good marks on this part after scoring very few in the earlier parts.

Q6 (a) A significant number knew the meaning of the term *nucleon* although some defined it as the number of neutrons and protons in a nucleus. The word *nuclide* was less familiar but any candidate who stated that it was a *nucleus* gained the mark even if he/she then continued to qualify particular conditions for the term to apply.

(b) More candidates correctly placed the nuclide after α- than after β-emission. Many failed to gain the last mark by not giving an adequate answer to why γ-decay could not appear on the chart.

(c) Marks were lost in part (i) through lack of detail or inaccurate thicknesses or incorrect materials. In part (ii) candidates were asked to describe an experiment so it was necessary to include a source, a detector and to acknowledge the presence of background radiation within their description to achieve all three marks.

Q7 (a) The idea of showing that the graph was an inverse square relationship was ignored by most although those who attempted it were usually correct. Most candidates knew what 'inversely proportional' meant and gave a example. Chosen laws were often inadequately named or described and rarely was a full word statement given. Common errors involved a confusion between fields and forces for both gravitation and electric charges. The term r in the formula was often treated as a 'radius' in some unspecified way. It was not unusual to see a suggestion that on the x-axis $1/r^2$ or r^2 should be plotted. Many candidates did not give 'any physical conditions necessary'. Few mentioned the idea of point mass or in the case of Coulomb's law point charges. Despite the above comments this seemed to be a good discriminating question with most gaining some credit and good candidates scoring close to full marks.

(b) Similarly candidates sometimes did not show that the given graph was exponential, although there was more success here than in part (a). The choice of radioactive decay or capacitor discharge was usually given but the formal title and word statement of it were often inadequate. Common errors included labelling the x-axis as time constant or introducing the idea of half life as the law. There was also some confusion between the symbols Q and C, i.e. in some equations C was the quantity which decayed exponentially.

The quality of presentation and the standard of writing varied considerably, from excellent to very poor. In this 'hybrid' question, spelling and punctuation were often of a lower standard and insufficient attention was given to continuity and layout.

2825/01 Cosmology

General comments
The entry for the Cosmology paper was up by about 5% compared to the January 2008 session, but this did not result in any decline of standards in the knowledge or ability of the candidates. A good number of scripts showed consistent achievement throughout the paper, with lucid written answers where required together with accurate analyses. Graphical skills were also good, although weaker candidates tended to make errors translating powers of ten from the axes to the gradient calculation. In this respect, candidates would be well advised to check their calculations for simple errors of this nature.

A good number of candidates used small diagrams to illustrate their answers, particularly to questions 1.b.i. and 6.c. and these frequently gained credit. But it should be emphasised that any such sketch must be labelled, as no marks will be awarded to anyone who can reproduce a picture from their notes without demonstrating its relevance to the answer.

Candidates were, on the whole, well prepared: extremely low marks were rare. Time was generally managed wisely: 90 marks were available on a 90 minute paper so a rough guide would be to spend 1 minute on each mark. Any candidate giving too much detail in the cosmology section risks running out of time in the last question, which has 20 marks allocated.

Comments on individual Questions

Q.1.(a) The numerical value of the parsec was well known, whilst the approximate mass of the Sun was known by very few candidates.

Q.1.(b).(i) The apparent motion of planets across the night sky is asked regularly, but candidates' answers still demonstrated a wide range in understanding of this topic. A majority referred correctly to retrograde motion but a significant number of answers failed to make clear what was meant by an epicycle and it was here, as mentioned above, that a labelled diagram could gain credit.

Q.1.(b).(ii) This was answered well. Most candidates realised that the heliocentric model of the Solar System could be the basis for an alternative explanation of planetary retrograde motion but fewer answers went on to explain that this was due to Earth overtaking superior planets. Many answers cited the differing speeds of planets, but this was not accepted, as it is the angular velocity or period which must be compared.

Q.1.(c) Answers which referred to Jupiter's satellites usually gained full credit whilst explanations of the phases of Venus were less reliable, suggesting that these candidates do not completely understand why the phases of Venus provide evidence for a heliocentric model.

Q.2.(a).(i) This question was not in itself particularly demanding, but a number of small errors were possible and a surprising number of candidates chose to avail themselves of these opportunities. Einstein's equation linking energy and mass loss was given by many but in the calculation some forgot the factor of 4 to give the initial mass; it was common not to convert the mass to kg and in their haste some candidates forgot to square the speed of light.

Q.2.(a) (ii) This was generally well known but many answers referred to electrons, not protons.

Q.2.(b) Very few candidates referred correctly to the increased coulomb repulsion between helium nuclei due to the larger charge.

Q.2.(c) Most candidates realised that the trigger for leaving the main sequence was a reduction in hydrogen burning within the star. Candidates found it less easy to reconcile a reduction in the core volume with an increase in the overall volume and it was necessary to link the increase in volume to a reduction in surface temperature. A minority of candidates used a lot of space and time explaining the full evolution processes leading to a black hole: in these instances candidates are well advised to read the question carefully.

Q.2.(d) This question was answered well. A majority of candidates knew that a white dwarf was very hot and very dense. Some qualification was required in describing its size and here most candidates chose to refer to it as 'small', but a large number of answers referred to the Chandrasekhar limit (or electron degeneracy pressure, which is not formally part of the syllabus) and so could gain full credit.

Q.3.(a) Most candidates knew that the change in wavelength occurred as a result of relative motion and any sensible expression of the idea was accepted, including answers which restricted themselves to one particular type of wave motion such as sound or light.

Q.3.(b).(i) The idea of a continuous spectrum was well understood, but a significant minority referred only to visible light.

Q.3.(b).(ii) Only few candidates could explain the formation of an absorption spectrum and most neglected the fact that the wave is re-radiated, but in all directions.

Q.3.(b).(iii) The correct interpretation of the red-shift in light from galaxies was given by just about all candidates.

Q.3.(b).(iv) This straightforward calculation was done by the great majority, the only error being to subtract the wavelength for galaxy A from that of D. In these cases the mark was lost but the error was carried forward through the remainder of the question.

Q.3.(b).(v) The calculation for the velocity of galaxy D was completed successfully by most candidates.

Q.3.(c) The graph was completed to a high standard. The points should be plotted to an accuracy of at least half a small square on the grid in both directions and the best straight line drawn.

Q.3.(d) About one third of candidates gained the correct answer in this part, but for many this calculation caused a number of problems: errors were made in measuring the lines for the gradient triangle; powers of ten were omitted or calculated incorrectly; having calculated Hubble's constant candidates forgot that inversion was required to get the age of the universe and lastly, the unit was frequently expressed incorrectly.

Q.4.(a) A good majority of candidates knew the Cosmological Principle. In place of homogeneous, many used the term homogenous, which was accepted, and a small number described the universe as homologous, which was also accepted, although it is more usually ascribed to biological and chemical structures.

Q.4.(b).(i) The majority of candidates completed this calculation successfully. Errors, where they occurred, were usually that of omitting one mass from the calculation; neglecting to square the distance or using a value of 9.81 for G.

Q.4.(b).(ii) Most candidates drew the force vector correctly, having the root of the arrow in the centre of galaxy X, pointing towards the centre of galaxy Y.

Q.4.(b).(iii) The prompt from the previous question enabled most candidates to give the correct explanation here.

Q.4.(c) The description of Olbers' paradox showed a wide range in the understanding of candidates. A good candidate would usually gain the first 3 marks for setting out the paradox itself, but very few answers were seen which gained full credit for its resolution. Most would be content with the assertion that an expanding universe resolved the dilemma, without going into more detail about the reasons for this.

Q.5.(a) This question was well answered by a good number of candidates, who could correctly describe the manifestation of forces and fundamental particles as the temperature of the universe dropped. There were fewer references than expected to the role of matter and antimatter and very few mentioned the proportion of helium produced compared to hydrogen.

Q.5.(b) This question produced a good number of correct answers. Candidates should be careful not to be vague: 'conditions were too extreme' cannot gain credit because it does not specify what is meant by either conditions or extreme.

Q.5.(c). (i) This was well known by many candidates. Answers which just explained the meaning of cosmic background microwave radiation could receive no credit, because this did not answer the question. The key points required were that the intensity was uniform in every direction and that it corresponded to a black body temperature of 2.7K

Q.5.(c). (ii) Few candidates were able to deduce that the small ripples in microwave intensity might correspond to areas where matter is beginning to coalesce.

Q.5.(d) The derivation of the required relationship proved straightforward for most candidates.

Q.5.(e) The three possible scenarios for the possible evolution of the universe were well understood by most candidates. The most common error was to confuse the conditions for a closed and open universe. Some candidates used their own symbols to represent the actual density and critical density of the universe. This could lead to the loss of credit, if the meaning of these symbols was not made clear.

Q.6.(a) Many candidates knew both assumptions required for the special Theory of Relativity. A small number stated that the speed of light could not be exceeded.

Q.6.(b) The idea of time dilation was not well expressed. An observer who measures the rate of clocks in another inertial frame will find that the rate is decreased compared to that of their own inertial frame. Many candidates simply stated that time goes slower as a person's velocity increases.

Q.6.(c) There were many good accounts of this thought experiment, showing that the candidates had prepared themselves well. Diagrams here were especially useful in establishing the idea of two different path lengths measured in the same time interval.
Answers which correctly recounted an actual experiment, such as the one based on muon half-life, were awarded some credit, but the question specifically asked for a thought experiment, so full marks were not available.

2825/02 Health Physics

General Comments
The general standard of the work submitted by candidates was similar to that in previous sessions. The quality of the responses to unstructured questions (which involved candidates expressing what they know in prose) was lower than the well-rehearsed numerical answers. It was clear that some AS work had been forgotten by a number of candidates.

Comments on Individual Questions

1. **(a)(i)** Most candidates were able to calculate a value for the contact force R.

(ii) Most were then able to proceed to form an equation by taking moments about X. The most common mistake was to take moments about the fulcrum instead of X. It is essential that candidates read carefully even the most apparently obvious of questions.
(iii) Candidates were allowed the errors to be carried forward without penalty from their answers to (i) and (ii).
(b) There were many confused responses which may have gained credit had they not been expressed in ambiguous ways.

2. **(a)** This showed generally well-rehearsed responses. Where candidates had an incorrect order of events, it was frequently not possible to award the marks. E.g. 'precession occurs when an r.f. signal is applied' etc.,
(b) Most candidates were able to state the advantages and disadvantages of MRI.

3. **(a)** Where the correct equation was used, the answer generated was right. Again the unit was consistent with the answer in most cases.
(b) A small number of candidates were unable to draw a single straight line, but other than that, this part scored well. A significant number of candidates did not show how they used their graph and many plucked figures directly from the table even though the points they chose were not on the line of best fit.
(c) This part of the question caused the most problem with few candidates being able to reason their workings through to an answer.

4. **(a)(i)** This part of the question was well answered.
(ii) Most were able to select the correct equation and use the correct value for the threshold intensity to gain the answer.
(c) Many candidates had forgotten the work they had done on standing waves at AS. It should be remembered that 10% of the health physics questions are synoptic together with the common question at the end of the paper. Many responses were too vague to score marks. For example it was common to find responses such as 'as the ear canal changes size, the resonant frequency alters'. It is essential to be more specific when answering questions of this type. The direction of any change should be stated, together with the equation and subsequent reasoning which then shows the relationship to the quantity being discussed.

5. **(a)(i)** Most candidates gained marks for the diagram. A numbered of candidates showed the rays meeting in front of the retina, with a minority showing the rays ending up below the fovea.
(ii) Most candidates gained some marks for recall of their knowledge about rods and cones even though they did not answer the question as stated. It was not uncommon to find irrelevant points such as the cones being responsible for colour etc., and this then caused these candidates a problem when trying to answer part (b). There were, however, many candidates who did gain full marks.

(b)(i) The most common error here was to show the rods as most responsive when there is zero intensity of light.
(ii) Once again many candidates scored here for their knowledge of rods and cones rather than gaining these marks as part of a constructive attempt at reasoning the answer.

6. **(a)** The only problem here arose when candidates used symbols which are not generally those used in current text books. Candidates should use word equations when asked specifically for relationships.
(b)(i) The most common error was to include the 0.10 MeV information given in the stem of the question, in their answer.
(ii) This provided a mixture of responses with a number stating the unit to be Sv.
(c) There were two student statements in the stem which in many responses were addressed in a mixed way so that it was unclear which argument was being applied to which suggestion.

7. **(a)(i)** This was well answered.
(ii) The most common error here was to use v=u +at together with the wrong time of 1.50 ms.
(iii) This was well answered by most candidates with error carried forward allowed from the previous part of the question.
(iv) While most candidates were able to spot a Newton's third law force, very few applied it specifically to the rifle. Vague responses such as 'due to Newton's third law the rifle experiences a recoil' were frequently seen.
(b)(i) This was well answered by most candidates although a number left rearrangement of the equation to the imagination. Where there are two marks for a 'show that….' question, every step of the workings should be shown.
(ii) This was well answered by most candidates.
(iii) It was common to find that the mass of the bullet after the collision was ignored. A number of higher level candidates lost this mark. They probably considered it to be insignificant and so omitted it from the working….but failed to show what they were doing.
(c)(i) This caused a variety of responses and hence produced a range of marks. It was not uncommon to find the wrong velocities attached to the masses.
(ii) There were many vague answers which discussed conservation of energy, but few started at the point which the energy enters the block as thermal and kinetic.

2825/04 Nuclear and Particle Physics

General Comments

Although there was the inevitable range of scores across the entry, there was a bigger proportion of candidates reaching higher marks in this January examination than in recent years. Most candidates were able to make a worthwhile attempt at most questions. Nevertheless weaknesses, most of which have been referred to in previous reports, were still in evidence. One which seemed to have become worse this year is the tendency to work to too few significant figures. This was particularly noticeable in questions where the answer to an earlier part was used later on. Candidates should always work to 3 or 4 significant figures so that they can give an answer to 2 or 3 significant figures. In some cases flagrant deficiencies in this area were treated as errors and penalised accordingly. And where an approximate answer was given, candidates should nevertheless have given their own answer (to 2 or 3 significant figures as usual) rather than simply copying the approximate answer given in the question. These approximate values are usually given to enable a candidate who has been unable to finish an earlier part to nevertheless continue to score in a later part of the question; they are not accepted as an alternative to a statement of the candidates' own answer.

The standard of candidates' spelling also seemed worse; this is particularly of concern when technical terms are being used as the meaning is thrown into doubt. As usual the words 'nucleus', 'nuclei', 'nuclide' and 'nucleon' were sometimes used incorrectly or written too indistinctly to be read clearly, in some cases resulting in mark penalties. 'Atoms' and 'molecules' were sometimes referred to when the candidate meant 'nuclei'. Happily the bogus term 'fussion' only rarely appeared. Clear setting out of numerical answers continues to be a problem for a significant minority of candidates.

Comments on Individual Questions

1(a) Candidates were given a graphical relationship between nuclear radius r and nucleon number A and asked to deduce the value of r_0 , the radius of the nucleon. Most were able to make measurements of values of r and A and so deduce r_0 . Candidates' success depended largely on their choice of point on the graph. Those who tried to read off the value of r corresponding to A = 1 failed to score. Otherwise this was generally done well.

(b(i)) Candidates then needed to use this value of r_o with the nucleon number of U-235 to find the radius of the uranium nucleus. This was well done though candidates needed to remember that they were expected to give their own value for the radius rather than merely copying the approximate value given.

(ii) Most candidates were able deduce the mass of the U-235 nucleus as 235 times the nucleon mass.

(iii) The volume of a spherical nucleus was well known and most candidates were able to use this to find the density of nuclear material. Candidates who lost credit here usually did so because they either used the radius of the nucleon, r_0 instead of the radius of the nucleus r, or they failed to raise the radius correctly to the third power.

(iv) Here candidates were expected to calculate, by simple arithmetic, the proton and nucleon numbers for the cerium nucleus. Although this calculation was very simple, significant numbers of candidates failed to score fully because they had not included the absorbed neutron i.e. they assumed that the fissioning nucleus was U-235 rather than U-236.

(v) Most candidates were able to find the ratio of the radii of the cerium and selenium nuclei though a few failed to take the cube root of the ratio.

(vi) This part was not well done. Candidates were expected to appreciate that since the nucleons all had sensibly the same mass and separation from each other, the densities of both product nuclei (and indeed any other nuclei) would all have the same value. Instead, many candidates argued (in words or using algebra) that since the volume and mass of a nucleus are proportional, the ratio of mass to volume must always be the same. This was invalid however because these candidates were assuming the point at issue, namely that the density is the same for all nuclei. Others simply stated baldly that the densities of all nuclei are the same. Those who did score usually did so by pointing out that the separation of the nucleons is constant; very few also said that their masses are the same.

2(a) This question clearly took a lot of candidates by surprise and revealed that they had little real understanding of thermal neutrons. They were expected to state that the kinetic energy of a thermal neutron cannot be less than the (mean) kinetic energy of the atoms through which they are moving and since this will not be at absolute zero, their kinetic energy cannot be zero. Some who had the right approach still lost the mark by referring to the neutrons themselves as being at absolute zero, forgetting that an individual particle cannot be said to have a temperature at all; temperature is a quantity which has meaning only in relation to a population of atoms or molecules. A common answer was to the effect that a thermal neutron could not have zero energy because of its rest mass energy. This disappointingly common misconception revealed a lack of understanding of the difference between kinetic energy and rest mass energy.

(b)(i) Candidates were state what happens after a U-235 nucleus has absorbed a neutron, stating any processes or nuclides which ensue. This was generally well done by candidates who gave beta-decay as the relevant process and stated one of the nuclides: U-239, Np-239 or Pu-239. A few wrote about fission reactions and a small number about alpha-decay. Providing it was made clear that the latter occurred to Pu-239, this was allowed.

(ii) This part tested two aspects of the candidates' knowledge in particular: whether they had read the question properly i.e. responded to the information given, namely that U-238 can absorb more energetic neutrons and whether they had realised that the absorption of a neutron by U-238 does not result in a fission. Few candidates were able to score both marks. A common response was to predict some sort of cataclysmic reaction which would cause a melt-down or similar. Others merely stated that the neutron would not reach thermal speeds quickly enough and this would slow down the reaction.

(c)(i) This was a straightforward question of a kind which has been set many times before and most candidates were able to use the binding energies given to find the energy released by the fission of a nucleus of U-235. Very few candidates lost credit by failing to multiply the binding energies by the nucleon number in order to find the binding energy per nucleus.

(ii) It was pleasing to note that many candidates were able to find an expression for the number of U-235 nuclei in 1.0 kg, to find the total energy released and then convert the value from MeV to joule. This is a type of question which has caused difficulties to candidates in the past but which was better done this year. Candidates were able to use either the proton/nucleon mass or the avogadro number; either led to a correct value for the energy. Where marks were lost the problem was often in powers of ten from either failing to realise that the molar mass of U-235 is 235 grams or errors in converting correctly from MeV to joule. A few candidates confused the nucleon mass with the value of the atomic mass unit. The two figures are very nearly equal but candidates should be clear that they represent quite different concepts.

(d) This question required candidates to give some thought to the principle of the nuclear bomb. In view of the propensity of candidates to resort to disaster scenarios in their explanations it was disappointing that so few seemed ever to have thought about this actual phenomenon. It was hoped that candidates would realise that the neutrons released inside a large mass of fissile material would have a smaller chance of escaping than those released inside a small mass and so would trigger further fissions. The situation could therefore arise inside a large mass whereby the chain reaction could accelerate rapidly and become totally unstable, leading to a nuclear explosion. Very few were able to do this but many postulated various forms of instability associated with large masses of uranium. Some, with previous knowledge, did refer to critical mass but then failed to explain how this arises.

3(a) Candidates were asked to explain, using the concepts of kinetic energy and potential energy why high temperatures are needed for fusion. This was done well by thoughtful and well prepared candidates. They were able to state that the like charges on protons cause repulsion and that the protons therefore need enough kinetic energy to provide the potential energy needed to bring them close enough to fuse. Mean kinetic energies are proportional to kelvin temperature so the plasma must be very hot. A few candidates, clearly confusing fission with fusion, referred to the supposed binding energy of the proton. Others regarded the Coulomb barrier as the energy needed to hold the electrons to the nucleus. This part also produced more than its fair share of terminology errors; 'atoms' and 'nuclides' were sometimes mistakenly quoted rather than 'nuclei'.

(b)(i) Most candidates were able correctly to calculate the mass defect of the given fusion reaction and to conclude that Reaction 2 was preferable because it had a higher mass defect and so would release more energy. Errors were usually arithmetic though a small minority of candidates thought that the smaller mass defect was preferable for reasons which were not very clear.

(ii) This was not well done. Candidates were expected to realise that since the use of atomic masses would result in the same number of electrons in both the mass of the reactants and the mass of the products, the electron masses would cancel out and so have no effect on the mass defect calculated. Most candidates either stated that the mass of the electron is negligible or that it is only the nuclei that react rather than the whole atom and so the electrons did not need to be considered. This was not accepted because the question related to the calculation of mass defect rather than to the reaction itself.

(iii) Only a minority of candidates were able to state that since all hydrogen isotopes have the same number of protons, the coulomb barrier is the same for each, so the mean kinetic energy needed, and the temperature, will be the same. Some lost credit for discussing the similarity of the masses rather than the charges. Again 'binding energy' appeared, irrelevantly, in some candidates' answers

4(a) Many candidates were able to calculate the energy equivalence in GeV of the proton mass. Some got only as far as expressing this energy in joule; others failed to quote the mass-energy relation altogether and so made no progress at all.

(b) Many candidates were able to express 600 GeV as a percentage of the mass-energy of the proton. A few lost the mark by calculating the total energy of the proton (rest mass-energy plus kinetic energy) as a percentage of the rest mass. Others seemed at a loss as to what was required.

(c)(i) A high proportion of candidates were able to arrive at the required energy input by simply doubling the mass-energy of the proton; a few better candidates pointed out that the anti-proton has the same mass as the proton. Those who showed four proton masses on the right hand side and then subtracted the two reacting proton masses to find the increase were allowed this mark.

(c)(ii) This part was not done well; candidates were expected to state that a moving proton colliding with a stationary proton is a system which has momentum and the products will possess the same amount of momentum. These product particles will therefore have kinetic energy which is therefore not available to create new mass. There was widespread failure to understand that momentum is the governing parameter and many tried to give an answer in terms of kinetic energy only. Some merely stated that two protons colliding head-on will have twice the kinetic energy of one. A few thought that the energy needed in the collision is due to the electrostatic repulsion between the protons, not realising that this is many orders of magnitude smaller than the energy available in a particle travelling near to the speed of light.

(e)(iii) Candidates were expected to realise that in order to create particles using only the amount of mass-energy created, it is necessary to collide the protons in such a way that they have no initial momentum i.e. to collide them head-on with equal speeds. A few better candidates did this but others who clearly had some appreciation still failed to score fully because they were not precise enough e.g. they stated that the particles had to collide head-on but failed to say that they also had to have equal speeds.

5(a) Nearly all candidates were able correctly to calculate the value of R at present.

(b) Most candidates realised that the half-life of U-235 must be less than the half-life of U-238 though a few claimed to have deduced this from the fact that there is much less U-235 now.

(c) This was a calculation of a type which has been tested before on many occasions and many candidates succeeded in finding the value of R when the Earth was formed. As always it was possible to solve this using either powers of 2 or powers of e and both methods were popular. In the former case candidates needed to find how many half-lives of the ratio R there are in the lifetime of the Earth and then to raise 2 to this power. It was particularly important to express R to 3 sig. figs. in this case as it represents a power so small differences have bigger effect on the answer. Some candidates lengthened their calculation needlessly by working in seconds rather than years but usually arrived at a correct answer eventually. A few gained some credit for an attempted solution by repeated doubling.

(d) Here candidates were expected to sketch a graph of the number of U-235 atoms, starting at about 1/3 of the initial number of U-238 atoms and then decaying exponentially at a much more rapid rate. This was not well done. Few candidates attempted to use the initial value of R (0.32) so many graphs met the vertical axis in the wrong place. Many did however show a more rapid decay for U-235. A few candidates seemed not to have noticed this part of the question and left the graph blank.

(e)(i)(ii)This straightforward part was not as well done as would have been expected; too many seemed not to have got clearly in their mind the difference between protons, neutrons and nucleons. Thus a significant number of candidates stated that an alpha-decay results in the neutron number decreasing by 4 and that in a beta-minus decay the neutron number is unchanged.

(iii) It had been expected that candidates would use the answers to (i) and (ii) to deduce the composition of the final nucleus in the decay series. Surprisingly few succeeded in doing this correctly though a few who had failed to score in (i) and (ii) deduced the final proton and neutron numbers using the proton and nucleon numbers in nuclear equations and were able to score fully.

6(a) Candidates were asked to describe the quark model of hadrons. Better candidates were able to score highly by listing the six quark flavours, stating that quarks are fundamental particles and that every quark has an antiquark counterpart. Some candidates also stated correctly that the antiquark has opposite values of the charge, baryon number and strangeness, that quarks are held together by the strong force and/or that charge, baryon number and strangeness are conserved in quark reactions. This part was generally well done.

Most candidates were then able to state the quark composition of either the proton or the neutron. Some lost credit however because they failed satisfactorily to relate the properties of the quarks to the corresponding property of the baryon. This could only be done by equating the sum of the charge, baryon number and strangeness to the corresponding values for the proton or neutron. Those who did attempt these equations usually scored well. However it was not considered satisfactory to state that the proton and neutron have no strangeness; they do have strangeness, but of value zero. Some omitted the strangeness equation altogether.

(b) This part was done well. Most candidates were able to list four kinds of lepton, to state that the weak force is responsible for lepton emission and to specify a particular decay which produces leptons. This could equally be the decay of a proton, neutron, an up quark or down quark; it could also be a radioactive decay of a U-239 or Np-239 nucleus. All were quoted correctly by some. A few lost credit however by stating that pions are leptons.

7 This question about speed, momentum and energy allowed candidates to display their knowledge and understanding of some general physics. Able candidates were able to score nearly full marks whereas weaker candidates, some of whom had not allowed

enough time for this final question, left some parts blank. In this question several approximate values were given to enable weaker candidates to progress through the question. These were not intended to replace the candidate's own value as derived from his/her calculation. A few lost credit for answers which were not set out clearly enough to follow. Not only are candidates asked on the front cover of the question paper to set out all steps in their answer; most of the parts of this question ask them to 'Show that…' an answer is correct. The mark scheme of this type of question always allocates marks for showing the intermediate working. Some candidates lost credit on this account.

(a)(i) Most were able to find the speed of the bullet from the distance and time given.

(ii) Here candidates were expected to use an equation of accelerated motion to find the acceleration of the bullet in the barrel of the gun. Many achieved this but a significant minority incorrectly assumed that the time spent in the barrel is 1.50 ms as given in part (a).

(iii) Most candidates were able to find the acceleration of the bullet by multiplying its acceleration by its mass.

(iv) Candidates were expected to state that an equal and opposite force will act on the rifle and then to make some sensible comment on the motion of the rifle such as that its acceleration will be much lower than that of the bullet because of its much greater mass or that it will acquire a momentum equal to that of the bullet but that it would have a much smaller speed, again because of its greater mass.

(b)(i) Many candidates were able to use another equation of uniformly accelerated motion to show that the block took about 0.7 s to fall but for full credit candidates were expected to show their rearrangement of the substituted equation, as well as their own answer (not just the quoted approximation).

(ii) Most candidates realised that the horizontal projection speed could be arrived at from the horizontal distance travelled and the time of flight derived in (i).

(iii) This part proved more difficult. Candidates were expected to form a momentum equation for the collision of the bullet with the block and so to derive the bullet's speed. Many failed to use momentum at all and so were unable to score.

(c)(i) The question had indicated that there would be both kinetic and thermal energy after the collision and candidates were therefore expected to form expressions for both the kinetic energy of the bullet before impact and the bullet plus block after impact and to equate the difference to the thermal energy gained. Solution of this gave the temperature rise of the block. Better candidates were able to score fully; weaker candidates often omitted the kinetic energy of the block plus bullet after impact. A few very weak candidates, having deduced the temperature rise, then added 273 K to it, clearly failing to understand the meaning of temperature rise.

(ii) Candidates were asked to state any assumptions made in their calculation. In the stem of this part it had already been stated that the kinetic energy of the bullet had been transferred to the block as kinetic energy and thermal energy. Any statements to the effect that energy had been lost as sound or light during impact were therefore inadmissible. Candidates were expected to refer instead to (for example) heat loss to the surroundings, friction losses between the block and the stand and energy used in deforming the bullet. Comments regarding the distribution of heat inside the block were allowed, recognising that the heat would initially be highly localised within the block and that it would take time for the temperature of the block to become uniform. Candidates who had (sensibly) ignored the heat capacity of the bullet when calculating the temperature rise of the block, were able to score for adding this as a further assumption.

2826/01 Unifying Concepts in Physics

General Comments
As last year this paper produced marks in the range 4 - 58 and with a good spread in between. At the top end there were almost 15% of the 270 candidates who were able to score more than 45 marks but at the other end of the scale 15% were unable to score 20 marks. One disappointing feature of writing a report such as this is that comments made in it do not appear to have reached the candidates. No doubt some of them are told the recommendations but generally they do not act upon them while in the examination room. Every year it is pointed out that careless working costs grades. At some point in the examination system even a single mark lost might result in downgrading and many candidates lose 10% of the available marks by carelessness. In a summer exam this can result in moving 1500 places down the graded candidate list and can result in a C or even a D grade instead of an A grade. Candidates whose working practices are sloppy are capable of losing 10% of the marks on several papers. Far too many candidates divorce physics exam papers from reality. They become exercises in manipulation of numbers with meaningless answers. Practice is necessary before the examinations to get candidates always to look critically at their own answers. This year, for example, it was amazing how many candidates translated 340 K into 613°C – and this was for the temperature of water! Surely candidates need to routinely be on the look out for nonsense. The handwriting standard was reasonable for most candidates but in some cases accurate marking became impossible. The main problem of layout was, as is always the case, the lack of words. Candidates are inclined to write equations and symbols all over the place with little linking of the sections together. When this is added to multiple crossing out it becomes almost impossible to mark. As usual, there were many occasions when not only did their lack of clarity make it difficult or impossible for the examiner to discern their meaning but also occasions when candidates confused themselves. There was no evidence at all that candidates did not have time to complete the paper in the allotted time.

Comments on Individual Questions

1. This question was very revealing about the candidates' knowledge of physics. Certainly some of the distinctions are difficult to express but there were far too many answers showing gross errors or misunderstandings. For example, 'power is energy when it is used' and 'temperature in °C is how you measure heat'. There was good correlation between a good mark on this question with the overall mark on the paper. The question made it apparent that many candidates cannot progress in their physics course unless they properly understand the basic facts. Many need to go 'back to basics'.

2. It was pleasing to see so many candidates realising that if spring constant were to be defined as extension per unit force then the two situations would correspond. What was less encouraging was the number of candidates who forgot the half in the expression $\frac{1}{2}Fx$ and the surprisingly large number who managed to get ⅓ and ⅔ coming into their answers. This was because they thought that the force stretching each spring was one-third and two-thirds of the total. Some even had one-third and two-thirds of the current in each resistor. A good proportion of candidates achieved 9 or more marks when answering this question.

3. The answers to this question were generally poor. The idea of putting high energy steam into a turbine, using some of its energy to provide electrical energy and losing the rest through some form of exhaust was not appreciated by many. A surprising number seemed to think that it was better to put in steam at a low temperature, use it to produced electricity and this somehow heats up the steam and the turbine so the steam comes out hotter than it went in. Parts (a)(i) to (iii) were answered well by most candidates but part (iv) was answered badly. Many candidates thought that an output temperature of near 0 K could be achieved by cooling the output and very few candidates mentioned the main problem of the limit placed on efficiency by the low output temperature being the temperature of the surroundings. Many also thought that raising the input

temperature would be expensive, despite the fact that it would result in higher efficiency. Part (b)(i) was answered badly by many for two reasons. The first was because many candidates assume that as soon as they see a number they must use it immediately. Here there were some numbers that were not required in (i). The second reason was because candidates will not use words at the start of a numerical problem. They need to begin with a statement such as

"42% of the input is an output of 20 MW". Then it should be easy to get

$0.42 \times P_{in} = 20$ MW,

$P_{in} = 20/0.42 = 47.6$ MW.

Around a half of all candidates got this question wrong, most of these because their approach to the problem was poor. Many had an input of 8.4 MW and with the power wasted as 11.6 MW, i.e. more power was wasted than was put in. In part (iii) there were many candidates who ignored the multiple M and had cooling water going into the power station at a rate of 0.00013 kg s^{-1}. This was yet another example of not thinking about the application of physics in the real world. Part (iv) produced some extraordinary answers. Apart from the temperature conversion error mentioned above, there were some extraordinary comments about a temperature of 67°C. Around 70% of candidates thought it was far too high for heating a building. Comments given were such as "it would be too dangerous as the pipes might burst", "the water would be radioactive", "it would be far too hot for people to live at such a temperature", "it would not be able to be controlled". One wonders whether these candidates have ever felt radiators in their own homes. Few mentioned the fact that a problem arises in the summer when people do not want their homes heated or that if a higher temperature system is required then the output temperature from the turbine is needed and that will reduce its efficiency. Sensible comments on the problems of distribution and the fact that people do not want to live near power station were seen from the more thoughtful candidates.

4. This question posed a completely different problem. The candidates who could handle the exponential equation well usually scored 17 – 20 marks. Those who could not cope with the mathematics could only progress as far as the graph and many of these worked on the common but erroneous idea that all graphs start at the origin. One common mistake for the better candidates was to take in their answer to (b)(v) the charge on the capacitor as 0.0010 rather than 0.0010 Q_0. Many of the weaker candidates still managed to find the gradient of the graph even though they had a curved graph.

2826/03 Physics Practical

This January just under 200 candidates sat the exam, and the standard was very much the same as last January, except for a longer tail of weaker candidates. There were no difficulties reported from centres about apparatus.

Question 1
The candidates were asked to plot the characteristics of a thermistor in the form of a graph of ln(R) against 1/T (R = resistance, T = absolute temperature). At the start the percentage uncertainty in the resistance R was asked for, and this proved to be difficult. Only a few candidates were aware that the % error in R is the sum of the % errors in voltage V and current I. The uncertainty in I was usually given as ± 0.1mA and this is too small, because in trials the current wavered around considerably.

Nearly all candidates produced a decent table of results and a well-presented graph. Credit was given for including all raw readings (temperature in ˚C, current, and voltage), and a surprising number omitted one or more of these. Common faults were the omission of units for 1/T and trailing zeros for the values of temperature i.e. quoting 20.0˚C instead of 20˚C to "make it more accurate". This was penalised if all the temperatures were expressed in this way. The graph should have been a good straight line and credit was given if at least five of the six points were within one square of the best straight line (over the whole area of the paper). There was a tendency for some to crowd the points into the top right hand corner of the graph to try to obtain a true y-intercept, and this was penalised.

Gradients were generally well measured but a large number of candidates forgot about the power of 10^{-3}, which most had attached to the 1/T axis. This was not penalised. y = mx + c needed to be used to find the intercept and this was usually successful, but there were some who spoilt their efforts by then using c = y/mx.

As expected, the logarithm calculation in part (f) proved more difficult and only the stronger candidates coped with it. The log equation is ln(R) = ln(A) + B/T and only a few candidates saw that the units of A and B are ohms and Kelvin. It was more surprising to see so few getting the significant figure mark (2 or 3 sf) for A and B.

The final part of the question asking for the average sensitivity of the thermistor over the whole range was well attempted by many. The figures were more easily obtained from the table of values than from the graph, but full credit was only given if the figures matched the best fit line on the graph.

Question 2
The candidates were asked to make measurements to determine the period T of torsional oscillations of different masses on a spring. Too many measured just one oscillation instead of five or ten, and hence lost credit. A mark was also given here for repeating readings (and so was not credited later as a suggestion for improvement in the evaluation). Raw readings were expected to be to two decimal places.

They were then asked to justify the number of significant figures (sf) used and this produced the usual confusion between sf and decimal places. "I used 3 sf because the raw readings were to 3 sf" is an acceptable answer, but was only credited if it matched the actual answer given. Candidates who explained that they reduced the sf because of the limitations of human reactions in timing were also credited. Calculations of constants of proportionality were well done and most results showed that period is proportional to √mass. Good results were usually obtained, despite all the problems detailed in the evaluation section.

There are several skills needed to correctly time oscillations, and the evaluation section was designed to test knowledge of these skills. The mark scheme lists 14 different marking points, of which 7 were needed for full marks, and only a few candidates scored more than 4 or 5 of these.

They were asked to start the oscillation by rotating the masses by about 360˚ before releasing, and this implied that the 360˚ was not an important figure. However, a large number stressed the difficulty of measuring this angle accurately and explained how protractors could be mounted to solve this problem, and none of this was credited. Real difficulties were the swaying and bouncing motion of the mass, and the component 100g masses sliding over one another.

To obtain more accurate results the usual remedies were credited, i.e. timing more oscillations, timing against a fiducial marker, using more masses and using these results to plot a graph of T against $\sqrt{m}$ (see the mark scheme for details). The use of a video recorder or camera was accepted, provided it was made clear that a timer was incorporated in the camera or visible on screen. Light gates were also accepted as long as the set up was explained.

Planning Exercise

This was the familiar exercise of determining the efficiency of a small electric motor. The main problem with this experiment is isolating the many variables involved because for a given motor the efficiency depends both on the load and the motor speed, and if they both vary the results are difficult to interpret. In this case the wording of the instructions implied that a fixed load was expected, so that the efficiency-speed graph could be obtained for a fixed load.

Marks were given for a good diagram of the experimental set-up. These diagrams were often clearly copied from books and showed motors dangling in mid-air with no support, and this was not credited. An extra detail mark was given for clamping the motor properly to a bench. A circuit diagram with a variable power supply or variable resistor was also expected.

Several schemes for measuring the rotational speed of the motor were given. Credit was given for a brief method and not just a statement. “I would use a stroboscope” was not good enough, nor was “I would use a rotary sensor connected to a computer” without a detailed reference. Normally, only apparatus available in a typical school laboratory is acceptable. Good extra details such as rotating discs and measurements of the circumference of the pulley used could earn an extra detail mark.

Marks were given for the power input, power output, and efficiency formulae, and it was pleasing to see that there was not much confusion between energy and power this time. Candidates were also asked how a suitable load would be chosen, and to say that it should rise not too slowly and not too quickly was not good enough; some estimated ideal times, such as 5 or 10 seconds, were expected.

As usual, credit was given for preliminary laboratory work, where the actual experimental figures obtained were needed to earn credit. A mark was also given for repeating readings.

Finally, candidates were asked to suggest why the motor was inefficient, and how the efficiency would vary with speed. Most mentioned friction, and a few mentioned heat losses from current carrying conductors. There was often a lot of explanation of back emf and how it would cause inefficiency and this was not credited. The expected efficiency graph shows the efficiency peaking at roughly 60% to 80% of maximum speed.

Most earned the two marks available for more than one good reference, from the web or from a book, quoting page numbers. There are still candidates who do not earn these easy marks. The two quality marks were given for most of the plans, which were generally well presented. Compressing all the information available into 500 words is not easy and it is a skill being tested here. There were more overlong plans (over 700 words) this time, and this was penalised.

Grade Thresholds

Advanced GCE Physics A (3883/7883)
January 2009 Examination Series

Unit Threshold Marks

Unit		Maximum Mark	A	B	C	D	E	U
2821	Raw	60	39	34	30	26	22	0
	UMS	90	72	63	54	45	36	0
2822	Raw	60	43	38	34	30	26	0
	UMS	90	72	63	54	45	36	0
2823A	Raw	120	101	91	81	71	61	0
	UMS	120	96	84	72	60	48	0
2823B	Raw	120	101	91	81	71	61	0
	UMS	120	96	84	72	60	48	0
2823C	Raw	120	97	89	81	73	65	0
	UMS	120	96	84	72	60	48	0
2824	Raw	90	65	58	51	45	39	0
	UMS	90	72	63	54	45	36	0
2825A	Raw	90	68	62	56	50	44	0
	UMS	90	72	63	54	45	36	0
2825B	Raw	90	63	56	49	43	37	0
	UMS	90	72	63	54	45	36	0
2825C	Raw	90	65	58	51	44	38	0
	UMS	90	72	63	54	45	36	0
2825D	Raw	90	62	56	50	44	39	0
	UMS	90	72	63	54	45	36	0
2825E	Raw	90	64	57	50	44	38	0
	UMS	90	72	63	54	45	36	0
2826A	Raw	120	90	80	70	60	50	0
	UMS	120	96	84	72	60	48	0
2826B	Raw	120	90	80	70	60	50	0
	UMS	120	96	84	72	60	48	0
2826C	Raw	120	88	80	72	64	57	0
	UMS	120	96	84	72	60	48	0

Specification Aggregation Results

Overall threshold marks in UMS (ie after conversion of raw marks to uniform marks)

	Maximum Mark	A	B	C	D	E	U
3883	300	240	210	180	150	120	0
7883	600	480	420	360	300	240	0

The cumulative percentage of candidates awarded each grade was as follows:

	A	B	C	D	E	U	Total Number of Candidates
3883	12.9	37.4	63.5	81.4	96.4	100	592
7883	12.0	30.0	56.0	81.0	96.0	100	113

For a description of how UMS marks are calculated see:
http://www.ocr.org.uk/learners/ums_results.html

Statistics are correct at the time of publication.

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